# THE EVALUATION AND OPTIMIZATION OF SENSORIAL COMFORT.

by

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# ABSTRACT

The factors which are commonly considered to be of prime importance in determining the comfort of garments are thermo-physiological comfort, garment fit and sensorial comfort. The last of these factors is the topic of this thesis. Although these three factors are separated into distinct groups, they are also dependant on one another. Therefore a knowledge of all of them is necessary for an assessment of overall clothing comfort.

Sensorial comfort has been a neglected area of clothing comfort in comparison to the other comfort factors. When research has been carried out it has been on specific sensations or fibres and no over-view of the range of sensations and their relative severity has been established. This means that different research studies in this area cannot be compared because they are so specific. This research programme has established the foundations for future sensorial comfort studies by providing this information.

This was done by an extensive wearer trial when a large selection of commercially available fibres and fabrics were worn next to the skin for a range of activities. Nine major discomfort sensations were identified. These were: tight fitting bands, tickle, prickle, scratchiness, local irriation due to labels, seams and trimmings, fibre shedding, initial cold feel, wet cling and tacky cling. Four of these sensations: tickle, local irritation, fibre shedding, and tacky cling had not been investigated before. A glossary of terms was compiled to describe these sensations and this is proposed as a standard terminology. This wearer trial also enabled a hierarchy of potential discomfort to be identified for these nine major discomfort sensations.

These sensations were further investigated by specific wearer trials to determine the main physical, physiological and psychological factors influencing their presence and severity. New test procedures were designed and developed to assess a fabric or garment for the presence of discomfort sensations. When test procedures were inappropriate, recommendations were made.

The attitude of the general public to the factors producing discomfort from their clothing was also determined. A range of 1004 people in the north of England were asked for their views on all aspects of clothing comfort. Some of the major findings were that people associate discomfort with the fibre type, and not the fabric or garment. Fibre absorbency is thought to be very important for clothing comfort, but wet cling is not thought to be an annoying sensation in comparison to other skin sensations, and the appearance of the fabric has an over-riding influence on the acceptance of a garment.

This research has provided the information necessary to describe and, in many cases predict the presence of sensorial discomfort sensations.

# CHAPTER 1

## INTRODUCTION.

The factors commonly considered to be of prime importance in determining the functional comfort of garments are the thermal insulation and the dissipation of sweat (known as thermo-physiological comfort), garment fit and sensorial comfort. The last of these is the topic of this thesis. Although the factors can be separated into three distinct groups, they are also dependant upon one another, and therefore this thesis includes certain aspects of all of them.

Comfort in clothing is a neutral or a pleasant sensation which is associated with how a fibre, fabric or garment 'feels' whilst it is being worn. Discomfort is experienced when a sensation is registered and it is unpleasant. Sensorial comfort/discomfort is a range of sensations originating from garments that are worn next to the skin, but some of the sensations, such as tight fit, apply to the garment assembly as a whole. In general the sensations can be classified as tactile; yet in reality a person judges the comfort of a garment using a combination of physical, physiological and psychological stimuli.

Most of the research work that has been carried out on clothing comfort has been concentrated on the thermo-physiological aspects, which is now well understood. In comparison very little work has been done on the individual sensations that are registered by the skin. Where research into sensorial comfort has been done, it was generally aimed at a restricted range of predetermined sensations. This means that some sensations could be over-looked and the relative importance and causes of the sensations that were considered could be insufficiently defined. This is more important than it may first appear owing to the complexity of the causes and inter-relationships of each sensation, and also the regular occurence of counter-stimuli. There is a distinct lack of information on the types of sensations that are actually experienced whilst wearing everyday garments and their relative importance to the wearer. There is, for example, no standard or commonly accepted set of terms to describe the skin sensations.

This gap in our knowledge means that garment designers can only rely on their own past experiences. On the face of it, this would appear to be satisfactory. However variations in fibre type, fabric construction and garment style together with the number of possible combinations is always increasing. A fashion designer aims to make a product a little different and more popular than that of a competitor. They are therefore more likely to choose new combinations of fibre, fabric and/or garment style of which they are unlikely to have in-wear past experience. Garment design, fabric construction and fibre type each have a large influence on in-wear comfort, but they are by no means independent of one another. One of the most famous mistakes that originated from lack of knowledge of the in-wear properties of a fabric is the nylon shirt of the 1960's and 70's. It gained the reputation of being uncomfortable because of wet cling. The reaction to this unpleasant sensation escalated into a wide-spread prejudice against nylon and, the avoidance of fabrics that looked like the nylon jersey. This was an expensive mistake and an awkward one to rectify. Only now is nylon becoming more acceptable and with care in the choice of fabric construction it is now being successfully used for sportswear.

A series of three year projects were based in a number of research centres in Europe with the ambitious goal of using the findings to predict clothing comfort. Each project evaluated a specific aspect of clothing comfort; the findings of which were to be used in a multi-dimensional diagram to predict the comfort of a total garment assembly for different end-uses and in different environments. This would incorporate predictive models and/or equations for the various factors that were considered to be of most importance in the functional comfort of garments. The development of cheap, easy to use test equipment was to be produced where conventional methods were unsatisfactory. The results from these tests would be a source for the data needed to describe the comfort of a fabric for use in the diagram. This would eliminate the need for costly and time-consuming wearer trials and produce a more reliable, accurate result. These research projects were jointly funded by the European Economic Community (E.E.C.) as part of the second Textile Research Programme and this project was also funded by the UK Department of Trade and Industry.

## 1.1 Aims

The aims of this research project can be split into four main areas:

1) Identify the major discomfort sensations that are registered when wearing apparel next to the skin, and decide on a glossary of terms to describe them.

2) Identify and evaluate the factors that cause or influence the severity of the sensation.

3) Develop new objective test procedures or utilise existing test methods to assess a garment or fabric for its potential to cause discomfort. The severity of a discomfort sensation should also be indicated, but where test methods cannot be used recommendations and guidelines should be made.

4) Application of the test results obtained to a multi-dimensional diagram, to predict the overall comfort of a garment assembly.

# CHAPTER 2

## LITERATURE REVIEW.

Comfort is an arbitary condition that is dependant on many factors. Knowledge of the principles of physiology, psychology, textile technology, dermatology and physics can give a basic understanding to the underlying factors governing comfort. However the attitude of the wearer, referred to here as psychology can have a large influence on the perception of a sensation and in many cases the physiological effect will dominate. For instance, if a person likes a garment and feels contented, they will be more tolerant if discomfort sensations are produced by the garment they are wearing (Stollery, 1984).

This literature review discusses the work carried out on the many different facets of comfort to create an overall picture of the state of current knowledge. An assessment of the work that has been carried out in the area of tactile comfort and related subjects, such as handle, thermo-physiological comfort (heat and moisture transport) and garment fit. Although some of these studies are not directly used in this research project, they all influence the overall comfort and hence the sensorial comfort of the wearer.

The sensations that are experienced when wearing a fabric next to the skin are dependant on the type of receptor that can receive a sensation. The skin is the main receptor and this is covered with hairs which also play a large part in the perception of discomfort.

### 2.1 The Skin as a Receptor.

A number of studies have been carried out in the medical field to determine the physiological factors that influence and produce skin sensations. The results of these studies have been reviewed by Iggo, Sinclair, Starling and Lovatt Evans and Woodson and Conver. It is known that the nerve supply to the skin is controlled by the central nervous system (the brain and the spinal cord). This enables the skin to act as a sensory organ and it can also protect the body by reflex actions.

It is widely accepted that over a range of severitty for a skin sensation, 'the sensation is a concious mental registration of change' (Jarrett, 1964). From this it can be concluded that a stimilus could be applied to the skin slowly enough so that the change would not be registered.

The skin can register four primary sensations: pain, touch, heat and cold, and there are sensitive spots in the skin to detect these sensations. Although these spots are not fully understood, the density of them is known to vary depending on the location on the body (Starling and Lovatt Evans, 1968). For instance, the volar surface of the finger has a high concentration of touch and warmth spots whereas the forearm, breast, thigh and dorsal surface of the hand have a high concentration of pain spots. The other sensations that can be perceived are interpreted by these four types of receptor. For example, itch is associated with the pain receptor, and pressure is associated with the touch receptor.

Experiments to investigate the sensitivity of the skin to these four primary sensations have mainly involved the determination of pain thresholds (Winslow and Herrington, 1949), Leithead and Lind, 1964). Nevertheless, it is known, although less widely documented, that each person has their own discomfort threshold that is related to their pain threshold. The threshold varies with age and psychological awareness (Stollery, 1984, Winslow and Herrington, 1949). Therefore when a fabric is being assessed for comfort, it should be assessed more than once to reduce the chance of the fabric being accepted or rejected unreasonably due to the attitude of a wearer on one occassion.

Body hairs are another major receptor or protector against discomfort sensations produced by fabrics. They can act as receptors and as spacers between the skin and a fabric. They exaggerate the intensity of a stimulus because they act like a lever, the fulcrum being located within a plexus of nerve endings which respond to a short or a sustained stimulus.

The two main ways in which fabric discomfort can be registered when a garment is worn next to the skin are by the skin and the body hairs. To accurately describe the sensations that are experienced it is necessary to use a precise glossary of terms.

One of the initial tasks in this project was to establish whether a common terminology had been adopted for the description of tactile comfort sensations. It was clear from the literature review that no such glossary of terms was available for comfort, and although one existed for handle (American Standard), it was not widely used. Therefore the research work that had been carried out on the comfort of clothing and the handle of fabrics by different researchers tended to be difficult to compare. Nevertheless, the different methods used to determine the subjective properties of a fabric or garment proved to be of interest and guidance during the design of a glossary of terms and the wearer trials for this research project.

## 2.2 Terminology and Wearer Trial Design.

Comfort in relation to clothing is described as "the freedom from pain, well-being" (Oxford English Dictionary). This indicates that the sensation is either neutral or pleasant. Therefore when conducting a wearer trial the choice of terms to describe discomfort, neutrality and preference are to be considered.

### 2.2.1 Comfort Assessments.

In most of the research investigations into the physiological comfort of clothing, comfort is achieved when a wearer is pleasantly concious or unaware of the presence of their clothing. During a wearer trial the comfort sensations that are experienced are likely to cover a range of severities, for instance, from pleasantly comfortable to neutral to uncomfortable and finally painful (depending on the sensation and fabric). Due to the subjective nature of such investigations, the relative importance of the severity of the discomfort is difficult to define, but a necessary quantity.

Many wearer trials have been carried out to determine the performance of a fabric in wear and its handle properties. One of the most experienced researchers in the field of clothing comfort is Hollies. He has conducted many research projects in the area of thermo-physiological comfort, and his methods for assessing the fabrics in wearer trials were of value in the design of the wearer trials for this research project.

In 1971 Hollies used a subjective scaling approach to determine the comfort of fabrics in contact with the skin. His comfort assessments were based on what he referred to as 'terms commonly used by men and women to describe comfort'. It is interesting to note that all of his terms describe unpleasant sensations.

He designed a subjective comfort rating chart. This enabled the wearer to allocate a score of between 1 and 5 (depending on the comfort of the sensation) at specified time intervals. The comfort rating chart is shown in table 2.1 below.

Table 2.1 Hollies subjective comfort rating chart.

| Comfort | Minutes in environmental chamber | | | | | |
|---|---|---|---|---|---|---|
| Description | 0 | 15 | 30 | 45 | 60 | 75 |
| Stiff | | | | | | |
| Staticky | | | | | | |
| Sticky | | | | | | |
| Non absorbent | | | | | | |
| Cold | | | | | | |
| Clammy | | | | | | |
| Damp | | | | | | |
| Clingy | | | | | | |
| Picky | | | | | | |
| Rough | | | | | | |
| Scratchy | | | | | | |

Comfort Intensity Scale

1 -- 2 -- 3 -- 4 -- 5

Totally comfortable — Completely uncomfortable

This chart highlights the value and need for an intensity scale. The use of pre-determined words to describe sensations was also considered of value, both in terms of consistency in the results and as guidance. However, some of the terms used in the table appear to have the same meaning (for example, rough and scratchy, sticky and clingy), and for clarity when interpreting the results a short description of the sensation may have been of value. This is the most common basis for subjective comfort assessment.

Other approaches have been tried to quantify the overall comfort of a fabric, for instance Olsen and Broome (1977) measured the dilation and contraction of the pupil of the eye. They showed that pupil dilations were greatest for the most comfortable subjectively rated fabric. This method of assessment has only been investigated by these researchers, and although the results seem encouraging, the test can only give results on the overall preference for fabrics, rather than specific sensations, and therefore it is of limited value.

In comparison to clothing comfort, the fabric handle has been well researched and attempts to evaluate it in an organised and quantitative manner were recorded as early as 1926. Many of the methods of assessment can be directly related to the assessment of the comfort of clothing and the most relevant of them are outlined below.

### 2.2.2 Handle Assessments.

When a garment/fabric is being assessed by a potential purchaser, the feel of the fabric in their hands has a major influence on the acceptance or rejection of the product. The fingers are very sensitive due to their high concentration of nerve endings and therefore they are able to detect small differences between fabrics which the general body surface can not detect. The fingers are also capable of detecting a wider range of sensations than the general body surface due to the high concentration of nerve endings and the mechanical action of handling a fabric. The Americans have standardised a selection of handle terms (ASTM, 1961) to describe this range of sensations. Many of the terms relate to fabric aesthetics, and overall they are said to describe both the handle and the texture of the fabric. However, at this time no standard glossary of terms exists to describe the sensations experienced by the general body surface. Therefore the handle terms are useful as a guide to the range of sensations that could be experienced when wearing a fabric, but a number of researchers have noted that the relationship between handle and in-wear comfort is not a simple one (Hollies, Yoon et al).

Handle has mainly been researched by two methods: by subjective assessment alone or the relationship between this and the mechanical properties of the fabric. Many different approaches have been tried within these methods to characterize the handle, and some of the most notable are mentioned below.

1) <u>The Subjective Assessment of Handle.</u>

The subjective assessment of handle can be of value both in terms of determining the relative importance and severity of a sensation, and this information can be used to relate the fabric properties to physical parameters. Some of the most common and a few novel ways of assessing a fabric(s) are briefly described below.

1) Matsuo (1971, 1972) introduced the concept of "differential limen". This is an expression of an observer's limit of discrimination for changes in a particular fabric mechanical property. An observer is characterized by a series of 'differential limen' for a range of fabric properties.

2) A range of fabrics can be ranked for specific handle properties in small groups or as pairs. Alternatively the specific handle properties are described by a set of polar words. For example, hard versus soft (Brand, 1964, 1967). Howarth and Oliver (1958, 1964) used factor analysis (devised by Thurlastone (1947)) to identify the specific handle properties deemed desirable in a range of suiting, lingerie and dress fabrics. All the descriptive terms used were noted, and the frequency with which each occured was calculated. This frequency was used to describe the fabric properties.

3) Bogaty et al (1956) used a seven point scale to evaluate sensory harshness by polar adjectives and Winakor et al (1980) used a 99 point scale. This had the advantage of providing a large amount of information for statistical ranking.

The ranking of fabrics in pairs or small groups would help the assessor to make a more realistic judgement as to the properties of a fabric, than if the fabric was considered on its own. The use of scales was found to cause variability between judges. Both Bogaty et al and Howarth and Oliver stated their concern about the inconsistent use of scales between judges and along the scale. It was obvious from the research work in this area that although the results of the handle assessments were conclusive from each of the studies, the method of assessment was suited to the particular aims of the study, and therefore the work could not be directly compared.

2) The Relationship Between Subjective Assessments and the Mechanical Properties of the Fabrics.

Many researchers have sought to relate objective measurement to subjective assessment of the handle of a fabric. This has been comprehensively reviewed by Ellis and Garnsworthy (1980).

Kawabata is one of the most successful and best known of these researchers. During the past 15 years he and fellow workers have assessed the main properties that are detected and prefered for a selection of end-uses when a fabric is handled. With this information, test equipment was developed to describe a number of physical properties that describe the handle of a fabric. There are six major fabric features that are tested: the tensile and shear forces, the bending hysteresis, resistance to compression, the coefficient of friction and the surface profile of the fabric surface. Kawabata has developed his handle evaluation system further with the inclusion of an instrument to measure the initial cold feel of a fabric. This equipment was developed by Kawabata and Akagi (1977) and Yoneda (1981). Similar equipment has also been produced by I.C.I. Fibres Ltd. in the UK, but it has not been reported in the literature.

Various properties can be determined from the test methods and by using a series of equations (to weight the importance of these properties), a primary or a total hand value can be quoted depending on the end-use of the woven fabric. The primary hand value (PHV) refers to a specific handle property, for instance smoothness or crispness, and it ranges from 0 (low) to 10 (high). The total hand value (THV) is used to describe the overall handle of the fabric, and it ranges from 0 (poor) to 5 (excellent).

The PHV and THV are of limited value, and in the latter case somewhat suspect. It can be envisaged that the importance of an extreme value for a particular property could be disguised in the equations and a seemingly average result produced. The THV is considered to be of suspect value because it is too simplistic to describe such a complex sensation/ series of sensations by one numerical value between 0 and 5. It is more than likely that two different fabrics could have the same THV but very different handle acceptability. Nevertheless, the concept of determining the sensations that can be experienced, and subsequentially developing test procedures to characterize them, enabled Kawabata to objectively define the sensations. The equations used to determine the total hand value weight the importance of each primary hand sensation for a specific end-use. For instance, the crispness of the fabric is of great importance for summer suiting and of less importance for winter suiting (for the Japanese). This information on its own is of greater interest than an accumulation of the results when a fabric is being developed for a particular market. Therefore the Kawabata Handle Evaluation System has its greatest value as a means of describing the individual physical properties of a fabric, rather than the production of a single value to describe the overall handle.

At present no such evaluation system exists to determine the comfort of a fabric in wear. However, there is equipment available to assess specific properties relating to wet cling sensation. To determine more about the general comfort of a wearer, the results and inferences of previous wearer trials that have been carried out to determine the factors governing specific discomfort sensations (prickle, wet cling and so on) were reviewed. The findings were assessed in connection with tactile comfort.

## 2.3 Research on Clothing Comfort.

Until recently the only factor thought to be of major importance in the comfort of clothing was its thermo-physiological features, and many researchers have explored the factors governing it. Other sensations were known to exist, but they were of little interest in comparison to the maintainance of the thermal balance and moisture regulation of the wearer. The presence of other comfort sensations was considered by a few researchers, but the studies were usually very specific (for example, for wool only) or related to thermo-physiological comfort with a limited range of fibre and fabric types. The research work on all aspects of clothing comfort is discussed and combined to create an overall view of the state of current knowledge on tactile comfort.

### 2.3.1 Thermo-physiological Comfort.

The transfer of heat and moisture through a garment or a fabric has been well researched and much is known about this subject. The thermo-physiological comfort of fabrics and garment assemblies has been related to objective measurements which can be made by many different techniques. These techniques can range from the sophisticated heated, moving manikin, a sweating hot plate, a dry hot plate to a water vapour transmission test (see below). In many cases the data from these test methods can be fed into comfort equations (outlined in Newburgh, 1968, Spencer-Smith, 1976, Anon, 1980) to predict comfort when the fabric is being worn. Although many researchers have investigated the factors influencing this aspect of comfort, one main concept is adopted by all of them: the body needs to maintain its temperature within a narrow limit. A fabric or garment should therefore be able to aid in the maintainance of this balance. This can be achieved by either retaining heat or releasing heat and/or water vapour to the ambient environment.

## 1) Methods of Assessment and Factors Effecting Thermo-physiological Comfort.

One of the most experienced researchers, Hollies has worked on the thermo-physiological comfort of clothing since 1950. In 1971 he reported that the comfort of a fabric was dependant on its water content. This in turn was related to the amount of sweating and the relative humidity of the atmosphere. In later experiments Hollies and Hall (1975) and Scheurell et al (1985) impregnated shirts with colbaltous chloride to determine the water content and comfort of the wearer by the colour changes of the fabric. The fabric passed through ten colour changes, from blue to pink as up to 30 per cent of water was added to the fabric. The fabric was tested on a sweating hot plate and it was assessed during wear. Although Farnham (1986) contested the assumption that the colbaltous chloride was an accurate measure of water content in such investigations, it was concluded that the comfort acceptance of a fabric worn next to the skin was in some way related to the ability of the fabric to remove the sweat from the skin:fabric interface.

One of the most advanced methods of assessment for the thermo-physiological comfort of a fabric or garment assembly has been developed by the Hohenstein Institute in Germany (reported by Mecheels and Umbach). They have developed a series of physical test methods (heated manikin and a sweating hot plate) to predict the discomfort of different fabric assemblies at various activity levels. Once the fabric or garment has been tested, the data can be entered into a multi-dimensional comfort chart, where the optimum activity level and ambient conditions for thermo-physiological comfort are determined.

Wet cling was considered to be a major discomfort sensation and it was found to be reduced by a hairy fabric surface and a high rate of water absorption. They characterized a hairy fabric surface by the number of protruding fibre ends and the length of the hairs from the centre of the fabric. They found good correlation between low fabric hairiness and wet cling discomfort. The wettability of a fabric was determined by timing the disappearance of a drop of water on the fabric surface. It was found that the time for the drop to be absorbed correlated with the subjective sensation of clamminess (r = 0.8).

Hollies et al (1979) assessed clothing comfort by human perception analysis. They compared the comfort of apparel garments during normal wear under different micro-climates and activity levels. The aim of their work was to determine the conditions that produce a difference in a sensation and the descriptors used by the individuals to describe the sensations experienced. They found good agreement between their results for different fabrics, even with a small wear panel. For instance, strong sensations were noted when mild or heavy sweating occured and during modest changes when the body was warming or cooling following the onset of sweating.

The results of this trial and earlier studies by Hollies (1965,1957) indicate that when there is no perspiration present, the differences between garments are quite small. They specified exceptions to the rule as apparel fabrics that are so slick and smooth that they feel cold and clammy all the time, or perhaps very rough and scratchy fabrics that give these sensations independent of the climate or the activity level. They concluded that the differences in the ability of clothing to accomodate any changes in the moisture level at the skin:fabric interface and the amount of skin:fabric contact are the major features of apparel that give rise to discomfort sensations.

Mehrtens and McAlister conducted environmental chamber trials to determine the fibre properties responsible for garment comfort. The subjects wore knitted sports tee-shirts of acrylic, nylon, viscose rayon and cotton next to their skin in an environment of 32°C and 80 per cent relative humidity. They found that the scratchiness of the fabric was the major factor determining comfort under these conditions.

Their wearer trials also identified the clinginess of a fabric as contributing significantly to the discomfort of the wearer. In spite of the low magnitude of this sensation, there was fair correlation between the subjective clinginess and the force required to remove a fabric from a wet surface (measured as a function of the water content of the fabric). The fabric was placed against a porous, water soaked surface of pressed asbestos, and then it was pulled nearly parallel to the surface by the Instron Tensile Tester. The maximum tension, which occured when the fabric began to slide, was plotted against the water content of the fabric. The range in clinging tension with water content for the series of fibres tested was greatest at approximately 150 per cent water (of the dry weight of the fabric). The sensation of clinginess was also found to be a function of the flexural rigidity of the fabric. The lower the flexural rigidity, the greater the clinginess. Overall, they attributed increased clinginess to a reduction in the ability of the fibres in the fabric to break up the water film causing adhesion between the fabric and the skin.

One of their most notable findings was that wickability had no detectable influence on the comfort of a wearer under the conditions of test. Wicking has and still is a popular marketing feature of a textile product in terms comfort. More recently there have been doubts as to its significance. One of the main arguments against the importance of wicking to the comfort of a fabric is that it is a measure of a fabrics ability to transport water along its length. For the wicking properties to be representative of an in-wear situation, a measure of the ability of the fabric to transport the water through the fabric, away from the skin would be more valuable, but as yet this can not be measured. Overall, they found that wet cling increased as the fibre flexural rigidity decreased and fabric wickability had no detectable effect on comfort.

Fuzek (1981) conducted wearer trials to determine the comfort of absorbent and non-absorbent fibre types. He found that a fibre blend was the most comfortable (50% polyester/50% cotton), with soft fabrics being the most favoured. Fibre modulus and the linear density of the fibre and the yarn inversely correlated with the comfort of the knitted fabrics he assessed ($r = 0.81$) and the fabric stiffness and the flexural rigidity measurements did not show a correlation ($r = -0.07$). He determined the effect of several moisture related parameters on the subjective comfort. Among these were moisture regain, wettability, water retention and absorption, wicking rate and water vapour transfer. Of these, he found that none showed highly definitive correlations with the subjective comfort ratings.

2) Hydrophilic and Hydrophobic Fibre Comfort.

A comparison of the relative comfort properties of hydrophobic and hydrophilic fibres has been a major issue for researchers in the field. Some of the researchers (Fuzek (1981) and Vokac, Køpke and Keul (1976) Chapman (1980), Lord (1969)) found that the hygroscopic properties of a fibre had little effect on the comfort of the wearer. Paek (1984) reported that the hygroscopic properties did have an influence on the comfort of the wearer, but it was most evident under the conditions of moderate environmental stress. However, Suzuki (1983/1 and 1983/2) and Suzuki and Ohira (1982) concluded that the absorption properties of a fibre have a great influence on the comfort of the wearer. They found that an absorbent fibre was more comfortable than a non-absorbent fibre, and that the use of double-sided fabrics with cotton on the inside and polyester on the outside surface could be used to reduce discomfort. They also found that variations in the fibre type reduced the feeling of wetness, for instance, polyester, cotton and wool had a decreasing feeling of wetness for a certain water content.

Although much has been reported on the benefits of absorbent or non-absorbent fibres on the comfort of the wearer, the author considers that the relative importance of the discomfort produced by sweating itself is somewhat over-valued by researchers and consumers. If the discomfort due to the hygroscopic properties of the fibre was as important as it is often portrayed by the marketing slogans, it would be unlikely that the range in findings on the comfort of the fibres would be so confused and contradictory by both independent researchers and those affiliated to a particular company. The perception of other discomfort sensations (besides moisture related properties like wet cling) has been reported to increase in the presence of sweat. This has been demonstrated by a few researchers such as Umbach and Mecheels, Hollies and indirectly by Mehrtens and McAlister.

3) Thermo-physiological Discomfort in Relation to Other Sensations.

The comfort trials conducted by Mehrtens and McAlister and Fuzek led them to conclude that the thermo-physiological discomfort sensations were of minor importance in comparison to other skin sensations. Mehrtens and McAlister proposed a comfort equation that included the four major factors that they consider influence the sensation of comfort: scratchiness (which was the greatest form of fabric discomfort), warmness, heaviness and clinginess of the fabric.

Fuzek (1981) concluded that the fit of a garment had an over-riding influence on the subjective comfort. Next in importance was the fibre and garment style the wearer was used to wearing and thirdly the aesthetic factors such as handle, softness, smoothness and fabric surface. Of much less importance were the moisture related properties and finally the thermal trans mission factor.

These studies highlight the importance of a number of sensations to the overall comfort of a wearer. However the work was still heavily orientated towards the performance of a fabric/fibre in relation to its thermo-physiological properties and the range of fabrics tested was very small. Some research has been directed towards understanding specific discomfort sensations related to certain fibre types or well known discomfort sensations - in particular, prickle discomfort produced by wool fibres, fabric scratchiness and garment fit.

### 2.3.2 Prickle.

Various studies have been carried out on the assessment of the comfort properties of wool and the factors producing the discomfort associated with the fibre. Hoschke (1982, 1983) investigated the adverse effects of wearing wool next to the skin. He carried out wearer trials in which the subjects wore both woven and knitted wool fabric samples as an arm-band, a vest and a shirt/blouse. The comments on the prickliness and skin reddening were recorded throughout the trial.

It was found that the feeling of prickliness in some wool fabrics was associated with the presence of coarser fibres, in particular those fibres with a diameter of greater than 40 µm. A fabric made from 23 µm wool fibres containing 7 per cent of 40 µm fibres was generally found to be prickly to wear, and it frequently caused skin reddening. Whereas, a fabric containing mainly 19 µm wool fibres was considered comfortable. Hoschke also noted that knitted fabrics were judged as being more comfortable than woven fabrics, and this was attributed to the high stiffness of the woven material and a large contact area with the skin.

The fabrics were assessed on the Kawabata Handle Evaluation System and the results did not show any relationship between the fabric properties measured and the prickliness sensations of the wearers. Work is continuing to examine the influence of fabric finishing on prickliness. The results so far have indicated that the chlorine-Hercosett treatment (to produce a superwash wool by removing the fibre surface scales) does not reduce prickliness, again endorsing their conclusions that the large fibre diameter is the major factor producing discomfort from wool.

### 2.3.3 Scratchiness.

The scratchiness of a fabric has been found to be a major discomfort sensation (Mehrtens and McAlister, Umbach and Mecheels) and it has been related to the presence of fabric surface hairs or the flexural rigidity and coefficient of friction of the fabric. Umbach and Mecheels of the Hohenstein Institute found that the upstanding hairs and fibre ends can be scratchy against the skin. Their index of hairiness was found to correlate with the sensations of smoothness, scratchiness and roughness, and when the hairs were long or there were many short hairs, this also produced a scratchy sensation. From this they concluded that the hairiness of a fabric needs to be optimized for overall comfort.

Mehrtens and McAlister developed a test method in which a microphone was passed over the fabric at approximately 7 m/min (arbitary speed) and the signal produced was found to correlate with the subjective scratchy sensation. They concluded that the scratchiness of a fabric was influenced by the flexural rigidity of the fibres and the friction of the fabric.

A series of experiments were carried out by LaMotte (1939) and Katz (1925) to determine the influence of vertical or lateral pressure on the perception of fabric properties on the skin. Their studies indicated that the perception of fabric weave and roughness is likely to depend on the following factors:

- The amount of skin displacement upon contact with the fabric.
- The density of the weave pattern.
- The rate of lateral movement between the skin and the fabric.
- The diameter of the yarn in relation to the space between the yarns.

This was investigated more fully by Swallow and Webb (1972) who undertook a series of experiments to evaluate the frictional properties of fabrics on human skin. The influence of fabric wetness, skin hairiness, operator differences, load and fabric weave relative to the direction of the pull were investigated. The equipment measured the frictional force needed to pull a fabric (mounted on a block of known weight) across the dorsal surface of the lower arm. For the fabrics they tested, weave direction was not demonstrated as being of any significance, but the wetness of the fabric did have an effect. The mean frictional force was 0.81 when the fabric was dry, and 0.41 when the fabric was wet. The coefficient of friction increased as the fabric became wetter and then there was a gradual reduction as the fabric became saturated. The higher friction of the wet fabric was more marked at lower loads and on a smooth skin rather than a hairy skin.

They found that the adhesion at zero loading was negligible for dry fabrics, but it was substantial for wet fabrics. The coefficient of friction corrected for adhesion at zero load was also greater for wet fabrics than for dry. The friction on smooth skin was higher in all conditions than a hairy skin and it increased with increasing the load. The scratchiness of a fabric in wear is therefore more noticable when the skin is damp due to the higher coefficient of friction which could lead to greater skin damage.

Comaish (1973) conducted a similar trial to determine the factors influencing blister formation. He concluded that the damage to the skin was best avoided by reducing friction between the skin and the rubbing surface. This was best achieved by lubrication with copious amounts of liquid or the inhibition of sweat. Both of these methods are impractical for everyday wear. Nevertheless, the work emphasises the importance of friction on the comfort of the skin.

From these studies the scratchiness discomfort of a fabric can be seen to be related to the rigidity of the fabric and the coefficient of friction between the skin and the fabric. Therefore the presence of sweat has an influence on the scratchiness and possibly skin damage when the friction is increased.

### 2.3.4 Garment Fit.

It is well known that a tight fitting garment can be uncomfortable, painful and restricting to wear. The optimum pressure that can be exerted on the body by the garment has been investigated by a number of researchers. Denton (1971) carried out a series of arm-band studies to determine the pressure associated with red-restriction marks on the skin. He deduced that at pressures above approximately $70 g/cm^2$ the persistence time for the marks increased rapidly after half an hour, and the arm-bands simultaneously became uncomfortable.

Kirk and Ibrahim (1966), Fentem and Goddard (1979) and Lemmens (1974) studied the comfort pressures exerted by stretch garments. Kirk and Ibrahim categorised stretch garments into three main types:

1) Comfort stretch garments. These are not necessarily close fitting and many garments will have this type of stretch.
2) Stretch to fit garments. These are designed to fit closely to the body contours without exerting pressure to shape the figure.
3) Power-stretch garments. These are designed to exert pressure to re-shape the figure.

They considered that for comfort, the fabric stretch should be at a level to provide 'dynamic comfort' (when the body is moving), taking into account the fabric stretch, garment slip and garment fit. They also assessed the percentage strain of different areas of the body (for example the knees, elbow, buttocks) relative to the standing position. From this work they recommended ranges of percentage available stretch for garments with a specific end-use and comfort requirement. This ranged form 20 per cent for a man's suiting to 50 per cent for slacks where comfort is paramount. Therefore stretch allowances should be made to accomodate for the strain at different body locations to maintain wearer comfort during various activities.

The most comprehensive investigation into the optimum fit of a garment was carried out by Johansson (1984) and Cednas (1985). Initially anthropometric measurements were taken on a large cross-section of the Swedish population and the average body sizes have been established for the different categories of the population. Using this anthropometric information they developed a set of apparatus to test various garments for the maximum and minimum body circumference that would be comfortable wearing them. The comfortable pressure of 0.25 $N/cm^2$ was selected (estimated value for comfort) for the chest and girth tension, and 1 N and 15 N were considered to be the maximum tension for the arm-hole and neck hole (to allow for the head) respectively.

The body can withstand different pressures comfortably at different locations. For instance, the buttocks can withstand a higher pressure than the shins (Scribano et al, 1970). As yet, there is no indication of the discomfort threshold for the common local fitting areas of garments (such as waistbands, sock tops, etc.) which would enable a more accurate sizing of garments for particular activities and body sizes.

## 2.4 Consumer Preference.

The use of wearer trials can demonstrate the potential performance of fabrics and fibres in somewhat artificial situations. The attitude of the general public to the comfort properties of various fibres and fabrics may be less well informed from on the spot questioning than in wearer trials, but it highlights the factors that are of importance to the consumer. Very few studies of this type have been carried out, the most notable is the survey by Paek (1983).

One hundred female American textile students participated in a survey to determine the consumer preference for fabrics to be worn next to the skin. The survey included questions regarding the fibres and fabrics that the interviewee prefered to wear against their skin as underwear, sleepwear and blouses. From the completed replies, 56 were randomly selected for final analysis. The results showed that knitted fabrics were prefered for underwear, and the type of fibre made little difference to comfort preference. Woven cellulosics were prefered for blouse fabrics, followed by blends, then silk and polyester, and cellulosic knitted fabrics were least liked for blouses. The main comfort attributes required for a blouse were thermo-physiological, but smoothness was also highly desirable. The most prefered fibre type for sleepwear were cellulosics, both woven and knitted.

The interviewees were also asked to rank the three most important comfort attributes (out of a selection of eight) for a blouse fabric. Absorbency, smoothness and thermal attributes were selected as the major comfort factors with 26.5, 23.5 and 22 per cent of the votes respectively. Thinness, compactness and bulkiness were less important with 5.5, 5 and 2 per cent of the votes respectively, and no one regarded roughness as a comfort attribute.

As concluded by Paek at the time of this study, most of the preferences for fibre type indicated that the interviewees liked the ones that were readily available for the particular end-uses indentified.

## 2.5 Conclusions.

The literature review revealed a large range of research studies that have been conducted on the various aspects of comfort. Most of the research has been done in isolated areas of interest and the conclusions from the different studies are muddled. This review emphasised the importance of assessing the comfort of a garment as a whole because of the many factors that can influence any one sensation. The specific discomfort sensations can only be usefully investigated once the overall comfort of the garment, and any possible factors influencing the sensation, have been established.

The presence of sweat on the comfort of the wearer was found to heighten their awareness of other skin sensations which are directly related to its presence, such as scratchiness. By itself, the discomfort produced by the presence of sweat was of conflicting importance depending on the fibre type being investigated and the research workers. Therefore despite all the effort that has been concentrated in this area of study, there are still many questions to be answered.

Ideally, to obtain knowledge on the major discomfort sensations that can be experienced from next to the skin apparel, a more extensive study needs to be conducted to include all aspects of clothing comfort. A full range of commercially available apparel fabrics need to be assessed during a range of activities. This will enable the spectrum of discomfort sensations which are experienced to be determined and assessed. From this type of study a hierarchy of the potential discomfort that these fabrics could produce under different conditions would then be more meaningful to everyday life. It would hopefully provide the foundations for more specific future studies. This research project aims to do this, with the ultimate aim for the future of producing a multi-dimensional comfort diagram to describe clothing comfort.

# CHAPTER 3.

## TERMINOLOGY.

The terminology used to describe the type and intensity of a tactile sensation has been surveyed in two main ways; first a review of published literature and second, extensive wearer trials using a revised list of words in questionnaires.

The literature survey revealed a large quantity of descriptive terms available to describe the handle of a fabric, but an overview of the type of sensations that might be felt whilst wearing a fabric does not exist.

To obtain the maximum amount of information and the most accurate description of subjective sensations from the wearer trials, an easily understood but precise glossary of terms is required. This enables both documented and undocumented sensations to be recorded and studied accurately.

Initially a large selection of words taken from a list of handle terms were presented for analysis to thirty men and women on the Shirley Institute staff. It should be noted that many of the staff were non-technical workers and from all levels within the company. They were asked to select the words they would prefer to use in describing the types of discomfort they have felt from garments. They also very briefly defined each word they had selected. It was evident that the sensations felt during wearing a garment were considerably fewer than those observed when handling a fabric. There was a definite preference for certain words, although there was some confusion as to their definitions. Many different words had equivalent definitions, presumably as a result of dialect and habit. A shorter revised list of terms was issued to the same staff for a second time. Each term was associated with a simile, for example, prickle (pin prick), scratchy (sandpaperish) and so on. Everyone agreed that the clarity and the scope of the list of terms was good.

This shortened list of terms was used, where appropiate, in the wearer trial questionnaires. As a knowledge of the types of discomfort sensation experienced from next to the skin apparel increased during the wearer trials, a few additional words were added to the list.

## 3.1 Definiton and List of Terms.

The definition of the main terms used in the wearer trials are listed below.

| | |
|---|---|
| Wet cling | When a garment adheres to the skin because either the skin or the fabric is wet. |
| Tacky cling | When a garment adheres to the skin because the skin is sticky from sweat residues . |
| Clamminess | The skin feels cold and damp simultaneously. |
| Scratchiness | An abrasive sensation, as if the skin is being rubbed with a piece of sandpaper. |
| Prickle | A sensation of being pricked with a sharp point. |
| Tickle | This is associated with a fabric passing over the skin under a light load. The sensation can be directly related to when a feather is passed over the skin. |
| Local fit | Areas of a garment where the fit is more exaggerated, for example at waist-bands, sock tops, arm-hole seams. |
| Local irritation | This term encompasses any sensation caused by garment accessories or stitching, for example seams, labels, trimmings. |
| Fibre shedding | When a fabric releases fibres into the air and onto the skin during normal wear and the wearer notices the loss. |

| | |
|---|---|
| Itch | This sensation can originate from many factors including all of the above mentioned sensations. It is a feeling of wanting to scratch the skin. Initially this term caused the most confusion because it was used universally to describe many of the more specific sensations. |
| Initial cold feel | The fabric surface feels cold when a garment is donned. The opposite is initial warm feel. |
| Pickiness | This is almost exclusively a handle sensation caused by loose skin and nails catching on a fabric surface. It can be likened to Velcro™, in that one surface has loops (fabric) and the other surface has hooks (hands). |

## 3.2 The Magnitude of a Sensation.

The magnitude of a sensation is somewhat harder to define. There are five main regions that could be included on such a scale for each sensation. At the top of the scale is 'pleasantly aware'; this is when the wearer registers and likes a sensation. Second is neutrality, when the wearer does not 'feel' a sensation. Third, is a region where the wearer can detect a sensation, but it is neither liked nor disliked. The next region is that of discomfort and finally the scale will end with pain. If a 10cm line is used to describe the "severity scale", the divisions between the five regions will not be equal for a particular sensation. If wet cling is taken as an example, the majority of the scale (9.5cm) will be dominated by neutrality, awareness and discomfort. Wet cling is never painful (0cm) and it would be very unusual for it to be considered pleasant (0.5cm). The scale will also vary from sensation to sensation; for instance scratchiness is invariably uncomfortable and painful and therefore the scale would be dominated by these regions. They are dependent on an individual's own preferences and prejudices, which will also influence the size of a region. A hierarchy can be developed for the severity of the skin sensations. This depends on the size of the five main regions which are occupied by the sensation on the severity scale, in particular the ability of the sensation to be painful and cause skin damage. This is termed the "Potential discomfort ladder" and it is shown in table 3.1 below.

Table 3.1 Potential discomfort ladder.

| |
|---|
| **Most Discomfort** |
| Tight fit, Scratchiness |
| Prickle |
| Tickle, Fibre shedding, Label irritation |
| Tacky cling |
| Wet cling |
| Initial cold feel |
| Least discomfort |

## 3.3 Conclusions.

The range of terms selected for this study were used throughout the project and enabled a precise assessment of a sensation to be made. Many of the terms are commonly used, but to eliminate any slight differences in the meaning of the words between people, a simile was used in conjunction with many terms. This practice may have to be adhered to until a standard terminology is accepted and widely understood. The range of terms selected for this study were able to describe in detail the sensations that were felt by the subjects in the wearer trials conducted, and it is proposed as a standard terminology.

# CHAPTER 4

## WEARER TRIALS.

The primary aim of the wearer trials was to determine the range and type of the most common, unpleasant skin sensations that are experienced whilst wearing garments next to the skin. In addition, a knowledge of the major factors causing the discomfort, the frequency and the severity of the sensations was to be gained. Although the comfort properties of different fibres and fabrics were of prime interest, any part of a garment that comes into contact with the skin during wear was considered. This included labels, seams, trimmings and local fitting areas (overall garment fit was outside the scope of this project).

It was decided from the start of this project that the first wearer trial should include a wide range of commercially available fibre types and fabric constructions and not development products. The fabrics were worn next to the skin as tee-shirts or vests. The wearers were not told the fibre content of the fabrics or any other information which might influence their decision on the types of sensation that they could experience from the fabric/garment. A particular significance was put on a wearer's own interpretation of the in-wear properties of the fabric. Thereby allowing a fresh look at the range of discomfort sensations that can be produced by next to the skin apparel, and avoiding any predetermined conclusions as to which sensations are and are not important. The next stage was to analyse each major discomfort sensation (as identified by the main wearer trial) individually using more specific wearer trials.

This proved to be a very successful approach:

(a) It led to the recognition of a common but undiscovered discomfort sensation, tacky cling.

(b) The majority of skin sensations which had been documented by past researchers were experienced; but the factors causing these sensations tended to vary between the results of the wearer trial and past research. For instance, the author considers discomfort due to wet cling to be at its worst when the fabric is weakly adhered to the skin. The opposite conclusion to other researchers. In addition a better insight into the factors which can produce a skin sensation was achieved. For example, it was found that garment fit can exaggerate or decrease the level of discomfort of a particular skin sensation.

(c) The relative importance of each discomfort sensation was indicated. Some sensations could be painful and cause skin damage (scratchiness) whereas others were less severe (initial cold feel).

(d) A comprehensive, but concise selection of terms as established for describing the common discomfort sensations (see chapter 3). These terms could also be used to precisely analyse less common sensations; hence the discovery of tacky cling (which in the past had presumably been assumed to be the same as wet cling).

## 4.1 Main Wearer Trial.

The main wearer trial involved 20 Shirley Institute staff as subjects. They included 10 men and 10 women, ranging in age from 20 to 60 years (appendix 1, table 3). The subjects were selected so that a range of different activities were covered by each age group. Three main levels of activity were categorised as strenuous, normal and sitting (not sleeping). Each subject was requested to continue with their chosen routine of activities throughout the trial.

The subjects were required to wear and assess knitted fabrics worn as a tee-shirt or vest and woven fabrics which were included as slip-on tops. The 22 fabrics selected for the wearer trial covered a wide range of fibre and fabric types, see table 4.1. This table is included in appendix 1 (table 1) so that it can be referred to for reference throughout this thesis. All of them (except fabrics 16 and 17 which were development grades) were commercially available for next-to-skin apparel. Where possible the fabrics were made-up into garments at the Shirley Institute so that a standard sizing system was achieved. Subject's had their own garment for each of the fabrics they assessed. The subjects were not told the fibre composition of the fabrics, and where possible the cloths were plain white to reduce the

Table 4.1 Technical data on the main wearer trial fabrics.

| Fabric number | Fibre compostion | Structure |
|---|---|---|
| 1 C | Polyester (65%), cotton (35%) | Honey-comb |
| 2 | PVC (90%), nylon (10%) | 1 x 1 rib |
| 3 C | Polypropylene (90%), nylon (10%) | String vest |
| 4 | Cotton (90%), nylon (10%) | Eyelet |
| 5 | Wool (50%), polypropylene (50%) | 1 x 1 rib |
| 6 | Polyester (50%), viscose (50%) | Interlock with 8x2 dropstitch. * |
| 7 | Wool (100%) | Interlock |
| 8 | PVC (85%), acrylic (15%) | Interlock. * |
| 9 | Cotton inside, polyester outside | Interlock with 8x2 dropstitch. * Double fabric |
| 10 C | Polypropylene (90%), nylon (10%) | 1 x 1 rib |
| 11 C | Superwash wool inside, polyester and nylon outside (90:10%) | Interlock. Looped inside |
| 12 | Polyester (100%) | 1 x 1 rib |
| 13 | PVC (85%), acrylic (15%) | Eyelet |
| 14 | Polyester (100%) | Interlock |
| 15 | Angora (40%), lambswool (40%), nylon (20%) | 1 x 1 rib |
| 16 | Superwash wool (100%) | 1 x 1 rib. * |
| 17 | Superwash wool (100%) | 1 x 1 rib |
| 18 C | Polypropylene inside, cotton outside | Interlock. * |
| 19 C | Polypropylene inside, acrylic, wool (80:20%) outside | 1 x 1 rib |
| 20 | Polyester (100%) | Plain weave |
| 21 | Acrylic (Dunova) (60%), cotton (30%), nylon (10%) | 1 x 1 rib |
| 22 | Viscose (100%) | Twill |

Note:
* The fabric has been sueded and has a hairy inside surface.
C The fabrics were made-up into garments commercially.
All the fabrics are knitted except fabrics 20 and 22 which are woven.

influence of personal preference or prejudice. Four fabrics were not white; fabric 18 was dark blue with thin green hoops, 19 was plain dark blue, 20 was plain middle blue and 21 was white, pink and blue hoops.

Subjects wore their garment at least twice, once before and once after it was washed. All the garments were machine washed at the Shirley Institute using the Home Laundering Consultative Council wash code 6; only fabrics 15 and 7 were carefully hand washed to avoid shrinkage. The washing powder used was non-biological Persil automatic. The majority of fabrics were tumble dried with the temperature setting midway on the synthetic range. The remainder of the fabrics (numbers 2,5,7,8,13,15,16, and 17) were line dried indoors to avoid shrinkage.

Subjects mainly wore their trial garments during the day, either at work, playing sports or at home. The maximum and minimum temperture and relative humidity was recorded for the period between 0900 to 2100 hours throughout the trial, the information was obtained from the records at the Manchester Weather Centre. A graph of the temperatures and relative humidities during the trial are shown in figure 4.1.

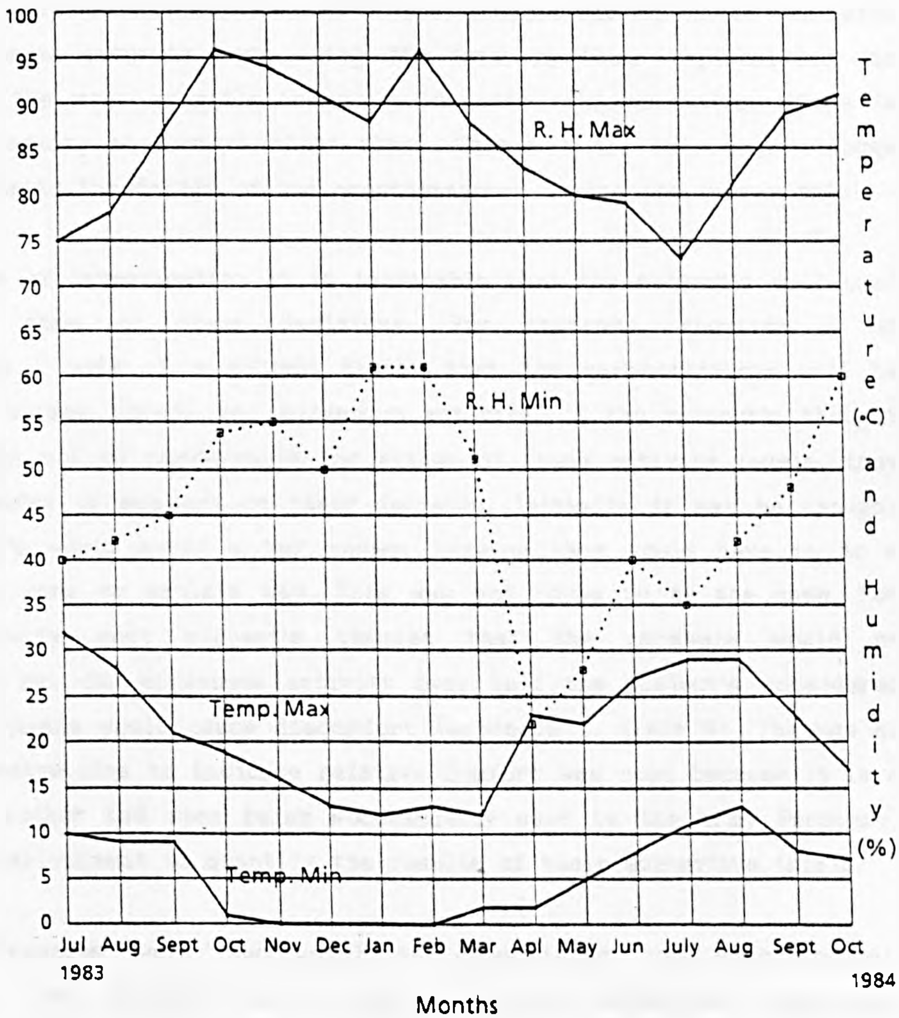
### 4.1.1 The Questionnaires.

Two questionnaires were issued when a trial garment was first given to a subject. The first, questionnaire 1, was used to analyse the initial response of the subject to the handle and the general appearance of the fabric and garment, and to predict any in-wear discomfort. In addition, a record of the discomfort after wearing the garment for the first five minutes was taken. Questionnaire 2 was used to record and analyse any discomfort sensations that were registered after wearing the garment for a number of hours. After the garment was worn and washed, questionnaire 2 was re-issued and completed by the subject. See tables 4.2 and 4.3.

The questionnaires were designed so that as much information could be obtained about the origins and the type of sensations which were being experienced whilst a subject was wearing a garment. The questions were designed to make the subject's think about all the discomfort sensations

**Figure 4.1**

The maximum and minimum temperature and relative humidity in Manchester between 0900 to 2100 hours during the wearer trial.



individually, so that none of them would be over-looked or forgotten by the wearer. The terminology used in the questionnaires was easily understood by the subject's. They tended to use the same terminology in the questionnaire in their explanations to describe the causes and the severity of the sensation being felt. Initially the term 'itchy' was not included in the questionnaire because it was considered to be a general term which was used to describe many sensations, such as tickle, prickle and so on. It was later included because subjects were using the term in their explanations (in addition to the more specific terms) to describe this sensation alone (a feeling of wanting to scratch their skin). This was the only major change that was made to the design of the questionnaires during the wearer trial.

In this type of investigation it is inevitable that the subject's will need to qualify some of their decisions. For instance, question 3 of questionnaire 1 asks if a subject thinks that the garment/fabric will be comfortable during normal and strenuous activity. If the subject's thought that it would not be comfortable for either of these activity levels, they were then asked to comment on their decision. Initially it may be thought that subject's would avoid a 'no' answer because they would have to do a little extra work to explain why. This was not found to be the case. For normal activity most subject's thought that the garments would be comfortable, but for strenuous activity over half the subject's considered that the garments would cause discomfort (appendix 1, table 9). The use of a ten centimetre line to indicate relative comfort was used because it is a method the author had seen being successfully used by the Army Personnel Research Establishment to quantify the results of their subjective trials.

The questionnaires were successful in determining the psychological, physiological and physical factors influencing the sensations experienced by the wearers.

Table 4.2

Date:

QUESTIONNAIRE 1

Name: Garment: Subject:

You have been issued with a garment to be used as a vest or tee-shirt for wearing next to the skin.

Before you put the garment on:

1. What is your initial reaction to the fabric and the garment itself?

   Do you like it?

   Would you buy a vest or tee-shirt made out of this material?

   Other comments:

2. What do you think the fabric is made of?

   cotton ☐

   wool ☐

   man-made fibre (specify) ☐ ______________

   blend wool/m-m ☐

   cotton/m-m ☐

3. Do you think the garment/fabric will be comfortable to wear during:

   (a) normal activity Yes ☐ No ☐

   (b) strenuous activity Yes ☐ No ☐

   If you answered 'no' to (a) or (b), please explain why:

4. Before wearing the garment for the first time, indicate on the 10 cm lines below

(a) how the fabric felt to you (its handle)
(b) the position or range in which you expect comfort to lie for this type of garment.

4.1 <u>Surface handle</u>

(a) very rough/scratchy ________________ smooth/slippery

(b) very rough/scratchy ________________ smooth/slippery

4.2

4.2 (a) hot/warm ________________ cold

(b) hot/warm ________________ cold

4.3 (a) stiff ________________ limp

(b) stiff ________________ limp

4.4 Do you have any other comments to make on the "feel" of the fabric?

4.5 Do you expect the fabric to produce static?

No ☐ slightly ☐ moderately ☐
badly ☐ very badly ☐



<u>Answer this next section in the first 5 mins of wearing the garment</u>

5. <u>Put the garment on</u>: does the fabric/garment feel as you expected?

Yes ☐ No ☐

(i) What type of fibre do you think the fabric is made of now?
(Cotton, wool, man-made fibre, blend)

(ii) Do you think the fabric will be comfortable for:

(a) normal activity Yes ☐ No ☐

(b) strenuous exercise Yes ☐ No ☐

If your opinion has changed from your initial reaction to the fabric/garment, please comment:

(iii) If the fabric feels different now you are wearing it, please use a different coloured pen on the 10 cm lines in section 4 and specify below how the handle has changed.

(iv) Any other comments:

Table 4.3

QUESTIONNAIRE 2

1. Name: ______________________ Subject Number: __________

2. Garment Number: ______________________ Washings: __________

3. Was the fit: (answer (a), (b), and (c))

(a) very good ☐ average ☐ uncomfortable ☐

(b) baggy ☐ average ☐ tight ☐

(c) Do you have any comments to make on the appearance?

4. Date you wore the garment: ☐☐☐☐☐☐

5. Was the weather:

- Hot ☐
- Warm ☐
- Cool ☐
- Cold ☐
- Humid ☐

6. What type of clothing were you wearing with the garment?

- Nothing ☐
- Vest ☐
- Bra ☐
- Full-length underskirt ☐

Anything on top (please specify):

7. How long were you wearing the garment?

| | |
|---|---|
| 0 - 3 hours | |
| 3 - 6 " | |
| 6 - 9 " | |
| 9 - 12 " | |
| longer than 12 " | |

8. Indicate below how your activity level changed during the time you wore the garment.

Time scale: start — time of wearing garment — finish

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Strenuous exercise | | | | | | | | | | |
| normal activity | | | | | | | | | | |
| sitting | | | | | | | | | | |

(Please tick approproate boxes)

9. Did you sweat? Yes [ ] No [ ]

If the answer is 'Yes', please indicate below when you sweated and where.

Use 'U.A' for under-arms

'A' for all over

start — time of wearing garment — finish

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

Was the fabric wet after you were sweating? Yes [ ] No [ ]

If Yes, How quickly did the fabric dry once it was wet?

| Immediately | quickly | moderately quickly | slow | not at all |
|---|---|---|---|---|
| | | | | |



Questions on the material

10. Did it feel?

| very rough | rough | coarse | slightly coarse | smooth | slippery |
|---|---|---|---|---|---|
| | | | | | |

| very stiff | moderately stiff | slightly crisp | slightly limp | limp | very limp |
|---|---|---|---|---|---|
| | | | | | |

11. Did you feel?

| very wet | wet | damp | sticky | dry |
|---|---|---|---|---|
| | | | | |

| very cold | cold | cool | neutral | warm | hot | very hot |
|---|---|---|---|---|---|---|
| | | | | | | |

N.B. If your reactions changed during different activities, to any of the above questions, please indicate by using the key letters.

:

se = strenuous exercise

n = normal activity

s = sitting

in the appropriate boxes.

12. Was the clothing at any time:
(Tick box if the answer is 'YES')

- Clammy ☐
- Clinging due to sweat ☐
- Charged with static electricity ☐
- Bulky ☐
- Stretchy ☐
- Scratchy (sand paperish) ☐
- Prickly (pin pricks) ☐
- Tickly (Feather, hair) ☐

Any other comments:

13. Did the fabric make you feel itchy and want to scratch?

| | | | |
|---|---|---|---|
| All the time | ☐ | wherever the garment touches you | ☐ |
| Some of the time | ☐ | on your shoulders and neck | ☐ |
| not at all | ☐ | seams, labels, welts, trimmings | ☐ |
| | | elsewhere (specify) | ☐ |



14.

14.1 Did you feel discomfort at any time, (no matter how slight)?

Yes ☐ No ☐

14.2 Was the discomfort due to:

- (i) nature of the fabric itself ☐
- (ii) localised factors (e.g. labels, seams) ☐
- (iii) fit ☐
- (iv) weather ☐

If (iv) was chosen, did the other factors ((i) (ii) and (iii)) aid, hinder or do nothing towards the discomfort?

Please give as many details as possible to accompany 14.2, for instance, where you felt discomfort?
Why (is it specific to you)?
Which factor was worst?

| | Yes | No |
|---|---|---|
| Was the discomfort increased by movement | ☐ | ☐ |
| " " " " " sweat | ☐ | ☐ |

Do you have any other comments to make?

## 4.1.2 First Impressions of a Fabric.

It was clear from the results of questionnaire 1 that the success rate for guessing the fibre composition of a fabric was low, with 6 out of 22 fabrics having a 75 percent success rate (see appendix 1, table 6). The wearer tended to look at the fabric as a whole and to generalise on its properties from these observations; for instance, was the fabric smooth, coarse or hairy, shiny or dull, natural or a man-made fibre. The assessor would then link these observations with past experiences.

Although the range of fabrics and number of people in the wearer trial was relatively small, the determination of the fibre content by handling a fabric was poor, even by the well informed such as Shirley Institute staff. The fabrics could be seen to be grouped into stereo-typed roles.
The wearer trial fabrics were grouped into three such categories:

(1) Cotton or cotton/ man-made,

(2) Wool,

(3) Man-made.

In the case of the latter group, when a subject did specify the man-made fibre (such as polypropylene, nylon, etc.), this was attributed to the awareness of textiles of the assessors. The general public would undoubtedly be less informed. The fabrics that the author considered to be typical of their fibre type were 1, 4, 7, 9, 15, 16, 17, 20. The success of guessing the fibre type correctly of the fabrics typical of their fibre type had a mean value of 11 (± 3.8). The remainder of the fabrics had a mean success rate for guessing fibre type of 4 (± 2.5). If the correct and partly correct values for these two groups of fabrics are taken, the mean values are 15 and 7 respectively. Therefore it can be seen that knowledgeable assessors can only predict fibre content of a fabric with just over a 50:50 chance of getting the correct answer, and 75 percent of a partly correct or correct answer, even when the fabrics are considered to be stereo-typed.

There were strong indications that the handle of a fabric was of little value in the prediction of discomfort sensations. A decision on the overall comfort of a garment/fabric is difficult due to the highly subjective nature of the decision. Questionnaire 1 found 19 out of the 22 fabrics to be considered comfortable by more than 75 percent of the wearers for normal activity levels. The overall comfort assessment was very rarely changed after wearing the garment for a number of hours. Most changes in comfort decisions were with the wool fabrics where approximately one quarter of the subjects thought that the fabric was more uncomfortable than expected (appendix 1, tables 9 and 17). Questionnaire 2 showed that whilst subject's wore their garments, most of them experienced and commented on the presence of discomfort of some kind. Once subject's had decided that the fabric was comfortable, unless extreme discomfort was experienced (which was highlighted with the wool fabrics), the overall decision on comfort remained the same.

The difference in the general attitude of a wearer to the fabric and its actual performance displays the large influence personal preference can have on their overall assessment of the fabric. However the presence of the discomfort sensations is not forgotten. The nylon shirt of the 1960's and 70's is a good example of this, where the shirt was worn because it was easy-care and fashionable. After a while the discomfort due to wet cling and static electrical build-up was perceived as highly objectionable. This was not due to the shirt suddenly producing the discomfort, but it was a decision which was built up over time due to the frequency of these sensations. If the discomfort was not present, the shirt could still be popular today. Therefore, although personal preference does influence the wear comfort of the garment, people do notice any discomfort sensations. If another fabric or garment is available which will satisfy their aesthetical needs equally, they will undoubtedly chose that product. Therefore, to ensure that new and existing garments, fabrics and fibres are suitable for a particular end-use it is necessary to assess the fabrics accordingly in a standard way. The most practical and useful assessment of the in-wear comfort of a product would be obtained from physical test methods which are quick, easy to use and reliable. The development of such equipment is discussed in chapters 6 to 13 according to the sensation being investigated.

The appearance of a fabric is therefore very important to a potential wearer. The comfort/discomfort properties of a fabric are usually associated with the fibre content and not the fabric construction or garment design. An example of this is again the nylon shirt which, due to its tight knitted construction, caused a wearer to feel (amongst other sensations) wet cling discomfort. However the general public linked the discomfort to the fibre (discussed in chapter 5) and assumed that all fabrics made from nylon would cause wet cling discomfort. The relationship of the assumed fibre content of a fabric and the opinion of the subject as to whether or not they like the fabric showed cotton and cotton or wool blends to be amongst the most favoured (80 percent liked the fabric), whereas only 36 and 27 percent respectively liked wool and nylon (appendix 1, table 7).

A person carries a typical image of the appearance of fabrics made from the fibres they most like and dislike in their minds. If the fabric they are observing should roughly fit one of these images, then a decision on the potential in-wear comfort is made. The ranking of fibres for comfort was investigated further in a public questionnaire, see chapter 5.

## 4.2 Handle and In-Wear Comparisons.

All the wearer trial subjects conventionally handled the fabrics. Therefore the majority of the information (besides visual inspection) came from the thumb.

During a handle assessment a concious effort is made to register every tactile sensation, and because the fingertips are highly sensitive, an accurate profile of the fabric can be achieved. Comments to question 4.4 (questionnaire 1) showed that handle can detect surface fabric structure, drape and some chemical finishes, but surprisingly, not fabric surface hairiness. This is because the thumb flattens any protruding fibres and gives the impression of a smooth surface. In contrast, when a garment is donned, the brain will register the change in conditions for the first few moments. After this time the brain will stop conciously acknowledging information from the skin, and the wearer will not notice the garment (assuming there are no major discomfort sensations). Initially and after a number of hours, one of the most noticable sensations when a garment was donned was the presence of fabric surface hairs and tickle (appendix 1, table 17, but no mention of the finishes or fabric construction were recorded by the subjects throughout the trial.

The results from the questionnaires showed that there was a large discrepancy between the prediction of the in-wear properties from handling a fabric, and the actual in-wear characteristics as discussed above. However, when purchasing or developing a new product, it is inpractical to test each new fabric in garment form, or to carry out physical tests to assess its comfort. A buyer, designer, research worker and consumer, to name but a few, need to be able to screen a range of fabrics as quickly and as cheaply as possible to ensure that the best products are obtained. What is needed is a quick and more reliable handle method to screen a fabric more thoroughly than the conventional technique.

Four methods of handle analysis were designed. These methods are described in appendix 4, Smith, 1986. In brief they include:

1) Conventional handle,
2) Rubbing the fabric with the finger-tips to determine the surface hairiness and the rigidity of the fibres.
3) Lightly passing the back of the hand over the fabric surface to determine prickle, scratchiness and initial cold feel.
4) The same as (3) but using the inner forearm.

A combination of all four techniques is necessary to obtain the most information, but they are listed above in order of the least (1) to the most (4) relevant method. Nevertheless, these handling methods are not totally reliable. Tickle, initial cold feel, scratchiness and prickliness may be indicated from this procedure, but wet cling, tacky cling, fibre shedding, label, seam and local fit discomfort cannot be predicted to any degree.

## 4.3 Sensations Identified.

The main wearer trial established the following as the most common major discomfort sensations that are experienced from next to the skin apparel.

1) Tight fit.
This could be due to local fitting areas (such as waist-bands) or to the garment fit as a whole. The fit of a garment has an overriding influence on all the other sensations because it governs the amount of relative movement between the skin and the fabric. This movement leads to the wearer registering a change in conditions on the skin surface, a sensation. Excessively loose clothing was also found to be uncomfortable and restricting, but to a lesser extent than tight fit. This thesis will only consider the fit of local areas.

2) Wet cling.
This is due to liquid sweat adhering the fabric to the skin, and when the body moves this bond is broken and the wearer feels wet and cooler due to an increased rate of sweat evaporation. Tacky cling is a similar sensation which is caused by the presence of damp sweat residues on the skin. As for wet cling, discomfort is experienced when the fabric moves over or is released from the skin.

3) Tickle.
This was a relatively common sensation that was mainly linked to the body hairs being moved when the fabric passed over the skin. The skin was more sensitive to tickle on the shoulders and around the neck, especially when the wearer was just starting to sweat.

4) Prickle.
This sensation can be likened to pin-pricks. It was only experienced from the wool fabrics in the wearer trial, but it can also be caused by monofilament sewing threads and label corners. A high density of prickle produced a scratchy sensation.

5) Scratchiness.

This can produce skin abrasion and it is therefore potentially very painful. It was associated with structured fabric surfaces (such as a honey-comb) and garment seams. The major factor which influences the discomfort is the movement of the fabric/seam over the skin, and in addition the presence of moisture reduces the ability of the skin to resist abrasion.

6) Local Irritation.

The term local irritation refers to the discomfort caused by any part of the garment other than the fabric or a tight fitting area. These additional factors can be garment labels, seams, fastenings and trimmings. The type of sensation that can be produced by these factors is varied, but it is commonly prickle and/or scratchiness.

7) Initial cold feel.

This is the cold feeling which is experienced when a garment at a lower temperature than the skin is donned. It is only felt in cold weather and it is associated with a smooth non-hairy fabric surface which allows a rapid transfer of heat from the skin to the fabric.

8) Fibre shedding.

Only one fabric in the wearer trial produced discomfort due to the fabric shedding fibres; however when it did occur the sensation was most uncomfortable. The released fibres caused tickle, prickle and general facial irritation, along with unsightly hairs attaching themselves to other surfaces. The fabrics which shed fibres had very hairy loose twist yarns.

9) Static electricity.

This proved to be a minor discomfort sensation, with the main discomfort being associated with the fabric clinging to the body and the presence of visible sparking during doffing, and after the fabric had been tumble dried. The sparking could be painful, but the wearers appeared to accept the fabric charging as inevitable and not a major discomfort sensation.

10) Allergies and dermatitis.

There was an isolated case of a suspected allergic reaction to a fabric in the wearer trial, but investigation into this topic was outside the scope of this project.

## 4.4 Counter-stimuli.

Depending on the number of skin sensations present at any one time, only the most uncomfortable/painful one will be noticed. The other sensations will be registered when the wearer conciously thinks about them; a situation known as counter-stimuli. This is also the case when the wearer is concentrating on an activity, when their attention is not on the clothing (unless of course the sensation is extremely objectionable and/or it impairs their performance). This means that when a garment is assessed for comfort/discomfort, it is necessary for the wearer to conciously think of every sensation individually, and to try to ignore the others. This procedure was encouraged in the wearer trials by the design of the questionnaires and by explaining counter-stimuli to the subjects. This means that each sensation was assessed on its own merits and it reduced the chances of not detecting a discomfort sensation.

## 4.5 Specific Wearer Trials.

Wearer trials and physiological tests were conducted to evaluate more fully many of the major discomfort sensations that were identified in the main trial. The people included in these specific trials were mainly Shirley Institute staff, many of whom had not taken part in the main wearer trial. The overall aim was to identify more fully the factors causing a particular sensation, and where possible, to determine a discomfort threshold. The results of these trials were used as the basis for the development of test procedures to measure the potential discomfort of fabrics and garments, for example instruments to test a fabric for wet cling, local fit and fibre shedding were produced. Where a new test procedure was not relevent or practical, recommendations were made which usually included routine test procedures to screen a fabric, as in the case of prickle.

An example of one of these trials is the investigation of tickle. The speed of the fabric moving over the skin, the hairiness of the skin and/or fabric and the pressure at the point of contact were analysed and ranked for their influence on the severity of the sensation. The discomfort caused by garment labels was also highlighted in these additional trials. The importance of which was further emphasised when over 65 percent of the people in the public questionnaire (see chapter 5) claimed to cut the labels out of their garments due to discomfort. These and other trials are discussed in the appropiate chapters of this thesis.

## 4.6 Conclusions.

The wearer trials were successful in identifying the major discomfort sensations that can be experienced from next to the skin apparel. Some of the sensations had been identified by other researchers, however the majority of the information gained from these trials was unique and original. This wearer trial was the first of its kind to establish the range and severity of sensations which can be experienced from next to the skin apparel, without concentrating on pre-determined sensations or fibre types which were of particular interest. The results of this wearer trial and some more specific wearer trials led the author to challenge many of the more established ideas on the comfort of clothing.

The terminology used to describe the range of sensations which can be experienced whilst wearing next to the skin apparel was established. The sensations registered by handle and whilst wearing the fabric were quite different, and therefore their terminology varied. It is doubtful if any additional major discomfort sensations would be experienced by the body from common next to the skin apparel due to the wide range of fibres and fabrics used in the trial. If other sensations do exist, they are likely to be linked to a specialist end-use which would be of limited significance to the general population. Although the number of people taking part in the wearer trial was relatively small (20), the range of ages, activities, personal preferences for both genders was large. The number of underwear fabrics included was also large considering the types of fibre and fabrics presently available on the market. The results are taken to be representative of the general population (which do not have allergies to the fibres and fabric finishes used) because the physiology and methods of stimulation will be the same for the trial subjects, as it is for the rest of the population.

The handle of a fabric was found to be a poor judge of the comfort or discomfort of a garment in wear. Four new methods to assess the in-wear properties of a garment were designed so that handle will be a more informative process. Nevertheless, handle will never be able to predict the comfort of clothing when it is being worn. This due to the physiological differences between the fingers and the general body surface, such as the presence of hairs and variations in the concentration of nerve endings. A more reliable method of predicting in-wear comfort is needed. One which will be cheaper, quicker and more reliable/consistent than wearer trials, which are avoided nowadays due to these problems. The development of test methods and recommendations are discussed for each major discomfort sensation in chapters 6 to 13.

# CHAPTER 5

# PUBLIC QUESTIONNAIRE.

The main wearer trial established that the majority of decisions on the in-wear performance of a fabric are made before the garment is worn. The appearance and handle of the fabric are therefore of prime importance, but what do people look for and why? To determine more about the general attitudes of the public, a series of questions were designed to discover just how important the aesthetics and handle are to the consumer, which properties they require or avoid and how they recognise their presence. The questionnaire provides an insight into the reasons why preferences and prejudices arise, what the public think is the main cause of discomfort and the frequency and severity of skin discomfort sensations.

## 5.1 The Questionnaire.

A public questionnaire was designed to determine the discomfort and comfort properties associated with particular fibres when worn against the skin. The questions were aimed at expanding on the knowledge gained so far in the main wearer trial. The questionnaire was initally written by the author. Advice was then sought from Dr. B. Stollery (University of Manchester Medical School), an experienced psychologist, on the design of the questions to ensure that they were not leading and that the terminology used would be self explanatory. Advice was also sought from Mr. Latham (University of Salford) and Dr. R. McNamee (University of Manchester) on the design of the questionnaire in terms of the statistical analysis of the results.

The relative severity of the sensations associated with the fibres, and the precautions people would take to avoid the fibres they thought to be the most uncomfortable was investigated. The differences in ranking for in-wear comfort by handle between a selection of fabrics when they are seen and when they are not seen was of major interest. This was done by comparing two sets of fabrics, one set of jumper fabrics and the other of blouse/shirting fabrics for this purpose. Finally, the overall comfort of garment parameters such as elastic bands at the waist, sock tops and in underwear and discomfort due to garment labels were assessed. The questionnaire is shown in figure 5.1.

The questionnaire was issued to 1004 men and women in the north-west of England in late summer 1984. The public were interviewed by professional market researchers to ensure maximum feed-back. The questionnaire was designed for people of 16 years and above; this is because they will have formed their own opinions as to the comfort of particular fibres and fabrics and they are likely to purchase their own garments. Four age groups were indentified, these were 16 to 25 years, 26 to 40 years, 41 to 54 years and 55 years and above. The first age group was seen as the highly fashion conscious the second, third and fourth groups were seen as prefering progressively more mature fashions and traditional wear. A cross section of the socio-economic classes was taken. This was divided into two groups of social class for the questionnaire, (1) the non-manual workers (approximately one third of the population), termed the ABC1 social class, and (2) the manual and the non-workers, termed the C2DE social classes. The social class of a respondent was determined from the occupation of the head of the household by the interviewer. The number of interviewees which answered the questionnaire in each age and socio-economic group is shown in table 5.1.

<u>Table 5.1</u> <u>The number of interviewees that answered the public questionnaire in each age group and social class.</u>

| Gender → Age ↓ | Males | | Females | | Males + Females | |
|---|---|---|---|---|---|---|
| Social class → | ABC1 | C2DE | ABC1 | C2DE | ABC1 | C2DE |
| 16-25 | 43 | 86 | 49 | 86 | 92 | 172 |
| 26-40 | 44 | 78 | 44 | 85 | 88 | 163 |
| 41-54 | 36 | 74 | 49 | 78 | 85 | 152 |
| 55+ | 39 | 82 | 44 | 87 | 83 | 169 |
| 16-55+ | 162 | 320 | 186 | 336 | 348 | 656 |

| Social class → | Males ABC1C2DE | Females ABC1C2DE | Males + Females ABC1C2DE |
|---|---|---|---|
| 16-25 | 129 | 135 | 264 |
| 26-40 | 122 | 129 | 251 |
| 41-54 | 110 | 127 | 237 |
| 55+ | 121 | 131 | 252 |
| 16-55+ | 482 | 522 | 1004 |

Figure 5.1 The public questionnaire.

PREFACE

We are trying to establish which fabrics are most comfortable to wear against the skin and we are asking the public to help us by telling us their likes and dislikes.

(I am representing a textile research organisation called the Shirley Institute which is based in Manchester and we are doing a project for the EEC and British Textile Industry).

Please print where possible

Name of interviewer (print) ______________________

TOWN/PLACE of interview ______________________

Date of interview ______________

Name ______________________

Address ______________________

Age group: [ ] 16-25 [ ] 26-40 [ ] 41-54 [ ] 55+

Class: [ ] A/B [ ] C1 [ ] C2 [ ] D/E

Male [ ] Female [ ]

Occ. of respondent ______________

Occ. of head of household ______________

(relationship of resp.) ______________

Q1 Would you say you were particular about the fibres/fabrics you wear against your skin? (tick box)

- Very particular [ ]
- not really particular [ ]
- will wear anything [ ]

Q2 Do you look at garment labels to find fibre type when buying clothes?

A [ ]
S [ ]
N [ ]

Always, Sometimes, Never (tick box)

Show CARD 1

Q3

(a)
Can you tell me the 3 fibres you would most like to wear against your skin in order of preference?
(write 1 (best), 2 and 3 in boxes)

| A | B | C | D | E | F | G | H | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|
| Ac | Co. | N. | Py | S | A | V | W | M | Ag | L |
| | | | | | | | | | | |

(b)
Can you tell me the 3 fibres you would most dislike against your skin (in order)?
(write 11 (worst) 10, 9 in boxes)

Q4 For each of the 3 fibres you most dislike:-

(a)
Would you wear them against your skin in 100% form?
(tick box)

| | 11 | 10 | 9 |
|---|---|---|---|
| Y | | | |
| N | | | |

For each fibre, if No:-

(b)
Would you wear a fabric against your skin if it was blended with less than 30% of your favourite fibre?

| | 11 | 10 | 9 |
|---|---|---|---|
| Y | | | |
| N | | | |

If No:-

(c)
Wear a fabric with more than 30% of your favourite fibre?

| | 11 | 10 | 9 |
|---|---|---|---|
| Y | | | |
| N | | | |

Show CARD 2 (covered up) ask them not to look

**Q5**

Put these 3 fabric in order of preference for wearing next to your skin
(Put 1 (best) 2 and 3 (worst)

| M | S | L |
|---|---|---|
| | | |

Show CARD 3 (covered up) ask them not to look

**Q6**

Put these 4 fabrics in order of preference for wearing next to your skin
(Put 1 (best) 2,3 and 4 (worst)

| S | P | C | M |
|---|---|---|---|
| | | | |

Show CARD 4 (not covered)

**Q7**

Put these fabric in order of preference for wearing n-t-s
Put 1 (best) 2,3 (worst)

| S | L | M |
|---|---|---|
| | | |

Show CARD 5

**Q8**

Put these fabric in order of preference for wearing n-t-s
Put 1 (best) 2 and 3 (worst)

| P | M | C | S |
|---|---|---|---|
| | | | |

**Q9**

Do you buy clothes for other people? Y ☐ N ☐
If Yes-

For each person they buy for, put in the appropriate age/relationship box either A Always, S Sometimes

AGE

| Relationship | 0 - 15 | | 16 - 54 | | 55+ | |
|---|---|---|---|---|---|---|
| | M | F | M | F | M | F |
| child | | | | | | |
| friend/spouse | | | | | | |
| parent | / | / | | | | |

Do the people you buy for specify the fibre of fabric type they do and don't want you to buy? Always, Sometimes or Never.

Show CARD 6

**Q10**

If a garment was all of these factors, which of these factors would you find

| | Tight | Wet | Tickle |
|---|---|---|---|
| a) most | | | |
| b) least annoying | | | |

(tick box)

**Q11**

Which fabric do you like best against your skin in:- (a) hot weather (b) cold weather

fibre (write in) ______ ______

Why? water absorption ☐ ☐
warmth/coolness ☐ ☐
washing ☐ ☐

other reasons (specify) ______ ______

**Q12**

Do you buy any special clothes for sports or strenuous activities? Y ☐ N ☐
If yes, probe:-

(a) which fabrics/fibres? ______

(b) Why these fabrics/fibres? ______

**Q13**

Do you ever find bands of elastic too tight for
a) underwear ☐
b) socks ☐
c) waistbands ☐

**Q14**

Do you ever find tights/stockings uncomfortable in (a) hot weather (b) cold weather?

Hot weather: Y ☐ N ☐
Cold weather: Y ☐ N ☐

If yes for either (a) or (b) ask why ______

**Q15**

Do labels ever annoy you in:-
(a) pants/briefs ☐
(b) at the neck ☐
(c) side seam ☐

Would you cut them out Y ☐ N ☐

## 5.2 Results and Comments.

The results and statistical analysis for the public questionnaire are shown in detail in appendix 2. The main findings of the questionnaire are discussed below.

### 5.2.1 How Particular are People about the Fibres they Wear Next to Their Skin.

Initially the interviewees were asked to state how much attention they pay to the type of fibres they wear against their skin. Secondly they were asked how regularly they look at garment labels for the fibre type when purchasing. It was found that:

1) 48 per cent of women as opposed to 38 per cent of men said that they were very particular about the fibres that they choose to wear next to their skin.
2) The ABC1 social class was more particular than the C2DE social class, with 62 to 40 per cent of very particular people respectively.
3) The younger age groups were less discerning about the fibres they choose to wear against their skin than the older age groups. The 55+ age group tend to look at garment labels more frequently than any other age group.

A comparison of the answers to questions 1 and 2 showed that there was a correlation between how particular a person said they were about next to the skin fibres, and the frequency with which they look for the fibre type when purchasing. The more particular they are, the more frequently they will look for the fibre type, as shown in table 5.2 below (also see table 3 and 3.1, appendix 2). It was found that 65 per cent of very particular people would always look at garment labels for the fibre type, whereas 74 per cent of the people who said that they wear anything next to their skin never looked at labels.

Table 5.2 The relationship between how particular an interviewee is about the fibres they wear next to their skin and whether they look for the fibre type when purchasing a garment.
(expressed as a percentage for all the interviewees)

| How particular → Look for fibre type ↓ | Very particular | Not really | Wear anything |
|---|---|---|---|
| Always | 64% | 26% | 16% |
| Sometimes | 24% | 48% | 10% |
| Never | 11% | 26% | 74% |

### 5.2.2 The Most Popular and Unpopular Fibres.

Eleven common fibres were presented to the interviewee typed on a card (card 1). The fibres were acrylic, cotton, nylon, polyester, silk, acetate, viscose, wool, mohair, angora and lambswool. The interviewees were asked to choose the three fibres they would most like, and the three they would least like to wear against their skin.

Cotton was by far the most popular fibre because it had 74 per cent of all the first choice votes. Silk and lambswool, with 11 and 3 per cent of the first choice votes were second and third respectively. There were signifcant differences between the choices of the men and women, social classes and the age groups:

1) Women prefered a wider range of fibres than men. Men mainly said that cotton, silk and wool were best, whereas women prefered mostly cotton and silk, with the rest of the fibres having a reasonable spread of votes (besides acetate).
2) The C2DE classes tended to choose the man-made fibres and cotton more frequently than the ABC1 social classes.
3) The differences in choice between the age groups were seen as a distribution of votes from cotton to the other natural and man-made fibres. The younger age groups tended to prefer a wider selection of fibres than the older age groups, in particular lambswool and angora became less popular with increasing age. Lambswool was the first choice for 2 per cent of 16-25 year olds, whereas 0.5 per cent of the 55+ age group gave it that ranking.

The first choice of each interviewee is shown in table 5.3 below.

Table 5.3 The number of males and females in each age group and social class (1 = non-manual workers, 2 = manual workers and unemployed) that chose each fibre as their first choice for wearing next to their skin.

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Acrylic | 2 | 2 | 4 | 0 | 5 | 5 | 0 | 4 | 4 | 0 | 3 | 3 | 2 | 14 | 16 |
| Cotton | 62 | 112 | 174 | 62 | 126 | 188 | 64 | 126 | 190 | 66 | 131 | 197 | 254 | 495 | 749 |
| Nylon | 2 | 6 | 8 | 2 | 2 | 4 | 1 | 5 | 6 | 1 | 8 | 9 | 6 | 21 | 27 |
| Polyester | 0 | 1 | 1 | 2 | 5 | 7 | 3 | 2 | 5 | 2 | 5 | 7 | 7 | 13 | 20 |
| Silk | 10 | 22 | 32 | 13 | 17 | 30 | 16 | 19 | 25 | 10 | 7 | 17 | 49 | 55 | 104 |
| Acetate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Viscose | 0 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 |
| Wool | 2 | 12 | 14 | 2 | 0 | 2 | 0 | 4 | 4 | 2 | 11 | 13 | 6 | 27 | 33 |
| Mohair | 0 | 0 | 0 | 1 | 3 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 4 |
| Angora | 6 | 2 | 8 | 2 | 2 | 4 | 0 | 1 | 1 | 0 | 0 | 0 | 8 | 5 | 13 |
| Lambswool | 8 | 14 | 22 | 3 | 2 | 5 | 1 | 1 | 2 | 2 | 3 | 5 | 14 | 20 | 34 |

In question 3b the interviewee was asked to state the three fibres that they would most dislike to wear against their skin. On analysis of the questionnaires it became apparent that in a number of cases some confusion as to the rank order of the fibres had been made. The worst fibre, ranked 11th, was found to be more acceptable for wearing against the skin than the fibres ranked 9th and 10th (question 4). Therefore the three worst fibres selected by each interviewee were given equal status, and so each group of people has three times its number of votes.

The three most unpopular fibres were mohair, angora and nylon, with 20, 13 and 13 per cent respectively of the votes. The results and statistical analysis of question 3b are shown in table 5, appendix 2.

There were signifcant differences in the answer given by different gender, social class and age group. Most notably, women thought that polyester and silk (having 6 and 4 per cent more of the votes respectively) were more desirable, and angora, wool and mohair (having 9, 6 and 3 per cent less votes respectively) less desirable than the men. This is probably due to a wider range of fibres being readily available and acceptable to the female market. This questionnaire has shown that polyester and silk are considered comfortable fibres whereas angora and mohair, common in ladies winter apparel, are considered uncomfortable to wear. The youngest age group was found to like angora and mohair and dislike nylon and polyester more than the older age groups.

The extent to which a wearer would avoid particular fibres was determined from question 4. Men and women would equally avoid wearing their three most disliked fibres. The 26-40 age group was more likely to wear the fibres they said they disliked than the younger or older age groups. The older age groups tended to favour blends with less than 50% of a disliked fibre in them, whereas the 16-25 age group showed a slight trend towards wearing the fibre in 100 per cent form. This implies that the younger age groups are more willing to experiment with fibres, and that they may not have formed strong opinions about fibre comfort properties. They may also be more tolerant to discomfort due to fashion dictating fabric trends, which also means that garments have a relatively short life due to changes in fashion. The older age groups may feel that there is no need to wear the fibres they disliked in blend form because they have experience of a selection of other, more comfortable fibres which they choose to wear.

### 5.2.3 The Influence of Sight on the Assessment of a Fabric.

One of the most important parts of the questionnaire was the determination of the influence of sight on the ranking of a fabric for next to the skin comfort. This was done on two separate occasions. The interviewee was asked to rank three fabrics for comfort against the skin by placing their hand inside separate pockets of a bag (so that they could not see the fabric), each containing a fabric sample. The fabrics were in the form of plain coloured (blue or beige or cream) swatches cut from commercial sweaters; they were shetland wool,lambswool/angora and mohair. A second bag containing commercial blouse/shirt weight fabrics was presented to the interviewee in the same way, and these were ranked for comfort against the skin. In this case the fabrics were tussah silk, medium and a light weight plain weave polyester (I.C.I. Mitrelle™) and a silk crepe. The polyester fabrics had been designed to look like silk. After a few questions inbetween, samples of the same fabrics were given to the interviewee for ranking for comfort when they could both see and handle the fabric. The order of presentation of the samples was randomly varied between individuals and also between the seen and unseen assessments.

When the first set of fabrics was ranked both unseen and seen, the lambswool was undoubtedly the most favoured, with mohair and shetland wool fabrics coming jointly last. The lambswool was ranked first choice by 82 per cent of the interviewees when assessed unseen and 75 per cent when the fabrics were both seen and handled. When the fabrics were seen, some more definite trends appeared as shown in table 5.4. The 16-25 age group and the ABC1 classes prefered the mohair to the shetland wool fabric, whereas the males in the C2DE group prefered the shetland wool to the mohair fabric. These changes are undoubtedly due to the 'image' the fabric portrayed, and whether or not it was acceptable, either for fashion or comfort to a particular sector of the population. The difference in colour of the fabrics may have influenced a few decisions between the seen and unseen rankings. However the change in ranking of the fabrics was specific to certain groups of people, such as males C2DE, and this is highly unlikely to be due to colour preference. The number of rank changes made between the seen and unseen handle tests were 69 per cent for the first comparison, the majority of which occured between the shetland wool and mohair fabrics. Therefore the aesthetics of the shetland wool and mohair fabrics had more influence on the ranking decision than the handle of the fabric, thus proving the importance of fabric appearance on consumer acceptance.

<u>Table 5.4 The number of people in each age group and social class (1 = non-manual workers, 2 = manual workers and unemployed) that did not change the ranking of the mohair, shetland wool and lambswool fabrics.</u>

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Males | 10 | 30 | 40 | 11 | 17 | 28 | 8 | 20 | 28 | 10 | 17 | 27 | 39 | 84 | 123 |
| Females | 24 | 61 | 85 | 14 | 22 | 36 | 13 | 17 | 30 | 12 | 27 | 39 | 63 | 127 | 190 |
| Males + females | 34 | 91 | 125 | 25 | 39 | 64 | 21 | 37 | 58 | 22 | 44 | 66 | 102 | 211 | 313 |

The two polyester fabrics were prefered to the two silk fabrics when they were ranked unseen (the polyester fabrics were first choice for 79 per cent of the assessors). This ranking remained the same when the fabrics were ranked seen, but a more definite order of preference had been established. In this case 76 per cent of the interviewees made at least two rank changes (that is a change in preference). The changes were approximately equally divided between the fabrics, thus indicating the over-riding influence of personal preference for a fabric's aesthetics over its handle properties and an impartiality to any predicted discomfort. This relationship can be seen in table 5.5 below.

Table 5.5 The number of people in each age group and social class (1 = non-manual workers, 2 = manual workers and unemployed) that did not change the ranking of the polyester and silk fabrics.

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Males | 10 | 19 | 29 | 15 | 19 | 34 | 8 | 28 | 36 | 13 | 17 | 30 | 46 | 83 | 129 |
| Females | 7 | 22 | 29 | 7 | 21 | 28 | 9 | 16 | 25 | 16 | 17 | 33 | 39 | 76 | 115 |
| Males + females | 17 | 41 | 58 | 22 | 40 | 62 | 17 | 44 | 61 | 29 | 34 | 63 | 85 | 159 | 244 |

### 5.2.4 Buying Clothes for Others.

A general question was aimed at finding out how particular people are about the fibres and fabrics that are bought for them, and the type of people who purchase and receive the clothes. As expected, women buy the majority of clothes, especially between the ages of 26 to 54 years old. They mainly buy clothes for children and/or a spouse. In more than half the cases the decision on fibre content of a garment is left up to the purchaser and the recipient does not state an opinion. The results are summarised for all the people taking part in the public questionnaire in table 5.6 below.

Table 5.6 The percentage of interviewees who buy clothes for other people (Y) and do not buy clothes for other people (N) in each social class (1 = non-manual workers, 2 = manual workers and unemployed) and age range.

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Y | 34 | 38 | 37 | 57 | 58 | 58 | 53 | 45 | 48 | 35 | 30 | 32 | 45 | 43 | 43 |
| N | 66 | 62 | 63 | 43 | 42 | 42 | 47 | 55 | 52 | 65 | 70 | 68 | 56 | 57 | 57 |

## 5.2.5 The Most Objectionable Skin Sensation.

Question 10 of the questionnaire was included to determine which common skin sensation is most disliked. Three of the most common and well known discomfort sensations were chosen from the findings of the main wearer trial and general knowledge. They were presented to the interviewee as shown below (typed on card 6):

A) The garment being too tight.

B) The garment clinging when wet.

C) The garment feeling tickly or hairy.

The interviewee was asked to imagine that a garment had all of the three discomfort properties, and to say which of the three they would find most and least annoying.

The results showed that tickle was the most annoying sensation; tight fit was second and wet cling was definitely the least annoying. The proportion of people choosing these sensations as the most uncomfortable was 60, 31 and 9 per cent respectively. The results of question 10 are shown in table 5.7 below and in table 15 in appendix 2.

Table 5.7 The number of interviewees in each age group and social class (1 = non-manual workers, 2 = manual workers and unemployed) who said that tickle, tight fit or wet cling would be the most annoying sensation if a garment produced all three sensations.

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Tight | 24 | 49 | 73 | 28 | 47 | 75 | 28 | 47 | 75 | 30 | 61 | 91 | 110 | 204 | 314 |
| Wet | 14 | 14 | 28 | 7 | 13 | 20 | 6 | 10 | 16 | 9 | 18 | 27 | 36 | 54 | 90 |
| Tickle | 54 | 109 | 163 | 53 | 103 | 156 | 51 | 95 | 146 | 44 | 91 | 135 | 202 | 398 | 600 |

This indicates that hairy surfaces and wool-like fabrics, which are commonly associated with tickle, may well be avoided. Tight fit, although ranked as the most uncomfortable sensation in the main wearer trial was placed second in this questionnaire. This could be due to many reasons. Some of the most likely are that it was a difficult question to answer without actually experiencing the sensations, and therefore the rank order is likely to vary. The perceived tightness of fit which is envisaged is also very much up to an individual to decide at the time of answering the question. A moderate discomfort level was probably chosen, otherwise the person would be unlikely to consider wearing the garment, but tight fit has the potential to be painful. Therefore in this case (for a moderate discomfort level) the rank order would agree with the wearer trial findings.

### 5.2.6 Fibres Prefered for Hot and Cold Weather.

The interviewee was asked to state which fibre they would choose to wear against their skin in hot weather, and the fibre they would choose for cold weather. They were also asked to say why they had made this choice.

In hot weather cotton was undoubtedly the most popular choice, taking 924 out of a possible 1004 votes. The other fibres which were of secondary preference were silk, nylon, polyester and a cotton/man-made blend. The main fibre property which over half the interviewees mentioned as their first priority for hot weather clothing was coolness. The ability of the fibre to absorb sweat, its easy-care properties and comfort were of secondary importance.

The fibres most favoured for cold weather clothing spanned a wider range than for hot weather. Cotton was still ranked the favorite with 39 per cent of the votes, but wool was also ranked highly with 33 per cent of the votes. Lambswool was the third most popular with 9 per cent of votes. The ranking of the fibres for all the interviewees is shown below (also see table 18, appendix 2):

Cotton and wool.

Lambswool.

Cotton/man-made, thermal, acrylic and nylon.

Silk, wool/man-made, polyester, don't know, angora, mohair and 'any fibre'.

Men and women had different preferences for fibres. Cotton was the most popular fibre for males with wool being a close second (219 to 165 of a possible 482 votes). Lambswool and a cotton/man-made blend had considerably fewer, but equal votes (27 votes each) and in particular they were selected by the younger and older age groups respectively. Females favoured cotton, but to a lesser extent than the males, with wool being slightly more popular (162 to 173 votes). The women mentioned a wider range of fibres that they would choose to wear for cold weather clothing; notably lambswool, thermal fabric, cotton/man-made blend, nylon and polyester. The most important property of a fibre for cold weather was, not surprisingly, warmth, where 61 per cent of the people interviewed stated this as the first reason for selecting a fibre. The next important reason was comfort with 10 per cent of the votes, and don't know and non-allergenic each had approximately 7 per cent of the votes. The most favoured fibres to be worn next to the skin in hot and cold weather and the reasons why the fibres were chosen are shown in table 5.8.

Table 5.8 The number of males and females who most liked to wear the particular fibre against their skin in hot weather, cold weather and the reason for their choice. (number of answers)

| Weather → Fibres ↓ | Hot | Cold |
|---|---|---|
| Acrylic | 1 | 27 |
| Cotton | 915 | 385 |
| Nylon | 21 | 19 |
| Polyester | 13 | 13 |
| Silk | 29 | 15 |
| Viscose | 1 | 3 |
| Wool | 2 | 341 |
| Man-made (mm) | 1 | 4 |
| Cotton/mm | 16 | 41 |
| Thermal | 1 | 30 |
| Any | 1 | 5 |
| Don't know | 3 | 10 |
| Mohair | 0 | 6 |
| Angora | 0 | 10 |
| Lambswool | 0 | 84 |
| Wool/mm | 0 | 7 |
| Linen | 0 | 2 |
| Towelling | 0 | 2 |

| Weather → Reasons ↓ | Hot | Cold |
|---|---|---|
| Absorbency | 93 | 18 |
| Coolness | 346 | 0 |
| Washing | 30 | 30 |
| Thin/light | 31 | 0 |
| Soft | 9 | 39 |
| Comfort | 47 | 54 |
| Natural | 3 | 5 |
| Clean/fresh | 3 | 6 |
| Durability | 2 | 1 |
| Non-allergenic | 21 | 56 |
| Always worn it | 5 | 3 |
| No wet cling | 8 | 1 |
| I don't sweat | 24 | 8 |
| No static | 2 | 1 |
| Retains shape | 3 | 0 |
| Cheap | 1 | 0 |
| Warmth | 0 | 430 |
| Don't know | 0 | 3 |

These results contradict the answers to question 3b when wool was ranked the fifth worst fibre with a high score of 278 votes (or approximately 10 per cent of the total votes) for an end-use in next to the skin garments. This difference in opinion implies that when wool is directly compared with other fibres (typed on a card in the case of question 3b), a person tends to think of wool as being more uncomfortable than when they are selecting a fibre without any guidance. In this latter case the interviewees were likely to have selected the first fibre that came into their heads. In most cases, the people who had selected wool did say that they chose it for warmth. This is a property commonly associated with wool and it is of obvious importance in cold weather. Nevertheless the likelihood of a person wearing wool, such as shetland wool against their skin is low. Most woollen garments are designed to have shirts or blouses worn underneath; the garments intended to be worn next to the skin are generally made from finer wools, such as lambswool, and they are generally for the fashion market. It is likely that an interviewee could have stated wool instead of lambswool, and therefore the difference between the ranking of the two fibres for this question is probably due to a generalization.

The man-made fibres were more highly rated for wearing next to the skin in cold weather. One of the main reasons for this is the lack of the need for the fibre to keep the wearer dry and to wick sweat away from the skin (a property that was appreciated by the general public). The ability of the fabric to absorb sweat and "breathe" (a phrase commonly used by the interviewees) were of low priority on the list of properties, being 4 and 1 per cent respectively of the total reasons stated.

### 5.2.7 Fibres Prefered for Sportswear.

The people who play sports were asked to say which fibres and fabrics they wear for their particular sport, and the first choice was noted down. One fifth of the interviewees answered this question and the majority of them played a racquet, team or track sport (this was recorded by the interviewer as an extra comment to question 12). These sports have similar fabric and garment requirements and therefore they were grouped together for statistical analysis (see table 20, appendix 2). The fibres that were mentioned were ranked in the following groups to a significant level of difference:

Cotton (63 per cent of votes).

Cotton/man-made, nylon, polyester (14, 7.5, 4.5 per cent of votes).

Acrylic, man-made fibre, towelling, wool and silk (all had 1.5 per cent of votes besides silk which had 1 per cent).

The reasons why these fibres and fabrics were chosen were similar to those mentioned for hot weather clothing, namely coolness, comfort, easy-care, absorbency and that a person had no choice in the garments they wear or buy (see table 21, appendix 2). Nowadays the majority of garments for these sports are a cotton/man-made fibre blend, with many fabrics being 100 per cent polyester or nylon. Relatively few garments are available in 100 per cent cotton. Assuming the interviewee purchases garments specifically for their sport (and does not wear everyday tee-shirts of 100 per cent cotton), their clothing probably looks like cotton. However it is most likely to be a cotton/man-made blend. The common image of cotton, being cool, comfortable and absorbent is evident in the reasons why a fibre/fabric was chosen for a sportswear end-use.

### 5.2.8 Garment Discomfort.

The women were asked to comment on any discomfort they have experienced from tights and stockings. This question was included because they are a very common next to the skin garment. In hot weather 65 per cent of the women said that they found them uncomfortable, 22 per cent did not feel discomfort and 14 per cent do not wear them. In cold weather 11 per cent of the women said that they had felt discomfort, 85 per cent did not feel discomfort and 4 per cent of women do not wear them. The percentage of women in each age group who found tights uncomfortable in hot and cold weather can be seen in table 5.9. The reasons for the discomfort were mainly related to the properties of nylon fibre and not the fabric construction. Some of the most common phrases used to describe the discomfort were: 'it doesn't breathe', 'it makes my legs hot', 'holds the heat', 'sweaty'. The health aspects of tights were also of importance; they were said to cause rashes, thrush and they were generally not healthy.

Table 5.9 The percentage of the women in each age group who find tights uncomfortable (Yes), comfortable (No) and do not wear tights (Don't wear).

| Age group → | 16-25 | | 26-40 | | 41-54 | | 55+ | | 16-55+ | |
|---|---|---|---|---|---|---|---|---|---|---|
| Weather → | Hot | Cold | Hot | Cold | Hot | Cold | Hot | Cold | Hot | Cold |
| Yes | 61 | 11½ | 72 | 17 | 68 | 8½ | 57 | 6 | 64½ | 10½ |
| No | 16 | 76 | 15½ | 80½ | 22 | 89 | 35½ | 91½ | 22 | 84½ |
| Don't wear | 23 | 12½ | 12½ | 2½ | 10 | 2½ | 7½ | 2½ | 13½ | 5 |

Questions 13 and 15 were included in the questionnaire to determine the general opinion on commercial garment comfort and design. The interviewees were asked if they experience discomfort (in garments of their own size) due to tight fitting elastic in underwear, socks and waistbands. The results are shown in table 5.10. Overall it was found that each of the areas of local fit mentioned were uncomfortable. Females found that elastic in socks was the least uncomfortable out of the three, which is probably due to the lower number of women who wear socks and possibly to the comfort of their socks. Elastic at the waist was marginally more uncomfortable than in underwear. Males however found elastic at the waist least uncomfortable and in socks the most uncomfortable. In the main wearer trial the fit of a garment was found to be very important to the well-being of the wearer. It caused discomfort and sometimes pain.

<u>Table 5.10 The number of males and females in each age group who find bands of elastic too tight in underwear, socks or at waistbands.</u>
(Yes = uncomfortable, No = comfortable)

| Age group → | 16-25 | | 26-40 | | 41-54 | | 55+ | | 16-55+ | |
|---|---|---|---|---|---|---|---|---|---|---|
| Answer → | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No |
| Underwear | 53 | 211 | 62 | 189 | 58 | 179 | 60 | 192 | 233 | 771 |
| Socks | 54 | 210 | 67 | 184 | 63 | 174 | 51 | 201 | 235 | 769 |
| Waistbands | 42 | 222 | 59 | 192 | 44 | 193 | 66 | 186 | 211 | 793 |

It would appear from the answers to this question that tight local fit of garments is a common, wide spread problem. It indicates that garment designers and manufacturers should pay more attention to the type of materials and making-up techniques that are used, and that the sizing system should be revised. Although more intermediate sizes are commercially unviable for most garments; a common, standard product such as a socks could well be made in differing sizes to accommodate various leg sizes because the market is so large.

The determination of the optimum position for garment labels was the aim of the final question. The interviewee was asked if they found labels annoying at the neck, in the side-seam of tops and at the back of briefs. If they did feel discomfort, they were asked if they would remove the label from the garment. The labels sewn into the neck of garments were found to annoy approximately 66 per cent of the interviewees and about 17 per cent found labels in side-seams and in underwear uncomfortable. Even more surprising, over 65 per cent of the people interviewed cut the labels out of their next-to-skin apparel. The numbers of people who cut the labels out of their garments is shown in table 5.11.

Table 5.11 The number of males and females in each age group and social class (1 = non-manual workers, 2= manual workers and unemployed) which cut labels out of their garments.

| Age group → | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class→ | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Yes | 59 | 110 | 169 | 49 | 105 | 154 | 54 | 104 | 158 | 50 | 98 | 148 | 212 | 417 | 629 |
| No | 25 | 43 | 68 | 28 | 39 | 67 | 31 | 33 | 64 | 24 | 57 | 81 | 108 | 172 | 280 |

Although the exact reasons for cutting the label out of a garment was not investigated in detail, there are two main reasons why this would occur:

1) If the label had caused sensorial discomfort when the corner of the label sticks into the skin.
2) The psychological discomfort when the label hangs outside the garment, or it is displayed when the wearer does not want it to be seen.

This high instance of discomfort due to garment labels led the author to investigate this specific source of discomfort more fully in this thesis. This work is discussed in chapter 11.

These findings are also of great significance to a retailer and garment producer. A label has washing instructions, trade name of the producer, fibre content, garment size and stock control data. When the label is removed this information will be lost and the consumer may forget the manufacturer, size and washing instructions. This information is important if the consumer is to care for the product properly and repeat the purchase.

## 5.3 The Major Findings from the Public Questionnaire.

The questionnaire provided information on the in-wear comfort properties of common apparel fibres and it determined more fully the method of selection of fabrics by the general public. Garment parameters and the severity of some common discomfort sensations were also investigated.

The results have shown that people put great emphasis on the appearance of a fabric when making a decision on its comfort. The appearance of the fabric is very important and a consumer is unlikely to reject a fabric made from a synthetic fibre if it looks like a natural fibre. This is even more the case because many people do not look at the label to determine the fibre content.

The most popular fibre was cotton for all end-uses. The main reasons for this choice was the perception of coolness, comfort and absorbency. The fibres which were least popular for next to the skin garments were the synthetic and the coarser animal hair fibres. In the latter case this could be due to the fact that most people thought that tickle was particularly annoying, a sensation commonly associated with wool-like fibres. The synthetic fibres could be disliked for many reasons. At present there is a tendency to want natural products, and the synthetics are believed to be non-absorbent and therefore unhealthy. In addition many people would not know the difference between the synthetic or the cellulosic fibres, and may for this reason avoid both.

The questionnaire showed that the majority of people have a definite idea of what they should require from a garment for a particular end-use. Nevertheless, the aesthetics of a fabric (and presumably a garment) will dominate a decision. Most comfort and discomfort properties of garments were associated with the fibre type, rather than the fabric or garment construction, but relatively few people look at a garment label for its fibre content before purchasing, therefore making the decision totally on handle and aesthetics.

Garment labels were found to be a common source of discomfort and many of the labels are cut out of the garments. The type of labels used for next to the skin apparel needs careful consideration and re-designing in some cases. The tight fit of underwear, socks and waistbands also caused wide spread discomfort. There is obviously a need for more tolerant garments to accommodate a larger range of body shapes within one size category. Ideally an extensive anthropometric study should be carried out so that garment sizing may be accurately determined. This would provide a sound base for future standardization.

The questionnaire was very successful in elaborating and endorsing the findings of the main wearer trial. It discovered the general outlook on garment comfort by non-textile related people and in doing so, some surprising results emerged.

# CHAPTER 6

## LOCAL FIT.

It is well known that if a garment is tight fitting it can be both uncomfortable and sometimes painful, and at the same time it can restrict blood flow and body movement. Nevertheless relatively little is known about the acceptable pressures that the body can withstand for the common local fitting areas of garments.

Tight fit is a very common sensation, the public questionnaire determined that over 30 per cent of interviewees thought that tight fit was more uncomfortable than tickle or wet cling, and 42 per cent put it second to tickle. Information on the general and local fit of garments is therefore needed so that they can be designed to be comfortable for a wider range of the population, something which is obviously lacking at the present time. Garment fit is also a very important facet in understanding the other sensations considered in this thesis because it controls the amount of relative movement between the skin and the fabric. Originally garment fit was not intended to be included in this thesis because research on garment drape and fit was being carried out by a French research organisation (C.E.T.I.H.) under the same research programme for the E.E.C.. The French concentrated on the drape and folds of a fabric and not the discomfort of garment fit. Meanwhile, comments from the subjects in the main wearer trial led the author to consider it to be an important, common source of discomfort which can influence the frequency and severity of all the other skin discomfort sensations considered in this thesis.

The ability of the fit of a garment to govern and often over-ride the other skin sensations was highlighted from the results of the main wearer trial (see table 12, Appendix 1).

Fit can influence the comfort of a wearer in three main ways:

1) It can cause discomfort and sometimes pain.
2) It can increase the discomfort of some sensations.
3) It can reduce the discomfort of some sensations.

If additional discomfort sensations were experienced at the same time as tight fit, they were often regarded to be less uncomfortable and less frequent than the rest of wearers had found them to be. In this case the wearer was experiencing counter-stimuli (see section 3.4).

## 6.1 Types of Garment Fit.

There are two types of tight fit within a garment:

(1) General fit which refers to the closeness of fit of the fabric in the garment. It can restrict movement, cause discomfort and influence other discomfort sensations.

(2) Local fitting areas such as seams and bands, for example, waistbands, arm-holes, underwear elastic. These areas apply greater pressure than general fit and invariably cause red pressure marks on the skin.

In this chapter general fit will be considered in terms of its influence on the severity and frequency of other skin sensations, whereas local fit will be investigated more fully as a discomfort sensation.

### 6.1.1 General Fit.

The general fit of a garment is not only capable of being uncomfortable due to tightness or excessive looseness, but it can dominate all the discomfort sensations considered in this thesis. It has a direct effect on prickle, tickle, scratchiness and skin abrasion, wet cling, local irritation, fibre shedding, initial cold feel and static electrical build-up. Fit is so influential to the comfort of clothing because it determines the amount of relative movement between the skin and the fabric. More movement produces a greater number of changes on the skin surface, for example hairs are moved and a sensation will be experienced.

Fit is determined by the style of the garment and the quantity, elasticity and drape of the fabric. In addition, the physique of the wearer, the type of body movement and the level of activity of the wearer also influence fit and the relative movement between the skin and fabric.

The tight or loose fit of a garment can reduce the discomfort of some sensations and increase others. Therefore it is important for a wearer to know the range and severity of sensations that could be experienced whilst doing a particular activity, and to choose a garment that fits appropriately (assuming the fabric and fibre type are also appropiate). For example, for long term, high levels of activity such as marathon running, a close fitting garment made from an open-structured highly extensible fabric is required so that skin abrasion is kept to a minimum. The skin can be easily abraded when it is damp and any movement between the skin and the fabric should therefore be avoided. A tight fitting, high stretch garment will move with the body rather than over it and thus reduce the chance of abrasion. For moderate activity levels, to avoid wet cling and thermal discomfort a loose, baggy garment is preferable to increase the "bellows motion" of the fabric. This will have the effect of increasing airflow and hence sweat evaporation, which will keep the body cooler. To reduce fibre shedding the garment should again be close fitting. The fabric will be restricted in its bellows motion which will reduce the number of hairs dislodged in this manner. The general fit of a garment is important to the comfort of a wearer as discussed above. It is a topic which will be noted throughout this thesis, but it is outside the scope of this project to investigate general fit any further.

### 6.1.2 Local Fit.

Local fitting areas are the parts of a garment which are used to hold the garment on the body and to add style to the clothing. These areas can be elasticated or non-elasticated when they are fastened with belts, buttons etc.. It is the pressure exerted by these areas of a garment in relation to comfort which is being investigated in this chapter.

## 6.2 The Determination of the Local Fit Discomfort Threshold.

The severity of discomfort that can be felt from tight fitting clothing depends on the pressure exerted on the body at a particular location. The skin senses pressure when it is bending or stretching. Strong pressure affects 'deep pressure' nerves (thought to be the Pacinian corpuscle) while light pressure stimulates only the hair bulbs and free nerve endings. The threshold for pressure and pain will vary with the area of the skin tested, it will depend on the concentration of nerve fibres and the thickness of the skin (Woodson and Conver, 1954-64). The ability of the body to withstand different pressures at various locations has been well documented in the medical literature. In general, bony prominences have a particularly low discomfort threshold, for example the shin and chest, whereas load-bearing areas such as the shoulders and buttocks have a particularly high threshold. Variations can also occur around the circumference of the body; the waist typically tolerates 3.5 times more force at the sides of the body than at the front (Denton 1971) due to its approximate oval shape.

In order to investigate the distribution of load around the body, a solid model of the authors waist was made from wood. This was achieved by taking measurements of the waist at 22 points around the circumference of the body using calipers. An elastic band (using 2 cm brief elastic) was placed around the model and the pressure was measured at 36 points (from centre front to centre back or half of the waist) underneath the band using a pressure transducer. The pressure transducer (designed and loaned by the Department of Orthopaedic Mechanics, Salford University) is 1.3 cm in diameter and 1 mm thick. The pressure was measured directly in millimetres of mercury (mmHg). The results of this trial showed that the pressure at the sides of the model was approximately 4 times the pressure at the front, 87 $cN/cm^2$ (65 mmHg) to 20 $cN/cm^2$ (15 mmHg) respectively. This value is similar to Denton's finding of 3.5 times the pressure at the side of the waist than at the front, with the small difference in the relationship being attributed to differences in the geometric shape of the body studied.

Researchers have chosen to quote their findings of comfort and discomfort thresholds in either mmHg, $gf/cm^2$ or $cN/cm^2$. The conversion factors are: 1 mmHg = 1.36 $gf/cm^2$ and 1 $cN/cm^2$ = 1.02 $gf/cm^2$.

A common physiological explanation of the limiting factor for comfort is the pressure at which blood flow is inhibited or prevented, that is diastolic pressure. This is typically 107 $cN/cm^2$ (80 mmHg) and pressures around or above this value are recommended to be avoided due to discomfort. Roth, Siegert and Unerricht (1971) investigated the passage of fluid through the tissues of the body. They injected a radioactive substance into subjects, and the time taken for the substance to travel a certain distance through the tissue was measured. Pressure was artifically induced over injection regions and participants assessed comfort during the test. They found that a compressive pressure of 160 cN/cm$^2$ (120 mmHg) was very uncomfortable and reduced the clearance of the radioactive substance by 80 per cent. 42 cN/cm$^2$ (30 mmHg) was comfortable and reduced the clearance by 20 per cent. They concluded that pressures should not exceed 14 cN/cm$^2$ (10 mmHg) with an expected reduction in tissue clearance of 7 per cent. On the basis of these findings a special production method for corsetry was developed in East Germany and the garments manufactured were assessed as comfortable in wearer trials.

A number of researchers have studied the comfort of garment fit at particular areas of the body for both general and local fit. The most notable are briefly considered below. Denton (1971) found that in general a pressure of between 51-71 cN/cm$^2$ to be the discomfort threshold for the arm. Johansson (1984) did not specify a discomfort threshold, but chose one pressure, 27 cN/cm$^2$, for comfort for most body areas. He used this value in the design of test equipment which he subsequentially developed to measure garment suitability for body size. The Institut Textil de France (1983) found that the bearable grip for waistbands of briefs is 36 cN/cm$^2$ (static pressure), and they suggest 31 cN/cm$^2$ for comfort. Lemmens (Denton, 1971) measured the pressure under figure control garments. Swimwear exerted pressures of 10 to 20 cN/cm$^2$, modern corsets of 31 to 51 cN/cm$^2$ and elasticated sock tops and medical stockings 31 to 61 cN/cm$^2$. These were not discomfort thresholds but tolerated pressures.

There is a lack of information on the pressure discomfort thresholds for common local fitting areas of the body. Therefore two local fit trials were designed. The first was to determine comfortable pressures experienced whilst wearing everyday clothing. This provided information on the range of acceptable pressures for a wide range of common local fitting areas. The second trial was to investigate more thoroughly the pressure range for the discomfort threshold at the waist.

### 6.2.1 Pressure of Everyday Clothing.

The pressure was measured under various local fitting areas of everyday workwear of thirty Shirley Institute staff. They were not told about the trial before they arrived at work so that their choice of clothing was not influenced in any way. The wearer was asked to comment on the comfort of each garment in terms of fit alone, however very few garments were described as uncomfortably tight. The results are shown in table 6.1. The mean of all the individual pressures measured at any one site are shown in the table.

The pressure under the local fitting area was measured by carefully placing the pressure transducer (loaned by the Department of Orthopaedic Mechanics) between the skin and the garment so that it was flat and totally covered by the local fitting area, then a reading was noted. This was repeated a number of times at the same location around the circumference of the body. The accuracy of the transducer has been investigated under circumstances similar to those used in the tests and found to be accurate to within ± 2.7 $cN/cm^2$ (± 2 mmHg).

This trial has provided an insight into the wide range of pressures that can be experienced without causing discomfort for long periods of time. Many of the mean pressures shown in table 6.1 are above 107 $cN/cm^2$ (80 mmHg), when arteriol diastolic pressure, and therefore blood flow could be impaired. The author considers that these higher pressures will be buffered by body fat so that the veins do not experience the high loads. However, the body did acknowledge the presence of the high pressures due to the production of red marks on the skin. The areas where the pressure was high are common tight fitting regions and are therefore more adapted to the loads.

Table 6.1 Pressures under local fitting areas of everyday workwear.

| Garment | Postion of reading (on the body) | | Mean cN/cm² | Mean mmHg | Minimum cN/cm² | Minimum mmHg | Maximum cN/cm² | Maximum mmHg | CV % |
|---|---|---|---|---|---|---|---|---|---|
| Bra | Front | Chest | 187 | 140 | 93 | 70 | 373 | 280 | 61 |
| | Back | Chest | 67 | 50 | 27 | 20 | 133 | 100 | 55 |
| | Strap | Shoulder | 53 | 40 | 13 | 10 | 133 | 100 | 63 |
| Female | Front | Hip | 53 | 40 | 13 | 10 | 133 | 100 | 102 |
| briefs | Side | Hip | 80 | 60 | 27 | 20 | 267 | 200 | 84 |
| Tights | Front | Waist | 40 | 30 | 27 | 20 | 80 | 60 | 37 |
| | Side | Waist | 80 | 60 | 27 | 20 | 107 | 80 | 30 |
| Underskirt | Front | Waist | 67 | 50 | 27 | 20 | 187 | 140 | 69 |
| | Side | Waist | 120 | 90 | 53 | 40 | 293 | 220 | 66 |
| Skirt | Front | Waist | 40 | 30 | 27 | 20 | 80 | 60 | 43 |
| | Side | Waist | 93 | 70 | 27 | 20 | 187 | 140 | 73 |
| Trousers | Front | Waist | 67 | 50 | 27 | 20 | 107 | 80 | 66 |
| | Side | Waist | 147 | 110 | 80 | 60 | 240 | 180 | 40 |
| Jumper | Cuff | Wrist | 27 | 20 | 7 | 5 | 53 | 40 | 84 |
| | Welt | Neck | 13 | 10 | 7 | 5 | 27 | 20 | 79 |
| Socks | Front | Shin | 80 | 60 | 13 | 10 | 160 | 120 | 73 |
| | Side | Calf | 53 | 40 | 20 | 15 | 80 | 60 | 47 |

The pressure exerted by bra elastic was surprisingly high, the straps often caused red pressure marks on the skin, but they were not said to be uncomfortable. Underskirts and tights also produced pressure marks under the waistband, but only one wearer commented on discomfort *. Womens briefs, underskirts and tights all gave higher readings at the side of the body than at the front due to the body's approximate kidney shape.

* She was wearing a new pair of tights with a wide elastic waistband. Originally the band gave a high reading because it was folded over, however, when the elastic was straightened the readings were similar to that of other women. This is an important design feature. If the elastic is wide (approximately 1 cm or above), its extensibility should be high at low loads so that the wearer is not uncomfortable if it curls over.

In this wearer trial the side of the body experienced approximately 50 per cent more pressure than the front. It was not 3½ times the front pressure, as found by Denton, or 4 times as found by the author for a solid model.

This is because the body deforms when under pressure at the waist by becoming more circular in cross section, and in effect it redistributes the load more evenly than if it was or assumed to be a solid model.

One wearer said that his jeans were restricting and tight. He wore them as a fashion garment and did not consider that they were so uncomfortable that he avoided wearing them. Unfortunately it was not possible to measure the pressure at the tightest areas (hip, thigh and crutch) because it was out of the range of the transducer (>400 cN/cm$^2$, 300 mmHg).

The knitted welts at the neck and cuff of jumpers exerted a very low pressure. Shirt collars also gave low readings; however discomfort due to scratchiness was mentioned frequently.

### 6.2.2 Wearer Trial.

The complexity of a subjective investigation of this type led the author to consider and study one area of the body which frequently experiences high pressures due to local fit, the waist. A wearer trial was designed to determine the discomfort threshold at the waist for an elastic band. The elastic used was 1.9 cm wide brief elastic. It was selected because it was not too thin so that it would 'cut into' the wearer, and not too thick so that it would curl over too readily during wear (which would exert a high pressure) and act like a thin elastic. It had a relatively high extensibility and it was a standard width sold in haberdashery shops for briefs.

Each subject in the trial was issued with an elastic belt which fastened with a metal tooth buckle. The elastic had lines drawn on it at 2.5 cm intervals. These lines were letter coded so that wearers would feel less self concious about revealing their waist measurements, and in addition, the wearer was told that all the results from this trial would be anonymous. Initially wearers were asked to put the belt on next to their skin, to adjust the belt until the elastic was unstretched but a close fit, then fasten the buckle one line tighter on the elastic. From the first wearing the waist size of the subject was deduced, that is, the belt size worn minus

2.5 cm. The teeth of the buckle were placed so that they coincided exactly with the line on the elastic, and the buckle was worn where it was most comfortable to the wearer. The subjects were asked to wear the belt for at least half a day, preferably a full working day. If they did wear the belt for half a day they were asked to wait at least one hour before wearing the belt again so that their body could re-equilibrate. After wearing the belt, the subject filled in a questionnaire describing the comfort of the belt during the different activities of the day. This trial was continued until the wearer felt uncomfortable wearing the belt. The questionnaire used during this trial is shown in table 6.2.

The wearer trial was carried out by sixteen members of the Shirley Institute staff (14 men and 2 women) who varied in age and stature. Men were more willing to volunteer for this trial and this is thought to be because women are more modest about their waist measurements; however the men were also concious about revealing their measurements. The majority of subjects wore their belt for a full working day, only when the belt became uncomfortable did the wearer remove the belt earlier.

Before the trial, the load-elongation curve for a 10 cm sample of the elastic was measured using the Instron Tensile Tester. The reduction in the width of the elastic as it was extended was also noted so that the pressure ($cN/cm^2$) could be calculated at a certain extension (pressure = load/area). The graphs refering to these measurements are shown in figure 6.1.

The changes in the load exerted by the elastic before and after flexing (which is commonly considered in the design of foundation wear) was not taken into account in this trial. This is because the elastic would be worn a maximum of 15 times, and the difference in the character of the elastic during this time was considered to be minimal.

Table 6.2 Local Fit Discomfort Threshold Questionnaire.

Subject number _____
Belt code __________
Number of hours you wore the belt ________________
Did you wear the belt during a meal? Yes/No

| Activity → / Sensation ↓ | All the time | Standing | Sitting | During a meal | After a meal | Exercising & bending |
|---|---|---|---|---|---|---|
| Too loose | | | | | | |
| Perfect fit | | | | | | |
| Very slightly tight | | | | | | |
| Slightly uncomfortable | | | | | | |
| Uncomfortable | | | | | | |
| Very uncomfortable | | | | | | |
| Unbearable | | | | | | |

PLEASE TICK
Note: If the belt was comfortable all the time please tick the activities you did whilst wearing the belt.

Where was the discomfort?
Sides ☐
Front ☐
All around the waist ☐

Do you have any other comments?

**When you have worn all the belt sizes to beyond your discomfort threshold please complete this section:**

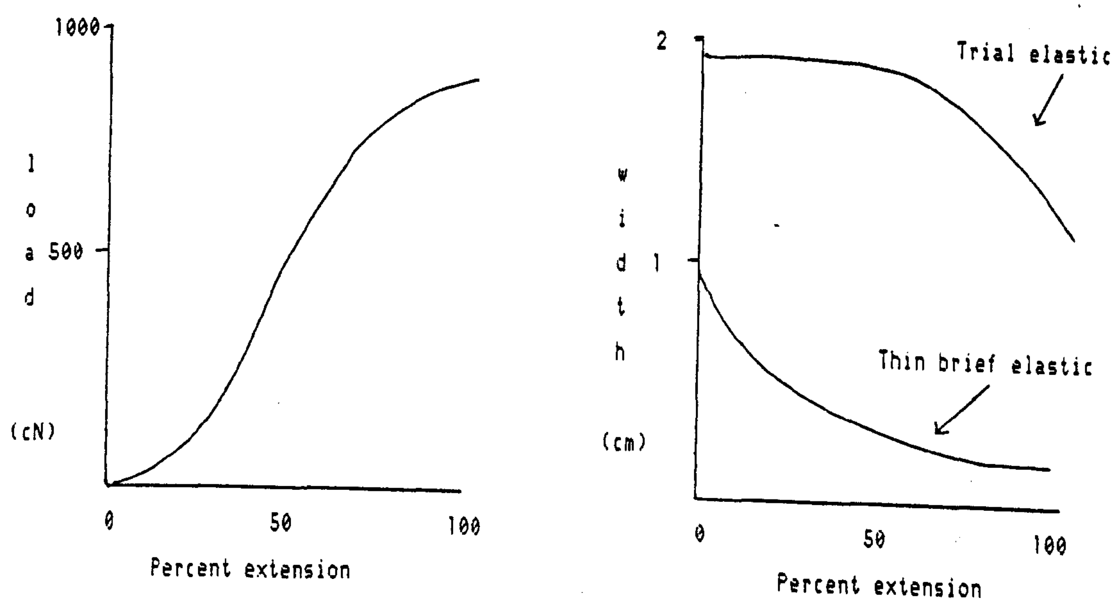
Which size or sizes of belt would you be happy wearing?

Which size or sizes of belt do you consider form the threshold for discomfort due to tight fit?

Which size or sizes of belt do you consider are too loose?

Figure 6.1

Load-extension curve of trial elastic 1 | Width of the elastic with extension




The original waist size of the wearer was used in the calculation of extension, with the assumption that it did not vary as the belt got tighter, the belt did not curl widthways and the waist was circular in cross-section. The extension of the belt in the trial was compared with the load-extension curve (calculated from the load-elongation curve), and the tension in the elastic was deduced. The pressure exerted on the body by a waistband is:

$$\text{Pressure} = \frac{\text{Tension in the elastic}}{\text{Circumference of the waist} \times \text{Width of the elastic}} \qquad \text{Equation 6.1}$$

The area of the belt was calculated taking into account the widthways shrinkage of the elastic, and hence the pressure was deduced. For example, if the waist size is 100 cm (radius of 15.9 cm) and the belt is originally 75 cm long, the belt is being extended 30 per cent. At 30 per cent extension the force exerted by the belt is 550 cN (as read from the graph). The width of the elastic is 1.9 cm. Therefore the pressure is (550 / (15.9 x

1.9)) 18.2 cN/cm² if the body is assumed to be circular in cross-section. This average pressure value is used as an indication of the pressure exerted around the waist. The results of this trial are summarised in table 6.3 according to the comfort/discomfort of the wearer.

Table 6.3 The relationship of the extension load and discomfort of the wearer.

| Subject number | Waist size (cm) | Physique (morphology) | Too loose | | Good fit | | Discomfort threshold | |
|---|---|---|---|---|---|---|---|---|
| | | | E % | P cN/cm² | E % | P cN/cm² | E % | P cN/cm² |
| 1 * | 91 | Ectomorph | 2,5 | 6 | 5,5 | 11 | 21,5 | 20 |
| 2 * | 74 | Ectomorph | 4 | 11 | 7,5-10 | 15-16,5 | 21 | 22 |
| 3 * | 107 | Endomorph | 2,5-11,5 | 5-12 | 14-21 | 13-15 | 23,5 | 16,5 |
| 4 * | 69 | Ectomorph | 0 | 0 | 3-11 | 9-18 | 14,5 | 20,5 |
| 5 * | 64 | Ectomorph | 4 | 12 | 4-8 | 12-17 | 8 | 17,5 |
| 6 * | 87 | Endo/meso | 3-6,5 | 6,5-12 | 14,5-17,5 | 16-17 | 26,5 | 21 |
| 7 * | 87 | Endo/meso | 0 | 0 | 3 | 6,5 | 6,5 | 12 |
| 8 ** | 94 | Endomorph | 2,5 | 8,5 | 5,5 | 15 | 18,5 | 21,5 |
| 9 ** | 79 | Ectomorph | 0 | 0 | 3,5 | 14,5 | 6,5 | 21,5 |
| 10 ** | 92 | Endo/meso | 2,5-8 | 9-18 | 11,5-19 | 19-22,5 | 27,5 | 24,5 |
| 11 ** | 69 | Ectomorph | 0 | 0 | 3 | 13 | 14,5 | 27 |
| 12 ** | 89 | Endomorph | 0 | 0 | 5,5 | 16 | 11 | 20 |
| 13 ** | 77 | Ectomorph | 3,5 | 15 | 3,5 | 15 | 7 | 20 |
| 14 * | 77 | Ectomorph | 3,5 | 8 | 3,5 | 8 | 20,5 | 20,5 |
| 15 ** | 89 | Mesomorph | 0 | 0 | 5,5 | 16,5 | 5,5 | 16,5 |
| 16 ** | 89 | Ecto/meso | 0 | 0 | 5,5-11 | 16-20 | 11 | 20 |
| Mean | | | 5,1 | | 13,5 | | 20,1 | |
| SD (n-1) | | | 5,0 | | 3,3 | | 3,3 | |

Where: E = Percentage extension of the belt.

P = Average pressure exerted by the belt per cm². (The mean was calculated using the lowest value if a range of pressures was indicated.

* = Elastic batch 1, ** = Elastic batch 2 (they have different load-elongation curves because they were obtained from different sources).

It was not possible to measure the pressure (using the transducer) under the belts during the trial because it was difficult to locate the subjects and to arrange a common time to meet. The waist size of the subjects was taken from the questionnaires and was assumed to be standard throughout the trial because it took less than one month to complete. Ideally skin fold calipers that measure the percentage fat on the body would have been used. The calipers measure the thickness of the skin/fat at various sites on the body and the overall percentage fat is deduced from these measurements. Skin fold calipers were not available, but the wearers would have been unlikely to consent to this test even if they were. Nevertheless the physique of the wearers was well defined and is summarised in table 6.3.

Some of the problems encountered in this wearer trial were inevitable, the elastic did fold over width-ways with increased stretching, therefore concentrating the load. The buckle itself also caused a lot of discomfort, but the wearers did say that they could exclude this discomfort when assessing the belt.

The separation of the results into groups to establish the relationship between the physique and activity of the wearer to their discomfort threshold showed no real trends. Statistical analysis of the relationships between the discomfort threshold for these groups is of limited significance due to the low numbers of people included in this trial.

Overall, the pressure range for the belt being too loose or comfortable showed a surprisingly small spread in the values, considering the subjective nature of the investigation. A very narrow range of pressures indicative of the discomfort threshold for the waist was found, with a mean value of 20.1 $cN/cm^2$ (with a standard deviation (n-1) of 3.3). This pressure was consistent between the wearers of differing physique and is considered to be an accurate value of the threshold for discomfort for the population. This pressure is lower than the pressures suggested by the Institut Textil de France, Denton and Johansson for comfort (31 $cN/cm^2$, 51-71 $cN/cm^2$ and 26 $cN/cm^2$ respectively). Different areas of the body will undoubtedly have different discomfort thresholds to pressure due to differences in the physiology of the area. At the waist it is unlikely that impedence of the blood flow will be major factor determining the discomfort because the major blood vessels are protected by the spine and would not be compressed by a belt. The compression of the intestine is likely to be the main cause of the discomfort threshold. The results of the local fit wearer trial for the waist indicate that a pressure of between 10 and 15 $cN/cm^2$ is recommended for comfort around the waist.

This discomfort threshold can be used as a guide in garment manufacture. For a certain size range a local fitting band can be tested or predetermined so that comfort can be more accurately predicted. Test methods to measure the pressure exerted by a local fitting area are proposed in section 6.3.

## 6.3 Test Methods to Measure Local Fit Comfort.

There are two main reasons for testing a local fitting area for its comfort in wear. First it is necessary to determine if the local fitting areas of an existing garment will be comfortable for the size range for which it is intended. Second, a method to test an elastic before it is used in garment manufacture is needed so that the amount of elastic required for comfort at a local fitting area can be predetermined. Two ways in which the comfort of a local fitting area can be measured are suggested below.

### 6.3.1 Adaptation of a British Standard Test Method.

The British Standard stretch and recovery method (BS4294: 1982) for an elastic band uses the Instron Tensile Tester to extend and relax a strip of elastic between its jaws. The force needed to extend a 10 cm strip of elastic is measured by the load cell in the instrument and recorded onto graph paper. In addition to this standard, the change in width of the elastic at a range of extensions is also noted. For a certain load, elastic width and body radius (corresponding to 10 to 15 $cN/cm^2$ pressure for a band going around the waist), the percentage extension of the elastic can be calculated from the graph using equation 6.1. This extension value can be used as a guide in the manufacture of garments for a particular size range.

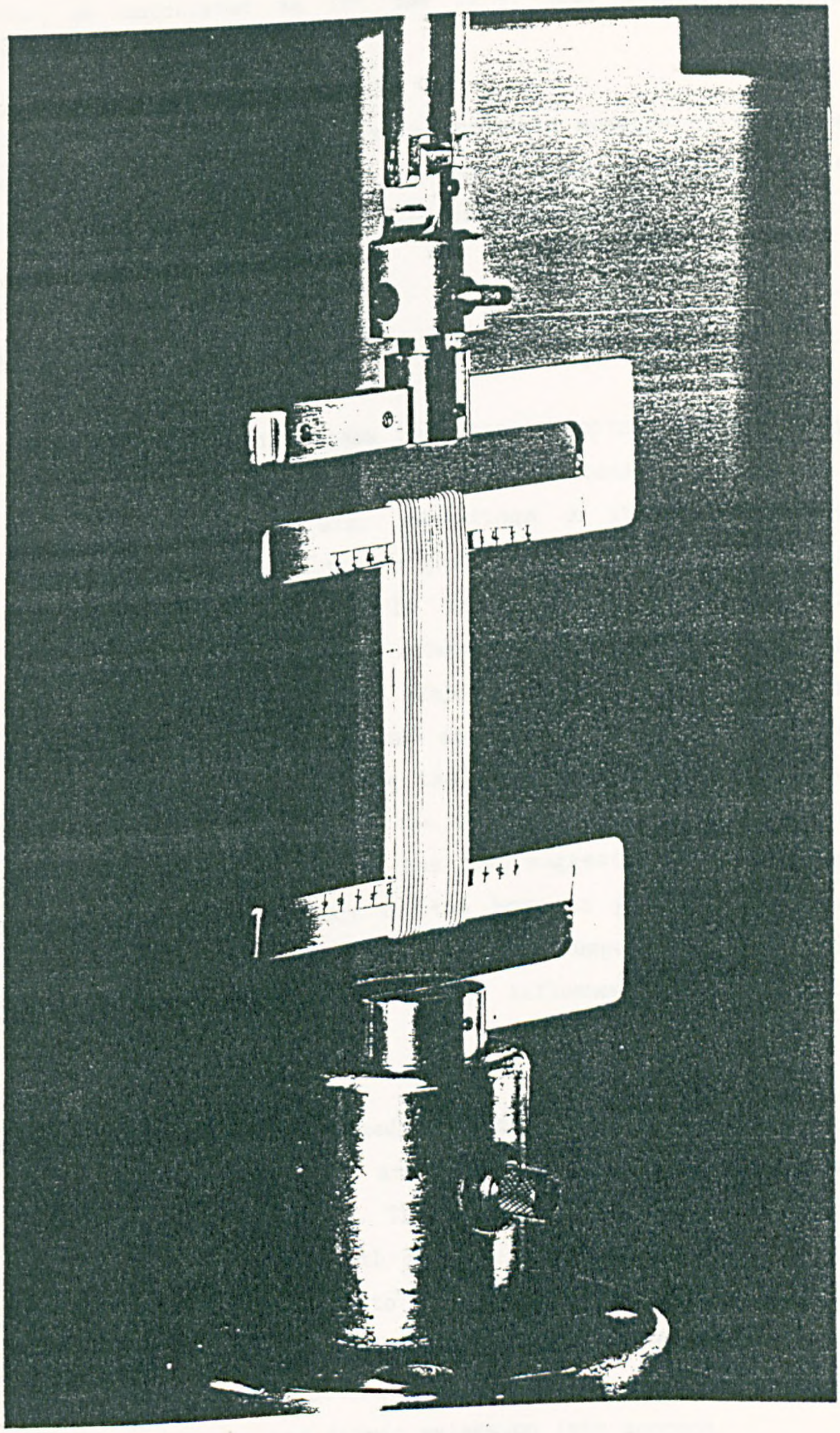
This method was used for the wearer trial described above. The method is quick and easy, however it does restrict the width-ways shrinkage of the elastic as the extension increases. This is because the jaws of the Instron clamp the specimen at its original width. It also requires that the local fitting area is cut out of a garment and so the effects of stitching may be lost due to slippage through the jaws of the Instron.

### 6.3.2 New Test Method.

To measure the performance of an extendable local fitting area in a made-up garment, taking into account the effects of stitching, elastic width-ways reduction and fabric extension on the restriction of elasticated bands, a simple, easy to use attachment for the Instron Tensile Tester was designed. The attachment consists of two stainless steel horizontal hooks, one of which fits into the cross-head of the Instron, the other into the C load cell fitting (range 0 to 5000 cN), as shown in figure 6.2. The hooks are tapered so that they have one 2mm wide edge touching the test band.

The band to be tested should be cut out of the garment so that none of the stitching holding the band in place is cut, but so that excess fabric is kept to a minimum. The band to be tested is placed on the hooks so that its centre is in line with the line of force, but it is in a relaxed state. The load cell of the Instron is zeroed so that the weight of the band is eliminated from the test results. The hooks are then slowly moved apart until a load is noted on the chart paper and the hooks are stopped. A clip is then placed at either edge of the band to prevent slippage during the test. The distance between the load-bearing edges of the hooks is measured and this is recorded as half the original test length. The test is ready to begin. The jaws of the Instron are moved apart at 12.5 cm/minute until a load of 1000g is reached (to ensure that it is beyond the discomfort threshold), the cross-head will be programmed to automatically stop at this load. At the same time the force needed to extend the band is recorded on the chart recorder of the instrument and the distance travelled by the cross-head is also deduced from the chart paper. The width of the load-bearing band may be difficult to measure accurately without disrupting the test. In this case the band should be tested again and the width of the

Figure 6.2 Local Fit Tester



band recorded at set intervals. The pressure for a specific waist size and band size is calculated as for the first test method described using equation 6.1.

The results of this test are a more realistic measure of the performance of a garment in wear than the British Standard extension method and therefore it is considered superior for this end-use.

## 6.4 Conclusions.

The comfort of local fitting areas is a very important factor which should be considered by both garment designers and consumers because it can induce or inhibit other discomfort sensations, or it can be uncomfortable, painful and restricting. The fit of a garment is an objective and subjective property, where differences in the results between wearers would be expected. However the wearer trial determined the threshold for discomfort where very little spread between subjects was observed. The discomfort threshold for the waist was 20 $cN/cm^2$ and the comfortable region was 10-15 $cN/cm^2$. The main factor determining the discomfort threshold in this case is taken to be the compression of the internal organs (intestine) and not the restriction of blood flow which has been suggested by other researchers for different areas of the body or the body in general. The discomfort threshold pressure is comparable with the one suggested Roth and Siergert and Unnericht, which indicates the large influence of the flow of body fluids on the discomfort.

Two test procedures were suggested for the analysis of extendable local fitting areas. Both of the tests are simple and easy to use on standard textile test laboratory equipment. They are both capable of indicating the range of waist sizes that a length of an elasticated band can be used for comfort. One test is most suited to evaluating elastic before it is in the garment and the second test is more versatile, because it can test extendable bands before manufacture or after the garment has been made up, therefore taking stitching and fabric extension into account.

# CHAPTER 7

## WET CLING.

Sweating is a vital bodily function which is used to regulate the temperature of the body within its narrow limits of thermal functioning. In a temperate climate sweat loss amounts to approximately 1½ litres per day. Such fluid loss is inescapable because sweat formation is man's only means of keeping cool. Warm climates, high activity levels and stress are the main factors which cause an increase in sweating, and the ability of a garment to allow maximum sweat evaporation is important to keep the body cool. If the garment does not allow the sweat to evaporate quickly enough, or if the sweat rate is too high for all the sweat to be evaporated, the garment will become wet and it will cling to the body, a condition known as wet cling. This wet cling can cause the wearer to feel discomfort.

Most of the research that has been carried out on garment comfort has concentrated on thermo-physiological aspects, and much is known about moisture transport through a fabric or garment assembly, but less known about wet cling. Nevertheless, there is confusion between researchers as to the benefits of an absorbent or a non-absorbent fibre for comfort. Wet cling is a well known, discomfort sensation, but so far no research has been conducted to determine how much influence wet cling has on the overall comfort of the wearer when other sensations are present. In this chapter a range of fabrics and fibres are studied to determine which are the most comfortable to wear in warm weather and during exercise. The reasons why the fabrics have these properties in terms of the frequency, severity and the mechanics of wet cling in-wear are investigated. These properties are used in the development of test equipment to rank fabrics for wet cling discomfort. Finally, the attitude of the general public to a garments role in the determination of sweat regulation is evaluated.

## 7.1 Sweating.

Wet cling is produced when sweat is present and it causes the fabric to cling to the skin. The rate at which the body sweats under different conditions and the quantity of sweat produced will influence the amount of discomfort felt. These factors are assessed in connection with the potential activities and situations where wet cling may be experienced.

### 7.1.1 Quantity of Sweat.

There are two ways in which the skin perspires:

1) Insensible perspiration due to fluid loss through the skin (not through sweat glands), which occurs continuously. Newburgh (1968) deduced an approximate value for insensible perspiration to be 16 $g/m^2$ of the body surface per hour. This is very low and no discomfort due to wet cling would be produced from this small amount of moisture.

2) Sensible perspiration due to sweat loss through glands in the skin. The amount of sweat produced varies greatly, depending on certain conditions, for example, the level of physical activity, ambient temperature and psychological stress. This type of perspiration is widely accepted as being the cause of wet cling discomfort because sweat production is many times greater than insensible perspiration. For instance, a man walking at a moderate speed in a temperature of 23°C perspires at a rate of 120-200$g/m^2$.hr. As stated above, this is a well researched area and comfort charts have been produced by, for example, ASHRAE (MacPhee, 1965-6) and the Hohenstein Institute (1983). They act as a guide to the prediction of the comfort of a person within different environments and activity levels, the latter of which enables different garment assemblies to be assessed.

The work of Weiner (1945) and Suzuki (1983) indentified the torso as the area of the body that sweats the most. In particular the area over the sternum and the spine. The torso is usually clothed and therefore it has the potential of being the most likely area of the body to experience wet cling discomfort.

## 7.1.2 Surface Tension of Sweat.

Sweat glands are present over the entire surface of the body. The secretion is a dilute fluid of many constituents. Some of the most common are salts, products of muscle action, acids and lipids.

An indication of the order of magnitude of the surface tension of sweat was obtained in order to examine its ability to aid in the resistance of a fabric to peel away from the body when there is a layer of sweat between them. This was achieved when two male members of the Shirley Institute staff collected their sweat in a glass tube for analysis. One man collected his sweat after a hot bath and the other after a jog. The sweat was cloudy, and this was attributed to the presence of dead skin cells (which could be seen under the microscope) and to a lesser extent the lipids in the sweat. The surface tension of the sweat was measured using equipment designed at the Shirley Institute by E.J. Lord (1969). The results were $34.9 \times 10^{7}$ N/m and $33.5 \times 10^{7}$ N/m respectively. Therefore the force needed to pull a fabric away from the skin normally to the surface and to overcome the surface tension when a layer of sweat is between them is very large.

## 7.1.3 Rate of Sweating.

The rate of sweating is influenced by many factors, it increases with (Fourt and Hollies):

1) Higher ambient temperatures.
2) Increased work rate.
3) Increased body weight (surface area).
4) Being in the sun rather than the shade.
5) Being nude rather than clothed.
6) Disease can increase or decrease sweating.

People in hot and very cold climates become heat acclimatised, either due to the warm ambient or the warm micro-climate inside their clothing. Heat acclimatised people sweat earlier and more profusely than others. It is also generally believed that athletes are heat acclimatised, and this is because the body anticipates its requirements for keeping cool. Therefore, these people have the capacity to experience wet cling more frequently than people that are not heat acclimatised.

The Hohenstein Institute (Germany) carried out a study on the thermo-physiological aspects of clothing comfort for the E.E.C. under the same research programme as this project. They are considered to be the most advanced in their predictive techniques for determining thermo-physiological garment comfort. They produced a series of equations to predict thermo-physiological comfort of a fabric or a garment assembly for different ambients and activity levels. The fabric(s) or garment(s) was tested on a heated manikin and/or a specially designed sweating hot plate and the results were used in the equations. They found that wet cling was reduced by a hairy fabric surface (due to a reduction in fabric:skin contact area), and that the hairiness could be linked to the discomfort due to wet cling. They characterized a hairy fabric surface by the number and length of hairs.

The work of many other researchers was of value in assessing the results of the main wearer trial questionnaires. The presence of discomfort due to sweat was evaluated in terms of its influence on other sensations, its frequency, severity and reasons for its occurence.

## 7.2 The Main Wearer Trial.

Whilst the main wearer trial was being conducted, the weather in the Manchester area (where the subjects were wearing their garments) was unusually warm. The maximum temperature between 0900-2100 hours was above 20°C for over half the duration of the trial (see figure 4.1). During this time, 12 out of the 22 trial garments were issued and worn. These were garment numbers 1,2,4,7,5,8,15,16,17,18,19 and 20 (see table 1, appendix 1 for fabric details). In addition, between five and ten subjects did strenuous exercise whilst wearing their trial garments. Therefore, these were suitable conditions for assessing wet cling.

Table 7.1 shows the percentage of the wearers in the main wearer trial that experienced clamminess when they sweated in each of their wearer trial garments. It also includes the wearer's assessment of the speed at which the fabrics dried once they had been wet.

Table 7.1 The per cent of wearers in the main wearer trial that felt sweat discomfort due to clamminess and the perceived drying rate of the fabrics.

| Fabric number | % who sweated | % felt clammy & sweated | Drying properties of the fabric | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | NAA | Slow | MQ | Q | Imm | NW |
| 1 | 55 | 36 | 10 | 5 | 52 | 14 | 5 | 14 |
| 2 | 43 | 28 | 11 | 18 | 18 | 18 | 11 | 24 |
| 3 | 15 | 0 | 33 | 0 | 17 | 17 | 0 | 33 |
| 4 | 50 | 15 | 10 | 10 | 15 | 25 | 10 | 25 |
| 5 | 25 | 0 | 20 | 0 | 40 | 30 | 10 | 0 |
| 6 | 28 | 9 | 18 | 9 | 9 | 36 | 0 | 27 |
| 7 | 30 | 17 | 17 | 7 | 42 | 17 | 0 | 17 |
| 8 | 38 | 7 | 20 | 20 | 13 | 20 | 7 | 20 |
| 9 | 36 | 28 | 18 | 27 | 46 | 0 | 0 | 9 |
| 10 | 38 | 13 | 13 | 0 | 53 | 7 | 7 | 20 |
| 11 | 25 | 0 | 0 | 40 | 50 | 0 | 0 | 10 |
| 12 | 20 | 20 | 20 | 10 | 60 | 0 | 0 | 10 |
| 13 | 33 | 30 | 17 | 8 | 50 | 17 | 0 | 8 |
| 14 | 44 | 40 | 12 | 0 | 38 | 31 | 0 | 19 |
| 15 | 53 | 38 | 10 | 23 | 10 | 0 | 0 | 57 |
| 16 | 25 | 10 | 0 | 0 | 0 | 0 | 0 | 100 |
| 17 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 18 | 33 | 23 | 22 | 0 | 45 | 0 | 0 | 33 |
| 19 | 45 | 28 | 22 | 11 | 11 | 0 | 0 | 56 |
| 20 | 33 | 31 | 15 | 15 | 23 | 32 | 0 | 15 |
| 21 | 33 | 25 | 20 | 10 | 0 | 40 | 0 | 30 |
| 22 | 38 | 20 | 25 | 25 | 0 | 0 | 0 | 50 |

Note: NAA = Not at all, MQ = Moderately quickly, Q = Quickly, Imm = Immediately, NW = The fabric was not wet.

Overall, ten times more subjects said that they felt damp or sticky rather than wet or very wet during all three levels of activity (appendix 1, table 15). Many wearers said that the discomfort produced by their sticky or damp skin was more uncomfortable than when their skin was wet. It is therefore a very important sensation. This discomfort sensation had not been documented by past researchers, and it was termed "tacky cling".

Tacky cling was experienced when the skin was damp; usually after a person had been sweating for a long period, for instance, after a hot day in the office. In this situation, a build-up of the constituents of sweat and sebum would be deposited on the skin and kept damp by the sweat. This produced an adhesive skin surface.

The fabric weakly adheres to the skin in this situation (from discussions with the wearer trial subjects), therefore it frequently releases when there is body movement. The subject's comments indicated that when the fabric releases or contacts the skin, they notice the change in conditions (on their skin), and discomfort is experienced. It was also noted that wet cling discomfort was said to be registered when the fabric released from their body. Wet cling was most noticable when the body was moderately sweaty. This would produce a similar adhesive surface to the skin to the one that produces tacky cling discomfort. In this situation the fabric will be less firmly adhered to the skin surface than if the person was saturated in sweat.

A wide range of fibre and fabric types were included in the main wearer trial. It was noted from the comments and answers to the questionnaire (summarised in table 13, appendix 1) that fabric 15, a lambswool/angora blend, made the wearers feel wetter than the other fabrics during strenuous activity. To determine the reasons for this observation, the influence of the hygroscopic properties of fibres and the structure of the main wearer trial fabrics were assessed by routine test procedures. They were tested for static immersion, water retention, water vapour resistance, surface drag, wicking, bending length, moisture content and moisture regain. The results are shown in table 2, appendix 1. During the static immersion tests on fabric 15, it was noted that it did not fully wet out like the other fabrics. After the test the fabric was observed under the microscope along with a selection of the other wearer trial fabrics. It was seen that the water was present as droplets on the surface of fabric 15, whereas it had been absorbed by the other fabrics. This difference is likely to be due to the high level of natural oils found on woollen fibres (which are present in fabric 15) which prevent water absorption. In addition the hairy fabric surface will restrict the passage of water into the main body of the fabric, thereby making the fabric surface wetter.

In the literature there are conflicting views on the benefits of a double-sided fabric with either a hydrophilic or a hydrophobic fibre on the inside surface. This was investigated in the main wearer trial with fabric 9; it had polyester on one side and viscose on the other. The subjects were asked to wear the garment the right way out (viscose inside) and then inside out (polyester inside). The results showed that there were no differences in the perception of fabric wetness between wearing either of the two fibre types next to the skin during any activity level.

To obtain more information on the influence of the fibre and fabric properties on wet cling a specific wearer trial was designed. It included a range of fabrics specifically made from a hydrophilic and a hydrophobic fibre in different fabric constructions. The trial was designed to assess four specific factors thought to influence wet cling and tacky cling.

## 7.3 Specific Wet Cling Wearer Trial.

Four main features of a fabric were identified as potentially having a large influence on the presence of wet and tacky cling. These are:

1) The hygroscopic nature of the fibre type.
2) The weight and the drape of the fabric when dry and wet.
3) The fabric structure, both in terms of contact surface area with the skin and the transport of sweat.
4) The use of a hydrophilic and a hydrophobic fibre in a double-sided fabric construction (to transport sweat away from the skin).

They were studied in a specific wearer trial to establish their effects.

### 7.3.1 Wearer Trial Fabrics.

Four sets of knitted fabrics (11 fabrics in total) were made for the wearer trial by I.C.I. Fibres Ltd.. The fabrics are described in table 7.2 below. Cotton was chosen as a typical absorbent fibre and a texturized nylon, Tactel (bright, textured nylon type K000) was chosen as a typical non-absorbent fibre.

Table 7.2 Fabric and fibre combinations to investigate four of the main features thought to influence wet and tacky cling discomfort.

| Set No. | Feature | Fabric number | Fabric structure | Fibre composition | Weight relative |
|---|---|---|---|---|---|
| 1 | Fibre type | V1 | Plain interlock | 100% cotton | |
| | | V2 | Plain interlock | 50/50 cotton/Tactel | |
| | | V3 | Plain interlock | 100% Tactel | |
| 2 | Fabric weight (drape) | V2 | Plain interlock | 50/50 cotton/Tactel | Light |
| | | V3 | Plain interlock | 100% Tactel Light | |
| | | V4 | Plain interlock | 50/50 cotton/Tactel | Heavy |
| | | V5 | Plain interlock | 100% Tactel Heavy | |
| 3 | Fabric structure | V5 | Plain interlock | 100% Tactel | |
| | | V6 | Mock eyelet | 100% Tactel | |
| | | V7 | Brushed interlock | 100% Tactel | |
| | | V11 | Single jersey tuck | 100% Tactel | |
| 4 | Fibre property | V8 | Single jersey tuck | 100% Tactel | Heavy |
| | | V9 | Single jersey tuck | 50/50 cotton */Tactel | |
| | | V10 | Single jersey tuck | 50/50 cotton/Tactel * | |
| | | V11 | Single jersey tuck | 100% Tactel | Light |

Note: * = Fibre worn next to the skin, on the inside surface of the fabric.

The fabrics in set 4 were single jersey tuck fabrics. They had a smooth knitted surface on the outside and a honeycomb surface on the inside. When these fabrics were made from both cotton and Tactel, one fibre was on the smooth surface and the other on the honeycomb; that is, fabric V9 had cotton on the inside face and fabric V10 had cotton on the outside face.

All the fabrics were assessed for a range of standard routine fabric tests and the results are shown in table 7.3 below.

Two of the main factors noted from the test results were:

1) The fabrics covered a wide range of abilities to absorb water.

2) The rigidity of the fabrics was reduced by the presence of water. In particular fabric V8, where its rigidity decreased four times from its dry test result.

Table 7.3 The routine test results on the wet cling wearer trial fabrics.

| Fabric number | Weight g/m² | Wales /cm | Courses /cm | Static immersion % | SD | Moisture content % | Moisture regain % | Water retention % | Bending length dry (cm) warp | Bending length dry (cm) weft | Bending length wet (cm) warp | Bending length wet (cm) weft |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 159,6 | 180,0 | 150,0 | 2,25 | ,06 | 6,87 | 7,38 | 2,25 | 1,53 | 0,81 | 1,04 | 0,69 |
| W2 | 139,0 | 155,0 | 181,7 | 2,27 | ,06 | 4,74 | 4,98 | 2,27 | 1,04 | 0,75 | 0,94 | 0,64 |
| W3 | 146,4 | 170,0 | 218,3 | 1,16 | ,16 | 3,79 | 3,02 | 1,16 | 1,17 | 0,79 | 0,76 | 0,64 |
| W4 | 157,5 | 145,0 | 178,3 | 0,65 | ,03 | 4,26 | 4,45 | 0,65 | 0,87 | 1,22 | 0,70 | 1,06 |
| W5 | 186,4 | 163,3 | 198,3 | 0,92 | ,16 | 2,88 | 3,02 | 0,92 | 1,19 | 1,02 | 1,12 | 0,80 |
| W6 | 182,0 | 121,7 | 136,7 | 1,36 | ,04 | 3,15 | 3,25 | 1,36 | 0,87 | 0,87 | 0,74 | 0,62 |
| W7 | 178,4 | 171,7 | 101,7 | 1,23 | ,37 | 3,02 | 3,12 | 1,23 | 1,49 | 1,18 | 1,14 | 0,87 |
| W8 | 262,0 | 101,7 | 161,7 | 1,10 | ,29 | 3,17 | 3,28 | 1,09 | 1,05 | 0,93 | 0,25 | 0,21 |
| W9 | 185,3 | 108,3 | 153,3 | 1,82 | ,13 | 3,14 | 4,29 | 1,82 | 1,06 | 1,12 | 0,86 | 0,97 |
| W10 | 191,6 | 110,0 | 156,7 | 1,51 | ,03 | 5,23 | 5,52 | 1,50 | 1,36 | 1,06 | 0,86 | 1,15 |
| W11 | 177,7 | 110,0 | 176,7 | 0,26 | ,06 | 3,14 | 3,24 | 0,25 | 1,07 | 1,06 | 0,94 | 0,85 |

The bending length of the fabrics was tested dry and wet, The fabrics were thoroughly wetted and then spun for 8 seconds in a centrifuge, The water contents varied between the fabrics, but the capacity for holding water in-wear was simulated,

### 7.3.2 Wearer Trial Design and Results.

The work of past researchers identified two main situations where wet cling discomfort is experienced: a warm/hot climate or during high levels of activity. A hot or warm climate is a situation specific to certain times of the year or certain areas of the World. In Great Britain, a hot chamber would be required for wet cling evaluation, but this proved to be too expensive to hire for this project. Nevertheless, there is an increasing interest from sportsmen and women in the performance of their clothing. Most research so far has been carried out in this area and therefore it was chosen for this trial. During this investigation it was assumed that the same factors producing wet cling discomfort in hot weather will apply to the wet cling produced during strenuous activity.

To obtain as many subjects as possible, the people involved in the trial were Shirley Institute staff and friends of the staff. There were 10 subjects in total (4 women, 6 men) and each person regularly did a strenuous activity sport. All these subjects assessed the fabrics in set 4, and the other sets were assessed by one man and one woman. The fabrics were made into short sleeved tee-shirts specifically for each wearer. The garments were issued in sets, and the subjects were asked to wear each garment twice, once before and once after washing it. The garments were washed at the Shirley Institute (and occasionally at home by the subjects) using Home Laundering Consultative Council (HLCC) wash code 6 and Persil automatic washing powder. All the garments were line dried. After each wearing the subjects completed a questionnaire designed to assess the type of discomfort being felt. Once all the garments within a set had been worn, a second questionnaire was completed. This enabled the subject to put the fabrics in order of wet cling comfort within the set. These questionnaires are shown in table 7.4 and 7.5.

The answers to questionnaire 1 for the fabrics in set 4 are shown in detail in table 1, appendix 3. The order in which the fabrics were ranked for comfort within a set is shown in table 7.6.

The results in table 7.6 show that in set 1, fabric V3, a 100 per cent nylon fabric was prefered to fabric V2, a cotton/nylon blend which was prefered to fabric V1, a 100 per cent cotton fabric. The cotton blend fabrics also performed badly against the 100 per cent nylon fabrics. The fabrics in set 2 were seen to be more uncomfortable if they were heavy, and the presence of cotton made the fabric less comfortable.

The fabrics in set 3 were included to observe the effect of fabric structure on comfort. The brushed interlock was the most prefered fabric, followed by the plain interlock. The mock eyelet and the single-jersey tuck fabrics were least liked. These results were surprising because the plain interlock fabric was not expected to be so highly favoured due to its high contact area with the skin in comparison to the other fabrics in the set. The results infer that a hairy surface is the most effective fabric surface at reducing wet cling discomfort.

Table 7.4

## QUESTIONNAIRE 1

SPORTSHIRT WEARER TRIAL (SHIRLEY INSTITUTE)

Tick where appropriate

Fill in one questionnaire per wearing

Subject No._________ Name ________________ Garment/Set No._______

1. Which activity did you do?

Jogging ☐ Squash ☐ Badminton ☐ Keep-Fit ☐

Weight Training ☐ Other (please specify) ____________________

2. No. of spare inches of double fabric on each side of your ribs

½" ☐ 1" ☐ 1½" ☐ 2" ☐ 2½" ☐ 3" ☐ 3"+ ☐

3. Whilst exercising did you wear additional clothing?

a) Under the tee-shirt YES ☐ NO ☐

If 'YES' please specify ____________________

fibre content if known ____________________

b) On top of the tee-shirt YES ☐ NO ☐

If 'YES' please specify garment _______________

fibre content if known _______________

c) Did you wear the additional clothing all the time ☐

some of the time ☐

4. Was the tee-shirt tucked in? YES ☐ NO ☐

5. How sweaty did you get?

Damp ☐ Wet ☐ Dripping Wet ☐

6. Did the fabric soak up your perspiration?

a) YES ☐ NO ☐

b) If 'YES' was the uptake of sweat

Immediate ☐ Moderately Quick ☐ Slow ☐ Nil ☐

7. Did the fabric cling to your body because either the fabric, you or both were wet?

YES ☐ NO ☐

If 'YES', press the fabric against your stomach at the end of your sports session, then pull the fabric off from your skin. Was the clinging force:-

Strong ☐ Moderately Strong ☐ Weak ☐

8. At the end of your sports session feel the inside and outside surfaces of the fabric, was there any differences in wettedness?

Wetter on inside ☐ Wetter on outside ☐ Both the same ☐

9. During your exercising did you notice the fabric releasing and then reclinging to your body?

Often ☐ Sometimes ☐ Not really ☐ Never ☐

10. Did you feel uncomfortable due to the wet fabric?

Yes definitely ☐ Sometimes ☐ Not really ☐ No ☐

11. When you stopped exercising did you feel chilly?

YES ☐ NO ☐

If 'YES' were you:-

a) Outside or in a draft ☐ Sat inside ☐

b) Were you wearing additional clothing YES ☐ No ☐

If YES please specify ____________________

12. Overall impression of the fabric, how would you rate this fabric out of 5 points for the following (circle the number)

| | Very Good | Good | Moderate | Poor | Very poor |
|---|---|---|---|---|---|
| Overall comfort | 1 | 2 | 3 | 4 | 5 |
| Wet cling comfort | 1 | 2 | 3 | 4 | 5 |
| Post-exercise chill | 1 | 2 | 3 | 4 | 5 |

Do you have any other comments on the comfort/discomfort of the fabric/garment?

Please return this questionnaire to Julia Smith at the Shirley Institute.

Table 7.5 QUESTIONNAIRE 2

Overall impression of the garments within a set.

Fill in this questionnaire after wearing all the garments in your set.

Subject No. ____________ Name ______________ Set No. _____________

How would you rank the fabrics? (Put garment nos in order of preference) (they can be equal).

BEST ———————————→ WORST

Circle the fabrics you would prefer not to wear for strenuous activity and also underline any you have a strong objection to

Do you have any additional comments?

Please return to Julia Smith Shirley Institute.

Table 7.6 The fabrics in each set ranked for comfort (questionnaire 2).

| Assessor → | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average rank | Rank order |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Set | Fabric number | Fibre C | Fibre N | | | | | | | | | | | | |
| 1 | V1 | * | | 3 | | | | 3 | | | | | | 3 | 3 |
| 1 | V2 | * | * | 2 | | | | 2 | | | | | | 2 | 2 |
| 1 | V3 | | * | 1 | | | | 1 | | | | | | 1 | 1 |
| 2 | V2 | * | * | 4 | | | | 4 | | | | | | 4 | 4 |
| 2 | V3 | | * | 2 | | | | 2 | | | | | | 2 | 2 |
| 2 | V4 | * | * | 3 | | | | 3 | | | | | | 3 | 3 |
| 2 | V5 | | * | 1 | | | | 1 | | | | | | 1 | 1 |
| 3 | V5 | | * | 2 | | | | 2 | | | | | | 2 | 2 |
| 3 | V6 | | * | 4 | | | | 3 | | | | | | 3.5 | 3.5 |
| 3 | V7 | | * | 1 | | | | 1 | | | | | | 1 | 1 |
| 3 | V11 | | * | 3 | | | | 4 | | | | | | 3.5 | 3.5 |
| 4 | V8 | | * | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 3.8 | 4 |
| 4 | V9 | * | * | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 2 | 3 | 1 | 1.9 | 1 |
| 4 | V10 | * | * | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 3 | 2 | 3 | 2.0 | 2 |
| 4 | V11 | | * | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 1 | 1 | 2 | 2.3 | 3 |

Note: 1 = best, 4 = worst.
Fibre C = cotton, fibre N = nylon.

From the routine test results (shown in table 7.3) the plain interlock fabric was found to retain a higher percentage of water than the ornate fabrics, and the force needed to release the wetter fabric during wear would therefore be higher. The mock eyelet fabric (V6) had a low bending rigidity. This would produce more contact points between the skin and fabric due to its ease in folding. More individual areas of skin would be stimulated when the fabric was released thereby increasing the discomfort. The single-jersey tuck fabric retained approximately one fifth of the water that the other fabrics retained. This would indicate that the wet cling force would be weaker, and the wearer would then experience more discomfort due to the fabric releasing from the skin.

In set 4 the cotton/nylon blends were found to be more comfortable than the 100 per cent nylon fabrics. The results of questionnaire 1 for the fabrics in set 4 are shown in table 1, appendix 3. Fabric V9, with the cotton next to the skin, was found to produce less wet cling discomfort than fabric V10 with the nylon next to the skin (4 people instead of 12 respectively remarked on discomfort). Both fabrics were said to absorb sweat at approximately equal rates, but the main difference would appear to be the surface of the fabric that felt the wettest. Overall, the wearers were undecided for fabric V9, but for fabric V10 they thought that the outside surface (cotton) was the wettest. This indicates that an absorbent fibre can be more comfortable than a non-absorbent fibre when it is worn next to the skin and, when the fabric structure is ornate. This is due to a reduced contact area.

Overall, the discomfort of the fabrics in set 4 was not seen to differ in terms of the rate of sweat absorption. Fabric V8 was seen to differ from the other fabrics because it had a stronger wet cling force (force needed to pull the fabric away from the skin). The wearers noticed wet cling more often whilst wearing the garment and more discomfort was felt due to post-exercise chill. This was attributed to it being a heavier fabric which could hold more sweat than the other fabrics within the set. It would be more likely to hang away from the skin and cool to the ambient temperature. Therefore when the fabric did touch the skin it would feel cold and this would increase any discomfort. The bellows motion of the garment would also increase, thereby cooling the wearer which is a major factor in the presence of post-exercise chill. This explanation was supported by the fact that most subjects said that fabric V8 (the heaviest fabric) had relatively poor comfort ratings for post-exercise chill, wet cling and overall comfort in comparison to the other fabrics in set 4 (results are shown in table 1, appendix 3).

### 7.3.3 Major Findings of the Main and Wet Cling Wearer Trials.

In the main wearer trial, wet cling was identified as a relatively minor discomfort sensation which was not common to everyday life. Tacky cling, was more frequent and uncomfortable.

The wet cling wearer trial was designed to examine four main factors which were considered to effect the presence of wet or tacky cling. The major findings for each factor are:

1) Fibre absorbency:

An absorbent fibre was found to be more uncomfortable in a fabric which provides a high skin contact area, such as a plain interlock fabric.

In a double-sided fabric, with an absorbent fabric on one side and a non-absorbent fabric on the other, the absorbent fibre was more comfortable worn next to the skin. This was observed when the contact area with the skin was low due to a honeycomb fabric construction.

2) Fabric weight and drape.

A heavy weight fabric is more uncomfortable than a light weight fabric within the range of ≈ 200g/m² to ≈ 300g/m². The discomfort was increased when an absorbent fibre was present in the fabric. The heavier weight fabrics produced more post-exercise chill and general wearer discomfort. This was attributed to the fabric hanging away from the body, allowing both the fabric and the skin to cool.

3) Fabric construction.

A hairy fabric surface was found to be the most comfortable fabric surface. This was attributed to the hairs acting like spacers and reducing the contact area between the skin and the wet fabric, thereby reducing the sensation of wetness and coldness. The mock eyelet and single-jersey tuck fabrics were found to be the least comfortable. This was attributed to the weight and hence the drape of the fabrics, where they were very limp and stiff respectively. These would allow cooling and a high frequency of fabric:skin contact and release. The only exception to a hairy fabric surface being the most comfortable was with an extremely hairy fabric made from wool fibres which held the water on the fabric surface (fabric 15 from the main wearer trial).

4) Fibre properties in double-sided fabrics.

The presence of an absorbent fibre in a double-sided fabric improved the comfort of the wearer. The most comfortable fabric had the absorbent fibre next to the skin when the fabric construction on the inside surface was ornate (a honeycomb). The most uncomfortable fabric was a heavy fabric made from a non-absorbent fibre only.

## 7.4 Public Opinion.

The ability of a fibre/fabric to keep a wearer warm in cold weather and/or cool and dry in hot weather is a well used marketing ploy which the public have come to accept and require. Although it is well known that the majority of the general public do not know the difference between the man-made fibres, most of them have heard of the most common fibres. Therefore they will have established an opinion as to the properties of these fibres, both in terms of their performance and comfort, if only to group them all as one. One of the main aims of the public questionnaire was to determine the attitude of people towards the various apparel fibres and the properties that are associated with them (the findings of the questionnaire are discussed in chapter 5). In particular the fibres which are associated with wet cling and perspiration comfort, and what the public want from a fabric for situations when they are hot and sweating.

The interviewees were asked to rank the sensations of wet cling, tight fit and tickle in order of the most irritating, assuming a garment had all of these properties. Wet cling was selected as being the least uncomfortable by 66 per cent of the interviewees and only 9 per cent thought that it would be the most annoying (table 15, appendix 2). The interviewees were then asked to state which fibres they would chose to wear next to their skin in hot and in cold weather, and the main reasons why they had made their choice. The results are shown in appendix 2, tables 16 to 19. For hot weather, 56 per cent of interviewees said that coolness was their main priority and absorbency was the second most important property, with 13 per cent of the votes. As expected, for cold weather, warmth was the main requirement and absorbency was less important, being seventh out of 14 reasons, with just over 3 per cent of the votes.

When the interviewees who played sport were asked to comment on the fabrics they choose to wear during exercise and their reasons; coolness, comfort and absorbency were all said to be highly desirable. Wet cling was mentioned individually (unprompted) and the requirement for no wet cling was seventh with 4 per cent of the votes.

The women were asked about the discomfort of tights or stockings in hot and cold weather. Many women said that in hot weather tights made them sweat, that they caused irritation and rashes, and that they were generally unhealthy due to the nylon fibre.

These answers to the questionnaire show that people are very aware of the hygroscopic properties of fibres. Non-absorbent fibres were thought to be unhealthy and people were aware of the ability of a fabric to cling to the body when wet. Overall, the public indicated that they want a fibre which can absorb their sweat but will not cling when wet.

## 7.5 The Factors Causing Wet and Tacky Cling.

Wet cling discomfort is only experienced when there is either sweat or water present in a garment, and it is due to the fabric adhering and releasing from the skin. There are two main forces which need to be overcome when a fabric releases from the skin. First the force needed to drag the fabric over the skin and second the force needed to release the fabric perpendicularly from the skin.

The force required to release a fabric normal to the skin will be a combination of the following factors:

1) Surface tension of a layer of sweat between the skin and the fabric. This will only be of importance when the fabric and the skin are saturated. It will decrease with a reduction in the quantity of sweat and contact area between the two surfaces.
2) Adhesive skin surface produced by the presence of sweat residues and sebum on the skin. This is usually associated with tacky cling.
3) Amount of sweat on the skin surface and in the fabric.
4) Fabric:skin surface contact area . This is dependent on the presence of hairs, design of the garment, the body shape and location, and the surface structure of the fabric.

All the above factors will affect the force required to slide a fabric over the skin, however the coefficient of friction is likely to be dominant in this case. This increases with increasing fabric speed, contact area, and viscosity, and it decreases with load and excess sweat (Morton and Hearle, 1975).

These factors are discussed below in connection with the development of test equipment to evaluate the wet cling discomfort of fabrics.

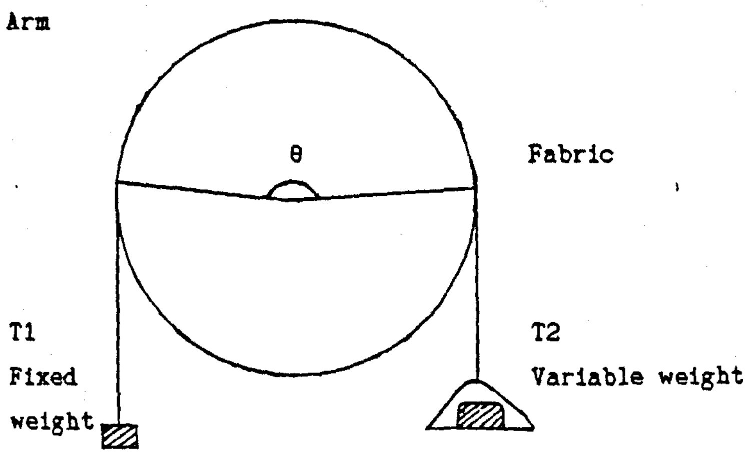
### 7.5.1 The Frictional Properties of the Skin.

The coefficient of friction of the skin is known to increase as it becomes damp, and then decrease as it becomes wet (Swallow and Webb, 1972). The coefficient of friction of the arm was investigated in this project on the arms of 4 men and 4 women. Two frictional methods were tried, the Capstan method (see figure 7.1) and the inclined plane (when the angle of the arm when the fabric just begins to move is measured). The arm was unsuitable for testing the coefficient of friction by the inclined plane method because the muscles in the arm produced an uneven surface, which deflected the fabric sample off the edge of the arm before the test was complete.

The forearm was chosen because it was easily accessible and it could be assumed to be cylindrical (for the purposes of the Capstan method). Therefore the coefficient of friction ($\mu$) of the arm was measured using the Capstan method. The tests were carried out using a plain weave polyester fabric sample which was draped over the arm. A standard weight was added to each side of the fabric; on one side the weight was gradually increased until the fabric just kept moving over the skin. This weight, T2 was noted and substituted into equation 7.1. The Capstan method is illustrated in figure 7.1.

Where $\frac{T2}{T1} = e^{\mu\theta}$, $\mu = \frac{\ln (T2/T1)}{\theta}$ Equation 7.1

Figure 7.1 The Capstan method for measuring the coefficient of friction.




The dorsal and volar surfaces of the forearm were measured separately. The hairiness of the arm (downy or coarse hair) and the direction in which the hairs were lying in relation to the test were noted. All the tests were carried out in a standard atmosphere of 20°C ± 2°C and 65% RH ± 2%. The mean of the results for the four males and females are shown in table 7.7.

Table 7.7 Coefficient of friction of the forearm obtained using the Capstan method.

| | With the hairs | | Against the hairs | |
|---|---|---|---|---|
| Surface | Volar | Dorsal | Volar | Dorsal |
| Males | 0.75 | 0.74 | 0.79 | 0.79 |
| Females | 0.77 | 0.74 | 0.78 | 0.78 |

The coefficient of friction did not vary more than 0.2 between the women. This was within any one direction of test in relation to their hairs on either surface of their arms. The variation between men was much larger, both on the dorsal and volar surfaces. This was attributed to the differences in the quantity and type of body hair between the men and also compared to the women.

The influence of water (sweat) on the coefficient of friction of the arm was also measured using the Capstan method. The coefficient of friction increased from ≈ 0.75 to a value of ≈ 1.10 as the amount of water increased when both the arm and the fabric were wetted. It did not reduce when the arm/fabric were saturated. This is likely to be due to the practical problems of wetting the arm and fabric evenly and realistically (to be like a sweating arm) and the amount of water required to reduce friction.

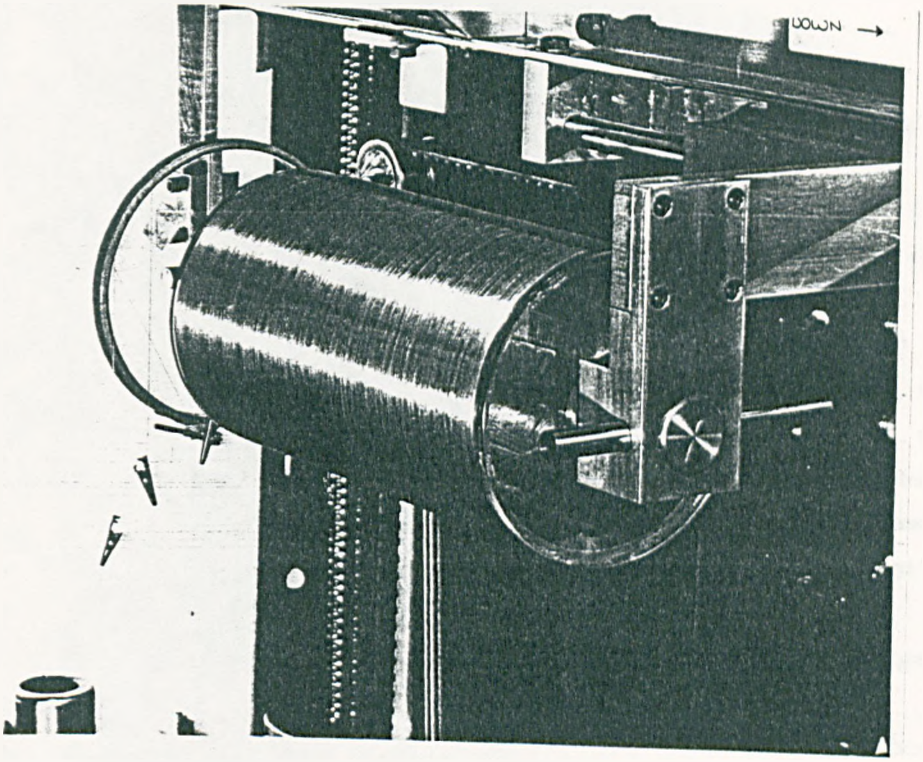
An artifical sweat and sebum (to immitate tacky cling situations) were also assessed during these tests. It was found that the artificial sweat had no appreciable influence on the coefficient of friction. The presence of the artificial sebum (Natuderm cream) was difficult to assess because no satisfactory technique of applying the cream to the arm in a realistic quantity was found.

This investigation identified two main factors which affect the coefficient of friction of the arm and fabric. First, the type and quantity of body hair, which determined the amount of fabric:skin contact. A hairy fabric surface or an ornate fabric structure would have the same effect (as observed from the specific wearer trial). Second, the presence and quantity of sweat.

## 7.6 Test Method to Measure the Surface Drag of Fabrics.

The results from the wearer trials were a useful guide to the frequency and severity of discomfort produced by sweat and the types of fabrics which produce discomfort. The investigation into the differences in the coefficient of friction of various types of skin showed that the differences are relatively minor. Therefore for the general population it was assumed that it would not be necessary to make allowances for them. However, to more fully investigate the potential discomfort of a fabric, a quicker method of assessment was needed. Equipment was designed and developed during this project to quantify the sliding wet cling force of fabrics. The equipment is shown in figure 7.2. The features which reduced or increased this force were determined from tests on the specific wearer trial fabrics.

Figure 7.2 Equipment to measure the surface drag force of fabrics.




The equipment consisted of a 45cm long, 13.3cm diameter perspex cylinder which was covered with 0.5mm stainless steel wire. An alternative skin simulant was not found from 40 possible products assessed in relation to the Capstan friction tests on the arm. The ends of the wire were attached to the cylinder at either end (through a hole in the perspex cylinder). The wire was wound onto the cylinder using a lathe and the wire was hand fed so that the edges of the wire were just about touching each other. The wire was supported along its length by five strips of double-sided adhesive tape which ran the length of the cylinder. The wire proved to be very successful. It performed three main functions:

1) It earthed the cylinder electrically.

2) It produced a ridged surface which acted as body hairs if fabric surface hairs were present.

3) It produced a surface similar to the ridges found on human skin (especially the hands). The same principle is used by the Kawabata KESF handle evaluation system to measure fabric friction.

A cylinder was chosen for this test instead of a flat plane so that the effects of fabric drape could be taken into account during testing. The cylinder was mounted horizontally on the Instron Tensile Tester so that as the cross-head moved downwards, the cylinder moved away from the Instron.

Initially a fabric sample was washed using HLCC wash code 6 and then it was line dried. A fabric sample was cut to 50cm long x 15cm wide, it was draped over the cylinder so that an equal length of fabric was on each side. The hanging edges of the fabric sample had a large bull-dog clip attached to them (≈ 30g each). This was done for three main reasons:

1) To ensure that the fabric was in contact with the cylinder.
2) The differences in fabric weight would be reduced.
3) The test would be more realistic to a fabric being in garment form (as being under its own weight).

The front edge of the sample was attached to a series of crocodile clips which were evenly spaced across the top of the sample. These crocodile clips were attached to 31cm long sewing threads which were secured at the other end between an embroidery ring and a perspex disc facing the cylinder vertically (of diameter 15cm so that the threads would not touch the cylinder). The perspex disc was linked to the load cell of the Instron as shown in figure 7.3. The end of the cylinder was positioned 1cm away from the perspex disc, and the fabric sample was placed onto the other end of the cylinder, so that it was flat and straight. The cross-head of the Instron (linked to the cylinder) was pre-programmed to move 35cm away from the Instron and then stop. The drag force exerted by the fabric was directly measured by the Instron load cell during this time and recorded on chart paper. A typical curve produced by the equipment is shown in figure 7.4.

**Figure 7.3 A fabric sample being tested on the surface drag equipment.**

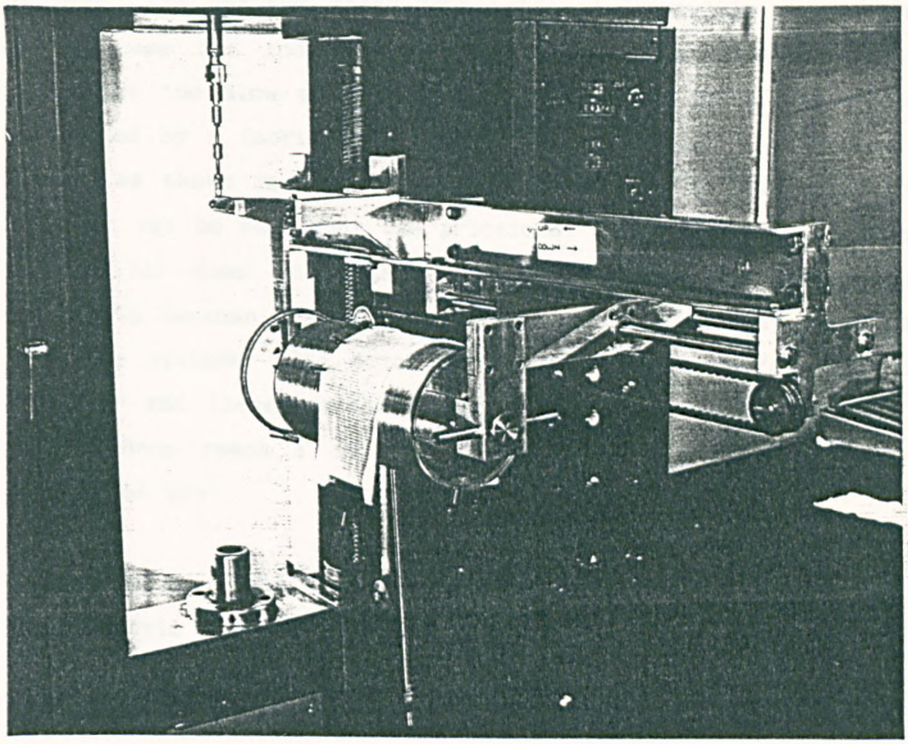
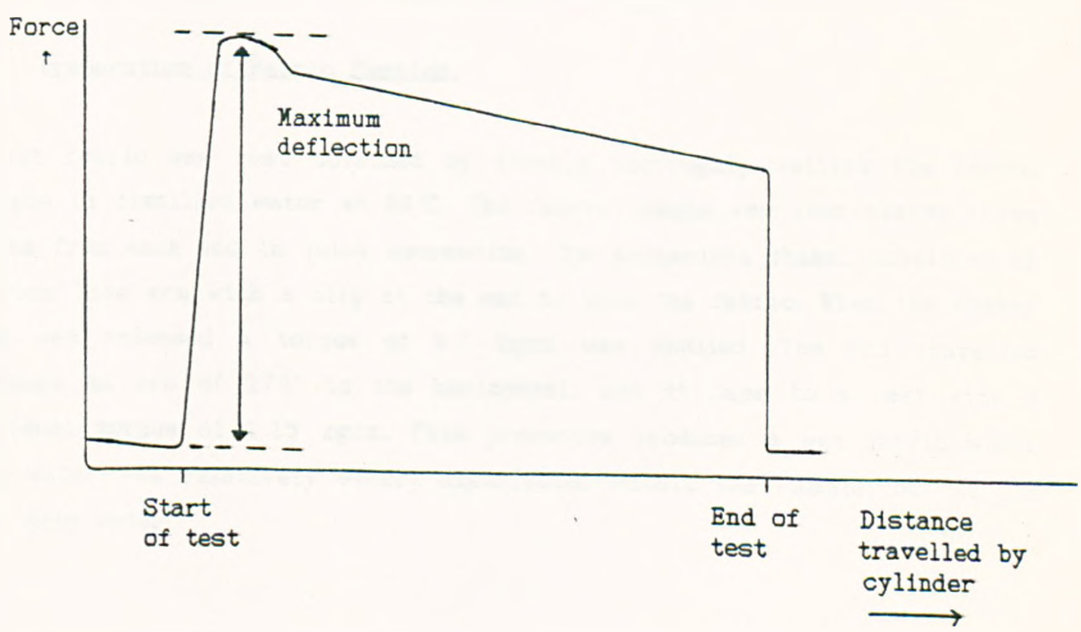


**Figure 7.4 A typical curve produced on the surface drag equipment for a wet fabric.**



The cross-head and chart recorder moved at 12.7 cm/minute (5 inches/min) which was found to be the optimum speed, and the B load cell (range 0 - 100gf) was used. The optimum speed was achieved by trials to determine the speed that was not too fast so that the maximum deflection was distorted, and not too slow so that the fabric sample dried. The maximum drag force exerted by a fabric during the test was measured directly from the chart paper as shown in figure 7.4. This is the static frictional force of the fabric. It can be seen that the frictional force for a wet (and also for a damp fabric) does not attain a steady state after the maximum deflection. This is because the fabric is becoming progressively drier as it passes over the cylinder. The drier fabric requires less force to move over the cylinder and therefore the force continues to decrease during the test. The force does reach a constant force relatively quickly when the fabrics were tested dry.

To ensure accuracy each fabric sample was tested four times: two wales and two course way fabric samples. The mean of the four test results was taken.

### 7.6.1 The Surface Drag Force of the Specific Wearer Trial Fabrics.

The wet cling wearer trial fabrics were tested on the cylinder to determine the effect of water content on different knitted fabric constructions and fibre types. The fabrics were tested wet, damp and dry.

1) Preparation of Fabric Samples.

A wet fabric was best obtained by firstly thoroughly wetting the fabric sample in distilled water at 20°C. The fabric sample was then shaken three times from each end in quick succession. The mechanical shaker consisted of a 20cm long arm with a clip at the end to hold the fabric. When the shaker arm was released a torque of 9.7 kgcm was applied. The arm travelled through an arc of 170° to the horizontal, and it came to a rest with a residual torque of 1.15 kgcm. This procedure produced a wet fabric where the water was relatively evenly distributed within the sample, but it did not drip water.

The damp fabrics were exposed to an atmosphere with a relative humidity of 97%. This was achieved by suspending the fabric sample over a concentrated salt solution of potassium sulphate in an ambient temperature of 20°C for 24 hours. It was essential that once the fabric had been removed from its conditioning atmosphere, the test had to be conducted as quickly as possible so that the fabric would not re-equilibrate.

These techniques were found to produce a better test sample than applying water by spraying, or removing water from a saturated sample by centrifuging, mangling or squeezing by hand. This is because the water was more evenly distributed within the fabric and the product was reproducible.

2) Results and Discussion.

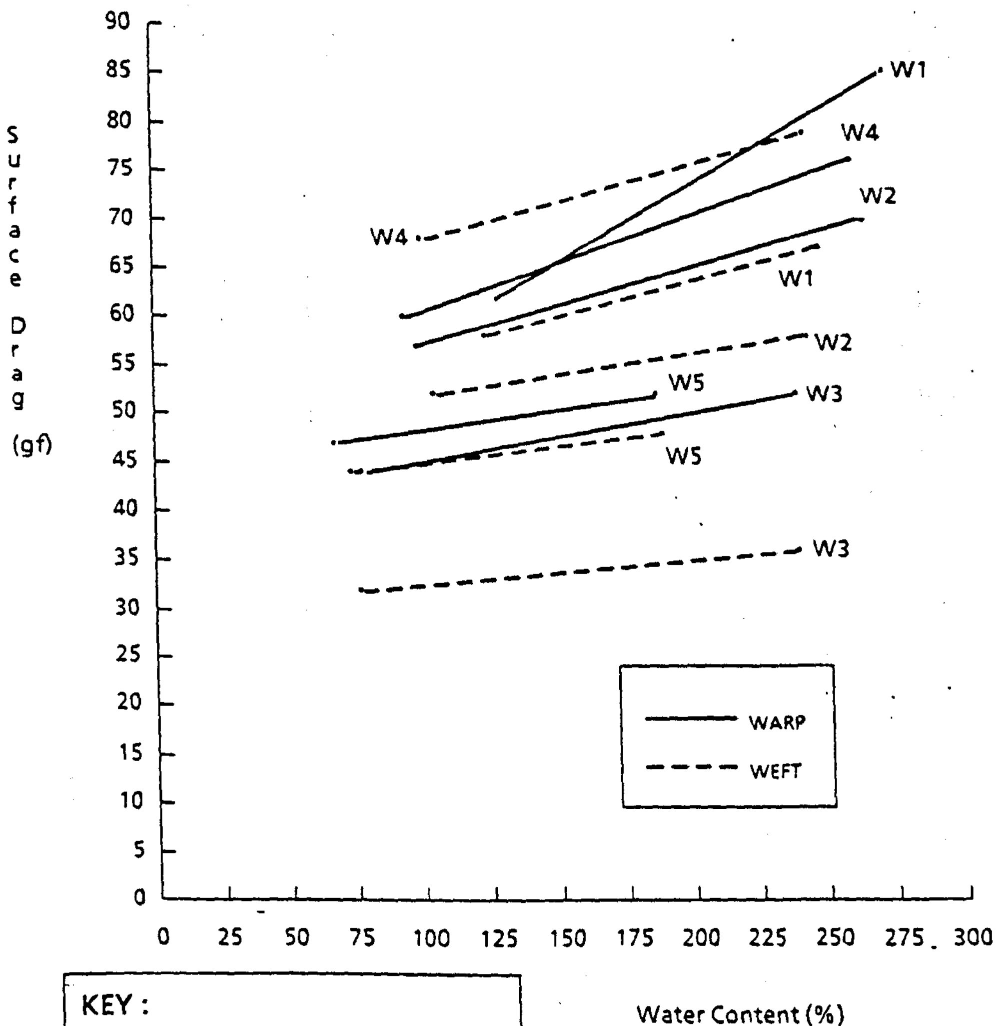
All the wet cling wearer trial fabrics tested, besides fabric V8, showed an increase in surface drag with an increase in water content. This is attributed to the water content being too low for a film of water to act as a lubricant between the fabric and the cylinder. Instead a sticky surface was produced. This is shown in figure 7.6 and 7.7. The results of these trials showed that the percentage water content of the majority of test samples had little effect on the surface drag. This is because most fabrics varied by less than 10gf for an approximate increase in water content of 200 per cent. However, fabric V6, a mock eyelet fabric, did increase in surface drag by approximately 30gf for an increase in water content of 100 per cent.

The fabric construction and fibre content were seen to have a greater effect on the magnitude of the surface drag force than water content. A plain interlock fabric made from nylon had a lower surface drag for a specific water content than a cotton/nylon blend, or a 100 per cent cotton (as shown in figure 7.6). This indicates that the water is held on the surface of the non-absorbent fabrics and it acts as a lubricant.

The influence of the fabric construction on the surface drag was assessed for 100 per cent nylon fabrics. The results are shown in figure 7.7. It was observed that the fabrics with a smooth surface had the lowest surface

# Figure 7.6 The influence of fibre absorbency on increasing the water content of the fabric.

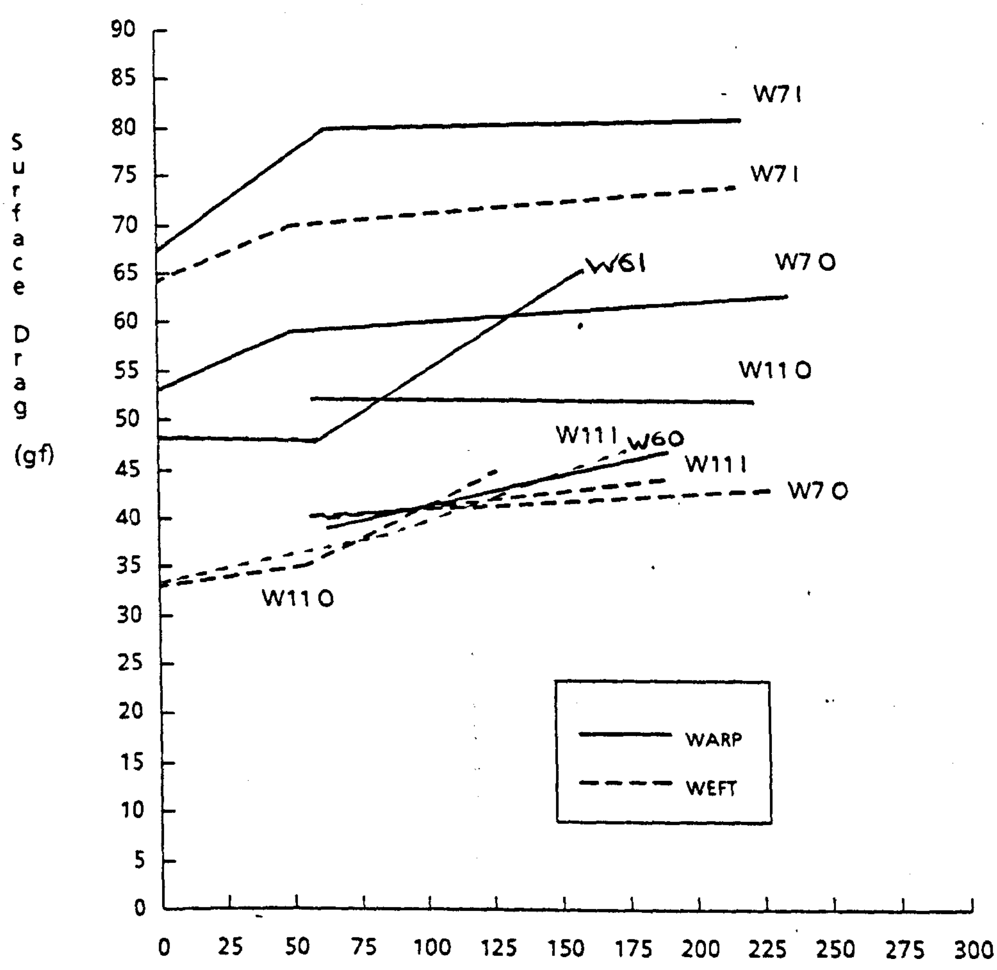
(all fabrics are plain interlock).




**KEY :**

| Fabric Code | Fibre | Weight |
|---|---|---|
| W1 | Cotton | - |
| W2 | Cotton/Nylon | Light |
| W3 | Cotton/Nylon | Heavy |
| W4 | Nylon | Light |
| W5 | Nylon | Heavy |

Figure 7.7 The influence of fabric construction on increasing the water content of the fabric.
(all fabrics are 100% nylon).




KEY :

| Fabric Code | Fibre Construction | Weight |
|---|---|---|
| W7 | Brushed interlock | - |
| W11 | s.j. tuck | Light |
| W6 | Mock eyelet | |

I = Outside Surface
O = Inside Surface

drag and that fabric W7, a brushed interlock fabric had the highest surface drag. The fabrics were ranked in approximately the same order as the wet cling wearer trial, indicating that a high surface drag is more comfortable than a low one.

## 7.7 Conclusions.

Wet cling was found to be a minor discomfort sensation, both in terms of its ability to produce discomfort and it was also rarely noticed. A new sensation (which had not been documented or mentioned by other researchers) was discovered. It was called tacky cling. It occured when a subject had been sweating at an elevated rate for a long period of time. It was more common than wet cling and it was considered to be more uncomfortable. Wet cling and tacky cling were noticed most when the fabric released from the skin. Therefore when doing strenuous activity it is beneficial to have a fabric that strongly clings to the skin to prevent fabric release or alternatively a fabric that reduces the skin:fabric contact area.

A high activity (wet cling) wearer trial was designed to evaluate the importance of fibre absorbency, fabric structure, fabric weight and the performance of double-sided fabrics (with an absorbent fibre on one side and a non-absorbent fibre on the other). The results of this trial showed that the presence of an absorbent fibre made the fabric more uncomfortable to wear than a non-absorbent fibre in a plain interlock fabric construction. In terms of overall comfort, wet cling comfort and post exercise chill the lighter weight fabrics were more comfortable than the heavier weight fabrics. The most comfortable fabric surface to wear against the skin was a brushed, hairy surface (except in lambswool/angora fabrics). This was attributed to the reduction in fabric surface contact with the skin. The hairs would act like spacers between the skin and the main body of the wet fabric. In a double-sided fabric the presence of an absorbent fibre improved the comfort of the wearer, whether it was on the inside or the outside surface. The most comfortable combination was to have the absorbent fibre next to the skin in an ornate construction, and the non-absorbent fibre on the outside.

The wet cling wearer trial fabrics were evaluated on a surface drag tester designed for the purpose. It was noted that the fabrics with a high surface drag when wet or damp were the most comfortable in the wearer trial, and vice versa. The water content had little effect on the surface drag, but the fabric surface construction and the hygroscopic properties of the fibre did influence the magnitude of the force.

One of the main aims of the public questionnaire was to determine the attitude of the public to different fibres. One thousand and four members of the general public were asked for their views on the properties of fibres in relation to comfort during hot weather or during strenuous activity. Their answers showed that they are conscious of the ability of different types of fibres to produce discomfort during these conditions. Their answers showed that they want an absorbent fibre which will not cling when it is wet.

These findings indicate that to optimise the comfort of a person when they are sweating, a fabric should either strongly cling to the body or even better, have a hairy surface to act as a spacer. The fabric should contain a percentage an absorbent fibre and the fabric weight should be such that it allows the clinging properties of the fabric to be optimised.

# CHAPTER 8

# TICKLE.

We are all familiar with being tickled as children both with the hands and also with a soft object such as a feather. Both of the sensations are refered to as tickle, but only the latter is relevant to the type of sensation experienced whilst wearing clothing. Research work has been carried out by physiologists into the mechanism of tickle from the hands, but after discussions with dermatologists at the Manchester Royal Infirmary, this type of tickle was considered to have a very different mechanism to fabric tickle. The latter is a skin surface property which stimulates the hairs and the nerves close to the skin, whereas hand tickling is a sensation which mainly comes about due to tensioning the muscles. The actual mechanism of garment tickle is not understood at all and no physiological information could be found in the literature. This was surprising because tickle is a well known sensation. Tickle is commonly used to describe an irritating, itchy sensation which is usually associated with hairy fabric surfaces and wool. This chapter investigates the major factors which produce a tickle sensation from a garment. For instance, is the hairiness of the fabric surface the only factor influencing the magnitude of tickle and if so are the long or the short hairs the major cause? What effect does the hairiness of the skin have on tickle and what part does the garment design play in the discomfort experienced?

## 8.1 Main Wearer Trial.

Initally it was recognised that tickle was used as a universal term (similar to irritation) which described many sensations, in particular prickle, itchiness, irritation and tickle itself. This was noted before the main wearer trial began and the subjects involved in the wearer trial were asked to be aware of the differences between these sensations. This was done by explaining that tickle was a sensation similar to a feather being passed over the skin. The other sensations were also explained using similes (as described in chapter 3). When a trial garment was issued, the first questionnaire answered by the wearer's determined their initial reaction to the fabric and their prediction of its in-wear comfort. Only 4 out of the 22 garments were predicted as producing a tickle sensation; these were fabrics 8, 15, 16 and 17. The first two fabrics had very hairy surfaces, and fabrics 15, 16 and 17 had a typical wool appearance. Once the fabric had been handled, the garment was worn for approximately five minutes, and after this time the subject was asked to comment on the initial comfort of the garment. In this case tickle was rarely mentioned, however 'itchy' and 'irritation' were terms which were used quite commonly. It is likely that the wearer was experiencing a combination of sensations at this early stage, one of which could be tickle. After the subject had worn the garment for a number of hours, tickle emerged as a common discomfort sensation.

Many subjects commented that they noticed tickle for the first time when they had just started to sweat, either due to strenuous activity or hot weather. Once the subject was past the initial stage of sweating the tickle discomfort subsided. This same effect was noted in a smaller wearer trial when four women wore woollen jumpers (mohair, lambswool and shetland wool) next to their skin. If the skin was dry, the occurence of tickle and prickle was less than when the skin was sweating slightly. There are two possible explanations for this increased discomfort: either the skin becomes more sensitive when it begins to sweat, or the higher adhesion force which is produced by sweat makes the release of hairs (both fabric and body) more pronounced. No information was available in the literature to explain the relative importance of these two factors, but it is likely that they are both involved in the increased tickle.

To normalise the answers so that the fabrics which were assessed by fewer than 20 subjects can be directly compared, the number of answers to a question was mutltiplied by (20 x 2) ÷ (n x 2), where n = the number of subjects who assessed the fabric. These corrected values are used in the comparison of the results. Six fabrics in particular were identified as being a major source of discomfort. These were fabrics 5, 7, 8, 11, 15, 16, 17 and 18. These results are shown in table 8.1 below along with the results for the other trial fabrics (see table 4.1 for the fabric information).

Table 8.1 The number of people that predicted (from handle observations) and experienced tickle (during wear) from the main wearer trial fabrics.

| Fabric number | Predicted Tickle | Sensation after 5 mins wear | | Tickle during wear (worn 2x per subject) |
|---|---|---|---|---|
| | | Tickle | Itch/irritation | |
| 1 | 0 | 0 | 2 | 3 |
| 2 | 0 | 0 | 2 | 4 |
| 3 | 0 | 0 | 0 | 2 |
| 4 | 0 | 0 | 0 | 3 |
| 5 | 0 | 0 | 1 | 11 |
| 6 | 0 | 0 | 0 | 2 |
| 7 | 0 | 0 | 2 | 17 |
| 8 | 5 | 0 | 0 | 7 |
| 9 | 0 | 0 | 0 | 3 |
| 10 | 0 | 0 | 0 | 2 |
| 11 | 0 | 1 | 1 | 9 |
| 12 | 0 | 0 | 0 | 2 |
| 13 * | 0 | 0 | 0 | 3 |
| 14 * | 0 | 0 | 0 | 2 |
| 15 * | 11 (10) | 1 | 1 | 27 (24) |
| 16 * | 6 (1) | 0 | 0 | 23 (4) |
| 17 * | 6 (1) | 0 | 0 | 17 (3) |
| 18 * | 0 | 7 (1) | 0 | 7 (1) |
| 19 * | 0 | 0 | 0 | 2 |
| 20 * | 0 | 0 | 0 | 1 |
| 21 * | 0 | 0 | 0 | 2 (1) |
| 22 * | 0 | 0 | 0 | 3 (2) |

* These fabrics were assessed by less than 20 subjects and therefore the values in the table have been normalised.
Figures in parenthesis refer to the actual number of answers given to a question before the figures were normalised.

Tickle was the most common discomfort sensation in the main wearer trial. The answers to the questionnaires indicate that tickle is a sensation which is experienced after a garment is worn for a number of hours, rather than in the first few minutes of wear. The handle and visual observation of a fabric are quite effective at selecting the most uncomfortable fabrics, as illustrated with fabric 15 which was excessively hairy. Nevertheless, some people who experienced discomfort in-wear did not predict it. In addition, every fabric in the trial produced a tickle sensation for at least one of the subjects. Therefore, the extreme hairiness of a fabric surface cannot be assumed to be the only factor causing or influencing tickle. To establish a greater understanding of the properties of both a fabric and a wearer in the mechanism of tickle, a subjective trial was designed. The trial was based on the consideration of the most likely factors which could be influencing the production of the sensation. These factors are discussed in section 8.2 below.

## 8.2 The Factors which could be Effecting Tickle.

The wearer trial has established that an excessively hairy fabric surface and wool were the main causes of discomfort due to tickle, but other underlying properties were obviously present which did not fit into these two categories. The most likely factors, either physiological or physical, which could also be influencing the presence of tickle are listed below.

Area of the body (the neck and shoulders are very sensitive).
Psychological awareness.
What the person is used to wearing or thinks desirable.
Sweating activity.
Skin hairiness (hair can act as a sensitive stimuli receptor and a barrier).
Gender.
Age.
Fabric hairiness (length distribution).
Fibre type.
Fibre bending properties.
Direction of movement of the fabric and body hairs.
Speed of the fabric over the skin.
Pressure of the fabric on the skin.
Fibre shedding.
Electrostatic properties of the fabric.

The quantity and type of hairs on the skin varies with gender, age, race and obesity. Women have more hairs per unit area than men, but their hairs are finer. Fat people, in particular women, have less finer hair because they produce more of the hormone testosterone which stimulates the production of coarse hair. Older people also have less body hairs than younger people. Women loose their body hair quite suddenly around the time of the menopause, whereas men tend to loose their body hair more gradually at approximately the same time of life. People from different races have different amounts of body hair, for instance the Japanese have very little hair in comparison to the Caucasians and Africans. To generalise it can be said that women and children have more finer hairs on their skin than men and obese women, that have fewer, but coarser hairs. Elderly people have fewer body hairs than younger people.

Different areas of the body are more sensitive than others, in particular the neck and shoulders, whereas the upper arm and the outer thigh are relatively insensitive (Starling and Lovett Evans, 1968). Information is not available in the literature on the physiological reasons why some areas of the body are more sensitive to tickle than others in particular. However, in general, the more sensitive areas of the torso tend to have fine body hairs which are easily stimulated. The density of the nerve endings in the skin will also influence the perception of the sensation. A dense distribution will make the skin more sensitive and discriminating between two stimuli.

When the main wearer trial subjects were asked to comment on where they had experienced tickle, invariably the shoulders were mentioned. In addition, if the body is just starting to sweat the occurence of tickle increased, whilst wearing both a hairy or a non-hairy fabric. This could be due to two main factors, either separately or a combination of the two. First, the skin could become more sensitive when it just starts to perspire, or second, the body and perhaps the fabric surface hairs lightly adhere to the skin due to the damp skin. When the fabric moves in relation to the body then the hairs are 'prised' off the skin and tickle is experienced.

The psychological awareness of the wearer will be important. If a wearer feels irritable and alert they are more likely to experience discomfort than if they are relaxed and sleepy. The initial attitude of the wearer to the fabric will also influence the registration of discomfort. If it is a totally new fabric which they have no past experience of, they are more likely to be critical. If they are used to wearing the fabric, they may have set views on its comfort or discomfort, and a wearer will judge it accordingly.

When wearing any garment, there is a certain amount of skin:fabric movement when the person moves. The amount of movement will depend on the design and of the garment, the stretch of the fabric and the type and speed of the body movement (sitting, stretching etc.). The skin is sensative to a change in conditions and therefore fabric:skin movement is undoubtedly the most common cause of tickle (and other sensations).

The direction of movement between the fabric and the body hairs is likely to be a major factor in determining the amount of tickle experienced by a wearer. If the fabric moves in the direction in which the hairs are lying, the fabric will in effect 'ride over' the hairs, therefore the skin and hairs will not be stimulated. If the fabric moves in the opposite direction, the body hairs will become entangled in the fabric, lifted from the skin surface and thereby stimulated. It is then that the wearer may experience tickle. The speed, acceleration and the directional changes of the fabric moving over the body will also effect the amount of body hairs which are stimulated and registered by the wearer.

If the body is under pressure at the position where the fabric is moving over the skin (for instance on the tops of the shoulders when a heavy overcoat is worn), the body and fabric hairs will be flattened and the fabric will be expected to stimulate the skin more than the body hairs. In this situation tickle would be expected to be minimal.

As shown by the answers to questionnaire 1 in the main wearer trial, the quantity and length of the fibres protruding from the fabric surface were recognised by the subjects to be a source of tickle discomfort and irritation. This proved to be a correct assumption for many of the fabrics (8, 15, and 16). However fabrics 6 and 9 also had a hairy surface, but they were not found to produce more tickle than a non-hairy surface, such as fabric 14. Therefore the tickliness of a fabric is either dependent on the number of the fibres protruding from the surface of a certain length and diameter (which effects its bending properties), or it is influenced by other factors which have not been recognised as yet. It is most likely that the bending rigidity of the fibres is the main reason why fabrics 6 and 9 do not produce as much tickle as the other hairy fabrics (which are wool). The hairs on the surface of fabrics 6 and 9 are fine and short and they are unlikely to be rigid enough to flex the body hairs more than a non hairy fabric surface, which also has many surface hairs (if it is made from a staple fibre).

There are various methods available to catergorise the hairiness of a fabric surface, the most advanced of which uses an image analyser (Umbach and Mecheels, 1984), a facility which was not available to the author for this project. Instead, the surface of the fabrics was photographed so that an enlarged silhouette was produced. This was achieved by placing the fabric over a stiff, but thin piece of cardboard. The fabric was secured at each edge with adhesive tape so that the folded edge of the fabric was flat against the cardboard, but not stretched. The mounted fabric was positioned between two glass plates and placed into a photgraphic enlarger, preset to have a magnification of 15 times. The silhouette photograph of the fabric was then assessed for the range in the length of protruding fibres by placing a grid next to the photograph, a method suggested by Fourt and Hollies (1970).

This method helps to quantify fabric hairiness, however it is common to see a surface fibre 'looped over', which is apparently attached to the fabric at both ends, and this method cannot quantify such fibres. This was a common occurence for the longer hairs. The author found that the wearer trial fabrics fell within a few categories of hairiness and that a subjective visual inspection of the photographs was sufficient to determine the type of fabric hairiness for this study. Some examples of the fabric profile photographs of the main wearer trial fabrics are shown in figures 8.1 a, b and c.

The wearer trial fabrics which shed fibres from their surfaces (discussed in chapter 13) also caused tickle discomfort, most notably fabric 15. This is mainly thought to be due to the loose fibres attaching themselves to the

**Figure 8.1** Fabric profile photographs of three main wearer trial fabrics.

a) Cotton/nylon eyelet (fabric 4).

b) Polyester interlock (fabric 14).

c) Polyester/viscose dropstitch, brushed (fabric 9).

wearers body. In this situation they are relatively free to move (maybe slighty out of phase with the body and fabric hairs), and therefore they provide an additional source of tickle by stimulating the body hairs (by acting like an extended lever arm) and skin.

A wide range of fibre types was included in the main wearer trial and therefore there were plenty of opportunities for differences in the comfort properties of these fibres to be shown. Wool, as discussed in chapter 9, was the only fibre to produce prickle, it also produced tickle more frequently than any other fibre in the main wearer trial. As mentioned in section 8.1, all of the fabrics in the wearer trial did cause tickle for at least one person. Overall, no specific fibre types were observed to influence tickle besides wool; therefore it is not considered to be a major factor.

The electrostatic properties of a fabric are also unlikely to contibute much to the amount of tickle discomfort. The wearer trial has shown that all fabrics produced tickle to some extent during wear. However the fibres most likely to produce static electrical build-up during wear, such as fibres made from PVC and acrylic (for example fabrics 8, 13, 21), were not noticably more tickly, even when the fabric was brushed. Nevertheless, static electrical build-up may cause the hairs on the skin to elevate, thereby making them easier to stimulate when the fabric moves over them. It may also sensitise the skin, making some individuals more prone to tickle than others, depending on their ability to ignore the electrical stimulation.

During this project the author had discussions with Dr.C. Smith from the University of Salford (Smith, 1985). He was working with people who experienced extreme universal allergic reactions. He was and still is investigating the possibility that their bodies could not cope with the electrical stimuli to the skin that man-made fibres and other synthetic materials gave rise to. An allergy was the result of their sensitised skin. There was obviously no-one in the main wearer trial who had such extreme allergies. However the possibility that a wider range of people with slightly less sensitive skin are effected by electrical stimuli from man-made fibres, could usefully be researched further.

## 8.3 Specific Wearer Trial to Determine Some of the Main Factors Influencing Tickle.

A selection of the most important factors discussed in section 8.2 were chosen to be evaluated further. A series of subjective tests were carried out to examine the effect of 5 factors which were considered to be important to tickle discomfort, but as yet they have not been investigated. These factors were:

1) Gender.
2) Skin hairiness (fine hair or coarse hair).
3) Speed of the fabric over the skin.
4) The effect of loading the fabric.
5) Fabric surface hairiness.

To investigate these factors, an instrument was designed which could evaluate different fabrics for tickle at various speeds of fabric movement over the skin and the loading on the fabric. To set up the test, a subject was asked to sit in a chair resting their arms on the arm-rests, and a fabric sample was draped over each arm. The fabric was drawn across their arms towards their hands (in the direction of their body hairs) by sewing threads which were wound up onto a rotating bar (see figure 8.2). The speed at which the fabrics travelled over the arm was determined by the diameter of the rotating bar. This was achieved by using two metal collars of different diameter, 2cm and 3cm. The bar was 1cm diameter. The collars could be slid along the bar to be in line with the sewing threads, and then fixed to the bar with a grub screw.

When the fabric stopped moving the subject was asked which of their arms was tickled the most, their left or right, and the combination of speed, pressure and/or fabric was noted. The subject was requested to keep their eyes closed during the trial so that their personal expectations of the fabrics or test parameters would not influence their final decision. The fabric samples were placed onto the arms of the subject so that they were as near to the elbow as possible, but still flat. Great care was taken to ensure that the sewing thread (which was attached to the rotating bar) did not touch the skin, but it did not raise the fabric away from the arm.

This meant that when the bar was rotated at one speed, the fabric could be pulled along one arm slowly (as the sewing thread wrapped itself around the bar), and pulled along the other arm fast (as the sewing thread for the other fabric wrapped itself around the 3cm diameter collar). Three speeds were chosen for this trial:

Slow = 0.15m/min = 0.25cm/s
Middle = 0.30m/min = 0.50cm/s
Fast = 0.45m/min = 0.75cm/s

The fabric was not pulled over the arm using a faster speed than 0.75cm/s because the test would be over too quickly, before the subject would have time to form an opinion. The bar was driven by a variable speed motor which was turned on and off by the operator.

To assess the effects of increased load on tickle, when the fabric was draped over the arm of a subject, a large bulldog clip (the width of the fabric sample) could be added, with or without additional weights, to load the fabric. The weights were chosen after a few trial runs by the author to determine an even, but realistic spread of loads over which to test. The weight added to each side of the fabric including the bulldog clip was:

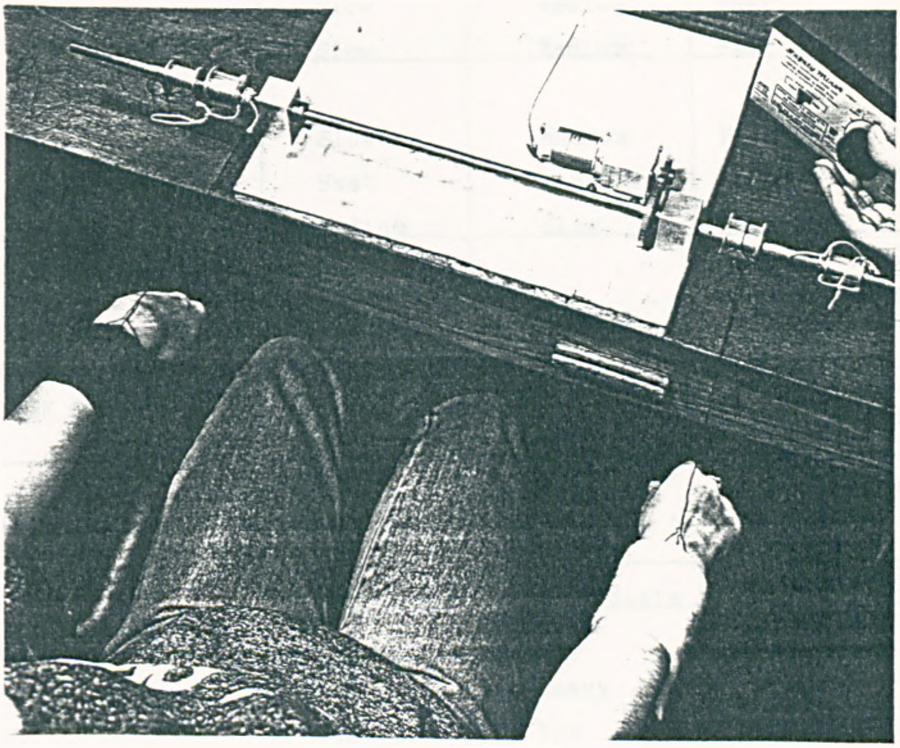
Non = 0.0g
Middle = 9.5g
Heavy = 40.0g

The fabric was drawn over the arm at the slowest speed so that the subject would have more time to assess the two fabrics.

Two fabrics were selected from the main wearer trial to evaluate tickle. They were chosen because they are the two extremes of fabric which are expected to produce and not to produce tickle, that is, one was a very hairy wool/angora fabric (number 15) and the other was a smooth polyester woven fabric (number 20). The fabric samples were 6cm x 30cm. They had raw edges so that stitching would not divert the attention of the subject away from the properties of the fabric. The raw edges did not curl under because the sewing thread were attached to very close to the edge and the fabric was pulled across the arm from a slightly elevated position. The fabrics were compared against each other at various speeds and loadings in addition to them being assessed individually for these factors.

In figure 8.2, where a female subject is being asked to assess whether her left arm (smooth fabric moving slowly with no load) was tickled more than her right arm (hairy fabric moving quickly with no load).

Figure 8.2 The equipment designed and used to assess the factors effecting tickle



Forty subjects were included in this trial, 24 men and 16 women. All were Shirley Institute staff. A note of the gender and hairiness of their arms (downy or coarse hair) was made at the time of the trial and the results were analysed accordingly. An assessment on the type of hairiness of their arms was made subjectively by the author. The differences between the coarser and finer type of hair was easy to distinguish. All of the women had fine hair as did a few of the men in the trial. The rank order of the fabric and skin hairiness, speed and loading in relation to tickle is shown in table 8.2.

**Table 8.2 The variation in speed and load which produced the most and least tickle when a hairy or a smooth fabric were assessed on people with either downy or hairy skin.** (The rank order of each factor was calculated.)

8.2.1 Speed of the fabric moving over the skin.

| Subject | Most Tickle | Intermediate | Least tickle |
|---|---|---|---|
| HAIRY FABRIC | | | |
| Males | Slow | Medium | Fast |
| Females | Slow | Medium | Fast |
| M + F | Slow | Medium | Fast |
| SMOOTH FABRIC | | | |
| Males | Slow | Medium | Fast |
| Females | Fast | Medium | Slow |
| M + F | Medium | Slow | Fast |
| HAIRINESS OF THE SKIN | | | |
| Fine hair | Slow | Medium | Fast |
| Coarse hair | Slow | Medium | Fast |
| OVERALL RANK FOR ALL THE SUBJECTS AND BOTH FABRICS | | | |
| | Slow | Medium | Fast |

8.2.2. The weight attached to the fabric.

| Subject | Most Tickle | Intermediate | Least tickle |
|---|---|---|---|
| HAIRY FABRIC | | | |
| Males | Non | Heavy | Medium |
| Females | Heavy | Non | Medium |
| M + F | Non | Heavy | Medium |
| SMOOTH FABRIC | | | |
| Males | Heavy | Non | Medium |
| Females | Heavy | Medium | Non |
| M + F | Heavy | Non | Medium |
| HAIRINESS OF THE SKIN | | | |
| Fine hair | Non | Heavy | Medium |
| Coarse hair | Non | Medium | Heavy |
| OVERALL RANK FOR ALL THE SUBJECTS AND BOTH FABRICS | | | |
| | Non | Heavy | Medium |

Overall it was found that the speed at which the fabric moved over the skin did influence the tickle produced. When the hairy fabric was assessed for the effect of speed, the slower speed produced the most tickle, and the fastest speed the least tickle. The smooth fabric had a slightly different order of ranking, the speed which produced the most tickle was the intermediate speed. The fastest speed produced the least tickle as did the hairy fabric. The type of skin hairiness did not effect the order in which the speeds were ranked for tickle for both the hairy and the smooth fabrics. The subjects found that the slowest speed was the most tickly and the fastest speed the least tickly.

The different loads applied to the fabrics also showed some interesting trends in relation to the amount of tickle experienced. Both the hairy and the smooth fabric had the intermediate load producing the least tickle. The most tickle was produced by no weight being added to the hairy fabric and the heavy weight being added to the smooth fabric. As for the effect of speed, no differences were seen between the results of the people with fine or coarse hair.

There were differences between the results of the males and females. The most notable was the effect of speed on the tickle of the smooth fabric. The males experienced the most tickle when no weight was added to the fabric, and least tickle when the heavy weight was added. In contrast, the females found that when the fabric had no weights attached, it was the least tickly, whereas the most tickle was experienced from the intermediate weight. The males tended to have coarser hair than the females and therefore the heavy weight would flatten these hairs, thereby reducing skin stimulation. When no weight was added, any hairs standing proud of the skin would be moved and stimulated. The females have finer, shorter body hair than males. When no weight was added to the fabric the hairs were not stimulated as much as when the intermediate weight was added. This could be due to the extra weight causing the fabric to touch the skin (rather than ride over the hairs) which is more sensitive to the smooth surface than the hairs on the arms.

### 8.3.1 The Influence of a Hairy or a Non-hairy Fabric Surface on Tickle.

The results of the tickle trial had shown that individually the hairy and the smooth fabrics produced more tickle at different speeds and weights to each other. In order to determine the variation in the speed or loading of the hairy and smooth fabric to produce the same amount of tickle, a second series of tests were conducted on the forty subjects. The results and combinations of factors used in this trial are shown in table 8.3. Many of the subjects commented on the difficulty in deciding on which fabric was the most tickly during a test. This indicates that many of the differences in tickle sensation were small and that tickle is not simply related to the fabric surface and that over-riding factors such as the speed of the fabric moving over the skin is a major influence.

Table 8.3 The number of subjects who stated that either the hairy or the smooth fabric was the most tickly when the speed or the load was varied.
(Each subject assessed the combination of speed or load twice, both assessments are recorded) (Test combination = fabric surface,speed or load)

8.3.1
Speed (no load)

| Test combination ↓ Fabric → Left arm / Right arm | Hairy | Equal | Smooth |
|---|---|---|---|
| Hairy slow/smooth slow | 24 | 25 | 31 |
| Hairy medium/smooth medium | 29 | 20 | 31 |
| Hairy fast/smooth fast | 27 | 22 | 31 |
| Hairy slow/smooth medium | 6 | 7 | 27 |
| Smooth slow/hairy medium | 30 | 6 | 4 |
| Hairy slow/smooth fast | 19 | 2 | 19 |
| Smooth fast/hairy slow | 31 | 7 | 2 |
| Hairy medium/smooth fast | 8 | 8 | 24 |
| Smooth medium/hairy fast | 25 | 12 | 3 |

8.3.2
Load (slow speed)

| Test combination ↓ Fabric → Left arm /Right arm | Hairy | Equal | Smooth |
|---|---|---|---|
| Hairy non/smooth non | 38 | 15 | 25 |
| Hairy medium/smooth medium | 33 | 26 | 19 |
| Hairy heavy/smooth heavy | 22 | 32 | 24 |
| Hairy non/smooth medium | 11 | 6 | 22 |
| Smooth non/hairy medium | 17 | 5 | 16 |
| Hairy non/smooth heavy | 14 | 2 | 23 |
| Smooth heavy/hairy non | 17 | 4 | 18 |
| Hairy medium/smooth heavy | 16 | 4 | 19 |
| Smooth heavy/hairy medium | 12 | 7 | 20 |

Tables 8.3.1 and 8.3.2 show that when the hairy and smooth fabrics were tested against each other at the same speeds or loads, there was little difference between the tickle produced from the two fabrics, and that many subjects gave them an equal rank. When the speed or the load on the fabric was varied for the two fabrics the subjects became more aware of the differences between the two fabrics.

The most noticable factor which effected tickle was the variation in the speed of the fabric over the skin. It was seen that the fabric moving the fastest always felt the most tickly. However, an exception to this was seen when a smooth fabric moved fast and the hairy fabric moved slowly, in this case equal votes were given to both fabrics. This implies that the hairiness of the fabric has little influence on tickle in comparison to a variation in speed.

From the results of the trial (table 8.2.1), when the influence of speed was being assessed using one fabric, this showed that fabric speed did have an effect. In this case the slowest speed (0.25cm/s) was nearly always the most tickly. This variation in the two sets of results indicates that when two different fabrics surfaces are being assessed, there is another factor influencing tickle. Although unlikely it may simply be due to the attitude of the subjects to having two different fabrics to test instead of one. They may have biased their answers according to what they thought should be felt, especially if the decision was difficult. A more extensive trial would be needed to solve this issue. However the effect speed of the fabric moving over the skin is obviously an important in terms of tickle discomfort.

When the loading on the two fabrics was varied, the differences in tickle became small. At lower loads the hairy fabric was found to be the most tickly. When the loading on the fabrics was varied, the votes were quite evenly spread between the two fabrics being assessed. However when the hairy fabric had no weights attached to it, and the smooth fabric had either the medium or heavy weight, approximately twice the number of subjects said that the smooth fabric was more tickly. The smooth fabric with the middle loading was also more tickly than the hairy fabric with the heavy load. In this trial the tickle produced by loading the fabric was seen to depend to some extent on gender and the fabric hairiness, which was also seen in the overall results shown in table 8.2.2.

### 8.3.2 The Main Factors Influencing Tickle.

The specific subjective trials have shown that the surface hairiness of a fabric and fibre shedding are by no means the only factors which influence tickle, it is one of many. The speed of the fabric moving over the skin and the load exerted on the skin can over-ride the influence of fabric hairiness in certain combinations. A change in the direction, and therefore acceleration of the fabric over the skin, will also effect tickle.

Fabrics containing wool produced more discomfort due to tickle than any other fibre. The wool fibres tend to be thicker and therefore more rigid (as discussed in chapter 9) than any other apparel fibre so that they can stimulate the skin more noticeably. This factor is thought to be the main reason for wool discomfort. The brushed surface of other fabrics not containing wool did not increase the occurence of tickle discomfort above the fabrics which had not been brushed.

The type of body hair affected the order in which a hairy or a smooth fabric were ranked for tickle when the speed and load were varied. When the skin just starts to sweat, the occurence of tickle increases, along with the discomfort it produces. When the skin is thoroughly wet the sensation of tickle is reduced. The type of skin surface is therefore very important to the discomfort experienced. The attitude of the wearer to a fabric will also affect their overall impression of its comfort in wear. If they like the fabric and if discomfort does occur, they will be more likely to ignore it.

## 8.4 Conclusions.

It has been assumed for a long time that the main factor affecting tickle was fabric hairiness. This work has started to unravel and identify the network of factors influencing tickle, some of which contradict common opinion.

Tickle was identified as a common and major source of discomfort when clothing is worn next to the skin, both from the main wearer trial and the public questionnaire. The main wearer trial showed that fabrics made from wool were the main source of discomfort and that a hairy fabric surface was the main factor people associated with tickle. However, all of the fabrics in the wearer trial produced tickle to some degree. The reasons why these other fabrics should produce tickle were investigated by examining some of the factors which were thought to be the most important. These were fabric and skin hairiness, the speed of the fabric over the skin, the loading on the body (flattening the hairs) and gender.

The trial showed that the type of body hair, either fine hair or coarse hair had no affect on the perception of tickle. Gender had a small affect on the perception of tickle. Most notably when a smooth fabric was passed over the skin at three different speeds. It was seen that men found the slow speed to produce the most tickle and women found it to produce the least tickle. This is most likely to be due to a combination of differences in body hair, sensitivity of the skin and what the subject is used to wearing next to their skin. The hairiness of the fabric surface had surprisingly little affect on the tickle experienced by the subjects. At the same speed (for three speeds), the smooth fabric was slightly more tickly than the hairy fabric, the opposite was found when the loading on the fabric was assessed. Overall the slowest speed, 0.25cm/s was the most tickly and the intermediate speed, 0.50cm/s produced the least tickle. Tickle was also found to be worst when no weight was added to the fabric and the intermediate load was the least tickly. A low load and a slow speed are the main factors affecting tickle, in this situation the body hairs can be easily caught in the fabric and stimulated as the fabric moves over the skin. The design of garments can therefore have a great influence on tickle discomfort in terms of fabric:skin movement and garment weight (due to the fabric weight), especially on the shoulders and fabric choice (surface properties and stretch).

# CHAPTER 9

# PRICKLE.

Prickle can be extremely unpleasant and in many cases the sensation is one of pain rather than discomfort. The sensation is very similar to having a pin stuck into the skin, but in cases where the concentration of prickle is high, the sensation is more one of abrasion. It may cause skin reddening due to abrasion, a symptom which can be mistaken to be a sign of an allergic reaction.

## 9.1 Fibre Properties.

Research work has been carried out by the C.S.I.R.O. (Australian Wool Research Institute) to investigate the influence of fibre diameter and the presence of scales on the fibre surface on the occurrence and magnitude of prickle (Hoschke, 1982). Prickle is of particular interest to them because it is well known that wool can cause this type of discomfort sensation. They conducted wearer trials in which the subjects wore both knitted and woven wool fabric samples as blouses/shirts, vests and armbands. From the results of these trials it was generally accepted that the diameter of the fibre was the major factor influencing prickle, and not the scale structure on the surface of the wool fibre. A fibre fineness distribution analyser (F.F.D.A.) was developed at C.S.I.R.O. and used in their studies. They tested the fibres used in their trial fabric on the F.F.D.A.. They concluded that a fabric containing coarse fibres in this case (7 per cent of fibres of 40 microns) or more was likely to cause prickle and not the presence of surface scales. It is acknowledged that a vast amount of wearer trial data is needed before a specific range of fibre diameters can be identified as the cause of prickle. This is because within one quality grade of wool there is a wide range of fibre diameters to be assessed and in addition, a wide selection of the general population would also need to be surveyed.

The reasons why the coarser fibres produce prickle discomfort were investigated. It is known that an increase in fibre diameter will increase the flexural and torsional rigidity of the fibre. The flexural rigidity of a fibre depends on the following properties: its tensile modulus (E), its density (ρ), and its cross-sectional shape factor (n). The shape factor progressively increases as the fibre becomes more distant from the centre, for example a circular fibre has a value of 1.0 and a crenulated fibre, such as viscose has a value of 0.74. The most influential fibre property which effects the rigidity is the cross-sectional area (T) of the fibre. The relationship is shown in equation 9.1 (Morton and Hearle, 1975).

$$\text{Flexural rigidity} = \frac{1}{4\pi}\, n\, \frac{E\,T^2}{\rho} \qquad \text{Equation 9.1}$$

The torsional rigidity of a fibre may be defined as the torque needed to produce unit twist in radians per unit length. This property is effected by the fibre shape (ε), density (ρ), specific shear modulus (n) and most importantly the fibre fineness (T). This relationship can be expressed as equation 9.2 (Morton and Hearle, 1975):

$$\text{Torsional rigidity} = \epsilon\; n\; T^2 \,/\, 2\pi\, \rho \qquad \text{Equation 9.2}$$

Typical values for the specific flexural and specific torsional rigidity (the inherent rigidity independent of fibre fineness) of a fibre at 65% relative humidity and 20°C are shown in table 9.1.

Table 9.1 Flexural and torsional rigidity of fibres. (Morton and Hearle)

| Fibre | Specific Flexural Rigidity (mN mm²/tex²) | Specific Torsional Rigidity (mN mm²/tex²) |
|---|---|---|
| Cotton | 0.53 | 0.16 |
| Wool | 0.24 | 0.12 |
| Silk | 0.60 | 0.16 |
| Nylon 66 | 0.15 - 0.22 | 0.04 - 0.06 |
| Polyester | 0.30 | 0.07 |
| Acrylic | 0.33 - 0.48 | 0.12 - 0.18 |

The specific flexural and torsional rigidity of wool is similar to the other fibres, if not lower than many. However no prickle occured when the other fibres mentioned in the table were worn (except for monofilament sewing threads which are thick and are likely to produce discomfort). Wool is unusual in a few main respects, it has surface scales, it has a circular cross-section (maximum shape factor value ($n$ or $\epsilon$) of 1) and the range of fibre diameters within a sample is large because it is a natural product. The average fibre diameter for a 70's quality wool grade is 20μm or 4.5 dtex, whereas man-made fibres which are used for apparel have typical fibre diameters of approximately 12-13μm for a 1.7 dtex fibre. This means that wool fibres are approximately twice the thickness of most man-made fibres for similar end-uses, and therefore wool will on average be four times more rigid.

The trials at C.S.I.R.O. (Hoschke, 1982) also showed that a knitted fabric made from the same fibre source as a woven fabric was less likely to produce prickle sensations. This was attributed to a decrease in fibre/skin contact area for an equivalent sample of a knitted fabric than for a woven fabric. Additional factors that the author considers to be relevant here are:

(a) The reduction in relative movement between the fabric and the skin with a knitted fabric (which is invariably stretchier than a woven fabric). This will reduce the frequency of the fabric passing over the skin.

(b) The drape of a fabric may also influence the contact area and the relative movement between the fabric and the skin, however this is also very dependant on the fit of the garment.

(c) Knitted fabrics usually use yarns with less twist than a woven fabric and therefore any protruding fibres will not be held so firmly and will buckle more easily.

## 9.2 Main Wearer Trial.

The only fabrics in the main wearer trial which were reported to cause prickle contained wool. The prickle discomfort was so extreme in some cases that a few subjects refused to wear a garment for more than a few minutes. The subjects were not told the fibre content of the fabrics before wearing their garments. Many of the wearers did not guess the fibre composition correctly and had predicted no forseeable discomfort before donning. Therefore the results are taken to be genuine because the subjects had no preconceived ideas as to the potential properties of the fabric. Prickle sensations ranged from being immediately painful through to a more intermittent occurence, depending on the person, their awareness of the fabric and the sensitivity of their skin that day. The results of the main wearer trial are shown in table 9.2 and they indicate the wide spread discomfort due to prickle.

Occasionally a wearer would comment on a fabric being abrasive and in a few instances a red rash was produced on the shoulders. This was assumed to be the effect of a high concentration of coarse fibre ends rubbing against 'sensitive' skin. In this situation the body will be unable to distinguish between the individual fibre ends, and so the sensation is one of abrasion. It is unlikely that skin reddening and the formation of a rash is an allergic reaction, but it is more likely to be caused by the fabric abrading and irritating the skin (Garrett, 1984).

At the time of a visit to the Deutches Wollforschunginstitut by the author, the main wearer trial fabrics that had caused discomfort due to prickle were submitted for testing using their fibre fineness distribution analyser (F.F.D.A.). Unfortunately the facility was not extended to the rest of the wearer trial fabrics. A fibre fineness distribution diagram for each sample was printed out by computer. The complete histogram of the fibre diameter distribution, including mean value, standard deviation, coefficient of variation and the number of fibre segments involved in the measurement are included in the printout. The results for the wool wearer trial fabrics are summarised in table 9.2.

A comparison of the results in table 9.2 shows that on average approximately half of the wearers experienced prickle from the wool fabrics. The wool fabrics included in the main wearer trial which did cause prickle were found to contain as little as 3 percent of fibres over 30 microns (fabric 15), and 0.6 percent of fibres over 40 microns (fabric 15). This indicates that very small amounts of these thicker fibres are necessary for prickle to be experienced; much less than the 7 percent of 40 micron fibres which were found to cause prickle in the C.S.I.R.O. trials.

Table 9.2 (1) The percent of wearers that experienced prickle from the trial fabrics before and after washing the garment and (2) the percent of coarser fibres present in these fabrics as measured by the F.F.D.A..

| Fabric number | 5 | 7 | 11 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|
| 1) No wash | 50% | 42% | 30% | 41% | 100% | 60% |
| After one wash | 57% | 50% | 30% | 50% | 40% | 40% |
| Before & after washing | 54% | 46% | 30% | 46% | 70% | 50% |
| 2) Percent > 30µm * | 3.5% | 6.5% | - | 3.0% | 4.6% | 5.5% |
| Percent > 40µm * | 0.7% | 0.8% | - | 0.6% | 0.8% | 0.7% |

* In some cases the crimpiness of the yarn can cause the fibres to stick together in clumps when it is being measured. This causes a long tail between 40 and 60 microns. The accumulative percentage is corrected by subtracting the fibres with an apparent diameter of greater than 50 microns (Standard practice for F.F.D.A. results of this type).

The results of the wearer trials at both the C.S.I.R.O. and at the Shirley Institute indicate that the Chlorine-Hercosett treatment (Superwash wool finishing which removes the surface scales) does not reduce prickle. This supports the C.S.I.R.O. conclusion that the rigidity of a fibre (mainly influenced by fibre cross-sectional area) is the factor which causes prickle from wool, and not the surface scales.

The fibre diameters of the other wearer trial fabrics was found in specification sheets from the fibre producers and Moncrieff (1975). The results are shown in table 9.3.

The data in table 9.3 indicates that the average diameter of the wearer trial fabrics which did not cause prickle was approximately half that of the wool fibres which did produce a prickle sensation.

Table 9.3 The diameter and cross-sectional shape of the fibres in the main wearer trial fabrics not containing wool. (values obtained from the literature)

| Fabric number | Average diameter (μm) | Fibre cross-sectional shape |
|---|---|---|
| 1 | 13 | circular |
| 2 | 19 | circular |
| 3 | 15.5 | circular |
| 4 | 15-17 | flat ribbon |
| 6 | 12/13 | circular |
| 8 | 19 | circular |
| 9 | 15.5 | circular |
| 10 | 15.5 | circular |
| 12 | 13 | circular |
| 13 | 19 | circular |
| 14 | 16 | circular |
| 18 | 15.5 | circular |
| 19 | 15.5 | circular |
| 20 | 10 | triangular |
| 21 | 15 | circular |
| 22 | 12 | circular |

Flexural and torsional rigidity are the major factors influencing prickle, but the length of the fibre which is protruding from the fabric surface is also important. The shorter the length of fibre protruding from the surface, the more support it will have against buckling under load, thus increasing the fibres resistance to compression and increasing the perceived sharpness of the fibre end in the skin. This is difficult to define and assess visually. However, the presence of fused fibre ends on the fabric surface that are produced during singeing can abrade and prick the skin. This aspect of fabric irritation was investigated by Dr. M. Hewson (1984) at the Shirley Institute. He found that fused polyester fibre ends were the cause of wide-spread irritation during garment manufacture.

## 9.3 Non-Fabric Sources of Prickle.

The other common source of prickle is monofilament nylon sewing thread. It was regularly used in apparel ten to twenty years ago. Nowadays it is still used to a lesser extent for sewing in garment labels and hems in cheaper garments. The diameter of a monofilament thread is typically 0.75mm for apparel end-uses (Coats, 1986). Its flexural rigidity is therefore very high due to its cross-sectional area and circular shape.

Garment labels were also found to produce prickle discomfort. This is discussed in chapter 11.

## 9.4 Conclusions.

Prickle is one of the most objectionable discomfort sensations that was identified in the wearer trials. It often caused pain and extreme irritation which could result in reddening of the skin.

The only fabrics in the wearer trial which produced a prickle sensation contained wool. This relationship was attributed to the wool fibres having larger diameters (approximately twice the size) than the other typical apparel fibres. This means that the wool fibres are at least approximately four times more rigid.

Prickle could not be reliably predicted from handle observations or from fabric friction tests (table 2, appendix 1). A recommended screening process to determine if a fabric will cause prickle would firstly establish the presence of wool in the fabric and secondly, to determine the range in diameter of the wool fibres. If the fibres have a diameter greater than 30µm the fabric is likely to cause prickle. The non-fabric sources of prickle (monofilament sewing threads and garment labels) can be looked for visually, and a judgement can be made as to the potential discomfort which could be caused by these features. In particular the cut ends of the sewing thread on the inside of the garment and sharp corners to garment labels which can irritate the skin.

# CHAPTER 10

## SCRATCHINESS.

Abrasion of the skin and 'jogger's nipple' are well known problems for marathon runners and people involved in long periods of physical activity. The damage to the skin in these situations often leads to the person abandoning their sport immediately or for a number of days whilst the skin heals. Marathon running is an extreme case when a fabric has ample opportunity to rub against the skin, but how common is discomfort due to a scratchy fabric in everyday wear? Do the same fabrics feel scratchy during high and low activity levels?

To lessen skin abrasion people involved in extended periods of exercise such as marathon running commonly take precautions. For instance, they coat their inner thighs with Vaseline™, choose hydrophobic fibres for their running shirts and shorts, and flat garment seams in areas where the body is susceptable to abrasion, such as between the legs and under the arms. Nevertheless, skin abrasion still occurs.

This chapter investigates the fibre, fabric, garment and physiological factors which cause scratchiness discomfort, and a determination of how common the sensation is during normal activity and strenuous activity is sought.

### 10.1 The Main Wearer Trial.

Scratchiness was a common sensation in the wearer trial. Out of a total of 742 wearings (each garment was worn twice by each subject), scratchiness was experienced during 104 wearings. The number of people that assessed each garment was usually 20, but some garments were assessed by fewer people (see table 3, appendix 1). To normalise the answers to the questionnaires, the answers were multiplied by (20 x 2) ÷ (n x 2) x the number of answers, where n is the number of subjects which did assess the garment. The number of subjects was multiplied by 2 because each garment was worn twice by each subject. These values are used in the comparisons of the fabrics. The fabrics which caused the most discomfort were numbers 1, 2, 3, 4, 5, 7, 11, 13, 14, 16, 17, 19 and 22 (see table 4.1 for fabric details). The number of times scratchiness was recorded for each of the trial garments is shown in table 10.1. Most of the discomfort due to scratchiness occured before a garment had been washed, as can be seen from the total number of people recording discomfort in table 10.1.

There were two sources of skin abrasion recorded from the trial garments: one due to the fabric and the other due to the garment seams (seams are discussed in chapter 11). The fabric mainly abraded the shoulders and around the neck, but 'jogger's nipple' was experienced by one subject when wearing fabric 14, a textured polyester interlock.

<u>Table 10.1</u> <u>The number of people who felt scratchiness from the main wearer trial garments when wearing them before and after washing.</u>

Discomfort in relation to the garment being washed

| Fabric Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No wash | 6 | 6 | 4 | 3 | 6 | 0 | 6 | 0 | 0 | 0 | 7 | 0 | 9 | 4 | 1 | 6 | 3 | 0 | 3 | 0 | 2 | 6 | 72 |
| One wash | 3 | 1 | 0 | 2 | 2 | 2 | 5 | 0 | 0 | 2 | 4 | 2 | 9 | 4 | 1 | 3 | 3 | 0 | 3 | 0 | 2 | 0 | 48 |

None of the trial garments were worn for marathon running. However two of the subjects did an half an hour jog during every wearing. They only commented on scratchiness due to garment seams and not the fabric itself, but fabric 14, (a textured polyester fabric with a very harsh handle) did cause skin abrasion for these two wearers whilst jogging. Therefore the majority of the information on the scratchiness of fabrics in the wearer trial was from people who were wearing the garments for normal activity. The weather during the trial was unusually warm for the north of England, with approximately half of the trial being carried out in temperatures which were on average above 20°C (see figure 4.1). From the comments on the questionnaires it was seen that more scratchiness discomfort was experienced during the warmer months, when the subjects would be perspiring more than in colder weather. The severity of the discomfort due to scratchiness of the wearer trial garments can therefore be assumed to be less than if a greater number of subjects were doing higher levels of activity which was the main situation when scratchiness was felt.

The fabrics which caused the most discomfort due to scratchiness were assessed to determine why they should produce this sensation. The relationship of fibre type, fabric construction and fabric properties were analysed and are discussed in sections 10.1.1 and 10.1.2 below.

### 10.1.1 The Effect of Fibre Type on Scratchiness.

The fibre composition of the fabrics was seen to have an effect on the occurrence of scratchiness. Many of the fabrics which caused a greater number of people to feel fabric abrasion were made from wool, namely fabrics 5, 7, 11, 16 and 17. The sensation of prickle was also present for these fabrics (as discussed in chapter 9). It is thought that when a fabric moves over the skin, the number of prickle sensations will be more wide-spread and frequent, and the body will be unable to differentiate between them. Therefore for these wool fabrics, the sensation of scratchiness is most likely to be due to the of rigid wool fibres rubbing against the skin, causing irritation and mild skin abrasion.

Cotton fabrics were also noted to be more uncomfortable than other fibres in the trial. Fabric number 1 was a commercial vest made in a honeycomb construction in a blend of cotton and polyester, but the presence of vegetable matter was also apparent from observing the fabric. The combination of an ornate fabric construction and the presence of burrs is likely to be the main cause of scratchiness in this case. In addition it was the first garment to be included in the wearer trial and therefore the subject's were more aware of the presence of discomfort sensations from this garment. Fabric 4 was also cotton, but the fabric was an eyelet construction. This same construction was used for fabric 13 which caused the most discomfort due to scratchiness in the trial. It is most likely that the fabric construction was the major cause of scratchiness for these cotton fabrics, rather than the fibre. An ornate fabric would produce hard 'knots' and 'holes' which could cause skin abrasion when rubbing the skin.

### 10.1.2 The Effect of Fabric Construction and Fabric Properties.

A more ornate fabric construction such as an eyelet or honeycomb was found to be more scratchy than a plain 1x1 rib or interlock construction. It was also observed that scratchiness discomfort was less frequently noted when a brushed fabric surface was worn.

Many of the fabrics found to be scratchy in-wear also had a rough handle (as shown in row 5 of table 10.2). The majority of fabrics which were ranked as having a rougher surface when handled also had an ornate fabric construction, and there was no evidence that the fibre type influenced the harshness. The fabrics with the roughest handle felt incompressible and they had tight prominent knots (areas where many yarns crossed) in their construction.

A number of routine tests were selected to be carried out on the 22 wearer trial fabrics. The physical properties which may be directly related to the occurrence of scratchiness were determined. The test results are shown in table 2, appendix 1. The rank order of the fabric properties is shown in table 10.2 below. The scratchiest wearer trial fabrics are listed in relation to the rank order of their fabric properties (taken from all 22 fabrics). It can be seen that the fabrics which produced the most discomfort due to scratchiness did not show any specific relationships with any of the physical properties measured.

Table 10.2 The relationship of the scratchiest fabrics in the main wearer trial to their physical properties (when compared with all the 22 wearer trial fabrics).

| Test method → | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| Fabric code | Number of wearings when scratchiness was noted | Bending length (rigidity) (rank) | Surface Drag (°) (friction) (rank) | Water retention (rank) | Stiffness (rank) | Subjective handle. Roughness (rank) |
| 13 | 18 | 4th | 16th | 15th | 2nd | 2nd |
| 7 | 11 | 20th | 8th | 10th | 21st | 13th |
| 11 | 11 | 6th | 9th | 9th | 4th | 4th |
| 16 | 9 | 11th | 7th | - | 10th | 10th |
| 1 | 9 | 16th | 21st | 2nd | 3rd | 1st |
| 5 | 8 | 14th | 3rd | 18th | 16th | 6th |
| 14 | 8 | 19th | 10th | 6th | 22nd | 17th |
| 2 | 7 | 3th | 18th | 14th | 7th | 9h |
| 17 | 6 | 12th | 4th | - | 9th | 8th |
| 19 | 6 | 11th | 1st | 13th | 15th | 14th |
| 22 | 6 | 2th | 12th | 8th | 14th | - |
| 4 | 5 | 15th | 17th | 3rd | 18th | 3rd |

Note: A rank order of 1 means that the fabric was the A, most rigid, B, had the highest surface drag, C, retained the most water, D, stiffest and E, had the roughest handle.
Key to the test methods used:
A = Fabric stiffness, BS 3356:1961, B = The angle at which a fabric sample mounted on a sledge starts to slide down a glass plate on an inclined plane, C = Static immersion test, BS 3449:1961, D = Shirley cyclic bending test, E = Subjective handle test carried out by the wearer trial subject's after the trial.

## 10.2 The Factors Causing Skin Abrasion.

The wearer trial identified three main fabric properties which caused a greater number of people to comment on the harshness of the fabric when they wore it against their skin.

1) The presence of wool.

2) The use of an ornate fabric construction, such as a honeycomb or eyelet which has hard knots on its surface or large holes.

3) The seams of the garment were a major source of scratchiness discomfort.

Further physiological research into the abrasion of the skin was not carried out on the Shirley Institute staff because of the skin damage and pain it would cause. The investigation into the factors influencing discomfort and skin abrasion due to a scratchy fabric was continued by collating and intepreting relevant studies which have already been carried out and reported. So far, no researcher has specifically applied the plethora of knowledge on skin abrasion and peripheral subjects to the comfort of clothing. The results of the main wearer trial are discussed in connection with the findings of other research workers in their different fields of study. From this, the major factors which produce fabric scratchiness are indentified and endorsed.

Research work into the scratchiness of fabrics has been carried out by a few researchers, and some projects have involved the production of test methods to characterize a fabric for this sensation. The work carried out by Mehrtens and McAlister is typical of the conclusions which were made as to the factors influencing skin abrasion and scratchiness.

Mehrtens and McAlister (1962) conducted an environmental chamber trial to investigate the comfort of knitted sports shirts of 4 different fibre types. They found that scratchiness was a major discomfort problem and subsequently developed an objective test method to assess fabrics for scratchiness. The method works by drawing a microphone over a fabric at 7 yards/minute (arbitary speed). The signal produced correlated with the subjective assessment of the scratchy sensation. Overall they concluded that a scratchy sensation was increased by both a high filament flexural rigidity and a high coefficient of friction between the skin and the fabric.

The fabric properties identified in the main wearer trial and the conclusions of Mehrtens and McAlister were considered for their importance in the production of a scratchy sensation and skin abrasion.

### 10.2.1 Flexural Rigidity of the Fibres.

The flexural rigidity of a fibre increases with an increase in fibre cross-sectional area. When prickle was considered in this project (chapter 9) it was found that the thicker and therefore more rigid fibres present in a wool sample cause discomfort due to them sticking into the skin. If the same fibres were dragged across the skin they would understandably scratch it. The other fibres used in the wearer trial fabrics all had relatively low flexural rigidities because they were finer than the wool fibres, and none of these fabrics produced prickle. Man-made and natural fibres other than wool are used in various diameters for apparel. It is possible that the wearer would be able to detect these size/rigidity differences in terms of abrasion and not prickle when the fibres protrude from the surface and are looped (as surface fibres often are). In some cases the presence of large fused ends of a molten man-made fibre (due to singeing) could be responsible (Hewson, 1985). Therefore the flexural rigidity of the fibres will have an influence, mainly for wool, but also with other finer fibres. The presence of as little as 3 per cent of wool fibres with a diameter of 30 μm and less than 1 per cent of fibres of 40 μm in a fabric can produce prickle, and it is likely that the same fibre diameters are responsible for scratchiness.

When the fibres were bent over and twisted (as in a yarn or a fabric) the fabric will become less compressible at the apex of the fold, and the harshness of the fabric will increase with increasing fibre diameter. However, this is most likely to be noticable in ornate fabric constructions, such as a honeycomb or eyelet, and not in a plain construction when the yarns are not be in such tight knots.

### 10.2.2 The Friction between Skin and Fabric.

Naylor (1955) and Swallow and Web (1972) carried out research work to determine the factors which influence the coefficient of friction of a material on the skin. Naylor tested the effect of oil, talcum powder, a drop of water and excess water on the frictional properties of polyethene on the skin. His research showed that the surface conditions of the skin at the time of the experiment were very important. He found that the friction between skin and polyethene was reduced when the skin was dry, greasy or very wet, but friction increased when the skin was moist.

Swallow and Web also undertook a series of experiments to evaluate the friction between the fabric and the skin in different conditions. The equipment measured the frictional force needed to pull a fabric (mounted on a block of known weight) across the dorsal surface of the lower arm. The effect of wetness, skin hairiness, operator differences, load and fabric weave to the direction of pull, were investigated. For the fabrics tested, weave direction was not demonstrated as being of any significance. However the wetness of the fabric did have an effect. For instance, the mean frictional force was 0.81 for a dry fabric and 0.41 for a wet fabric. The adhesion at zero load was negligible for dry fabrics, but substantial for wet. They found that the force increased as the fabric became wet, then it reduced as the fabric became saturated, as found by Naylor. The higher friction of wet fabrics was most marked at lower loads and on a smooth skin rather than a hairy skin.

Comaish (1973) studied the factors influencing the production of friction blisters, and many of his findings are relevant to garment skin abrasion. He rubbed the forearm with an oscillating metal head and observed the physiological effects during the time to produce a blister. He noted that the coefficient of friction of the skin steadily increases during rubbing in the vast majority of cases, but after erosion the coefficient of friction decreased greatly due to the moist surface produced. During the course of rubbing the skin, sweat is removed and it may be impeded by partial closure of the sweat ducts over the area being abraded. After many subjective laboratory tests and field trials using various agents to reduce the friction, Comaish concluded that friction was the principle factor governing blister formation. He suggested that the coefficient of friction could be reduced by the presence of a liquid or a solid lubricant and/or a substance which reduced sweating (impractical for general garment use).

From their research it can be concluded that the frictional force between the skin and a fabric increases as the body begins to sweat and therefore, in this situation any movement between the fabric and the skin is more likely to cause skin abrasion. When the fabric and skin are very wet, the frictional force between them will reduce, but the skin cells will be hydrated and therefore they can be easily removed. In either case the skin is likely to become abraded if fabric:skin movement persists. Therefore the relative movement between the fabric and the skin needs to be eliminated when the skin is damp, wet or dry.

### 10.2.3 The Presence of Sweat.

As mentioned in section 10.2.2, the coefficient of friction increases with an increase in sweat on the skin surface. When strenuous activity is conducted for long periods of time the body produces more sweat than it can evaporate from its surface. Therefore the fabric and skin will be wet regardless of the wicking properties of a fabric. If a fabric is made from a hydrophobic fibre, the sweat will be held between the fibres and yarns, but it will not be absorbed. Therefore it retains less water than an absorbent fabric. When a hydrophilic fibre absorbs water it swells and becomes stiffer and heavier than its non-absorbent counter-part. It is therefore more likely to abrade the skin than a hydrophobic fabric.

As the skin becomes very wet the coefficient of friction drops. At the same time the skin is absorbing sweat and the skin cells hydrate. When the cells are in this swollen state they can be easily removed (the same principle used to remove rough skin from the feet). Since the skin will already have been rubbed during the time leading up to the presence of excess sweat, the skin will be more sensitive to abrasion. In this situation it is unlikely that excess sweat will be an effective lubricant, and therefore the skin will probably become abraded quickly once this stage has been reached.

Body hairs and fabric hairs reduce the area of contact between the fabric surface and the skin, thereby reducing the skin area that can be abraded. This is one of the reasons why the brushed fabrics in the main wearer trial did not feel scratchy during strenuous exercise. In addition these fabrics have a soft surface with no hard prominent knots to abrade the skin.

## 10.3 Recomendations on How to Avoid Skin Abrasion During Extended Levels of Strenuous Activity.

Marathon runners were chosen to be an example of people who commonly experience discomfort due to the fabric rubbing against their skin. They often take precautions against skin abrasion, nevertheless, abrasion still occurs. From this research, a prediction of the best garment assembly for a runner can be made, and theoretically it is posible to eliminate skin abrasion form this sport.

If a tight fitting, but highly extensible fabric is worn so that it moves with the body rather than over it, this will reduce the source of abrasion. The areas of the skin susceptible to abrasion will be covered with a plain knitted construction, possibly with a brushed surface to make the fabric soft and smooth. The rest of the garment can be made in a very open construction to help to cool the body. The garment should be knitted in one piece so that it has no seams, and labels should be stuck to the outside of the garment. To ensure that the skin is totally protected, it should be coated with Vaseline™ to lubricate the skin and to reduce abrasion if the fabric does move over it. To maintain the softness of the fabric throughout a run, the fabric should be made from a hydrophobic fibre.

## 10.4 Conclusions.

The scratchiness of a fabric can be divided up into two main areas: general discomfort due to a harsh fabric surface and a more serious condition when the skin becomes abraded. The harshness of a fabric in wear could not be predicted by handle observations or general fabric properties. The main factors influencing its occurence were determined from the main wearer trial and confirmed by the research of other workers. The main wearer trial identified the presence of wool (with rigid fibres) and ornate fabric structures (with prominent knots and holes on the surface) as being the most common- factors to produce the most scratchiness discomfort. Other researchers had in the past related scratchiness and skin abrasion to a high coefficient of friction between the skin and the fabric, and Mehrtens and McAlister also related it to high flexural rigidity of the fibres.

Overall the flexural rigidity of the fibres will have an influence on scratchiness. First, the presence of the thick wool fibres will be a major source of the discomfort when they are present and second, the presence of thicker fibres in an ornate fabric construction will have a less compressible, scratchier surface than a fabric made from finer fibres. When hydrophilic fibres absorb water, they swell and increase in dimensions and rigidity, thereby producing a stiffer cloth (a property used in Ventile ™ fabrics to prevent water penetration). In addition they will help to keep the skin moist, which will increase the coefficient of friction and hence skin abrasion. This implies that hydrophilic fibres are not used for long periods of active sports such as marathon running, but hydrophobic fibres are used.

A high coefficient of friction between the skin and the fabric greatly increases skin abrasion. The coefficient of friction increases with an increase in moisture on the skin, and then drops as an excess of moisture becomes available. By this time the wearer's skin will be sore and hydrated. To reduce the coefficient of friction the skin must be lubricated.

# CHAPTER 11

## LOCAL IRRITATION.

Local irritation is a broad term used to describe the many types of discomfort which can be caused by garment features other than the fabric and garment fit. The most common garment features are labels, seams, fasteners and trimmings. These features were assessed to find out if they produced discomfort and how often the experience was felt. This research found that some of the most common garment accessories are a major source of discomfort and therefore they need to be carefully considered when designing future garments. In this chapter section 11.1 deals with garment labels, 11.2 with garment seams and sewing threads and section 11.3 with trimmings and fasteners.

### 11.1 Garment Labels.

Labels are present in all garments which are worn next to the skin. There are standard positions in a garment where they are placed; some of the common ones are in the neck seam, side-seam or in the waist-band. A label acts as a permenent reminder of the garment producer, washing instructions, size, fibre composition and country of origin. This information is included to help the purchaser select a garment, care for the garment, and eventually make a repeat purchase.

From general discussions with Shirley Institute staff it appeared that labels could be very uncomfortable, and to prevent further discomfort some people said that they cut their labels out. The occurence of label discomfort and the proportion of people who cut their labels out of garments to avoid it, was investigated in the public questionnaire.

### 11.1.1 Public Questionnaire.

The general public were asked if their labels ever annoy them in briefs, at the neck or in the side-seam of garments. They were also asked if they would remove the labels if discomfort was experienced. The results were quite surprising. From the 1004 people that answered the questionnaire only 184 people said that labels did not annoy them and 820 people felt discomfort. 689 people said that labels annoyed them in the neck of garments, and approximately equal numbers of people (171 and 143 respectively) said that labels in briefs and in the side seam of garments annoy them. The results of this question are shown in table 11.1 below.

Table 11.1 The number of people in each age group that said that labels annoy them in briefs, at the neck or at the side seam of garments.

| Age Group | 16-25 | 26-40 | 41-54 | 55+ | 16-55+ |
|---|---|---|---|---|---|
| Pants/briefs | | | | | |
| Yes | 48 | 51 | 34 | 38 | 171 |
| No | 216 | 200 | 203 | 214 | 832 |
| At the neck | | | | | |
| Yes | 183 | 168 | 170 | 168 | 689 |
| No | 81 | 83 | 67 | 84 | 315 |
| Side-seam | | | | | |
| Yes | 40 | 40 | 27 | 36 | 143 |
| No | 224 | 211 | 210 | 216 | 861 |
| Labels don't annoy you | | | | | |
| | 38 | 48 | 40 | 58 | 184 |

The questionnaire also found that just over 65 per cent of the interviewees cut the labels out of their garments. The labels are removed to prevent both physiological and psychological discomfort (when a label hangs outside the garment). However, some additional comments on the questionnaires revealed that some people actively try to make prestige labels hang outside their garment and these labels are rarely removed.

The findings of the public questionnaire confirmed that garment labels are a major, common source of discomfort to the general population, and that well over half of the population will remove labels because of the discomfort.

### 11.1.2 Labels Used for Next to the Skin Apparel.

A large selection of labels presently used in apparel were provided by Berrisfords (a leading label manufacturer) to determine their comfort and physical properties. Typical commercial label sizes and folded configurations were provided in each label type (including some resinated labels) which are listed below.

The main types of garment label used for apparel (garment folding is shown in figure 11.1):

1) Woven heat sealed edge.

They have a heat-sealed edge. They can be centre fold, Manhattan fold or all edges can be heat-sealed. The information is woven into the fabric. Approximately 90% of all labels found in garments to be worn next to the skin are of this type.

2) Conventional woven.

They have a woven edge. They are usually centre fold or end-fold and information is woven into the fabric. These labels are not normally used for next to the skin apparel.

3) Needle loom.

They have a woven edge. They can be end-fold, mitre fold or have heat-sealed ends and information is woven into the fabric.

4) Broad-width fabric.

They have a fused (heat sealed) edge. They are usually centre folded and the information is woven into the fabric.

These labels are cheap to make. They are not recommended by the label manufacturers to be used where body contact is inevitable.

5) Polymer film.

They have cut edges. They can be centre fold or cut and information is printed onto the fabric.

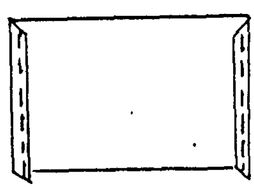
These are uncommon in the UK but they are more popular on the continent. Samples were not provided.

6) Woven fabrics with an adhesive backing.
They have cut edges. The label is flat and commonly rectangular in shape, information is printed onto the fabric. These labels are not wash fast. Samples were not provided.

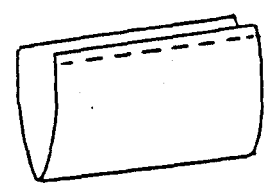
The number coding used above to describe each label type is maintained throughout this chapter. For instance, a needle loom label will be coded 3.*n*; '*n*' being the number given to a label within each type.

Figure 11.1 Common label folds and sewing lines.

a) End-fold

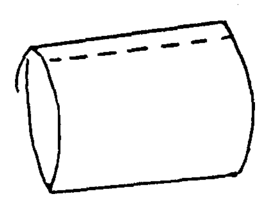


b) Centre-fold

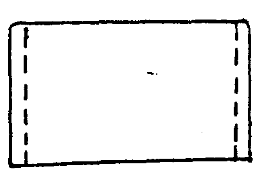


c) Mitre fold

d) Manhattan fold



e) Heat sealed edge



A selection of each of the four main label types (labels 1 to 4) in different folded configurations were used to investigate which labels produced physiological discomfort and the reasons. Initially this included a subjective wearer trial and later a more extensive subjective label prickle test.

### 11.1.3 Subjective Wearer Trial.

A label wearer trial was conducted (after the main wearer trial) to determine the type of discomfort which is experienced from different labels located at the neck and at the side-seam of a tee-shirt.

Garment 12 from the main wearer trial was chosen for this investigation because most wearers had found it comfortable, especially in terms of fit. Labels were sewn into each garment by hand using polyester/cotton thread. One label was placed in the centre of the back of the neck seam and another label of the same type was sewn into the side-seam (approximately 15cm below the bottom of the arm-hole seam). Care was taken so that the sewn edges of the label did not protrude from the seam and the label lay flat, as it would in a commercial garment.

A selection of ten of the main wearer trial subjects (both men and women) were asked to wear their garment for a number of hours. They were asked to complete the questionnaire provided (shown in figure 11.2) to determine any discomfort experienced from the labels. Once the garment had been worn, it was returned for washing. The label was removed and another label of a different type was sewn into the garment. It was then re-issued with another questionnaire. A total of 9 labels (coded as in section 11.1.2) were assessed and these are listed in table 11.2 below:

**Table 11.2 Labels used in the wearer trial.**

| Code | Description | Folding | Size (length x width) |
|---|---|---|---|
| 1.1 | Woven heat sealed edge | Centre fold | 7cm x 3.2cm |
| 1.2 | Woven heat sealed edge | Centre fold | Label 1 with the corners cut into a semi-circle. |
| 1.3 | Woven heat sealed edge Highly resinated. | Centre fold | 3.8cm x 2.0cm. |
| 2.1 | Conventionally woven Highly resinated. | End-fold | 5.2cm x 3.6cm. (not in the side seam). |
| 3.1 | Needle loom | Centre fold | 4.0cm x 3.4cm. |
| 3.2 | Needle loom | Mitre fold | 1.8cm x 4.5cm. |
| 3.3 | Needle loom | Centre fold | 1.8cm x 4.0cm. |
| 3.4 | Needle loom | Centre fold | 3.1cm x 3.7cm. |
| 4.1 | Broad width | Centre fold | 3.7cm x 5.1cm. |

Figure 11.2 Questionnaire for the label wearer trial.

Name: ________________________________

Label code: ______________

Fit: (number of inches of double fabric that is spare on each side of the ribs) ________________

Activity: Sitting ☐ Walking ☐ Strenuous ☐

Label Comfort:

Time you wore the garment? _____ hours

Did the label in the neck lie flat? Yes ☐ No ☐

Did the label "stick" in you at all? Yes ☐ No ☐

If Yes: When (type of activity): ______________________________

Would you cut the label out of a garment with this type of discomfort? Yes ☐ No ☐

Any additional comments:

Did the label in the side seam lie flat? Yes ☐ No ☐

Where did the label touch you?

Waist ☐ Ribs ☐ Below waist ☐ Other ________________

Was the garment tucked in? Yes ☐ No ☐

Was the label under the waistband? Yes ☐ No ☐

Did the label "stick" in you at all? Yes ☐ No ☐

If yes: When (type of activity) ______________________________

Would you cut the label out? Yes ☐ No ☐

Any additional comments:

Although not all of the subjects involved in the trial assessed the 9 labels, some interesting results were observed from the questionnaires. These are listed below:

The discomfort sensation experienced was prickle.

The discomfort was caused by the bottom folded corner of the label sticking into the skin. To investigate this further the corners of a centre fold label were cut to make them rounded (label 1.2), and this eliminated the prickle discomfort.

The mitre fold was the most comfortable label design and the end fold the second most comfortable. The centre fold was the most likely to produce discomfort.

A label with a fused edge and a resinated fabric was the most uncomfortable, and the woven edged label did not produce any discomfort.

The label in the side-seam produced slightly more discomfort than the label in the neck.

The discomfort due to the side-seam label was directly related to increased body movement (the label was situated over the ribs in all cases).

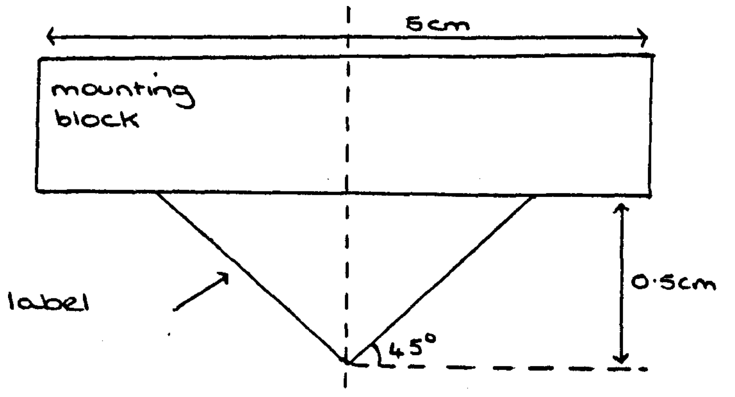
The discomfort due to the label in the neck was related to the label not laying flat against the fabric.

To more fully investigate the characteristics of labels which produced the most discomfort, a second subjective trial was designed.

### 11.1.4 Subjective Label Prickle Test.

Five labels were selected for this trial (4 labels were included in the wearer trial) so that a range of typical label edges and fabric stiffness were included. Each label was mounted between two metal plates so that its corner was at 45° to the horizontal and so that it protruded 0.5cm from the bottom face of the plates. See figure 11.3. One hundred Shirley Institute staff, 50 men and 50 women covering a range of ages were asked to assess the labels. Every pair combination of labels (except two labels of the same type) were assessed by each subject.

Figure 11.3. Mounting the label for the subjective trial.



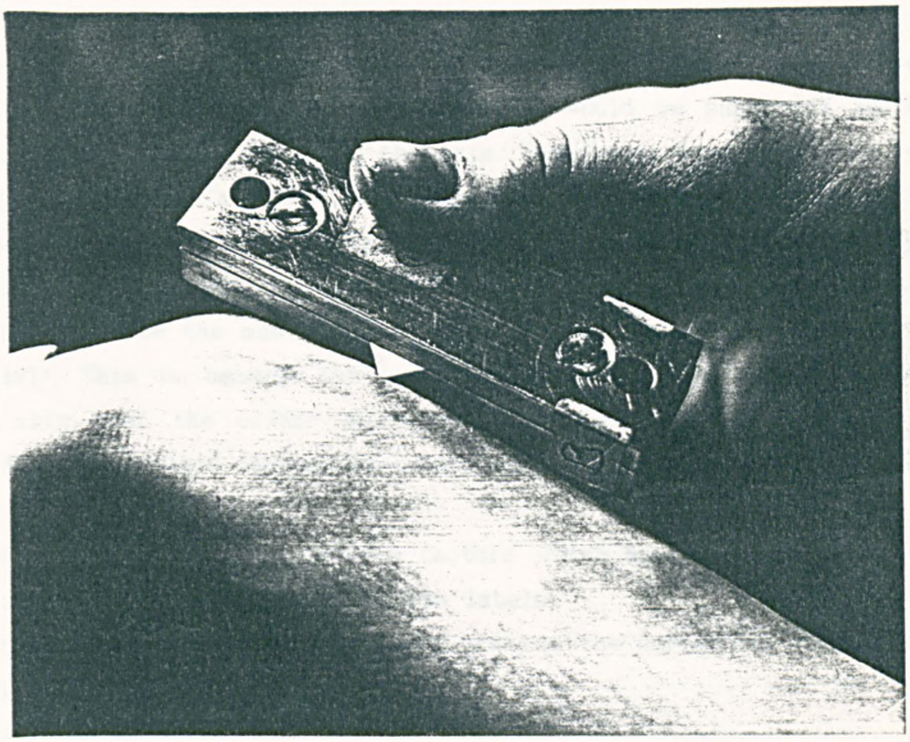

Each subject was briefed as to the purpose of the trial and were asked not to look at their arms during the assessment. They were asked to rest both of their arms on a desk infront of them. The author placed the corner of each label (of a pair) consecutively onto the skin of the forearm; taking care not to touch the arm with the metal mounting plates. The labels were reciprocated downwards and along the arm (maintaining the original position of the label corner in the skin) so that the maximum pressure was exerted on the skin by the tip of the label, but without the label collapsing. Only one person applied the labels and therefore the testing was consistent between subjects. The subject was asked to state which label corner was the sharpest. This was repeated until all the label combinations had been tested. The results of this trial are shown in table 11.3 the application of the label to the arm is shown in figure 11.4.

Table 11.3 The number of people in the subjective trial who said that one label was sharper than another when the labels were assessed in pairs.

| Label code → ↓ | Sharpest label → | 1.3 | 1.1 | 3.1 | 3.5 | 4.1 |
|---|---|---|---|---|---|---|
| | Description → ↓ | Heat sealed (resinated) | Heat sealed | Woven | Woven | Fused |
| 1.3 | Heat sealed (resinated) | - | 52 | 13 | 10 | 16 |
| 1.1 | Heat sealed | 48 | - | 8 | 6 | 13 |
| 3.1 | Woven | 87 | 92 | - | 37 | 42 |
| 3.5 | Woven | 90 | 94 | 63 | - | 56 |
| 4.1 | Fused | 84 | 87 | 58 | 42 | - |

Note: For example, 48 people said that label 1.3 was sharper than label 1.1, and 52 people said that label 1.1 was sharper than label 1.3.

Figure 11.4. The mounting and application of the label corner to the forearm in the subjective trial.



The labels were ranked in order of sharpness by calculating the coefficient of agreement between pairs of subjects (Moroney, 1979). Once achieved and an agreement shown, the row and column totals of the agreement table were used to give the rank order of the labels. The labels were ranked in order of sharpness. This is shown below and the distances between the label codes (described in table 11.3) are semi-quantitative.

SHARPEST ----------------------------------------→ LEAST SHARP

1.1 1.3 3.1 4.1 3.5

There was a significant difference between the sharpness of the heat sealed edged labels and the woven edged labels. The results show that most people said that the labels with a heat sealed edge were sharper than the woven edged labels. One of the sharpest labels, label 1.3, was a highly resinated label which is used for childrens next to the skin clothing, and it had a very stiff, papery feel. In wear this label produced more discomfort than a heat sealed label with less resin. This is probably due to the resinated label (1.3) being shorter and therefore it would be supported better when the corner applied pressure to the skin. The fused edged label was not as uncomfortably sharp as expected. This is probably due to the corner being somewhat larger than the other labels (because the fabric and edge were thicker) and therefore the pressure would be reduced. In practice this label is likely to be the most uncomfortable (which was indicated from the wearer trial). This is because the label would be unlikely to buckle away from the skin when the corner stuck into the wearer (when it is in a garment) due to the rigid fabric and reinforcing edge.

The wearer trials identified two main factors which appear to be effecting the production of prickle discomfort from labels.
1) The type of label edge and hence the area at the corner tip (where the load is applied to the skin).
2) The stiffness of the fabric.
These two factors and other physical properties were assessed both subjectively and objectively for a wide range of labels.

### 11.1.5 Physical Properties of Labels.

Many labels are heavily resinated to produce and maintain a pristine appearance. This greatly increases the rigidity of the fabric of the label, with many cases of woven, fused edged labels being similar to stiff paper in their characteristics. The labels (both resinated and unresinated) provided by Berrisfords were tested for their bending properties. The labels were assessed in terms of their discomfort (as determined from the subjective trial), and the relative amount of resination. In addition, the corners and edges of the labels were observed microscopically.

## 1 Label Fabric Properties.

The stiffness and liveliness of a wide variety of labels (with their edges removed) were measured on the Shirley Cyclic Bending Tester. From its measurements the frictional ($C_o$, the coercive couple, Nm/m) and the elastic component ($G_o$, the flexural rigidity, $Nm^2/m$) of the fabric can be obtained. It has been shown (Owen, 1965,66,67,68) that $G_o + A\ C_o$ ($Nm^2/m$), (where A is a constant (m)) is a measure of the stiffness, and $G_o/C_o$ (m) is a measure of the liveliness of the fabric (a good bending recovery is expected of fabrics with a low value). The results of the test carried out on 27 labels showed that the bending properties were dependent on the amount of resin that was applied to the fabric. The heavily resinated labels had higher values of liveliness, and therefore they have a greater ability to recover from gentle crumpling. In practical terms this means that when a label corner is sticking into the skin, these labels will resist collapsing away from the skin, and therefore the prickle sensation will be more pronounced.

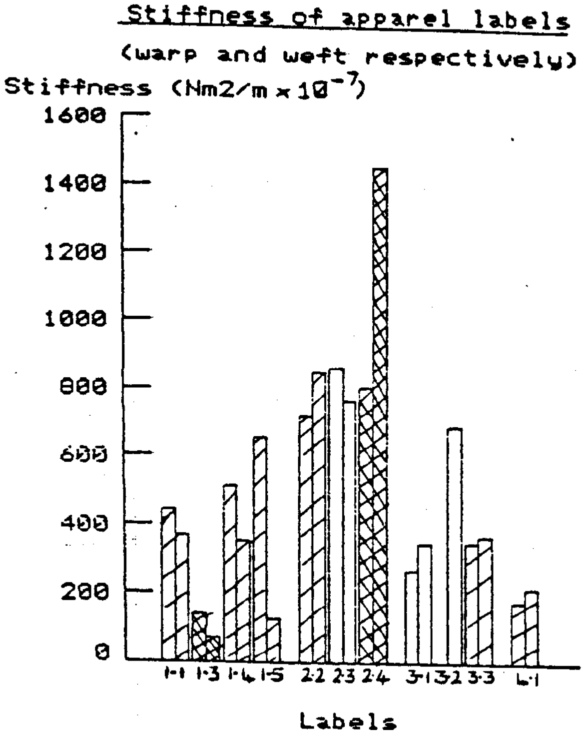
The resinated labels were also stiffer than the unresinated labels. The relationship for both the liveliness and the stiffness of the fabric is shown in figure 11.5 a and b respectively. In a conventionally woven or a needle loom label the brocade weft (used to form the lettering) is usually continuous filament viscose rayon, polyester or nylon yarn. This tends to stiffen the label due to the extra yarns in the fabric, but the folded corner of the fabric is "rounded" and therefore discomfort will be rare.

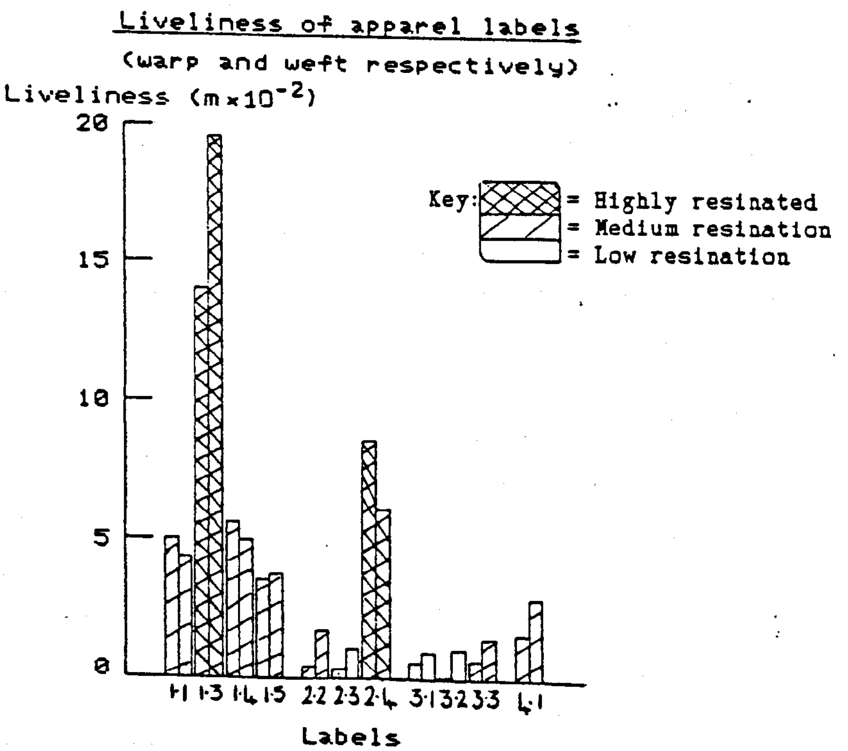
If the brocade weft is lurex or another metallic thread, it will form sharp points or folds on the surface of the label and discomfort is likely to occur when they are in contact with the skin.

## 2 The Edge of the Label.

The findings from the specific wearer trial (section 11.1.3), the label prickle test (table 11.3) and the bending rigidity tests (figure 11.5) showed that the over-riding factor in all label discomfort is the type of label edge. This is because it directly effects the sharpness of the folded corner.

Figure 11.4 The stiffness and liveliness of a range of typical apparel labels.



The edge of the label can be one of three main types:

1) Woven.
2) Heat sealed (including fused).
3) Folded.

The specific wearer trial showed that the woven edged (needle loom) labels did not produce any discomfort, but a label with a heat sealed edge frequently irritated the wearer.

Scanning electron micrographs of the edges and corners of a range of commercially available labels were taken. These proved to be very informative. Micrographs of a sample of four of the most common types of label are shown in figure 11.6 a and b. The heat sealed label can be seen to have a serrated edge and a similar label, cut with badly aligned knives can take on the appearance of a toothed saw. The fused edge of the label was smooth and thick, and the woven edge was smooth and undulating.

The folded corner also showed the different characteristics of the labels. The heat sealed label had a very flat, pointed corner with some molten polymer protruding from it. The fused edge was split at the apex of the fold and clearly displayed the sharp edges of the break (which could be felt when the finger tip was rubbed over the corner). The woven edge produced a smooth, rounded corner with no jagged protrusions.

These electron micrographs were very informative, but visual examination with a microscope at 60 x magnification would also reveal the typical edge fold characteristics of the labels. A comparison with existing photographs could then be used to evaluate a label in relation to its potential discomfort. However, from the micrographs obtained on the wide selection of labels tested, the potential discomfort of labels is obvious from general examination of the corner.

Figure 11.6.a Electron micrographs of the edge of typical garment labels. (magnification x80)

Figure a1: Woven edge (label 3.1)

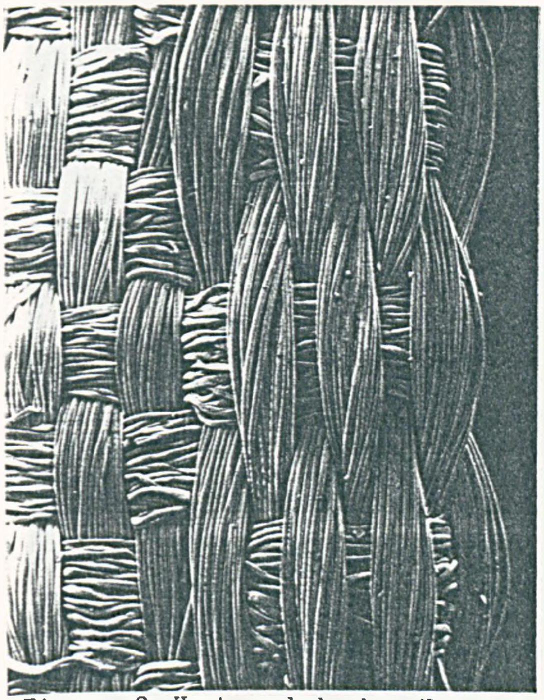


Figure a2: Poorly cut heat sealed edge (label 1.4)

Figure a3: Heat sealed edge (label 1.1)

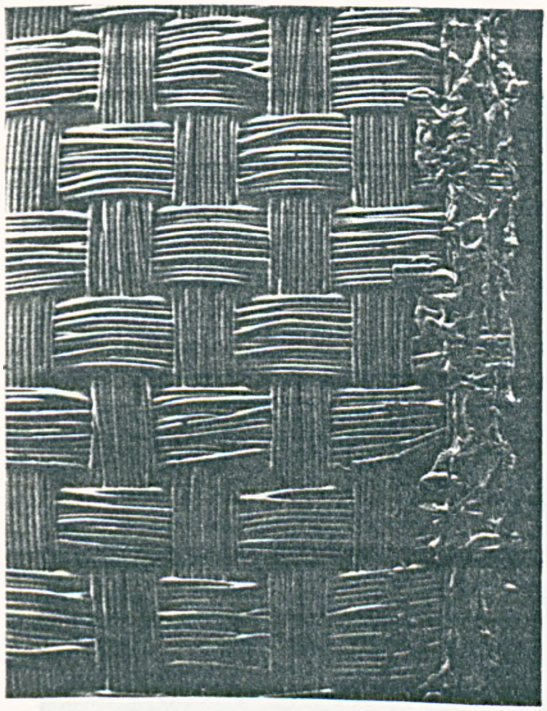


Figure a4: Fused edge (label 4.1)

Figure 11.6.b Electron micrographs of the folded corner of typical garment labels showing rounded and pointed corners. (magnification x 80)

Figure b1: Woven edge (label 3.1)

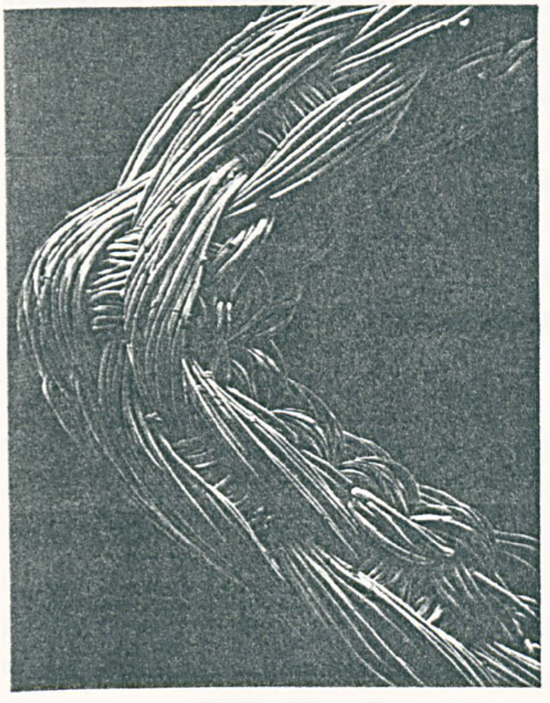


Figure b2: Fused edge (label 4.1)

Figure b3: Heat sealed edge (label 1.1)

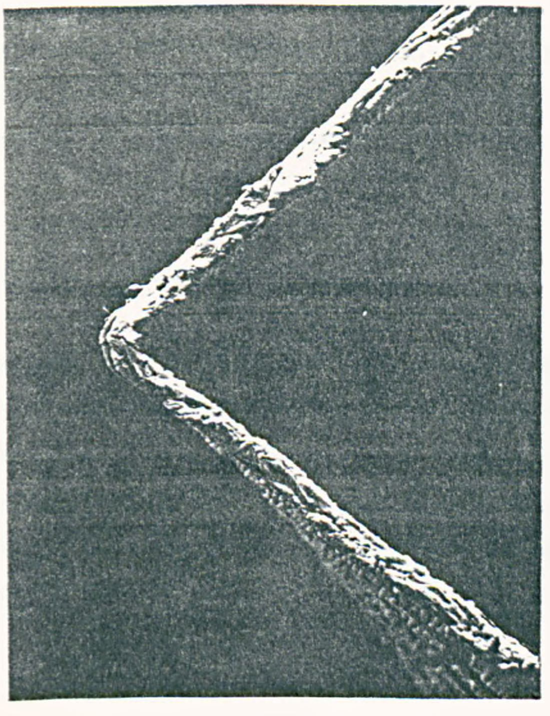
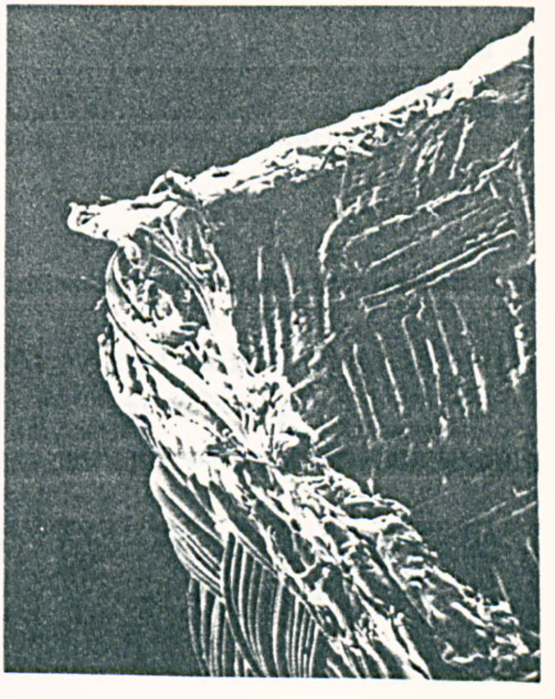


Figure a4: Heat sealed edge (label 4.1) mag x180



### 11.1.6 Psychological Label Discomfort.

The psychological discomfort caused by a label being on view on the outside of a garment is also an important local irritation factor. This type of discomfort is almost exclusively the result of a long label being sewn into the neck seam. When the wearer puts on their garment the label invariably hangs outside. Unless the wearer remembers to put the label back inside the garment, they will be unaware of this situation until someone points it out to them. At this stage they experience psychological discomfort. Other reasons for psychological discomfort due to labels are that a dark or a light label can show through a fabric and spoil the appearance of a garment, and also labels advertising unfashionable manufacturers can cause discomfort if they are on view.

The public questionnaire did not identify the proportion of people who remove garment labels due to physiological or psychological discomfort. This type of investigation would needed to have been conducted independently, when a large number of people noted the reasons and frequency of removing garment labels at home for approximately six months. Nevertheless, from the discussions with many people on this subject, it is clear that labels are frequently cut out of garments to avoid both psychological and physiological discomfort.

As mentioned in section 11.1.1, prestige labels are rarely removed because they portray the image that the wearer requires. They will therefore not produce psychological discomfort for the majority of the population.

### 11.1.7 Conclusions.

Garment labels were the most common source of local irritation discomfort. The public questionnaire revealed that 82 per cent of the population said that they had experienced label discomfort. The most common source of this type of discomfort is due to labels in the neck seam of garments. Subjective trials showed that the discomfort was due to the sharp folded corner of the label. The labels with a heat sealed edge (used in over 90 per cent of next to the skin apparel) were the most uncomfortable because they had the sharpest corners. Some of these labels are resinated, this reinforces the label against collapsing away from the skin when the corner is under pressure. These labels are popular because they are cheap and they maintain a pristine appearance over a long time. The woven edged labels had rounded corners and no discomfort was recorded from these, but they are not widely used because they crease in wear. Psychological discomfort caused by the label hanging outside the garment is also a common source of discomfort.

Discomfort produced by garment labels is rarely tolerated because 65 per cent of the people answering the public questionnaire said that they remove their labels if they feel uncomfortable. Nevertheless, the problem could be solved easily if moderately sized needle loom woven edged labels (with information printed onto the fabric) were used for next to the skin applications. Already, a few leading manufacturers (such as Mothercare and Debenhams) appreciate the problem with garment labels and they specify that their garment labels should have woven edges to eliminate discomfort.

## 11.2 Garment Seams and Sewing Threads.

A potential source of discomfort is garment seams. They are used both for functional and decorative reasons, and invariably they are in contact with the skin. The range of sensations which can be produced by seams was assessed in relation to the type of seam construction, the sewing thread, the fabric used and the position of the seam within a garment.

### 11.2.1 Main Wearer Trial.

The comments from the main wearer trial showed that seams can feel uncomfortably scratchy, prickly, bulky and in a few cases they can cause skin abrasion. The discomfort was mainly associated with fabrics which were bulky, scratchy or prickly and also the construction of the seam (when the garments had been made commercially).

The main areas where seam discomfort in a short sleeved vest were acknowledged were the neck and the armhole, not the side seams or along the hem. It was clear from additional comments on questionnaires 1 and 2 of the wearer trial that seam discomfort was rarely an isolated sensation and fabric properties had an influence on its occurence. The most common discomfort sensations mentioned in relation to seams were scratchiness and prickliness of the fabric, with the tight fit of the garment being an inevitable common factor. In the wearer trial all the knitted fabrics (besides fabric 11) had overlocked seams (type 504, ISO 4915:1981) of 3mm width) which are typically used for commercial vests and tee-shirts. The garments produced at the Shirley Institute were sewn with a 276-316 decitex (100's cotton count) core spun, polyester/cotton thread and the needle thread was an 354-388 decitex (80's cotton count) polyester seam covering thread. The woven garments were lock-stitched (seam type 301, ISO 4916:1982) which is commonly used for commercial shirts and blouses using a 276-316 decitex (100's cotton count) polyester core spun thread.

In table 11.3 the number of male and female subjects that commented on discomfort due to seams in a wearer trial garment are assessed in relation to the garment being worn.

<u>Table 11.3 The number of people that commented on prickle and scratchiness of seams from the main wearer trial garments.</u>

| Garment Number | 1 * | 2 | 3 * | 4 | 5 | 6 | 7 | 8 | 9 | 10 * | 11 * | 12 | 13 | 14 | 15 | 16 | 17 | 18 * | 19 * | 20 | 21 | 22 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Males | 4 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 |
| Females | 0 | 2 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 4 | 4 | 0 | 4 | 2 | 4 | 0 | 0 | 0 | 3 | 1 | 1 | 4 | 33 |
| M + F | 4 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 4 | 6 | 2 | 6 | 3 | 4 | 0 | 0 | 0 | 3 | 1 | 1 | 4 | 47 |

* = The garment was made commercially.

From the table it can be seen that the women experienced approximately twice as much discomfort due to the seams as the men, and usually different garments produced discomfort for the two sexes. Although the discomfort of the seams in the table above refers to scratchiness and prickle, these were not the only discomfort sensations experienced. Garment 8 and 13 were critized for having very bulky seams, especially under the arms.

Following the wearer trial results, seam discomfort was discussed individually with 30 Shirley Institute staff (not in the wearer trial) to determine how often they experience it and why they think it occurs. The most common answer to the question was in connection with tight inextensible arm holes which were said to cause a lot of discomfort when experienced. However, most people said that they would not wear such a garment, and would assume that the garment design and sizing was at fault rather than the seam. Another source of discomfort was said to be monofilament sewing threads, either used for the hems of skirts (which tend to ladder tights and occasionally cause prickle) or when it is used to sew labels into garments. Bulky seams in the side of briefs and under the arms of thick jumpers were also mentioned, but only by a few people. On the whole, seams were not considered to be a common source of scratchiness or prickle discomfort. The main discomfort associated with them was inextensibility and tightness.

### 11.2.2 Monofilament Sewing Threads.

For the past 20 years monofilament sewing thread has been a cheap alternative for many garment makers. The thread is colourless and is aptly named "invisible thread". It enabled a manufacturer to substantially reduce their stock levels of different coloured sewing threads, and was therefore very popular. In recent years the wide-spread use of this thread in garments has decreased due to the well known discomfort it can cause. This is because it has a large fibre diameter (0.75mm) and therefore it is rigid (as discussed in section 9.3). From discussions with a representative of a leading sewing thread manufacturer (Coats, 1984), it appears that monofilament sewing threads are no longer used for next to the skin apparel, and they are rarely used for skirt hems and pocket linings. Coats actually recommend that this thread should not be used for next to the skin apparel. Nevertheless, the thread is still used in some cheaper garments to sew in the labels. It is likely that at least one end of the thread will protrude on the inside of the garment. Therefore the wearer will undoubtedly feel great discomfort during wear from the end(s) sticking into the skin. In addition, where the thread folds due to the stitching, a 'sharp', hard surface is produced because the thread is rigid. This will rub the skin if there is movement between the two surfaces. In this situation the wearer will probably cut the label out of the garment, wrongly assuming that the discomfort is due to the label. However this can make the discomfort worse if the monofilament thread is not removed as well, because the cut edge of the label can be an additional source of discomfort. Only when the monofilament thread has been totally removed will the discomfort be alleviated, and this is usually difficult to do without unpicking the garment seams.

### 11.2.3 Conclusions and Recommendations.

The garments used in the wearer trial, although limited in their range of stitches and sewing thread, are typical of the seams used in commercial next to the skin apparel. They produced a variety of discomfort sensations attributed to the type of seam and the fabric used in the garments. To avoid the main types of seam discomfort a number of recommendations are made.

If a garment is made from a stiff, bulky, or potentially scratchy or prickly fabric, seams should be hidden. This can be easily achieved by an inner yoke. However the bottom edge of the yoke should be bound, preferably with soft ribbon. Flat seams can also reduce discomfort when bulky fabrics are used, but again, care needs to be taken when binding raw edges.

Seam discomfort is of particular importance to sportsmen and people involved in high levels of activity. For these people extra attention should be paid to the type of seam and sewing thread in their garments; as well as a consideration for the thickness and discomfort properties of the fabric itself. Where possible the seams should be hidden or flat and ideally the garment should be tubular knitted to reduce the number of seams.

The recent trend away from the use of monofilament sewing thread for next to the skin apparel confirms that seam discomfort is recognised as a potential discomfort problem. Unfortunately the thread is still used in areas of garments where it can irritate the wearer. Garment designers and manufacturers should ensure that if their products are to incorporate monofilament thread, the seam is hidden or bound with ribbon. Where possible the thread should be avoided.

With greater demands and expectations being required by the public from their clothing, designers need to pay more attention to the comfort of a garment when it is being worn. It was clear from the wearer trials that more care needs to be taken in deciding on the type of seam, its position within the garment (location on the body), the end-use of the garment (high or low activity) and the thread used in relation to the properties of a fabric. A universal seam cannot be used for all knitted or woven fabrics. Each garment design should be considered individually with respect to the fabric being used and a suitable seam selected. Ideally no open seams should be in contact with the skin around the neck, and if the fabric is bulky it should be sewn using a flat seam.

## 11.3 Garment Trimmings and Fasteners.

The terms 'trimming' and 'fastener' encompass any garment accessory; for instance, lace, ribbon, motifs, eyelets, buttons, embroidery and so on. The potential source of discomfort is therefore wide-spread, and yet it is a very specific discomfort because it is dependent on the particular trimming or fastener and its relationship with the body.

From individual discussions with approximately 50 Shirley Institute staff, and from the comments in the public questionnaire, the most common sources of discomfort were identified.

### 11.3.1 Lace.

Lace inserts, found on ladies briefs, bras and tee-shirt necklines were said to be scratchy. As identified in chapter 10, an ornate fabric structure produces more discomfort than plain fabrics. Lace is very ornate, being made up of tight knots and large holes. The yarns used to make lace are usually tightly twisted and incompressible, this produces a lace with a harsh handle. In addition, if the edge of the lace sewn onto the garment is next to the skin and unbound, this can feel like a saw edge when it moves relative to the body, and it can abrade the skin. Therefore, like fabric abrasion, discomfort is due to the lace rubbing against the skin.

Although the different types of lace were not investigated in this research programme, they all have the potential of abrading the skin when they are in contact with it due to their ornate structure. Because of the complexity of the structure of lace it is difficult to propose any simple objective test that can assess its potential scratchiness next to the skin. A combination of the following tests are the most likely to produce the most information:

1) Light transmission (to determine the percentage of light which passes through the fabric and hence the openness of the lace structure).

2) Bending length test (to determine the stiffness of the fabric).

3) Surface profile photographs (to determine the different heights of the knots protruding from the fabric surface).

Garment designers and makers should make sure that if lace is used next to the skin in a garment, the edges are bound with a satin type ribbon and the lace is either lined or in a position of infrequent lace:skin movement.

### 11.3.2 Postioning of Fasteners.

Another common cause of discomfort were buttons, zips and press-studs if they are located in areas of pressure. Some of the most common areas on the body which experience this type of discomfort due to garments are:

1) The spine when a button or a zip is positioned in the centre back seam of skirts. When a women sits down and leans back on a chair the button or zip will press on the spine and be very uncomfortable.
2) The centre, front of the waist when a large button, belt buckle or press-stud presses into the stomach when the wearer sit or bends.
3) The buttocks can feel discomfort when buttons or press-studs are in a position (usually on pockets) where a wearer applies pressure to them when he/she sits down.

Buttons, zips and to a lesser extent press-studs are common, functional garment fasteners which are widely accepted in most apparel. Nevertheless discomfort due to their positioning can occur. To avoid any discomfort caused by placing them in inappropiate positions, the garment designer should always consider where on the body they will be located, and whether they are likely to cause discomfort when the wearer sits down and bends. For instance, one simple and effective design which has been used for many years in skirts is to have the fastening down the side seam, thus avoiding spine discomfort.

### 11.3.3 Metal Eyelets.

Unclosed metal eyelets, where a sharp tooth has failed to be bent into shape can easily cut the skin and cause pain. This type of discomfort can be associated with both shoes and clothes. Eyelets on shoes can be used as decoration or as lace holes. Discomfort due to eyelets on shoes is most common in the summer when the wearer does not wear socks or tights, and the tongue (if present) within the shoe does not cover the skin sufficiently. In garments, eyelets are usually present as decoration, for example on shorts, trousers, tops etc., but they can also be used as guides for laces, and their presence is mainly dictated by fashion trends.

The machinery inserting the eyelets and inadequate attention to detail during quality control is the cause of eyelet discomfort, both in shoes and garments. However, if the product is designed so that the teeth of the eyelet are covered with a lining, the incidence of this source of discomfort would be greatly reduced.

### 11.3.4 Other Possible Sources of Discomfort.

There was no mention of discomfort due to ribbons, embroidery or motifs. This could be because these accessories are usually located on the outside of garments, and so they rarely come into contact with the skin.

### 11.3.5 Conclusions and Recommendations.

Lace is a highly ornate fabric which was said to produce discomfort due to scratchiness, and in a few cases skin abrasion when it is in contact with the skin. The discomfort produced by lace is due to its ornate structure, which was identified as a major cause of scratchiness discomfort in chapter 10.

Garment design features such as the positioning of buttons, zips and press-studs over areas of the body where pressure is regularly applied were stated as being a common source of discomfort. The areas which were mentioned as being the most common and uncomfortable were over the spine and in the middle at the front of the waist.

The teeth of metal eyelets in shoes and to a lesser extent garments can cut the skin if the are not closed properly on the inside of the article. This discomfort is worst in the summer for shoes because socks and tights are rarely worn and so the skin is unprotected.

All of the above mentioned sources of discomfort caused by garment trimmings and fasteners could be easily avoided by careful design and attention to detail by both the manufacturer and the quality control department. Before production, the garment (or shoe) designer should consider where the trimming or fastener will be in relation to the body, and adequate protection for the skin and the general body should be taken. This can be achieved by either protecting the skin by a lining, or placing the trimming or fastener in a slightly different position. Once the garment is in production, care should be taken to ensure that the trimming or fastener has been attached to the garment properly, and that there are no sharp edges present that will protrude into the skin. A few moments to consider where the trimming or fastener will be located when the garment is worn, can save the wearer much discomfort.

# CHAPTER 12

# INITIAL COLD FEEL.

Initial cold feel (ICF) is invariably associated with cooler climates. It is experienced when a fabric at or close to ambient temperature is placed against the skin, and there is a transfer of heat from the skin to the fabric until thermal equilibrium is achieved. If this heat transfer is rapid the wearer will experience ICF - a sensation that usually lasts for a few seconds. However, the reactions (physiological and psychological) to initially feeling uncomfortably cold can make the wearer feel cooler for much longer; sometimes for the duration of wearing the garment.

## 12.1 Physiology.

The size of the temperature difference between the skin and a fabric for ICF to be experienced has not been specifically investigated for this thesis or by other researchers. The facilities, such as a temperature controlled room and trial subjects, were not available to carry out such an investigation in this project. Nevertheless, the work done on thermal insulation (reported by Woodson and Conover, 1954-64) indicates that a thermally comfortable wearer will not feel an air temperature change of 1°C to 2°C, which is very small. The majority of comments on ICF in the main wearer trial occured when the ambient temperature was less than approximately 16°C. For most people a comfortable air temperature in the winter is between 17°C and 22°C (Woodson and Conover, 1954-64) when wearing appropriate clothing indoors. The mean skin temperature for a person at thermal equilibrium is usually taken to be 33°C. This value is achieved by taking the temperature at five sites on the body, applying a weighting factor to each of them and then taking an average of the values (Hardy and DuBois 1968). The rate of heat transfer increases as the difference in temperature of the contact surfaces becomes greater.

The skin is sensitive to changes in temperature because the body needs to maintain its core temperature of 37°C to within ± 1.5°C to avoid permenent damage. Hanada et al (1982) investigated the effects of an evenly distributed thermal stimuli on the sensation of warmth and coolness. They removed small portions of garments to expose the skin to a cool ambient, and found that the whole body behaved as if it was cold. Some areas of the body were more influential than others, in particular the spine. The result of the temperature change caused the milder forms of physiological reaction to the cold. These include the formation of 'goose-pimples' on the skin causing the body hairs to elevate. Vaso-constriction may also occur which can lead to the re-direction of blood from the skin to the body core, and it is also thought to increase the sensation of being cold (the opposite reaction to vaso-dilation). This means that the wearer will feel colder for longer, because the body will have to reverse these reactions before thermal equilibrium can be achieved.

Women are more likely to experience ICF because they have less coarse body hair than males, which is so effective at reducing the contact area with the fabric surface. Their basal metabolic rate tends to be lower and it fluctuates with the reproductive cycle; therefore it takes longer for a female to re-establish equilibrium after feeling cold.

## 12.2 Heat Transfer.

The two main properties of a material that influence the quantity of heat which is transfered from one body to another are (1) specific heat and (2) thermal conductivity. This relationship is shown in equation 12.1 (Perry 1969) and it is discussed below.

$$Q = \frac{k\,\theta}{\rho\ Cp\ X^2} \qquad \text{Equation 12.1}$$

Where:- Q = quantity of heat, k = thermal conductivity,
$\theta$ = temperature difference, $\rho$ = density, Cp = specific heat,
X = distance from the contact surfaces of the two bodies.

1) Thermal conductivity:

Fibres are poor heat conductors and their values of thermal conductivity range from 50 to 250 $mWm^{-1}{}^{\circ}K^{-1}$ with the synthetic fibres having the higher values. For example, the values for wool and cotton are 54 and 71 $mWm^{-1}{}^{\circ}K^{-1}$ respectively, whereas polypropylene, polyester, PVC and nylon range from 120 to 140, 160, 250 $mWm^{-1}{}^{\circ}K^{-1}$ respectively. These values can be compared with still air which is a very good insulator (25 $mWm^{-1}{}^{\circ}K^{-1}$) and copper which is a very good conductor (390 $Wm^{-1}{}^{\circ}K^{-1}$). The magnitude of ICF is determined by the rate of heat transfer which is primarily governed by thermal conductivity. This in turn is dependent on the contact area between the skin and the fabric, and the difference between their temperatures.

2) Specific heat:

The values for specific heat of the common apparel fibres are very similar. They typically range (for dry fibres) from 1.21 $Jg^{-1}{}^{\circ}K^{-1}$ for cotton to 1.34, 1.36 and 1.38 $Jg^{-1}{}^{\circ}K^{-1}$ for viscose rayon, wool and silk respectively. Values for the synthetic fibres range from 1.9, 1.7 to 1.25 $Jg^{-1}{}^{\circ}K^{-1}$ for polypropylene, nylon 66 and PVC and polyester respectively. These values usually increase (not necessarily uniformly) with higher temperatures and relative humidity. Nevertheless the ambient is unlikely to vary more than -15°C and ± 25% relative humidity (RH) from a comfortable environment for the majority of people, which is within the limits of only a small change in specific heat capacity for most fibres.

The fabric structure can influence the rate of conduction heat transfer by variations in the contact area. An apparel fabric can be woven, knitted and in rare cases non-woven. In general woven cloths tend to have a smoother surface, are stiffer and less extensible than knitted fabrics. This is mainly due to them being a more compact weave, the use of less hairy yarns, and the chemical and physical finishing processes that are commonly used. Woven fabrics are therefore more likely to have a greater contact area with the skin where heat conduction can occur. A hairy fabric surface and/or an open or structured (such as a honeycomb) fabric construction is the most effective means of reducing skin/fabric contact area and ICF. The fabric surface can often over-ride the differences in the thermal properties of fibres because the area of contact is the main factor influencing the ICF.

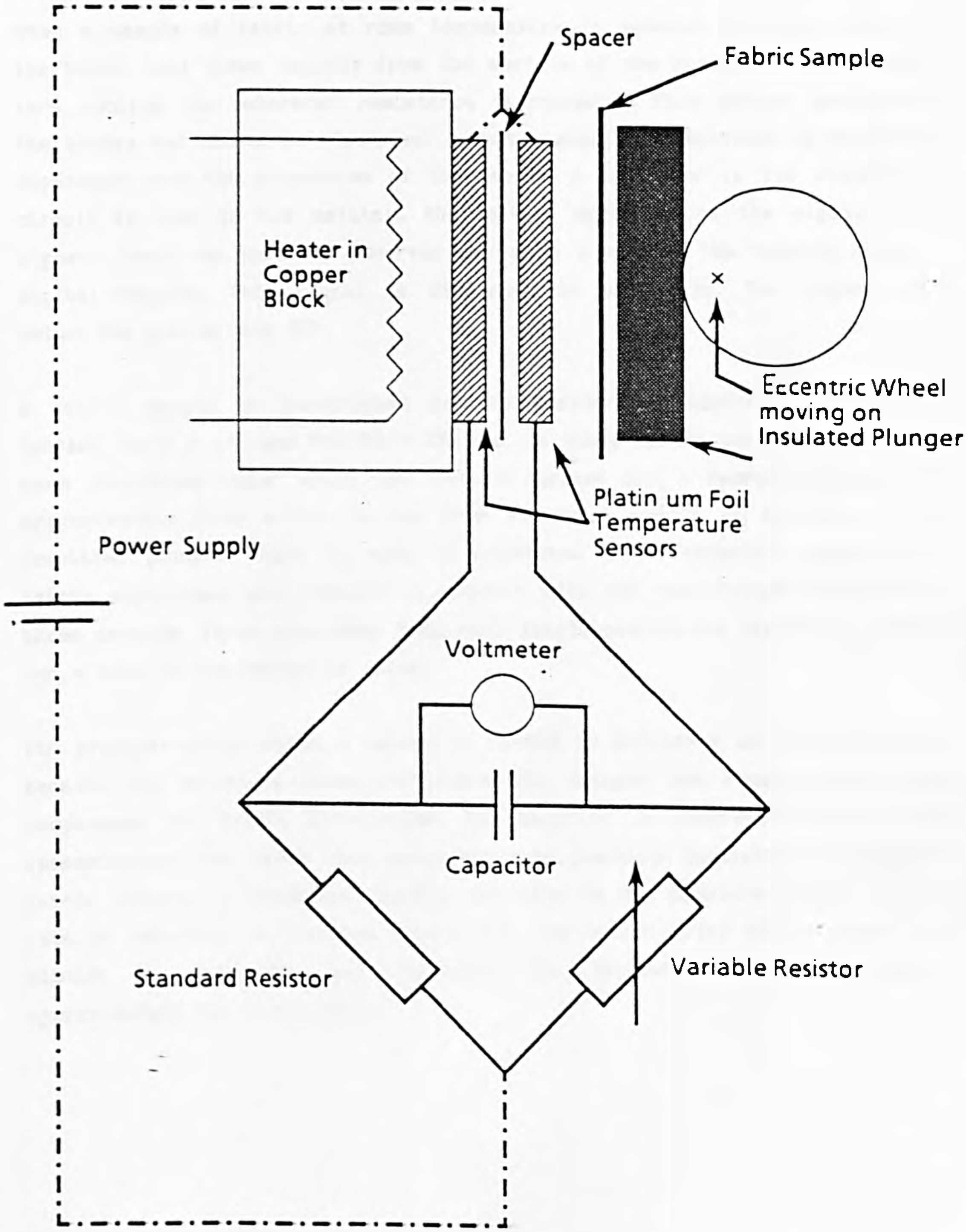
The answers to the public questionnaire showed that the thermal properties of a fabric are of prime importance in hot and cold weather. The initial warmth and coolness of a fabric will effect the perception of thermal comfort whilst wearing a garment and when handling a fabric before purchase. The initial cold or warm feel can be assessed subjectively by comparing pairs of fabrics, one in each hand, but this can be difficult. A quantitative method of assessment would have the advantage of being quick, reliable and unbiased. A piece of equipment designed for this purpose was used in this study to evaluate ICF.

## 12.3 Test Procedure.

I.C.I. Fibres Limited designed a thermal impression meter to rank fabrics in order of ICF. In 1982 I.C.I. gave the Shirley Institute a thermal impression meter on long loan. Since that time the apparatus has been considerably altered and refined, in particular the electronics, to make the equipment easier to use and the results more reproducible. The apparatus is illustrated in figure 12.1.

The tester consists basically of a heated copper block, the temperature of which is maintained at a constant 50°C by a resistance thermometer and a temperature controller. Fitted to the face of the block are two foil resistance thermometers separated by a thin layer of insulating material (spacer). The resistance thermometers are used in an electrical bridge circuit (Wheatstone bridge) which is balanced when the block reaches its operating temperature of 50°C. The mean skin temperature is 33°C, but the reading produced by the equipment was not large enough when the heated block was at this temperature. The difference in temperature between the ambient and block was not large enough. Therefore, the temperature of the copper block was raised to 50°C.

Figure 12.1




THERMAL IMPRESSION METER (T.I.M)

When a sample of fabric at room temperature is pressed onto the face of the block, heat flows rapidly from the surface of the block into the fabric thus cooling the outermost resistance thermometer. This effect unbalances the bridge and causes an electrical output signal, the magnitude of which is dependant upon the properties of the fabric. A capacitor in the electrical circuit is used to the maintain the initial magnitude of the signal (its highest level) so that the observer can make a note of the reading from a digital display. This signal is displayed in millivolts. The higher the value, the greater the ICF.

A fabric sample is conditioned in the standard atmosphere for textile testing (20°C ± 1°C and 65% RH ± 2%) for 24 hours before testing, it is the same conditions under which the test is carried out. A fabric specimen of approximately 10cm × 5cm is cut from a sample and it is mounted on an insulated plunger which in turn is connected to an eccentric wheel. The fabric approaches and remains in contact with the temperature sensor for three seconds. Three specimens from each fabric sample are tested ten times and a mean of the values is taken.

The pressure under which a fabric is tested is dependant on its thickness because the eccentric wheel and hence the plunger are fixed and do not compensate for fabric differences. The majority of underwear fabrics are approximately 2mm thick when under moderate pressure. Initially a compresed fabric reduces in thickness rapidly and then as the pressure increases the rate of reduction in thicknes levels out. The wearer trial fabrics were all similar in thickness and therefore the fabrics were tested under approximately the same loads.

## 12.4 Results and Comments.

The main wearer trial fabrics, numbers 1 to 22, were tested on the thermal impression meter as described above. The fabrics were ranked in order of their ICF results, as shown in table 12.1. The results show that in general the fabrics with a brushed or structured surface have a low value, and therefore have little or no initial cold feel. Fibre trends also appear; PVC tends to have a warmer feel than polypropylene in an equivalent fabric construction. However, as mentioned above, the fabric construction and surface hairs usually overide fibre type influences. This can be seen by a comparison of fabrics 16 (brushed) and 17 (unbrushed) which originate from the same fibre source. The difference in their values is due to variations in contact area with the heated block.

The thermal impression meter has been used successfully in this study to rank any potential differences in the ICF of fabrics. However, the results from the meter did show some scatter, and the greatest degree of consistency was obtained when the tests were carried out on the same day. Although the tester has been shown to give variable results on different occasions, the ranking order of the fabrics remained constant. A number of experimental details that the author considers to be the cause of some errors in the test results are mentioned below. Firstly the pressure exerted by the plunger is very high. It is equivalent to a wearer sitting or leaning on the fabric which is not usual when a garment is first donned. This high pressure means that differences in fabric surface hairiness are thought to be lost because the surface is compacted. Secondly, repeated tests on the same fabric sample will compress the surface hairs which have very little time to recover. The variability of results will therefore be reduced and may not be representative for the fabric.

The thermal properties of a fibre do have an influence on the rank order of ICF as can be seen in table 12.1. This can be seen by comparing two very similar 1 x 1 rib fabrics, numbers 10 and 12 for their thermal impression meter values, the polyester fabric is initially colder than its polypropylene counterpart. This conclusion is also supported by unpublished work that was been carried out at the Shirley Institute before the start of this project where fibre trends were seen.

**Table 12.1 Wearer trial fabrics ranked for ICF by the thermal impression meter.**

| Fabric code | Fibre content | I.C.F. (millivolts) ** |
|---|---|---|
| 12 | Polyester (PE) | 783 (16.3) |
| 18 | Polypropylene (PP) | 775 (18.4) |
| 5 | Wool/PP | 741 (22.1) |
| 7 | Wool | 739 (28.0) |
| 9 | Cotton | 736 (23.1) |
| 19 | PP | 730 (29.5) |
| 17 | Wool | 719 (11.6) |
| 22 | Viscose | 714 (32.5) |
| 21 | Acrylic/cotton | 706 (32.0) |
| 4 | Cotton | 704 (36.0) |
| 6 | Brushed PE/viscose | 691 (19.2) |
| 10 | PP | 646 (14.8) |
| 2 | PVC | 620 (15.2) |
| 15 | Wool/angora | 599 (11.1) |
| 16 | Brushed wool | 598 (24.1) |
| 14 | PE | 575 (26.3) |
| 1 | PE/cotton * | 556 (34.6) |
| 20 | PE | 538 (38.3) |
| 13 | PVC * | 503 (23.0) |
| 11 | Wool * | 476 (12.6) |
| 3 | PP * | 427 (18.7) |
| 8 | Brushed PVC | 333 (21.4) |

NOTE:-
* Fabrics have an exaggerated structured surface.
** Numbers in parnethesis are the standard deviation for 10 test results.

It will also be observed from the results that the influence of the fibre type is over-ridden by seemingly very small differences in the fabric surface. For instance fabric 16 has a warmer initial feel than fabric 17; both fabrics originate from the same fibre source but fabric 16 has been brushed. The difference in ICF is not surprising when it is considered that a fabric is approximately 90% air and 10% fibre. The heat transfer properties of air are very poor and so any variation in the contact area of the fibres within a fabric is highly important to the ICF. The presence of surface hairs (either on the fabric or the skin) and/or a structured fabric construction has the effect of increasing the percentage volume of air in a fabric, reducing the fibre/skin contact area and thus reducing ICF. In some cases the presence of hairs can produce an initial warm feeling; this is usually seen as an advantage in cold weather but it is rarely noticed in warmer climates. Fabric construction is by far the most influencial factor in determining the ICF.

## 12.5 Wearer Trials and Handle Trials.

As part of the main wearer trial the subjects were asked to handle the garment and to indicate on a 10cm line how warm or cool the fabric felt in relation to a neutrality. When the garment was donned, the subject indicated the initial thermal properties of the fabric surface in relation to their idea of comfort on another 10cm line. The question was aimed at making the subject contemplate the sensation individually, which was especially important for a mild discomfort sensation like ICF. The differences between the actual thermal properties they experienced and the subject's idea of comfort were used for the analysis of the results and a rank order emerged. However, the assessments were carried out at different times of the year and the subsequent differences in ambient temperature effected the ranking. This is due to initial cold feel being much more noticable in cold climates when there is a large difference between the skin and ambient temperature.

An assessment of all the main wearer trial fabrics together in paired comparisons would yield most information on the rank order of the fabrics for this property. This is because it is a difficult property to judge individually and it needs a controlled environment. The main wearer trial subjects were asked to take one fabric at a time and to do paired comparisons with other fabrics until it was ranked. Only the side of the fabric that was to be worn next to the skin, the inside face, was assessed. In many cases the fabrics were ranked in groups when the subject was unable to distinguish between them. The tests were carried out in a conditioned room kept at 20°C (± 2°C) and 65% (± 2%) relative humidity. The results are shown in table 12.2 where the fabrics are divided into five groups to show where they are significantly different to the 5% confidence level using the chi-square method. Group 1 had the coldest initial feel and group 5 the warmest. Although this was informative, a degree of prejudice and/or past experience had obviously influenced the subject's judgement. This was noted due to the comments and many rapid decisions that were made by fabric appearance rather than touching the fabric.

Table 12.2 The subjective ranking of the ICF of the main wearer trial fabrics. (Fabrics 18 and 22 were not included in this trial)

| Group | Fabric code |
|---|---|
| 1 (coldest) | 20, 21, 4 |
| 2 | 6, 7, 12, 1, 14, 9 |
| 3 | 10, 2 |
| 4 | 5, 13, 17, 16, 19, 3 |
| 5 (warmest) | 8, 11, 15 |

Another test was designed to eliminate these factors and to include people who were not in the main wearer trial. An additional asset of this trial was the elimination of sight, and thus the reduction of psychological influences. The test was based on a complete block design using pairs of fabrics. The assessor put their hands through two holes in a cardboard box (to shield the fabrics from view), and placed them flat onto two fabric samples. They were not allowed to hold or handle the fabric. This made their assessment similar to a garment being placed against the body when it is donned. The main wearer trial fabrics used in the comparison were numbers 1,5,8,11,12,19 and 20. They were chosen because they represented a various fibre and fabric types which the author considered to be a typical of the range of fabrics which covered a large range of ICF. The number of people involved were 44, they included 36 women (2 from the wearer trial) and 8 men (1 from the wearer trial). The trial was carried out in a conditioned room at 20°C (± 2°C) and 65% (± 2%) RH. The results were calculated using an adaption of Kendals rank correlation coefficient (Koroney, p350-352) and are shown in table 12.3.

**Table 12.3 I.C.F. of unseen fabrics in order of ranking.**
(ranked coldest to warmest)

| Fabric code |
|---|
| 20 |
| 19 |
| 12 |
| 5 |
| 11 |
| 1 |
| 8 |

There are differences in the rank order of the fabrics ranked subjectively and using the T.I.M.. The biggest difference is seen with the thin woven polyester fabric, number 20. Subjectively it was found to be the coldest to touch, but objectively it was 18th coldest out of 22 fabrics. This large difference in the rank order for this fabric is most likely to be due to the T.I.M. applying very little pressure to the test specimen due to its fineness. The transfer of heat would be reduced and the readings would be low. The subjective rankings show a trend from the most sheer and compact fabric structures as being the coldest, through to the uneven and brushed fabrics as having an initial warm feel.

## 12.6 Conclusions.

The ICF of a fabric is a comparatively mild discomfort sensation which is only experienced in cool climates. Skin sensations are all relative to the conditions of the skin at any one moment, therefore the magnitude of ICF is governed by the difference in temperature of the skin and fabric which are in contact. Nevertheless, the presence of fabric surface hairs can make the wearer feel initially warm and therefore counteract the temperature differences. The main properties that increase the severity of the sensation in any one climate are the ones that aid in the rapid transfer of heat from the skin to the fabric surface. The absence of surface hair on the fabric or the skin, and/or a smooth fabric surface are the most influencial factors for increasing ICF. They increase the contact area between the two surfaces so that more heat can be transfered by conduction. The specific heat capacity of the fibre is thought to be the major property responsible for the differences in ICF between fibres of the same fabric construction, but its effects can be easily over-riden by fabric construction variations.

The results have shown that the ICF of a fabric can be assessed and ranked sucessfully by the thermal impression meter so long as the fabric are not too thin. The results do tend to vary slightly from the blind subjective rankings, however the T.I.M. results did have the same grouping of fabrics (assessed using the chi-square statistical method) when fabric 20 was eliminated from the statistical analy sis. The blind paired comparison handle test was undoubtedly the most reliable method because it eliminated preconceived ideas about the properties of a fabrics ICF which was so apparent when the fabrics were seen and ranked. Many of the fabrics in the handle trial were ranked in groups rather than individually, and it is thought that the general body surface would rank them similarly. The additional influence of evaporation due to sensible and the ever present insensible perspiration may also play a part in the handle assessment.

The main wearer trial identified the discomfort caused by ICF as being relatively mild and the sensation was one of the least objectionable. The subjects did not record the ICF of a fabric being so uncomfortable that they would prefer not to wear the garment. The main comments were ones of preference for the fabrics with an initial warm feel for cold weather. If the discomfort sensations that could be experienced due to ICF were outlined the majority would be mild discomfort and impartiality. However, in hot weather ICF can be considered an asset and therefore the perception of this discomfort sensation is seasonal. The relatively mild forms of discomfort that are experienced means that ICF can be easily forgotten if another discomfort sensation is present at the same time.

# CHAPTER 13

# FIBRE SHEDDING.

Fluffy knitted jumpers, tops, scarves, gloves etc. which feel soft and warm are a recurring major fashion trend, especially in ladies apparel. The garments are usually worn next to the skin or as a secondary layer over a blouse, and they are very popular. But, they have one well known major drawback: they shed fibres. The type of sensations experienced and the range of fabrics which produce the discomfort were investigated firstly in the main wearer trial when one underwear fabric was found to produce this form of discomfort, and secondly by more specific trials. The properties of the fibres which were shed were assessed in terms of this discomfort, and a test method was developed to rank the fabrics.

## 13.1 Main Wearer Trial.

The only fabric in this trial to produce discomfort due to fibre shedding was number 15, a knitted angora/lambswool/nylon fabric which has been used for many years in Germany for mens underwear. It was very similar to a ladies jumper fabric. It caused 70 per cent of the subjects to complain strongly about the annoying, uncomfortable fibres which were shed. The loose fibres were alleged to fly into the face, nose and mouth, and to stick to the body when the skin was slightly damp or wet. They also became entangled with the body hairs which produced tickle discomfort when they were moved in the wind and they acted like an extension to the body hair. Another factor of major concern was the psychological discomfort caused by the loose fibres becoming attached to other clothing and furniture.

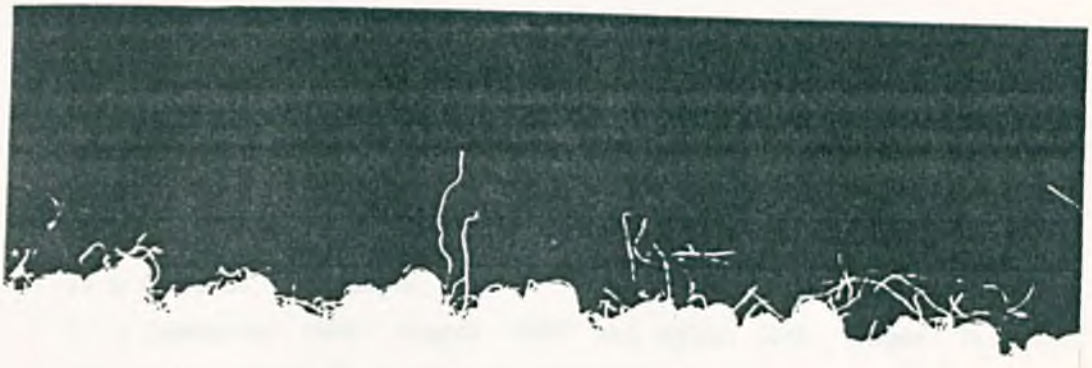
The results of the main wearer trial showed that the discomfort due to loose fibres was limited to a certain type of fabric and, when it did occur it was considered to be very uncomfortable. The fabric had a very hairy surface in comparison with the other fabrics in the trial (see figure 13.1) which was attributed to a low twist yarn (produced on the woollen system).

Figure 13.1 Photographs of two main wearer trial fabrics to show the difference in surface hairiness of a fibre shedding (uncomfortable) and a non-fibre shedding (comfortable) fabric.

(See table 4.1 for fabric details and section 8.2, for the photographic method)

Fabric 15 This fabric caused 70 per cent of the wearers to feel fibre shedding discomfort.

Fabric 2 This fabric produced no fibre shedding discomfort.
(It is typical of the other main wearer trial fabrics).



The author discussed this source of discomfort with a leading chain store, Marks and Spencer, who sell jumpers which are made from fabrics very similar to fabric 15 in the main wearer trial. Their representative confirmed that they were aware of the problem of fibre shedding, but said that they had no record of garments being returned for this reason. This was expected because from general discussions with women who wear garments made from these types of fabric, they are aware of the problem before buying the garment due to past experience. If they did return the garment to the retailer due to fibre shedding discomfort they would be likely to take the passage of least resistance and say that the garment was the wrong size.

Marks and Spencer provided the author with five different ladies wool jumpers (which were in the autumn range for 1984) to help in the study of this form of discomfort.

## 13.2 Specific Wearer Trial.

A specific wearer trial was carried out using four female members of the Shirley Institute staff. Each subject wore three of the jumpers provided by Marks and Spencer at least twice, and then commented on any discomfort due to any fibres being shed. The fabrics included in the trial were:

1) A cable-knit mohair (26%), wool (26%), acrylic (26%) and nylon (22%) jumper.
2) A shetland wool jumper.
3) A lambswool (60%), angora (20%) and nylon (20%) jumper. This was similar to fabric 15 in the main wearer trial.

The two remaining garments were cardigans, one in a similar material to the lambswool/angora fabric and the other was similar to the mohair fabric. These were not included in the wearer trial because the garment size was too large for the subjects. Therefore these fabrics were retained for the development of test equipment.

The subjects said that the mohair jumper was very uncomfortable. The shed fibres produced both physiological and psychological discomfort sensations.

They experienced prickle (through a blouse in most cases) and general body and facial irritation due to the shed fibres. In addition the loose fibres became attached to adjacent surfaces which looked unsightly. The lambswool/angora jumper also produced physiological and psychological discomfort. The sensation produced was tickle when the fabric was worn next to the skin, and the fine fibres which were shed produced body and facial discomfort. The shetland wool jumper produced prickle and scratchiness with no fibre shedding discomfort.

The mohair jumper was said to be the most uncomfortable jumper to wear next to the skin. This is likely to be due to the thicker fibres producing prickle, whereas the finer fibres in the lambswool/angora fabric produced tickle. The shed fibres were most uncomfortable when the subject was just beginning to sweat. Both fabrics shed fibres which adhered to other surfaces. The mohair fibres were said to be the most unsightly, and this is because they are longer and therefore more noticable in comparison to the angora fibres shed by the lambswool/angora fabric.

The subjects were asked to note if an increase in the release of the fibres from the jumper occurred. They said that most of the discomfort was experienced when they were walking around. The fibres would become loose due to air movement and then fly onto the skin or into the face. Therefore most physiological discomfort was due to fibres being very loosely held into the fabric. The psychological discomfort caused by the fibres attaching to an adjacent surface was increased by rubbing against a surface, such as a chair, or wearing another garment ontop of the jumper.

From the wide range of fabrics in the main wearer trial and the three jumper fabrics, (representative of commercial fabrics which shed fibres) only two main types of fabric were identified as being a source of fibre shedding discomfort. They can be characterized by their fibre content because no other fabrics/fibres are known to produce this type of discomfort (due to the fabrics that are produced from them). These were:

1) Angora containing fabrics which shed short, fine fibres (fluff).

2) Mohair containing fabrics which shed long thick fibres.

Both types of fabric had a hairy surface and low twist yarns.

The ability of these fabrics to shed fibres and produce discomfort was investigated further. The quantity of fibres shed and the type of fibres (long or short) were assessed for fabrics which did and did not produce discomfort due to fibre shedding. Equipment was designed and developed to induce fibre shedding in a standard way so that different types of fabrics could be assessed.

## 13.3 Fibre Shedding Equipment.

Equipment was designed to determine the ability of a fabric to readily shed fibres. It worked on the principle of shaking a fabric sample and collecting any shed fibres for inspection later. The equipment is shown in figure 13.2.

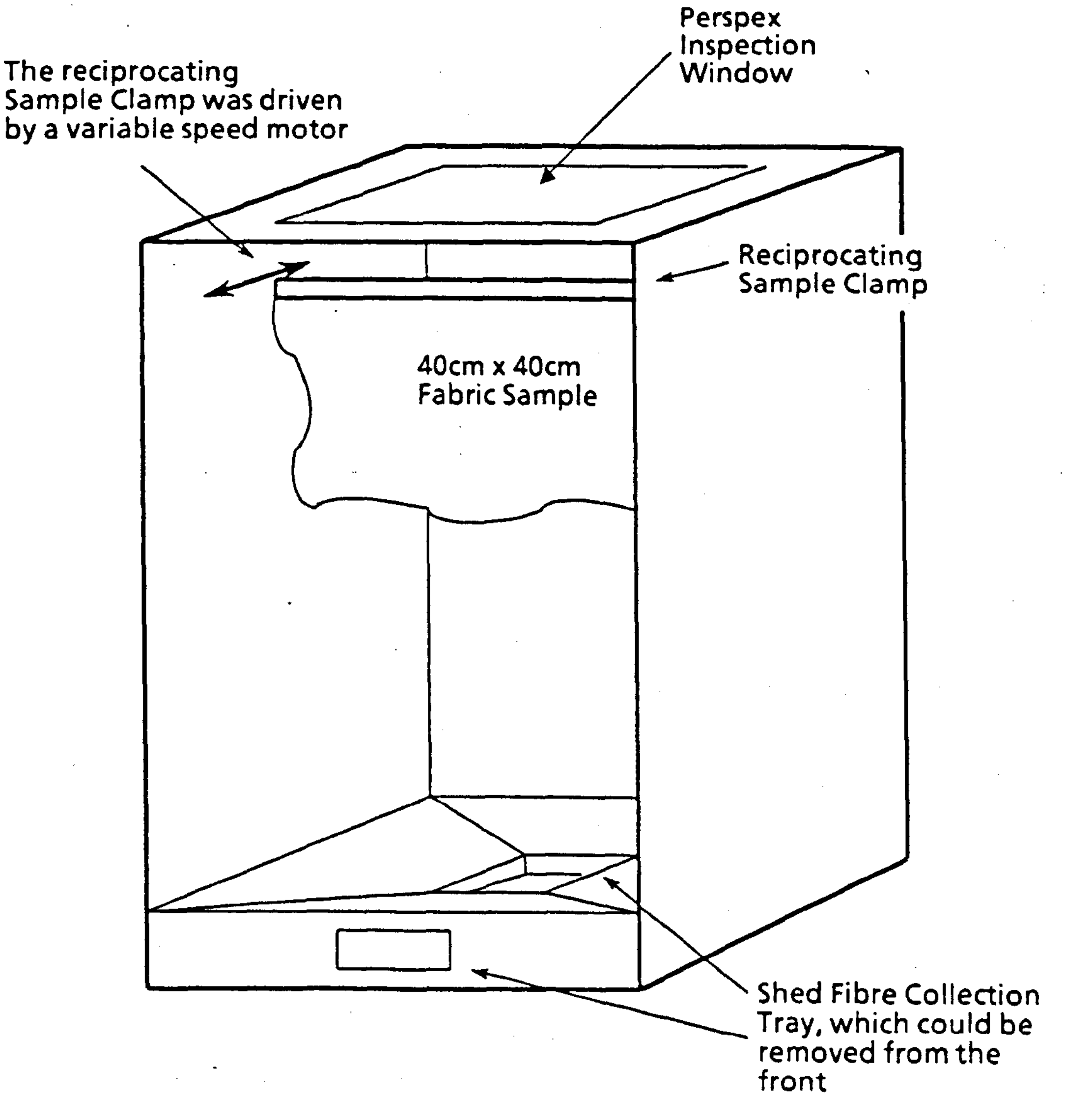
The fabrics from the specific wearer trial, an additional mohair cardigan and a lambswool/angora cardigan fabric and the main wearer trial fabrics were used to develop the test method. This enabled a wide range of commercially available fabrics to be covered, including some that did and some that did not shed fibres and produce discomfort.

The fabric sample was mounted securely between two clamps which have metal teeth protruding from their surface. The clamp was attached to a reciprocating arm (a doffer from a card), and the speed of the arm was altered by a variable speed motor. The shaking assembly was encased in a stainless steel cage to contain the fibres as they were shed during the test. A metal cage was chosen so that the number of fibres adhering to the sides of the chamber (owing to static or a rough surface) would be reduced. The metal cage measured approximately 115cm high x 75cm wide x 75cm deep. A perspex inspection window in the top of the cage allowed the operator to observe the fabric when it was being shaken without interupting the test.

The front panel of the cage was removable so that the fabric could be easily mounted, and the inside of the cage could be cleaned after a test. The front panel was replaced during the test.The cage was cleaned thoroughly between tests using a 3.5 cm wide paint brush to prevent the

Figure 13.2

Fibre Shedding Equipment




Note: The front panel has been removed

contamination of the results of other fabric samples. A shelf, approximately 10cm from the floor, was angled so that the fibres would be guided into a hole in its centre. A sliding tray (removable from the front of the cage) was positioned under the hole to collect all the shed fibres. The tray was painted with matt black paint to enable the fibres to be seen more easily.

### 13.3.1 Development of the Test Method.

The equipment was designed to determine any differences in the quantity of fibres shed from comfortable and uncomfortable fabrics. This information would then lead to the equipment being suggested as a means of screening fabrics for this type of discomfort. Initially the optimum shaking time had to be established and then the differences in the quantity and type of fibres shed by a wide selection of fabrics was assessed.

1) Shaking Time of the Fabric.

The optimum time for the fabric to be shaken to release the majority of its loose fibres was investigated. The three specific wearer trial jumper fabrics and fabric 15 from the main wearer trial were shaken over a time period of 165 minutes. The test was stopped after 5, 10, 15, 20, 30, 45, 60, 135, 165 minutes during the test, and the amount of fibre shed within each time period was assessed visually (and at every third time interval the tray was photographed) and by weighing (which later proved to be an unsatisfactory method because small differences in the relative humidity had a large influence on the measured weight). This test was carried out three times on each type of fabric. Approximately 80 to 90 per cent of the fibres were shed within 20 and 30 minutes, and so half an hour was chosen to be the standard shaking time for all fabrics.

2) The Type of Fibres Shed and the Development of Photographic Standards.

Once the optimum shaking time had been established, a selection of the jumper and main wearer trial fabrics (which did and did not shed fibres) were tested on the equipment to determine the type of fibres which were shed. After each test the tray was photographed and the shed fibres were collected in a plastic bag.

There was a marked difference between the amount of fibre shed by the uncomfortable fabrics and the fabrics which did not produce any fibre shedding discomfort. The uncomfortable fabrics shed copious amounts of loose fibre and sometimes the angora type fabrics shed balls of tangled fibre (flat large pills of approximately 1cm diameter) which could be seen on the surface of the fabric before shaking. The fabrics which did not produce discomfort tended to produce small amounts of lint (very short fibres and dust) and very few fibres.

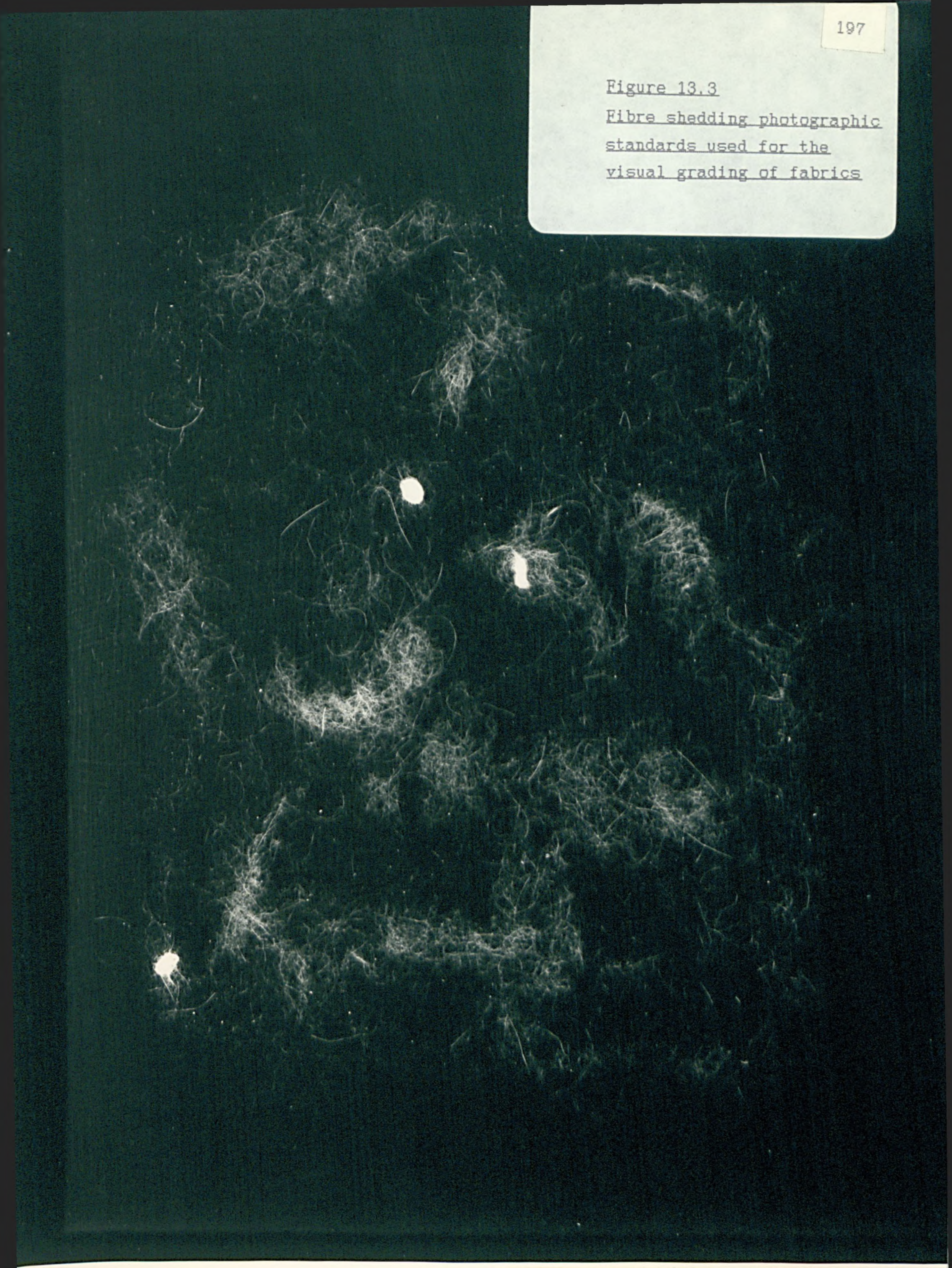
These photographs showed that the shed fibres were either long and mohair-like or short and fluffy. This difference was also observed in the wearer trials. The difference in the appearance of the trays or photographs of these two types of shed fibres was large, and the comparison of one fibre type with the other was very difficult. Therefore two distinct types of photograph were selected for future reference:

1) Short, fluffy fibre.
2) Long fibre.

To enable a judgement on the quantity of shed fibre and the discomfort of the wearer for future fabric comparisons, each of the two types of photograph covered a range in the quantity of fibre that could be shed by fabrics. In each photographic set a scale of increasing fibre shedding was produced. The jumper fabrics were used as the top end of the scale, and the other fabrics in the main wearer trial were used as the basis for the two levels at the bottom end of the scale (no mohair fabric for the bottom of the scale was available). Two extra standards were included between the two extremes to complete the set. They were produced by progressively reducing the quantity of shed fibre from the tray which had the most fibres in it. Therefore, each set of photographic standards consisted of 5 grades, from 5 (very bad fibre shedding) to 1 (no fibres shed). The photographic standards for grades 1 and 5 are shown in figure 13.3.a to d for both the angora and the mohair fabric types. The photographs are the same size as the collection tray to make the comparison during a test easier.

Figure 13.3

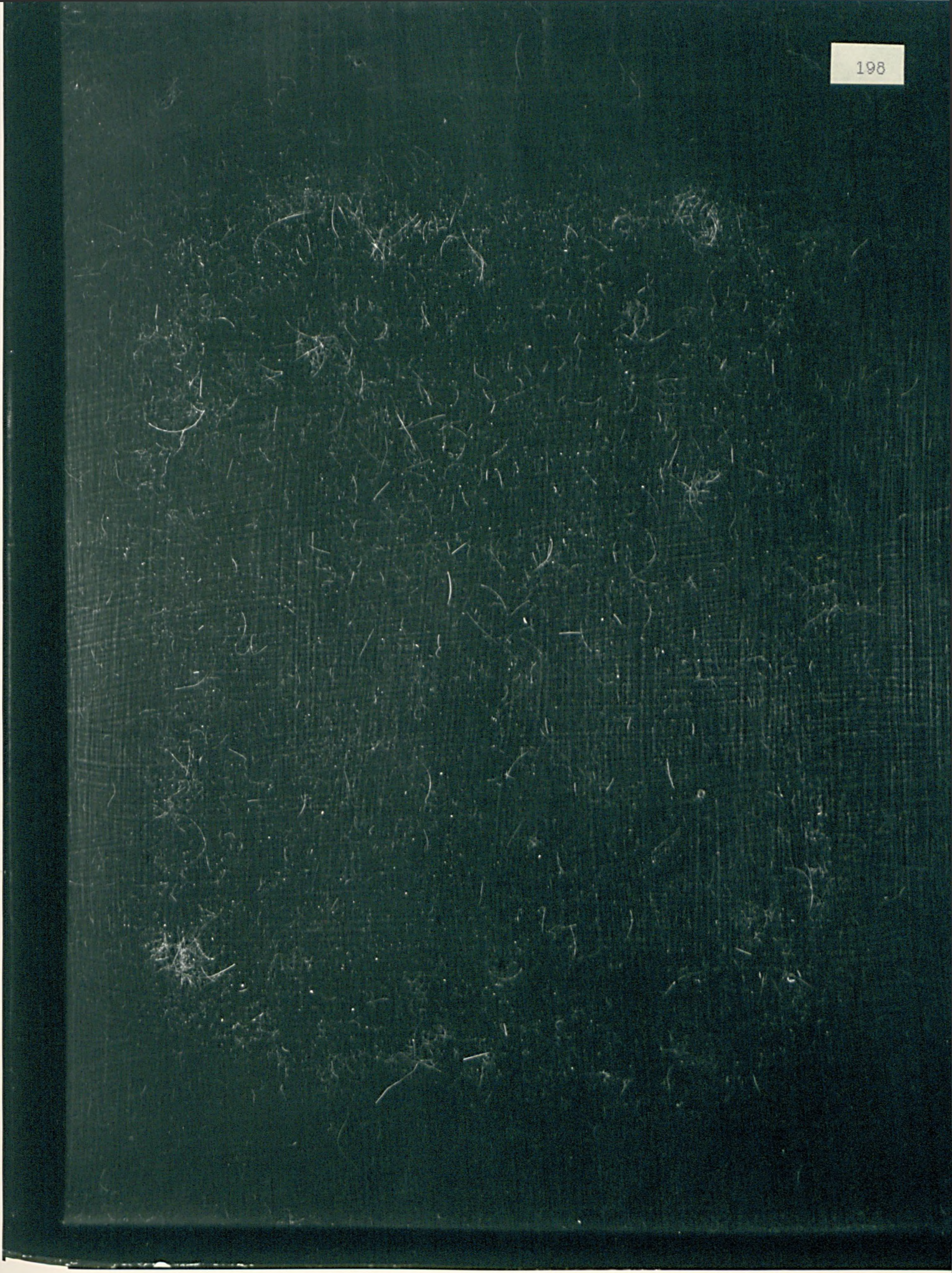
Fibre shedding photographic standards used for the visual grading of fabrics



13.3.a Grade 5

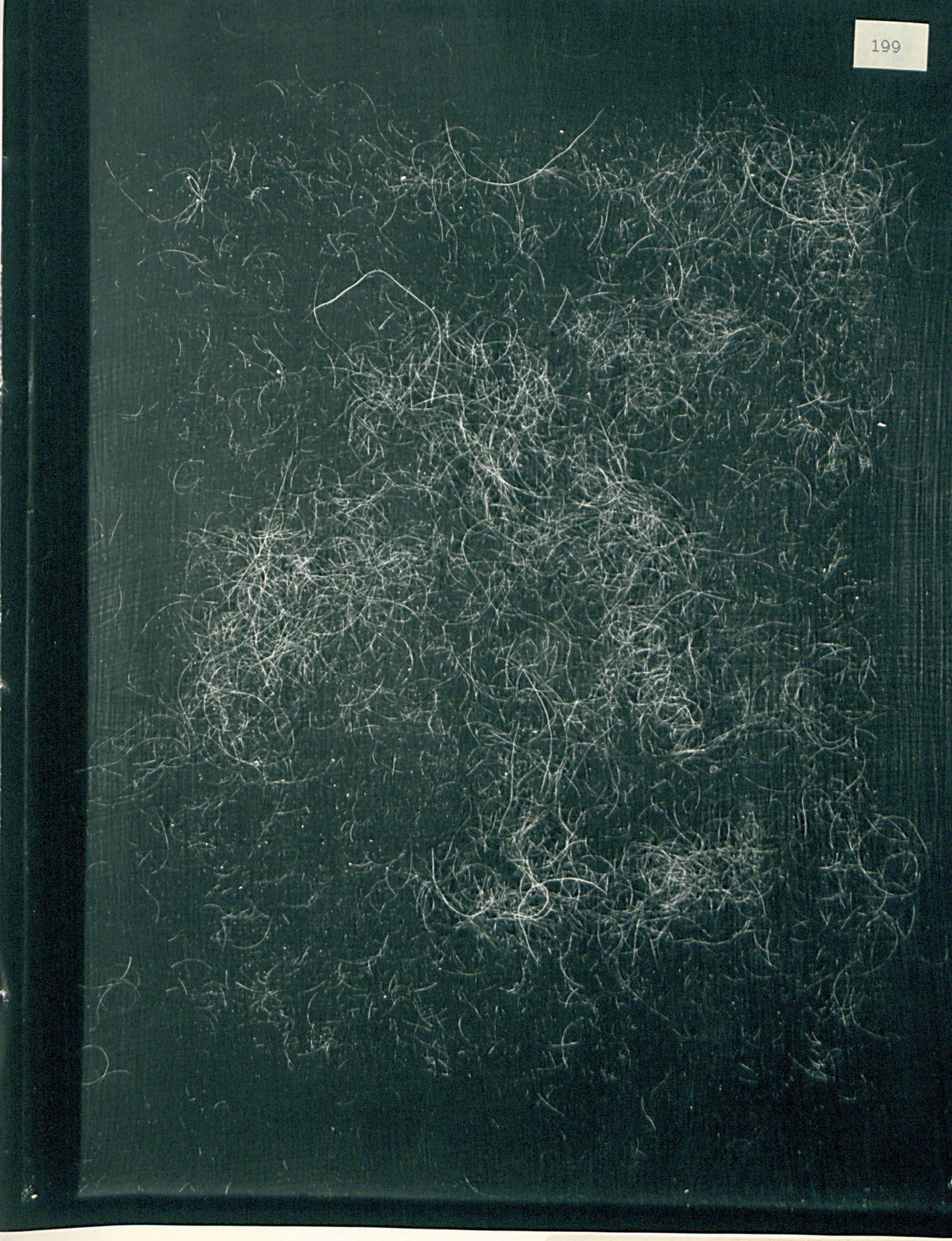
Angora type fabrics

198



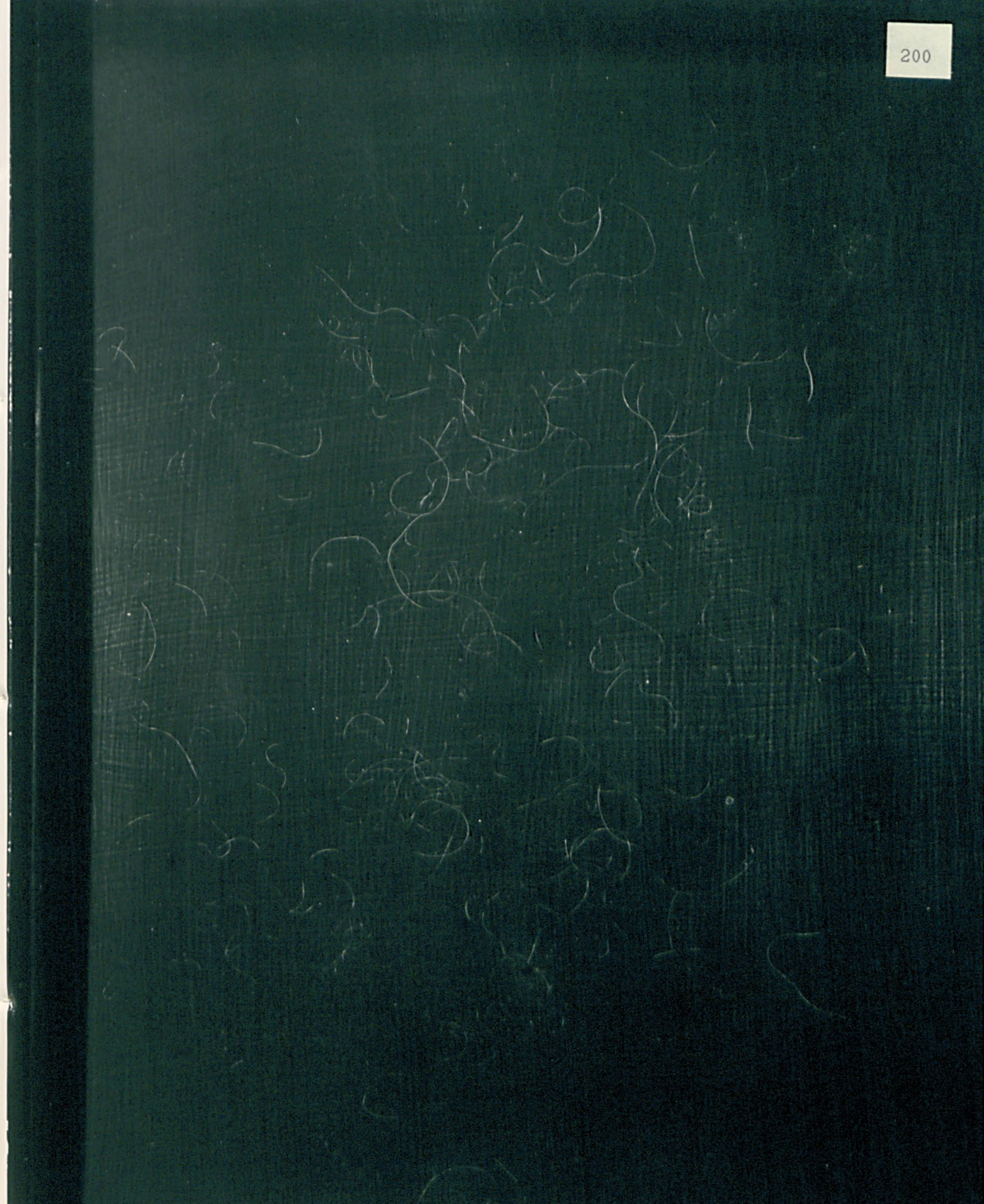
13.3.b Grade 1

Angora type fabrics



13.3.c Grade 5

Mohair type fabrics



13.3.d Grade 1

Mohair type fabrics

### 13.3.2 Test Method for Assessing Fibre Shedding of Fabrics.

The collection tray and the inside surfaces of the fibre shedding equipment were thoroughly cleaned with a paint brush so that no fibres were present before the test. A sample of the test fabric was cut to 40.5cm x 40.5cm. The cut edges of the sample were sealed with 2.5cm wide electrical insulating tape to leave an exposed area of fabric of 40cm x 40cm. The sample was carefully mounted (with its warp vertical) between the teeth of the clamp, making sure that the fabric lost as few fibres during handling as possible. The tray was slid into the bottom of the equipment and the front panel was replaced.

The fabric sample was shaken for 30 minutes at a speed of 125 cycles per minute, to an amplitude of 10cm (for the clamp). This enabled the fabric sample to assume an approximate sinusoidal wave form which occasionally led to the fabric rubbing against itself (equivalent to an arm rubbing against the torso). After 30 minutes the fabric sample was removed and the inner surface of the equipment was cleaned with a paint brush so that all the fibres which had adhered to the sides of the metal cage were directed into the tray.

The collection tray was carefully removed so that none of the fibres were lost. The tray was inspected for pieces of yarn or any foreign particles which were not directly shed from the fabric surface. These were removed with tweezers. The fibres were then brushed from the sides of the tray so that they were evenly distributed, but there was a clear band of 1cm around the edge of the tray. The extent of the fibre shedding was then assessed visually by at least two individuals against the appropiate set of photographic standards. The major decision as to the standard chosen was the number of fibres present.

## 13.4 Test Results on the Main Wearer Trial Fabrics.

The main wearer trial fabrics were tested using the fibre shedder, and they were graded using the angora type (none of the fabrics contained mohair) photographic standards. The results are shown in table 13.1 below.

Table 13.1 The main wearer trial fabrics graded for fibre shedding.

| Fibre shedding grade | 1 | 1-2 | 2 | 5 |
|---|---|---|---|---|
| Fabric code | 2; 7, 10, 12, 13, 14, 20, 21, 22 | 1, 3, 4, 5, 8, 11, 16, 17, 18, 19 | 6, 9 | 15 |

The results show that fabric 15, an angora/lambswool/nylon blend shed fibres very badly and the rest of the fabrics in the trial shed very little fibre. These results correlate with the findings of the comfort of the main wearer trial because fabric 15 was the only fabric to produce this type of discomfort.

It is considered that if a fabric sheds fibres under these conditions of test, it is not completely satisfactory. Interpretation of the results on a particular fabric should be based on an evaluation of the relative importance of the appearance of the fabric and the discomfort likely to be produced when it is worn as a garment.

In practice, it is envisaged that only the extremes of the photographic standard ranges will be encountered, as found from the extensive range of commercially available fabrics which were included in this study. Nevertheless, with the increased awareness of major retailers to this source of discomfort this may lead todevelopments in the future and the production of fabrics with intermediate fibre shedding capabilities.

## 13.5 Conclusions.

The discomfort caused by loose fibres being released into the air from a fabric was found to be very objectionable when it occured. The discomfort was wide-spread amongst wearer's of fibre shedding fabrics, which produced both physiological and psychological discomfort. The main discomfort was due to the fibres adhering to the body, causing facial discomfort and the shed fibres adhering to adjacent clothing and furniture which was unsightly.

The main factor influencing fibre shedding was a hairy fabric when the fibres were loosely held to the surface. This is mainly due to a low twist, hairy yarn. There were two types of fibres which were typically made into fibre shedding fabrics. These were angora (the most common fabric) and mohair (less common but more uncomfortable).

Equipment was designed and developed to assess the fibre shedding capabilities of fabrics which was quick and easy to use. It can assess existing or development fabrics, and from the results the potential comfort of a fabric in wear can be indicated. A grading system was developed to rank the fabrics with a scale from 1 (no fibres shed) to 5 (very bad fibre shedding). From the results of the wearer trials, it was concluded that fabrics with a fibre shedding rating of 4 or 5 would be likely to cause much wide spread discomfort, whereas fabrics with a rating of 1 and 2 would not cause fibre shedding discomfort.

It is known that retailers are aware of this discomfort problem, but as yet fashion dictates the fabric properties. In the future retailers will ultimately require a fabric with the same aesthetics and handle, but with reduced fibre shedding. This would be a worthy topic for future research, especially in terms of the yarn properties of the fabrics.

# CHAPTER 14

# DISCUSSION AND CONCLUSIONS.

Prior to this research programme sensorial comfort was a neglected area of research. When it had been investigated, the studies were aimed at determining the properties of particular fibres or a particular sensation. Therefore no overall assessment of the sensations that can be experienced from next to the skin apparel, their relative importance with one another, or a standard terminology were available. This meant that the studies that had been carried out could not be compared with one another.

This research project aimed to establish the range of major discomfort sensations that can be experienced from everyday next to the skin apparel and the importance of these sensations in relation to one another. It was decided that a standard glossary of terms should be produced which could be used to describe these sensations, thereby providing a sound basis for future studies into this area of research.

## 14.1 Identified Discomfort Sensations.

One of the first tasks in this research project was to establish the range of skin sensations that could be felt from next to the skin apparel. This was done by a wearer trial. At the same time it was necessary to select a precise range of descriptive terms to define these skin sensations so that the subjects in the wearer trial and the observer knew exactly what each other meant.

The terminology used to describe the discomfort sensations was established by two main methods. Initially the terminology was selected from a list of handle terms which was reviewed by 30 people. This list of terms was used for the wearer trial in which 20 subjects wore 22 fabrics as tee-shirts. The fabrics were made from a range of fibre types in a variety of common fabric constructions. The subjects included men and women over a range of ages engaged in different levels of activity.

During the trial nine major discomfort sensations were identified, some of which had not previously been reported or studied for clothing comfort. These were tacky cling, garment label irritation, initial cold feel and the difference between prickle, tickle and scratchiness was also established. The nine major skin sensations identified were:

Tight fitting seams and bands.

Wet cling due to sweat (when a fabric is released from the skin).

Tacky cling due to damp sweat residues (when a fabric is released from the skin).

Tickle (like a feather).

Prickle (pin-pricks).

Scratchiness (sand-paperish). This can produce skin abrasion.

Local irritation due to labels, seams and trimmings. The type of skin sensation varies depending on the irritant.

Shed fibres can produce a range of skin sensations and psychological discomfort.

Initial cold feel when a garment is donned (in cold weather only).

The terminology used to describe and define these sensations in the wearer trial was modified (small additions were made) as the wearer trial progressed. The final list of terms produced is proposed as a standard terminology for future comfort analysis and description.

Each major discomfort sensation was assessed further to determine the physical, physiological and psychological factors producing the sensation. Subsequently, methods were developed to test these factors, together with recommendations for their assessment as described below.

## 14.2 The Factors Producing and Influencing the Severity of the Skin Sensations and the Equipment Designed to Measure the Sensations.

The nine major discomfort sensations were investigated further by specific wearer trials which were designed to determine factors influencing the presence and severity of the sensation. This information was used in the development of objective test methods for five of the sensations. The equipment designed can be used to test a fabric for its potential comfort in wear. Recommendations for all the sensations were made to ensure that discomfort is avoided where possible.

The specific wearer trials identified numerous factors which influence the presence and severity of each sensation. These are outlined below. In addition a description of the test methods and/or recommendations that were made following these investigations are described:

1) **Tight Fit** - The discomfort threshold for the waist was found to be 20 $cN/cm^2$ and the comfortable region was 10-15 $cN/cm^2$. The main factors which determined this threshold was restriction of internal organs rather than blood flow.

   Two methods were suggested for determining the comfort of a local fitting area. The first was a modified version of a British Standard method which measured the extension of a strip of elastic at a pressure of 20 $cN/cm^2$. The second was an attachment for the Instron Tensile Tester which was specially designed to measure the extension of an elastic band in garment form at a force of 20 $cN/cm^2$. The latter test method was the most informative.

2) **Wet cling** - The greatest intensity of wet cling discomfort was experienced when the fabric frequently released and adhered to the skin. In addition the wearer could feel cold. Fabrics with a high surface drag force when wet or damp were found to be the most comfortable because they did not release from the skin as often. However, a heavy weight fabric (when wet or dry) also increased the frequency of fabric:skin release.

Equipment was designed to measure the surface drag force of a fabric (under a small loading) at different water contents. It is an attachment for an Instron Tensile Tester and both knitted and woven fabrics can be tested on the equipment.

3) **Tacky Cling** - This sensation was more uncomfortable and common than wet cling. It is caused by the fabric frequently releasing from the skin surface due to the low adhesion force between the two surfaces. Tacky cling can be measured using the same apparatus as wet cling.

4) **Tickle** - This was a very common sensation and all the fabrics in the wearer trial produced tickle discomfort to some degree. It was observed that when a person just starts to sweat, the discomfort is heightened.

   Equipment was designed to test the subjective tickle discomfort caused by a variety of factors. These were gender, fabric or skin hairiness, fabric:skin speed and the loading on the fabric. This showed that the main factors producing tickle were the fabric (a) moving slowly over the skin and/or (b) at a low loading. Other less important, but influential factors were fabric hairiness, fibre rigidity (especially the presence of wool) and the body location (the shoulders were particularly sensitive).

5) **Prickle** - This is produced by thick, rigid fibres sticking into the skin. Wool is the main source of this type of discomfort due to the large range of fibre diameters present in a fabric. In this study the presence of very small amounts of fibre with a diameter of 30μm and above produced prickle discomfort.

   Recommendations were made to avoid prickle discomfort. These were to determine if the fabric is made from wool and to establish if there are any fibres of 30μm diameter or above present in the fabric. No test method was found to determine potential prickle discomfort directly from a fabric. The other source of prickle discomfort is mono-filament sewing thread. A garment should be checked for the presence of this thread, and ensure that it can not be in contact with the skin.

6) **Scratchiness** - A scratchy fabric has the potential of being very painful because it can abrade the skin. Two main factors influence the presence of scratchiness, (a) an ornate fabric structure and (b) the presence of coarse wool fibres. However, when a wearer is sweating the skin can be abraded more easily due to a higher fabric:skin coefficient of friction and the reduced abrasion resistance of the skin.

It is recommended that fabrics with an ornate construction (especially when the garment is likely to be worn for high levels of activity) are avoided. Other sources of scratchiness discomfort are fabrics containing coarse wool fibres, lace inserts and prominent 'hard' seams.

7) **Local irritation** - (a) Garment labels were a common major source of prickle discomfort. A heat-sealed edge to the label was the main factor influencing the presence of discomfort because it produced a sharp folded corner which sticks into the skin. The stiffness of the label fabric was also important. (b) Garment seams and sewing threads produce discomfort when a bulky, scratchy or prickly fabric is used or a mono-filament sewing thread is present. These can cause prickle and scratchiness discomfort. (c) Trimmings can produce a wide range of discomfort sensations depending on the irritant. Some of the most common irritants were found to be lace (scratchiness was caused by the ornate structure), positioning of fasteners over bony prominences and areas where the body frequently experiences pressure and metal eyelets (when the sharp teeth protrude from the surface and cut the skin).

The main recommendations that were made to avoid local irritation were to use woven-edged garment labels, to avoid skin contact with bulky seams, mono-filament sewing threads, lace and trimmings, especially where there is frequent skin:fabric movement. Fasteners should not be positioned over bony prominences or where load is applied reguarly to the body.

8) **Initial Cold Feel** - This is only experienced in cold weather because it is produced when there is a large difference between the ambient and the skin temperature. It occurs when a garment is donned, and the transfer of heat from the skin to the fabric is rapid. The main fabric

properties that reduce initial cold feel also reduce the contact area with the skin (by reducing the rate of heat transfer). These properties are usually fabric surface hairiness and ornate fabric constructions.

A Thermal Impression Meter was designed by I.C.I. and modified at the Shirley Institute to measure the initial cold feel of fabrics. This method ranks fabrics in order of initial cold feel, although paired handle evaluations ranked the fabrics more generally (in groups). It is thought that a combination of the handle and the Thermal Impression Meter results gives an indication of the initial cold feel in wear.

9) **Fibre Shedding** - Only two types of fabric produce tickle, prickle, facial irritation and psychological discomfort due to loose fibres being released from a fabric and attaching themselves to adjacent surfaces. The fabrics were made from two fibre types, angora or mohair. The fabrics had a fashionable appearance. They were made from low twist yarns and had very hairy surfaces which released fibres to the surroundings with very little agitation.

Equipment was designed to shake a fabric sample for 20 minutes at a standard rate, after that time the amount of loose fibre shed is compared with a set of photographic standards.

To analyse a specific skin sensation it was found to be necessary to have knowledge of any other sensations that were being experienced at the same time. For instance, if wet cling was being assessed and the garment was tight fitting, the wearer will probably not notice the presence of any wet cling due to the more severe sensation of tight fit. This is known as counter-stimuli. Research has been carried out by physiologists into the effects of counter-stimuli, but it had not been researched for garment physiology until this research project, where a hierarchy of sensations was identified.

The potential severity of a skin sensation and its ability to damage the skin (by abrasion or piercing) was used to establish the hierarchy of the skin sensations. It is called the 'potential discomfort ladder'. It can be used as a guide to the types of sensation that could be ignored if more than one sensation is present at any one time (that is, when counter-stimuli is present).

**Potential Discomfort Ladder**

| | | |
|---|---|---|
| Tight fit, Scratchiness | | Most Painful |
| Prickle | | |
| Tickle | | |
| Local irritation | Fibre shedding | |
| Tacky cling | | |
| Wet cling | | |
| Initial cold feel | | Least Painful |

The spacing between the sensations is relative to the discomfort that can be produced.

The wearer trials and test equipment provided information on the fibres, fabrics and garment constructions that can produce discomfort. The attitude of the public to the discomfort properties of next to the skin apparel products was assessed to determine the features that they thought were the most important.

## 14.3 Public Opinion on Fibre, Fabric and Garment Discomfort.

A questionnaire was designed to determine the comfort features that the general public requires from its clothing and, the influence of handle and sight on their acceptance of a product. The questionnaire was answered by 1004 people ranging from 16 years old and upward. It showed that the public are very conscious of the comfort properties of their clothing. In particular they want a fibre to absorb sweat, a feature which the wearer trials and test equipment had proved to be wrong. They also associated any discomfort sensation with the fibre properties and not the garment or fabric construction. This again was found to be of little signifcance to the comfort of a wearer from the trials; the only major exception was wool.

The relative importance of three commonly mentioned discomfort sensations was assessed in the public questionnaire. The sensations were wet cling, tickle and tight garment fit. Each interviewee was asked to imagine that a garment had all of these discomfort sensations to equal degrees, and to choose the most and the least annoying. The answers showed that tickle was thought to be the most uncomfortable sensation, then tight fit, and wet cling was by far the least uncomfortable. This ranking was similar to the potential discomfort ladder (assuming that the tight fit was at a moderate level). This indicates that the general public are aware of the severity of different discomfort sensations, and that although the wet cling of a fabric is a well known, well researched form of discomfort, this does not mean that the public think that it is the most uncomfortable when compared to other sensations.

The consistency of the answers did tend to change between questions that were worded slightly differently. For instance, polyester was not a very popular fibre in comparison with silk when it was chosen from a list of fibres. However, when a silk and polyester fabric were compared by handle, the polyester was most prefered. The public were obviously influenced by what they thought they should like (due to prestige, marketing information or health reasons) and what they actually liked when they felt or saw a fabric. The latter decision being the most influential.

## 14.4 Comparison of the Wearer Trials and the Public Questionnaire Results.

Both the wearer trials and the public questionnaire have emphasised the importance of the appearance of the fabric in creating the 'right image'. For instance, is the fabric rough or smooth, is the fibre natural or man-made. The individuals response to the fabric image is to associate it with past experiences of similar looking fabrics, and predict the comfort properties with this knowledge. However, the appearance of the fabric can be misleading, and fabrics with the same appearance can have very different properties. Therefore the handle is of little value in predicting the comfort in wear for the general population.

## 14.5 Multi-Dimensional Diagram to Describe the Comfort of a Fabric.

At the outset of this project it was anticipated that the physical parameters measured on test equipment to describe the major discomfort sensations would be applied to a multi-dimensional diagram to predict the overall comfort of a garment. The author considers that this is an unsuitable method to represent the comfort of a garment. A multi-dimensional diagram would simplify a very complex mixture of sensations (due to the physical, physiological and psychological state of the wearer), which combine to produce overall comfort. The simplification of such a subjective, complex sensation cannot be reliably defined by a number of points on a graph and possibly one numerical value.

The use of the individual test methods designed and developed during this project, in conjunction with the recommendations and discomfort thresholds specified, are considered to provide a reliable screening process for the in-wear comfort of a fabric/garment for the majority of the population.

## 14.6 Suggestions for Further Work.

This project was the first of its kind to establish the basic principles behind the understanding of sensorial comfort. Further work is now required to take these concepts into the design and development of commercial clothing, to ensure that the garments that are available for a particular end-use can fulfil their total purpose.

1) Chapter 6 discussed the importance of the comfortable fit of a garment to the overall comfort of the wearer. A study to determine the discomfort thresholds for tight fit for different ages, body locations and genders would enable the design of future garments to be more suited to the end-use.

2) Tickle was found to be a major discomfort sensation. Further work on the sensitivity of different areas of the body to tickle and garment design on the speed of fabric movement would merit investigation.

3) Prickle discomfort has been associated with the presence of rigid fibres in a fabric, but the quantity and rigidity of the fibres causing the discomfort have not been exactly determined. Further wearer trials including a range of fabrics containing fibres of specific diameters/ rigidities would enable a more accurate assessment of the proportion and properties of the fibres that produce the discomfort.

4) Chapter 13 discussed the discomfort that can be experienced when a fabric sheds fibres. A further study designed to optimise the fibre shedding qualities of a fabric so that the fashionable appearance of the fabric is maintained, but fewer (and preferably no) fibres are shed so that discomfort is reduced or eliminated would be value. Some of the most likely factors which could achieve a reduction in fibre shedding are altering the yarn twist, yarn design or fabric construction and/or the application of fabric finishes.

5) In this project it was shown that the general comfort of a wearer can be greatly influenced by the presence of sweat in a garment assembly. Sweat can both produce wet cling and tacky cling discomfort, but perhaps more importantly it also affects the severity of the other major discomfort sensations. Further investigation into: (a) The severity of a discomfort sensation with sweat rate and the quantity of sweat present. (b) The severity of a discomfort sensation when more than one sensation is present and the wearer is sweating.

This research work was designed to obtain a back-ground knowledge of the sensorial comfort of clothing. The findings can be used either by researchers in future clothing studies or by manufacturers in fabric and garment design. It is anticipated the greatest impact will be made by the attention to detail during garment design and manufacture, especially for high activity end-uses. This is because this work has identified the need to consider the whole garment (fabric, seams, labels and so on) rather than just the fibre content. In the future it is hoped that a series of fabric and garment test methods and recommendations will be available so that standards may be established for the sensorial comfort of clothing.

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# APPENDIX

**Table 1 Technical data on the main wearer trial fabrics.**

| Fabric number | | Fibre compostion | Structure |
|---|---|---|---|
| 1 | C | Polyester (65%), cotton (35%) | Honey-comb |
| 2 | | PVC (90%), nylon (10%) | 1 x 1 rib |
| 3 | C | Polypropylene (90%), nylon (10%) | String vest |
| 4 | | Cotton (90%), nylon (10%) | Eyelet |
| 5 | | Wool (50%), polypropylene (50%) | 1 x 1 rib |
| 6 | | Polyester (50%), viscose (50%) | Interlock with 8x2 dropstitch. * |
| 7 | | Wool (100%) | Interlock |
| 8 | | PVC (85%), acrylic (15%) | Interlock. * |
| 9 | | Cotton inside, polyester outside | Interlock with 8x2 dropstitch. * Double fabric |
| 10 | C | Polypropylene (90%), nylon (10%) | 1 x 1 rib |
| 11 | C | Superwash wool inside, polyester and nylon outside (90:10%) | Interlock. Looped inside |
| 12 | | Polyester (100%) | 1 x 1 rib |
| 13 | | PVC (85%), acrylic (15%) | Eyelet |
| 14 | | Polyester (100%) | Interlock |
| 15 | | Angora (40%), lambswool (40%), nylon (20%) | 1 x 1 rib |
| 16 | | Superwash wool (100%) | 1 x 1 rib. * |
| 17 | | Superwash wool (100%) | 1 x 1 rib |
| 18 | C | Polypropylene inside, cotton outside | Interlock. * |
| 19 | C | Polypropylene inside, acrylic, wool (80:20%) outside | 1 x 1 rib |
| 20 | | Polyester (100%) | Plain weave |
| 21 | | Acrylic (Dunova) (60%), cotton (30%), nylon (10%) | 1 x 1 rib |
| 22 | | Viscose (100%) | Twill |

Note:
* The fabric has been sueded and has a hairy inside surface.
C The fabrics were made-up into garments commercially.
All the fabrics are knitted except fabrics 20 and 22 which are woven.

**Table 2 Routine test results on the main wearer trial fabrics**

| Fabric number → <br> Property ↓ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fabric construction | | | | | | | | | | | |
| Wales/cm | 11.0 | 17.0 | 8.3 | 16.5 | 24.7 | 23.7 | 10.5 | 26.0 | 27.3 | 17.3 | 4.3 |
| Courses/cm | 8.5 | 12.5 | 7.0 | 11.2 | 9.8 | 9.8 | 11.1 | 15.2 | 12.3 | 13.0 | 7.0 |
| Pattern repeat | | | | | | | | | | | |
| Wales/cm | | | 4.2 | 4.1 | | | | | | | |
| Courses/cm | | | 1.2 | 2.8 | | | | | | | |
| Weight (g/m²) | 170 | 318 | 138 | 126 | 197 | 246 | 188 | 358 | 234 | 165 | 266 |
| Thickness at 6.9 Pa (cm) | 0.21 | 0.23 | 0.25 | 0.12 | 0.18 | 0.26 | 0.13 | 0.30 | 0.21 | 0.17 | 0.44 |
| Fibre distribution (Shirlastains) | sep. yarns | uniform blending (uni.) | | | | | - | uni. | Double sided | uni. | Double sided |
| Bending length BS5636 | | | | | | | | | | | |
| Wales (cm) | 2.0 | 2.2 | 1.9 | 1.5 | 1.4 | 1.9 | 0.9 | 1.8 | 1.6 | 2.0 | 1.6 |
| Courses (cm) | 1.1 | 0.8 | 1.0 | 1.1 | 1.1 | 1.1 | 0.8 | 1.7 | 1.0 | 1.0 | 1.4 |
| Flexural rigidity BS5636 | | | | | | | | | | | |
| Wales (mg.cm) | 136 | 338 | 95 | 42 | 54 | 169 | 14 | 209 | 96 | 132 | 109 |
| Courses (mg.cm) | 23 | 16 | 14 | 17 | 26 | 33 | 10 | 176 | 23 | 17 | 73 |
| Angle of surface drag | | | | | | | | | | | |
| Face to glass (°) | 4 | 5.5 | - | 5.5 | 9.5 | 10.5 | 7 | 5 | 7.5 | 6.5 | 7.5 |
| Reverse to glass (°) | 4 | 5.5 | - | 5.5 | 8.5 | 10.5 | 7 | 6.5 | 7 | 7 | 6 |
| Pilling (BS5811) | | | | | | | | | | | |
| Wales (face/back) | 5 | 5 | 5 | 5 | 4-5 | 4-5 | 5 | 5/4-5 | 3-4/4 | 4 | 5/4 |
| Courses | 4 | 5 | - | 5 | 4-5 | 4-5 | 5 | 5/4-5 | 3-4/3-4 | 4 | 5/4 |
| Thermal resistance (togs) | 0.42 | 0.48 | 0.50 | 0.20 | 0.37 | 0.50 | 0.23 | 0.68 | 0.42 | 0.30 | 1.09 |
| Warmth:weight ratio BS4745 (tog cm²/g) | 25 | 15 | 35 | 16 | 19 | 20 | 12 | 19 | 18 | 18 | 41 |
| Air permeability (pressure drop across fabric of 498Pa) | | | | | | | | | | | |
| Relative air permeability | 20 | 19 | 44 | 27 | 18 | 16 | 20 | 9 | 11 | 19 | 22 |
| Water vapour resistance (cm) | 0.21 | 0.23 | 0.19 | 0.15 | 0.15 | 0.23 | 0.13 | 0.30 | 0.19 | 0.15 | 0.38 |
| wvr/unit thickness | 1.0 | 1.0 | 0.8 | 1.2 | 0.8 | 0.9 | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 |
| Water retention (%) (static immersion test) | 192 | 96 | - | 189 | 60 | 204 | 133 | 120 | 176 | 144 | 140 |

Note: sep. yarns = separate yarns of each fibre. DS = double sided fabric (one fibre on each side).

Table 2 contd. Routine test results on the main wearer trial fabrics

| Fabric number → / Property ↓ | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fabric construction | | | | | | | | | | | |
| Wales/cm | 8.8 | 17.5 | 15.0 | 14.5 | 26.2 | 25.8 | 23.2 | 9.7 | 40.2 | 10.4 | 33.7 |
| Courses/cm | 12.5 | 13.7 | 14.7 | 10.1 | 10.9 | 11.6 | 12.3 | 11.7 | 35.7 | 17.5 | 28.4 |
| Pattern repeat | | | | | | | | | | | |
| Wales/cm | | 4.5 | | | | | | | | | |
| Courses/cm | | 1.8 | | | | | | | | | |
| Weight (g/m²) | 236 | 294 | 121 | 243 | 259 | 298 | 208 | 171 | 63 | 139 | 133 |
| Thickness at 6.9 Pa (cm) | 0.14 | 0.26 | 0.07 | 0.33 | 0.24 | 0.26 | 0.22 | 0.17 | 0.02 | 0.12 | 0.10 |
| Fibre distribution (Shirlastains) | - | uni. | - | uni. | - | - | Double sided | Double sided | - | uni. | - |
| Bending length BS5636 | | | | | | | | | | | |
| Wales (cm) | 1.4 | 2.0 | 1.1 | 1.6 | 1.5 | 1.5 | 1.4 | 1.7 | 1.5 | 1.2 | 2.0 |
| Courses (cm) | 0.7 | 1.1 | 0.8 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.5 | 0.8 | 1.5 |
| Flexural rigidity BS5636 | | | | | | | | | | | |
| Wales (mg.cm) | 65 | 235 | 16 | 100 | 88 | 101 | 57 | 84 | 21 | 24 | 106 |
| Courses (mg.cm) | 8 | 39 | 6 | 42 | 45 | 40 | 28 | 23 | 21 | 7 | 45 |
| Angle of surface drag | | | | | | | | | | | |
| Face to glass (°) | 4.5 | 5.5 | 6.5 | 5 | 7 | 8.5 | 7 | 9 | 5.5 | 4.5 | 6.5 |
| Reverse to glass (°) | 4.5 | 5.5 | 6.5 | 5 | 7 | 8.5 | 7 | 9 | 5.5 | 4.5 | 6.5 |
| Pilling (BS5811) | | | | | | | | | | | |
| Wales (face/back) | 5 | 5 | 5/4-5 | 5 | 4-5/4-5 | 4-5 | 5/5 | 4-5/4-5 | 5 | - | 4-5 |
| Courses | 5 | 5 | 4-5/4-5 | 5 | 5/4-5 | 4-5 | 5/5 | 5/5 | 4-5 | - | 4-5 |
| Thermal resistance (togs) | 0.22 | 0.59 | 0.08 | 0.78 | 0.49 | 0.53 | 0.37 | 0.33 | 0.01 | 0.18 | 0.18 |
| Warmth:weight ratio BS4745 (tog cm²/g) | 9 | 9 | 6 | 32 | 19 | 18 | 18 | 19 | 0.5 | 13 | 13 |
| Air permeability (pressure drop across fabric of 498Pa) | | | | | | | | | | | |
| Relative air permeability | 18 | 21 | 19 | 15 | 17 | 17 | 14 | 21 | 2 | 13 | 5 |
| Water vapour | | | | | | | | | | | |
| resistance (cm) | 0.19 | 0.19 | 0.11 | 0.11 | 0.18 | 0.20 | 0.20 | 0.12 | 0.03 | 0.08 | 0.07 |
| wvr/unit thickness | 1.4 | 0.7 | 1.5 | 0.3 | 0.7 | 0.8 | 0.9 | 0.7 | 1.5 | 0.7 | 0.7 |
| Water retention (%) (static immersion test) | 94 | 95 | 145 | 88 | - | - | - | 114 | 120 | 167 | 143 |

Note:
Fabrics 20 and 22 are woven fabrics, therefore the wales and courses refer to warp and weft respectively.

## Appendix 1

**Table 3** The number of subjects in the main wearer trial

| Fabric number | Males | Females | Males + Females | Age group 20's M | 20's F | 30's M | 30's F | 40's M | 40's F | 50's M | 50's F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| 2 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| 3 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| 4 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| 5 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| 6 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| 7 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| 8 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| 9 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| .10 | 6 | 7 | 13 | 2 | 1 | 0 | 1 | 1 | 4 | 3 | 1 |
| 11 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| 12 | 10 | 10 | 20 | 2 | 4 | 1 | 1 | 1 | 4 | 6 | 1 |
| 13 | 8 | 10 | 18 | 1 | 4 | 0 | 1 | 1 | 4 | 6 | 1 |
| 14 | 9 | 9 | 18 | 1 | 3 | 1 | 1 | 1 | 4 | 6 | 1 |
| 15 | 8 | 10 | 18 | 2 | 3 | 1 | 1 | 1 | 4 | 4 | 2 |
| 16 | 3 | 4 | 7 | 1 | 1 | 0 | 0 | 0 | 2 | 2 | 1 |
| 17 | 3 | 4 | 7 | 1 | 1 | 0 | 0 | 0 | 2 | 2 | 1 |
| 18 | 4 | 2 | 6 | 0 | 1 | 0 | 0 | 1 | 1 | 3 | 0 |
| 19 | 8 | 10 | 18 | 2 | 3 | 1 | 1 | 1 | 4 | 4 | 2 |
| 20 | 5 | 10 | 15 | 1 | 3 | 0 | 1 | 1 | 4 | 3 | 2 |
| 21 | 5 | 6 | 11 | 1 | 1 | 0 | 1 | 1 | 4 | 3 | 0 |
| 22 | 5 | 8 | 13 | 0 | 3 | 0 | 1 | 1 | 3 | 4 | 1 |

**Table 4** Questionnaire 1, question 1: The number of people who liked, disliked and were impartial to the fabric and the number of people who said that they would probably buy a garment made from the fabric.

| | Do you like the fabric? | | | | | | | | | Would you buy it? | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Like | | | Impartial | | | Dislike | | | Yes | | | Impartial | | | No | | |
| Fabric number | M | F | B | M | F | B | M | F | B | M | F | B | M | F | B | M | F | B |
| 1 | 2 | 4 | 6 | 5 | 3 | 8 | 3 | 3 | 6 | 5 | 1 | 6 | 2 | 2 | 4 | 3 | 7 | 10 |
| 2 | 4 | 0 | 4 | 2 | 0 | 2 | 4 | 10 | 14 | 3 | 0 | 3 | 1 | 1 | 2 | 6 | 9 | 15 |
| 3 | 6 | 2 | 8 | 2 | 0 | 2 | 2 | 8 | 10 | 5 | 3 | 8 | 0 | 0 | 0 | 5 | 7 | 12 |
| 4 | 7 | 7 | 14 | 2 | 3 | 5 | 1 | 0 | 1 | 5 | 10 | 15 | 1 | 0 | 1 | 2 | 0 | 2 |
| 5 | 5 | 1 | 6 | 2 | 5 | 7 | 3 | 4 | 7 | 4 | 2 | 6 | 0 | 1 | 1 | 6 | 7 | 13 |
| 6 | 7 | 7 | 14 | 2 | 3 | 5 | 1 | 0 | 1 | 4 | 6 | 10 | 1 | 1 | 2 | 5 | 3 | 8 |
| 7 | 5 | 4 | 9 | 3 | 2 | 5 | 2 | 4 | 6 | 5 | 4 | 9 | 2 | 2 | 4 | 3 | 4 | 7 |
| 8 | 6 | 1 | 7 | 2 | 3 | 5 | 2 | 6 | 8 | 6 | 1 | 7 | 1 | 0 | 1 | 3 | 9 | 12 |
| 9 | 8 | 4 | 12 | 0 | 2 | 2 | 2 | 4 | 6 | 6 | 4 | 10 | 1 | 0 | 1 | 3 | 6 | 9 |
| 10 | 2 | 2 | 4 | 0 | 2 | 2 | 4 | 3 | 7 | 3 | 4 | 7 | 0 | 1 | 1 | 3 | 2 | 5 |
| 11 | 3 | 2 | 5 | 2 | 2 | 4 | 5 | 6 | 11 | 3 | 2 | 5 | 1 | 1 | 2 | 6 | 7 | 13 |
| 12 | 7 | 3 | 10 | 1 | 2 | 3 | 2 | 5 | 7 | 6 | 2 | 8 | 1 | 1 | 2 | 3 | 7 | 10 |
| 13 | 3 | 4 | 7 | 2 | 2 | 4 | 3 | 4 | 7 | 4 | 3 | 7 | 0 | 2 | 2 | 4 | 5 | 9 |
| 14 | 3 | 2 | 5 | 0 | 0 | 0 | 6 | 7 | 13 | 3 | 2 | 5 | 0 | 0 | 0 | 6 | 7 | 13 |
| 15 | 3 | 5 | 8 | 0 | 0 | 0 | 5 | 5 | 10 | 7 | 1 | 8 | 0 | 0 | 0 | 1 | 9 | 10 |
| 16 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 0 | 2 | 2 | 0 | 0 | 0 | 3 | 2 | 5 |
| 17 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 0 | 1 | 1 | 0 | 1 | 1 | 3 | 2 | 5 |
| 18 | 4 | 2 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 6 | 7 | 13 | 0 | 0 | 0 | 2 | 3 | 5 | 4 | 6 | 10 | 2 | 1 | 3 | 2 | 3 | 5 |
| 20 | 2 | 7 | 9 | 0 | 2 | 2 | 3 | 1 | 4 | 1 | 6 | 7 | 0 | 0 | 0 | 4 | 4 | 8 |
| 21 | 4 | 6 | 10 | 0 | 0 | 0 | 1 | 0 | 1 | 4 | 6 | 10 | 0 | 0 | 0 | 1 | 0 | 1 |
| 22 | 2 | 1 | 3 | 2 | 1 | 3 | 1 | 5 | 6 | 3 | 2 | 5 | 0 | 0 | 0 | 2 | 5 | 7 |

Table 5 Questionnaire 1, question 2: **What do you think the fabric is made of?**

(Number of people)

| Fabric number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fibre content guessed before wearing the garment↓ | | | | | | | | | | | | | | | | | | | | | | |
| Cotton (C) | 2 | 2 | 0 | 14 | 0 | 3 | 1 | 2 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 3 |
| Wool (W) | 0 | 0 | 0 | 0 | 1 | 0 | 8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 7 | 4 | 4 | 0 | 0 | 0 | 0 | 0 |
| * Man-made (mm) | 3 | 15 | 13 | 2 | 9 | 8 | 3 | 14 | 12 | 8 | 12 | 14 | 11 | 18 | 2 | 1 | 0 | 2 | 13 | 14 | 6 | 2 |
| C/mm | 14 | 2 | 7 | 4 | 8 | 8 | 4 | 4 | 5 | 4 | 3 | 6 | 5 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 4 | 7 |
| W/mm | 1 | 1 | 0 | 0 | 2 | 1 | 4 | 0 | 1 | 0 | 4 | 0 | 1 | 0 | 9 | 2 | 3 | 0 | 2 | 1 | 0 | 0 |

* In the occurence of the man-made fibre being specified ↓

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acrylic | 0 | 4 | 0 | 0 | 4 | 2 | 1 | 4 | 2 | 0 | 3 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 5 | 0 | 1 | 0 |
| PP | 1 | 0 | 9 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 5 | 0 | 1 | 0 |
| Polyester (PE) | 0 | 3 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 3 | 2 | 2 | 4 | 7 | 0 | 0 | 0 | 0 | 0 | 10 | 2 | 0 |
| PE/viscose | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Viscose | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| Nylon | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 2 | 2 | 1 | 2 | 3 | 2 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| PVC | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Acetate | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |

Appendix 1

Table 6 Questionnaire 1, question 2: The number of subjects who correctly guessed the fibre content of the fabrics by handle observations.

| Fabric number | Correct fibre content | | Partly correct fibre content | | Correct + partly correct fibre content | |
|---|---|---|---|---|---|---|
| 1 | 13 | | 3 | | 16 | |
| 2 | 0 | | 7 | | 7 | |
| 3 | 9 | | 1 | | 10 | |
| 4 | 19 | | 0 | | 19 | |
| 5 | 5 | | 5 | | 10 | |
| 6 | 2 | | 4 | | 6 | |
| 7 | 8 | | 2 | | 10 | |
| 8 | 3 | | 5 | | 8 | |
| 9 | 5 | | 0 | | 5 | |
| 10 | 2 (1) | | 0 | | 2 (1) | |
| 11 | 4 | | 7 | | 11 | |
| 12 | 2 | | 3 | | 5 | |
| 13 | 2 | | 0 | | 2 | |
| 14 | 8 (7) | | 1 | | 9 (8) | |
| 15 | 8 (7) | | 10 (9) | | 18 (16) | |
| 16 | 11 (4) | | 6 (2) | | 17 (6) | |
| 17 | 11 (4) | | 9 (3) | | 20 (7) | |
| 18 | 3 (1) | | 3 (1) | | 7 (2) | |
| 19 | 5 | | 3 | | 9 (8) | |
| 20 | 13 (10) | | 1 | | 15 (11) | |
| 21 | 7 (4) | | 2 (1) | | 9 (4) | |
| 22 | 3 (2) | | 0 | | 3 (2) | |
| | Mean | SD | Mean | SD | Mean | SD |
| | 6.5 | 4.6 | 3.3 | 2.9 | 9.9 | 5.3 |

Note:
The figures in parentheses are the actual number of answers given to the question when less than 20 people answered the question. The adjacent value has been corrected to be equivalent to 20 people answering the question.

Table 7 The relationship of the assumed fibre content of the fabric and the opinion of the subject as to whether they like the fabric or not.

| | Numbers of people | | Percentage | |
|---|---|---|---|---|
| Assumed Fibre Content | Like fabric | Do not like fabric | Like fabric | Do not like fabric |
| Cotton | 28 | 8 | 78 | 22 |
| Cotton/man-made | 62 | 23 | 73 | 27 |
| Polyester | 23 | 16 | 59 | 41 |
| Nylon | 7 | 19 | 27 | 73 |
| Wool/man-made | 25 | 13 | 66 | 34 |
| Wool | 9 | 16 | 36 | 64 |
| Polypropylene | 16 | 6 | 73 | 27 |
| Man-made | 19 | 9 | 68 | 32 |
| P.V.C. | 11 | 5 | 69 | 31 |
| Acrylic | 15 | 14 | 52 | 48 |
| Viscose | 6 | 3 | 67 | 33 |
| Polyester/viscose | 1 | 5 | 17 | 83 |
| Acetate | 3 | 1 | 75 | 25 |

Appendix 1

**Table 8** Question 5 (i): The number of people who changed their minds about the fibre content of the fabric after the garment had been worn.

| Fabric number → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of → changes | 2 | 3 | 1 | 1 | 4 | 0 | 1 | 0 | 2 | 2 | 2 | 1 | 1 | 0 | 2 | 3 | 0 | 0 | 2 | 0 | 3 | 1 |

The changes in fibre content were:

Fabric 1 Viscose → blend, polypropylene → blend
Fabric 2 2 x PVC → wool/man-made, Cotton/man-made → man-made
Fabric 3 Polypropylene → blend
Fabric 4 Cotton → Cotton/man-made
Fabric 5 Cotton/man-made → man-made, wool/man-made → cotton, wool/man-made → man-made, nylon → wool/man-made
Fabric 7 Acrylic → wool/man-made
Fabric 9 Acylic → blend, polypropylene → blend
Fabric 10 Polyester → blend, cotton → blend
Fabric 11 Cotton/man-made → man-made, Acrylic → wool/man-made
Fabric 12 Cotton/man-made → man-made
Fabric 13 Cotton/man-made → man-made
Fabric 15 Wool → man-made, acrylic → wool
Fabric 16 Wool → wool/man-made, wool/man-made → man-made, acrylic → wool/man-made
Fabric 19 Cotton → blend, acrylic → Cotton/man-made
Fabric 21 Cotton/man-made → man-made, acrylic → blend, nylon → blend
Fabric 22 Cotton → blend

**Table 9** Questionnaire 1, question 3: The prediction of the in-wear comfort of a fabric by the assessment of aesthetics and handle.

(The table shows the number of people who thought that the fabric would be comfortable.)

| Fabric number | STRENUOUS ACTIVITY | | | NORMAL ACTIVITY | | |
|---|---|---|---|---|---|---|
| | Males | Females | Males + Females | Males | Females | Males + Females |
| 1 | 2 | 5 | 7 | 10 | 8 | 18 |
| 2 | 1 | 0 | 1 | 8 | 9 | 17 |
| 3 | 8 | 9 | 17 | 10 | 9 | 19 |
| 4 | 10 | 10 | 20 | 10 | 10 | 20 |
| 5 | 5 | 4 | 9 | 9 | 9 | 18 |
| 6 | 7 | 8 | 15 | 10 | 10 | 20 |
| 7 | 5 | 6 | 11 | 9 | 10 | 19 |
| 8 | 3 | 1 | 4 | 7 | 9 | 16 |
| 9 | 7 | 5 | 12 | 9 | 10 | 19 |
| 10 | 4 | 4 | 12 (8) | 5 | 7 | 19 (12) |
| 11 | 5 | 4 | 9 | 8 | 9 | 17 |
| 12 | 8 | 6 | 14 | 10 | 10 | 20 |
| 13 | 5 | 8 | 14 (13) | 6 | 9 | 17 (15) |
| 14 | 6 | 1 | 8 (7) | 7 | 8 | 17 (15) |
| 15 | 2 | 1 | 3 | 3 | 4 | 8 (7) |
| 16 | 2 | 1 | 9 (3) | 2 | 2 | 11 (4) |
| 17 | 2 | 1 | 9 (3) | 2 | 1 | 9 (3) |
| 18 | 4 | 2 | 20 (6) | 4 | 2 | 20 (6) |
| 19 | 3 | 3 | 7 (6) | 7 | 8 | 17 (15) |
| 20 | 3 | 6 | 12 (9) | 4 | 10 | 19 (14) |
| 21 | 4 | 5 | 16 (9) | 5 | 6 | 20 (11) |
| 22 | 3 | 4 | 13 (7) | 5 | 6 | 20 (12) |

**Note:**
The figures in parentheses are the actual number of answers given to the question when less than 20 people answered the question. The adjacent value has been corrected to be equivalent to 20 people answering the question.

Table 10 Questionnaire 1, question 5(ii): The changes in the prediction of the in-wear comfort of a fabric after wearing the fabric for approximately 5 minutes. (The number of people who changed their minds)

| Fabric number | STRENUOUS ACTIVITY | | NORMAL ACTIVITY | |
|---|---|---|---|---|
| | Comf→Uncomf | Uncomf→Comf | Comf→Uncomf | Uncomf→Comf |
| 1 | 0 | 1 | 3 | 0 |
| 2 | 1 | 1 | 2 | 1 |
| 3 | 1 | 1 | 1 | 1 |
| 4 | 0 | 0 | 0 | 0 |
| 5 | 4 | 0 | 5 | 0 |
| 6 | 0 | 1 | 0 | 0 |
| 7 | 3 | 0 | 4 | 0 |
| 8 | 0 | 1 | 1 | 2 |
| 9 | 0 | 3 | 0 | 1 |
| 10 | 0 | 3 (2) | 0 | 0 |
| 11 | 1 | 2 | 0 | 2 |
| 12 | 0 | 1 | 0 | 0 |
| 13 | 2 | 0 | 1 | 0 |
| 14 | 0 | 1 | 0 | 0 |
| 15 | 0 | 0 | 1 | 5 (4) |
| 16 | 3 (1) | 0 | 0 | 3 (1) |
| 17 | 3 (1) | 0 | 0 | 6 (2) |
| 18 | 3 (1) | 3 (1) | 0 | 0 |
| 19 | 1 | 0 | 0 | 1 |
| 20 | 3 (2) | 3 (2) | 0 | 0 |
| 21 | 0 | 2 (1) | 0 | 0 |
| 22 | 2 (1) | 0 | 2 (1) | 0 |

Note:
The figures in parentheses are the actual number of answers given to the question when less than 20 people answered the question. The adjacent value has been corrected to be equivalent to 20 people answering the question.-

Appendix 1

Table 11 Questionnaire 1, question 4.1, 4.2, 4.3 and 5(iii): The difference in the handle properties of the fabric in relation to comfort after 5 minutes of wear and after wearing the garment for a number of hours.
(The numbers in the table are centimeters (as a proportion of a 10cm line).

| | Rough → slippery | | Hot → cold | | Stiff → limp | |
|---|---|---|---|---|---|---|
| Fabric number | Diff 1 Mean SD | Diff 2 Mean SD | Diff 1 Mean SD | Diff 2 Mean SD | Diff 1 Mean SD | Diff 2 Mean SD |
| 1 | -0.8 (1.8) | -1.3 (1.8) | -0.5 (2.5) | -2.8 (0.9) | -0.2 (1.3) | 1.7 (2.2) |
| 2 | -0.8 (1.5) | -2.0 (1.3) | -0.5 (2.2) | 0.3 (1.4) | -0.1 (1.2) | -0.1 (0.3) |
| 3 | -0.4 (1.1) | -1.8 (1.1) | -0.1 (1.9) | -1.5 (1.1) | 0.3 (1.0) | -2.6 (0.0) |
| 4 | -0.3 (1.0) | -1.1 (1.5) | 0.3 (1.6) | -0.1 (0.0) | -0.4 (1.5) | -1.5 (1.7) |
| 5 | -0.6 (1.2) | -3.6 (0.1) | 0.1 (0.9) | -2.9 (0.0) | 0.0 (0.9) | -2.8 (0.0) |
| 6 | 0.1 (1.1) | | 0.0 (1.3) | 0.1 (0.0) | -0.2 (1.0) | |
| 7 | 0.2 (1.3) | -2.4 (2.3) | 0.1 (1.4) | 0.1 (0.0) | 0.7 (1.1) | 0.7 (0.5) |
| 8 | 0.5 (1.3) | -1.4 (2.8) | -0.3 (2.0) | -0.9 (1.8) | -0.1 (1.2) | 1.0 (0.0) |
| 9 | 0.7 (0.9) | -2.3 (0.0) | -0.3 (1.7) | | 0.4 (0.8) | |
| 10 | -0.4 (0.7) | -1.7 (0.0) | 0.1 (0.3) | | -1.9 (0.5) | |
| 11 | -1.0 (1.4) | -1.2 (2.0) | -0.5 (1.8) | 1.3 (0.9) | -0.1 (0.8) | -2.1 (0.0) |
| 12 | 1.4 (0.8) | 0.3 (0.3) | 0.4 (0.6) | -0.6 (0.7) | 0.5 (0.8) | |
| 13 | -0.7 (1.0) | -1.1 (1.1) | 0.1 (0.8) | -3.1 (0.0) | -0.1 (0.6) | 0.1 (0.0) |
| 14 | 0.3 (1.0) | -1.1 (1.4) | -0.8 (1.7) | -1.6 (0.0) | 0.0 (0.7) | |
| 15 | 1.4 (2.0) | -3.7 (0.0) | -0.7 (1.9) | | 0.6 (0.7) | |
| 16 | -1.6 (0.8) | -1.3 (1.4) | -1.7 (1.4) | | 0.0 (0.5) | |
| 17 | -1.1 (1.1) | -1.8 (1.7) | -1.7 (2.0) | -2.0 (1.3) | -0.2 (0.4) | 1.0 (0.0) |
| 18 | -0.2 (0.6) | | -0.2 (0.5) | | 0.1 (0.2) | |
| 19 | -0.4 (2.0) | -1.1 (1.1) | 0.3 (1.4) | -1.0 (2.3) | 0.1 (0.9) | |
| 20 | 0.5 (0.9) | | 0.3 (0.8) | | 0.3 (0.7) | |
| 21 | -0.7 (1.1) | -0.4 (0.9) | 0.2 (0.7) | 0.1 (0.0) | -0.1 (0.7) | |
| 22 | -0.6 (1.8) | -2.2 (0.0) | 0.4 (1.4) | | -0.8 (1.4) | |

NB.
Diff 1 = The assessment of the handle properties of the fabric minus the comfort assessment (indicated on the same line). A positive value means that the fabric is considered to be more slippery, cold or limp than comfort.

Diff 2 = The assessment of the in-wear properties of the fabric after 5 minutes minus the comfort assessment (indicated on the same line). A positive value means that the fabric is considered to be more slippery, cold or limp than comfort. If the number is missing from the cell it means that the subjects did not change their rating for the property between handle and wearing the fabric.

Numbers in parentheses are the standard deviation. The mean is taken from all the subjects.

Table 12 Questionnaire 2, question 3 : The comfort of the garment in terms of its fit before and after washing the garment. (Number of answers)

| | Comfort | | | Fit | | |
|---|---|---|---|---|---|---|
| Fabric number | Very good | Average | Uncomfortable | Baggy | Average | Tight |
| 1 | 3 | 23 | 14 | 1 | 16 | 23 |
| 2 | 1 | 36 | 3 | 20 | 19 | 1 |
| 3 | 12 | 21 | 7 | 0 | 19 | 21 |
| 4 | 6 | 33 | 1 | 5 | 33 | 2 |
| 5 | 7 | 33 | 0 | 5 | 33 | 2 |
| 6 | 14 | 26 | 0 | 5 | 33 | 2 |
| 7 | 2 | 36 | 2 | 9 | 26 | 5 |
| 8 | 8 | 25 | 7 | 10 | 23 | 7 |
| 9 | 3 | 34 | 3 | 11 | 28 | 1 |
| 10 | 7 | 13 | 6 | 0 | 8 | 18 |
| 11 | 3 | 32 | 5 | 7 | 26 | 7 |
| 12 | 4 | 35 | 1 | 9 | 29 | 2 |
| 13 | 3 | 33 | 0 | 10 | 24 | 2 |
| 14 | 7 | 24 | 5 | 4 | 25 | 7 |
| 15 | 10 | 23 | 3 | 3 | 22 | 11 |
| 16 | 4 | 8 | 2 | 6 | 8 | 0 |
| 17 | 2 | 10 | 2 | 4 | 9 | 1 |
| 18 | 3 | 9 | 0 | 4 | 6 | 2 |
| 19 | 8 | 24 | 4 | 4 | 17 | 15 |
| 20 | 0 | 24 | 6 | 22 | 8 | 0 |
| 21 | 8 | 14 | 0 | 4 | 15 | 3 |
| 22 | 1 | 21 | 4 | 16 | 7 | 3 |

Appendix I

TABLE 13

Questionnaire 2, question 10: How does the fabric feel against the skin during different activity levels (Number of people)

ROUGH TO SLIPPERY

| | STRENUOUS ACTIVITY | | | | | | NORMAL ACTIVITY | | | | | | SITTING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SENSATION | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| FABRIC NUMBER | | | | | | | | | | | | | | | | | | |
| 1 | 0 | 3 | 1 | 12 | 4 | 0 | 0 | 3 | 1 | 29 | 7 | 0 | 0 | 4 | 0 | 19 | 5 | 0 |
| 2 | 0 | 1 | 0 | 15 | 4 | 0 | 0 | 3 | 1 | 25 | 11 | 0 | 0 | 2 | 0 | 18 | 8 | 0 |
| 3 | 0 | 0 | 1 | 4 | 8 | 0 | 0 | 2 | 2 | 21 | 15 | 0 | 0 | 0 | 1 | 19 | 11 | 0 |
| 4 | 0 | 0 | 3 | 9 | 7 | 0 | 0 | 0 | 3 | 18 | 19 | 0 | 0 | 0 | 1 | 15 | 14 | 0 |
| 5 | 1 | 1 | 1 | 5 | 1 | 0 | 3 | 1 | 6 | 19 | 10 | 1 | 2 | 1 | 1 | 13 | 9 | 1 |
| 6 | 0 | 0 | 0 | 1 | 11 | 1 | 0 | 0 | 0 | 13 | 26 | 1 | 0 | 0 | 0 | 10 | 20 | 1 |
| 7 | 0 | 1 | 1 | 10 | 1 | 0 | 3 | 4 | 2 | 22 | 9 | 0 | 2 | 2 | 1 | 15 | 8 | 0 |
| 8 | 0 | 0 | 0 | 1 | 12 | 0 | 0 | 0 | 1 | 1 | 37 | 1 | 0 | 0 | 0 | 1 | 20 | 0 |
| 9 | 0 | 0 | 0 | 2 | 15 | 1 | 0 | 0 | 0 | 3 | 35 | 2 | 0 | 0 | 0 | 0 | 24 | 0 |
| 10 | 0 | 0 | 0 | 3 | 7 | 0 | 0 | 0 | 1 | 10 | 15 | 0 | 0 | 0 | 1 | 6 | 11 | 0 |
| 11 | 0 | 0 | 0 | 3 | 7 | 2 | 0 | 0 | 1 | 14 | 5 | 0 | 0 | 0 | 0 | 15 | 8 | 0 |
| 12 | 0 | 0 | 0 | 0 | 9 | 2 | 0 | 0 | 0 | 2 | 15 | 3 | 0 | 0 | 0 | 2 | 18 | 4 |
| 13 | 0 | 0 | 1 | 4 | 4 | 2 | 0 | 2 | 3 | 6 | 7 | 1 | 0 | 3 | 3 | 6 | 10 | 2 |
| 14 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 3 | 6 | 7 | 2 | 0 | 1 | 1 | 10 | 15 | 2 |
| 15 | 0 | 0 | 1 | 5 | 4 | 0 | 0 | 0 | 3 | 12 | 20 | 1 | 0 | 0 | 0 | 8 | 9 | 1 |
| 16 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 8 | 4 | 0 | 0 | 0 | 0 | 6 | 4 | 0 |
| 17 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 7 | 5 | 0 | 0 | 0 | 0 | 5 | 5 | 0 |
| 18 | 0 | 0 | 0 | 1 | 6 | 0 | 0 | 0 | 0 | 3 | 9 | 0 | 0 | 0 | 0 | 1 | 7 | 0 |
| 19 | 0 | 0 | 2 | 9 | 8 | 0 | 0 | 0 | 4 | 15 | 16 | 0 | 0 | 0 | 0 | 9 | 12 | 0 |
| 20 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 16 | 11 | 1 | 0 | 0 | 0 | 1 | 18 | 3 |
| 21 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 7 | 15 | 0 | 0 | 0 | 0 | 3 | 8 | 0 |
| 22 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 9 | 16 | 0 | 0 | 0 | 1 | 3 | 11 | 0 |

WHERE THE SENSATION CODES ARE:
1 = VERY ROUGH, 2 = ROUGH, 3 = COARSE, 4 = SLIGHTLY COARSE, 5 = SMOOTH, 6 = SLIPPERY

TABLE 14

Questionnaire 2, question 10: How does the fabric feel against the skin during different activity levels

STIFF TO LIMP

| | STRENUOUS ACTIVITY | | | | | | NORMAL ACTIVITY | | | | | | SITTING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SENSATION | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| FABRIC NUMBER | | | | | | | | | | | | | | | | | | |
| 1 | 0 | 1 | 8 | 9 | 2 | 0 | 0 | 2 | 12 | 21 | 5 | 0 | 0 | 2 | 9 | 14 | 3 | 0 |
| 2 | 0 | 0 | 4 | 12 | 4 | 0 | 0 | 0 | 9 | 22 | 9 | 0 | 0 | 0 | 5 | 18 | 6 | 0 |
| 3 | 0 | 0 | 3 | 5 | 5 | 0 | 0 | 2 | 10 | 20 | 8 | 0 | 0 | 2 | 7 | 16 | 7 | 0 |
| 4 | 0 | 1 | 4 | 7 | 4 | 2 | 0 | 1 | 9 | 11 | 16 | 0 | 0 | 1 | 5 | 10 | 11 | 0 |
| 5 | 0 | 1 | 1 | 6 | 1 | 0 | 0 | 1 | 11 | 22 | 6 | 0 | 0 | 1 | 5 | 16 | 6 | 0 |
| 6 | 0 | 0 | 1 | 11 | 2 | 0 | 0 | 1 | 11 | 23 | 5 | 0 | 0 | 1 | 8 | 15 | 4 | 0 |
| 7 | 0 | 0 | 3 | 7 | 4 | 0 | 0 | 0 | 5 | 23 | 12 | 0 | 0 | 0 | 2 | 16 | 10 | 0 |
| 8 | 0 | 3 | 1 | 8 | 2 | 0 | 0 | 6 | 7 | 18 | 8 | 0 | 0 | 3 | 2 | 12 | 3 | 0 |
| 9 | 0 | 0 | 1 | 10 | 7 | 0 | 0 | 0 | 3 | 21 | 15 | 1 | 0 | 0 | 1 | 12 | 11 | 0 |
| 10 | 0 | 0 | 2 | 5 | 2 | 0 | 0 | 0 | 5 | 15 | 5 | 1 | 0 | 0 | 2 | 8 | 5 | 0 |
| 11 | 0 | 0 | 1 | 10 | 1 | 0 | 0 | 1 | 9 | 28 | 2 | 0 | 0 | 0 | 5 | 16 | 2 | 0 |
| 12 | 0 | 0 | 0 | 9 | 2 | 0 | 0 | 0 | 2 | 25 | 13 | 0 | 0 | 0 | 1 | 17 | 7 | 0 |
| 13 | 0 | 1 | 1 | 8 | 1 | 0 | 0 | 3 | 11 | 15 | 7 | 0 | 0 | 1 | 5 | 7 | 6 | 0 |
| 14 | 0 | 0 | 1 | 5 | 6 | 0 | 0 | 1 | 9 | 11 | 14 | 1 | 0 | 0 | 6 | 10 | 13 | 0 |
| 15 | 0 | 0 | 0 | 2 | 7 | 1 | 0 | 0 | 2 | 14 | 19 | 1 | 0 | 0 | 1 | 8 | 8 | 0 |
| 16 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 4 | 8 | 2 | 0 | 0 | 0 | 1 | 7 | 2 | 0 |
| 17 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 9 | 2 | 0 | 0 | 0 | 0 | 8 | 2 | 0 |
| 18 | 0 | 0 | 2 | 4 | 1 | 0 | 0 | 0 | 3 | 5 | 4 | 0 | 0 | 0 | 1 | 4 | 3 | 0 |
| 19 | 0 | 0 | 3 | 8 | 9 | 0 | 0 | 2 | 4 | 17 | 13 | 0 | 0 | 0 | 2 | 8 | 9 | 0 |
| 20 | 0 | 0 | 1 | 1 | 3 | 1 | 0 | 1 | 5 | 6 | 15 | 1 | 0 | 0 | 2 | 7 | 12 | 0 |
| 21 | 0 | 0 | 2 | 6 | 3 | 0 | 0 | 0 | 2 | 17 | 3 | 0 | 0 | 0 | 2 | 7 | 4 | 0 |
| 22 | 0 | 0 | 1 | 7 | 0 | 0 | 0 | 0 | 13 | 13 | 0 | 0 | 0 | 0 | 5 | 10 | 0 | 0 |

WHERE THE SENSATION CODES ARE:
1 = VERY STIFF, 2 = MODERATELY STIFF, 3 = SLIGHTLY STIFF, 4 = SLIGHTLY LIMP, 5 = LIMP, 6 = VERY LIMP

TABLE 15

Questionnaire 2, question 10: How does the fabric feel against the skin during different activity levels

WET TO DRY

| | STRENUOUS ACTIVITY | | | | | NORMAL ACTIVITY | | | | | SITTING | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SENSATION | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| FABRIC NUMBER | | | | | | | | | | | | | | | |
| 1 | 0 | 1 | 11 | 4 | 2 | 0 | 1 | 5 | 8 | 24 | 0 | 0 | 0 | 2 | 25 |
| 2 | 0 | 0 | 6 | 6 | 9 | 0 | 0 | 2 | 2 | 34 | 0 | 0 | 0 | 3 | 27 |
| 3 | 0 | 0 | 2 | 2 | 9 | 0 | 0 | 0 | 0 | 37 | 0 | 0 | 0 | 0 | 31 |
| 4 | 0 | 1 | 5 | 0 | 12 | 0 | 0 | 1 | 0 | 38 | 0 | 0 | 1 | 0 | 29 |
| 5 | 0 | 0 | 3 | 2 | 3 | 0 | 0 | 1 | 0 | 36 | 0 | 0 | 0 | 0 | 28 |
| 6 | 0 | 1 | 3 | 2 | 7 | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 1 | 0 | 27 |
| 7 | 0 | 1 | 3 | 2 | 8 | 0 | 0 | 0 | 1 | 37 | 0 | 0 | 0 | 0 | 28 |
| 8 | 1 | 2 | 1 | 4 | 1 | 0 | 0 | 1 | 3 | 35 | 0 | 0 | 0 | 1 | 20 |
| 9 | 0 | 1 | 4 | 4 | 9 | 0 | 0 | 0 | 2 | 35 | 0 | 0 | 0 | 0 | 24 |
| 10 | 0 | 0 | 5 | 3 | 1 | 0 | 0 | 0 | 2 | 24 | 0 | 0 | 0 | 0 | 18 |
| 11 | 0 | 1 | 3 | 0 | 8 | 0 | 0 | 1 | 1 | 38 | 0 | 0 | 0 | 0 | 23 |
| 12 | 0 | 0 | 3 | 2 | 6 | 0 | 0 | 0 | 2 | 37 | 0 | 0 | 0 | 1 | 30 |
| 13 | 0 | 1 | 3 | 2 | 5 | 0 | 0 | 0 | 1 | 31 | 0 | 0 | 0 | 0 | 24 |
| 14 | 0 | 1 | 5 | 4 | 2 | 0 | 0 | 1 | 4 | 31 | 0 | 0 | 0 | 2 | 27 |
| 15 | 1 | 2 | 1 | 5 | 1 | 0 | 0 | 2 | 8 | 25 | 0 | 0 | 0 | 3 | 14 |
| 16 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 3 | 0 | 11 | 0 | 0 | 0 | 2 | 10 |
| 17 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 12 | 0 | 0 | 0 | 0 | 10 |
| 18 | 0 | 0 | 6 | 0 | 1 | 0 | 0 | 1 | 1 | 10 | 0 | 0 | 0 | 1 | 8 |
| 19 | 2 | 0 | 6 | 3 | 9 | 0 | 0 | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 20 |
| 20 | 1 | 2 | 0 | 0 | 3 | 0 | 1 | 2 | 2 | 25 | 0 | 0 | 1 | 0 | 21 |
| 21 | 0 | 0 | 3 | 2 | 6 | 0 | 0 | 0 | 1 | 21 | 0 | 0 | 0 | 0 | 11 |
| 22 | 0 | 0 | 2 | 1 | 5 | 0 | 0 | 0 | 2 | 24 | 0 | 0 | 0 | 0 | 15 |

WHERE THE SENSATION CODES ARE:
1 = VERY WET, 2 = WET, 3 = DAMP, 4 = STICKY, 5 = DRY

TABLE 16

Questionnaire 2, question 10: How does the fabric feel against the skin during different activity levels

COLD TO HOT

| | STRENUOUS ACTIVITY | | | | | | | NORMAL ACTIVITY | | | | | | | SITTING | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SENSATION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| FABRIC NUMBER | | | | | | | | | | | | | | | | | | | | | |
| 1 | 0 | 0 | 0 | 7 | 14 | 15 | 3 | 0 | 0 | 0 | 15 | 19 | 4 | 0 | 0 | 0 | 3 | 20 | 13 | 0 | 0 |
| 2 | 0 | 0 | 0 | 16 | 15 | 8 | 1 | 0 | 0 | 1 | 26 | 10 | 3 | 0 | 0 | 0 | 3 | 27 | 8 | 2 | 0 |
| 3 | 0 | 0 | 2 | 15 | 23 | 1 | 0 | 0 | 0 | 4 | 21 | 16 | 0 | 0 | 0 | 4 | 2 | 22 | 13 | 0 | 0 |
| 4 | 0 | 0 | 3 | 19 | 13 | 2 | 1 | 0 | 0 | 4 | 31 | 1 | 2 | 0 | 0 | 0 | 6 | 30 | 2 | 0 | 0 |
| 5 | 0 | 0 | 1 | 23 | 10 | 6 | 0 | 0 | 0 | 0 | 25 | 14 | 0 | 0 | 0 | 0 | 0 | 29 | 10 | 0 | 0 |
| 6 | 0 | 0 | 0 | 18 | 15 | 4 | 0 | 0 | 0 | 0 | 27 | 10 | 0 | 0 | 0 | 0 | 2 | 29 | 6 | 0 | 0 |
| 7 | 0 | 2 | 1 | 21 | 14 | 2 | 0 | 0 | 2 | 1 | 30 | 7 | 0 | 0 | 0 | 3 | 3 | 28 | 6 | 0 | 0 |
| 8 | 0 | 0 | 0 | 13 | 20 | 5 | 2 | 0 | 0 | 0 | 18 | 21 | 1 | 0 | 0 | 0 | 0 | 21 | 19 | 0 | 0 |
| 9 | 0 | 0 | 2 | 16 | 15 | 6 | 0 | 0 | 0 | 2 | 25 | 10 | 2 | 0 | 0 | 0 | 4 | 24 | 9 | 2 | 0 |
| 10 | 0 | 0 | 1 | 11 | 11 | 2 | 1 | 0 | 0 | 1 | 16 | 7 | 2 | 0 | 0 | 0 | 3 | 17 | 5 | 1 | 0 |
| 11 | 0 | 0 | 1 | 19 | 14 | 5 | 1 | 0 | 0 | 2 | 24 | 12 | 2 | 0 | 0 | 1 | 1 | 27 | 9 | 0 | 0 |
| 12 | 0 | 0 | 0 | 26 | 12 | 2 | 0 | 0 | 0 | 0 | 34 | 6 | 0 | 0 | 0 | 0 | 5 | 31 | 4 | 0 | 0 |
| 13 | 0 | 0 | 2 | 15 | 14 | 2 | 1 | 0 | 0 | 2 | 19 | 15 | 0 | 0 | 0 | 1 | 3 | 19 | 13 | 0 | 0 |
| 14 | 0 | 0 | 3 | 12 | 14 | 3 | 1 | 0 | 0 | 3 | 22 | 8 | 0 | 0 | 0 | 2 | 5 | 19 | 7 | 0 | 0 |
| 15 | 0 | 0 | 0 | 7 | 21 | 7 | 1 | 0 | 0 | 0 | 14 | 18 | 4 | 0 | 0 | 0 | 0 | 17 | 16 | 3 | 0 |
| 16 | 0 | 0 | 0 | 1 | 9 | 3 | 1 | 0 | 0 | 0 | 5 | 8 | 1 | 0 | 0 | 0 | 0 | 5 | 8 | 1 | 0 |
| 17 | 0 | 0 | 0 | 2 | 9 | 3 | 0 | 0 | 0 | 0 | 2 | 12 | 0 | 0 | 0 | 0 | 0 | 2 | 12 | 0 | 0 |
| 18 | 0 | 0 | 1 | 2 | 4 | 4 | 1 | 0 | 0 | 1 | 7 | 3 | 1 | 0 | 0 | 0 | 1 | 6 | 4 | 0 | 0 |
| 19 | 0 | 0 | 3 | 7 | 14 | 8 | 4 | 0 | 0 | 4 | 18 | 11 | 1 | 1 | 0 | 0 | 5 | 20 | 9 | 0 | 1 |
| 20 | 0 | 1 | 5 | 12 | 8 | 3 | 0 | 0 | 1 | 5 | 18 | 2 | 2 | 0 | 0 | 0 | 0 | 18 | 0 | 2 | 0 |
| 21 | 0 | 0 | 5 | 14 | 1 | 0 | 0 | 0 | 0 | 5 | 5 | 9 | 0 | 0 | 0 | 1 | 3 | 16 | 1 | 0 | 0 |
| 22 | 0 | 0 | 7 | 10 | 8 | 0 | 0 | 0 | 0 | 10 | 11 | 4 | 0 | 0 | 0 | 1 | 9 | 13 | 2 | 0 | 0 |

WHERE THE SENSATION CODES ARE:
1 = VERY COLD, 2 = COLD, 3 = COOL, 4 = NEUTRAL, 5 = WARM, 6 = HOT, 7 = VERY HOT

**Table 17** Questionnaire 2, question 12 : The number of people who commented on the occurrence of a discomfort sensation whilst wearing the trial garment.
(The table takes into account the wearings before and after washing)

| Fabric number | Clammy | | Wet cling | | Static | | Scratchy | | Prickle | | Tickle | | Itchy | | Bulk | | Stretch | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Washes→ | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 1 | 4 | 4 | 3 | 3 | 1 | 0 | 6 | 3 | 4 | 3 | 0 | 3 | 1 | 0 | 3 | 4 | 5 | 2 |
| 2 | 4 | 2 | 0 | 0 | 2 | 12 | 6 | 1 | 3 | 1 | 2 | 2 | 0 | 0 | 5 | 3 | 6 | 3 |
| 3 | 0 | 0 | 1 | 0 | 4 | 5 | 4 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| 4 | 3 | 0 | 2 | 1 | 0 | 0 | 3 | 2 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 2 | 2 |
| 5 | 0 | 0 | 0 | 0 | 2 | 0 | 6 | 2 | 6 | 7 | 6 | 5 | 1 | 2 | 2 | 2 | 0 | 2 |
| 6 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 0 | 4 | 1 | 3 | 2 |
| 7 | 1 | 1 | 1 | 1 | 1 | 1 | 6 | 5 | 7 | 5 | 8 | 9 | 4 | 3 | 1 | 2 | 2 | 0 |
| 8 | 0 | 1 | 3 | 2 | 0 | 12 | 0 | 0 | 1 | 2 | 4 | 3 | 0 | 0 | 13 | 10 | 0 | 1 |
| 9 | 4 | 0 | 3 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 1 | 0 | 4 | 1 |
| 10 | 0 | 2 | 1 | 0 | 6 | 8 | 0 | 2 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 2 |
| 11 | 0 | 1 | 0 | 0 | 3 | 1 | 7 | 4 | 5 | 3 | 3 | 6 | 4 | 4 | 10 | 5 | 3 | 3 |
| 12 | 1 | 0 | 2 | 1 | 5 | 6 | 0 | 2 | 2 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 2 | 3 |
| 13 | 0 | 4 | 0 | 0 | 3 | 10 | 8 | 8 | 1 | 2 | 1 | 2 | 1 | 1 | 7 | 4 | 0 | 0 |
| 14 | 4 | 3 | 2 | 3 | 4 | 8 | 4 | 4 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 15 | 4 | 4 | 2 | 2 | 4 | 0 | 1 | 1 | 10 | 8 | 12 | 12 | 10 | 9 | 2 | 2 | 2 | 3 |
| 16 | 0 | 1 | 0 | 0 | 2 | 3 | 2 | 1 | 5 | 4 | 1 | 3 | 3 | 2 | 1 | 2 | 1 | 3 |
| 17 | 0 | 0 | 0 | 0 | 3 | 3 | 1 | 1 | 4 | 3 | 1 | 2 | 4 | 3 | 1 | 1 | 1 | 2 |
| 18 | 1 | 2 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 19 | 3 | 2 | 2 | 2 | 0 | 3 | 3 | 3 | 4 | 2 | 1 | 1 | 2 | 3 | 2 | 2 | 4 | 5 |
| 20 | 2 | 2 | 2 | 1 | 6 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 4 | 0 | 0 |
| 21 | 1 | 2 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 2 |
| 22 | 2 | 1 | 0 | 1 | 1 | 0 | 4 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 2 | 1 | 0 | 0 |
| Total | 34 | 33 | 25 | 20 | 48 | 81 | 62 | 42 | 56 | 42 | 44 | 56 | 36 | 32 | 57 | 46 | 40 | 40 |
| Total | 67 | | 45 | | 129 | | 104 | | 98 | | 100 | | 68 | | 103 | | 80 | |
| Rank | 8 | | 9 | | 1 | | 2 | | 5 | | 4 | | 7 | | 3 | | 6 | |

NB. A rank of 1 means that it is the most common sensation.

## Appendix 2

### The statistical methods:

The methods used to assess the public questionnaire data were chosen from the wide selection of tests available with the help of Mr Latham (University of Salford, Mathematics Dept.) and Dr. R. McNamee (University of Manchester, Medical School).

The two main methods, Friedmans test for multiple comparisons and the $Chi^2$ test are outlined below.

#### Statistical analysis using the Friedman test for multiple comparisons.

(Conover, 1980)

The following formulae was used:

$$T_2 = \text{test statistic} = \frac{(b-1)[B_2 - bk(k+1)^2/4]}{A_2 - B_2}$$

Where:
$A_2$ is computed by squaring each rank value in the table and summing.
$B_2$ is 1 divided by the number of judges multiplied by the sum of the square of the rank totals.
b = the number of interviewees answering the question.
k = the number of different factors (eg fibre, sensation).
To calculate the degrees of freedom = $(b-1)(k-1)$, where $k_1 = b-1$ and $k_2 = (b-1)(k-1)$
For the degress of freedom calculated, if the value of $T_2$ is greater than the value in the 0.975 quantile of the F-distribution (from the distribution table), the null hypothesis is rejected at $\alpha = 0.05$
If the null hypothesis is rejected, then a multiple comparison can be made to determine the difference between the results:

$$t_{.975} = \left[\frac{2b(A_2-B_2)}{(b-1)(k-1)}\right]^{1/2}$$ = the sum total of any two factors which are more than this value apart, may be regarded as unequal

For example, question 10, if males ABC1 55+ are considered, the sensations were ranked in the following manner:

| | Tickle | Wet cling | Tight fit |
|---|---|---|---|
| Ranked 1 | 13 | 3 | 23 |
| Ranked 2 | 14 | 15 | 10 |
| Ranked 3 | 12 | 21 | 6 |
| Rank total | 77 | 96 | 61 |

$A_2 = 546$, $B_2 = 1/3\ (77^2 + 96^2 + 61^2) = 483.7$
$b = 39$ $k = 3$ $k_1 = 38$ $k_2 = 76$

$$T_2 = \frac{(39-1)[483.7 - 39\text{x}3\ (3+1)^2/4]}{546 - 483.7} = 9.6$$

# Appendix 2

The F-distribution for the .95 quantile with $k_1 = 2$ and $k_2 = 76$ is 3.13
The null hypothesis is rejected.

$$t_{.975} = \left[\frac{2\text{x}39\ (546-483.7)}{(39-1)(3-1)}\right]^{½} = 7.99$$

$t_{.975}$ is 1.99 for 76 degrees of freedom (from the t-distribution table), therefore, any two sensations with a rank sum of more than 7.99 units difference may be regarded as unequal.

## Statisical analysis using the chi-square method.

(Moroney, 1979)

This method was chosen because it is a well known standard statistical method. It is suitable for determining significant differences between factors which have been assessed by dffering numbers of people (subjective results). When comparing separate groups with the same numbers in each group the goodness of fit was used.

Initially a null hypothesis is put forward and the aim is to see if the hypothesis is supported. The factors to be compared are set out in a table and the observed numbers inserted. Secondly the expected numbers are calculated using the following formulae:

$$\text{Expected number} = \frac{\text{column total x row total}}{\text{grand total}}$$

Thirdly the $\chi^2$ value for each cell of the table is calculated.

$$\chi^2 \text{ value} = \frac{(\text{observed number} - \text{expected number})^2}{\text{expected number}}$$

The sum total of the $\chi^2$ values is taken.
The degrees of freedom are calculated, (number of rows - 1) x (number of columns - 1)

The total $\chi^2$ value is compared to the $\chi^2$ values in statistical tables for the appropiate degrees of freedom to the 5%, 1% and 0.1% significance level. If the $\chi^2$ value calculated is lower than the table value, then the null hypothesis is supported.

The certainty with which a statistical analysis is supported is termed:
Significant for the 5% level.
Highly significant for the 1% level.
Very highly significant for the 0.1% level.

## Appendix 2

Table 1 Question 1: How particular are you about the fibres you wear next to your skin? (Number of answers).

| Age Group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| Very | 42 | 48 | 90 | 37 | 66 | 103 | 44 | 69 | 113 | 48 | 80 | 128 | 171 | 263 | 434 |
| Not really | 39 | 80 | 119 | 42 | 70 | 112 | 33 | 61 | 94 | 32 | 64 | 96 | 146 | 275 | 421 |
| Wear anything | 11 | 44 | 55 | 9 | 27 | 36 | 8 | 22 | 30 | 3 | 25 | 28 | 31 | 118 | 149 |
| **Males** | | | | | | | | | | | | | | | |
| Very | 20 | 26 | 46 | 15 | 29 | 44 | 14 | 27 | 41 | 20 | 33 | 53 | 69 | 115 | 184 |
| Not really | 18 | 39 | 57 | 24 | 31 | 55 | 15 | 34 | 49 | 17 | 32 | 49 | 74 | 136 | 210 |
| Wear anything | 5 | 21 | 26 | 5 | 18 | 23 | 7 | 13 | 20 | 2 | 17 | 19 | 19 | 69 | 88 |
| **Females** | | | | | | | | | | | | | | | |
| Very | 22 | 22 | 44 | 22 | 37 | 59 | 30 | 42 | 72 | 28 | 47 | 75 | 102 | 148 | 250 |
| Not really | 21 | 41 | 62 | 18 | 39 | 57 | 18 | 27 | 45 | 15 | 32 | 47 | 72 | 139 | 211 |
| Wear anything | 6 | 23 | 29 | 4 | 9 | 13 | 1 | 9 | 10 | 1 | 8 | 9 | 12 | 49 | 61 |

Key:
Social class 1 = non-manual workers (ABC1), social class 2 = manual workers or unemployed (C2DE), social class 1+2 = ABC1C2DE.

Statistical analysis of question 1 using the chi-square method.

The null hypothesis: The fibres are equally acceptable to males and females.
Chi-square value = 13.71 with 2 degrees of freedom.
The null hypothesis is disproved and there is a highly significant difference in how particular men and women are about the fibres they wear next to their skin. Women are more particular.

The null hypothesis: The fibres are equally acceptable to the different age groups.
Chi-square value = 21.49 with 6 degrees of freedom.
The null hypothesis is disproved and there is a highly significant difference in how particular different age groups are about the fibres they wear next to their skin. In general the older age group was more particular than the younger age group.

The null hypothesis: The fibres are equally acceptable to the different social classes.
Chi-square value = 21.44 with 2 degrees of freedom.
The null hypothesis is disproved and there is a highly significant difference between the social classes. In general the social classes C2DE had a higher proportion of people who said that they were not particular and not really particular than classes ABC1. The majority of ABC1 social classes were very particular.

Table 2 Question 2: The number of people who look at garment labels to determine the fibre content of a garment when purchasing.

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| Always | 24 | 42 | 66 | 43 | 57 | 100 | 40 | 61 | 101 | 47 | 75 | 122 | 154 | 235 | 389 |
| Sometimes | 30 | 56 | 86 | 26 | 59 | 85 | 33 | 42 | 75 | 25 | 54 | 79 | 114 | 211 | 325 |
| Never | 38 | 74 | 112 | 19 | 47 | 66 | 12 | 49 | 61 | 11 | 40 | 51 | 80 | 210 | 290 |
| **Males** | | | | | | | | | | | | | | | |
| Always | 11 | 23 | 34 | 16 | 26 | 42 | 9 | 20 | 29 | 18 | 24 | 42 | 54 | 93 | 147 |
| Sometimes | 13 | 29 | 42 | 13 | 25 | 38 | 16 | 20 | 36 | 12 | 30 | 42 | 54 | 104 | 158 |
| Never | 19 | 34 | 53 | 15 | 27 | 42 | 10 | 35 | 45 | 9 | 28 | 37 | 53 | 124 | 177 |
| **Females** | | | | | | | | | | | | | | | |
| Always | 13 | 19 | 32 | 27 | 31 | 58 | 31 | 41 | 72 | 29 | 51 | 80 | 100 | 142 | 242 |
| Sometimes | 17 | 27 | 44 | 13 | 34 | 47 | 17 | 22 | 39 | 13 | 24 | 37 | 60 | 107 | 167 |
| Never | 19 | 40 | 59 | 4 | 20 | 24 | 2 | 14 | 16 | 2 | 12 | 14 | 27 | 86 | 113 |

Key:
Social class 1 = non manual workers (ABC1), social class 2 = manual workers or unemployed (C2DE), social class 1+2 = ABC1C2DE.

Statistical analysis of question 2 results using the chi-square method.

The null hypothesis: Men and women are equally likely to look at garment labels to determine the fibre composition of a fabric.
Chi-square value = 38.1 with 2 degrees of freedom
The null hypothesis is disproved and there is a very highly significant difference between men and women. Women tend to look more often.

The null hypothesis: People in the different age groups are equally likely to look at garment labels for the fibre type.
Chi-square value = 48.4 with 6 degrees of freedom.
The null hypothesis is disproved and there is a very highly significant difference between the age groups. The 55+ age group tended to look at garment labels more frequently than all the other age groups and the 16-25 age group looked at labels the least.

The null hypothesis: People in different social classes are equally likely to look at the garment label for the fibre type.
Chi-square value = 11.24 with 2 degrees of freedom.
The null hypothesis is disproved to a significant level. The social classes ABC1 are more likely to look at the garment label to determine the fibre content before purchasing clothing.

## Appendix 2

**Table 3** Question 1 and 2: The relationship between how particular people said they were about the fibres they wear next to their skin and whether they would look for the fibre type when purchasing a garment.

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| VP/A | 18 | 30 | 48 | 24 | 43 | 67 | 32 | 48 | 80 | 37 | 61 | 98 | 111 | 182 | 293 |
| VP/S | 12 | 7 | 19 | 9 | 18 | 27 | 10 | 14 | 24 | 10 | 13 | 23 | 41 | 52 | 93 |
| VP/N | 12 | 11 | 23 | 4 | 5 | 9 | 2 | 6 | 8 | 1 | 6 | 7 | 19 | 28 | 47 |
| NRP/A | 6 | 11 | 17 | 15 | 14 | 29 | 8 | 10 | 18 | 9 | 13 | 22 | 38 | 48 | 86 |
| NRP/S | 18 | 36 | 54 | 17 | 34 | 51 | 21 | 26 | 47 | 14 | 36 | 50 | 70 | 132 | 202 |
| NRP/N | 15 | 33 | 48 | 10 | 22 | 32 | 4 | 26 | 30 | 9 | 15 | 24 | 38 | 96 | 134 |
| VA/A | 0 | 1 | 1 | 4 | 0 | 4 | 0 | 3 | 3 | 1 | 1 | 2 | 5 | 5 | 10 |
| VA/S | 0 | 13 | 13 | 0 | 7 | 7 | 2 | 2 | 4 | 1 | 5 | 6 | 3 | 27 | 30 |
| VA/N | 11 | 30 | 41 | 5 | 20 | 25 | 6 | 17 | 23 | 1 | 19 | 20 | 23 | 86 | 109 |
| **Males** | | | | | | | | | | | | | | | |
| VP/A | 8 | 15 | 23 | 10 | 19 | 29 | 7 | 15 | 22 | 15 | 20 | 35 | 40 | 69 | 109 |
| VP/S | 5 | 5 | 10 | 3 | 5 | 8 | 6 | 6 | 12 | 4 | 9 | 13 | 18 | 25 | 43 |
| VP/N | 7 | 6 | 13 | 2 | 5 | 7 | 1 | 5 | 6 | 1 | 4 | 5 | 11 | 20 | 31 |
| NRP/A | 3 | 7 | 10 | 5 | 7 | 12 | 2 | 3 | 5 | 2 | 4 | 6 | 12 | 21 | 33 |
| NRP/S | 8 | 18 | 26 | 10 | 15 | 25 | 10 | 13 | 23 | 8 | 18 | 26 | 36 | 64 | 100 |
| NRP/N | 7 | 14 | 21 | 9 | 9 | 18 | 3 | 19 | 22 | 7 | 10 | 17 | 26 | 52 | 78 |
| VA/A | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 2 | 4 |
| VA/S | 0 | 6 | 6 | 0 | 5 | 5 | 1 | 2 | 3 | 0 | 3 | 3 | 1 | 16 | 17 |
| VA/N | 5 | 14 | 19 | 4 | 13 | 17 | 6 | 11 | 17 | 1 | 14 | 15 | 16 | 52 | 68 |
| **Females** | | | | | | | | | | | | | | | |
| VP/A | 10 | 15 | 25 | 14 | 24 | 38 | 25 | 33 | 58 | 22 | 41 | 63 | 71 | 113 | 184 |
| VP/S | 7 | 2 | 9 | 6 | 13 | 19 | 4 | .8 | 12 | 6 | 4 | 10 | 23 | 27 | 50 |
| VP/N | 5 | 5 | 10 | 2 | 0 | 2 | 1 | 1 | 2 | 0 | 2 | 2 | 8 | 8 | 16 |
| NRP/A | 3 | 4 | 7 | 10 | 7 | 17 | 6 | 7 | 13 | 7 | 9 | 16 | 26 | 27 | 53 |
| NRP/S | 10 | 18 | 28 | 7 | 19 | 26 | 11 | 13 | 24 | 6 | 18 | 24 | 34 | 68 | 102 |
| NRP/N | 8 | 19 | 27 | 1 | 13 | 14 | 1 | 7 | 8 | 2 | 5 | 7 | 12 | 44 | 56 |
| VA/A | 0 | 0 | 0 | 3 | 0 | 3 | 0 | 2 | 2 | 0 | 1 | 1 | 3 | 3 | 6 |
| VA/S | 0 | 7 | 7 | 0 | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 3 | 2 | 12 | 14 |
| VA/N | 6 | 16 | 22 | 1 | 7 | 8 | 0 | 6 | 6 | 0 | 5 | 5 | 7 | 34 | 41 |

Key: VP = Very particular (Q1) A = Always look at label (Q2)
NRP = Not very particular (Q1) S = Sometimes look at label (Q2)
VA = Wear anything (Q1) N = Never (Q2)

Social class 1 = non-manual workers (ABC1), social class 2 = manual workers and unemployed (C2DE), social class 1+2 = ABC1C2DE.

**Statistical analysis of question 1 versus 2 using the chi-square method.**

The null hypothesis: The extent to which people look at garment labels for the fibre content is not related to how particular they say they are about the fibres they choose to wear next to their skin.
Chi-square value = 578.1 with 2 degrees of freedom.
The null hypothesis is disproved and there is a very highly significant difference between the people who look at garment labels and how particular they say they are about the fibres they choose to wear next to their skin.

**Table 3.1** The relationship between the answer an interviewee gave to question 1 expressed in terms of a percentage of the answer the same interviewee gave to question 2.

| | Very Particular | Not really | Wear anything |
|---|---|---|---|
| Always | 64.9% | 26.0% | 16.1% |
| Sometimes | 24.0% | 48.0% | 9.7% |
| Never | 11.1% | 26.0% | 74.2% |

**Table 4 Question 3a: The first, second and third choice of fibre type to be worn next to the skin.** (Number of answers)

## 4.1 THE FIRST CHOICE

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| 1)Acrylic | 2 | 2 | 4 | 0 | 5 | 5 | 0 | 4 | 4 | 0 | 3 | 3 | 2 | 14 | 16 |
| 2)Cotton | 62 | 112 | 174 | 62 | 126 | 188 | 64 | 126 | 190 | 66 | 131 | 197 | 254 | 495 | 749 |
| 3)Nylon | 2 | 6 | 8 | 2 | 2 | 4 | 1 | 5 | 6 | 1 | 8 | 9 | 6 | 21 | 27 |
| 4)Polyester | 0 | 1 | 1 | 2 | 5 | 7 | 3 | 2 | 5 | 2 | 5 | 7 | 7 | 13 | 20 |
| 5)Silk | 10 | 22 | 32 | 13 | 17 | 30 | 16 | 19 | 25 | 10 | 7 | 17 | 49 | 55 | 104 |
| 6)Acetate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7)Viscose | 0 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 |
| 8)Wool | 2 | 12 | 14 | 2 | 0 | 2 | 0 | 4 | 4 | 2 | 11 | 13 | 6 | 27 | 33 |
| 9)Mohair | 0 | 0 | 0 | 1 | 3 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 4 |
| 10)Angora | 6 | 2 | 8 | 2 | 2 | 4 | 0 | 1 | 1 | 0 | 0 | 0 | 8 | 5 | 13 |
| 11)Lambswool | 8 | 14 | 22 | 3 | 2 | 5 | 1 | 1 | 2 | 2 | 3 | 5 | 14 | 20 | 34 |
| **Males** | | | | | | | | | | | | | | | |
| 1)Acrylic | 2 | 1 | 3 | 0 | 2 | 2 | 0 | 2 | 2 | 0 | 0 | 0 | 2 | 5 | 7 |
| 2)Cotton | 28 | 56 | 84 | 33 | 66 | 99 | 33 | 62 | 95 | 31 | 60 | 91 | 125 | 244 | 370 |
| 3)Nylon | 2 | 2 | 4 | 0 | 1 | 1 | 0 | 2 | 2 | 1 | 6 | 7 | 3 | 11 | 14 |
| 4)Polyester | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 0 | 2 | 2 | 1 | 4 | 5 |
| 5)Silk | 3 | 8 | 11 | 6 | 6 | 12 | 2 | 4 | 6 | 4 | 4 | 8 | 15 | 22 | 37 |
| 6)Acetate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7)Viscose | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8)Wool | 2 | 9 | 11 | 2 | 0 | 2 | 0 | 3 | 3 | 2 | 8 | 10 | 6 | 20 | 26 |
| 9)Mohair | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 10)Angora | 2 | 1 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 4 |
| 11)Lambswool | 4 | 9 | 13 | 2 | 0 | 2 | 1 | 0 | 1 | 1 | 2 | 3 | 8 | 11 | 19 |
| **Females** | | | | | | | | | | | | | | | |
| 1)Acrylic | 0 | 1 | 1 | 0 | 3 | 3 | 0 | 2 | 2 | 0 | 3 | 3 | 0 | 9 | 9 |
| 2)Cotton | 34 | 56 | 90 | 29 | 60 | 89 | 31 | 64 | 95 | 35 | 71 | 106 | 129 | 251 | 380 |
| 3)Nylon | 0 | 4 | 4 | 2 | 1 | 3 | 1 | 3 | 4 | 0 | 2 | 2 | 3 | 10 | 13 |
| 4)Polyester | 0 | 1 | 1 | 1 | 4 | 5 | 3 | 1 | 4 | 2 | 3 | 5 | 6 | 9 | 15 |
| 5)Silk | 7 | 14 | 21 | 7 | 11 | 18 | 14 | 5 | 19 | 6 | 3 | 9 | 34 | 33 | 67 |
| 6)Acetate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7)Viscose | 0 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 |
| 8)Wool | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 3 | 0 | 7 | 7 |
| 9)Mohair | 0 | 0 | 0 | 1 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 |
| 10)Angora | 4 | 1 | 5 | 2 | 1 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 6 | 3 | 9 |
| 11)Lambswool | 4 | 5 | 9 | 1 | 2 | 3 | 0 | 1 | 1 | 1 | 1 | 2 | 6 | 9 | 15 |

## 4.2 THE SECOND CHOICE

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| 1)Acrylic | 2 | 8 | 10 | 6 | 12 | 18 | 2 | 10 | 12 | 2 | 11 | 13 | 12 | 41 | 53 |
| 2)Cotton | 17 | 33 | 50 | 13 | 26 | 39 | 13 | 16 | 29 | 12 | 23 | 35 | 55 | 98 | 153 |
| 3)Nylon | 8 | 8 | 16 | 4 | 15 | 19 | 5 | 19 | 24 | 6 | 17 | 23 | 23 | 59 | 82 |
| 4)Polyester | 9 | 19 | 28 | 20 | 21 | 41 | 14 | 47 | 61 | 12 | 32 | 44 | 55 | 119 | 174 |
| 5)Silk | 17 | 44 | 61 | 14 | 51 | 66 | 31 | 42 | 73 | 30 | 48 | 78 | 92 | 186 | 278 |
| 6)Acetate | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 4 |
| 7)Viscose | 0 | 4 | 4 | 2 | 3 | 5 | 1 | 0 | 1 | 1 | 4 | 5 | 4 | 11 | 15 |
| 8)Wool | 13 | 16 | 29 | 13 | 14 | 27 | 10 | 13 | 23 | 17 | 28 | 45 | 51 | 71 | 122 |
| 9)Mohair | 4 | 6 | 10 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6 | 11 |
| 10)Angora | 7 | 8 | 15 | 4 | 3 | 7 | 1 | 1 | 2 | 0 | 0 | 0 | 12 | 12 | 24 |
| 11)Lambswool | 15 | 26 | 41 | 10 | 16 | 26 | 9 | 4 | 13 | 2 | 5 | 7 | 36 | 51 | 87 |
| **Males** | | | | | | | | | | | | | | | |
| 1)Acrylic | 2 | 6 | 8 | 3 | 6 | 9 | 1 | 4 | 5 | 0 | 7 | 7 | 6 | 23 | 29 |
| 2)Cotton | 9 | 19 | 28 | 6 | 8 | 14 | 1 | 9 | 10 | 6 | 15 | 21 | 22 | 51 | 73 |
| 3)Nylon | 5 | 5 | 10 | 4 | 12 | 16 | 1 | 11 | 12 | 4 | 13 | 17 | 14 | 41 | 55 |
| 4)Polyester | 5 | 9 | 14 | 9 | 8 | 17 | 10 | 21 | 31 | 5 | 14 | 19 | 29 | 52 | 81 |
| 5)Silk | 8 | 18 | 26 | 5 | 18 | 23 | 14 | 16 | 30 | 12 | 8 | 20 | 39 | 60 | 99 |
| 6)Acetate | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| 7)Viscose | 0 | 1 | 1 | 0 | 2 | 2 | 0 | 0 | 0 | 1 | 2 | 3 | 1 | 5 | 6 |
| 8)Wool | 8 | 6 | 14 | 10 | 7 | 17 | 6 | 10 | 16 | 11 | 21 | 32 | 33 | 44 | 77 |
| 9)Mohair | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| 10)Angora | 0 | 2 | 2 | 1 | 3 | 4 | 1 | 1 | 2 | 0 | 0 | 0 | 2 | 6 | 8 |
| 11)Lambswool | 6 | 18 | 24 | 5 | 13 | 18 | 3 | 2 | 5 | 0 | 2 | 2 | 14 | 35 | 49 |
| **Females** | | | | | | | | | | | | | | | |
| 1)Acrylic | 0 | 2 | 2 | 3 | 6 | 9 | 1 | 6 | 7 | 2 | 4 | 6 | 6 | 18 | 24 |
| 2)Cotton | 8 | 14 | 22 | 7 | 18 | 25 | 12 | 7 | 19 | 6 | 8 | 14 | 33 | 47 | 80 |
| 3)Nylon | 3 | 3 | 6 | 0 | 3 | 3 | 4 | 8 | 12 | 2 | 4 | 6 | 9 | 18 | 27 |
| 4)Polyester | 4 | 10 | 14 | 11 | 13 | 24 | 4 | 26 | 30 | 7 | 18 | 25 | 26 | 67 | 93 |
| 5)Silk | 9 | 26 | 35 | 9 | 34 | 43 | 17 | 26 | 43 | 18 | 40 | 58 | 53 | 126 | 179 |
| 6)Acetate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 1 | 2 |
| 7)Viscose | 0 | 3 | 3 | 2 | 1 | 3 | 1 | 0 | 1 | 0 | 2 | 2 | 3 | 6 | 9 |
| 8)Wool | 5 | 10 | 15 | 3 | 7 | 10 | 4 | 3 | 7 | 6 | 7 | 13 | 18 | 27 | 45 |
| 9)Mohair | 4 | 4 | 8 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 4 | 9 |
| 10)Angora | 7 | 6 | 13 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 6 | 16 |
| 11)Lambswool | 9 | 8 | 17 | 5 | 3 | 8 | 6 | 2 | 8 | 2 | 3 | 5 | 22 | 16 | 38 |

## 4.3 THE THIRD CHOICE

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| 1)Acrylic | 11 | 18 | 29 | 10 | 26 | 36 | 10 | 23 | 33 | 9 | 18 | 27 | 40 | 87 | 127 |
| 2)Cotton | 6 | 17 | 23 | 5 | 4 | 9 | 5 | 4 | 9 | 3 | 10 | 13 | 19 | 35 | 54 |
| 3)Nylon | 10 | 16 | 26 | 5 | 13 | 18 | 10 | 18 | 27 | 3 | 12 | 15 | 28 | 59 | 87 |
| 4)Polyester | 3 | 32 | 35 | 17 | 38 | 55 | 19 | 38 | 57 | 17 | 53 | 70 | 56 | 161 | 217 |
| 5)Silk | 20 | 17 | 37 | 22 | 23 | 45 | 16 | 26 | 42 | 18 | 32 | 50 | 76 | 98 | 174 |
| 6)Acetate | 0 | 0 | 0 | 1 | 3 | 4 | 0 | 3 | 3 | 5 | 4 | 9 | 6 | 10 | 16 |
| 7)Viscose | 1 | 2 | 3 | 5 | 3 | 8 | 1 | 6 | 7 | 1 | 5 | 6 | 8 | 16 | 24 |
| 8)Wool | 12 | 22 | 34 | 8 | 16 | 24 | 10 | 12 | 22 | 9 | 15 | 24 | 39 | 65 | 104 |
| 9)Mohair | 7 | 6 | 13 | 1 | 5 | 6 | 0 | 2 | 2 | 1 | 1 | 2 | 9 | 14 | 23 |
| 10)Angora | 1 | 10 | 11 | 2 | 7 | 9 | 4 | 0 | 4 | 1 | 1 | 2 | 8 | 18 | 26 |
| 11)Lambswool | 21 | 32 | 53 | 12 | 25 | 37 | 10 | 20 | 30 | 16 | 17 | 33 | 59 | 94 | 153 |
| **Males** | | | | | | | | | | | | | | | |
| 1)Acrylic | 6 | 12 | 18 | 5 | 15 | 20 | 3 | 11 | 14 | 2 | 8 | 10 | 16 | 46 | 62 |
| 2)Cotton | 1 | 10 | 11 | 3 | 2 | 5 | 2 | 3 | 5 | 2 | 6 | 8 | 7 | 21 | 28 |
| 3)Nylon | 8 | 10 | 18 | 5 | 9 | 14 | 6 | 12 | 18 | 0 | 5 | 5 | 19 | 36 | 55 |
| 4)Polyester | 2 | 17 | 19 | 7 | 16 | 23 | 6 | 18 | 24 | 12 | 20 | 32 | 27 | 71 | 98 |
| 5)Silk | 7 | 11 | 18 | 7 | 7 | 14 | 9 | 12 | 21 | 6 | 18 | 24 | 29 | 48 | 77 |
| 6)Acetate | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 3 | 1 | 4 | 3 | 3 | 6 |
| 7)Viscose | 1 | 1 | 2 | 4 | 1 | 5 | 0 | 2 | 2 | 1 | 3 | 4 | 6 | 7 | 13 |
| 8)Wool | 7 | 11 | 18 | 5 | 6 | 10 | 5 | 5 | 10 | 2 | 10 | 12 | 19 | 32 | 51 |
| 9)Mohair | 2 | 1 | 3 | 0 | 4 | 4 | 0 | 1 | 1 | 1 | 1 | 2 | 3 | 7 | 10 |
| 10)Angora | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 0 | 1 | 0 | 1 | 1 | 3 | 5 | 8 |
| 11)Lambswool | 8 | 11 | 19 | 7 | 14 | 21 | 4 | 10 | 14 | 10 | 9 | 19 | 29 | 44 | 73 |
| **Females** | | | | | | | | | | | | | | | |
| 1)Acrylic | 5 | 6 | 11 | 5 | 11 | 16 | 7 | 12 | 19 | 7 | 10 | 17 | 24 | 39 | 63 |
| 2)Cotton | 5 | 7 | 12 | 2 | 2 | 4 | 3 | 1 | 4 | 1 | 4 | 5 | 11 | 14 | 25 |
| 3)Nylon | 2 | 6 | 8 | 0 | 4 | 4 | 4 | 6 | 10 | 3 | 7 | 10 | 9 | 23 | 32 |
| 4)Polyester | 1 | 15 | 16 | 10 | 22 | 32 | 13 | 20 | 33 | 5 | 33 | 38 | 29 | 90 | 119 |
| 5)Silk | 13 | 6 | 19 | 15 | 16 | 31 | 7 | 14 | 21 | 12 | 14 | 26 | 47 | 50 | 97 |
| 6)Acetate | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 3 | 3 | 2 | 3 | 5 | 3 | 7 | 10 |
| 7)Viscose | 0 | 1 | 1 | 1 | 2 | 3 | 1 | 4 | 5 | 0 | 2 | 2 | 2 | 9 | 11 |
| 8)Wool | 5 | 11 | 16 | 3 | 10 | 13 | 5 | 7 | 12 | 7 | 6 | 13 | 19 | 34 | 53 |
| 9)Mohair | 5 | 5 | 10 | 1 | 1 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 6 | 7 | 13 |
| 10)Angora | 0 | 8 | 8 | 1 | 5 | 6 | 3 | 0 | 3 | 1 | 0 | 1 | 5 | 13 | 18 |
| 11)Lambswool | 13 | 21 | 34 | 5 | 11 | 16 | 6 | 10 | 16 | 6 | 8 | 14 | 30 | 50 | 80 |

Key:
Social class 1 = non-manual workers (ABC1), social class 2 = manual workers and unemployed (C2DE), social class 1+2 = ABC1C2DE.

## Appendix 2

### Statistical analysis of question 3a using the chi-square method.

#### First choice

The null hypothesis: All fibres are equally preferred.
Chi-square value: 34.65 with 10 degrees of freedom.
The null hypothesis is disproved to a very highly significant level.

The fibres are ranked in the following order of preference to a highly significant level using the chi-square method:
Cotton
Silk
Lambswool, wool, nylon, polyester
Acrylic, angora
Viscose, mohair, acetate.

The null hypothesis: The two social classes have equal preference for the fibres specified.
Chi-square value for all the fibres 34.65 with 10 degrees of freedom
The null hypothesis is disproved to a very highly significant level.

The null hypothesis: Males and females have equal preference for the fibres specified.
Chi-square value = 43.39 with 10 degrees of freedom.
The null hypothesis is disproved to a very highly significant level.

The null hypothesis: The four age groups specified have equal preference to the fibres.
Chi-square value for all the fibres = 73.62 with 33 degrees of freedom.
The null hypothesis is disproved to a very highly significant level.

#### Second Choice

The rank order of the fibres (as determined by simple rank totals) is as follows:
Silk, Polyester, Cotton, Wool, Lambswool, Nylon, Acrylic, Angora, Viscose, Mohair, Acetate.

#### Third Choice

The rank order of the fibres (as determined by simple rank totals) is as follows:
Polyester, Silk, Lambswool, Acrylic, Wool, Nylon, Cotton, Angora, Viscose, Mohair, Acetate.

The values in the table for cotton are greater than the number of people answering the questionnaire, and the values for cotton as a second and third choice appears large because some interviewees said that cotton was their first, second and third choice, and the fibre was allocated this ranking. It is suggested that the first choice is the most accurate value for cotton. When an interviewee did not specify cotton as their first choice they invariably specified it as their second choice.

## Appendix 2

**Table 5 Question 3b: The three fibres you would most dislike to wear against your skin.**

THE 9th, 10th AND 11th CHOICES COLLECTIVELY

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| Acrylic | 31 | 53 | 84 | 34 | 43 | 77 | 29 | 37 | 66 | 27 | 43 | 70 | 121 | 176 | 297 |
| Cotton | 1 | 2 | 3 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 4 | 5 |
| Nylon | 50 | 67 | 117 | 42 | 69 | 111 | 31 | 36 | 67 | 30 | 66 | 96 | 153 | 238 | 391 |
| Polyester | 32 | 44 | 76 | 15 | 27 | 42 | 13 | 14 | 27 | 13 | 17 | 30 | 73 | 102 | 175 |
| Silk | 11 | 26 | 37 | 4 | 7 | 11 | 1 | 14 | 15 | 4 | 17 | 21 | 20 | 64 | 84 |
| Acetate | 21 | 37 | 58 | 18 | 31 | 49 | 19 | 22 | 41 | 28 | 35 | 63 | 86 | 125 | 211 |
| Viscose | 25 | 45 | 70 | 17 | 37 | 54 | 23 | 18 | 41 | 22 | 31 | 53 | 87 | 131 | 218 |
| Wool | 23 | 46 | 69 | 30 | 49 | 79 | 18 | 55 | 73 | 19 | 52 | 71 | 90 | 202 | 292 |
| Mohair | 47 | 98 | 145 | 46 | 105 | 151 | 46 | 112 | 158 | 47 | 97 | 144 | 186 | 412 | 598 |
| Angora | 13 | 54 | 67 | 32 | 58 | 90 | 39 | 74 | 113 | 39 | 80 | 119 | 123 | 266 | 389 |
| Lambswool | 20 | 37 | 57 | 21 | 54 | 75 | 25 | 62 | 87 | 19 | 41 | 60 | 85 | 194 | 279 |
| No more * | 2 | 7 | 9 | 5 | 12 | 17 | 11 | 8 | 19 | 1 | 24 | 25 | 19 | 51 | 70 |
| **Males** | | | | | | | | | | | | | | | |
| Acrylic | 12 | 23 | 35 | 21 | 20 | 41 | 9 | 16 | 25 | 14 | 28 | 42 | 56 | 87 | 143 |
| Cotton | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Nylon | 18 | 30 | 48 | 22 | 36 | 58 | 12 | 18 | 30 | 18 | 32 | 50 | 70 | 116 | 186 |
| Polyester | 12 | 25 | 37 | 9 | 18 | 27 | 6 | 9 | 15 | 7 | 13 | 20 | 34 | 65 | 99 |
| Silk | 5 | 13 | 18 | 2 | 5 | 7 | 1 | 10 | 11 | 2 | 12 | 14 | 10 | 40 | 50 |
| Acetate | 9 | 17 | 26 | 7 | 14 | 21 | 10 | 9 | 19 | 12 | 19 | 31 | 38 | 59 | 97 |
| Viscose | 11 | 21 | 32 | 10 | 19 | 29 | 13 | 9 | 22 | 13 | 18 | 31 | 47 | 67 | 114 |
| Wool | 15 | 23 | 38 | 13 | 18 | 31 | 6 | 30 | 36 | 8 | 20 | 28 | 42 | 91 | 133 |
| Mohair | 28 | 54 | 82 | 20 | 48 | 68 | 19 | 52 | 71 | 20 | 39 | 59 | 87 | 193 | 280 |
| Angora | 7 | 24 | 31 | 16 | 20 | 36 | 15 | 33 | 48 | 18 | 32 | 50 | 56 | 109 | 165 |
| Lambswool | 11 | 23 | 34 | 8 | 27 | 35 | 9 | 31 | 40 | 5 | 16 | 21 | 33 | 97 | 130 |
| No more * | 0 | 5 | 5 | 4 | 9 | 13 | 8 | 5 | 13 | 0 | 17 | 17 | 12 | 36 | 48 |
| **Females** | | | | | | | | | | | | | | | |
| Acrylic | 19 | 30 | 49 | 13 | 23 | 36 | 20 | 21 | 41 | 13 | 15 | 28 | 65 | 89 | 154 |
| Cotton | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 4 | 4 |
| Nylon | 32 | 37 | 69 | 20 | 33 | 53 | 19 | 18 | 37 | 12 | 34 | 46 | 83 | 122 | 205 |
| Polyester | 20 | 19 | 39 | 6 | 9 | 15 | 7 | 5 | 12 | 6 | 4 | 10 | 39 | 37 | 76 |
| Silk | 6 | 13 | 19 | 2 | 2 | 4 | 0 | 4 | 4 | 2 | 5 | 7 | 10 | 24 | 34 |
| Acetate | 12 | 20 | 32 | 11 | 17 | 28 | 9 | 13 | 22 | 16 | 16 | 32 | 48 | 66 | 114 |
| Viscose | 14 | 24 | 38 | 7 | 18 | 25 | 10 | 9 | 19 | 9 | 13 | 22 | 40 | 64 | 104 |
| Wool | 8 | 23 | 31 | 17 | 31 | 48 | 12 | 25 | 37 | 11 | 32 | 43 | 48 | 111 | 159 |
| Mohair | 19 | 44 | 63 | 26 | 57 | 83 | 27 | 60 | 87 | 27 | 58 | 85 | 99 | 219 | 318 |
| Angora | 6 | 30 | 36 | 16 | 38 | 54 | 24 | 41 | 65 | 21 | 48 | 69 | 67 | 157 | 224 |
| Lambswool | 9 | 14 | 23 | 13 | 27 | 40 | 16 | 31 | 47 | 14 | 25 | 39 | 52 | 97 | 149 |
| No more * | 2 | 2 | 4 | 1 | 3 | 4 | 3 | 3 | 6 | 1 | 7 | 8 | 7 | 15 | 22 |

Social class 1 = non-manual workers (ABC1), social class 2 = manual workers and unemployed (C2DE), social class 1+2 = ABC1C2DE.

* = No more dislikes.

**Statistical analysis of question 3b using the chi-square method.**

The null hypothesis: All fibres are equally prefered.
Chi-square value = 959.08 with 10 degrees of freedom.
The null hypothesis is disproved to a very highly significant level.

The null hypothesis: The fibres are equally unacceptable to males and females.
Chi-square value = 22.1 with 10 degrees of freedom.
The null hypothesis is disproved to a significant level.

The null hypothesis: The fibres are equally unacceptable to the different social classes.
Chi-square value = 1627.24 with 10 degrees of freedom.
The null hypothesis is disproved to a very highly significant level.

The null hypothesis: The fibres are equally unacceptable to the different age groups.
Chi-square value = 110.05 with 33 dgrees of freedom.
The null hypothesis is disproved to a very highly significant degree.

Table 6 Question 3b v 4: For the three fibres which were most disliked, would you wear them against your skin in 100%, > 50% or < 50% as a blend with your favorite fibre? (Number of answers).
The figures for the six most unpopular fibres are shown.

MOHAIR

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Males and Females | | | | | | | | | | | | | | | |
| 100% | 7 | 9 | 16 | 4 | 11 | 15 | 3 | 12 | 15 | 3 | 8 | 11 | 17 | 40 | 57 |
| 99%-50% | 17 | 46 | 63 | 16 | 30 | 46 | 15 | 31 | 46 | 14 | 24 | 38 | 62 | 131 | 193 |
| 49%-1% | 12 | 26 | 38 | 16 | 41 | 57 | 19 | 28 | 47 | 17 | 29 | 46 | 64 | 124 | 188 |
| 0% | 12 | 17 | 29 | 9 | 23 | 32 | 9 | 38 | 47 | 13 | 34 | 47 | 43 | 112 | 155 |
| Males | | | | | | | | | | | | | | | |
| 100% | 4 | 4 | 8 | 4 | 5 | 9 | 0 | 4 | 4 | 2 | 2 | 4 | 10 | 15 | 25 |
| 99%-50% | 9 | 25 | 34 | 5 | 13 | 18 | 6 | 15 | 21 | 3 | 9 | 12 | 23 | 62 | 85 |
| 49%-1% | 8 | 13 | 21 | 8 | 16 | 24 | 9 | 13 | 22 | 9 | 14 | 23 | 34 | 56 | 90 |
| 0% | 8 | 12 | 20 | 3 | 14 | 17 | 4 | 18 | 22 | 6 | 13 | 19 | 21 | 57 | 78 |
| Females | | | | | | | | | | | | | | | |
| 100% | 3 | 5 | 8 | 0 | 6 | 6 | 3 | 8 | 11 | 1 | 6 | 7 | 7 | 25 | 32 |
| 99%-50% | 8 | 21 | 29 | 11 | 17 | 28 | 9 | 16 | 25 | 11 | 15 | 26 | 39 | 69 | 108 |
| 49%-1% | 4 | 13 | 17 | 8 | 25 | 33 | 10 | 15 | 25 | 8 | 15 | 23 | 30 | 68 | 98 |
| 0% | 4 | 5 | 9 | 6 | 9 | 15 | 5 | 20 | 25 | 7 | 21 | 28 | 22 | 55 | 77 |

ANGORA

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Males and Females | | | | | | | | | | | | | | | |
| 100% | 8 | 14 | 22 | 5 | 17 | 22 | 5 | 13 | 18 | 4 | 12 | 16 | 22 | 56 | 78 |
| 99%-50% | 23 | 53 | 76 | 17 | 43 | 60 | 20 | 40 | 60 | 14 | 30 | 44 | 74 | 166 | 240 |
| 49%-1% | 16 | 30 | 61 | 18 | 51 | 69 | 22 | 38 | 60 | 17 | 33 | 50 | 73 | 152 | 225 |
| 0% | 16 | 18 | 34 | 11 | 32 | 43 | 11 | 43 | 54 | 16 | 41 | 57 | 54 | 134 | 188 |
| Males | | | | | | | | | | | | | | | |
| 100% | 5 | 7 | 12 | 4 | 8 | 12 | 1 | 5 | 6 | 2 | 5 | 7 | 12 | 25 | 37 |
| 99%-50% | 14 | 28 | 42 | 6 | 18 | 24 | 11 | 20 | 31 | 3 | 12 | 15 | 34 | 78 | 112 |
| 49%-1% | 10 | 15 | 25 | 8 | 21 | 29 | 10 | 16 | 26 | 8 | 12 | 20 | 36 | 64 | 100 |
| 0% | 10 | 11 | 21 | 4 | 17 | 21 | 4 | 23 | 27 | 7 | 15 | 22 | 25 | 66 | 91 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Females** | | | | | | | | | | | | | | | |
| 100% | 3 | 7 | 10 | 1 | 9 | 10 | 4 | 8 | 12 | 2 | 7 | 9 | 10 | 31 | 41 |
| 99%-50% | 9 | 25 | 34 | 11 | 25 | 36 | 9 | 20 | 29 | 11 | 18 | 29 | 40 | 88 | 128 |
| 49%-1% | 6 | 15 | 21 | 10 | 30 | 40 | 12 | 22 | 34 | 9 | 21 | 30 | 37 | 88 | 125 |
| 0% | 6 | 7 | 13 | 7 | 15 | 22 | 7 | 20 | 27 | 9 | 26 | 35 | 29 | 68 | 97 |

NYLON

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| 100% | 10 | 10 | 20 | 6 | 13 | 19 | 6 | 6 | 12 | 1 | 8 | 9 | 23 | 37 | 60 |
| 99%-50% | 27 | 36 | 63 | 21 | 18 | 39 | 13 | 16 | 29 | 12 | 19 | 31 | 73 | 89 | 162 |
| 49%-1% | 11 | 28 | 39 | 17 | 34 | 51 | 14 | 13 | 27 | 15 | 25 | 40 | 57 | 100 | 157 |
| 0% | 16 | 15 | 31 | 5 | 21 | 26 | 4 | 13 | 17 | 8 | 26 | 34 | 33 | 75 | 108 |
| **Males** | | | | | | | | | | | | | | | |
| 100% | 3 | 5 | 8 | 3 | 4 | 7 | 3 | 3 | 6 | 0 | 5 | 5 | 9 | 17 | 26 |
| 99%-50% | 10 | 17 | 27 | 10 | 8 | 18 | 6 | 8 | 14 | 6 | 7 | 13 | 32 | 40 | 72 |
| 49%-1% | 4 | 10 | 14 | 9 | 20 | 29 | 3 | 7 | 10 | 9 | 10 | 19 | 25 | 47 | 72 |
| 0% | 7 | 7 | 14 | 4 | 13 | 17 | 2 | 7 | 9 | 5 | 13 | 18 | 18 | 40 | 58 |
| **Females** | | | | | | | | | | | | | | | |
| 100% | 7 | 5 | 12 | 3 | 9 | 12 | 3 | 3 | 6 | 1 | 3 | 4 | 14 | 20 | 34 |
| 99%-50% | 17 | 19 | 36 | 11 | 10 | 21 | 7 | 8 | 15 | 6 | 12 | 18 | 41 | 49 | 90 |
| 49%-1% | 7 | 18 | 25 | 8 | 14 | 22 | 11 | 6 | 17 | 6 | 15 | 21 | 32 | 53 | 85 |
| 0% | 9 | 8 | 17 | 1 | 8 | 9 | 2 | 6 | 8 | 3 | 13 | 16 | 15 | 35 | 50 |

ACRYLIC

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| 100% | 8 | 10 | 18 | 8 | 8 | 16 | 6 | 7 | 13 | 5 | 8 | 13 | 27 | 33 | 60 |
| 99%-50% | 11 | 24 | 35 | 14 | 11 | 25 | 9 | 14 | 23 | 10 | 12 | 22 | 44 | 61 | 105 |
| 49%-1% | 7 | 14 | 21 | 13 | 11 | 24 | 9 | 10 | 19 | 8 | 9 | 17 | 37 | 44 | 81 |
| 0% | 4 | 3 | 7 | 0 | 12 | 12 | 6 | 6 | 12 | 4 | 14 | 18 | 14 | 38 | 52 |
| **Males** | | | | | | | | | | | | | | | |
| 100% | 2 | 6 | 8 | 5 | 4 | 9 | 4 | 3 | 7 | 2 | 5 | 7 | 13 | 18 | 31 |
| 99%-50% | 4 | 10 | 14 | 9 | 3 | 12 | 2 | 5 | 7 | 5 | 8 | 13 | 20 | 26 | 46 |
| 49%-1% | 3 | 5 | 8 | 7 | 5 | 12 | 3 | 6 | 9 | 4 | 8 | 12 | 17 | 24 | 41 |
| 0% | 2 | 1 | 3 | 0 | 7 | 7 | 0 | 2 | 2 | 3 | 7 | 10 | 5 | 17 | 22 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Females | | | | | | | | | | | | | | | |
| 100% | 6 | 4 | 10 | 3 | 4 | 7 | 2 | 4 | 6 | 3 | 3 | 6 | 14 | 15 | 29 |
| 99%-50% | 7 | 14 | 21 | 5 | 8 | 13 | 7 | 9 | 16 | 5 | 4 | 9 | 24 | 35 | 59 |
| 49%-1% | 4 | 9 | 13 | 6 | 6 | 12 | 6 | 4 | 10 | 4 | 1 | 5 | 20 | 20 | 40 |
| 0% | 2 | 2 | 4 | 0 | 5 | 5 | 6 | 4 | 10 | 1 | 7 | 8 | 9 | 18 | 27 |

LAMBSWOOL

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Males and Females | | | | | | | | | | | | | | | |
| 100% | 0 | 7 | 7 | 3 | 7 | 10 | 9 | 9 | 18 | 4 | 7 | 11 | 16 | 30 | 46 |
| 99%-50% | 7 | 28 | 35 | 12 | 23 | 35 | 13 | 22 | 35 | 11 | 29 | 40 | 43 | 102 | 145 |
| 49%-1% | 4 | 23 | 27 | 12 | 22 | 34 | 17 | 28 | 45 | 15 | 24 | 39 | 48 | 97 | 145 |
| 0% | 6 | 11 | 17 | 9 | 21 | 30 | 12 | 28 | 40 | 13 | 29 | 42 | 40 | 89 | 129 |
| Males | | | | | | | | | | | | | | | |
| 100% | 0 | 2 | 2 | 3 | 3 | 6 | 4 | 2 | 6 | 2 | 3 | 5 | 9 | 10 | 19 |
| 99%-50% | 4 | 12 | 16 | 3 | 5 | 8 | 7 | 15 | 22 | 3 | 12 | 15 | 17 | 44 | 61 |
| 49%-1% | 3 | 9 | 12 | 7 | 6 | 13 | 7 | 11 | 18 | 8 | 12 | 20 | 25 | 38 | 63 |
| 0% | 4 | 6 | 10 | 5 | 8 | 13 | 3 | 13 | 16 | 5 | 8 | 13 | 17 | 35 | 52 |
| Females | | | | | | | | | | | | | | | |
| 100% | 0 | 5 | 5 | 0 | 4 | 4 | 5 | 7 | 12 | 2 | 4 | 6 | 7 | 20 | 27 |
| 99%-50% | 3 | 16 | 19 | 9 | 18 | 27 | 6 | 7 | 13 | 8 | 17 | 25 | 26 | 58 | 84 |
| 49%-1% | 1 | 14 | 15 | 5 | 16 | 21 | 10 | 17 | 27 | 7 | 12 | 19 | 23 | 59 | 82 |
| 0% | 2 | 5 | 7 | 4 | 13 | 17 | 9 | 15 | 24 | 8 | 21 | 29 | 23 | 54 | 77 |

WOOL

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Males and Females | | | | | | | | | | | | | | | |
| 100% | 7 | 14 | 21 | 4 | 13 | 17 | 3 | 10 | 13 | 1 | 16 | 17 | 15 | 53 | 68 |
| 99%-50% | 9 | 18 | 27 | 13 | 15 | 28 | 5 | 16 | 21 | 7 | 10 | 17 | 34 | 59 | 93 |
| 49%-1% | 2 | 6 | 8 | 7 | 10 | 17 | 7 | 17 | 24 | 5 | 16 | 21 | 21 | 49 | 70 |
| 0% | 4 | 10 | 14 | 6 | 11 | 17 | 3 | 19 | 22 | 7 | 13 | 20 | 20 | 53 | 73 |
| Males | | | | | | | | | | | | | | | |
| 100% | 4 | 1 | 5 | 2 | 4 | 6 | 0 | 3 | 3 | 1 | 3 | 4 | 7 | 11 | 18 |
| 99%-50% | 7 | 13 | 20 | 5 | 5 | 10 | 3 | 8 | 11 | 2 | 5 | 7 | 17 | 31 | 48 |
| 49%-1% | 1 | 3 | 4 | 4 | 5 | 9 | 3 | 8 | 11 | 2 | 6 | 8 | 10 | 22 | 32 |
| 0% | 2 | 5 | 7 | 2 | 5 | 7 | 0 | 11 | 11 | 3 | 7 | 10 | 7 | 28 | 35 |

| Females | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100% | 3 | 13 | 16 | 2 | 9 | 11 | 3 | 7 | 10 | 0 | 13 | 13 | 8 | 42 | 50 |
| 99%-50% | 2 | 5 | 7 | 8 | 10 | 18 | 2 | 8 | 10 | 5 | 5 | 10 | 17 | 28 | 45 |
| 49%-1% | 1 | 3 | 4 | 3 | 5 | 8 | 4 | 9 | 13 | 3 | 10 | 13 | 11 | 27 | 38 |
| 0% | 2 | 5 | 7 | 4 | 6 | 10 | 3 | 8 | 11 | 4 | 6 | 10 | 13 | 25 | 38 |

Social class 1 = non-manual workers (ABC1), social class 2 = manual workers and unemployed (C2DE), social class 1+2 = ABC1C2DE.

Statistical analysis of question 3b verses 4a,b,c using the chi-square method.

The null hypothesis: The fabrics are worn equally in 100%, >50%, <50% and not at all by males and females.
Chi-square value to 1 degree of freedom.
Mohair 1.64 Angora 0.69 Nylon 3.76
Acrylic 0.97 Lambswool 0.29 Wool 11.22
The null hypothesis is supported for all the fibres except wool where there is a very highly significant difference.

The null hypothesis: The fabrics are worn equally in 100%, >50%, <50% and not at all by social classes ABC1 and C2DE.
Chi-square value to 1 degree of freedom.
Mohair 1.22 Angora 0.89 Nylon 5.75
Acrylic 6.47 Lambswool 0.64 Wool 5.00
The null hypothesis is supported for all the fibres except nylon, wool and acrylic where there is a significant difference.

The null hypothesis: The fabrics are worn equally in 100%, >50%, <50% and not at all by the four age groups.
Chi-square value to 6 degrees of freedom.
Mohair 18.54 Angora 17.74 Nylon 15.08
Acrylic 9.63 Lambswool 9.14 Wool 15.25
The null hypothesis is supported for acrylic and lambswool. The null hypothesis is disproved for the other fibres to a significant level for nylon and wool, a highly significant level for mohair and angora.

Table 7 Question 4: For the three fibres that an interviewee most disliked, the table shows the number of people in each group which would wear them against their skin in 100%, more than 50% or less than 50% as a blend with their favorite fibre?

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| Males and Females | | | | | | | | | | | | | | | |
| 100% | 51 | 72 | 123 | 35 | 67 | 102 | 40 | 61 | 101 | 27 | 71 | 98 | 153 | 271 | 424 |
| 99%-50% | 102 | 232 | 334 | 108 | 145 | 253 | 74 | 135 | 209 | 77 | 136 | 213 | 361 | 648 | 1009 |
| 49%-1% | 54 | 136 | 190 | 84 | 167 | 251 | 95 | 121 | 216 | 85 | 130 | 215 | 318 | 554 | 872 |
| 0% | 69 | 76 | 145 | 37 | 110 | 147 | 46 | 139 | 185 | 60 | 170 | 230 | 212 | 495 | 707 |
| Males | | | | | | | | | | | | | | | |
| 100% | 24 | 35 | 59 | 25 | 33 | 58 | 22 | 27 | 49 | 13 | 40 | 53 | 84 | 135 | 219 |
| 99%-50% | 48 | 118 | 166 | 45 | 58 | 103 | 32 | 73 | 105 | 30 | 65 | 95 | 155 | 314 | 469 |
| 49%-1% | 27 | 58 | 85 | 45 | 78 | 123 | 39 | 56 | 95 | 46 | 66 | 112 | 157 | 258 | 415 |
| 0% | 30 | 47 | 77 | 17 | 65 | 82 | 15 | 66 | 81 | 28 | 75 | 103 | 90 | 253 | 343 |
| Females | | | | | | | | | | | | | | | |
| 100% | 27 | 37 | 64 | 10 | 34 | 44 | 18 | 34 | 52 | 14 | 31 | 45 | 69 | 136 | 205 |
| 99%-50% | 54 | 114 | 168 | 63 | 87 | 150 | 42 | 62 | 104 | 47 | 71 | 118 | 206 | 334 | 540 |
| 49%-1% | 27 | 78 | 105 | 39 | 89 | 128 | 56 | 65 | 121 | 39 | 64 | 103 | 161 | 296 | 457 |
| 0% | 39 | 29 | 68 | 20 | 45 | 65 | 31 | 73 | 104 | 32 | 95 | 127 | 122 | 242 | 364 |

Key: Social class 1 = non-manual workers (ABC1), social class 2 = manual workers and unemployed (C2DE), social class 1+2 = ABC1C2DE.

Statistical analysis of question 4 using the chi-square method.

The null hypothesis: Males and females equally avoid wearing the fibres they specified for least wanting to wear next to their skin.
Chi-square value = 3.3 with 3 degrees of freedom.
The null hypothesis is correct.

The null hypothesis: The different age groups equally avoid wearing the fibres they had specified for least wanting to wear next to their skin.
Chi-square value = 89.8 with 9 degrees of freedom.
The null hypothesis is disproved to a very highly significant level.
The 26-54 age groups are more likely to wear the fibres they dislike in 100% form than the younger and older age groups. The older age groups tended to favour blends with less than 50% of the fibre in them, whereas the 16-25 age group showed a slight trend towards wearing the fibre in 100% form.

The null hypothesis: The different social classes equally avoid wearing the fibres they had specified for least wanting to wear next to their skin.
Chi-square value = 9.0 with 3 degrees of freedom.
The null hypothesis is disproved to a significant level.
The ABC1 social class are less likely to wear the fibres they specified as least wanting to wear next to their skin in 100% form and as a blend than the C2DE social class.

## Appendix 2

**Table 8 Question 5: The number of people in each age group and social class which ranked a mohair, lambswool and shetland wool jumper fabric as their first, second or third choice for comfort next to the skin when they handled the fabric, but could not see it.**

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| 1st/mohair | 6 | 17 | 23 | 3 | 7 | 10 | 3 | 5 | 8 | 3 | 6 | 9 | 15 | 35 | 50 |
| 1st/shet. | 7 | 7 | 14 | 5 | 18 | 23 | 7 | 12 | 19 | 6 | 24 | 30 | 25 | 61 | 86 |
| 1st/lambs. | 80 | 146 | 226 | 79 | 132 | 211 | 71 | 122 | 193 | 63 | 130 | 193 | 293 | 530 | 823 |
| 2nd/mohair | 52 | 91 | 143 | 44 | 61 | 105 | 31 | 53 | 84 | 30 | 56 | 86 | 157 | 261 | 418 |
| 2nd/shet. | 29 | 54 | 83 | 28 | 55 | 83 | 36 | 56 | 92 | 25 | 72 | 97 | 118 | 237 | 355 |
| 2nd/lambs. | 8 | 19 | 27 | 7 | 15 | 22 | 7 | 11 | 18 | 8 | 17 | 25 | 30 | 62 | 92 |
| 3rd/mohair | 34 | 64 | 98 | 41 | 95 | 136 | 51 | 94 | 145 | 50 | 106 | 156 | 176 | 359 | 535 |
| 3rd/shet. | 56 | 111 | 167 | 55 | 90 | 145 | 42 | 84 | 126 | 52 | 73 | 125 | 205 | 358 | 563 |
| 3rd/lambs. | 4 | 7 | 11 | 2 | 16 | 18 | 7 | 19 | 26 | 12 | 23 | 35 | 25 | 65 | 90 |
| **Males** | | | | | | | | | | | | | | | |
| 1st/mohair | 3 | 10 | 13 | 3 | 6 | 9 | 3 | 4 | 7 | 3 | 2 | 5 | 12 | 22 | 34 |
| 1st/shet. | .4 | 6 | 10 | 3 | 8 | 11 | 4 | 4 | 8 | 3 | 14 | 17 | 14 | 32 | 46 |
| 1st/lambs. | 36 | 68 | 104 | 38 | 61 | 99 | 29 | 63 | 92 | 28 | 63 | 91 | 131 | 255 | 386 |
| 2nd/mohair | 19 | 40 | 59 | 19 | 26 | 45 | 12 | 23 | 35 | 18 | 32 | 50 | 68 | 121 | 189 |
| 2nd/shet. | 18 | 31 | 49 | 13 | 28 | 41 | 16 | 33 | 49 | 6 | 32 | 38 | 53 | 124 | 177 |
| 2nd/lambs. | 3 | 12 | 15 | 4 | 6 | 10 | 4 | 5 | 9 | 6 | 7 | 13 | 17 | 30 | 47 |
| 3rd/mohair | 21 | 36 | 57 | 22 | 46 | 68 | 21 | 37 | 68 | 18 | 47 | 65 | 82 | 176 | 258 |
| 3rd/shet. | 21 | 49 | 70 | 28 | 42 | 70 | 16 | 47 | 53 | 30 | 36 | 66 | 95 | 164 | 259 |
| 3rd/lambs. | 4 | 6 | 10 | 2 | 11 | 13 | 3 | 6 | 9 | 5 | 13 | 18 | 14 | 36 | 50 |
| **Females** | | | | | | | | | | | | | | | |
| 1st/mohair | 3 | 7 | 10 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 4 | 4 | 3 | 13 | 16 |
| 1st/shet. | 3 | 1 | 4 | 3 | 10 | 13 | 3 | 8 | 11 | 3 | 10 | 13 | 11 | 29 | 40 |
| 1st/lambs. | 44 | 78 | 122 | 41 | 71 | 112 | 42 | 59 | 101 | 35 | 67 | 102 | 162 | 275 | 437 |
| 2nd/mohair | 33 | 51 | 84 | 25 | 35 | 60 | 19 | 30 | 49 | 12 | 24 | 36 | 89 | 140 | 229 |
| 2nd/shet. | 11 | 23 | 34 | 15 | 27 | 42 | 20 | 23 | 43 | 19 | 40 | 59 | 65 | 113 | 178 |
| 2nd/lambs. | 5 | 7 | 12 | 3 | 9 | 12 | 3 | 6 | 9 | 2 | 10 | 12 | 13 | 32 | 45 |
| 3rd/mohair | 13 | 28 | 41 | 19 | 49 | 68 | 30 | 47 | 77 | 32 | 59 | 91 | 94 | 183 | 277 |
| 3rd/shet. | 35 | 62 | 97 | 27 | 48 | 75 | 26 | 47 | 73 | 22 | 37 | 59 | 110 | 194 | 304 |
| 3rd/lambs. | 0 | 1 | 1 | 0 | 5 | 5 | 4 | 13 | 17 | 7 | 10 | 17 | 11 | 29 | 40 |

Key:
Social class 1 = non-manual workers (ABC1), social class 2 = manual workers and unemployed (C2DE), social class 1+2 = ABC1C2DE.
1st, 2nd and 3rd refer to the rank order in which the fibres were put (1st is the
Mohair, shetland (shet.) and lambswool (lambs.) are the fabrics.

**Statistical analysis of question 7 using the Friedman test for multiple comparisons.** (See appendix 2, page 1 for the statistical method)

The null hypothesis: All fabrics were equally preferred.
The null hypothesis is disproved.
The rankings for each group of people is shown below.

| | Mohair | Shetland | Lambswool |
|---|---|---|---|
| Males ABC1 | 2 | 3 | 1 |
| Females ABC1 | 2.5 | 2.5 | 1 |
| Males C2DE | 3 | 2 | 1 |
| Females C2DE | 2.5 | 2.5 | 1 |
| Males ABC1C2DE | 2.5 | 2.5 | 1 |
| Females ABC1C2DE | 2.5 | 2.5 | 1 |
| Males + females ABC1 | 2 | 3 | 1 |
| Males + females C2DE | 2.5 | 2.5 | 1 |
| Males + females ABC1C2DE | 2.5 | 2.5 | 1 |
| Males + females 16-25 | 2 | 3 | 1 |
| Males + females 26-40 | 2.5 | 2.5 | 1 |
| Males + females 41-54 | 2.5 | 2.5 | 1 |
| Males + females 55+ | 2.5 | 2.5 | 1 |

**Table 9 Question 6: The number of people in each age group and social class which ranked two polyester and two silk fabrics as their first, second, third or fourth choice for comfort next to the skin when they handled the fabric, but could not see it.**

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males** | | | | | | | | | | | | | | | |
| 1st/silk | 14 | 21 | 35 | 6 | 13 | 19 | 6 | 15 | 21 | 4 | 18 | 22 | 30 | 67 | 97 |
| 1st/poly. | 16 | 34 | 50 | 14 | 40 | 54 | 20 | 36 | 56 | 21 | 31 | 52 | 71 | 141 | 212 |
| 1st/crepe | 18 | 24 | 42 | 12 | 19 | 31 | 15 | 18 | 33 | 8 | 17 | 25 | 53 | 78 | 131 |
| 1st/Mitr. | 17 | 37 | 54 | 14 | 33 | 47 | 9 | 30 | 39 | 6 | 32 | 38 | 46 | 132 | 178 |
| 2nd/silk | 5 | 13 | 18 | 6 | 11 | 17 | 3 | 9 | 12 | 3 | 8 | 11 | 17 | 41 | 58 |
| 2nd/poly. | 10 | 23 | 33 | 15 | 18 | 33 | 6 | 17 | 23 | 8 | 18 | 26 | 39 | 76 | 115 |
| 2nd/crepe | 6 | 17 | 23 | 9 | 17 | 26 | 9 | 9 | 18 | 3 | 23 | 26 | 27 | 66 | 93 |
| 2nd/Mitr. | 15 | 24 | 39 | 10 | 18 | 28 | 15 | 22 | 37 | 15 | 19 | 34 | 55 | 83 | 138 |
| 3rd/silk | 7 | 23 | 30 | 16 | 14 | 30 | 8 | 17 | 25 | 9 | 30 | 39 | 40 | 84 | 124 |
| 3rd/poly. | 9 | 18 | 27 | 11 | 10 | 21 | 8 | 10 | 18 | 4 | 13 | 17 | 32 | 51 | 83 |
| 3rd/crepe | 12 | 26 | 38 | 15 | 26 | 41 | 8 | 25 | 33 | 13 | 20 | 33 | 48 | 97 | 145 |
| 3rd/Mitr. | 8 | 13 | 21 | 12 | 14 | 26 | 6 | 9 | 15 | 9 | 22 | 31 | 35 | 58 | 93 |
| 4th/silk | 17 | 29 | 46 | 16 | 40 | 56 | 19 | 33 | 52 | 23 | 26 | 49 | 75 | 128 | 203 |
| 4th/poly. | 8 | 11 | 19 | 4 | 10 | 14 | 2 | 11 | 13 | 6 | 20 | 26 | 20 | 52 | 72 |
| 4th/crepe | 7 | 19 | 26 | 8 | 16 | 24 | 4 | 22 | 26 | 15 | 22 | 37 | 34 | 79 | 113 |
| 4th/Mitr. | 3 | 12 | 15 | 8 | 13 | 21 | 6 | 13 | 19 | 9 | 9 | 18 | 26 | 47 | 73 |
| **Females** | | | | | | | | | | | | | | | |
| 1st/silk | 11 | 15 | 26 | 9 | 23 | 32 | 4 | 22 | 26 | 10 | 17 | 27 | 34 | 77 | 111 |
| 1st/poly. | 19 | 33 | 52 | 22 | 44 | 66 | 25 | 30 | 55 | 19 | 35 | 54 | 85 | 142 | 227 |
| 1st/crepe | 10 | 29 | 39 | 11 | 24 | 35 | 9 | 21 | 30 | 12 | 20 | 32 | 42 | 94 | 136 |
| 1st/Mitr. | 13 | 32 | 45 | 13 | 25 | 38 | 11 | 32 | 43 | 17 | 29 | 46 | 54 | 118 | 172 |
| 2nd/silk | 4 | 6 | 10 | 9 | 13 | 22 | 6 | 9 | 15 | 7 | 12 | 19 | 26 | 40 | 66 |
| 2nd/poly. | 9 | 29 | 38 | 9 | 17 | 26 | 16 | 23 | 39 | 12 | 26 | 38 | 46 | 95 | 141 |
| 2nd/crepe | 9 | 16 | 25 | 8 | 17 | 25 | 9 | 17 | 26 | 8 | 19 | 27 | 34 | 69 | 103 |
| 2nd/Mitr. | 20 | 28 | 48 | 17 | 27 | 44 | 19 | 17 | 36 | 12 | 25 | 37 | 68 | 97 | 165 |
| 3rd/silk | 8 | 13 | 21 | 10 | 15 | 25 | 15 | 13 | 28 | 9 | 17 | 26 | 42 | 58 | 100 |
| 3rd/poly. | 9 | 16 | 25 | 9 | 13 | 22 | 4 | 15 | 19 | 6 | 13 | 19 | 28 | 57 | 85 |
| 3rd/crepe | 14 | 27 | 41 | 12 | 26 | 38 | 18 | 22 | 40 | 9 | 29 | 38 | 53 | 104 | 157 |
| 3rd/Mitr. | 10 | 16 | 26 | 8 | 18 | 26 | 10 | 21 | 31 | 8 | 15 | 23 | 36 | 70 | 106 |
| 4th/silk | 26 | 52 | 78 | 16 | 34 | 50 | 24 | 34 | 58 | 18 | 41 | 59 | 84 | 161 | 245 |
| 4th/poly. | 12 | 8 | 20 | 4 | 11 | 15 | 4 | 10 | 14 | 7 | 13 | 20 | 27 | 42 | 69 |
| 4th/crepe | 16 | 14 | 30 | 13 | 18 | 31 | 13 | 18 | 31 | 15 | 19 | 34 | 57 | 69 | 126 |
| 4th/Mitr. | 6 | 10 | 16 | 6 | 15 | 21 | 9 | 8 | 17 | 7 | 18 | 25 | 28 | 51 | 79 |

Table 9 continued.

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| 1st/silk | 25 | 36 | 61 | 15 | 36 | 51 | 10 | 37 | 47 | 14 | 35 | 49 | 64 | 144 | 208 |
| 1st/poly. | 35 | 67 | 102 | 36 | 84 | 120 | 45 | 66 | 111 | 40 | 66 | 106 | 156 | 283 | 439 |
| 1st/crepe | 28 | 53 | 81 | 23 | 43 | 66 | 24 | 39 | 63 | 20 | 37 | 57 | 95 | 172 | 267 |
| 1st/Mitr. | 30 | 69 | 99 | 27 | 58 | 85 | 20 | 62 | 82 | 23 | 61 | 84 | 100 | 250 | 350 |
| 2nd/silk | 9 | 19 | 28 | 15 | 24 | 39 | 9 | 18 | 27 | 10 | 20 | 30 | 43 | 81 | 124 |
| 2nd/poly. | 19 | 52 | 71 | 24 | 35 | 59 | 22 | 40 | 62 | 20 | 44 | 64 | 85 | 171 | 256 |
| 2nd/crepe | 15 | 33 | 48 | 17 | 34 | 51 | 18 | 26 | 44 | 11 | 42 | 53 | 61 | 135 | 196 |
| 2nd/Mitr. | 35 | 52 | 87 | 27 | 45 | 72 | 34 | 39 | 73 | 27 | 44 | 71 | 123 | 180 | 303 |
| 3rd/silk | 15 | 36 | 51 | 26 | 29 | 55 | 23 | 30 | 53 | 18 | 47 | 65 | 82 | 142 | 224 |
| 3rd/poly. | 18 | 34 | 52 | 20 | 23 | 43 | 12 | 25 | 37 | 10 | 26 | 36 | 60 | 108 | 168 |
| 3rd/crepe | 26 | 53 | 79 | 27 | 52 | 79 | 26 | 47 | 73 | 22 | 49 | 71 | 101 | 201 | 302 |
| 3rd/Mitr. | 18 | 29 | 47 | 20 | 32 | 52 | 16 | 30 | 46 | 17 | 37 | 54 | 71 | 128 | 199 |
| 4th/silk | 43 | 81 | 124 | 32 | 74 | 106 | 43 | 67 | 110 | 41 | 67 | 108 | 159 | 289 | 448 |
| 4th/poly. | 20 | 19 | 39 | 8 | 21 | 29 | 6 | 21 | 27 | 13 | 33 | 46 | 47 | 94 | 141 |
| 4th/crepe | 23 | 33 | 56 | 21 | 34 | 55 | 17 | 40 | 57 | 30 | 41 | 71 | 91 | 148 | 239 |
| 4th/Mitr. | 9 | 22 | 31 | 14 | 28 | 42 | 15 | 21 | 36 | 16 | 27 | 43 | 54 | 98 | 152 |

Key:
Social class 1 = non-manual workers (ABC1), social class 2 = manual workers and unemployed (C2DE), social class 1+2 = ABC1C2DE.
1st, 2nd, 3rd and 4th refer to the rank order in which the fibres were put (1st is the most preferred).
Polyester (poly.), silk crepe (crepe), artificial silk polyester (Mitr.) and silk are the fabrics.
Note: The individual values for each choice do not add up to the group total due to shared preferences when two or more fabrics were equally ranked.

Statistical analysis of question 6 using the Friedman test for multiple comparisons. (See appendix 2, page 1 for the statistical test method)
The null hypothesis: All the fabrics are equally preferred.
The null hypothesis is disproved.
The rankings for each group of people is shown below.

| | Silk | Polyester | Crepe | Mitrelle |
|---|---|---|---|---|
| Males ABC1- | 4 | 2 | 2 | 2 |
| Females ABC1 | 3.5 | 1 | 3.5 | 2 |
| Males C2DE | 3.5 | 1.5 | 3.5 | 1.5 |
| Females C2DE | 4 | 1.5 | 3 | 1.5 |
| Males ABC1C2DE | 4 | 1.5 | 3 | 1.5 |
| Females ABC1C2DE | 4 | 1.5 | 3 | 1.5 |
| Males + females ABC1 | 4 | 1.5 | 3 | 1.5 |
| Males + females C2DE | 4 | 1.5 | 3 | 1.5 |
| Males + females ABC1C2DE | 4 | 1.5 | 3 | 1.5 |
| Males + females 16-25 | 4 | 1.5 | 3 | 1.5 |
| Males + females 26-40 | 4 | 1.5 | 3 | 1.5 |
| Males + females 41-54 | 4 | 1.5 | 3 | 1.5 |
| Males + females 55+ | 3.5 | 1.5 | 3.5 | 1.5 |

Appendix 2

Table 10 Question 7: The number of people in each age group and social class which ranked a mohair, lambswool and shetland wool jumper fabric as their first, second or third choice for comfort next to the skin when they handled the fabric and could see it.

| Age group | 16-25 | | | 26-40 | | | 41-54 | | | 55+ | | | 16-55+ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social class | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 | 1 | 2 | 1+2 |
| **Males and Females** | | | | | | | | | | | | | | | |
| 1st/mohair | 7 | 11 | 18 | 7 | 8 | 15 | 4 | 6 | 10 | 4 | 6 | 10 | 22 | 31 | 53 |
| 1st/shet. | 5 | 7 | 12 | 9 | 18 | 27 | 5 | 17 | 22 | 6 | 17 | 23 | 25 | 59 | 84 |
| 1st/lambs. | 79 | 149 | 228 | 69 | 125 | 194 | 61 | 97 | 158 | 56 | 120 | 176 | 265 | 491 | 756 |
| 2nd/mohair | 52 | 87 | 139 | 35 | 60 | 95 | 30 | 42 | 72 | 30 | 39 | 69 | 147 | 228 | 375 |
| 2nd/shet. | 26 | 65 | 91 | 30 | 51 | 81 | 29 | 49 | 78 | 20 | 74 | 94 | 105 | 239 | 344 |
| 2nd/lambs. | 8 | 13 | 21 | 10 | 20 | 30 | 6 | 14 | 20 | 9 | 15 | 24 | 33 | 62 | 95 |
| 3rd/mohair | 33 | 74 | 107 | 46 | 95 | 141 | 51 | 104 | 155 | 49 | 124 | 173 | 179 | 397 | 576 |
| 3rd/shet. | 61 | 100 | 161 | 49 | 94 | 143 | 51 | 86 | 137 | 57 | 78 | 135 | 218 | 358 | 576 |
| 3rd/lambs. | 5 | 10 | 15 | 9 | 18 | 27 | 18 | 41 | 59 | 18 | 34 | 52 | 50 | 103 | 153 |
| **Males** | | | | | | | | | | | | | | | |
| 1st/mohair | 7 | 7 | 14 | 4 | 6 | 10 | 4 | 4 | 8 | 3 | 4 | 7 | 18 | 21 | 39 |
| 1st/shet. | 4 | 6 | 10 | 6 | 9 | 15 | 2 | 8 | 10 | 2 | 6 | 8 | 14 | 29 | 43 |
| 1st/lambs. | 31 | 69 | 100 | 34 | 59 | 93 | 27 | 49 | 76 | 27 | 62 | 89 | 119 | 239 | 358 |
| 2nd/mohair | 21 | 36 | 57 | 20 | 26 | 46 | 15 | 21 | 36 | 14 | 24 | 38 | 70 | 107 | 177 |
| 2nd/shet. | 11 | 38 | 49 | 14 | 24 | 38 | 12 | 30 | 42 | 9 | 36 | 45 | 46 | 128 | 174 |
| 2nd/lambs. | 7 | 8 | 15 | 5 | 11 | 16 | 4 | 5 | 9 | 4 | 8 | 12 | 20 | 32 | 52 |
| 3rd/mohair | 15 | 43 | 58 | 20 | 46 | 66 | 17 | 49 | 66 | 22 | 54 | 76 | 74 | 192 | 266 |
| 3rd/shet. | 28 | 42 | 70 | 24 | 45 | 69 | 22 | 36 | 58 | 28 | 40 | 68 | 102 | 163 | 265 |
| 3rd/lambs. | 5 | 9 | 14 | 5 | 8 | 13 | 5 | 20 | 25 | 8 | 12 | 20 | 23 | 49 | 72 |
| **Females** | | | | | | | | | | | | | | | |
| 1st/mohair | 0 | 4 | 4 | 3 | 2 | 5 | 0 | 2 | 2 | 1 | 2 | 3 | 4 | 14 | 14 |
| 1st/shet. | 1 | 1 | 2 | 3 | 9 | 12 | 3 | 9 | 12 | 4 | 11 | 15 | 11 | 30 | 41 |
| 1st/lambs. | 48 | 80 | 128 | 35 | 66 | 101 | 34 | 48 | 82 | 29 | 58 | 87 | 146 | 252 | 398 |
| 2nd/mohair | 31 | 51 | 82 | 15 | 34 | 49 | 15 | 21 | 36 | 16 | 15 | 31 | 77 | 121 | 198 |
| 2nd/shet.- | 15 | 27 | 42 | 16 | 27 | 43 | 17 | 19 | 36 | 11 | 38 | 49 | 59 | 111 | 170 |
| 2nd/lambs. | 1 | 5 | 6 | 5 | 9 | 14 | 2 | 9 | 11 | 5 | 7 | 12 | 13 | 30 | 43 |
| 3rd/mohair | 18 | 31 | 49 | 26 | 49 | 75 | 34 | 55 | 89 | 27 | 70 | 97 | 105 | 205 | 310 |
| 3rd/shet. | 33 | 58 | 91 | 25 | 49 | 74 | 29 | 50 | 79 | 29 | 38 | 67 | 116 | 195 | 311 |
| 3rd/lambs. | 0 | 1 | 1 | 4 | 10 | 14 | 13 | 21 | 34 | 10 | 22 | 32 | 27 | 54 | 81 |

Key:
Social class 1 = non-manual workers (ABC1), social class 2 = manual workers and unemployed (C2DE), social class 1+2 = ABC1C2DE
1st, 2nd and 3rd refer to the rank order in which the fibres were put (1st is the most preferred).
Mohair, shetland (shet.) and lambswool (lambs.) are the fabrics.

Statistical analysis of question 5 using the Friedman test for multiple comparisons.
(See appendix 2, page 1 for the statistical method)

The null hypothesis: All fabrics are equally preferred.
The null hypothesis is disproved.

The rankings for each group of people is shown below.

| | Mohair | Shetland | Lambswool |
|---|---|---|---|
| Males ABC1 | 2.5 | 2.5 | 1 |
| Females ABC1 | 2.5 | 2.5 | 1 |
| Males C2DE | 2.5 | 2.5 | 1 |
| Females C2DE | 2.5 | 2.5 | 1 |
| Males ABC1C2DE | 2.5 | 2.5 | 1 |
| Females ABC1C2DE | 2.5 | 2.5 | 1 |
| Males + females ABC1 | 2.5 | 2.5 | 1 |
| Males + females C2DE | 2.5 | 2.5 | 1 |
| Males + females ABC1C2DE | 2.5 | 2.5 | 1 |
| Males + females 16-25 | 2.5 | 2.5 | 1 |
| Males + females 26-40 | 2.5 | 2.5 | 1 |
| Males + females 41-54 | 2.5 | 2.5 | 1 |
| Males + females 55+ | 2.5 | 2.5 | 1 |

Appendix 3

TABLE 1

The number of answers to each question of the wet cling questionnaire when the fabrics in set 4 were assessed
Each fabric was worn as a tee-shirt by ten subjects before and after the garment was washed

| Fibre code | | | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|
| Question | | | | | | |
| 1 | Sport | Jogging | 10 | 10 | 12 | 10 |
| | | Squash | 6 | 6 | 6 | 6 |
| | | Weight training | 2 | 2 | 0 | 2 |
| | | Other | 2 | 2 | 2 | 2 |
| 2 | Spare fabric | 1 inch | 10 | 8 | 8 | 8 |
| | | 1.5 inches | 4 | 6 | 6 | 4 |
| | | 2 inches | 2 | 2 | 2 | 4 |
| | | 2.5 inches | 2 | 0 | 2 | 0 |
| | | 3 inches | 2 | 4 | 2 | 4 |
| 3 a,b,c | Additional clothing | Yes | 0 | 0 | 0 | 0 |
| | | No | 20 | 20 | 20 | 20 |
| 4 | Shirt tucked-in | Yes | 18 | 18 | 18 | 16 |
| | | No | 0 | 2 | 2 | 4 |
| 5 | How sweaty you felt | Damp | 2 | 4 | 2 | 2 |
| | | Wet | 6 | 8 | 6 | 6 |
| | | Dripping wet | 12 | 8 | 10 | 12 |
| 6 a | Fabric absorption | Yes | 18 | 16 | 18 | 18 |
| | | No | 2 | 4 | 2 | 2 |
| b | | Immediate | 0 | 6 | 2 | 4 |
| | | Mod. quick | 10 | 10 | 10 | 8 |
| | | Slow | 8 | 0 | 6 | 6 |
| | | Nil | 2 | 4 | 2 | 2 |
| 7 a | Wet cling | Yes | 10 | 4 | 12 | 12 |
| | | No | 10 | 16 | 8 | 8 |
| b | Wet cling force | Strong | 2 | 4 | 2 | 0 |
| | | Mod. strong | 10 | 0 | 2 | 2 |
| | | Weak | 0 | 0 | 8 | 10 |
| 8 | Wettest surface | Inside | 12 | 8 | 14 | 12 |
| | | Outside | 2 | 6 | 0 | 0 |
| | | Equal | 6 | 6 | 6 | 8 |
| 9 | Notice fabric cling | Often | 8 | 0 | 0 | 0 |
| | | Sometimes | 2 | 6 | 4 | 4 |
| | | Not really | 6 | 8 | 10 | 10 |
| | | Never | 4 | 6 | 6 | 6 |
| 10 | Discomfort | Yes | 8 | 4 | 0 | 0 |
| | | Sometimes | 2 | 0 | 4 | 8 |
| | | Not really | 8 | 2 | 12 | 8 |
| | | No | 2 | 14 | 4 | 4 |
| 11 | Post-exercise chill | Yes | 6 | 4 | 6 | 4 |
| | | No | 14 | 16 | 14 | 16 |
| a | | Outside | 4 | 4 | 6 | 4 |
| | | Inside | 2 | 0 | 0 | 0 |
| b | Additional clothing | Yes | 0 | 2 | 2 | 0 |
| | | No | 20 | 18 | 18 | 20 |
| 12 a | Overall comfort | Very good | 0 | 2 | 2 | 1 |
| | | Good | 3 | 5 | 3 | 5 |
| | | Moderate | 3 | 2 | 4 | 3 |
| | | Poor | 4 | 1 | 1 | 1 |
| | | Very poor | 0 | 0 | 0 | 0 |
| b | Wet cling comfort | Very good | 3 | 3 | 1 | 0 |
| | | Good | 1 | 3 | 3 | 5 |
| | | Moderate | 2 | 3 | 4 | 2 |
| | | Poor | 3 | 1 | 2 | 2 |
| | | Very poor | 1 | 0 | 0 | 1 |
| c | Post-exercise chill comfort | Very good | 1 | 4 | 3 | 2 |
| | | Good | 5 | 5 | 6 | 5 |
| | | Moderate | 3 | 1 | 1 | 3 |
| | | Poor | 1 | 0 | 0 | 0 |
| | | Very poor | 0 | 0 | 0 | 0 |

# COMFORT IN CASUALS

T-shirts and tops in a variety of fibres and fabrics have been assessed for comfort in wear by Julia Smith. Tight fit and tickle proved more problematic than wet cling.

The 'sensorial' comfort of clothing (the comfort or discomfort associated with how a fabric or garment 'feels' next to the skin) has been a neglected science.

It is unquestionably a very difficult quantity to assess and define scientifically. Most of the work on clothing comfort up until now has concentrated on thermophysiological comfort, of which a reasonable level of understanding and background information has been obtained. On the other hand, the amount of research work that has been carried out on 'sensorial' comfort of clothing is very small, although the type of skin sensations produced by next-to-skin apparel are a major factor in determining the overall comfort of a garment.

The type of skin sensations that are encountered range from the relatively mild tickle and wet-cling sensations through to the more severe discomfort associated with an allergic reaction.

Here I outline some recent work at Shirley Institute to assess and quantify sensorial comfort and describe the main factors that influence it.

A necessary step was to determine the specific skin sensations caused by next-to-skin apparel and to decide on a glossary of terms to describe these sensations. The physical and physiological factors that influence each sensation were then analysed and, finally, simple test procedures were developed for evaluating a fabric or garment for a particular discomfort sensation (their development is not described here).

## Work in hand

A major project is being undertaken as part of the second Textile Research Programme of the European Economic Community on garment physiology and construction. The factors that are considered to be of prime importance in determining the functional comfort of garments are warmth, the dissipation of perspiration and sweat, and fit.

Shirley Institute's part in this project is concerned with the additional factors associated with skin contact in next-to-skin apparel, the 'tactile' or 'sensorial' comfort of clothing. The Institute's work is funded in part by the European Economic Community and in part by the Department of Trade and Industry via The Textile and Other Manufactures Requirements Board).

The aim of the overall project is to develop test procedures, comfort models and formulae to enable a complete evaluation of the comfort characteristics of apparel to be made by means of a restricted number of comparatively low-cost laboratory measurements. This will help to accelerate the rate of product development in textiles and clothing and give the manufacturer an added assurance of product quality and serviceability for a specific end-use.

It will reduce the possibility of a product being marketed which for one reason or another is uncomfortable to wear for a particular end-use. The result therefore will be an improved possibility of consumer acceptance of a particular fabric or garment.

## Importance of psychology

So how do we measure next-to-skin comfort and what do we mean by this term? The *Oxford English Dictionary* defines comfort as 'freedom from pain, well-being'. In the context of clothing it is considered to be a neutral sensation, when a person is physiologically *unaware* of the garments being worn.

Comfort is condition dependent on many factors. A knowledge of range of disciplines such as textile technology, physiology, psychology, physics and dermatology will lead to a basic understanding of the underlying factors governing garment comfort. However, psychology is undoubtedly the over-riding factor that influences the perception of a sensation. It can over-ride sensations of discomfort, especially in the case of fashion garments or, alternatively, it can emphasize minor discomfort sensations.

In extreme cases when a prejudice or high mental stress situation is apparent, allergic reaction can be the result. It is essential therefore that to investigate the type and severity of discomfort sensations scientifically, the psychological factors, such as fashion and individual prejudice, should be minimized.

## Terminology

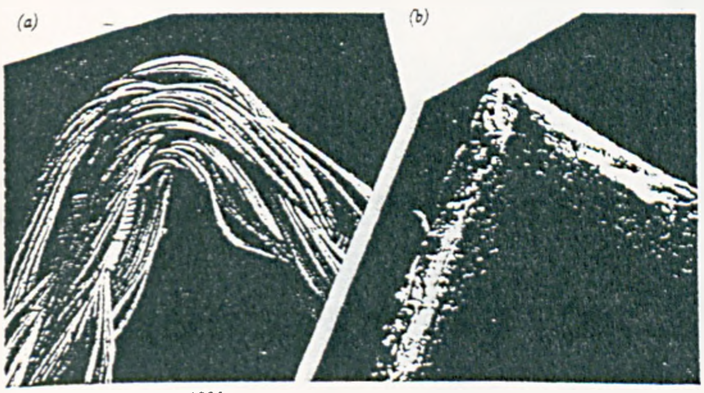
The type of tactile sensations registered by the body and the terminology used to describe these sensations were surveyed in two main ways: by a review of published literature, and by extensive wearer trials.

The literature survey revealed a large quantity of descriptive terms available to define the handle of a fabric. There were a few specific terms to describe next-to-skin sensations caused by fabrics; these had been selected for use in wearer trials from a list of terms relating to handle, or when a specific well-known discomfort sensation was being investigated.

An overview of the types of sensation caused by next-to-skin apparel was not in evidence. A few researchers had discovered that handle was not a reliable method of determining in-wear comfort.

*Electron micrographs showing the relative sharpness of the corners of centre-fold labels (X 20). (a) Typical woven edge. (b) Typical heat-sealed edge.*

(a) (b)



# Casual Clothing

For the Institute's wearer trials it was necessary to have an easily understood but precise glossary of terms available so that any discomfort sensations would be recorded accurately.

Initially, a large selection of terms used to describe handle were assessed by Shirley Institute staff; it should be noted that some of the staff were non-technical workers. They were asked to select the words they would prefer to use to describe the types of discomfort sensations that they have felt from garments. They also briefly defined each word selected.

From this exercise it was evident that the sensations felt during the wearing of a fabric are considerably fewer than those observed during the assessment of handle. There was a definite preference for certain words, although there was some confusion as to their exact definition.

The most common terms were selected and each term was associated with a simile; for example, prickle (pin pricks), tickle (like a feather), scratchy (sand-paperish). This revised list of terms was issued to the staff a second time, when it proved to be acceptable and more informative. This terminology was used, where appropriate, in the wearer-trial questionnaires.

The terms used in the wearer trial were: local fit; tickle (like a feather); prickle (pin pricks); scratchiness (sand-paperish); wet cling; tack cling; fibre shedding; local irritation.

## Wearer-trials

The objective of the wearer-trials at the Shirley Institute was to determine the range, severity, frequency and causes of skin sensations experienced when wearing garments next to the skin. Not only the fabric is considered, but any part of the garment that is touching the body, for instance, labels, seams, 'local fitting' areas (such as waistbands) and trimmings.

The main wearer-trial involved 20 subjects, 10 men and 10 women ranging in age from 20 to 60 years, and covered a range of activities.

The subjects were required to wear and assess knitted fabrics as a tee-shirt or vest; woven fabrics were included as slip-on-tops. The 22 fabrics in the wearer trial covered a wide range of fibre and fabric types, all commercially available for next-to-skin apparel.

Where possible the fabrics were made up into garments at the Institute, so that a standard sizing system was achieved.

All the fabrics were worn at least twice by each subject, once before and once after the garment was washed. The subjects were not told the fibre content of the fabrics, and where possible the fabrics were white. This reduced the influence of preconceived ideas on fibre properties and fashion.

Two questionnaires were issued when a trial garment was worn by a subject: the first to record initial reactions and the second longer-term reactions and opinions. After the garment was washed the second questionnaire was repeated by the same subject.

The first questionnaire analysed the subject's response to the handle and general appearance of the fabric and garment. Any discomfort while wearing the garment was also recorded. Also, an assessment of comfort after wearing the garment for five minutes was recorded. The second questionnaire records and analyses any discomfort sensations registered after wearing the garment for a number of hours.

It was clear from the first questionnaire that the success rate for guessing the fibre type of a garment was very low, with a nil success rate with some fabrics. The wearer tended to look at the fabric as a whole and generalize its properties: was it smooth, rough or hairy, shiny or dull, made of a natural or a man-made fibre?

A fabric's handle as assessed by feeling with the hands proved unreliable as a guide in the prediction of the sensorial comfort of a garment or fabric. Observations of handle were able to detect differences between fabrics associated with fabric structure, drape, and fabric finish; but not, perhaps surprisingly, hairiness.

However, the same fabrics worn as next-to-skin garments could not readily be differentiated by sensorial comfort in respect of differences in fabric structure, drape or fabric finish, whereas fabric hairiness is a major factor in determining sensorial comfort.

It is evident that handle and aesthetics are of little value in the prediction of how sensorially comfortable a fabric is likely to be when worn next to the skin. This conclusion is perhaps not unexpected because the fingertips have a higher density of nerve endings than the general body surface. The threshold for touch in the fingertips is $2g/mm^2$, whereas over the forearm it is $33g/mm^2$ and on the abdomen it is $26g/mm^2$.

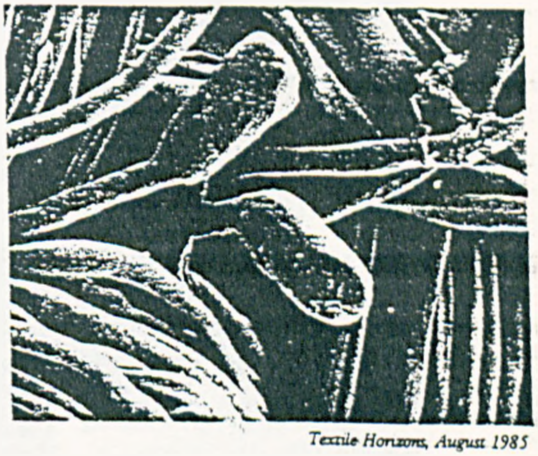
When a fabric is being handled conventionally the thumb flattens any protruding surface fibres to give the impression of a smooth, soft, resilient fabric. During the assessment of handle a conscious effort is being made to register every tactile sensation, and because of the high density of nerve-endings in the fingertips an accurate profile of the fabric surface can be achieved.

When a garment is donned, the brain will register the change in the conditions for the first few minutes, after which time equilibrium will be reached, assuming there are no major discomfort sensations.

Four methods of analysis are suggested to assess subjectively how a particular fabric is likely to feel when work next to skin. They are listed below in increasing order of preference — the fourth is the most likely to represent sensations felt when wearing a fabric next to the skin.

*A fabric surface profile showing surface hairiness. This fabric caused discomfort due to tickle and fibre shedding (X 8).*

*Polyester/cotton fabric showing fused polyester ends (formed during singeing) which can cause skin reddening (X 550).*



# Casual Clothing

- Take one layer of fabric between finger and thumb. The thumb should be in contact with the fabric surface to be worn next to the skin (ie inside surface). Rub the fingers and thumb over the fabric surface. This will give an indication of the fabric's 3-dimensional structure, of the finishes used and the fabric stiffness. Now compress the fabric between thumb and finger to analyse the 3-dimensional structure that will be felt under pressure.
- Lay the fabric on a flat surface, inside face upwards. Pass the fingertips lightly over the fabric. The most important factors to note are the number, length and bending properties of any protruding fibres.
- Place a strip of fabric over the back of the hand, inside face downwards. Pull the fabric slowly over the hand. This will give an indication of the amount of hairiness, scratchiness, and prickliness felt in wear.
- Place the fabric on a flat surface, inside face upwards. Pass the inside of the lower arm slowly over the fabric. Use approximately half the weight of the lower arm as load. This is a particularly useful method of analysing next-to-skin comfort. An indication of the initial cold feel, prickliness, hairiness and abrasion properties of a cloth can be obtained.

A combination of all four methods is suggested for preliminary analysis of a cloth. However, it must be remembered that these methods are only effective up to a point. Whereas tickle, initial cold, feel, scratchiness and prickliness may be indicated from this procedure, wet cling, tacky cling, fibre-shedding, label, seam and local fit properties cannot be predicted to any degree.

## Sensations identified

The Shirley Institute wearer trail established the following as the major discomfort sensations experienced by the wearer of next-to-skin apparel.

*Local tightness* or *excessive looseness* caused by poor garment fit. This was overriding discomfort sensation.

*Tickle*, caused by fabric hairiness and influenced by garment fit.

*A prickly sensation* caused by coarse and therefore stiff fibres protruding from the fabric surface.

*'Wet cling'* and *'tacky cling'*; wet cling is caused by sweating; tacky cling is associated with the presence of damp and sticky sweat residues on the skin. A main factor influencing the amount of cling is the area of fabric in contact with the skin, which is influenced by the fabric structure.

*Local irritation* caused by sewn-in garment labels and to a lesser degree by abrasion associated with seams. Most of the cases of 'label prickle' have been attributed to the hard, sharp corners that are sometimes present on labels, the edges of which are heat-sealed.

*Skin and nasal irritation* caused by loose fibres that have been released from the fabric surface. These loose fibres also attach themselves to other garments in an unsightly manner that causes annoyance.

*Skin abrasion*, mainly attributed to physical activity when the relative movement between fabric and skin is frequent. The presence of sweat aggravates the situation, making abrasion of the skin easier.

*Initial cold feel* when a garment is first donned. This discomfort sensation is associated with cold weather clothing and is predominantly influenced by fabric surface contact areas with the skin.

*Static electrical effects* proved to be a minor discomfort sensation. However the effect of a fabric visibly sparking and clinging to the body can be unpleasant and therefore detrimental to a person's comfort.

*Allergies*: although no cases of an allergic reaction were recorded by the wearer trial subjects, this is obviously an area of importance to the study of sensorial garment comfort. They can be associated with many factors, physiological, psychological and physical; however, the presence of excess levels of certain chemical finishes on a fabric surface are of particular interest in connection with clothing allergies.

Smaller and more specific trials were conducted in addition to the main wearer trials. The aim was to identify more fully the discomfort thresholds and to identify relationships between garment, fabric and physiological properties for a particular discomfort sensation. The results have been used as a basis for the development of test procedures to assess the sensorial comfort of fabrics.



In decreasing order of severity for the discomfort sensations perceived in the Shirley Institute wearer trial were:

**Most uncomfortable**

Tight fit
Prickle, Scratchiness
Tickle
Label irritation Fibre shedding
Tacky cling
Wet cling
– Initial cold feel

**Least uncomfortable**

In a situation when more than one discomfort sensation was experienced when wearing a garment, counter-stimuli influence the sensation acknowledged. This means that the stimuli causing the most discomfort will be noticed; the other sensation(s) will be forgotten unless consciously thought about. For instance, if a fabric is clinging to the skin due to sweat, and is prickly with a tight fitting neckband, the tight neckband would probably be predominantly the factor to be noticed; the prickle sensation would probably become more obvious in times of active body movements, whereas the wet cling, being a relatively minor discomfort sensation in this instance, would probably not be noticed.

## Public questionnaire

A public questionnaire to help to determine the discomfort properties associated with particular fibres and fabrics was issued to 1000 men and women in a range of ages and social classes in the north west of England. The results obtained so far have indicated that the main fibres the public tends to associate with feelings of discomfort against the skin are wool, mohair, and nylon; the most acceptable fibre in this respect is cotton.

Order of severity for the discomfort sensations indicated by the public questionnaire was

Tickle ≅ Tight fit > > Wet cling

The interviewees were invariably unable to associate the fibres with specific comfort or discomfort sensations. Perhaps not surprisingly, few people are fully aware of the differences between the various man-made fibres, with many instances of people commenting that man-made fibres are all hydrophobic.

Despite the strong preferences that were sometimes stated for fibre type for next-to-skin apparel, consumers do not take note of the fibre composition when purchasing a new garment. The label is mainly referred to for the size and in a few cases for the name of the garment manufacturer and for the washing instructions.

One finding (as determined by the public questionnaire) of considerable importance to the apparel industry is that over 65% of the population cut the label out of next-to-skin apparel. This is for two main reasons: sensorial discomfort if the label corner sticks into the skin, and the psychological discomfort mainly due to the label hanging outside the garment. Prestigious labels are rarely removed, regardless of any sensorial discomfort.

When the public was asked to rank tight fit, tickle and wet cling in order of discomfort, it was discovered that tickle was assessed as being marginally more objectionable than a tight fitting garment. Wet cling was nearly always considered least objectionable.

## And next?

Both the Shirley wearer trials and the public questionnaire have emphasized the importance of the apearance of the fabric and its handle in creating the right image for a garment: is the fabric smooth or hairy, man-made or natural? The response to the image will be to associate the effect with past experience, which will ultimately influence the wearer's judgement of garment comfort.

The major discomfort sensations caused by next-to-skin apparel have been indentified, and a standard terminology that has been successfully used to describe these sensations has been established.

The next stage of the project is to identify more fully the factors and conditions that influence each major discomfort sensation. In particular to describe threshold values for discomfort for each sensation and to design and develop a series of simple, low-cost laboratory tests to rank or categorize a fabric's suitability for a particular end-use. Encouraging progress has been made in both of these areas.

The results of the project will be reported in a European Textile Research Symposium in Luxembourg on 18–19 September this year. The Symposium will present the results of the entire second EEC Textile and Clothing R&D Programme, of which the Institute is part. The full results and conclusions of the Institute project will be published in due course. ■

# PERCEIVED COMFORT

**Despite sophisticated scientific work aimed at offering the consumer improved clothing with improved comfort, it seems that the image of the fibre, related to handle and appearance of fabric, is still the major factor for the consumer. Julia Smith, now at Courtaulds Research, describes a study by the Shirley Institute to determine how the public perceives fibres and fabrics for underwear and innerwear.**

Designers have an ever-increasing number of combinations of fibre types, yarn and fabric constructions available, and use a wide variety of garment styles to make their product that bit different and, they hope, more popular than that of their competitors. Which materials do they use? How important is their choice? What will the consumer think of the garment?

Fabric construction and garment design are both extremely important for physiological comfort, because they determine the majority of the most objectionable sensations such as skin abrasion, tight fit, tickle, and so on. The perceived differences in the discomfort due to the fibre type becomes increasingly significant to a wearer as the level of moisture on the skin increases. In such a situation, the ability of a garment assembly to wick away this moisture is important to overall comfort.

The wickability of an assembly is by no means dependent on fibre properties alone. The garment design, fabric construction and fibre type each have a large influence on this property, but it must be stressed that they are by no means independent of one another.

## Unease Objectified

A recent scientific study was carried out at the Shirley Institute to determine the main discomfort sensations experienced while wearing next-to-skin apparel. The factors influencing these sensations were investigated and the ways in which the physical properties of the garment, fabric and/or the fibre could be optimized for particular end-use were evaluated. The work was described in *Textile Horizons*, August 1985, pages 35–38.

The project was funded partly by the EEC as part of the second Textile Research Programme and partly by the UK Department of Trade and Industry. The object was to devise laboratory tests to measure or characterize the discomfort sensations associated with next-to-skin apparel. As a result, the Institute is now in a position to apply these tests to clients' samples and to give guidance on the suitability of fabrics for use in next-to-skin garments.

## Mind Matters

It was clear very early on in the study that personal preferences and prejudices could outweigh the potential physiological comfort/discomfort properties of a garment. A prejudice towards a garment usually originates from a knowledge of discomfort previously experienced from similar garments. Alternatively, the garment may be unfashionable or unsuitable for an occasion and it may not convey the 'right image'. This attitude can explain the sometimes otherwise restricting clothes the fashion-conscious can 'comfortably' wear: a situation where the psychological comfort over-rides any physiological discomfort.

## Public Perception of Fibres

A questionnaire was devised by the Shirley Institute and formed the basis of a survey conducted by professional market researchers. It was designed to discover how the general public perceive the various commercial fibres and fabrics that are used for underwear and innerwear, and to determine the properties that they associate with them.

One thousand people, forming a cross-section of the population, were interviewed in late summer, 1984. Men and women ranging from 16 years and above, spanning all ranges of social class, completed the questionnaire in the north-west of England. The answers showed that the vast majority of the population have distinct preferences and dislikes for particular fibres that they would choose to wear next to their skin and also that any garment discomfort was invariably associated with the fibre type alone.

One indication of the extent of individual preferences and prejudices is the trouble a consumer will go to in discovering the fibre content of a garment when purchasing. Table 1 shows the percentage of people who look at garment labels to determine the fibre type and how particular they are about choosing the fibres they wear next to the skin when purchasing a garment. The number of people always, sometimes and never looking for the fibre type are roughly equal, so that a large proportion of fibre analysis and in-wear comfort assessment is done by the more dubious methods of sight and handle.

People usually carry a picture in their minds of what the most common fibres 'should' look like. For example, cotton is usually assumed to be dull and soft, silk is very smooth and lustrous, and nylon is smooth and shiny; thus the majority of the analysis of a fabric is done before it is handled. The label is mainly referred to for the size of the garment and less frequently the name of the garment manufacturer and the washing instructions.

The public questionnaire also revealed, rather unexpectedly, that over 65% of those people who were interviewed tend to cut the labels out of garments that they wear next to the skin. This was attributed to two main factors, either discomfort due to the label corner sticking into the skin, or the tendency of the label to hang outside the garment. From additional comments from the interviewees, it was also clear that prestigious labels were very rarely removed.

When interviewees were shown a list of the common fibres used in garments worn next to the skin and asked to rank the three they liked the most, cotton was invariably the first choice. However, few people could say why they preferred it. When the question was rephrased to discover any specific preferences for hot and cold weather, cotton was the clear favourite for both, though wool came a close second for cold weather. Reasons for the choice in hot weather were coolness, followed by moisture absorption and washability. In cold weather cotton was chosen primarily for warmth, with 'comfort' being the second, but less important, property involved in the choice.

**Table 1. A comparison of the people who look at garment labels to determine fibre type and how particular they claim to be about the fibres they will wear next to the skin.**

| | *Look for fibre type* | | |
|---|---|---|---|
| | *Always* | *Sometimes* | *Never* |
| 'Very particular' | 29% | 9.5% | 4.5% |
| 'Not really particular' | 8.5% | 20.5% | 13% |
| 'Will wear anything' | 1% | 3% | 11% |

# Functional Fabrics

Table 2. Ranking of fabrics for jumpers and blouses, seen(2) and unseen(1) (numbers of people making the choice).

| (1) | First choice | | | Second choice | | | Third choice | | |
|---|---|---|---|---|---|---|---|---|---|
| | M | S | L* | M | S | L | M | S | L |
| A | 50 | 86 | 822 | 419 | 355 | 92 | 535 | 563 | 90 |
| B | 53 | 84 | 756 | 375 | 344 | 95 | 576 | 576 | 153 |

| (2) | First choice | | | | Second choice | | | | Third choice | | | | Fourth choice | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TS | CS | LP | MP* | TS | CS | LP | MP | TS | CS | LP | MP | TS | CS | LP | MP |
| A | 208 | 439 | 267 | 350 | 124 | 256 | 196 | 303 | 224 | 168 | 302 | 199 | 448 | 141 | 239 | 152 |
| B | 170 | 439 | 259 | 359 | 113 | 261 | 204 | 299 | 281 | 181 | 259 | 186 | 440 | 123 | 282 | 160 |

Note: The 'first choice' refers to the fabric the interviewee thought would be the most comfortable to wear next to the skin.
* See text for key to fabric types.

## Judging Fabrics

Two sets of commercially-available fabric samples were selected for use in the public questionnaire to determine the importance of sight in the prediction of comfort/discomfort when a fabric is handled. The first set contained three typical jumper fabrics, one of mohair (M), one of shetland wool (S) and one of lambswool (L). The second set contained typical blouse fabrics including two silk, a plain weave tussah (TS) and a fine crepe fabric (CS), and two polyester samples, a light (LP) and a medium (MP) weight plain-weave fabric. The polyester fabrics had been designed to look like silk.

The interviewee was asked to put the samples within each set in order of preference to be worn next to the skin. Initially each set was presented so that the interviewees could not see the samples they were handling, then different swatches of the same fabrics were assessed by handle while they could see them. The order of presentation of the fabrics was varied between individuals and also between the two assessments of an interviewee.

The results in Table 2 show that there is little, or more commonly, no change in the ranking order of each of the fabrics when they are assessed with and without seeing the fabric. These results may be misleading when it is considered that, in set 1, 69% of people made at least two rank changes and, in set 2, 76% of people made rank changes between seen and unseen fabrics. The two groups that changed their minds the most between A and B were the 16–25-year age-group and also the lower middle and lower social classes; surprisingly, there were no notable differences in ranking between the sexes.

One of the main inferences that can be made from these results is that the younger age groups and the lower classes are more prone to base their assessment of in-wear comfort on the appearance rather than the handle of a fabric.

## Ranking Sensations

The interviewees were asked to rank three specified discomfort sensations in order of the most objectionable to the least objectionable to tolerate while wearing a garment. The rank order was the same for all the age-groups and social classes and both sexes. Tickle was considered to be the most unpleasant sensation, followed by tight fit; almost invariably wet cling was the least unpleasant. It should be noted that the respondents were concerned with everyday wear, and not with garments used for sports or athletics. The Shirley Institute wearer trials had discovered that tight fit could be more uncomfortable and painful than tickle, but agreed with the public's ranking of wet cling. It is assumed that the public had disregarded the painful and restrictive nature of garment fit as being inevitable if the wrong size was chosen, and therefore excluded extreme situations when they ranked the sensations.

## The Final Choice

To conclude, therefore, although the public are aware of discomfort from clothing they will invariably associate the sensation with the fibre type. The questionnaire has shown that relatively few people will actually look at a garment label to determine the fibre type and that the image the fabric portrays is very important. Therefore, when designers select a fabric for a garment style they should carefully consider what the fabric looks like, the market sector it is aimed at, whether it is fashionable, traditional or functional, the requirements of the situation for which the garment is likely to be used, and the in-wear comfort, both physiological and psychological, to avoid discomfort and future prejudice. ■

Appendix 4

# The comfort of clothing

Julia E. Smith

All of us at some time have felt uncomfortable in our clothing. We can all remember the times we attended a function in the wrong outfit or one which was uncomfortably tight.

How do we choose our clothes, do we take comfort into account and, if so, in what ways?

During the past few years there have been increasing public awareness of the fibres and fabrics we are wearing next to the skin and a general move away from man-made fibres towards the natural fibres. These trends can be linked to the very popular health food and fitness phase. Leisure activities and sports have become more popular and people are more aware of the way in which not only food but fabrics affect their wellbeing.

In this article we shall look at the aspects the typical consumer considers when assessing a garment before purchase: aesthetics, handle, fit, suitability for the required end-use, and any past experience of similar fabrics or garment styles. We shall outline two types of negative sensation, psychological and physiological discomfort, experienced when wearing a garment, and finally discuss the best methods of assessing a fabric or garment with respect to comfort.

## What is comfort?

Comfort is defined in the Oxford English Dictionary as "freedom from pain, wellbeing". In the context of general clothing assessment, comfort is a neutral sensation, when we are physiologically and psychologically unaware of the clothing we are wearing. There are physiological and psychological *positive* comfort sensations but these tend to be more individualistic and less frequently noticed when we are wearing a garment than are the discomfort sensations. Therefore, in the assessment of a fabric or garment for a particular end-use, the comfort of that product for the general population is considered to be neutral.

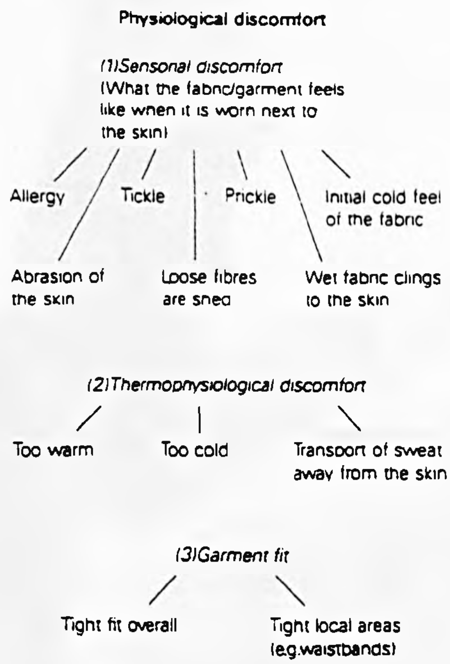
Discomfort, with which this article will mainly be concerned, is a situation when we are conscious of the garments we are wearing and the experience is unpleasant. Such discomfort sensations can range from the extreme case of an allergic reaction, through to less painful sensations such as being unhappy in clinging fabric or feeling awkward when we have odd socks on at a job interview. We can thus distinguish two major types of discomfort sensation : first, psychological discomfort when the clothing we are wearing is inappropriate for us personally or for an occasion; and secondly, physiological discomfort when the body feels uncomfortable, as for example when we feel too cold, have an allergic reaction, feel itchy, or the garment is too tight. Both psychological and physiological discomfort can be subdivided into more specific forms of discomfort, as set out in Diagrams 1 and 2.

## Approach to purchasing a garment

When a consumer considers purchasing a garment, a series of basic steps is followed, as set out below, with

*Diagram 1*

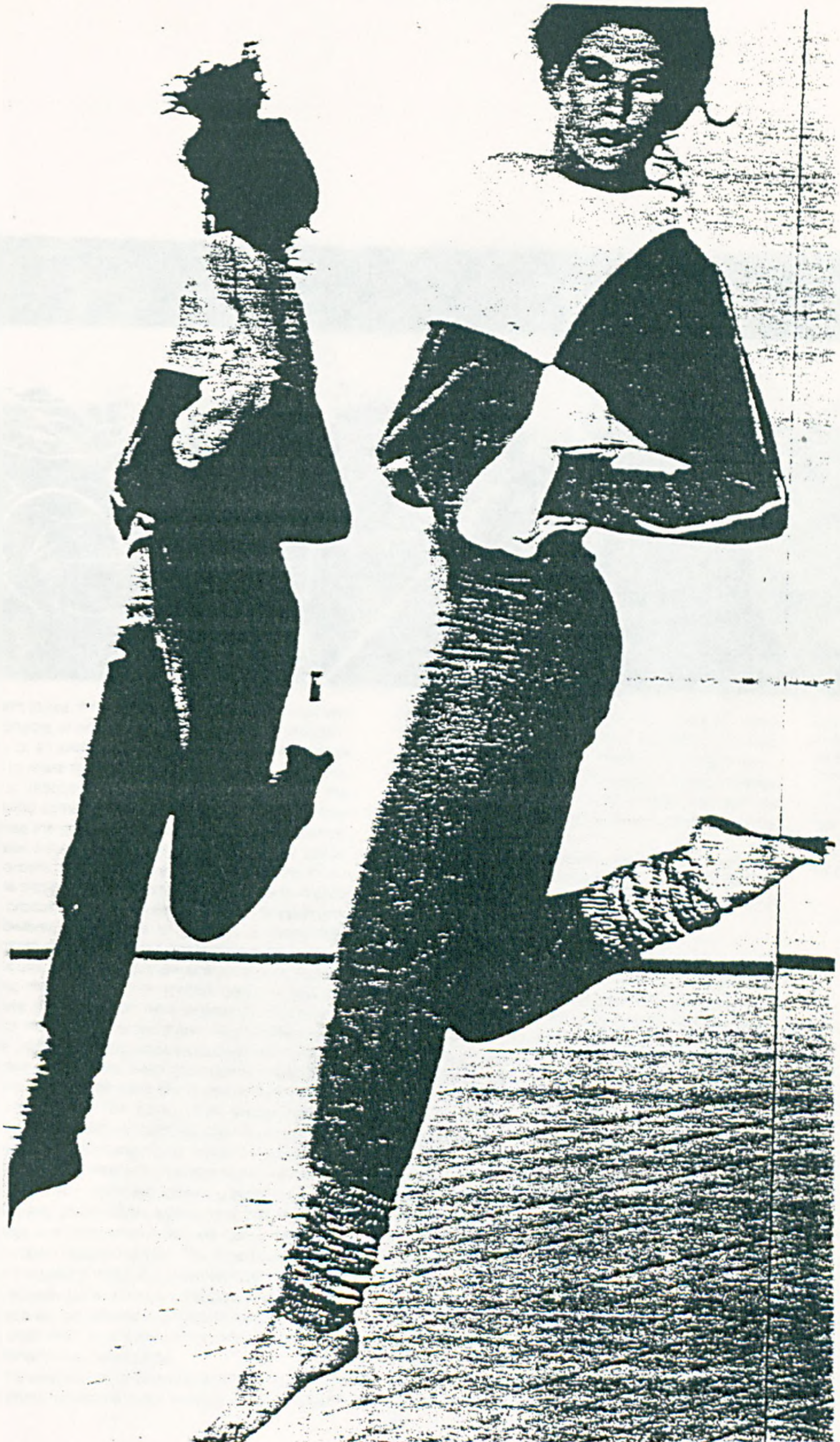

*Diagram 2*




most decisions being made subconsciously and simultaneously.

*(i)Aesthetics* The consumer looks at a garment to see if it is the right style, if it is fashionable or traditional, whether it would be flattering. At the same time the aesthetics and comfort of the fabric are also being assessed. Decisions are being made on whether the fabric colour or print design and surface properties are acceptable. Is the fabric hairy, smooth, rough, or silky? Does it look as if it might be uncomfortable? This last decision will be based on past experience of fabrics and

Sports and leisure wear are subject to technical development, to ensure maximum comfort. (Here, a jogging suit in a cotton-acrylic sports-action fabric from the Umbro Keep-fit collection.



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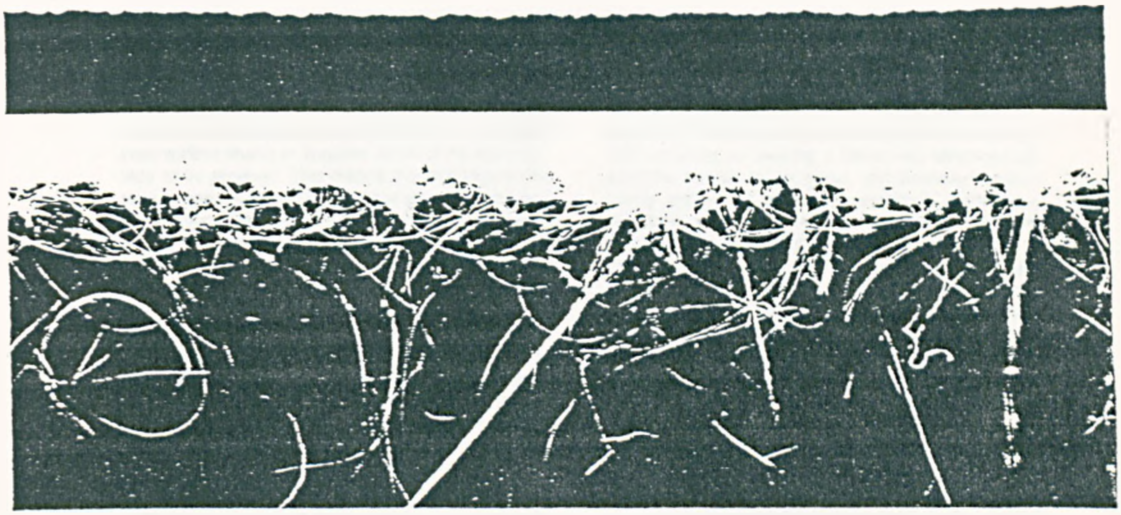

Fabric surface profiles of knitted fabrics, magnified to show surface hairiness. (Upper) Smooth surface. (Lower) This fabric caused discomfort owing to tickle and fibre shedding.

garment styles. If in the past a particular fabric was uncomfortable to wear next to the skin causing irritation, a rash, or an allergic reaction, a prospective purchaser tends to relate that sensation to the fibre content. This type of reaction is undoubtedly influenced by the marketing strategies of the fibre producers when they advertise the properties of their products: for instance, polyester is durable and non-absorbent whereas cotton is absorbent. In the case of these two fibres, the intrinsic fibre properties are significant when the performance of the product depends on either durability or absorbency. However, the degree of comfort or discomfort associated with a fabric can depend on many factors, in particular, the fabric structure and surface properties. A fabric may be woven or knitted, dense or open in structure, stretchy or not, hairy or smooth, limp or stiff, shiny or matt, to name but a few. All of these effects can be produced during fabric production and finishing, they have a significant bearing on comfort properties and tend to be independent of the type of fibre involved.

In the relatively few cases of an allergic reaction reported in the literature there has been no evidence to suggest that man-made fibres were the cause; it is believed that such reactions are due to the finishes used on the fibres — the dyes, softening agents, washing powders and so on. Many people think that they have an allergy to a fibre when in fact the rash is caused by fabric rubbing against the skin. This is particularly common in the case of wool. It is uncertain how many people do actually suffer from fibre allergies, since very few cases actually get referred to a hospital consultant, most being dealt with by a local doctor and therefore not comprehensively investigated.

Of the selection of fibres available to the public, man-made fibres tend to be more versatile in their aesthetic and intrinsic fibre properties than natural fibres. Nowadays there are commercially available man-made fibre fabrics that resemble cotton in handle and appearance. Therefore at the first stage of product assessment the man-made fibres are comparable with the natural fibres, when the consumer is unable to tell the difference between the two.

If the consumer considers that the fabric and garment aesthetics are pleasant and look comfortable, he/she will move on to the next stage of product analysis.

*(ii)Handling the fabric* This is usually done by rubbing and crushing the fabric between the fingers. When the garment is intended to be worn next to the skin most consumers usually want a soft, smooth handle and will tend to go for a fabric that they are used to wearing.

Although the handle of a fabric has been shown to be an unreliable method of predicting any discomfort that will be experienced whilst the garment is being worn, nevertheless it remains an important step in the assessment of a garment before purchase. It is a relatively short process, when a conscious effort is all the time being made to register every tactile sensation. Handle observations can detect differences between most fabrics in respect of fabric structure, drape, finish and so on, but they are unable to assess fabric surface hairiness, thermal insulation, moisture-transfer properties, and garment fit. The general body surface area is less able to discriminate between fabrics than the hands and when there is discomfort the sensation is not usually directly related to the handle observations. When the method of handling a cloth is analysed it can be seen how the movement between skin and the fabric surface differs from that occurring when a garment is being

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worn. Using a conventional handle technique the thumb flattens any protruding surface fibres to give the impression of a smooth, soft, resilient fabric.

The high density of nerve endings and the low touch threshold in the fingertips as compared with the general body surface enable an accurate profile of the fabric surface to be achieved. This means that the fingers can register fine details in fabric surface properties that the body cannot. The range of handle sensations experienced is vast in comparison to those felt by the general body surface. However, the sensations registered by the general body surface whilst wearing a fabric in garment form tend to be the unpleasant ones.

*(iii) Trying on the garment* If the handle is acceptable, then the garment will be tried on. This stage is mainly to determine if the fit is good and the style is flattering, and the decisions are greatly influenced by fashion trends. Any physiological discomfort that is likely to be caused by the fabric or garment during prolonged wear is rarely noticed at this stage, unless it is extreme.

*(iv) Wearing the garment* The final stage of garment and fabric assessment is made whilst the clothing is being worn for its intended end-use. This is the time when most discomfort sensations are felt and when the prejudices against fibres are established. Everyone has his or her own discomfort threshold relating to the individual's pain threshold. Each person also has certain views on what is and is not an acceptable type of discomfort sensation. For instance, someone may prefer a coarse fabric surface whereas someone else may feel that that is unacceptable. These individual tastes have to be catered for, but there is no doubt that most people prefer a garment or fabric to be unnoticeable.

**Comfort assessment**

A public questionnaire, devised by Shirley Institute and conducted by a professional market research company, was answered by a thousand people in England in 1984. It was designed to determine the public's attitude towards the comfort and discomfort properties of fabrics and garments. Although there was a strong preference for cotton, most people were unable to say why they preferred it. They were also unable to describe the discomfort sensations they had felt from the fibres they had selected as uncomfortable to wear next to the skin. One of the most surprising results from the survey was the discovery that garment labels are a major source of discomfort. Well over half of the people interviewed regularly remove these labels, because of either the physiological discomfort when a corner of the label sticks in the skin or the psychological discomfort when a label hangs outside the garment.

There is only one accurate method of assessing fabric and garment comfort and that is by extensive wearer-trials. Any other methods of assessment such as physical tests have to be based on the results and observations from wearer-trials. To ensure the information obtained by wearer-trials is technically and statistically sound, a standard terminology has to be established, as a means of ensuring that both the people running the trial and those analysing the data know exactly what the subjects in the wearer-trial have experienced. To illustrate this point, the same skin sensation produced by wearing a fabric was described as scratchy, coarse, rough, harsh, and abrasive, without taking account of the colloquialisms. It is therefore necessary to identify all the common skin sensations that are likely to be perceived in a wearer-trial and to define them. If a person experiences an undefined sensation, he/she will be able to describe the sensation more accurately using terms from the standard vocabulary. In many investigations a scale of intensity is required so that the garments or fabrics being tested can be put in order. They can either be ranked (so that the differences between the fabrics are unknown) or they can be graded on a scale (which enables the relative differences between them to be known).

Wearer-trials are an accurate but expensive and time-consuming method of testing a product, and therefore it is not cost-effective for most garment, fabric, or fibre manufacturers to assess their products in this way. The handle of the fabric, as explained above, is also not an accurate or reliable method of determining the discomfort sensations that are likely to be experienced in wear. For these reasons the most practical method of product assessment is to use physical tests that are specially designed to measure a certain property of the fabric or garment that is known to influence a discomfort sensation.

The manufacturer has to depend on the relationship between the physical property (for example, fabric extensibility, fabric surface hairiness, or thermal insulation) and the discomfort sensation already having been established from a wearer-trial. In many cases more than one physical property contributes to producing a sensation. If the fabric is found to produce a tickle sensation, the hairiness of the fabric surface is a major factor influencing this sensation, but the fit of the garment is also important. Fit determines the amount of relative movement between the fabric and the body; the more times the fabric moves over the skin, the more frequently will a tickle sensation be acknowledged by the wearer.

When more than one property is known to influence a skin sensation, a weighting factor to indicate the significance of each property has to be applied to the final analysis of results. This is to ensure that when a fabric is measured on physical test equipment, the most influential property is not overshadowed by the less important ones.

When a physical test method is being developed from subjective wearer-trials it is necessary to isolate personal preference and prejudice from the actual sensations registered. To minimize these effects, the appearance of the test fabrics should be as similar as possible with respect to colour, texture, and lustre. The results are very dependent on the attitude of the wearer

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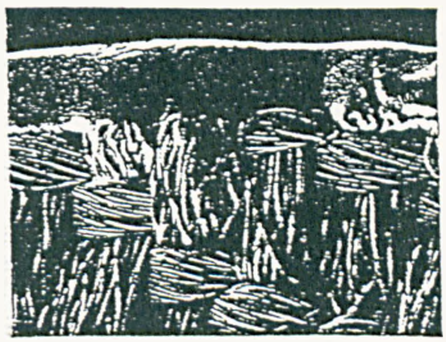
*Discomfort from garment labels arises from the folded corner where the edging often pricks the skin. These photographs show label edges, as magnified by the scanning electron microscope.*

a) Woven edge, usually comfortable

c) Heat-sealed edge, inaccurately cut, causing more discomfort than (b)

(b) Heat-sealed edge, found on 90% of labels in the UK, causing some irritation to the skin



(d) Heat-fused edge, liable to crack at fold and therefore very uncomfortable in wear

to the fabric. If the person thinks the fabric will cause discomfort, because it looks like one which was uncomfortable in the past, the reaction is more likely to be unfavourable and vice versa. The magnitude of an uncomfortable sensation isdependent on the fabric and garment properties, any personal preferences, and an individual's discomfort threshold. Considering all the above points it is necessary to have a large cross-section of the population involved in a wearer-trial so that any differences between the comfort of fabrics or garment styles will be statistically significant.

## Conclusions

Both the public questionnaire and wearer-trials conducted at Shirley Institute to determine the discomfort sensations from fabrics and garments have emphasised the importance of fabric aesthetics in creating the correct image for a garment. The response to the image will be to associate the fabric with past experiences which will ultimately influence the wearer's judgement of garment comfort.

Certain fabric properties and garment styles can cause discomfort sensations in a proportion of the population, the type of discomfort sensations depending on the end-use. During strenuous activity the fabric or garment style will have the greatest demands made on it for comfort in wear. The wearer will be hot and sweating and the garment will be moving over the skin regularly, which is the most likely situation for wet cling and, more seriously, skin abrasion.

Garment and fabric designers are becoming more aware of public demands for comfort and good performance linked to desirable aesthetics. New designs are now commercially available especially in the sportswear field where a lot of progress has been made.

The ultimate aim of much current research work on the comfort of clothing is to develop scientific understanding to the point where designers and manufacturers can accurately predict the comfort/discomfort properties of their products before production and hence improve the attractiveness and quality of the clothes we buy.