THE DEVELOPMENT OF A METHOD FOR DETERMINING THE BEST-FIT SHAPE
FOR THE CROTCH SEAM OF MEN'S PANTS

by

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(ABSTRACT)

The fit of ready-to-wear clothing is an area of concern for the consumer and the apparel manufacturer. Pants are one of the most difficult articles of clothing to fit due to the crotch area. The manufacturer strives to provide the best fit possible, but measurement, and pattern making techniques currently available may not be sufficient to satisfy the fit needs of many of their customers.

The purpose of this research was to develop a method for determining the best-fit shape for the crotch seam of men's pants. A measurement method and instrument (flexicurve) for reproducing the crotch shape were developed including identification of the crotch point. Crotch shape reproductions and specific anthropometric measurements were taken from a sample of five subjects.

The crotch shapes for each subject (n=3) were aligned on an "x" and "y" coordinate grid using the crotch point and a second reference based on back waist height and a common "x" bar. The shapes were plotted into a load analyzer to establish a data base of "x" and "y" coordinates.

Descriptive statistics were used to compare anthropometric data and
the standard deviations between shapes within subjects. Crotch shapes were diagrammed using scatter plots. A regression function was modeled to the subjects average crotch shapes to determine the best-fit shape.

The method and instrument for crotch shape reproduction seems to have potential, however, further work needs to be done on the establishment of a second reference point, so that the shapes could be meaningfully analyzed. The best-fit shape differed from the pattern crotch curve, but meaningful analysis was hampered by lack of pre-established, scientifically based methods for incorporating ease and style features (such as darts and pleats) being incorporated into the shape of the crotch seam. From this study it has been learned that an instrument can be developed which can identify the crotch point and reproduce the crotch shape for male subjects. Future research needs to be conducted with a larger sample to resolve unanswered questions.
Dedication

The author would like to dedicate this thesis to her parents, Dr. and Mrs. Ervin T. Kornegay, who have provided inspiration, support and encouragement throughout the pursuit of the Master's degree.
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Introduction

The fit of ready-to-wear clothing is an area of concern for the consumer and the apparel manufacturer. Fit is an important selling feature and consideration for consumers in the purchase of garments. It is one of the final steps in a consumer's search for a garment they will buy (Seiben, 1988). Consumer satisfaction with their product is a major area of concern of the manufacturer, but they are also concerned with developing garments that fit over a range of bodies.

Good fit is influenced by many things and its assessment is both physical and visual. The appropriate fit of the crotch curve area is especially important for men, due to their anatomy and the fact that for the majority of men, pants are the primary lower apparel. Pants are difficult articles of clothing to fit due to the complex construction in the crotch area. The manufacturer strives to provide the best fit possible, but measurement, and pattern making techniques currently at their disposal are not sufficient to satisfy the fit needs of many of their customers.

Determination of a given pattern dimension requires an orientation in space of the three-dimensional body form related to the two-dimensional pattern shape. Pattern makers have had to cope with the inexact science of constructing a "flat" pattern which forms to the curvatures of the human body. While the body is most often described two-dimensionally, it is necessary to consider the three-dimensional nature of the body in accurately measuring it, so that a pattern may be constructed which fits appropriately.
While some areas of the body (shoulder, abdomen, derriere, and side hip) have benefited from detailed contour analysis provided by newly developed measurement methods (Douty, 1968 and 1978; Farrell-Beck & Pouliot, 1983), the crotch curve continues to cause problems in accurate measurement and fitting. It is an area of the body which is visually and mechanically difficult to quantify. Farrell-Beck and Pouliot (1983) in their study of Pants Alteration by Graphic Somatometry Techniques stated that, "... further research is needed to perfect the development of front and back crotch seams".

Traditionally, pattern making and alterations have been based on measures of body circumference and length without attention to actual body shape. "The history of standard patterns and drafting systems reveals the absence of a logical link between body form and pattern shape" (Gazzuolo, 1986, p.77).

At present, body measurements that are taken for pattern making and alterations provide only circumference and vertical length measurements. "The character of the curve of the abdomen and the buttocks, required for the shape of the crotch seam, defy the tape measure" (Old and Csizensky, 1977). Several recent studies expressed a need for a more scientific, analytical approach to pattern making and alterations (Heisey, 1984; Heisey, Brown and Johnson, 1986; Douty, 1978).

In traditional pattern making methods, the crotch curve portion of the pattern is based on derivations from other body measurements. One would not expect a pattern to accurately describe the crotch curve area without consideration of the actual body shape of that curve. Current
methods and studies merely estimate the crotch curve area by extrapolating measurements of data from other body areas. A method of determining the shape of the body from the front waist to the back waist along the crotch (the crotch shape) is needed.

The purpose of this study was to develop a method of determining the best-fit shape for the crotch seam of men's pants. The could have implications for a number of pant-related garments including slacks, shorts, jeans and activewear.

This study was conducted in cooperation with a regional apparel company. The initial concept for the study was shared with the apparel company who expressed an interest in improving the fit of their men's trousers. The company cooperated with researchers and relayed information and some material support for the present developmental project. There is further interest from the company in sponsoring a larger study beyond the present one. The tentative purpose of the later study would be to further test the method and wear test garments incorporating the crotch shape(s) obtained using the new method.
Review of Literature

A garment provides a covering or shell for the body and if it is cut and structured appropriately, it can serve to enhance one’s outward appearance as well as their positive self-image. (Douty, 1978). Proper fit includes both physical and visual aspects. The qualities of a garment with which one generally associates positive feelings are comfort, freedom of movement, attractive appearance and fashion. These qualities are affected by how well or how poorly a garment fits (Farmer and Gotwals, 1982).

Ease of movement provided by a garment also affects the assessment of fit. As it is related to garment fit Hollen and Kundel (1987) define comfort as being able to walk, bend, reach and sit in a garment without feeling restricted or straining seamlines. A personal assessment of fit may or may not include comfort, but in the determination of comfort, fit is a primary factor (Delk and Casill, 1989).

The purpose of this study is to develop a method for determining the best-fit shape for the crotch seam of men’s pants. The literature is reviewed in the following format: 1) relationship of garment fit to body structure, 2) three-dimensional body form related to two-dimensional pattern shape, 3) body contour reproduction methods, 4) components of the crotch definition, 5) methods of crotch shape determination, 6) altering the fit of pants.

Relationship of Garment Fit to Body Structure

dimensions of the garment to the dimensions and contours of the figure, while functional fit accommodates the dimensions of the garment to the motion and activities of the wearer. The concept of fit, therefore, encompasses both physical and psychological aspects, conformity to the body and aspects of mobility related to the particular activity.

Hulme (1949) defines fit as when the garment follows closely the contours of the body, i.e. fitting the body at all points. A good fit is defined by Hollen and Kundel (1987) as:

...when the garment lies smoothly over the body with no pull, wrinkles, or baggy areas. Vertical side seams hang straight, the hemline is even and parallel to the floor, darts are tapered and stop before the fullest part of the area that they shape, waistline seams follow the natural waistline and are not binding...(p.3)

Douty (1978) conducted a study to develop better ways of fitting garments to persons with noticeable figure irregularities. These individuals have difficulty getting clothing which fits well and is flattering. She outlined several criteria included in fitting a garment to the body. Fitting a garment to the body involves shaping a two-dimensional material into a three-dimensional structure which can cover the figure smoothly with no distracting wrinkles or folds when the body is static. Adequate ease should be allowed so that the garment can adjust to the body in motion and return to its original appearance when the motion has ended. An appropriately fitted garment can also camouflage figure irregularities and emphasize positive characteristics of the wearer.
There are several anatomical considerations when determining the appropriate fit of men's pants (Gardner, Gray and O’Rahilly, 1963). Within the groin area are the testis, the cremaster muscle and the surrounding scrotal tissue, as well as the seminal vesicles and the penis. The testis are subject to severe often sickening or shocking pain when squeezed or swollen. A contraction of the cremaster muscle, which covers the spermatic cord, testis and the epididymis, results in a raising of the testis to a higher position within the scrotum. This contraction can be caused by stroking of the skin of the medial area of the thigh and is called the cremaster reflex. The scrotum can become contracted or relaxed depending upon certain conditions. Contraction is caused by the influence of cold, exercise or sexual stimuli and is characterized by a shortening and wrinkling of the tissue, while relaxation results from the influence of warmth.

The seminal vesicles, which produce a large part of the seminal fluid, are not as prone as some of the male genitals to receiving pressure or stress from external sources, such as one's pants, since they are positioned posterior to the bladder and anterior to the rectum, in other words up within the body. They are however very sensitive to pressure when full of fluid. In addition the vesicles can change position depending on the size of the bladder. When the bladder is distended, the vesicles are positioned somewhat vertically, and when the bladder is empty they are more horizontally positioned.

The last anatomical consideration is the penis. The penis contains a large number of sensory nerve fibers which include pain fibers from the
skin and urethra and other touch receptors. The nerves in the penis also contain many sympathetic and parasympathetic fibers which can effect blood circulation. These anatomical considerations emphasize the physical need for men’s trousers to fit well in the crotch area.

Fit is difficult to assess or define objectively. It is an individualized concept i.e. each person has their own standards and requirements based on their body type and their preferred style. "Clothes do more than cover the body - they have intimate, personal implications" (Douty, 1968, p.22). How well a garment fits is predominantly based on a visual assessment by the wearer.

LaBat and DeLong (1990) in their research investigated the relationship between body cathexis and the perceptions of fit of clothing for a sample of female consumers. Body cathexis is, "the evaluative dimension of body image and is defined as positive and negative feelings toward one’s body" (p.43). They examined the relationship between body cathexis and consumer satisfaction/dissatisfaction with the fit of ready-to-wear clothing. Body cathexis scores for the subjects showed that they were least satisfied with their lower body as compared with the upper and total body. The strongest positive correlation for measures of physical fit satisfaction, that is the consumer’s perception of how well a garment fits their body, and body cathexis, was for the lower body. A similar study has not been done on men.

In a study, comparing pants fit, Giddings (1982) compared specific anthropometric measurements and measured the contour of the buttocks for a group of Black males and White males, as well as fitting a pants pattern
to specific Black subjects. She found that Black males do have significantly different anthropometric morphologies than White males.

To determine the buttocks curve the men stood with their side against a wall, while the researcher traced the contour (silhouette) of the buttocks on a piece of paper on the wall. Using the a computer program she determined the average curve for each race. Giddings found that the buttocks curves for Black males were higher and more round than for White males.

A basic pants pattern was constructed in muslin and tried on specific subjects from the sample group. Alterations were made to the pattern based on this fitting and a second muslin proof was made. Additional fitting refinements were made and the pattern was altered a second time and a third proof was made. The fit of the third proof was then subjectively assessed by a panel of judges using specific criteria. The use of a panel of impartial judges and defined criteria provides the most accurate method of assessing fit that has been developed thus far in the apparel field. She confirmed that a pattern could be developed to accommodate the fit problems of the Black males in the study.

Three-dimensional Body Form Related to Two-dimensional Pattern Shape

Traditionally, pattern making and altering have been based on proportional methods (Carlstrom, 1905; Simons, 1933; Hulme, 1949; Doblin, 1974;). Proportional methods use body measurements and a formula to translate the data into a pattern (Hutchinson and Munden, 1978; Heisey, 1984). This method however has potential for error since pattern dimensions are extrapolated from a minimal number of body measurements.
A more accurate representation of the body could be achieved if consideration were also given to 3-dimensional contours.

Wampen (1864) compared the body shape to geometric relationships and proportions. In his study he measured the body using a tape measure and caliper compass for circumference measures and a tape measure for the length measures. He based his work on "proportionate", "broad" and "slender" figure types. These data were used to make comparisons of proportions between body parts and how they are related in space. The relationships and data he presented were extensive, but were not successfully applied to pattern making. His study was important in the fact that it recognized the existence of different body types and the need to consider three-dimensional relationships between various body segments.

Kroemer (1989) stated, "Having data that are essentially two-dimensional, insufficiently related to each other in space, and without a common origin is a highly deficient condition" (p.770). He also pointed out that classical anthropometric techniques result in two-dimensional measures, at most, but the human body is three-dimensional. "At present, no standardized reliable procedure exists for determining the three-dimensional body shape based on classical anthropometric data" (p.781). Photographs, he noted, can record three-dimensional aspects of the human body from which measurements can be taken. There are several problems with this method, however. Actual depiction is two-dimensional, scales may be difficult to establish and parallax distortions exist.

Kroemer (1989) and Wender (1990) reviewed several techniques for measuring contours, but none of these have proven to be the complete
answer to defining body forms. Some of the new techniques include stereophoto processes and methods using lasers. Stereophoto techniques involve projecting a regular geometric grid onto the human body. When viewed from an angle the grid appears distorted, these displacements can be used to determine the shape of the surface onto which the grid is projected. There were however a number of practical problems with this method, related to subject alignment, coordinate origin, data acquisition, manipulations and summarizations, and display. Lasers are a technological development which can be used as a distance measuring device. In current methods either the body to be measured is rotated or the laser device moves around the body. The lasers can be used to determine the shape and the graphical and numerical descriptions of irregular bodies. The methods using lasers are cumbersome, costly and the subject or equipment must move constantly.

Heisey, Brown and Johnson (1988) sought to develop a theoretical framework for drafting patterns based on modeling the physical process of fitting a garment. It was their contention that functional relationships between the body and patterns had not been fully investigated. In their research they attempted to show how the drafting method of pattern-making which presently utilizes a two-dimensional approach, could incorporate aspects of the draping method, a more three-dimensional approach, and thus be more accurate in describing the three-dimensional body. Heisey (1984) noted the following:

The accuracy of a draped pattern can be attributed to the process of forming the three-dimensional garment with fabric
in relationship to the body, and then flattening the three-
dimensional garment to produce a two-dimensional pattern.
Drafting and pattern alteration methods generally produce
patterns that do not fit as well as draped patterns. This
lack of fit can be attributed to the incomplete representation
of the body that is used in methods....(p.23)

Heisey (1984) and Kroemer (1989) agree that the development of
algorithms that are compatible with computer processing are needed to
better describe body contours. Heisey (1984) recommends further
investigations into mechanisms that allow flat fabrics to conform to
three-dimensional surfaces.

Heisey et al. (1988) utilized mapping techniques to model the
draping of a three-dimensional form on the body with fabric and the
flattening of this garment into a two-dimensional shape. The authors hoped
through this process to establish a framework for pattern development
which incorporated the benefits of both the drafting and the draping
methods. They were successful in establishing a framework that modeled the
physical process of draping with mapping and projecting procedures. They
suggested that more work needed to be done to implement and test the
development of specific relationships.

With a better method to quantify the contours of the body,
specifically the crotch shape, a pattern can be made which will better
represent the body and provide a more accurate fit. Crotch length and
curve must be made to conform to the body. In other words, the two-
dimensional pattern must be drafted to accurately reflect the three-
dimensional body. This presumably will create a more flattering appearance and more comfortable fit.

**Body Contour Reproduction Methods**

Contour reproductions of the body are important because in addition to length and circumference measurements they help provide a clear picture of the body's shape and size, thus, contributing to the process of pattern construction. The intricacies, flexibility and yielding qualities of the body form can also complicate the taking of measurements. Traditional methods of pattern making and alterations use only body circumference and length measurements to make original patterns and adjustments to previous patterns.

One of the few studies dealing with measurements of male subjects was reported by Sheldon, Stevens and Tucker (1970). In their study involving 46,000 men over a 10 year period, standardized photographs were used to derive anthropometric measurements of diameter. They compared anthropometric measurements from the body itself to measurements taken from the photographs of the same subjects (photogrammetric measures). Anthropometric measurements of body diameters (eg. hip, waist and thigh) taken from standardized photographs were prone to be a more accurate technique for measuring the soft parts of the body. They discovered, however, that these photographs were not useful in measuring length along a curved surface.

Douty (1968, 1978, 1980) conducted several studies which sought to better identify body contours, mass and proportions. Douty (1968) was instrumental in the development of somatographs - silhouette photographs
projected onto a grid-screen - which are used to get a lateral (side) view and anterior-posterior (Front-back) view of each subject. In Douty’s 1978 and 1980 studies her goal was to develop a more scientifically engineered method for adjusting standard dress patterns to individual with problem figures. Douty did not study contours or proportions of the legs or crotch area. Examination of her methods, however, reveals that they are not able to capture the contour of the crotch curve as it is obscured by the legs in a lateral view and only the crotch point is visible in an anterior-posterior view.

In a recent study by Mollard, Pineau and Sauvignon (1982), photogrammetric measurements were used to establish the relationship between overall and segmentary dimensions of the body (e.g. height vs. leg length), surfaces and body volumes, and to evaluate the variability of these parameters. The conventional anthropometric method and photogrammetry were compared using male subjects. The photogrammetric method utilized one pair of cameras and two mirrors. The mirrors were set up in an angular configuration to enable the photographs to capture the front, back and sides of the body simultaneously. Results indicated that the dimensions collected by the conventional anthropometric method and the photogrammetric method were significantly different. The authors did not, however, indicate which method was preferred.

Wender (1990) reviewed most methods currently available to measure and assess the body for pattern making purposes. From this analysis she developed her own method, utilizing the Computer-graphics Augmented Design And Manufacturing (CADAM) system developed by Lockheed Corporation.
Photographs were used to capture two dimensional views of the body and were then digitized. These digitized points were used to define the silhouette of the body. After defining the silhouette into points, they were written into a CADAM program, which transformed them into three dimensions. The three dimensional structure was then analyzed using this program.

Wender (1990) tested her method using a manikin and found there were problems with distortion in the body form. She tried several techniques to alleviate the problems but did not succeed. In order for this method to be successful she concluded that a central axis or reference system needed to be developed, so that the body silhouette in several views can be accurately related.

Components of the Crotch Definition

In the past, fitting of clothes has been considered an art rather than a science. Some guidelines have been established, but decisions on adjustments and control have been left largely to the intuition of the designer or fitter. A more scientific approach would allow the designer to utilize more logical, analytical measurement techniques and pattern-making strategies, rather than the intuitive functioning that has been done in the past. Currently pants, because of the complicated anatomical configuration and the great diversity of movement which is possible in the crotch area, require more alterations than other types of garments, to achieve a good fit (Minott, 1974). The refinement of the crotch curve, or the seam which intersects the inseam, front to back, on a pants pattern, is critical to attaining a well fitting garment.
The crotch area, which includes the crotch shape, is predominantly concealed between the legs and close to the perineum. It is a difficult, if not impossible, area to accurately measure using currently available methods. The crotch shape is defined as the contour or silhouette between the legs from the center front waist to the center back waist (body measurement). The incorporation of the crotch shape into pants patterns has developed informally. This evolvement has included tradition as well as trial and error. No scientific method of determining the crotch shape has been utilized.

The crotch shape incorporates two other aspects - the crotch length and the crotch point. NASA in their Anthropometric Source Book (1978) defines the crotch length as:

...the distance from the anterior midpoint of the waist to the waist level above the buttock measured with the tape passing through the crotch and over the maximum protrusion of the buttock.(p. 38)

Most instructional books describe the crotch length as the distance between the legs from center front to center back, close to the body (Old and Csizinsky, 1977; Palmer and Pletsch, 1978; Rocha, 1977; O’Brien, 1941 and Wolfe, 1977). Palmer and Pletsch further specify that the crotch length should be divided into front and back lengths, separating at the inseam or crotch point.

The crotch point is indicated as the meeting point of the front and back crotch shapes (on the body) or the intersection of the inseam and the crotch curve (on the pattern) (NASA, 1978; Palmer and Pletsch, 1978; O’Brien, 1941; and Wolfe, 1977). The crotch point allows the measurer to
apportion the appropriate amount of the crotch seam to the front and to the back and allows the inseam to fall perpendicular to the floor. None of the cited methods, however, describes how this point can be accurately measured.

Other aspects of crotch shape, which have been utilized in various methods, are the crotch depth and crotch height. There are numerous definitions for these terms. According to several sources the crotch depth measurement is the distance from the waist level to the crotch level while seated on a flat surface (Old and Csizinsky, 1977 and Bame, 1978 and Palmer and Pletsch, 1978). In contrast crotch height is the distance from the floor to the lowest point of the crotch (O'Brien, 1941).

On the pants pattern both the crotch depth and height are represented by a horizontal line - the crotch line - from the crotch point to the sideseam parallel to the floor (Old and Csizinsky, 1977 and Bame, 1978 and Palmer and Pletsch, 1978). This line is the distance of the crotch depth from the waist or the distance of the crotch height from the floor. In traditional men's pattern drafting techniques the crotch line is referred to as the rise line. The rise line was determined as the distance from center front waist along center front the amount the measure of 1/8 of the entire height of the figure, plus 1 1/2 inches for the average figure ("Modern garment design and grading", 1978). It is not clear if the 1 1/2 inches is part of a formula or if it is added merely as ease to the pattern.

Methods of Crotch Shape Determination

Lenker (1984) suggested a that the crotch point could be identified
by sliding a paper clip onto a tape measure, putting the tape around the
crotch shape and moving the paper clip to the lowest point on the tape.
Lenker assumes this point to be the midpoint of the body. This
measurement could give a more representative crotch point than estimations
from the hip measurements, however the unstated assumption is that the
crotch area is not level. No proof of this assumption could be found in
the literature.

O'Brien's (1941) research involved taking 55 measurements on each
of 10,042 female subjects. The measurements were taken using standard
anthropometric tools. The study resulted in the compilation of a major
data base representing Caucasian American women. The crotch point in
O'Brien's (1941) study was determined by what he called the "crotch
center" method. O'Brien describes it as "the intersection of the inside
seams of trouser legs with the crotch seams". The crotch center is taken
with the subject standing and resting the left foot on a chair. The
measurer sights, at eye level, the middle line of the inner surface of the
right thigh and marks it with a vertical line, thus indicating the "crotch
center" location.

Rather than measuring the crotch depth, O'Brien (1941) measured the
crotch height. The subject was measured while standing, utilizing an
anthropometer. The anthropometer apparatus rested on the floor, the
moveable arm was raised by the measurer to the crotch level and the
distance from the floor to the crotch level was recorded. It was assumed
that the crotch height could be used in a similar way to the crotch depth,
in determining where the crotch line should be drawn on the pattern. In
using the crotch height the finished length of the pants or the distance from the lower edge of the pants to the floor would need to be determined as a reference line.

In traditional pattern drafting methods, the crotch curve seam is developed from body measurements of the crotch depth and the hip circumference (Old and Csizinsky, 1977 and Bame, 1978). According to Old and Csizinsky, the crotch depth is taken with the subject, having a string or tape tied around their waist, sitting on a flat surface and facing straight ahead in a relaxed manner. The crotch depth is measured at the side seam from the bottom of the waist tape, along the curve of the figure, down to the stool surface. Palmer and Pletsch in their book, Pants For Any Body (1976) indicate that this method adds about one half inch of ease. The factor of any added ease, however, was not considered in the Old and Csizinsky or Bame methods. In addition, there was no research found which demonstrated that the length along the curve of the hip from the waist to the stool accurately described the depth of the crotch. Further, some of the body's flesh may become compressed when seated, thus distorting the accuracy of the measurement. Using the crotch depth measurement the crotch line is then drawn across the pattern by measuring down from the waist the distance of the crotch depth length.

The crotch point is determined as the extension of the crotch line beyond the center front line and center back line (Figure 1). The amount of extension is approximately one-fourth of the front hipline width for the front pattern piece and one-half the back hipline width for the back pattern piece (Bame, 1978). The hipline width is the amount on the pattern
Figure 1
Pattern markings
allowed for the hip measurement plus ease.

The crotch curve seam is completed by drawing a curved line which begins as an extension of the centerline, front or back, at the top and continues through the crotch area and ends at the crotch point (Bame, 1978, Minott, 1974, Old and Csizensky, 1977). Hollen and Kundel in their book, Pattern Making by the Flat- Pattern Method (1987), simply described the crotch curve seamline as a "nice curve", with no definition of "nice".

To verify the distributions of the center front and back seam lengths, Old and Csizensky (1977) suggested that the center front and back seam lengths of the pattern be compared to the crotch lengths measured from the body. The total crotch length is measured between the legs from the bottom of the waist tape at the center front to the bottom of the tape in the center back, close to the body.

Heisey et al. (1988) indicated that draping is the only truly accurate method of producing an individually fitted pattern. Draping methods of pattern development require one to smooth a fabric over the body or a manikin, inserting fitting devices in appropriate locations to produce the desired style and fit. "No drafting system, two-dimensional or three-dimensional, can consistently produce patterns as accurately as draping" (Heisey et al., 1988, p.5). In many cases garments produced from traditional drafting methods must be corrected through trial and error alterations on the body. This occurrence is because drafting methods only utilize a limited number of body measurements, whereas, in draping a garment the actual body or body substitute is modeled with the fabric.

Upon close examination of the draping methods for pants, however,
it was found that the process begins as a drafting process on the muslin to be used for draping. Specific body measurements are taken, transferred to the muslin, and the crotch curve is established on the muslin before the pants are draped on the body or manikin (Jaffe and Relis, 1973). The accuracy of the draping method is not utilized when designing pants. The problem a designer has when attempting to drape pants in the crotch curve area is that manipulating the fabric between the legs is difficult, if not impossible. The area is not easily accessible with a piece of fabric. It may be that if the style were loose or baggy in the crotch the pants could be draped, but traditional mens' trousers are fitted in this area.

In the article "Who Needs Calvin Klein?", Sider (1990) discussed the drafting of mens' jeans patterns. He said that achieving a good fit depended on the shape, and the shape depended on the design of the crotch. He pointed out several traditional tailoring techniques for shortening or extending the crotch point, but did not offer any new solutions to characterize the crotch shape.

**Altering the Fit of Pants**

Minott (1974) shows numerous examples, including sketches, to illustrate the different types of fit problems that can occur when wearing pants. She also offers the instructions for altering the pattern to correct the illustrated problems. The majority of the problems are corrected by adjustments to the crotch curve, either lengthening or shortening the depth or altering the crotch point. For example, if one has small hips, they are instructed to subtract three-quarters of an inch from the crotch point along the crotch line toward the center of the
pattern piece. Minott also illustrates how pants will hang on different figure types (e.g. "average", "hip (pelvis) tilted forward" and "hip (pelvis) tilted backward"), indicating alterations would have to be made to correct the fit problems caused by these figure variations. Many fit problems, however, cannot be corrected by performing only one alteration. Often, two or more steps must be taken to correct a fit problem.

The most recent research which examined the alterations and fit of pants was reported by Farrell-Beck and Pouliot (1983) and Pouliot (1990). Pouliot compared the traditional methods of pants pattern alteration to an "experimental method", both methods utilized female subjects. The experimental method incorporated graphic somatometry and computer programs to mathematically analyze the body so that basic patterns could be altered to fit variable bodies. The crotch point was determined by placing a rod between the subjects legs at the lowest point of the perineum and parallel to the floor. Because it is impossible to see body contour in the crotch area on the somatograph, the crotch curve had to be estimated by a computer program. Pouliot used the mathematical concept of approximating length along a line to determine the front and back crotch length. When compared with actual body measurements she found in several cases that the computer program over estimated the length, and adjustments had to be made. For all of Pouliot's subjects, there was excess fabric in the front crotch area. She suggested that the crotch curve needed to be deeper (into the stomach area), but recommended that additional research needed to be done regarding the crotch area of pants.
The Problem Statement

Manufacturers incur high cost each year from garments returned due to poor fit (Seiben, 1988). They are interested in consumer satisfaction with their product, but custom fitting garments to the individual is not feasible for a ready-to-wear market. The solution to the problem of poor fit of pants may not necessarily lie in the development of more individual sizes or ranges.

The primary problem of fit in pants is the crotch area. These fitting problems may occur because of the complex anatomy and range of motion of the body in the crotch area. While most manufacturers utilize all available measurement tools to accurately assess the body when developing patterns, the crotch area of pants has never been directly measured when developing patterns.

The common goal for most experts is to design pants which fit the body shape, however the means for achieving this goal still remain obscure, i.e. an instrument and a method do not exist that is simple, inexpensive and reliable for the average designer to use in assessing the crotch curve. If patterns were developed based on scientific measurements of the body, some of the problems which face manufacturers might be resolved. Although there are problems in the estimation and fitting of the crotch curve area which have not been resolved, no actual research has been reported on perfecting the measurement or fitting of the crotch curve.

Purpose

The purpose of the study was to develop a method for determining
the best-fit shape for the crotch seam of men’s pants from a size specific sample.

Objectives
1. Determine a method for measuring where the crotch point should be located along the crotch curve seam.
2. Develop a reliable method for reproducing and defining the crotch shape.
3. Develop a procedure for incorporating the crotch shapes into a computer program so that the best-fit shape can be established.
4. Compare the best-fit shape to the crotch curve on the apparel company’s current pants pattern.

Hypotheses
1. The inseam (crotch point) is located at a straight line (perpendicular to the floor) plumbed from a point on the crotch shape to the tip of the medial malleous (ankle bone).
2a. The waist thickness, back waist height and crotch shape length can be measured using the method described.
2b. The instrument (flexicurve device) gives a reliable measure of the crotch shape from measurement period to measurement period for each subject.
3a. The variability between the average crotch shape measures for each subject is not significant enough to invalidate the method.
3b. The variability between the best-fit crotch shape and the most extreme crotch shape is not significant enough to invalidate the method.
4a. The best-fit crotch shape can be successfully matched to the crotch point and the back waist point of an appropriately sized pants pattern.

4b. There is a difference in the shape of the best-fit crotch shape and the crotch curve on the apparel company's current pants pattern.

Assumptions

1. The crotch point established on the cadet's fitted trousers is accurate.

2. The crotch shape sample used in this study, while not necessarily representative of the average man wearing size 36 inch waist pants, is suitable for the development of a method.

3. The best-fit crotch shape is the crotch shape which most closely models the mean crotch shape for each subject.

4. The crotch length is not abnormally affected within the height range of 5'8" to 6'0".

Definitions

1. best-fit crotch shape - the crotch shape which most closely resembles the mean crotch shapes of each subject, as determined by a regression function.

2. good fitting pants - pants which conform smoothly (without any distracting wrinkles or looseness) to the contours of the front and back crotch area, as well as the waist and buttocks and do not pull or bind the wearer in these areas.

3. crotch curve - the seam which intersects the inseam - front to back (on a pants pattern).
4. **crotch shape** - the contour or silhouette between the legs from the center front waist to the center back waist (body measurement).

5. **crotch length** - the length of the contour following the crotch shape, as measured with the tape measure from the traced crotch shape.

6. **crotch point** - the meeting point of the front and back crotch shapes (on the body) or the intersection of the inseam and the crotch curve (on the pattern) as measured with the plumbline device.

7. **waist thickness** - the distance through the body from the center front waist to the center back waist, as measured with calipers.

8. **waist height** - the vertical depth of the crotch shape from the lowest point of the crotch to the center back waist as measured with a sliding arm anthropometer.
Methods and Materials

The purpose of this research was to develop a method for determining a best-fit shape for the crotch seam of men's pants. This research was conducted in cooperation with the Virginia Apparel Corporation and the Va Tech tailor shop. Virginia Apparel provided information relating to their customer and areas of fitting concern. In addition, they provided material support in the form of a pair pants for each of the participants in the crotch shape reproduction phase of the study and a pants pattern which was used during analysis. The staff at the tailor shop offered expert opinions, the shop provided a subject resource and the tailor acted as the measurer for the study. The procedure for this study is presented as follows: 1) crotch point location (on the body), 2) development of crotch shape instrument, 3) sample selection for crotch shape reproduction, 4) the method for crotch shape reproduction, and 5) analysis of data.

Crotch Point Location

The location of the crotch point is critical to the accurate translation of the crotch shape to the pattern and ultimately in accurate alignment of the inseam on the body. The method of identifying the crotch point was determined prior to completion of the instrument or method for crotch shape measurement, so that it could be incorporated into the overall crotch measurement process.

It was hypothesized that the inseam, if correctly positioned perpendicular to the floor, falls along a line which could be plumbed from the crotch point to the medial malleolus (ankle bone). The researchers adapted an instrument and selected a standard against which
to measure the crotch point. The instrument for measuring the crotch point was developed as an adaptation of the Pant-o-meter by Vogue Patterns (Figure 2). The Pant-o-meter is included in pattern number 1001, which is a female trousers pattern and provides the consumer with detailed instructions to custom fit their own pants. This device was the only one currently available for the purpose of pinpointing the crotch point.

The tape strings, attached to the Pant-o-meter card were used for holding onto by the consumer so the device could be shifted along the crotch shape to determine the front and back crotch lengths. The tape strings were not needed for this study, as the crotch point measurement device would be attached to the crotch shape measurement instrument. In addition, the Pant-o-meter did not have a cord (plumbline) long enough to hang to the ankle bone, nor was it felt that the cord and bottom weight used in the device, were heavy enough to hang straight and true the length of the leg.

Therefore, a length of metal ball and chain rope (hereafter referred to as "the chain") was attached to the card in the place of the cord. At the end of the chain a large bolt was attached by threading the chain through the center of the bolt and securing the lower portion of the chain against the upper part of the chain (above the bolt) with a small wire. The bolt in addition to providing weight to the plumb line, was also be used as a site to line up with the ankle bone. The chain was left long enough for a tall man, but could be adjusted for a shorter man. The chain's length was adjusted by pulling up the excess chain at the ankle, repositioning the bolt and securing it with a piece of wire (Figure 3).
Figure 2

Pant-o-meter device
Figure 3
Plumbline device
Before pretesting the plumb line device, a standard inseam was selected. The inseam on the Virginia Tech cadet corp’s dress trousers had been fitted and altered through an extensive trial and error process for many years to achieve a superior fit and hang. An almost perfect overall fit, including the hang of the inseam perpendicular to the floor, was required to satisfy the cadet corp’s high standards of dress. It was assumed, therefore, that if the cadets trousers were well fitted on a subject, that the inseam would be hanging in the correct position. The cadet’s trousers were set up as the standard against which the plumb line device could be pretested.

A sample of 25 Virginia Tech cadets were used to pretest the plumb line device and measurement technique. Each cadet was instructed to stand with their legs about shoulder width apart. The inseam measurement was taken using a tape measure, which had a card on the zero end (a standard tailor’s tape), the measurer held the card up under the crotch at approximately the crotch point and measured down to the lower hem of the trousers. The recorder noted the results. The measurer turned up the lower hem on the cadet’s trousers to expose the ankle bone. While the measurer held the plumb line device (by the card) under the subject’s crotch, the recorder adjusted the length of the chain so that the bolt hung at the ankle bone level. The measurer then lined up the heavy line on the device’s card - the top of the line was matched to the crotch point on the trousers and, following along the inseam, the bottom of the line was matched up with the inseam.

The recorder steadied the plumb line chain so that there was no
"swinging motion" in the chain. The recorder then noted the relative position of the bolt and ankle bone - whether it was "in line" with the ankle bone, or how many centimeters "anterior to" or "posterior to" the ankle bone the bolt fell (Appendix A). Also recorded at this time was whether or not the plumb line overlapped the heavy line along the card and followed the trouser’s inseam along the entire length ie. was the inseam perpendicular to the floor. This data served to substantiate the accuracy of the cadet’s inseam.

If the bolt did not line up with the ankle bone the measurer shifted the device along the crotch shape until the bolt did align with the ankle. With the device in this position, the recorder then noted how many centimeters anterior or posterior the crotch point was from the center line on the device. The measurer removed the device and the recorder measured and recorded the length of the device from the top of the card to the bottom of the bolt ie. the plumbline length.

Selection and Development of Crotch Shape Instrument

A device called an flexible curve (flexicurve) was selected for use in this research. This type of device has been used in fields such as apparel design (pattern making), engineering and architecture. The personal and professional experience of a university faculty member and an extension specialist suggested that this flexicurve could be used to reproduce the body shape in the crotch area. These professionals were successful in translating a duplicated shape directly into a female pants pattern and producing a well-fitting pair of pants for a given individual. They did not extend the work to a larger female sample nor did they use
the device on male subjects.

Literature related to other body measurement techniques was reviewed, and the anatomy and flesh properties of the body in the crotch area were considered in the selection of the flexicurve. The device is narrow and flexible enough to assess and conform to the intricate body shape, but firm enough to hold the shape of the curve when it was handled. The flexicurve material has a metal core surrounded by a rubber outer material (a "Gumby" type material) and is made by the Alvin Co.

In most cases, after molding the device to the body it will curve inward at the waist, in both the front and back, to accommodate the stomach and buttocks. In removing the flexicurve the shape would be distorted trying to get over the fuller stomach and buttocks curves. For this reason a hinge device was incorporated into the initial material. After considering several hinge devices, such as a metal "piano-type" hinge and a plexiglass clamp, a hook and loop fastening application was utilized. This material was flexible and easy for the measurer to manipulate during the measurement process. It was also found to mesh well with the rest of the flexicurve device and was more unobtrusive for the subjects than the other hinge possibilities.

The flexicurve was cut into two pieces, toward one end. This was designated the back of the instrument, so that the hinge could be easily accessible for adjustment and releasing. A strip of the loop material (two inches long) was cut and applied to the inside of the flexicurve to bridge the two pieces of the instrument. Two pieces of the hook material, each one inch long, were applied to either side of the opening in the
flexicurve, on the outside. A waterbed repair glue (joins plastic to plastic) was used to adhere the hook and loop material to the flexicurve. The opening was joined on the outside by a two inch strip of the loop material which interlocked with the hook material to provide a flexible and adjustable hinge, i.e. to close the gap in the flexicurve (Figure 4).

The crotch point device was incorporated into the flexicurve by removing the card and looping the end of the chain over the flexicurve. The looped end was secured by twisting a small wire around the chain length and the looped end, forming a large loop at the top of the chain which could slide easily along the flexicurve (Figure 5).

In addition to the flexicurve, other equipment used is as follows:

1) a tape measure with a card attached to the zero end (as is standard in the tailor trade)
2) yarn to tie around the subject's waist
3) a standing anthropometer - to determine the waist height from the crotch level
4) calipers - to determine the waist thickness at the center front and center back, so that the shape of the flexicurve may be trued before tracing
5) men's jockey-type briefs - to be worn by all subjects during the measurement session

Sample Selection for Crotch Reproduction

In working with a specific apparel company, certain criteria concerning the subjects in the sample were specified. The particular style of trouser into which the crotch shape was incorporated was provided by
Figure 4
Flexicurve instrument

Back

Hinge

total length 42"

Front
Figure 5
Flexicurve with plumbline attached
the company. The trouser used in the study was a double-pleated casual trouser in a heavy-weight prewashed twill fabric. This style of trouser was selected because it is a top-seller for the company and they were therefore interested in having it fit as well as possible. The company also provided a pair of trousers to use for the preliminary fitting and one for each subject as payment for their participation in the study.

To accommodate the specific company's target customer and eliminate some variables in the study, certain criteria were designated. The age of the apparel company's typical customer was 30 to 50 years old. The most frequently purchased size was a 36 inch waist. The height range for this study was limited to men 5 feet 8 inches to 6 feet tall. To summarize, the following criteria were established regarding the preliminary selection of subjects:

1) Male
2) Caucasian (to limit variables)
3) Age - 30 to 50 years old
4) Waist - 36 inches
5) Height - 5 feet 6 inches to 6 feet tall

Potential subjects were located by canvassing several sources - local men's specialty stores and the Virginia Tech tailor shop. An informational flier was distributed regarding the subject criteria and a brief description of the study and what was required of the subjects (Appendix B). The cooperation of a retail store manager and the tailor shop director was elicited in the location of subjects. Fliers were also posted in several prominent Virginia Tech buildings, however no response was gained from these sources.
The researchers were given the names of several potential subjects from both the retail store and the tailor shop. These men were contacted by phone to determine if they, first, met the specific requirements of the sample and secondly, if they would be willing to participate in the study. Of the men contacted five met the specifications and were willing to participate.

It was then necessary to determine if the subjects fit the specific trousers well enough in areas other than the crotch area. This evaluation was conducted to determine if the potential subjects had the correct body type/shape to wear the specified trousers. Each subject was evaluated using a fit guidelines questionnaire (Appendix C) by a convenient panel of judges which was comprised of three - four clothing and textiles faculty and staff. (Note: whether the trouser length was appropriate was not considered as a criteria, for evaluation because it had no bearing on the crotch area). The evaluation included actual measurement of the subjects waist size and height by the researcher, trying on of the trousers by the potential subject and completion of the fit evaluation questionnaire by the panel of judges.

All of the potential subjects scored acceptably on the fit guidelines questionnaire and were chosen to participate in the study. Each of the five subjects was scheduled to return for measurements on three separate days to decrease measurement error and determine reliability.

Method for Crotch Shape Reproduction

Each of the subjects were assigned a number and a pair of jockey briefs to be worn during the measurement session. During each session the
subject donned their assigned briefs and tied a piece of yarn around their waist (as determined comfortable by the subject). The measurer used the tape measure to measure the waist, over the yarn. The outseam was measured with the tape measure from the side waist (at the yarn) to the lower portion of the lateral malleolus (ankle bone on outer side of leg). Both of these results were recorded by the measurer on the subject information sheet (Appendix D).

The flexicurve was positioned around the subject’s crotch shape so that the open hinge (top flap unhooked on one side) was easily accessible, toward the back (Figure 6a). In order to measure the entire crotch shape it was important that the end of the flexicurve met or extended above the waist at the center front and the center back. Center front was specified as a line intersecting the navel, and center back as a line following the spine, both perpendicular to the floor. As the flexicurve was molded along the front, between the legs and up the buttocks, care was taken not to allow the instrument to fall between the buttocks. This precaution was taken so that the pants when sewn would not be too snug or cut sharply between the buttocks, due to the crotch shape being unrealistically shallow in this area. The measurer then smoothed down the top flap (loop material) of the hinge and pressed gently to adhere to the hook material securely (Figure 6b). This defines the shape in this area while giving leverage to remove the flexicurve.

The subject was instructed to hold the flexicurve in place in the front and back. The measurer marked the waist, front and back, with tailor’s chalk on the flexicurve. The measurer then adjusted the plumbline
Figure 6
Flexicurve on the body
length at the ankle slid the chain loop along the flexicurve, until the bolt lined up with the ankle bone (Figure 7). The point at which the adjusted plumbline loop crossed the flexicurve was marked on the flexicurve by the measurer with tailor’s chalk. This denoted the crotch point.

The molding of the flexicurve to the body was rechecked by the measurer. To remove the flexicurve, the measurer stood or knelt facing the side of the subject. The measurer then grasped the flexicurve carefully in the front and back and allowed the instrument to slip down between the legs. The flexibility at the hinge was used to open the flexicurve outward slightly to clear the stomach and buttocks without distorting the molded shaped in the instrument (Figure 8). The subject stepped out of the flexicurve as it was lowered toward the floor.

The flexicurve was carefully laid on a sheet of brown paper. The shape of the flexicurve was restored by shifting the upper back portion of the instrument until the upper flap of the hinge formed a smooth line (no buckles) over the lower part of the hinge (Figure 9).

The measurer returned to the subject and measured the waist thickness. The calipers were placed with one tip on the center front and the other tip on center back of the waist tape as positioned by the wearer (Figure 10).

The investigator, using the waist thickness measure, did a final trueing of the flexicurve by adjusting the distance between the front and back waist points. The crotch shape was then traced onto the paper marking the crotch point and front and back waist points.
Figure 7

Positioning of the plumbline
As flexicurve is lowered away from the body, the subject should step out of it.

FIGURE 8

Removal of flexicurve
Figure 9
Restoration of shape and tracing of flexicurve
Figure 10
Waist thickness
Using the tape measure turned on its side, the length of the traced crotch shape was measured from the front waist to the crotch point and from the crotch point to the back waist. The total crotch shape length was also measured as a check to improve reliability. These three measures were recorded. This process was repeated for each of the five subjects during each of three separate measurement sessions.

After each crotch shape was traced onto paper and measured it was traced onto an "x" and "y" coordinate grid which was marked off in one half inch blocks. The grid was drawn on clear acetate film, so that the crotch shapes could be easily traced. The crotch point was used as one reference point and was plotted at the intersection of the "x" and "y" axis. A second reference was needed, so that all the shapes for each individual subject were positioned relative to each other.

It was originally thought that the shapes could be positioned so that the back waist height could be used as the second reference. Measurement of the subject's waist height or vertical depth of the crotch shape (Figure 11) was taken by standing the anthropometer behind the subject close to the body. The horizontal arm was moved up the apparatus until it "just touched" the crotch area, between the legs, as indicated by the subject. The reading at the crotch level and the waist level was subtracted to indicate the distance from the crotch to the waist. On the grid, the back waist height was indicated by the appropriate measures on the "y" axis. The crotch shape was rotated using the crotch point as a pivot until the back waist point was at the determined waist height on the grid (Figure 12). Examination of the crotch shapes indicated that while
Figure 12
Crotch shapes on grid using only back waist height reference
the shapes for a given subject appeared similar, the use of back waist height as a second reference point caused the curves to be positioned on the grid such that few points (other than the crotch point) coincided. If placed on top of each other matching the crotch point and the back waist point, the shapes similarities were more apparent.

Therefore, rather than use the back waist height alone to align the crotch shapes on the coordinate grid, the back waist height was used in conjunction with a common "x" coordinate (Figure 13). The back waist height was used to align the crotch shape for each subject's first measurement session and for each subsequent session the back waist point of the shapes would be aligned along the same "x" bar as the first shape, still using the crotch point as the pivot point. When the common "x" coordinate was used in conjunction with the back waist height, similarity of the shapes was improved.

The three curves for each subject were traced onto and overlapped on one grid. Therefore, there were five grid drawings, one representing each of the five subjects.

The literature related to pattern drafting, states that the extension for the crotch point from the center back is determined as 1/2 of the back pattern piece hilinese width and from the center front, 1/4 of the front pattern piece hilinese width (Bame, 1978). This proportion guideline was used to verify the positioning of the crotch shapes on the grid. Various subjects shapes were "spot-checked" to validate the chosen method of alignment of the crotch shapes on the grid. The absolute distance between the (0,0) crotch point and the "x" coordinate for the
Figure 13
Crotch shapes using back waist height and "x" bar reference
front and back waists was compared to the hipline measure for the corresponding subject and measurement session.

The crotch shapes were plotted as "x" and "y" coordinates and read into an IBM personal computer which was interfaced with a Numonics Model 1224 electronic digital analyzer. The acetate grid which contained the crotch shapes for each of the three measurement sessions was taped to the screen and a light was placed behind the screen, which allowed the screen to act as a light board. The analyzer's digitizing arm was moved along each shape beginning at the crotch point (0,0) and continuing up the front, then beginning at the crotch point and continuing up the back, plotting points at regular intervals. Points were plotted every 0.5 inches along the "x" axis (following the crotch shape) until the "x" values ceased to increase at 0.5 inch increments. The points were then plotted every 0.5 inches along the "y" axis ending at the front and back waist points.

A program was written using the Basic computer language which stored subject, measurement session and front and back crotch shape information. In addition the program read each point from the digitizer, rounded it to the two nearest decimal places (1/100) and stored the data on a floppy disk.

Analysis of Data

Appropriate methods were chosen to analyze the data from all phases of the procedure and data collection. Methods for each hypothesis are presented below.
**Hypothesis 1:** The inseam (crotch point) is located at a line (perpendicular to the floor) plumbed from a point on the crotch shape to the tip of the medial malleolus (ankle bone).

Data for Hypothesis 1 were analyzed by reviewing the responses to questions on the observation sheet for determination of inseam location method (Appendix A).

**Hypothesis 2a:** The waist thickness, back waist height and crotch shape length can be reliably measured using the method described.

**Hypothesis 2b:** The instrument (flexicurve device) gives a reliable reproduction of the crotch shape from measurement period to measurement period for each subject.

**Hypothesis 3a:** The variability between the average crotch shapes for each subject is not significant enough to invalidate the method.

**Hypothesis 3b:** The variability between the best-fit crotch shape and the most extreme crotch shape is not significant enough to invalidate the method.

Descriptive statistics (Number Cruncher package) was used to determine the means and standard deviations for the waist thicknesses, back waist heights and crotch shape lengths, for each individual subject for each measurement session to test Hypothesis 2a. The mean standard deviation between subjects for each of the above measures was calculated using each subject’s mean measures.
The data for hypotheses 2b, 3a and 3b were statistically analyzed using the Number Cruncher Package. Scatter plots were produced which plotted the "x" and "y" coordinates for all subjects shapes for all sessions. Standard deviations were calculated for the crotch shapes for each subject from measurement session to measurement session at specific points along the "x" axis. The mean standard deviations for all subjects were also calculated. Scatter plots were also generated that diagramed the average shape for each subject.

The best-fit crotch shape was determined by establishing a regression function which most closely fit the average crotch shapes of all subjects. Two different equations were derived - one which modeled the front and one which modeled the back. Using a scatter plot the best-fit shape was overlayed with the average shapes for all subjects. A qualitative analysis was made of the scatter plot diagrams.

**Hypothesis 4a:** The best-fit crotch shape can be successfully matched to the crotch point and the back waist point of an appropriately sized pattern.

Hypothesis 4a was tested by observing the best-fit crotch shape as it was incorporated into the pants pattern, and noting the position of the crotch point and the back waist point.

**Hypothesis 4b:** There is a difference in the shape of the best-fit crotch shape and the crotch curve presently used in the apparel company’s pants pattern.

To test Hypothesis 4b, a qualitative, visual comparison was made between the best-fit crotch shape and the crotch curve in the pattern the
apparel company presently uses. The crotch curve in the apparel company's pattern was digitized, scatter plotted and compared in two ways. 1) The front and back crotch shapes were aligned by matching up the inseam (along the first two inches) to the central "x" axis (crotch point at (0,0)) (Figure 14) and compared to the best-fit shape (regression model). This was referred to as the "inseam curve". 2) For the front and back crotch curves the straight grain on the pattern was lined up parallel to the "x" bars of the grid with the crotch points, front and back, lined up with (0,0) (Figure 15) and compared to the best-fit shape. This was referred to as the "straight grain curve". Areas or points of similarity and dissimilarity were noted.
Figure 14
Alignment of the "inseam curve"
Figure 15

Alignment of the "straight grain curve"
Results and Discussion

The purpose of this research was to develop a method for determining the best-fit shape for the crotch seam of men's pants. The results are based on data collected during July and August of 1990 from a sample of 25 male Virginia Tech cadets (phase one of research) and a primary sample of 5 males between the ages of 30 and 50, between 5'8" to 6'0" tall and who had a 36" waist (phase two of research). The data were examined using, qualitative as well as statistical analysis.

The results are presented in the following categories: 1) determination of crotch point, 2) variability within subjects for specific body measures, 3) variability within subjects for crotch shape 4) variability between subjects for crotch shape, 5) comparison of best-fit crotch shape to most extreme crotch shape, 6) comparison of the best-fit shape to the current pattern shape.

Determination of Crotch Point

In establishing a method of determining the crotch point the plumbline device was tested on a group of 25 male Virginia Tech cadets wearing their fitted trousers. During the measurement process the recorder steadied the plumb line chain and noted the relative position of the bolt and ankle bone on the observation sheet (Appendix A).

Of the 25 subjects measured during the crotch point assessment, the plumbline position for 23 of the subjects hung from the crotch point to the ankle bone. The other two subjects produced results in which the plumbline fell in front of the ankle bone for one subject and behind the ankle bone for the other subject. The inconsistency of these two subjects
could be the result of different body configurations or measurer error, however, the differences attributed to these two subjects were not investigated. These results suggested that the plumbline device would provide an acceptable method for determining the crotch point on men's trousers, and therefore, Hypothesis 1 was accepted.

Variability within Subjects for Specific Body Measures

Waist thickness

Waist thickness was measured using standard anthropometric calipers positioned at the center front waist point and the center back waist point on the waist tape which was positioned by the subject. The waist thickness was used to true the width at the top of the flexicurve (front waist to back waist) after the instrument had been molded and removed from the body (before tracing). The amount of trueing necessary for the curves was negligible, providing some evidence that the flexicurve was an accurate reproduction of the upper portion of the crotch shape.

Descriptive statistics were conducted for the waist thickness. Examination of the results of the analysis shows that the mean standard deviation within subjects was .24 inches and the standard deviation of subject means was at .29 inches (Table 1). These low standard deviations suggest that the calipers provide a reliable method of measuring waist thickness and that the waist thickness measure provides a reliable reference for establishing the width of the crotch shape from center front to center back. Therefore, Hypothesis 2a is accepted for waist thickness.

Crotch shape length

The total crotch shape length was measured with a tape measure from
Table 1

Means and Standard Deviations for Waist Thickness by Subject Across Measurement Periods

<table>
<thead>
<tr>
<th>Waist Thickness</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(inches) (n=3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject</td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>1</td>
<td>9.58</td>
<td>.12</td>
</tr>
<tr>
<td>2</td>
<td>9.25</td>
<td>.34</td>
</tr>
<tr>
<td>3</td>
<td>8.86</td>
<td>.34</td>
</tr>
<tr>
<td>4</td>
<td>8.99</td>
<td>.30</td>
</tr>
<tr>
<td>5</td>
<td>9.38</td>
<td>.12</td>
</tr>
</tbody>
</table>

Mean for all subjects: a \( \frac{9.21}{5} \)

S.D. of subject means: c \( \sqrt{\frac{.24}{5}} \)

---

\( a \quad \text{Mean for all subjects} = (\text{Mean 1} + \text{Mean 2} + \text{Mean 3} + \text{Mean 4} + \text{Mean 5}) / 5 \)

\( b \quad \text{Mean for all subjects} = (\text{S.D. 1} + \text{S.D. 2} + \text{S.D. 3} + \text{S.D. 4} + \text{S.D. 5}) / 5 \)

\( c \quad \text{S.D. of subject means} = \text{Variability between means for subjects 1 through 5} \)
front waist to back waist along the traced crotch shape. Also measured were the back and front crotch shape lengths - back waist to crotch point and front waist to crotch point - both along the traced crotch shape. The mean standard deviation within subjects for the total crotch length was .89 inches (Table 2). The mean standard deviation between subjects for total crotch length was even higher at 1.56 inches. As the crotch shape length is dependent on the waist point location this high variability further illustrates inconsistency in the waist designation.

Examination of the back and front crotch lengths individually shows the standard deviation for front crotch length within subjects was higher than the standard deviation for back length within subjects. The differences in front and back crotch lengths between subjects were even greater. Over 2/3 of the standard deviation of subject means was in the front crotch length (1.19 inches). The back crotch length had standard deviation of subject means of .53 inches, approximately 1/3 of the total standard deviation of subject means. These results indicate that the greatest inconsistencies in waist point designation occurred in the front waist with the back waist designation somewhat more consistent. Hypothesis 2a was not accepted based on this evidence.

**Back waist height**

The back waist height was measured using the sliding arm anthropometer from the crotch level to the back waist level. The sliding arm anthropometer has been established in the field as a reliable measure of anthropometric dimensions (O’Brien, 1941), however, the measures are only as reliable as the landmarks on which they are based. It has been
### Table 2

**Means and Standard Deviations for Crotch Shape Length by Subject Across Measurement Periods**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Mean Back Length</th>
<th>S.D.</th>
<th>Mean Front Length</th>
<th>S.D.</th>
<th>Mean Total Length</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.92</td>
<td>.29</td>
<td>11.92</td>
<td>1.01</td>
<td>26.75</td>
<td>1.32</td>
</tr>
<tr>
<td>2</td>
<td>15.58</td>
<td>.95</td>
<td>13.50</td>
<td>1.15</td>
<td>28.83</td>
<td>.80</td>
</tr>
<tr>
<td>3</td>
<td>15.92</td>
<td>.38</td>
<td>12.25</td>
<td>.25</td>
<td>28.17</td>
<td>.14</td>
</tr>
<tr>
<td>4</td>
<td>14.58</td>
<td>.72</td>
<td>10.17</td>
<td>.80</td>
<td>24.75</td>
<td>.66</td>
</tr>
<tr>
<td>5</td>
<td>15.33</td>
<td>.87</td>
<td>11.75</td>
<td>.75</td>
<td>27.08</td>
<td>1.63</td>
</tr>
</tbody>
</table>

| a       | Mean for all subjects = (Mean 1 + Mean 2 + Mean 3 + Mean 4 + Mean 5) / 5 |
| b       | Mean for all subjects = (S.D. 1 + S.D. 2 + S.D. 3 + S.D. 4 + S.D. 5) / 5 |
| c       | S.D. of subject means = Variability between means for subjects 1 through 5 |

Means for all subjects:
- a: 15.27
- b: 11.92
- c: 0.53

S.D. of subjects means:
- a: 0.64
- b: 0.79
- c: 1.19

Total:
- a: 27.12
- b: 0.89
- c: 1.56
previously indicated that the method of waist designation used in this study allowed for large variation in the crotch length measures. Using this method, standard deviations for back waist height within subjects ranged from .23 to 1.83 inches, with a standard deviation of subject means of 1.11 inches (Table 3). Subject 3 was extremely variable with a standard deviation almost three times that of the next most variable subject. These high standard deviations indicate a problem in the designation of the waist points, but since the mean standard deviations for back crotch length were not as high or as variable, all of the back waist height variance is probably not due to the waist designation. Some of the variance in waist height could be attributed to the soft and sensitive part of the body (crotch point area) which the sliding arm anthropometer is raised against. These inconsistencies will be reflected in the following discussions of the flexicurve. Due to the high variations Hypothesis 2a is rejected for back waist height.

Variability Within Subjects for Crotch Shape

A qualitative visual analysis of the crotch shapes revealed some variation within subjects in the front and back waist levels, across measurement sessions (Figure 16), again indicating problems in the reliability of the designation of the waist.

Standard deviations between the crotch shapes for each subject from measurement session to measurement session were determined at specific points along the "x" axis up to the point at which the "x" values ceased to increase (fullest part of the shapes - front and back). Standard deviations were calculated only on these areas on the shape because they
Table 3

Measures and Standard Deviations for Back Waist Height by Subject Across Measurement Periods

<table>
<thead>
<tr>
<th>Back Waist Height (inches) (n=3)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>1</td>
<td>11.02</td>
<td>.59</td>
</tr>
<tr>
<td>2</td>
<td>11.29</td>
<td>.63</td>
</tr>
<tr>
<td>3</td>
<td>13.65</td>
<td>1.83</td>
</tr>
<tr>
<td>4</td>
<td>11.29</td>
<td>.41</td>
</tr>
<tr>
<td>5</td>
<td>12.47</td>
<td>.23</td>
</tr>
<tr>
<td>Mean for all subjects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean for all subjects</td>
<td>11.94</td>
<td>.74</td>
</tr>
<tr>
<td>S.D. of subject means</td>
<td></td>
<td>1.11</td>
</tr>
</tbody>
</table>

a Mean for all subjects = (Mean 1 + Mean 2 + Mean 3 + Mean 4 + Mean 5) / 5

b Mean for all subjects = (S.D. 1 + S.D. 2 + S.D. 3 + S.D. 4 + S.D. 5) / 5

S.D. of subject means = Variability between means for subjects 1 through 5
Overlay of each subject's crotch shapes for all measurement sessions

(units in inches)
(front of the shape is to the right & back of the shape is to the left side)
session 1 = 
session 2 = ........
session 3 = -------
appeared to have the greatest variability and the computer could not compute standard deviations on areas in which the "x" values were duplicated. The results reveal that the deviations increased as one moved further away from the (0,0) crotch point, in both the front and back (Table 4). For example, on Subject One in the front, at x = -1 inch, the standard deviation between the three measurement sessions was .03 inches and at x = 4 inches the standard deviation had increased to .37 inches. The back shapes showed even higher standard deviations for all subjects as one moved from the crotch point toward the waist. These variations occurred even though the back waist point was fixed on a common "x" bar, for each subject’s three measurement sessions.

When the crotch shapes for each measurement session for each individual subject were laid on top of each other using the crotch point as a pivot point, the shapes appeared very similar, although large variations were evident in the waist levels. The method of alignment of the shapes using the back waist height/point and a common "x" bar is affected by the inconsistent designation of the waist and the variability in the back waist height measurement method. Until such time (future study) that the alignment issue has been resolved Hypothesis 2a can not be answered.

Variability Between Subjects for Crotch Shape

The average crotch shapes for each subject were printed on scatter plots (Figure 17). A visual assessment of the individual average shapes revealed that the curvature of the shape around the crotch point was relatively flat. This invalidates Lenker’s (1984) crotch point location
Table 4

Standard Deviations Between Shapes Obtained at the 3 Measurement Periods for each Subject at Specific Points on the "x" Axis

<table>
<thead>
<tr>
<th>&quot;x&quot; value (inches)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Mean.S.D. (n=3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-6</td>
<td>1.30</td>
<td>1.10</td>
<td>-</td>
<td>.71</td>
<td>.35</td>
<td>1.08</td>
</tr>
<tr>
<td>-5</td>
<td>.68</td>
<td>.82</td>
<td>.35</td>
<td>1.77</td>
<td>1.77</td>
<td>.87</td>
</tr>
<tr>
<td>-4</td>
<td>.45</td>
<td>.83</td>
<td>5.66*</td>
<td>.59</td>
<td>1.20</td>
<td>.77</td>
</tr>
<tr>
<td>-3</td>
<td>.32</td>
<td>.61</td>
<td>.95</td>
<td>.36</td>
<td>.72</td>
<td>.59</td>
</tr>
<tr>
<td>-2</td>
<td>.10</td>
<td>.31</td>
<td>.52</td>
<td>.22</td>
<td>.42</td>
<td>.31</td>
</tr>
<tr>
<td>-1</td>
<td>.03</td>
<td>.16</td>
<td>.24</td>
<td>.11</td>
<td>.19</td>
<td>.15</td>
</tr>
<tr>
<td>0 (crotch point)</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>1</td>
<td>.09</td>
<td>.09</td>
<td>.10</td>
<td>.05</td>
<td>.18</td>
<td>.12</td>
</tr>
<tr>
<td>2</td>
<td>.22</td>
<td>.16</td>
<td>.27</td>
<td>.22</td>
<td>.37</td>
<td>.25</td>
</tr>
<tr>
<td>3</td>
<td>.24</td>
<td>.49</td>
<td>.43</td>
<td>.82</td>
<td>.57</td>
<td>.51</td>
</tr>
<tr>
<td>4</td>
<td>.37</td>
<td>.35</td>
<td>1.06</td>
<td>.07*</td>
<td>2.12</td>
<td>.29</td>
</tr>
</tbody>
</table>

(negative "x" values represent the area to the widest point of the back crotch shape)

(positive "x" values represent the area to the widest point of the front crotch shape)

*value not included in mean

66
Figure 17
Individual average crotch shapes
method which allowed a paper clip to slide along a crotch curve measurement device (tape measure) to the lowest point of the crotch. If the shape of the crotch around the crotch point is a plateau there is no low point toward which the paperclip (or plumbline) could easily fall. Therefore, the crotch point location method used in the present study (which uses a plumbline to the ankle bone), since it does not require a particular crotch shape, is further validated.

Through a visual comparison of an overlay of the average crotch shapes of each subject (Figure 18), it can be seen that there were large disparities in the upper portions of the back (buttocks) and front (stomach), from subject to subject. Review of the data related to the waist thickness shows a range of between subjects of .72 inches (from 8.86 to 9.58 inches). Assuming the variability is evenly distributed, front to back, the shapes, if aligned accurately, should vary over a total range of only .36 inches from each other. The disparities evidenced above indicate that the problem lies in the alignment of the shapes in relation to each other (pivoting around the (0,0) crotch point) and not to problems in the shape reproduction method. In other words the body (crotch shape) can be accurately reproduced, but the accurate alignment of the shapes on a grid, which is essential to meaningful analysis of the data, is hampered by unspecific establishment of reference points. Hypothesis 3a is cannot be answered until such time (future study) that the alignment problem can be resolved.

Comparison of Best-fit Crotch Shape to the Most Extreme Crotch Shape

The best-fit crotch shape was identified by fitting the average
Figure 18
Overlay of all average shapes for each subject
crotch shapes to a regression model, which is quantified by the following equations and diagramed on a scatter plot in relation to the average crotch shapes of all subjects in Figures 19 and 20:

**Front**  
\[ y = -0.772 + 3.557 \left( \frac{1}{x} \right) + 0.306 \left( \frac{1}{x^2} \right) \]  
\( (r^2 = .96) \)

**Back**  
\[ x = -1.1151 + 1.732 (y) + 0.2086 (y^2) + -0.00747 (y^3) \]  
\( (r^2 = .87) \)

A most extreme shape could not be identified for comparison to the best-fit crotch shape from the five subjects average shapes because there appeared to be an equal number of crotch shapes on either side of the best-fit shape (ie. the best-fit shape was almost an average of all subjects). The best-fit shape appeared to fit closely to the subject’s average crotch shapes in the front crotch point area. The average crotch shapes began to diverge from the best-fit shape (on both sides-narrower and wider) as the shape began to curve over the stomach area. The average crotch shapes varied over a range of approximately 1.2 inches narrower than the best-fit shape at the front waist and over a range of approximately 1 inch wider than the best-fit shape at the front waist. In addition the waist point of the best-fit shape appeared approximately 1 inch higher than the majority of waist points on the subject’s average crotch shapes.

The back best-fit shape appeared to parallel the curve of the subject’s average crotch shapes well in the crotch area, but it was approximately one inch narrower than the average crotch shapes. As the shapes began to curve upward over the buttocks, the average crotch shapes
Figure 19
Overlay of the best-fit shape with the average shapes for each subject (front)
Figure 20
Overlay of the best-fit shape with the average shapes for each subject (back)
varied approximately .75 to .50 inches on either side (narrower and wider) from the best-fit shape. The largest difference could be seen in the upper part of the shapes (waist area). In this area the average crotch shapes appeared approximately 1.4 inches wider than the best-fit shape, in other words the best-fit shape curved inward (toward the center of the body) substantially. The best-fit shape describes a more rounded buttocks (Figure 20) than the subject’s average shapes appear when examined individually (Figure 17). The waist levels of the back best-fit shape and the subject’s back average crotch shapes appear to be very close.

In addition, as pointed out previously, the alignment of the shapes is in question. This alignment problem could cause significant variations in the identification of the most extreme crotch shape, as well as in the identification of a best-fit curve through a regression function. Therefore, Hypothesis 3b could not be answered.

Comparison of the Best-fit Shape to the Current Pattern Shape

The best-fit shape was compared to the curve of the crotch seam in the apparel company’s pattern. The data were analyzed in two ways: 1) aligning the inseam of the pants pattern (front to back) and 2) aligning the straight grain of the pattern parallel to the "x" bars of the grid. The pattern was digitized into "x" and "y" coordinates and scatter plots were used to overlay the "inseam curve" (I.curve) with the best-fit shape and the "straight grain curve" (S.G.curve) with the best-fit shape.

The I.curve and the S.G.curves were overlayed to show the extreme variations between the two methods of alignment (Figure 21). The front I.curve and the front S.G.curve fit well in the crotch point area, but
Figure 21
Overlay of I. curve and S.G. curve

(back waist)

(front waist)

(crotch point area)

(units in inches)

o is I. curve

* is S.G. curve
the I.curve becomes deeper and wider than the S.G.curve as the curves move upward and over the stomach area. The front waist point on the I.curve is approximately 1 inch lower and approximately 2 inches wider than the front waist point on the S.G.curve. The front S.G.curve appears very flat (vertical) over the stomach and waist, while the I.curve is very wide with no indentation at the waist.

The back I.curve is also wider that the back S.G.curve, but unlike the front curves the I.curve is deeper in the crotch point area than the S.G.curve. The differences in the back waist point heights and widths is similar to the front. Neither of the curves has any indentation at the waist, but rather they flair outward at the waist points a phenomena which could be attributed to the incorporation of darts in a finished pattern.

A visual analysis of the front I.curve overlayed with the front best-fit shape reveals some similarity in shape under the crotch area, but large discrepancies as one approaches the curve of the stomach and moves up toward the waist (Figure 22). Similar results are evident when examining the back I.curve and best-fit shape (Figure 23). The back curve, however, does not fit as well in the crotch area, as the front curve and it fits better toward the middle of the curve/shape (fullest part of the buttocks) than the front curve.

Both the front and the back I.curves are fuller than the best-fit shape a result which could be attributed to an allowance for ease in a completed pattern as opposed to no ease in a body measurement/reproduction. The large "wedge" of variation at the top of both curves could be ascribed to darts which are incorporated into a
(units in inches)
* is best-fit shape
o is I. curve

Figure 22
Overlay of the best-fit shape with the I. curve (front)
Figure 23

Overlay of the best-fit shape with the I. curve (back)
completed pattern to provide shape.

Examination of the S.G. curve and the best-fit curve shows that in the front, as with the I.curve, the two curve/shapes fit very well in the area around the crotch point (Figure 24). As one rounds up over the stomach, however, the S.G. curve and the best-fit shape diverge significantly. The S.G. curve becomes almost vertical while the best-fit shape continues upward in a slightly rounded manner.

The back S.G. curve follows much more closely the best-fit shape (Figure 25). The middle of the buttocks and the toward the waist of the back S.G. curve appear to flatten out somewhat as compared to the best-fit shape.

The waist levels for both the I.curve and the S.G. curve are lower in the front and the back than the best-fit shape. This could be due to the fact that a waistband would be attached to the pants extending the waist. The plateau effect which was evident in the crotch point area on the crotch shapes reproduced from the body, is also reflected in the I.curve and the S.G.curve.

While there appear to be some similarities between the crotch curve seam on the apparel company’s pattern and the best-fit shape, it is not felt that the comparison is entirely valid, because like objects are not being compared. There are many differences between what is incorporated into the pants pattern and the body reproduction of the crotch shape. Factors such as, the inclusion of ease (amount and location), darts, pleats and the curvature of the inseam all serve to differentiate the crotch curve seam on the pants pattern from the actual
Figure 24
Overlay of the best-fit shape with the S.G. curve (front)
Figure 25
Overlay of the best-fit shape with the S.G. curve (back)
crotch shape of the body. More work is needed on the incorporation of the crotch shape reproduction into the pants pattern before it can be meaningfully compared to a pants pattern.
Recommendations for Further Study

It has been shown that the flexicurve can provide valuable information regarding the crotch shape. There does, however, need to be further research which clarifies certain measurement problems and consequent problems related to alignment of shapes for analysis so that the shapes may be compared more meaningfully to each other, such as, 1) specifying the waist location and 2) defining reliable reference points.

In future studies, it is thought that the method of waist designation used in this study does not give a consistent landmark on which to base other measures. It is felt that specific anatomical landmarks need to be established for the waist designation (such as one inch above the navel in the front and continuing to the back, parallel to the floor or having the subject bend sideways), so that all measures and comparisons (which are based on the waist points) can be meaningfully and reliably compared. Further research could also be conducted which utilizes the "hipline proportion method" of distributing the front and back crotch shapes around central "x" axis or the (0,0) crotch point.

Other problems related to incorporating the shape into a pants pattern also need to be resolved, namely, 1) a method for determining the affects of fitting devices such as darts, and 2) establishing ease amounts and locations. It is also recommended that a basic sloper be used for incorporation of the reproduced crotch shape rather than a stylized pattern.

In addition to the above problems which could be addressed with
future studies, the following are areas for further research which would expand and further test the findings in the present study:

1. A larger sample size could be used.
2. A wear test comparing pants incorporating the best-fit shape and pants made using a current pattern.
3. A study investigating problems related specifically to the crotch shape length for men.
4. A study could be designed which uses female subjects.
References


Appendix A

Observation Sheet for Determination of Inseam Location Method

Recorder_________________________ Date________________

Measurer_________________________ Time________________

Subject #__________ Inseam length________________

Plumb line length________________

Plumb line Method

1. At what point, in relation to ankle, does the plumb line fall from the crotch point, on the cadets trousers?

   a) Plumb line is in line with the ankle bone (i.e. perpendicular to the floor).

   b) Plumb line is _____ centimeters anterior to the ankle bone.

   c) Plumb line is _____ centimeters posterior to the ankle bone.

2. Does the cadet’s inseam follow the plumb line along the whole length?

   YES            NO

3. When the plumb line intersects the ankle bone the inseam point on the cadet’s trousers is ...

   a) in line with the plumb line.

   b) _______centimeters anterior.

   c) _______centimeters posterior.

   - Comments:


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Appendix B

Subject Recruitment/Informational Flier

MEN WANTED --- 30 to 50 years old
----------
--- 5’8” to 6’0” tall
--- 36” waist
--- Caucasian

YOUR HELP IS NEEDED FOR A CLOTHING STUDY

This study is being conducted by the Department of Clothing and Textiles, as both a thesis and departmental project in conjunction with a Virginia apparel company. In this study we propose to develop a measurement method which leads to better fitting men’s trousers. The specific area we want to improve the fit of is the crotch area.

We are seeking approximately ten male subjects to participate in the initial phase of the study. Each subject must meet the above specifications. During this phase each subject will try on a specific pair of trousers and the fit will be evaluated by a panel of three experts. This should take about ten minutes for each subject.

The five men who best fit the specific trousers will be selected to participate in the final measurement phase. Those five will be required to come back on three separate days for approximately 30 minutes a session. They will be measured by the Va Tech tailor in their underwear in a private room. Each participant who completes the three sessions will receive a FREE article of clothing.

Your participation is greatly needed to help a master’s student through her thesis study and support Va Tech’s research effort.

PLEASE CALL 231-4331 - IF YOU WOULD BE WILLING TO PARTICIPATE
ask for Susan Kornegay Henson
or Peggy Quesenberry
Appendix C

Fit Guidelines for Determination of Crotch Curve Subjects

Observer_________________________ Date______________
Subject ID #______________________ Time______________
Height________ Waist size (actual)________ Age________

Evaluate the fit of the prescribed trousers on the subject, circle the response which best describes the fit on the subject. Write any comments in the appropriate section below.

1. Waistband fits smoothly and securely.

Very snug  Somewhat snug  Good  Somewhat loose  Very loose

2. Front pleats (plts.) not pull open.

Plts. pull open and flatten across front Plts. hang straight Plts. pull open slightly

3. Onseam pockets do not pull open (i.e. pocket (pkt.) edge and side seam match exactly)

Pkts. pull open more than 1/2" Pkts. do not pull open between 0" and 1/2"


Very tight  Somewhat tight  Good  Somewhat baggy  Very baggy

5. Thigh area has adequate room.

Fabric is Somewhat snug  Good  Somewhat loose  Very loose skin tight

6. In your opinion, does the crotch area fit the subject adequately ?

   Yes       No

7. Comments: (if any)

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Appendix D

Subject Information Sheet - Crotch Shape Determination

Subject ID #___________
Height___________ Age___________
Measurer_______________ Date_____________
Recorder_______________ Time_____________

1. Actual waist size____________
2. Distance from waist down center front to hipline____________
3. Hip size (at fullest point)____________
4. Back waist height (inseam point to back waist)____________
5. Inseam length (inseam point to ankle bone)____________
6. Outseam length (waist string to ankle bone)____________
7. Waist thickness (front to back)*____________
8. Crotch shape length - total**____________
9. Front crotch shape length**____________
10. Back crotch shape length**____________

* using calipers
** measured from traced crotch curves
Vita

Susan Kornegay Henson, the daughter of Dr. and Mrs. Ervin T. Kornegay, was born on March 28, 1960 in Raleigh, N.C. She graduated from Blacksburg High School in 1978. In June, 1982, she received a Bachelor of Science degree in Clothing, Textiles and Related Arts from Virginia Tech, in Blacksburg, Virginia.

In August, 1989, Susan began her advanced studies and received a Master of Science degree from Virginia Tech in May, 1991. Her professional experiences include, product development with an apparel manufacturer, retail management, and various graduate teaching assistantships in the Department of Clothing and Textiles at Virginia Tech.