The Physical Properties That Influence The Drape Of Knitted Fabrics

by

Marian Louise Gaucher

A Thesis
presented to the University of Manitoba
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ABSTRACT

The drape of a fabric is defined as a description of the deformation of a fabric produced by gravity when only part of it is directly supported (Cusick, 1965). Several physical properties have been suggested as contributors to the drape of woven fabrics, but the literature lacks information concerning the physical properties that influence the drape of knitted fabrics. The present research investigated certain deformation properties and certain structural characteristics in order to determine the best predictors of the drape coefficient of twenty knitted fabrics. The deformation properties included stiffness, shear, and extensibility, while the structural characteristics included weight, thickness, and density. The measurements obtained were bending length, secondary shear modulus, extension at a 100 gram load, fabric weight, fabric thickness, and fabric density. The study also investigated the reliability of the properties as predictors for the two main types of knitted constructions- warp knits and weft knits.

Regression analysis was performed and several predictor equations were developed. The variables that predicted the drape coefficient varied according to the knit structure. For the twenty fabrics, the best predictor variables were bending length, thickness, secondary shear modulus, and transformations of these variables. Bending length, thickness, and extension were the best predictor variables for the warp knit subgroup, while bending length and secondary shear modulus were the best predictor variables for the weft knit subgroup.

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Chapter 1

INTRODUCTION

Fabric drape is one of the visual components in the aesthetic assessment of fabrics. Cusick (1965) defines the drape of a fabric as "a deformation of the fabric produced by gravity when only part of it is directly supported." Since the particular type and style of a garment determines the amount of drape required, some prediction of how a fabric will drape is necessary.

Several physical properties have been suggested as contributors to the drape of woven fabrics (Chu et al, 1963; Cusick, 1965; Sudnik, 1972, 1978; Kim and Vaughn, 1974; Morooka and Niwa, 1976), but the literature lacks information concerning the physical properties that influence the drape of knitted fabrics. The drape of woven fabrics is influenced by a combination of certain deformation properties and structural characteristics. Stiffness, shear, and extension are the relevant measures of deformation, while fabric weight and thickness are the appropriate structural characteristics.

The type of basic woven construction is a factor in the drape of woven fabrics, for example, twill, satin, and plain weaves (Cooper, 1960; Chu et al, 1963; Howorth, 1964). Researchers found than when yarns are woven into fabrics a wide range of stiffness is possible depending on the fibre movement permitted.

FOCUSSED STATEMENT OF THE PROBLEM

The major purpose of this research project is to determine if certain deformation properties and structural characteristics predict the drape coefficient of knitted fabrics. The deformation properties include stiffness, shear, and extension, while the structural characteristics include fabric weight, fabric thickness, and fabric density. Since density is calculated from weight and thickness, it is proposed that it could influence the drape coefficient.

In addition to studying knitted fabrics in general, the research project will also investigate the reliability of the properties and characteristics as predictors of the drape coefficient for the two main types of knitted constructions-- warp knits and weft knits.

All of the directional and face and back components of the deformation properties will be measured in order to determine which ones are the most reliable predictors of the drape coefficient.

Once the properties that influence the drape coefficient in knitted fabrics are determined, equations will be developed so predictions concerning the drape of a knitted fabric can be made if one or more of the fabric properties are known.

The objectives of this study are:

1. To determine whether the fabric properties of stiffness, shear, extension, weight, thickness, and density are reliable predictors of the drape coefficient in knitted fabrics.

2. To determine which directional and/or face and back components of these properties are the most reliable predictors of the drape coefficient in knitted fabrics. This would be limited to the properties found to be the most reliable in objective #1.
3. To determine whether the relationships existing in objectives #1 and #2 are consistant for the warp knit and weft knit subgroups.
4. To develop predictor equations in order to make predictions concerning the drape coefficient of a knitted fabric if measurements of one or more of the fabric properties are known.

JUSTIFICATION FOR THE RESEARCH PROJECT

The major justification for the research project was to establish a better understanding of the physical properties that contribute to the drape of knitted fabrics. The findings would fill a void in the current literature concerning the drape of knitted fabrics and its relation to various physical properties. In addition, both knitted fabric and garment manufacturers could utilize the predictor equations to allow knitted fabrics to be designed or modified to give the drape desired. Ultimately, this would ensure consumer satisfaction in this area of aesthetic assessment.

THESIS FORMAT

The remainder of the thesis is presented in four chapters. Chapter 2 is a review of the current literature. Chapter 3 outlines the experimental methods and materials. Chapter 4 includes a presentation of the results of the study and a discussion of these results. Chapter 5 includes a summary of the research project, implications of the research findings, and several recommendations for future study.

Chapter 2

REVIEW OF LITERATURE

The review of literature deals with two main topic areas-- a basic review of the knit structure and a discussion on fabric drape and its related deformation properties and structural characteristics. The basic types of knits are reviewed, including their structural arrangements, properties, and end uses. The literature on fabric drape and its related physical properties is limited to woven fabrics. This area of discussion, therefore, focusses on the properties that influence drape in woven fabrics. These properties include three deformation properties-- stiffness, shear, and extension, and two structural characteristics-- weight and thickness. Since fabric density is also included in the research, it is discussed as well. Drape is defined, the method of measurement is discussed, and the properties that influence drape in woven fabrics are briefly mentioned. The deformation properties and structural characteristics are defined and discussed in terms of their measurements and their relationships with drape. In addition, the relationships of the knit structure with each deformation property and structural characteristic are discussed.

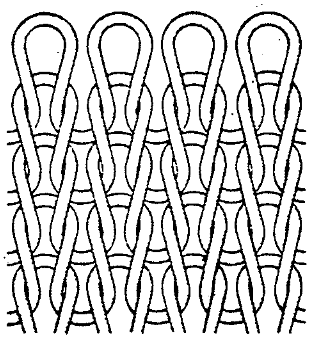
THE KNIT STRUCTURE

A knitted fabric is composed of a series of interconnected loops. The properties of the fabric depend on the method of production and the geometric relationships of these loops (Thomas, 1971). The two basic types of knitted fabrics are named after the general direction of loop formation in the fabric. In weft knitting the yarn is introduced in a weftwise direction, at right angles to the direction of fabric growth. In warp knitting the yarn follows a warpwise progression (Thomas, 1971). The vertical or lengthwise columns of interconnected loops, corresponding to the warp direction in a woven fabric, are called wales. The horizontal or crosswise rows of interconnected loops, corresponding to the weft dirction in a woven fabric, are called courses (Lyle, 1976).

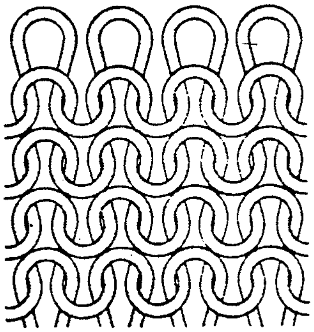
Weft Knits

The basic types of weft knits are plain or single jersey, purl, rib, interlock, and double knits. The basic repeat unit of each of these structures is a loop of yarn interconnected by a previously formed loop in the same course (Smirfitt, 1975).

The plain or single jersey is the simplest in construction (see Figure 1). All loops are interconnected in the same direction, are side by side in the same plane, and are drawn to one side of the fabric. The wales are on the face side while the courses are on the reverse side. The different loop structure of the face and back tends to cause curling of the fabric edges. The loops are easily distorted, primarily along the courses, making the weft direction very extensible. For this reason plain knits are used widely in sweaters, sportswear, underwear, and hosiery (Labarth, 1964; Wignall, 1964; Smirfitt, 1975).



(a) Face



(b) Back

Figure 1: Plain Weft Knit Structure
(Stout, 1967)

In the purl knit the courses are interconnected on opposite sides, resulting in similar appearances of both sides of the fabric. The simplest form is a 1/1 purl where alternate courses are knitted on opposite sides. Extensibility is particularly high in the walewise direction (Wignall, 1964; Smirfitt, 1975). For this reason, purl knits are used primarily in infant and children's wear and in non-fitted end uses such as scarves.

In the rib knit the wales are interconnected on opposite sides. The wales lie in different planes producing a thick fabric with high lateral extension and negligible longitudinal extension. Both sides of fabric have similar appearances. The simplest form is a 1/1 rib where alternate wales are knitted to the front and the back (Wignall, 1964; Smirfitt, 1975). Rib knits are utilized where a close fit is important, such as wristbands, waistbands, underwear, sweaters, and socks (Corbman, 1975).

The interlock knit is formed by interlocking two, 1 X 1 rib structures. The lateral extensibility is not as high as that in rib knits due to one set of ribs being between the other, interferring with the mobility of the loops (Smirfitt, 1975). The excellent longitudinal extensibility of the interlock knit contributes to its success in end uses such as shirts, dresses, suits, coats, and sportswear (Labarthe, 1964; Corbman, 1975).

A double knit is a type of jersey construction composed of two sides of fabric interlocked. One side of the fabric has a fine ribbed appearance, while the other side can assume various patterns, such as honeycomb or diamond. A double knit fabric is thicker, heavier, and more stable that a single knit and due to balanced yarn tension across the fabric, it has no curling tendancy (Stout, 1967). Double knits have been used in sportswear, suits, dresses, and slacks (Corbman, 1975).

Warp Knits

In warp knitting many yarns from a warp beam are fed into the knitting needles simultaneously, forming adjacent warpwise loops. The fabric is formed by interconnecting individual warp yarns into these warpwise loops (see Figure 2). The yarns follow a zigzag progression which helps to close the structure, making it more compact and dimensionally stable than a weft knit (Thomas, 1971; Darlington, 1971; Joseph, 1972). The wales are on the face of the fabric, while the courses are on the back. The two basic classifications of warp knits are tricot and raschel (Lyle, 1976). The basic differences between the tricot and raschel structures are the type of needle used and the number of sets of yarns used.

A tricot knit is classified according to the number of sets of yarns used in its structure. It has vertical wales on the face and horizontal ribs on the back (Lyle, 1976). The difference in the loop geometry on the face and back tends to cause curling of the fabric. Tricot knits do not extend as easily as weft knits. End uses include lingerie and outerwear items (Labarthe, 1964).

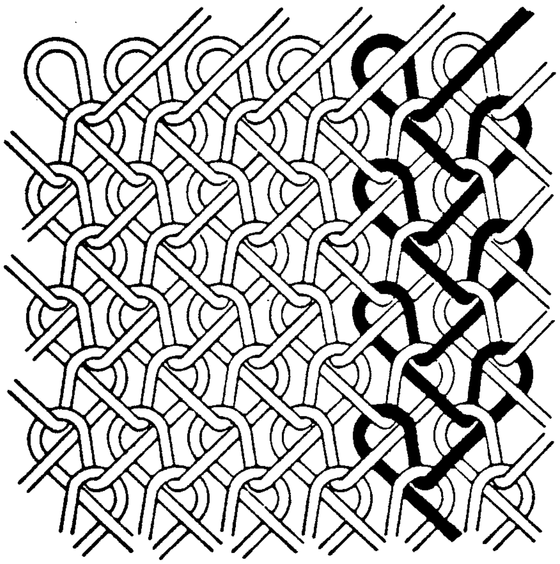


Figure 2: Warp Knit Structure
(Cowan and Jungerman, 1969)

The raschel knit machine is very versatile, allowing a great number of yarn sets to be used. This leads to many different possibilities of structural design, from an open-work crochet to solid structures with three-dimensional effects (Lyle, 1976). This versatility extends the properties and end uses of the fabric. End uses include dresses, suits, drapes, and lingerie.

DRAPE

Cusick (1965) defines the drape of a fabric as "a description of the deformation of a fabric produced by gravity when only part of it is directly supported". The major mode of deformation in drape is bending, but the occurence of multi-directional curvature implies that shearing is also taking place. There are also tensile and compressive deformations occurring in draping but these are usually small due to yarn stiffness (Hearle, Grosberg, and Backer, 1969; Morooka and Niwa, 1976; Sudnik, 1978). Fabric weight and thickness are the structural characteristics that influence drape (Chu et al, 1963; Kim and Vaughn, 1974; Morooka and Niwa, 1976; Sudnik, 1978), however, no relationships between drape and fabric density have been reported in the literature.

The Measurement of Drape

The drapemeter is the instrument that is generally adopted to measure drape (Chu ėt al, 1950, 1963; Cusick, 1965, 1968; Kim and Vaughn, 1974; Sudnik, 1972, 1978). The drapemeter allows measurement of drape when the fabric is distorted into multi-directional curvature. A circular specimen is supported by a smaller horizontal disc allowing an annular ring of fabric to drape under its own weight. Three different specimen sizes may be used, allowing different ratios of the supported and unsupported areas, and thus, enabling more accurate measurement of three ranges of drape. The specimen size used depends on the drapeability of the fabrics, however, the results using different specimen sizes are not directly comparable (Cusick, 1968; Sudnik, 1972).

Drape is quantitatively expressed by the drape coefficient. It is calculated as the ratio of the area of the shadow projected when the fabric is allowed to drape, to the area of the annular ring of fabric which is allowed to drape. The drape coefficient is expressed as a percentage with a theoretical maximum of one-hundred and a minimum of zero. A high drape coefficient corresponds to low drapeability or a stiff fabric (Cusick, 1968).

Very drapeable fabrics tend to form pleats under the projection of the disc. These pleats are referred to as re-entrant folds. The extent of this folding cannot be measured and therefore, the drapemeter is limited in this respect (Chu et al, 1963).

Research Related to Drape

The major research in the area of drape has been accomplished by Chu et al (1950, 1963), Cusick (1965, 1968), Sudnik (1972, 1978), Kim and Vaughn (1974), and Morooka and Niwa (1976). All have done research on woven fabrics and there has been general agreement on the deformation properties and structural characteristics which relate to drape. The deformation properties are stiffness, shear, and extension. The structural characteristics are weight and thickness. Studies have also shown that the type of woven construction influences drape. Researchers found that when yarns are woven into fabrics a wide range of stiffnesses is possible depending on the fibre movement permitted (Cooper, 1960; Chu et al, 1963).

Predictor equations have been established for woven and nonwoven fabrics by Cusick (1965) and for woven fabrics by Morooka and Niwa (1976). In Cusick's equations the dependent variable was the drape coefficient (DC), while the independent variables included bending length (c), bending length squared (c^2), the shear angle at a specified load (A), and the shear angle at a specified load squared (A^2). One set of equations was derived for the entire group of fabrics only. The significance of the simple regression of DC on c was tested, followed by testing the significance of the difference made by including additional variables. The regression of DC on c was significant at a level higher than 0.001. The difference made by the addition of c^2 to c and A to c and c^2 were highly significant at a level higher than 0.001. However, the difference made by the further addition of A^2 was of lesser significance than the 0.05 level.

Morooka and Niwa (1976) measured sixteen properties including tensile, bending, shearing, compressional, and surface properties, weight, and thickness. Bending, weight, and shear were the most accurate predictors of the drape coefficient. When these three variables were included in the regression equation, the correlation coefficient was 0.78. High correlation resulted when the ratio of bending rigidity to weight was related to the drape coefficient. Shear did not have to be included for high correlation, but weight was necessary. Correlation improved when warp and weft directions were considered separately.

Past research has not established predictor equations concerning the drape of knitted fabrics.

THE DEFORMATION PROPERTIES

Stiffness

Stiffness is defined as the resistance offered by a fabric to bending. Bending is considered to be the major mode of fabric deformation in draping (Hearle, Grosberg and Backer, 1969).

The Measurement Of Stiffness

Stiffness is measured most often by the cantilever method or one of the hanging loop methods. In the cantilever method a fabric strip of a specified size is extended over a horizontal edge until the tip of the strip subtends a specified angle (Abbott, 1951; Kaswell, 1953). In Peirce's Heart Loop test a specimen of known dimensions is formed into a heart-shaped loop and suspended from a horizontal bar (Abbott, 1951; Brown, 1978; Peirce, 1930). Brown (1978) conducted a study to determine whether Peirce's Heart Loop Test could be used to measure the stiffness of single jersey fabrics with and without a tendancy to curl. An increase in strip width did decrease the curling edge effect and the variability. Evenso, meaningful results were obtained for the various strip widths tested.

One measure of stiffness is the bending length, c, which is calculated through the use of the following equations:

$$c = l_o f(\theta),$$

$$f(\theta) = (\cos \theta / \tan \theta)^{1/3},$$

$\theta = 32.85\ d/l_o$

$d = l - l_o$ and

$l_o = 0.1337L$

where l is the loop length and L is the strip length (Peirce, 1932; ASTM, 1978). The bending length is expressed in centimeters. Fabrics with a bending length of less than 2 cm are too flexible to be tested by the cantilever method and a heart loop method is advised (Kaswell, 1963).

Another measure of the stiffness is the flexural rigidity which measures the actual forces produced in bending and is therefore dependent on fabric weight.

Stiffness and the Knit Structure

Researchers state that the bending characteristics of warp- and weft-knitted fabrics are determined by fabric thickness, fabric weight, run-in-ratio, fabric tightness (yarn linear density in tex/loop length), stitch type, fabric directions, fabric face and back, and overall construction (Knapton, 1973; Hamilton and Postle, 1974; Knapton and Lo, 1975; Gibson and Postle, 1978).

Knapton and Lo (1975) stated that structurally unbalanced knitted fabrics resulting from different warp and weft counts, the different number of loops on the face and back, and/or different stitch arrangements on each side, have different directional and/or face and back bending characteristics.

Gibson and Postle (1978) found that overall fabric construction also determines bending characteristics. They measured the frictional bending moment (one-half the hysteresis at zero deformation) and the flexibility (the slope in the linear region of the hysteresis curve) of several types of knitted fabrics. Plain knits had very low frictional bending moments and very high flexibilities. Polyester double knits and warp knits had low frictional bending moments and high flexibilities. Wool double knits had medium to high frictional bending moments and low flexibilities. However, generally plain knits were similar to double knits.

Research Related to Stiffness and Drape

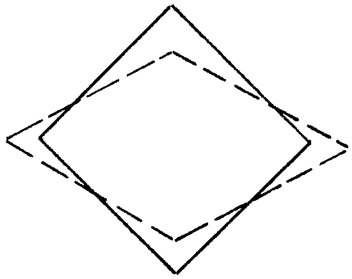
F.L. Peirce discovered that stiffness was an important factor contributing to drape as early as 1930. He found that stiffness and drape were negatively related, and more recently, other researchers have found similar trends. Cusick (1965) tested woven and nonwoven fabrics and reported that when drape coefficient values were plotted against bending length values the gradient increased as bending length increased. Also, the coefficients of determination were high for the multiple regression equations developed. Sudnik's work (1972) on woven, nonwoven, and knitted fabrics and Kim's and Vaughn's work (1974) on woven fabrics also resulted in high correlation between bending length and drape coefficient values. Morooka and Niwa (1976) found bending properties were the most closely related to the drape coefficient but weight was also included in the predictor equation.

Despite the fact that bending length is very highly correlated with drape, it cannot be equated with it (Chu et al, 1963). The strip test exhibits monoplanar deformation only, while the drape test exhibits multiplanar deformation.

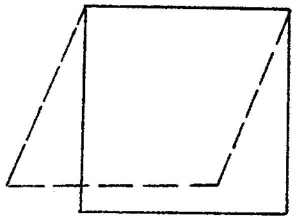
Shear

The American Society for Testing and Materials defines a shearing force as "the force that causes adjacent layers of an object to slide relative to each other in a direction parallel to their plane of contact, to obtain a separation in the object and a change in position" (ASTM, 1972).

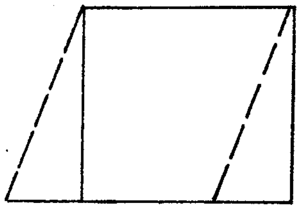
Shear strain can occur in various forms. Pure shear strain is defined as the deformation by extension in one direction and the contraction in the perpendicular direction, so that the area remains constant (Hearle, Grosberg, and Backer, 1969; Hamilton, 1975), (see Figure 3a). Simple shear strain also maintains constant area, but the sides which are initially perpendicular to the direction of shear move through a deformation angle (Hearle, Grosberg, and Backer, 1969; Hamilton, 1975), (see Figure 3b). Simple shear strain at constant length of sides is the type of shear deformation encountered most often in laboratory situations. This results in a decrease in area (Hearle, Grosberg, and Backer, 1969; Hamilton, 1975), (see Figure 3c).



a. Pure Shear Strain
(Hearle, Grosberg, and Backer, 1969)



b. Simple Shear Strain
(Hearle, Grosberg, and Backer, 1969)



c. Simple Shear Strain
at Constant Length of Sides
(Hamilton, 1975)

Figure 3: Forms of Shear Strain

Hearle et al (1969) define a shear stress as "the force acting tangentially on a plane in the material which must be balanced by an equal force in the opposite direction on a parallel plane, and then by a second couple to prevent rotation."

A simple shear test is illustrated in Figure 4. The shearing force, S, is calculated as follows:

$$S = F - W(\tan\theta)$$

where F is the shear stress per unit width of the specimen, expressed in g/cm, W is the tensile load applied to the fabric in grams, and tanθ is the shear strain (θ is the angle of inclination in the deformed state) (Cusick, 1961; Spivak and Treloar, 1968). The value W(tanθ) is usually negligible compared with F, so it is sometimes ignored (Spivak, 1966).

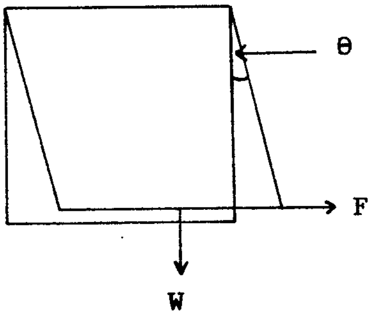


Figure 4: Simple Shear Test
(Spivak and Treloar, 1968)

Shear has been reported as an important aspect of drape of woven, knitted, and nonwoven fabrics by many researchers (Morner and Eeg-Olofsson, 1957; Cusick, 1965; Treloar, 1965; Carnaby and Postle, 1974; Hamilton and Postle, 1976; Goswami, 1977, and Gibson and Postle, 1978). Shear is especially important when fabrics are required to drape around the chest or in the sleeves of a garment where the fabric deforms with multidirectional curvature (Sudnik, 1972).

In most woven fabrics shearing can be explained by a change in angle between intersecting yarns. Bending and twisting of the yarns between intersections also contributes to the shear deformation (Cusick, 1966). The resistance to shear deformation is provided mainly by the frictional contact of yarns at the intersections (Skelton, 1976).

Very little research on the shearing of knitted fabrics has been reported in the literature but the major causes of deformation are thought to be interfibre and interyarn slippage, twisting and bending of the yarns, and jamming (Carnaby and Postle, 1974).

The Measurement of Shear

Several researchers have developed equipment to measure the shearing properties of textile materials (Dreby, 1941; Morner and Eeg-Olofsson, 1957; Behre, 1961; Treloar, 1965; Spivak, 1966; Carnaby and Postle, 1974; Hamilton and Postle, 1976). Many have adapted vertical strain gauge testing instruments, while others have designed equipment that can operate independently. In all of the tests the fabric specimen is mounted under tension along two parallel edges. A shearing force is applied through an angle until a compressive stress develops which leads to buckling of the fabric (Hearle, Grosberg, and Backer, 1969).

Dreby (1941) was one of the first to develop an instrument to study the shear of textile fabrics. Dreby's Planoflex was simple in design and measured the shear angle required to produce buckling.

Later, Morner and Eeg-Olofsson (1957) developed an apparatus which is mounted on an Instron tensile tester. It was the first to yield a fabric hysteresis curve. The specimen is held between two clamps. The top clamp rests on two knife edges, one of which is rigidly mounted, while the other is connected to the strain gauge of the Instron by a rigid rod. The bottom clamp is moved through a connection to the Instron crosshead. Horizontal movement of the botton clamp shears the specimen. The apparatus measures $R\cos\theta$ where R is the resistance offered to shearing and θ is the shear angle. Dawes and Owen (1971) were successful in utilizing this method to measure the shearing behavior of the warp-knitted components of fabric laminates. This method was also used by Cusick (1961) to study wovens.

Behre (1961) developed an instrument similar to that of Morner and Eeg-Olofsson, however, R could be measured directly. Behre tested various wovens and nonwovens (Behre, 1961; Lindberg, Behre, and Dalberg, 1961).

Treloar (1965) developed an apparatus that is manually operated. The specimen is mounted between two clamps. A vertical load is suspended from the center of the bottom clamp from where a horizontal load is applied. Measurements of the displacements are made with a travelling venier microscope.

Spivak's apparatus (1966) utilizes the Instron tensile tester to apply and measure the load and the resulting shear deformation. This apparatus is illustrated in Figure 5. The specimen is mounted between two vertical clamps, F_1 and F_2. Clamp F_2 is attached to the cross-head of an Instron tensile tester and clamp F_1 is suspended from the load cell. A normal load W is applied perpendicular to clamp F_1 to prevent premature buckling of the specimen. Vertical movement of clamp F_2 shears the specimen.

The apparatus has several advantages. It can be adapted to different specimen dimensions. However, Treloar (1965) found that the maximum shear strain which can be applied without the onset of buckling increases as the ratio of width to length of the specimen decreases. The shearing characteristics are much less sensitive to the magnitude of the normal load with a specimen ratio of width to length of one to ten. A second advantage of this apparatus is that the specimen is mounted vertically. This eliminates the clamp weight so that low normal loads may be used. The application of as low a normal load as possible is important in drape since the forces causing deformation during drape are small (Spivak, 1966). Spivak's work on wovens included experimentation with normal loads from 0 to 120 g/cm of the specimen width. He found that a combination of a low normal load and a long, narrow specimen resulted in the shearing stress being less sensitive to the normal load. Goswami (1977) and Spivak and Treloar (1965) who used the same apparatus for woven fabrics, used normal loads of 2.5 g/cm and 10 g/cm, respectively. A further advantage of the apparatus is the absence of possible frictional couples. Kim and Vaughn (1974) also utilized Spivak's apparatus.

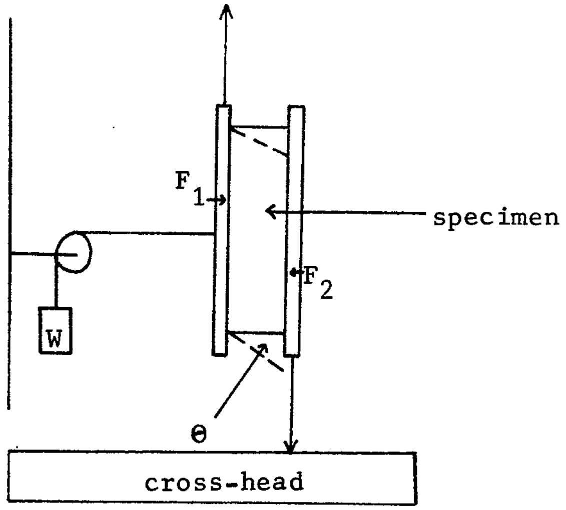


Figure 5: Spivak's Shearing Apparatus
(Spivak, 1966)

Carnaby and Postle (1974) were among the first to study the shearing properties of knits. Their instrument which is similar in design to those previously mentioned, consists of a top clamp which is rotated through an angle while a fixed bottom clamp provides the tensile and shearing stress. A square specimen is used. The shearing force obtained is equivalent to that defined by Morner and Eeg-Olofsson (1957) and Treloar (1965) for shearing at constant length of sides. However, Carnaby and Postle found that in order to ensure shear at constant length of sides in knitted fabrics, some constraint had to be included. Without this constraint they found deformation occurred that could not be classified as shear (Carnaby and Postle, 1974).

More recently, Hamilton and Postle (1976) have devised a shearing apparatus to accommodate this constraint required when shearing knitted fabrics. The apparatus operates independently of an Instron tensile tester. The specimen is mounted between two clamps. A stepper-motor is attached to a strain gauge which moves the bottom clamp. The shear strain is measured by a potentiometer.

Various measures of shear can be obtained from the hysteresis curves yielded by the various instruments. A typical hysteresis curve is illustrated in Figure 6. Spivak and Treloar used the resistance to shearing at a specified angle, the hysteresis at zero strain (XY), and the relative energy loss of the hysteresis ((ABC+DEF)-(BCD+EFA)/(ABC+DEF)) to measure shear. Goswami measured the latter two in addition to the shear stress and strain at the buckling point B.

Carnaby and Postle used the secondary shear modulus G, ie. the slope of the curve in the linear region, and the coercive force (XO), ie. half the width of the hysteresis loop at zero strain, and the shear strain. Some measurements are more reliable than others. For instance, the mean shearing modulus at zero strain (Cusick, 1961) and the estimate of the buckling point (Treloar, 1965; Spivak, 1966) are subject to high experimental error. The first involves the small forces in the initial stages of shear and a rapidly changing slope. The later involves error because definition of the point at which buckling occurs is highly subjective. The other measures of shear are reliable, their usage depending on the type of shear characteristic which is meaningful to the researcher.

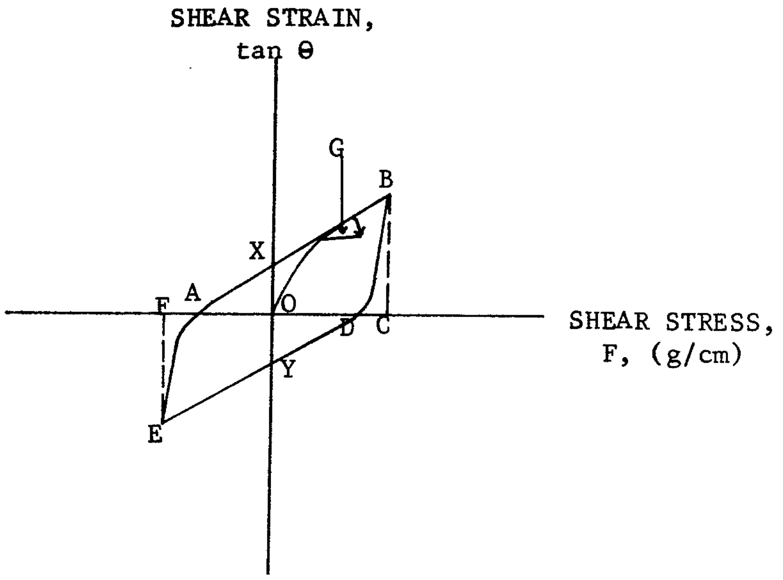


Figure 6: Hysteresis Curve
(Spivak, 1966
Carnaby and Postle, 1974)

Shear and the Knit Structure

Shear in knitted fabrics is not dependent on structural characteristics such as fabric thickness, weight, and tightness, but is more a function of fabric type (Gibson and Postle, 1978). Gibson and Postle (1978) measured the frictional shear stress (one-half the hysteresis at zero deformation) and the shearability (the slope in the linear region of the hysteresis curve) of several knitted fabrics. They found that weft-knitted fabrics had medium frictional shear stress and reasonable shearability, while warp knits had high frictional stress and low shearability.

The shearing behavior of a knitted fabric tends to be independent of the direction of the applied strain for warp knits and double knits (Gibson and Postle, 1978) but for the plain-knitted structure the application of the tension modifies the loop shape and therefore values of the shear measurements vary according to direction (Hamilton and Postle, 1977).

Research Related to Shear and Drape

In general, the research indicates moderate to high correlation between the drape coefficient and shear measurements. Cusick (1965) reported that woven and nonwoven fabrics with a high shear angle at a specified load have higher than average drape coefficients and those with a low shear angle at a specified load have lower than average drape coefficients. Research by Kim and Vaughn (1974) indicated a high positive correlation between the shear stiffness and the drape coefficient for woven fabrics. Morooka and Niwa (1976) found that shear was related closely to the drape coefficient but was not necessary for high correlation if bending and weight measurements were included. Sudnik's shear measurements (1978) on woven, knitted, and nonwoven fabrics showed only moderate agreement with drape and shear measurements.

Extension

The extensibility of a fabric under a tensile stress is a third component of the drape of woven fabrics. Extensibility is defined as the ease of stretching (Kaswell, 1963). The number of studies relating extension to drape has been limited, although this factor was included in research by Chu et al (1963) and Kim and Vaughn (1974).

The Measurement of Extension

One method of measuring extensibility is with a vertical strain gauge testing machine such as the Instron tensile tester. Other instruments are available, but the Instron tensile tester is one of the most precise.

Extensibility can be expressed in several ways. The ratio of tensile stress to strain or Young's modulus is one measurement of extensibility. Low modulus materials have high extensibility. Peirce (1930) advised that to relate extension to handle and stiffness, the measure of extensibility should be taken from the initial slope, because the tensile deformation experienced in bending is small. Two other methods of describing extensibility are the load at a specified extension or the extension at a specified load. Doyle (1953) advised that the latter is a more appropriate measure when a wide range of extensibilities has to be considered. Kim and Vaughn (1974) measured the percent extension of woven fabrics at a load of 1000 grams.

Extension and the Knit Structure

Knits have a low resistance to extension due to their low bending and tortional restraints (Hearle, Grosberg, and Backer, 1969). When a plain knit undergoes extension the loop structure changes shape (Doyle, 1953). This initial load is taken up by bending and twisting couples in the yarn and frictional constraints a loop intersections. As adjacent loops compress and bend into high curvature the load rises. Slippage of the loops over each other also occurs (Hearle, Grosberg, and Backer, 1969). When a warp knit undergoes extension the loop structure changes shape and similar couples and constraints occur (Hearle, Grosberg, and Backer, 1969). However, as the loop extends, yarns move from the crosslink into the loop.

Extension in plain knits varies according to fabric tightness, fabric direction and yarn structure (Doyle, 1953). In double knits extension depends on fabric tightness, fabric direction, stitch type, and stitch arrangements (Knapton and Lo, 1975). In warp knits extension depends on fabric tightness, fabric direction, and yarn stiffness (Cook and Grosberg, 1961).

Research Related to Extension and Drape

Research by Peirce in 1930 indicated that the drape of woven fabrics increased as extensibility increased. Other researchers found similar results in testing various woven constructions (Chu et al, 1963; Kim and Vaughn, 1974). Kim and Vaughn (1974) found very high correlation between the percent extension at a specified load and the drape coefficient. Morooka and Niwa (1976) found that extension was a poor predictor of the drape coefficient. The literature did not report relationships between drape and extension for knitted fabrics.

THE STRUCTURAL CHARACTERISTICS

The structural characteristics that are discussed are fabric weight, fabric thickness, and fabric density. Fabric density is defined as fabric weight divided by fabric thickness. Density is a measure of the degree of compactness of the structure.

The Measurement of the Structural Characteristics

To measure fabric weight, specimens of known dimensions are taken from fabric in moisture equilibrium with the standard atmosphere and weighed. Fabric weight is usually expressed in g/m^2.

To measure fabric thickness the specimen is subjected to a low specified compression between two parallel planes. Their perpendicular separation is taken as the thickness of the specimen at the pressure applied. Thickness is usually expressed in centimeters.

Fabric density is calculated as fabric weight divided by fabric thickness.

The Structural Characteristics and the Knit Structure

The weight of the weft knit structure is related to the loop length and the linear density of the yarn (Hearle, Grosberg, and Backer, 1969; Knapton, 1973). When these are held constant the weight depends on the knit structure.

Postle (1971) and Knapton and Lo (1975) have found that the thickness of weft knits is largely dependent on the yarn diameter but is marginally affected by the loop length and tightness of the structure.

The density of weft knits is markedly dependent on tightness and increases linearly with an increase in tightness (Postle, 1971; Knapton, 1973; Knapton and Lo, 1975). Fibre specific gravity is also influential but the type of knitted structure and yarn do not contribute.

Information regarding the structural characteristics of warp knits was not found in the literature.

Research Related to the Structural Characteristics and Drape

Chu et al (1963) and Morooka and Niwa (1976) stated that for wovens, fabric weight and the drape coefficient are negatively related. However, Kim and Vaughn (1974) found that weight and the drape coefficient were positively related, but the correlation was poor. Sudnik (1978) stated that the drape of woven fabrics is weight dependent, but did not explain the relationships involved. The weight of knitted fabrics as related to drape has not been discussed in the literature. The apparently conflicting results and the lack of research indicate further investigation into the relationship between weight and the drape coefficient is necessary.

Thickness has not been related to drape very often in previous research. Kim and Vaughn (1974) and Morooka and Niwa found that for woven fabrics, thickness tends to decrease as the drape coefficient decreases but the correlation is low. Fabric thickness has been found to influence the bending characteristics of knitted fabrics (Knapton, 1973, Hamilton and Postle, 1974; Knapton and Lo, 1975; Gibson and Postle, 1978), therefore it is possibly a good predictor of drape in knitted fabrics.

No relationships between density and drape have been reported in the literature. However, since weight and thickness have been found to influence drape (Chu et al, 1963; Kim and Vaughn, 1974; Morooka and Niwa, 1976; Sudnik, 1978) it is proposed that density may influence drape as well.

Chapter 3

EXPERIMENTAL METHOD

In addition to measuring the drape of several knitted fabrics, the present research project investigated three deformation properties and three structural characteristics in order to determine the accuracy of these properties and characteristics as predictors of the drape of knitted fabrics. The deformation properties included stiffness, shear, and extensibility, while the structural characteristics included weight, thickness, and density.

This chapter is presented in four sections. They are: (i) Pretest, (ii) Fabric Selection and Preparation, (iii) Physical Analysis of Fabrics, and (iv) Statistical Analysis. The 'Pretest' section outlines the justifications and overall results of the pretest only, as the specific influences of the pretest are mentioned in 'Physical Analysis of Fabrics.' 'Fabric Selection and Preparation' includes the selection of fabrics for screening, the fabric screening procedure, and fabric preparation. 'Physical Analysis of Fabrics' discusses each of the properties tested in relation to its method, equipment, measurement, specimen size, and sample size. 'Statistical Analysis' includes an outline of the statistical model and a description of the methods of analysis.

All testing was done according to standard test methods except for shear where no standard method exists for textiles. All fabric cutting and testing was conducted in the standard atmosphere of 21 ± 1 C and 65 ± 2 % relative humidity.

PRETEST

In order to determine the feasibility of the study in terms of time, equipment, and test methods; a pretest was conducted. The pretest fabrics included one warp knit and two weft knits. The knits exhibited different degrees of drape. The seven physical properties-- drape, stiffness, shear, extensibility, weight, thickness, and density-- were measured.

The pretest indicated the most appropriate method of testing and specimen sizes, the most reliable measurements, and the variability and limitations of the equipment and the test methods.

FABRIC SELECTION AND PREPARATION

Selection of Fabrics for Screening

Forty-two warp- and weft-knitted fabrics were selected from the Winnipeg market for screening purposes. Because of the exploratory nature of the study and the need for a wide range of drape coefficient values, a variety of different knit constructions was chosen. Fabrics whose end use is apparel were chosen because this end use encompasses all types of knitted constructions. Fibre content was not a controlled variable in fabric selection because fabric construction is the predominant variable in drape.

The fabric constructions selected were of two main types-- warp knits and weft knits. The warp knits included tricot and raschel, the two most prevalent warp knits. The weft knits included plain or single jersey, rib, interlock, and double knits. Warp- and weft-knitted pile fabrics were also selected for screening. Purl knits were not selected because of their limited application in apparel and their limited availability.

Fabric Screening

Prior to the screening procedure the fabrics were laundered according to the Canadian National Standard CAN2-4.2-M77 Method 58-1977 (CGSB, 1977) in order to remove any water-soluble finishes and soil and to relax the fabrics.

The purpose of screening the fabrics was to limit the number of fabrics to be tested, while maintaining a wide range of drape coefficients for the entire group of fabrics chosen, as well as for the warp- and weft-knitted subgroups.

The drape coefficients of the forty-two fabrics were determined according to the British Standard Method BS:5058-1973 (BSI, 1974), except that the face and back were each tested once on one drape specimen. The drape coefficients ranged from 15 to 70% for the forty-two fabrics. From these, twenty fabrics were chosen for the research project, including ten warp knits and ten weft knits. The range of drape coefficients for each of these subgroups was also 15 to 70%.

Fabrics were excluded from the group of forty-two for several reasons. Rib knits were excluded because of their directional drape characteristics. They also had poor draping properties, and thus, did not provide a good range of drape. Pile knits were excluded because of the difference in the drape coefficients between the face and the back. Other types of fabrics with very different face and back drape coefficients were also excluded. Fabrics with a tendancy to curl were excluded. When two or more fabrics had the same drape coefficient, only one was used in the study. This selection was made randomly.

In order to ensure that the drape properties of the twenty fabrics were due to construction rather than finishes, the presence of finishes was determined on all fabrics using the American Association of Textile Chemists and Colorists test method 94-1977 (AATCC, 1977), Identification of Finishes in Textiles. Finish detection included extractions with trichloroethylene, ethanol, and 0.1N hydrochloric acid. The acetone extraction specified in the test method was omitted because it was unlikely that the fabrics contained alkyd resins, cellulose acetate, chlorinated rubber, or polyvinyl chloride. Water extraction was omitted because the fabrics had previously been laundered.

Fabric yielding less than 1% residue were retained for the study. Fabrics yielding greater than 1% residue with minimal loss of dye or brightener, and fabrics yielding greater than 2% residue, were tested further for bending length and shrinkage (fabric count) before and after extraction. If the bending lengths and/or fabric counts were significantly different before and after extraction, the fabric was either replaced by one with a similar drape coefficient or drycleaned to remove the finish, so as to ensure that the finish did not influence the drape of any of the twenty fabric samples.

The final twenty fabrics chosen for the study included ten warp knits and ten weft knits. The warp knits included eight tricot and two raschel knits. The weft knits included five single, three double, and two interlock knits. A description of the fabric characteristics is included in Table 1. Fabric count was determined according to the Canadian National Standard CAN2-4.2-M77 Method 7-1977 (CGSB, 1977). Fabric weight was determined according to the Canadian National Standard CAN2-4.2-M77 Method 5.A-1977 (CGSB, 1977).

Fabric Preparation

The fabric preparation for all tests was done in a standard atmosphere of 21 ± 1 C and 65 ± 2% relative humidity. Walewise specimens were cut from the lengthwise dirction parallel to the fabric wales. Coursewise specimens were cut from the widthwise direction parallel to the fabric courses. Specimens were cut for each test so that they did not contain the same wales or courses.

Table 1
Description of Fabric Characteristics*

Fabric**	Fabric Count		Type of Knit	Fibre Content	Weight (g/m^2)
	(wales/cm)	(courses/cm)			
A	15.6	17.4	tricot	85/15 nylon/spandex	200.22
B	22.0	25.6	tricot	100% nylon	74.95
C	16.0	15.4	tricot	100% nylon	24.46
D	11.8	14.4	tricot	100% triacetate	165.92
E	5.0	16.0	raschel	50/50 polyester/acetate	207.28
F	12.0	14.0	tricot	100% polyester	194.42
G	18.8	19.6	tricot	100% nylon	88.86
H	19.0	16.2	tricot	100% nylon	167.16
I	8.0	7.4	raschel	100% rayon	177.75
J	8.0	6.0	tricot	100% polyester	133.85
K	9.0	8.0	single	90/10 cotton/flax	192.27
L	13.8	18.4	single	50/50 polyester/cotton	159.76
M	8.6	12.0	single	50/50 polyester/cotton	227.01
N	15.0	17.0	interlock	100% polyester	137.02
O	5.0	7.0	single	100% polyester	138.77
P	13.8	21.0	single	100% nylon	152.12
Q	12.4	9.0	double	100% polyester	252.47
R	13.6	11.0	double	100% nylon	237.27
S	12.0	13.6	interlock	100% polyester	153.11
T	11.4	13.0	double	100% polyester	215.11

* Values are mean determinations according to standard test methods

** Fabrics A-J are warp knits, fabrics K-T are weft knits

PHYSICAL ANALYSIS OF FABRICS

Drape

To assess drape, the British Standard Method BS:5058-1973 (BSI, 1974), Assessment of Drape of Fabrics, was utilized. Two, 30-cm-diameter fabric circles were tested using a Rotrakote model tester with an 18-cm-diameter disc. Each specimen was tested three times on each side yielding six face and six back drape coefficients which were averaged to yield three mean values. They were: (i) drape coefficient face, (ii) drape coefficient back, and (iii) drape coefficient overall.

The test method suggests a specimen diameter of 24 cm if the drape coefficient of a 30-cm-diameter specimen is less than 35% and a specimen diameter of 36 cm if the drape coefficient of a 30-cm-diameter specimen is greater than 85%. The 36-cm-diameter specimen size was not selected because screening indicated that none of the fabrics had drape coefficients greater than 85%. The 24-cm-diameter specimen size was not selected because initial trials indicated it was not as capable of discriminating among the fabrics as the 30-cm size. The 30-cm-diameter specimen was utilized throughout this study because it was proposed that for most fabrics this size would be the most accurate and most discriminatory.

Drape was quantitatively expressed by the drape coefficient which was calculated as the mass of the shaded area of the paper ring divided by the total mass of the paper ring and expressed as a percentage. Drape coefficient results obtained during screening were not used in the testing.

The pretest and the screening trials confirmed the limitation of the drape tester mentioned by Chu et al (1963). Very drapeable fabrics formed re-entrant folds under the projection of the disc. Since the specimen and the disc are both opaque, the size of these folds could not be measured. The occurance of re-entrant folds was noted and the fabrics were included in the project. There were three fabrics whose face and back exhibited re-entrant folding and three fabrics whose face or back exhibited re-entrant folding.

The Deformation Properties

All of the deformation properties have face and back and/or directional components. All such components were tested because past research indicated that these properties can vary due to the different structural arrangements of the face and back or warp and weft directions (Doyle, 1953; Cook and Grosberg, 1961; Knapton and Lo, 1975; Hamilton and Postle 1977, 1978).

Stiffness

To obtain a measure of fabric stiffness, the American Society for Testing and Materials 1975 Designation: D1388-64, Stiffness of Fabrics, was used (ASTM, 1978). The pretest included measurements by both the cantilever and heart loop methods.

The heart loop method was used for the research project because the pretest fabrics were too limp to be assessed by the cantilever method.

In addition, the heart loop method eliminated fabric curl and reduced variability. The bending length was calculated according to the formula outlined in the Review of Literature, page 15, and was expressed in centimeters.

The 15 cm strip length used was determined by a bending length trial for each fabric, as specified in the test method. The appropriate specimen width was determined in the pretest. Widths of 2.5, 3.5 and 5.5 cm were tested for ease of handling, tendancy to curl, and variability. A width of 3.5 cm was chosen because it was sufficient to eliminate curl and it was the easiest to handle. The variability of the results was similar for all three widths.

Four walewise and four coursewise specimens were tested on the face and back. The nine mean values of bending length obtained were: (i) bending length walewise, (ii) bending length coursewise, (iii) bending length walewise face-in, (iv) bending length coursewise face-in, (v) bending length walewise face-out, (vi) bending length coursewise face-out, (vii) bending length face-in (viii) bending length face-out, and (ix) bending length overall.

Shear

Since no standard method for measuring the shearing properties of textile fabrics exists, a method reported in the literature was followed. The appartus developed by Spivak (1966) was adopted because it is simple in design, relatively inexpensive, and has several operational advantages (See Chapter 2, page 24). While there was no evidence in the literature that Spivak's apparatus had been used to test knitted fabrics, the pretest results indicated that the apparatus was accurate for knitted fabrics. The specimens did shear at constant length of sides and thus the shearing problem encountered by Carnaby and Postle (1974) did not occur. It was thought that this problem was avoided by using long, narrow specimens and extra screws to prevent fabric slippage. In addition to the shearing apparatus, the Instron tensile tester (Model TM) was used to apply and record the shearing force. The apparatus is pictured in Plates I through III.

Four components of the apparatus were attached to the Instron throughout the testing (see PLATE I). These included the base (A), which was attached to the cross-head, the uprights (B), extending from the base, the pulley (C), and the thin rod (D), which connected the apparatus to the load cell. The mounting frame consisted of two plates (E_1 and E_2) and two clamps (F_1 and F_2) (see PLATE II). The plates were screwed together as one and the fabric specimen was sandwiched between the plates and clamps with its shorter dimension perpendicular to the clamps. The entire frame was fixed to the uprights and the rod to the load cell and the normal load (W) were attached (see PLATE III). A normal load of 5g/cm was utilized in the present research. This load was high enough to delay fabric buckling, but low enough so as not to distort the knit structure. The load was similar to that used by other researchers (Spivak and Treloar, 1965; Goswami, 1977).

To test the fabric's shear properties, the screws that held the plates together were removed, leaving one clamp (F_1) and plate (E_1) suspended from the load cell. This clamp and plate unit remained stationary. The other clamp (F_2) and plate (E_2) unit was rigidly fixed to the Instron cross-head. As the cross-head moved vertically downwards, the fabric was sheared through an angle, referred to as θ. The cross-head speed was adjusted each time to allow the fabric specimen to buckle in about one minute.

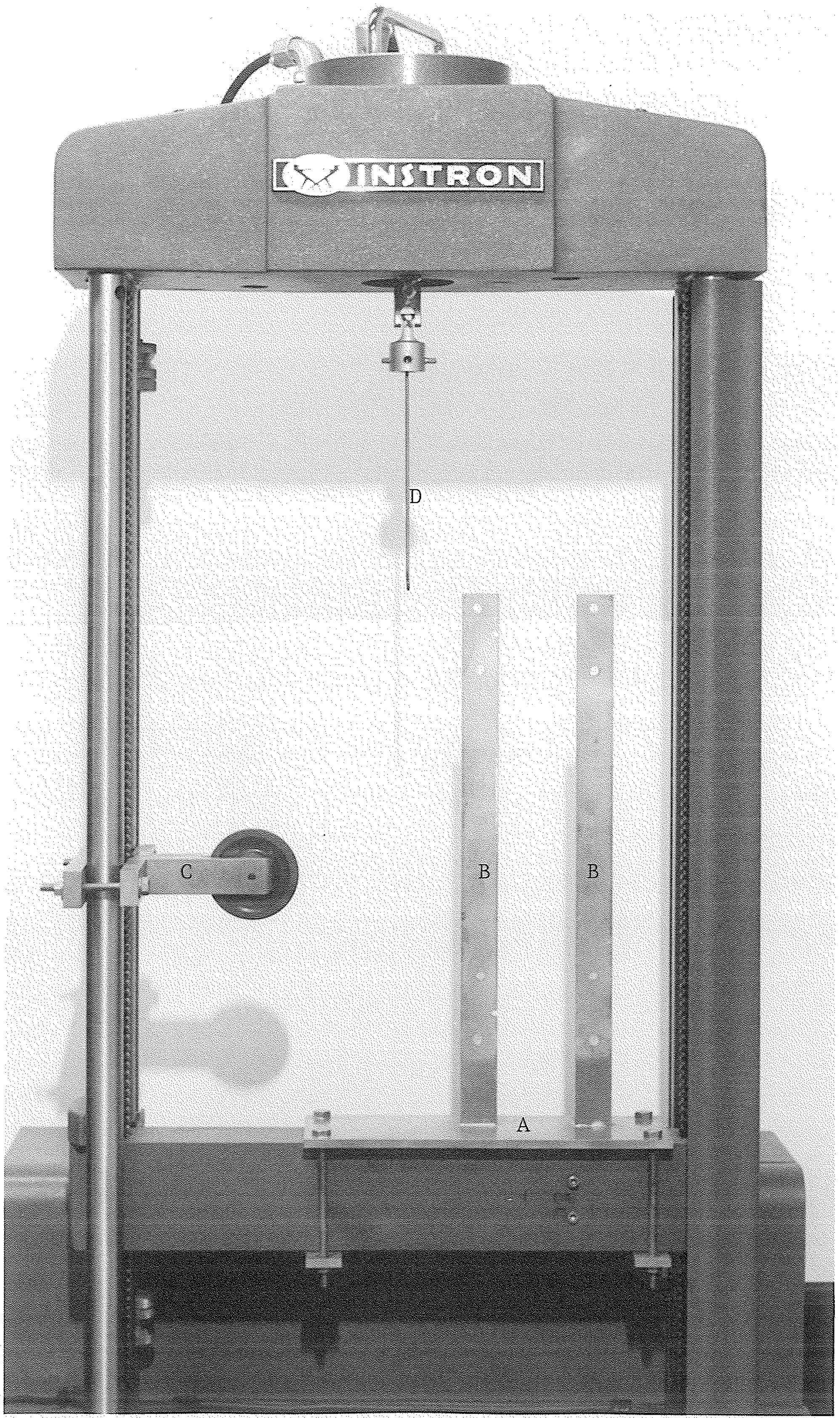


PLATE I: The Instron tensile tester and four components of the shearing apparatus: A-base, B-uprights, C-pulley, D-connecting rod.

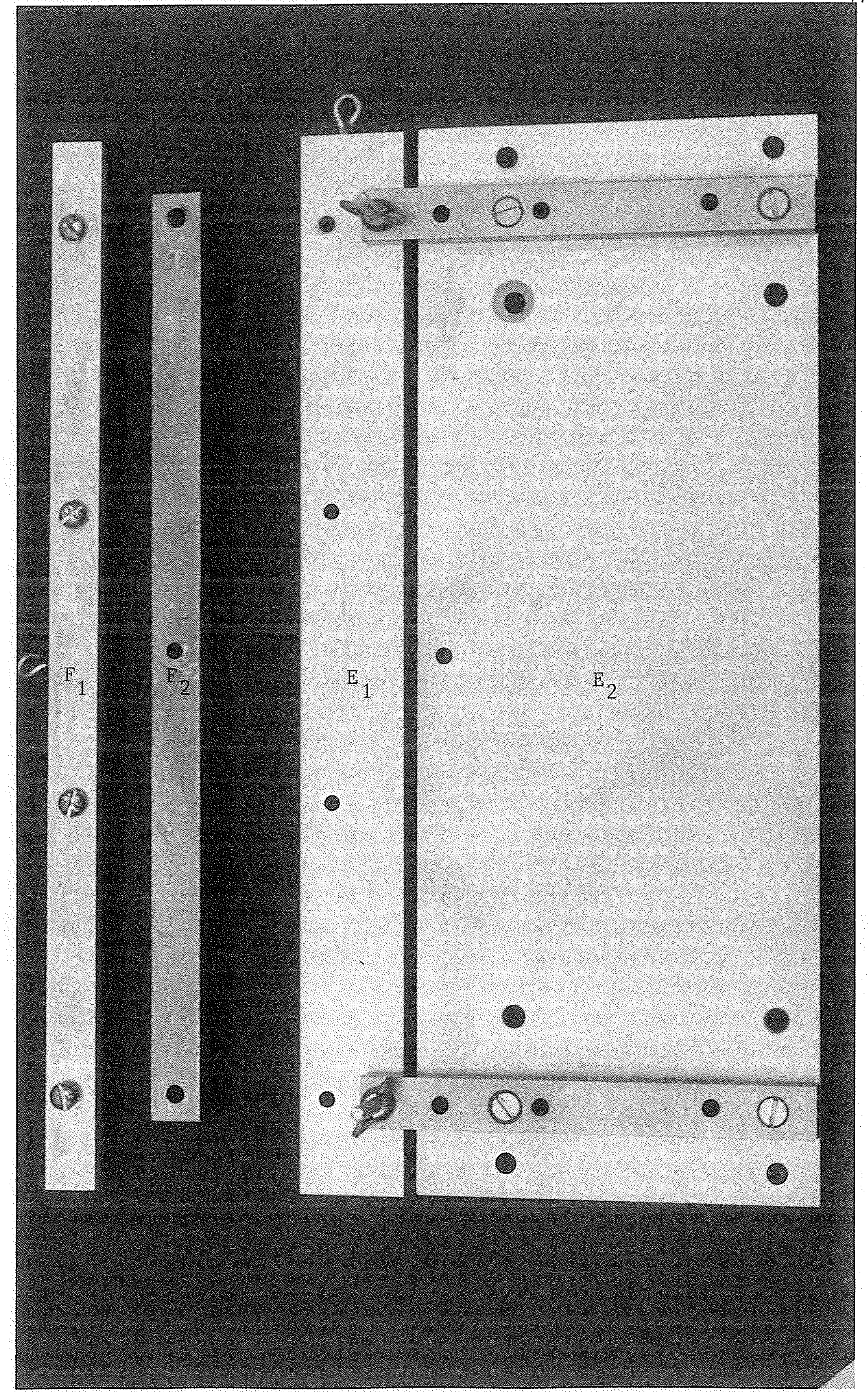


PLATE II: The mounting frame: E_1 and E_2-plates, F_1 and F_2-clamps.

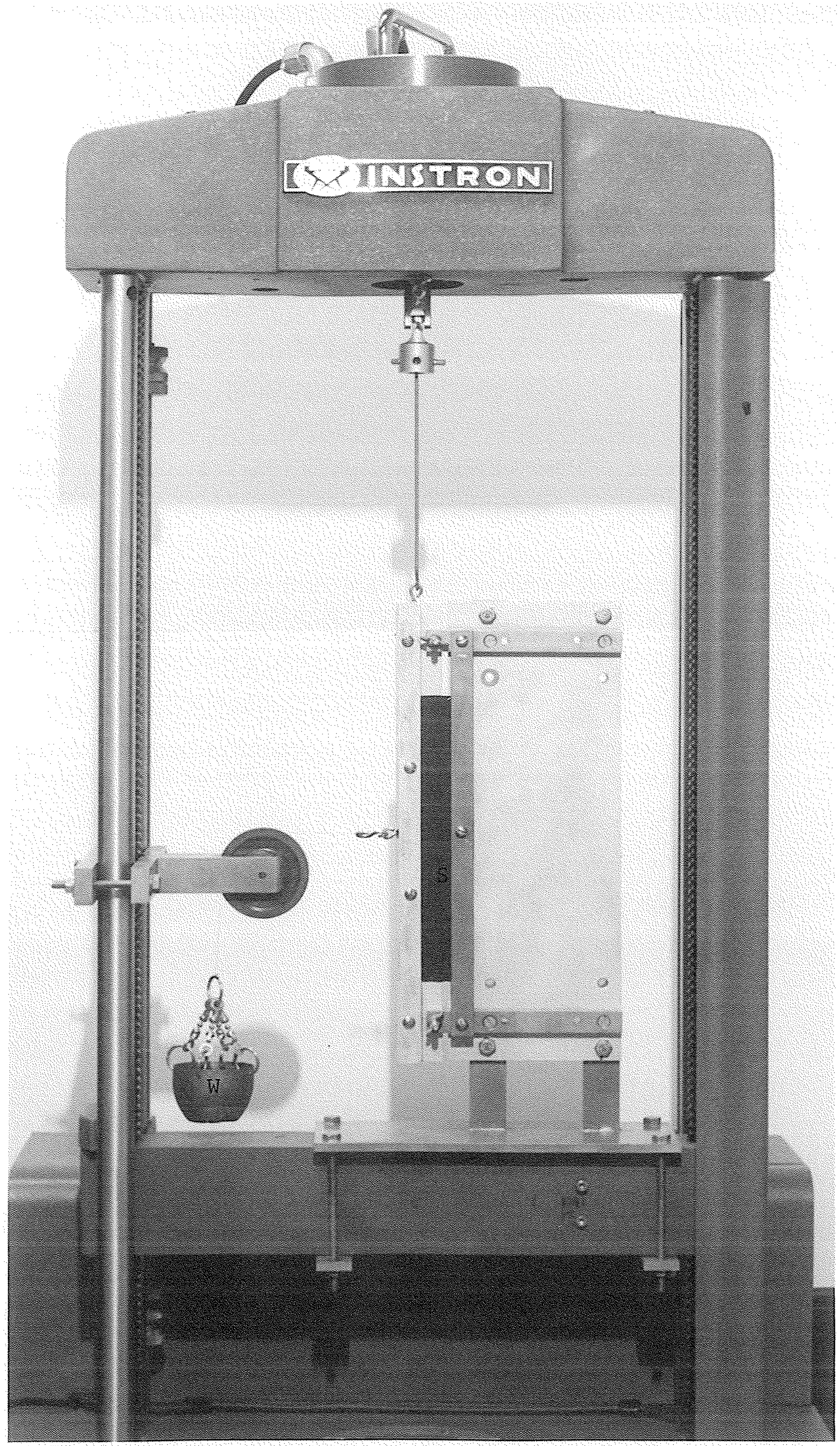


PLATE III: The entire shearing apparatus assembled on the Instron tensile tester: S-fabric specimen, W-normal load.

The specimen size for the shear test was 5.5 by 20 cm, but the actual dimensions sheared were 2 by 20 cm. The larger size allowed the edges of the specimen to be held securely between the plates and clamps. In addition, three holes were punched in each specimen to accommodate the clamping screws which also prevented specimen slippage. Wider specimens could have been used but long, narrow specimens were known to delay the onset of buckling (Treloar, 1965).

The Instron tensile tester recorded curves of shear stress versus shear strain which is equal to the tangent of the shear angle, θ. The shearing force, S, was calculated according to the following formula:

$$S = F - W(\tan\theta)$$

where W is the normal load, θ is the shear angle, and F is the shear stress per unit fabric width. Since $W(\tan\theta)$ was small, it was eliminated, and the above equation was approximated as $S = F$.

The measurement used to express the shear characteristics of the fabrics was the secondary shear modulus. This modulus is equal to the slope in the linear portion of the shear stress-strain curve (see Figure 6, page 28). Seven walewise and seven coursewise specimens were tested to yield three mean values: (i) secondary shear modulus walewise, (ii) secondary shear modulus coursewise, and (iii) secondary shear modulus overall. The slope was not measured at the beginning of the curve because this measurement is subject to experimental error (Cusick, 1961). Consequently, it was measured at one-half the buckling point as a point of reference for all samples. Shear stress at a specific strain or shear strain at a specific stress were not measured because of the wide range of shear behaviors exhibited by the different fabrics.

Extension

Extensibility was determined with reference to the ASTM 1975 Designation D1682-64 (ASTM, 1978), Breaking Load and Elongation of Textile Fabrics. The Grab Method was performed using the Instron tensile tester (Model TM). Pneumatic rubber forced jaws, measuring 25.4 mm wide by 38.1 mm long, clamped the specimen. The gauge length was 75.0 mm and the air pressure was 380 kN/m^2. The cross-head speed was adjusted to ensure extension of the specimen to a specified load within 20 ± 3 seconds. A low load of 100 g was chosen to simulate the extension occurring in drape. The pretest indicated that at this load, the extension was at least 1%. A lower percentage extension would have lacked accuracy. The reason for measuring percent extension at a specified load rather than the mean load at a specified extension was due to the wide range of extensibilities within the fabrics selected.

Specimens were extended with and without pretensioning during the pretest. Pretensioning was not found to improve the reproduceability, and merely gave consistently lower extension values. Therefore, it was decided to test the specimens without pretensioning. Each specimen was centrally mounted in the top jaw and allowed to hang freely before being fixed in the bottom clamp.

Five walewise and five coursewise specimens were tested. They measured 150 mm by 100 mm, and yielded three mean values: (i) extension walewise, (ii) extension coursewise, and (iii) extension overall.

The Structural Characteristics

Fabric weight was determined according to the Canadian National Standard CAN2-4.2-M77 Method 5A-1977 (CGSB, 1977). Five die cut specimens of 6.129 cm diameter were taken from the fabric in moisture equilibrium with the conditioned atmosphere and weighed on a Sartorius Automatic Preweighing Balance.

Fabric thickness at a given pressure was determined according to the standard CGSB 4-GP-2 Method 37-1977 (CGSB, 1971). A Frazier Compressometer with a 25.4 mm diameter pressure foot, was used. The pressure applied was 0.69 KN/m^2. Five thickness measurements were taken from each fabric and the mean value was expressed in centimeters.

Fabric density was calculated from the mean values of fabric weight and fabric thickness. It was determined following the relationship:

$$\text{fabric density, mg/cm}^3 = \text{fabric weight/fabric thickness.}$$

STATISTICAL ANALYSIS

The results of the research project were analyzed in terms of their descriptive statistics, simple linear correlation, and multiple linear regression. The descriptive statistics included the mean data for each fabric and the univariate statistics for the three knit groups. The dispersions of the data were studied with reference to the histograms. However, these histograms are not included in the thesis. Simple linear correlation analysis between the drape coefficients and each of the independent variables was also performed but emphasis was placed on multiple linear regression analysis.

The most reliable predictors of the drape coefficient in knitted fabrics were established using regression analysis. The Biomedical Computer Program (BMDP) developed by the Health Sciences Computing Faculty, University of California, was used (Dixon, 1973). Multiple linear regression (P1R), stepwise regression (P2R), and all possible subsets regression (P9R), were the analyses used. The P1R analysis estimated multiple linear regression equations using various combinations of independent variables that were specified by the researcher. In the P2R analysis, independent variables were entered into and removed from a multiple linear regression equation in a stepwise manner. The P9R analysis developed regression equations using the best subsets of predictor variables. In the P2R and P9R analyses the variables were selected for entry into the equations by the computer. In this study, P2R and P9R were used to confirm the analysis using P1R. All three methods of analysis were used to develop predictor equations for the warp and weft knit subgroups as well as for the entire group of knitted fabrics.

Predictor equations were developed where high correlations were identified, according to the following model:

$$y = a + b_1x_1 + b_2x_2 + \dots + b_px_p + e$$

where:

y is the dependent or predicted variable, ie. drape coefficient,

$x_1, \ldots x_p$ are the independent or predictor variables, ie. bending length, shear, extension, weight, thickness, and density,

$b_1, \ldots b_p$ are the regression coefficients,

a is the intercept,

p is the number of independent variables, and

e is the error which is assumed to be normally distributed with mean zero and a constant variance.

Several transformation variables were also included in the regression analysis.

Chapter 4

RESULTS AND DISCUSSION

The results of this research project, attained by the preceding methods are reported and discussed in terms of: (i) description of the data, (ii) simple linear regression, and (iii) regression analysis. Each section includes discussions of the all knit group and the warp and weft knit subgroups. Comparisons were made with the research findings mentioned in the 'Review of Literature'. The tables presented in this chapter include: variable abbreviations, mean results, univariate statistics, correlation matrices, and predictor equation constants.

Throughout this chapter several abbreviations were used for the variables. These are listed and defined in Table 2.

DESCRIPTION OF THE DATA

The mean results of each independent variable and the dependent variable (drape coefficient), for each of the twenty fabrics are presented and briefly discussed. Tables 3, 4, and 5 contain these results. In addition, the univariate statistics of each variable for the three knit groups are recorded and discussed. These univariate statistics include the means, standard deviations, and the ranges of the data. They are presented in Tables 6a (all knit group), 6b (warp knit subgroup), and 6c (weft knit subgroup). The dispersions of the data are mentioned with reference to the histograms.

Table 2

Variable Abbreviations

Abbreviation	Variable
DCface	drape coefficient face
DCback	drape coefficient back
DCmean	drape coefficient mean
blwalein	bending length walewise face-in
blwaleout	bending length walewise face-out
blcoursein	bending length coursewise face-in
blcourseout	bending length coursewise face-out
blmeanin	bending length mean face in
blmeanout	bending length mean face out
blmean	bending length overall mean
blwalemean	bending length walewise mean
blcoursemean	bending length coursewise mean
shearwale	secondary shear modulus walewise
shearcourse	secondary shear modulus coursewise
shearmean	secondary shear modulus mean
extwale	extension walewise (100 g load)
extcourse	extension coursewise (100 g load)
extmean	extension mean (100 g load)
weight	fabric weight
thickness	fabric thickness
density	fabric density

The Mean Data for Each Fabric

The mean data (see Tables 3, 4, and 5) illustrate that the face and back components of the drape coefficient and the bending length values for each fabric are similar. In addition, the directional components of the bending length, secondary shear modulus, and extension values for each fabric are generally similar.

Most of the mean values for the seven properties are similar for the warp and weft knit subgroups, with one exception. Generally, the extension of the fabrics was slightly greater in the coursewise direction, but for the warp knits the coursewise extension was often more than twice the walewise extension. This suggests that extension for the warp knit subgroup is more directionally dependent than extension for the weft knit subgroup.

An additional observation related to the mean data was the occurrance of re-entrant folding in drape. The fabrics with drape coefficients of less than 25% formed re-entrant folds under the projection of the drapemeter disc. The face and back of fabrics H, L, and N and the face or back of fabrics A, D, and G formed re-entrant folds. Three of these fabrics were warp knits while three were weft knits. The re-entrant folding was not associated with fabric edge curling. Because the folding under the disc could not be measured, there is error involved in the drape coefficients of the fabrics which exhibited re-entrant folding. The amount of error involved is minimal, but could not accurately be estimated.

Table 3
Mean Drape Coefficients and Secondary Shear Modulus Values

Fabric*	Mean Drape Coefficients(%)			Mean Secondary Shear Modulus Values (g/cm)		
	Face**	Back**	Overall Mean	Walewise*** Direction	Coursewise*** Direction	Mean
A	23.70	28.85	26.28	1226	914	1070
B	30.10	29.02	29.56	320	330	325
C	37.09	35.35	36.22	320	330	325
D	27.12	25.94	26.53	434	518	476
E	57.66	59.11	58.39	266	269	268
F	66.56	65.87	66.22	1289	1327	1308
G	26.72	24.33	25.53	480	504	492
H	17.52	17.86	17.70	164	169	167
I	45.34	39.43	42.39	288	258	273
J	48.63	49.30	48.97	543	580	562
K	34.99	32.65	33.82	347	414	382
L	21.38	18.12	19.75	203	189	196
M	54.52	50.33	52.42	591	655	623
N	18.99	18.60	18.80	230	244	237
O	39.48	35.88	37.68	154	246	200
P	29.39	29.61	29.50	381	560	471
Q	49.46	46.31	47.89	447	347	397
R	67.11	64.22	65.67	669	731	700
S	29.08	29.04	29.06	386	420	403
T	59.85	63.33	61.59	411	364	388

* Fabrics A-J are warp knits, fabrics K-T are weft knits

** Mean of 6 observations, mean standard deviation equal to 15.82%

*** Mean of 7 observations, mean standard deviation equal to 295.90 g/cm

Table 4
Mean Bending Length Values (cm)

	Walewise Direction			Coursewise Direction					
Fabric*	Face-in**	Face-out**	Mean	Face-in**	Face-out**	Mean	Face-in Mean	Face-out Mean	Overall Mean
A	1.12	.92	1.02	.92	.97	.95	1.02	.95	.99
B	.93	1.31	1.12	1.11	.99	1.05	1.02	1.15	1.09
C	1.15	1.57	1.36	.88	1.18	1.03	1.02	1.38	1.20
D	.78	1.23	1.01	1.38	1.01	1.20	1.08	1.12	1.10
E	1.45	1.20	1.33	1.59	1.66	1.63	1.52	1.43	1.48
F	1.57	1.98	1.78	2.14	1.87	2.01	1.86	1.93	1.90
G	.87	1.37	1.12	1.01	.86	.94	.94	1.12	1.03
H	1.04	1.01	1.03	.83	.82	.83	.94	.92	.93
I	1.32	1.43	1.38	1.24	1.21	1.23	1.28	1.32	1.30
J	1.49	1.10	1.30	1.72	1.94	1.83	1.61	1.52	1.57
K	1.01	1.25	1.13	1.16	1.06	1.11	1.09	1.16	1.13
L	.78	1.05	.92	.90	.82	.86	.84	.94	.89
M	.98	1.39	1.19	1.26	1.00	1.13	1.12	1.20	1.16
N	1.04	1.14	1.09	.86	.88	.87	.95	1.01	.98
O	.98	1.25	1.12	1.43	1.42	1.43	1.21	1.34	1.28
P	.95	1.10	1.03	1.04	.89	.97	1.00	1.00	1.00
Q	1.61	1.87	1.74	1.64	1.74	1.69	1.63	1.81	1.72
R	1.59	1.71	1.65	1.44	1.41	1.43	1.52	1.56	1.54
S	1.46	1.52	1.49	.87	.87	.87	1.17	1.20	1.19
T	2.00	1.78	1.89	1.80	1.69	1.75	1.90	1.74	1.82

* Fabrics A-J are warp knits, fabrics K-T are weft knits

** Mean of 4 observations, mean standard deviation equal to 0.30 cm

Table 5
Mean Extension Values and Structural Characteristics

	Mean Extension Values			Fabric Geometric Characteristics		
Fabric*	Walewise** Direction (%)	Coursewise** Direction (%)	Mean (%)	Weight (g/m^2)	Mean*** Thickness (cm)	Density (mg/cm^3)
A	13.93	11.37	12.65	200.22	.070	287.68
B	10.10	18.51	14.31	74.95	.049	154.53
C	8.87	46.42	27.65	24.46	.021	118.75
D	5.55	7.07	6.31	165.92	.050	335.19
E	7.25	16.05	11.65	207.28	.140	147.85
F	1.48	2.69	2.09	194.42	.070	278.13
G	4.02	13.46	8.74	88.86	.031	286.64
H	7.95	12.59	10.27	167.16	.051	325.85
I	4.43	11.41	7.92	177.75	.109	163.52
J	3.07	1.72	2.40	133.85	.045	297.44
K	11.94	12.47	12.21	192.27	.095	202.60
L	12.13	18.67	15.40	159.76	.056	287.33
M	4.32	7.37	5.85	227.01	.096	236.47
N	6.52	12.63	9.58	137.02	.063	217.84
O	10.90	5.88	8.39	138.77	.073	191.14
P	26.67	28.03	27.35	152.12	.083	183.71
Q	3.94	5.03	4.49	252.47	.113	224.42
R	7.10	8.14	7.62	237.27	.104	227.93
S	2.23	14.21	8.22	153.11	.061	252.24
T	5.25	5.20	5.23	215.11	.109	198.26

* Fabrics A-J are warp knits, fabrics K-T are weft knits
** Mean of 5 observations, mean standard deviation is equal to 1.86%
*** Mean of 5 observations, mean standard deviation is equal to .03 cm

The Univariate Statistics

The Drape Coefficient

The overall mean drape coefficients of the twenty selected fabrics (all knit group) ranged from 17.69 to 66.22% with a mean of 38.70% and a standard deviation of 15.82% (see Table 6a). The t-test indicated that the face and back drape coefficient values were not significantly different at the 0.10 level. The data were normally distributed between the minimum and maximum values on the histogram. The warp knit subgroup and weft knit subgroup drape coefficient values were not significantly different (see Tables 6b and 6c) and there were no significant differences between DCface and DCback. The ranges and standard deviations were similar for the two groups. The drape coefficient range in this research was larger than Sudnik's (1972) range for knitted fabrics. His drape coefficient values using a 30-cm-specimen size ranged from 20.8 to 40.5%, however, he tested tricot knits only. No measures of variability were given.

The Bending Length

The overall mean bending lengths (calculated from blwalemean and blcoursemean) for the twenty fabrics ranged from 0.89 to 1.90 cm, with a mean of 1.26 cm and a standard deviation of 0.30 cm (see Table 6a). The other bending length mean values did not vary significantly (0.10 level) from the overall mean and no significant differences were identified between the face (blmeanin) and back (blmeanout) and directional components (blwalemean and blcoursemean). Most of the data for each bending length variable were close to the minimum bending length value on the histogram.

The warp knit subgroup and weft knit subgroup bending length values were not significantly different (see Tables 6b and 6c). As for the all knit group, there were no significant differences identified between the overall mean and the other bending length values or between the face and back and directional components. The ranges and standard deviations were similar for the two groups. The range of bending length values could not be compared to the range found by Brown (1978), who also used the heart loop method for knitted fabrics, because different strip widths were used.

The Secondary Shear Modulus

The overall mean secondary shear modulus values for the twenty fabrics ranged from 152.14 to 1308.86 g/cm, with a mean of 454.31 g/cm and a standard deviation of 295.90 g/cm (see Table 6a). There was no significant difference (0.10 level) between the directional components. This is in agreement with Gibson and Postle (1978) who stated that the shearing behavior of a knitted fabric tends to be independent of the direction of the applied strain. Most of the data were in the lower region on the histogram. The mean, standard deviation, and range for the warp knit subgroup were larger than those for the weft knit subgroup, however, the means were not significantly different (0.10 level) (see Tables 6b and 6c). This does not concur with statements by Gibson and Postle who reported that shear in knitted fabrics is a function of fabric type. As for the all knit group, there were no significant differences between the directional components for the subgroups. Measures of the ranges and variablities of the secondary shear modulus values for knitted fabrics were not available in the literature.

The Extension

The overall mean extensions at a 100 g load for the twenty fabrics ranged from 2.09 to 27.65%, with a mean of 10.42% and a standard deviation of 6.86% (see Table 6a). There was a significant difference between the directional components for the all knit group at the 0.05 level. Most of the data were close to the minimum value on the histogram. There were no significant differences between the warp and weft knit subgroups' extension values. However, as for the all knit group, there was a significant difference between the directional components for the warp knit group (see Table 6b). There was no significant difference between the directional components for the weft knit subgroup (see Table 6c). The ranges for the warp and weft knit subgroups were similar with one exception. The maximum percent extension in the coursewise direction for the warp knit group was 46.42%. With the exception of this fabric the maximum percent extension in coursewise direction for the warp knit subgroup was 18.51%. Ranges and variabilities of the percent extension at a 100 g load were not found in the literature.

Fabric Weight

The weights for the twenty selected fabrics ranged from 24.46 to 252.47 g/m^2, with a mean of 164.99 g/m^2 and a standard deviation of 56.41 g/m^2 (see Table 6a). The mean weight values for the warp and weft knit subgroups were significantly different at the 0.05 level (see Tables 6b and 6c). Most of the data were in the upper region on the histogram. Standard deviations were similar for the two subgroups, but the range for the weft knit subgroup was narrower.

Fabric Thickness

The thickness values for the twenty selected fabrics ranged from 0.02 to 0.14 cm with a mean of 0.07 cm and a standard deviation of 0.03 cm (see Table 6a). The distribution of the data was normal on the histogram. The mean thickness values for the warp and weft knit subgroups were significantly different at the 0.05 level (see Tables 6b and 6c). The standard deviations were similar, but the range was greater for the warp knit subgroup.

Fabric Density

The range of densities for the weft knit subgroup was narrower than that for the warp knit subgroup (see Tables 6a, 6b, and 6c). The warp knits had a density range of 118.75 to 335.19 mg/cm^3 compared to 183.71 to 287.33 mg/cm^3 for the weft knits. The means, however, were not significantly different. The data appeared normally distributed on the histogram.

Table 6a
Univariate Statistics - All Knit Group

Variable	Mean	Standard Deviation	Minimum	Maximum
DCface (%)	39.23	15.90	17.52	67.11
DCback (%)	38.16	15.84	17.86	65.87
DCmean (%)	38.70	15.82	17.69	66.22
extwale (%)	7.88	5.65	1.48	26.67
extcourse (%)	12.95	10.06	1.72	46.42
extmean (%)	10.42	6.86	2.09	27.65
shearwale (g/cm)	448.52	312.41	141.43	1288.57
shearcourse (g/cm)	460.11	286.45	162.86	1327.14
shearmean (g/cm)	454.31	295.90	152.14	1307.86
blwalein (cm)	1.21	.33	.78	2.00
blwaleout (cm)	1.36	.30	.92	1.99
blcoursein (cm)	1.26	.37	.83	2.14
blcourseout (cm)	1.21	.38	.82	1.94
blmeanin (cm)	1.23	.32	.84	1.90
blmeanout (cm)	1.30	.30	.92	1.93
blmean (cm)	1.26	.30	.89	1.90
blwalemean (cm)	1.28	.29	.92	1.89
blcoursemean (cm)	1.24	.37	.83	2.01
weight (g/m^2)	164.99	56.41	24.46	252.47
thickness (cm)	.07	.03	.02	.14
density (mg/cm^3)	230.88	61.68	118.75	335.19

Table 6b
Univariate Statistics - Warp Knit Subgroup

Variable	Mean	Standard Deviation	Minimum	Maximum
DCface (%)	38.04	15.99	17.52	66.56
DCback (%)	37.51	15.84	17.86	65.87
DCmean (%)	37.78	15.85	17.69	66.22
extwale (%)	6.67	3.72	1.48	13.93
extcourse (%)	14.13	12.55	1.72	46.42
extmean (%)	10.40	7.29	2.09	27.65
shearwale (g/cm)	515.04	411.85	141.43	1288.57
shearcourse (g/cm)	503.14	369.24	162.86	1327.14
shearmean (g/cm)	509.09	387.29	152.14	1307.86
blwalein (cm)	1.17	.28	.78	1.57
blwaleout (cm)	1.31	.31	.92	1.98
blcoursein (cm)	1.28	.43	.83	2.15
blcourseout (cm)	1.25	.42	.82	1.94
blmeanin (cm)	1.23	.32	.93	1.86
blmeanout (cm)	1.32	.31	.92	1.93
blmean (cm)	1.25	.31	.92	1.89
blwalemean (cm)	1.24	.24	1.00	1.78
blcoursemean (cm)	1.27	.41	.83	2.01
weight (g/m^2)	143.49	61.52	24.46	207.28
thickness (cm)	.06	.04	.02	.14
density (mg/cm^3)	239.56	82.99	118.75	335.19

Table 6c
Univariate Statistics - Weft Knit Subgroup

Variable	Mean	Standard Deviation	Minimum	Maximum
DCface (%)	40.42	16.58	18.99	67.11
DCback (%)	38.81	16.66	18.12	64.22
DCmean (%)	39.62	16.58	18.80	65.67
extwale (%)	9.10	7.08	2.23	26.67
extcourse (%)	11.76	7.26	5.03	28.03
extmean (%)	10.43	6.79	4.49	27.35
shearwale (g/cm)	382.00	163.09	154.29	668.57
shearcourse (g/cm)	417.07	181.04	188.57	731.43
shearmean (g/cm)	399.54	167.87	195.71	700.00
blwalein (cm)	1.24	.39	.78	2.00
blwaleout (cm)	1.41	.30	.05	1.87
blcoursein (cm)	1.24	.33	.86	1.80
blcourseout (cm)	1.18	.36	.82	1.74
blmeanin (cm)	1.24	.33	.84	1.90
blmeanout (cm)	1.29	.31	.93	1.81
blmean (cm)	1.27	.32	.89	1.82
blwalemean (cm)	1.32	.34	.92	1.89
blcoursemean (cm)	1.21	.34	.86	1.75
weight (g/m^2)	186.49	43.67	137.02	252.47
thickness (cm)	.09	.02	.06	.11
density (mg/cm^3)	222.19	31.28	183.71	287.33

SIMPLE LINEAR CORRELATION

The simple linear correlation between the drape coefficients and each of the independent variables are briefly discussed. The correlation matrices are presented in Table 7 (all knit group), Table 8 (warp knit subgroup), and Table 9 (weft knit subgroup).

The Drape Coefficient and the Deformation Properties

The Drape Coefficient and the Bending Length

Generally, the highest correlation was found between the nine bending length variables and the drape coefficients. The high, positive correlation concurs with the findings of Peirce (1930), Kim and Vaughn (1974) and Morooka and Niwa (1976) for woven fabrics; Cusick (1965) for woven and nonwoven fabrics; and Sudnik (1972) for woven, nonwoven, and knitted fabrics. The correlation coefficients (r) in the present research ranged from 0.67 to 0.90 for the all knit group, from 0.53 to 0.96 for the warp knit subgroup, and from 0.67 to 0.85 for the weft knit subgroup.

The correlations did not vary with the components of the drape coefficient variable, however, they did vary with the bending length variables. For instance, in the warp knit subgroup, correlation of blwaleout with DCmean resulted in an r value of 0.58, whereas, correlation of blmean with DCmean resulted in an r value of 0.96.

The Drape Coefficient and the Secondary Shear Modulus

The secondary shear modulus values were found to be positively correlated with the drape coefficient in this research. This is in agreement with the results reported by Cusick (1965) for woven and nonwoven fabrics, Sudnik (1972) for woven, nonwoven, and knitted fabrics, and Kim and Vaughn (1974) and Morooka and Niwa (1976) for woven fabrics. In the present research the correlation coefficients ranged from 0.35 to 0.46 for the all knit group and from 0.27 to 0.45 for the warp knit subgroup. These values were lower than the Spearman rank coefficients reported by Kim and Vaughn (1974) for woven fabrics and by Sudnik (1972) for woven, nonwoven and knitted fabrics. Kim and Vaughn reported a coefficient of 0.89 between the drape coefficient and the initial shear modulus, while Sudnik reported a coefficient of 0.59 between the drape coefficient and the shear angle. In the present research, correlations between the drape coefficient values and the secondary shear modulus values were higher for the weft knit subgroup. The r values ranged from 0.60 to 0.77. The correlations did not vary with the face and back components of the drape coefficient or the directional components of the shear modulus values for any of the three knit groups.

The Drape Coefficient and Extension

The values for percent extension at a 100 g load were negatively related to the drape coefficient values in this research. This concurs with the findings of Peirce (1930), Chu et al (1963), and Kim and Vaughn (1974) for woven fabrics. These researchers, however, found that extension and the drape coefficient were highly correlated. For instance, Kim and Vaughn reported a Spearman rank coefficient of 0.88 between the percent extension at a 1000 g load for woven fabrics. However, the r values in this research ranged from -0.36 to -0.42 for the all knit group, from -0.19 to -0.58 for the warp knit subgroup, and from -0.35 to -0.65 for the weft knit subgroup. These low correlations, however, concur with the findings of Morooka and Niwa (1976) for wovens. The degree of correlation did not vary with the drape coefficient face and back components for any group, but varied with the directional components of the extension for the warp and weft knit subgroups.

The Drape Coefficient and the Structural Characteristics

The Drape Coefficient and Fabric Weight

Fabric weight was found to be positively related to the drape coefficient values, concurring with research by Kim and Vaughn (1974) but not with Chu et al (1963) and Morooka and Niwa (1976). All researchers tested woven fabrics. In the present research the r value was 0.82 for the weft knit subgroup, 0.32 for the warp knit subgroup, and 0.51 for the all knit group. The degree of correlation did not vary with the face and back components of the drape coefficient.

The Drape Coefficient and Fabric Thickness

Correlation was positive between fabric thickness and the drape coefficient values, supporting previous findings for woven fabrics (Kim and Vaughn, 1974; Morooka and Niwa, 1976). The r values were approximately

0.60 for the all knit group, 0.52 for the warp knit subgroup, and 0.85 for the weft knit subgroup. The Spearman rank coefficient reported by Kim and Vaughn was 0.55. Again, the degree of correlation did not vary with the face and back components of the drape coefficient.

The Drape Coefficient and Fabric Density

Fabric density was negatively related to the drape coefficient values in this research but the correlation was poor for all three knit groups. The r value ranged from -0.22 to -0.33. In most cases, the correlations were higher between weight and the drape coefficient and thickness and the drape coefficient than between density and the drape coefficient. Past research was not available in the literature for comparison. The degree of correlation did not vary with the face and back components of the drape coefficient.

REGRESSION ANALYSIS

In order to develop the best predictor equations, three different strategies of estimating regression equations were performed using the BMDP computer program. They were: multiple linear regression analysis (P1R), stepwise regression analysis (P2R), and all possible subsets regression analysis (P9R). Multiple linear regression was the original analysis used and the other two were used subsequently to confirm the findings. Approximately 150 program executions were completed for each of the all knit group and the warp and weft knit subgroups. Sample program executions are included in Appendix B.

Table 7
Correlation Matrix - All Knit Group

	DCF	DCB	DCM	EW	EC	EM	SW	SC	SM	BWI	BWO	BCI	BCO	BMI	BMO	BM	BWM	BCM	WT	TH	DEN
DCF	1.0																				
DCB	.99	1.0																			
DCM	1.0	1.0	1.0																		
EW	-.39	-.36	-.37	1.0																	
EC	-.36	-.36	-.36	.49	1.0																
EM	-.42	-.41	-.42	.76	.93	1.0															
SW	.35	.41	.38	-.14	-.40	-.35	1.0														
SC	.42	.46	.44	-.11	-.39	-.33	.95	1.0													
SM	.39	.44	.41	-.13	-.40	-.35	.99	.99	1.0												
BWI	.74	.79	.77	-.44	-.34	-.43	.28	.23	.26	1.0											
BWO	.70	.67	.69	-.51	-.17	-.33	.26	.30	.28	.67	1.0										
BCI	.84	.85	.84	-.40	-.59	-.59	.41	.47	.45	.65	.59	1.0									
BCO	.81	.83	.82	-.40	-.43	-.48	.29	.30	.30	.76	.54	.91	1.0								
BMI	.87	.90	.89	-.46	-.52	-.57	.38	.39	.39	.90	.69	.92	.92	1.0							
BMO	.83	.82	.83	-.48	-.32	-.43	.29	.31	.30	.76	.83	.85	.87	.89	1.0						
BM	.88	.90	.89	-.49	-.44	-.53	.35	.37	.37	.87	.78	.91	.93	.98	.94	1.0					
BWM	.79	.80	.80	-.52	-.28	-.42	.29	.29	.29	.92	.90	.68	.72	.88	.87	.91	1.0				
BCM	.84	.86	.85	-.41	-.52	-.55	.36	.39	.38	.72	.58	.98	.98	.94	.88	.94	.72	1.0			
WT	.50	.51	.51	-.14	-.65	-.53	.38	.34	.37	.46	.25	.46	.34	.51	.24	.43	.40	.41	1.0		
TH	.60	.59	.60	.001	-.36	-.26	.06	.04	.05	.51	.26	.45	.40	.52	.33	.47	.43	.44	.80	1.0	
DEN	-.27	-.25	-.26	-.24	-.51	-.48	.38	.37	.38	-.18	-.23	.002	-.14	-.09	-.28	-.15	-.22	-.07	.22	-.35	1.0

Key

DCF - drape coefficient face
DCB - drape coefficient back
DCM - drape coefficient mean
EW - extension walewise
EC - extension coursewise
EM - extension mean
SW - secondary shear modulus walewise
SC - secondary shear modulus coursewise
SM - secondary shear modulus mean
BWI - bending length walewise face in
BWO - bending length walewise face out
BCI - bending length coursewise face in
BCO - bending length coursewise face out
BMI - bending length mean face in
BMO - bending length mean face out
BM - bending length overall mean
BWM - bending length walewise mean
BCM - bending length coursewise mean
WT - weight
TH - thickness
DEN - density

Table 8
Correlation Matrix - Warp Knit Subgroup

	DCF	DCB	DCM	EW	EC	EM	SW	SC	SM	BWI	BWO	BCI	BCO	BMI	BMO	BM	BWM	BCM	WT	TH	DEN
DCF	1.0																				
DCB	.98	1.0																			
DCM	1.0	1.0	1.0																		
EW	-.58	-.48	-.53	1.0																	
EC	-.19	-.22	-.21	.44	1.0																
EM	-.31	-.31	-.31	.63	.97	1.0															
SW	.27	.36	.32	-.03	-.49	-.42	1.0														
SC	.38	.45	.42	-.24	-.54	-.53	.97	1.0													
SM	.33	.41	.37	-.13	-.52	-.48	.99	.99	1.0												
BWI	.87	.89	.88	-.39	-.22	-.29	.31	.35	.33	1.0											
BWO	.62	.53	.58	-.57	.14	-.02	.22	.38	.30	.34	1.0										
BCI	.87	.87	.87	-.69	-.56	-.66	.44	.60	.52	.70	.51	1.0									
BCO	.91	.93	.92	-.55	-.31	-.41	.30	.41	.36	.89	.38	.88	1.0								
BMI	.94	.95	.95	-.62	-.46	-.55	.42	.54	.48	.88	.48	.95	.96	1.0							
BMO	.87	.83	.85	-.54	-.10	-.22	.26	.41	.33	.67	.76	.81	.79	.81	1.0						
BM	.96	.96	.96	-.66	-.32	-.44	.38	.52	.45	.86	.63	.95	.94	.98	.89	1.0					
BWM	.90	.86	.88	-.59	-.04	-.18	.32	.44	.38	.80	.84	.73	.76	.82	.87	.90	1.0				
BCM	.91	.93	.93	-.64	-.45	-.55	.38	.52	.45	.82	.46	.97	.97	.98	.83	.97	.77	1.0			
WT	.29	.36	.32	-.10	-.70	-.63	.46	.42	.45	.40	-.19	.44	.28	.45	.04	.29	.11	.37	1.0		
TH	.51	.52	.52	-.03	-.28	-.25	.04	-.01	.01	.51	-.06	.36	.34	.45	.15	.34	.26	.36	.73	1.0	
DEN	-.33	-.27	-.30	-.22	-.68	-.64	.42	.45	.44	-.22	-.29	.11	-.10	-.02	-.34	-.12	-.32	.01	.38	-.31	1.0

Key

DCF - drape coefficient face
DCB - drape coefficient back
DCM - drape coefficient mean
EW - extension walewise
EC - extension coursewise
EM - extension mean
SW - secondary shear modulus walewise
SC - secondary shear modulus coursewise
SM - secondary shear modulus mean
BWI - bending length walewise face in
BWO - bending length walewise face out
BCI - bending length coursewise face in
BCO - bending length coursewise face out
BMI - bending length mean face in
BMO - bending length mean face out
BM - bending length overall mean
BWM - bending length walewise mean
BCM - bending length coursewise mean
WT - weight
TH - thickness
DEN - density

Table 9
Correlation Matrix - Weft Knit Subgroup

	DCF	DCB	DCM	EW	EC	EM	SW	SC	SM	BWI	BWO	BCI	BCO	BMI	BMO	BM	BWM	BCM	WT	TH	DEN
DCF	1.0																				
DCB	.99	1.0																			
DCM	1.0	1.0	1.0																		
EW	-.36	-.35	-.35	1.0																	
EC	-.65	-.62	-.64	.79	1.0																
EM	-.53	-.51	-.52	.95	.95	1.0															
SW	.77	.76	.77	-.26	-.25	-.27	1.0														
SC	.62	.60	.61	.06	.02	.04	.90	1.0													
SM	.71	.69	.70	-.09	-.11	-.11	.97	.98	1.0												
BWI	.67	.74	.70	-.51	-.54	-.55	.47	.20	.34	1.0											
BWO	.78	.81	.80	-.61	-.68	-.68	.62	.31	.47	.92	1.0										
BCI	.84	.85	.84	-.27	-.70	-.51	.37	.17	.27	.69	.76	1.0									
BCO	.73	.74	.74	-.34	-.73	-.57	.26	.02	.14	.74	.80	.96	1.0								
BMI	.81	.85	.83	-.44	-.66	-.58	.46	.20	.33	.93	.92	.91	.91	1.0							
BMO	.80	.81	.81	-.49	-.74	-.65	.45	.16	.31	.86	.94	.91	.96	.96	1.0						
BM	.81	.84	.83	-.47	-.71	-.62	.46	.18	.32	.91	.94	.92	.94	.99	.99	1.0					
BWM	.73	.78	.76	-.57	-.61	-.62	.55	.25	.40	.98	.97	.74	.78	.95	.92	.94	1.0				
BCM	.79	.80	.80	-.31	-.72	-.55	.32	.09	.20	.72	.79	.99	.99	.92	.95	.94	.77	1.0			
WT	.83	.80	.82	-.41	-.55	-.51	.80	.52	.67	.58	.78	.70	.64	.69	.74	.72	.68	.67	1.0		
TH	.84	.85	.85	-.16	-.50	-.36	.69	.52	.61	.61	.74	.84	.76	.78	.79	.79	.68	.81	.88	1.0	
DEN	-.22	-.27	-.24	-.39	-.06	-.17	.02	-.15	-.07	-.16	-.07	-.42	-.38	-.30	-.25	-.28	-.12	-.40	.04	-.42	1.0

<u>Key</u>

DCF - drape coefficient face
DCB - drape coefficient back
DCM - drape coefficient mean
EW - extension walewise
EC - extension coursewise
EM - extension mean
SW - secondary shear modulus walewise
SC - secondary shear modulus coursewise
SM - secondary shear modulus mean
BWI - bending length walewise face in
BWO - bending length walewise face out
BCI - bending length coursewise face in
BCO - bending length coursewise face out
BMI - bending length mean face in
BMO - bending length mean face out
BM - bending length overall mean
BWM - bending length walewise mean
BCM - bending length coursewise mean
WT - weight
TH - thickness
DEN - density

The estimation of multiple regression equations utilizing P1R included all the independent variables specified by the researcher. The possible combinations of variables which included bending length were selected for the analysis. One of the bending length variables was always included because the literature indicated that it might be a good predictor of the drape coefficient and because the r value was high in simple linear correlation in the present research. The criteria utilized to choose the best predictor equation included the R^2 value (coefficient of multiple determination), the probability level of the F-ratio (indicates whether all the regression coefficients are significantly different from zero), the standard error of the estimate (a measure of the variation of the Y value about the regression line), and the probability level of the t-statistic (indicates whether the individual regression coefficient for each variable is significantly different from zero in the presence of the other variables). Appendix A, Table 16 contains the R^2 and standard error of the estimate values as well as the F-ratios and the t-statistics for all of the combinations that were attempted.

The stepwise method of analysis entered variables into a multiple linear regression equation in a stepwise manner. Forward stepping (beginning with no predictors) was performed. The F-to-enter and F-to-remove values were 3.9 and 4.0, respectively. At each step, the variable that had the highest partial correlation with the drape coefficient was added. The criteria utilized to choose the best predictor equation were similar to those for multiple linear regression analysis (P1R).

The all possible subsets method identified the best subsets of predictor variables. In the analysis the best subset was the subset that maximized R^2. Stepwise and all possible subsets regression analyses indicated the best regression equations and thereby combinations which did not include bending length were analyzed.

By using these three types of regression analysis and studying transformation variables as well as the original independent variables, one best predictor equation was identified for each of the all knit group and the warp and weft knit subgroups. In addition, several other good predictor equations were developed. The number of variables introduced into the regression equation was limited for each analysis in order to ensure that an adequate number of degrees of freedom remained for error. Also, because the independent variables of the same measurement were linearly correlated with each other (see Tables 7, 8, and 9), only one was introduced at a time into the equation.

All Knit Group

Multiple Linear Regression Analysis

Since the literature indicated that bending length was the physical property most highly correlated with the drape coefficient, bending length was grouped with the secondary shear modulus (shear), extension, weight, thickness, and density in two, three, four, five, and six variable combinations. This was done in order to examine the relationships between the drape coefficient and all the possible combinations of variables which included bending length. A listing of these combinations is presented in Table 10. Only the overall mean measurements were utilized in this analysis. The BMDP-P1R computer program was utilized.

Table 10

Variable Combinations Including Bending Length

Key

bl - bending length
sh - shear
ext - percent extension
wt - weight
th - thickness
den - density

2 variable combinations

- bl-sh
- bl-th
- bl-ext
- bl-den
- bl-wt

3 variable combinations

- bl-sh-ext
- bl-sh-th
- bl-sh-den
- bl-sh-wt
- bl-ext-th
- bl-ext-wt
- bl-ext-den
- bl-den-wt
- bl-den-th
- bl-wt-th

4 variable combinations

- bl-sh-ext-wt
- bl-sh-ext-th
- bl-sh-ext-den
- bl-sh-den-wt
- bl-sh-den-th
- bl-ext-wt-den
- bl-ext-th-wt
- bl-ext-den-th
- bl-wt-th-den
- bl-sh-wt-th

5 variable combinations

- bl-sh-wt-th-den
- bl-sh-wt-th-ext
- bl-sh-wt-den-ext
- bl-sh-den-ext-th
- bl-den-th-ext-wt

6 variable combinations

- bl-sh-ext-wt-th-den

For the all knit group the F-ratios invariably had probability levels of 0.01 or less (see Appendix A, Table 16a).

Analysis of the two-variable combinations indicated that the blmean-thickness combination had the highest R^2 value (0.84) and the lowest standard error of the estimate (6.71). It was the only combination where both variables had probability levels of 0.10 or less in the t-test. Therefore, the addition of thickness as a variable added new information. The R^2 values for the other two-variable combinations ranged from 0.80 to 0.81 and the standard errors of the estimate ranged from 7.21 to 7.46.

Analysis of the three-variable combinations indicated that the addition of a third variable did not increase the R^2 value or decrease the standard error of the estimate enough to justify using a third variable in the equation. The blmean-shearmean-thickness combination had an R^2 value of 0.85 and a standard error of the estimate equal to 6.58, but shearmean did not contribute additional information. That is, the probability level of the t-statistic for shearmean was greater than 0.10. In the blmean-shearmean-density and blmean-weight-density combinations all three variables had probability levels equal to 0.10 or less in the t-test. When shearmean and density were both included with blmean, they added new information. The same was true for weight and density. The R^2 value was 0.84 and the standard error of the estimate was 6.8 for both of these three-variable combinations. Generally, for the other three variable combinations, the probabiliy levels of the t-statistics were greater than 0.10 for all of the the variables except blmean and thickness. For these combinations the R^2 values ranged from 0.81 to 0.84 and the standard errors of the estimates ranged from 6.58 to 7.47.

In all of the four-variable combinations the R^2 values ranged from 0.83 to 0.87 and the standard errors of the estimates ranged from 6.33 to 7.21. However, these changes were not appreciable and therefore there was no justification to include a fourth variable in the equation. As in the three-variable combinations, in most cases only blmean and thickness had t-test probability levels of 0.10 or less. None of the four-variable combinations resulted in t-test probability levels of 0.10 or less for all of the variables.

The ranges of the R^2 values and the standard errors of the estimates for the five-variable combinations were similar to those for the four-variable combinations. In addition, only one or two variables had t-test probability levels of 0.10 or less. None of the five-variable combinations were considered useful.

The six-variable combination had an R^2 value of 0.87 and a standard error of the estimate equal to 7.03, but only blmean had a t-test probability of 0.10 or less.

The multiple linear regression analysis yielded four useful variable combinations for the prediction of the drape coefficient. They were: (i) blmean-thickness, (ii) blmean-shearmean-density, (iii) blmean-weight-density, and (iv) blmean-shearmean-thickness, the best being blmean-thickness.

Stepwise Regression Analysis

Stepwise regression analysis was used to confirm the conclusions arrived at by multiple linear regression analysis. The BMDP-P2R program was used.

In order to determine which independent variables were the best predictors, each of the eighteen independent variables had an equal chance of being entered into the equation. That is, in addition to the overall means, any of the directional and face and back means could be entered into the equation. The analysis entered blmean and thickness into the equation. Shearcourse was the next variable for entry into the equation but the F-level was insufficient for further stepping. Stepwise regression analysis confirmed the best two- and three-variable combinations as indicated in the multiple linear regression analysis.

All Possible Subsets Analysis

The all possible subsets analysis also allowed entry of any of the eighteen independent variables into the equation. The estimation of the best subsets of predictor variables carried out via BMDP-P9R indicated that the blmean-thickness combination was the best two-variable subset. This is consistent with the multiple linear and stepwise regression analyses conclusions. The best three-variable subset was blmean-shearcourse-thickness with an R^2 value of 0.86. In addition, the blmean-shearmean-thickness combination had an R^2 value of 0.85. These results are in agreement with stepwise and multiple linear regression analyses, respectively. Either three-variable combination is useful.

Warp Knit Subgroup

Multiple Linear Regression Analysis

The procedure followed and criteria used for selecting the predictor variables for the warp knit subgroup were identical to that for the all knit group. Like the all knit group, the F-ratios for the warp knit subgroup invariably had a probability level of 0.01 or less (see Appendix A, Table 16b).

The two-variable combination analysis indicated that blmean-thickness and blmean-density were good predictor combinations. The former had an R^2 value of 0.97 and a standard error of the estimate equal to 3.15, while the latter had an R^2 value of 0.96 and a standard error of the estimate equal to 3.41. These were the only combinations where both variables had t-test probability levels of 0.10 or less. In the other two-variable combinations the R^2 values ranged from 0.93 to 0.94 and the standard error of the estimate ranged from 4.28 to 4.73.

Analysis of the three-variable combinations indicated that in four of the combinations the addition of the third variable appreciably affected the R^2 and standard error of the estimate values. In addition, the third variable added new information, as the t-test probability levels were 0.10 or less for all the variables. The four combinations were: blmean-extmean-thickness (R^2=0.99, standard error of the estimate=1.87), blmean-weight-density (R^2=0.98, standard error of the estimate=2.40), blmean-weight-thickness (R^2=0.99, standard error of the estimate=2.26), and blmean-thickness-density (R^2=0.99, standard error of the estimate=2.17). In the other three-variable combinations the R^2 values ranged from 0.94 to 0.97 and the standard error of the estimate ranged from 3.30 to 4.71.

In the four-variable combinations the R^2 and standard error of the estimate values did not change enough to justify including a fourth variable in the equation. In all of the four variable groups the R^2 values ranged from 0.97 to 0.99 and the standard errors of the estimates ranged from 1.88 to 3.86. In addition, there was always one variable and sometimes two or three variables that had probability levels greater than 0.10 in the t-test.

In the five-variable combinations the R^2 values were 0.99 and the standard errors of the estimates ranged from 1.76 to 2.80, but only one or two variables had t-test probability levels equal to 0.10 or less.

In the six-variable combination all six variables had t-test probability levels of 0.05 or less. The R^2 value was 0.99 and the standard error of the estimate was 0.73.

The multiple linear regression analysis yielded seven acceptable variable combinations for prediction of the drape coefficient. They were: blmean-thickness, blmean-density, blmean-thickness-density, blmean-extmean-thickness, blmean-weight-density, blmean-weight-thickness, and blmean-shearmean-extmean-weight-thickness-density, the best being blmean-extmean-thickness.

Stepwise Regression Analysis

Stepwise regression analysis confirmed the conclusions arrived at by multiple linear regression analysis. The stepwise analysis entered blmean, thickness, and extmean into the equation. This three-variable combination was superior to blmean-thickness as the standard error of the estimate decreased from 3.15 to 1.87.

All Possible Subsets Regression Analysis

All possible subsets regression analysis confirmed blmean-thickness as the best two-variable combination for prediction, and blmean-extmean-thickness as the best three-variable combination.

<u>Weft Knit Subgroup</u>

Multiple Linear Regression Analysis

The procedure and criteria used for variable selection for the weft knit subgroup were the same as those used for the all knit group and the warp knit subgroup. The probability levels of the F-ratios varied and will be quoted where applicable (see Appendix A, Table 16c).

Of the two-variable combinations, the blmean-shearmean combination had the highest R^2 and F values and the lowest standard error of the estimate. The R^2 value was 0.90, the F-ratio had a probability level of less than 0.01, and the standard error of the estimate was 6.01. This was the only combination where both variables had t-test probability levels of 0.10 or less. The other two-variable combinations had R^2

values ranging from 0.69 to 0.79, standard errors of the estimates ranging from 8.62 to 10.52, and F-ratio probability levels between 0.10 and 0.01.

The ranges of the regression coefficients, the standard errors of the estimates, and the probability levels for the F-ratios for the three-variable combinations were similar to those for the two-variable combinations. In addition, blmean and shearmean were the only variables with t-test probability levels of 0.10 or less. The blmean-shearmean-thickness combination had the highest R^2 value and lowest standard error of the estimate value.

The four-variable combinations had regression coefficients ranging from 0.80 to 0.91, but the standard errors of the estimates did not decrease and the F-ratios had probability levels of 0.05 or 0.10. In addition, the probability levels of the t-tests were usually greater than 0.10 for all of the variables. Similar results were observed for the five- and six-variable combinations.

Multiple linear regression analysis of the weft-knit group yielded one good variable combination: blmean-shearmean.

Stepwise Regression Analysis

Stepwise regression analysis was able to confirm the conclusions arrived at by multiple linear regression analysis. When all eighteen independent variables had an equal chance of being entered into the equation, the analysis entered thickness, only. The R^2 value was 0.72 and the standard error of the estimate was 9.27. Thickness was the variable most highly correlated with the drape coefficient in simple linear correlation (see Table 6c). When the tolerance levels were lowered, the stepwise analysis entered thickness, blmean, and shearcourse into the equation. The R^2 value was 0.91 and the standard error of the estimate was 6.26. However, multiple linear regression analysis indicated that the blmean-shearmean combination had an R^2 value of 0.90 and a standard error of the estimate equal to 6.01. The inclusion of thickness as a third variable did not improve prediction. In addition, the thickness-blmean combination had an R^2 value of 0.79 and a standard error of the estimate equal to 8.46 and therefore, the blmean-shearcourse combination was a better two-variable predictor combination.

By arranging for bending length to be entered into the equation before any other variables, the analysis entered blcoursein, shearmean, and thickness into the equation. The blcoursein-shearmean combination had an R^2 value of 0.95 and a standard error of the estimate equal to 4.07, while the blcoursein-shearmean-thickness combination had an R^2 value of 0.97 and a standard error of the estimate equal to 3.25. The addition of thickness, therefore, did not improve prediction appreciably.

All Possible Subsets Regression Analysis

All possible subset regression analysis confirmed blcoursein-shearmean as the best two-variable combination for prediction and blcoursein-shearmean-thickness as the best three-variable combination.

Directional and Face and Back Components

Extensive analysis was not done on the face and back and directional components of the variables because the correlation matrices (Tables 7,8, and 9) indicated that the components within each variable were linearly related and that the correlations between the drape coefficients and the components of each variable were similar. However, analysis of the directional and face and back components of the independent variables of the best two- and three-variable predictor equations was carried out using multiple linear regression analysis. Stepwise and all possible subsets regression analyses indicated the best regression equations and thereby included analysis of all the directional and face and back components.

All Knit Group

Multiple linear regression analysis of the directional components of the bending length in the bending length-thickness combination indicated that the mean component was the best predictor. In addition, the coursewise direction was found to be superior to the walewise direction. In the bending length-shear-thickness combination the same trends were present for bending length and the direction of shear was found to have very little influence (for an example, see page 79).

Stepwise regression analysis confirmed these findings by entering blmean and thickness into the equation. Shearcourse was next in line for entry.

All possible subsets regression analysis indicated blmean-shearcourse-thickness was the best three-variable combination. In addition, blmean-shearmean-thickness and blmean-shearwale-thickness had R^2 values essentially as high, so were acceptable. This method of analysis indicated that blmean was a better predictor than blcoursemean which was a better predictor than blwalemean.

The face-in variables (blwalein, blcoursein and blmeanin) and the face-out variables (blwaleout, blcourseout and blmeanout) were equally good predictors. The mean variables were better for prediction than the coursewise variables which were better than the walewise variables.

Warp Knit Subgroup

Multiple linear regression analysis of the directional components of bending length in the bending length-thickness combination indicated the same trends as for the all knit group. Analysis of the bending length-extension-thickness combination indicated the same trends for bending length and showed that the mean, walewise, and coursewise components of extension were all equally good predictors.

Stepwise regression analysis entered blmean and extmean into the equation.

The all possible subsets analysis confirmed these results. It indicated that extmean, extwale, and extcourse were equally good predictors and that the bending length components followed the tendancies mentioned for the all knit group.

Weft Knit Subgroup

Multiple linear regression analysis of the directions of the bending length-shear combination indicated that the coursewise component of bending length was a better predictor than the mean, but they were both satisfactory. However, the walewise component was a poor predictor. The mean, walewise, and coursewise components of shear were equally good.

Stepwise regression analysis entered blcoursein and shearmean into the equation and all possible subsets analysis confirmed these as the best subset. The coursewise variables were better for prediction than the the mean variables which were better than the walewise variables.

Analysis of the directional and face and back components indicated that the walewise direction of bending length was a poor predictor for the all knit group and the warp and weft knit subgroups. However, blmean was the best predictor for the all knit group and warp knit subgroup, whereas blcoursein was the best predictor for the weft knit group.

Study of Residuals

The computer plots and listings of the residuals were studied. (An example is presented in Appendix B1.) The residuals are the differences between the fitted or calculated value, Y, and the observed value, y. It was proposed that the observations which were not close to the line were either inaccurate values, were contributing to a nonlinear curve, or were influenced by a variable not accounted for in this research project.

While some fabrics gave high residuals depending on the predictor equation, fabrics M and Q invariably had residuals larger than one standard error. The equations predicted the drape coefficient of fabric M too high and the drape coefficient of fabric Q too low. Both fabrics were weft knits (M was a single knit and Q was a double knit), but they did not appear to have features that would distinguish them from the other fabrics.

Fabrics M and Q were partially retested in order to determine the accuracy of their measurements and to observe any peculiarities. The retested results were not appreciably different from the original results. Fabric M was also drycleaned to remove the finish, but the DC results did not change. It was thought that fabric M's tendancy to curl was influencing its draping and bending properties. The behavior of Q could not be accounted for.

In order to determine whether nonlinear curves would lead to smaller residuals, transformations of the variables were performed. This is discussed in the following section.

Transformation Variables

Some of the independent variables were transformed into new variables because it was proposed that improved equations would result in that the R^2 values would increase and the standard errors of the estimates and the size of the residuals would decrease. The variables that were transformed were limited to those included in the best two- and three-variable predictor equations for each knit group. The variables were multiplied in pairs and squared in order to obtain transformation variables. These particular transformation variables were analyzed because of the exploratory nature of this part of the analysis. The transformation variables developed for the all knit group and warp and weft knit subgroups are presented in Table 11. Table 12 contains the univariate statistics.

Table 11

Transformation Variable Abbreviations

Abbreviation	Definition
thick2	thickness
blmeanthick	blmean x thickness
shearcourse2	shearcourse
extmean2	extmean
blmean2	blmean
blmeanshearcourse	blmean x shearcourse
blmeanextmean	blmean x extmean
thickextmean	thickness x extmean
thickshearcourse	thickness x shearcourse
blcoursein2	blcoursein
shearmean2	shearmean
blcourseinshearmean	blcoursein x shearmean
thickblcoursein	thickness x blcoursein
thickshearmean	thickness x shearmean

Table 12
Univariate Statistics - Transformation Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
All Knit Group				
blmean	1.68	0.84	0.79	3.59
thick2	0.01	0.01	0.00	0.02
shearcourse2	289651.38	401676.56	26522.40	1761308.00
blthick	0.10	0.06	0.03	0.21
extmean2	153.17	215.87	4.37	764.52
blshearcourse	610.93	518.82	155.93	2513.61
blextmean	12.08	7.12	3.73	33.07
thextmean	0.72	0.50	0.11	2.26
blcoursein2	1.72	1.04	0.69	4.60
shearcoursethick	34.50	23.88	3.35	92.77
shearmean2	289578.88	418835.63	23147.49	1710489.00
blcourseshearmean	619.69	584.00	134.19	2805.35
thickblcoursein	0.10	0.06	0.02	0.22
thickshearmean	34.20	24.27	3.13	91.42
Warp Knit Subgroup				
blmean	1.66	0.85	0.86	3.59
thick2	0.01	0.01	0.00	0.02
shearcourse2	375856.38	543755.00	26522.40	1761308.00
blthick	0.08	0.06	0.02	0.21
extmean2	155.95	223.55	4.37	764.52
blshearcourse	684.20	692.07	155.93	2513.61
blextmean	12.16	8.56	3.73	33.07
thextmean	0.60	0.46	0.11	1.63
blcoursein2	1.81	1.24	0.69	4.60
shearcoursethick	31.75	27.30	3.35	92.77
shearmean2	394167.88	569147.00	23147.49	1710489.00
blcourseshearmean	730.35	786.89	134.19	2805.35
thickblcoursein	0.09	0.06	0.02	0.22
thickshearmean	32.45	28.70	3.13	91.42

Table 12 (continued)

Variable	Mean	Standard Deviation	Minimum	Maximum
Weft Knit Subgroup				
blmean	1.70	0.87	0.79	3.31
thick2	0.01	0.00	0.00	0.01
shearcourse2	203446.69	168619.06	35559.02	534988.310
blthick	0.11	0.05	0.05	0.20
extmean2	150.38	219.98	20.16	748.02
blshearcourse	537.67	278.16	167.64	1124.21
blextmean	12.00	5.79	6.78	27.19
thextmean	0.84	0.54	0.50	2.26
blcoursein2	1.64	0.86	0.74	3.24
shearcoursethick	37.25	21.02	10.48	76.14
shearmean2	184990.25	148666.69	38303.96	4900000.00
blcourseshearmean	509.04	271.33	176.93	1005.20
thickblcoursein	0.11	0.05	0.05	0.20
thickshearmean	35.94	20.32	10.88	72.87

Stepwise and multiple linear regression analyses were performed in order to determine which of the transformation variables were the best predictors of the drape coefficient.

All Knit Group

Stepwise regression analysis was performed on the best two-variable combination (blmean-thickness) and the related transformation variables (blmean2, thick2, and blmeanthick). The transformation variables were forced into the regression but were not allowed entry into the equation until after the original two variables were entered. The remainder of the variables were excluded from the analysis. The stepwise analysis entered blmean and thickness into the equation but no transformation variables.

The analysis was repeated on the best three-variable combination (blmean-shearcourse-thickness) and the related transformation variables (blmean2, shearcourse2, thick2, blmeanshearcourse, blmeanthick, and thickshearcourse). The best equation included blmean, shearcourse, thickness, thickshearcourse, and thick2. The R^2 value was 0.93, the standard error of the estimate was 4.89, and the F-ratio was highly significant. Without the transformation variables the R^2 value was 0.84 and the standard error of the estimate was 6.71. The other transformation variables that were entered into the equation did not increase R^2 or decrease the standard error of the estimate enough to warrant using them in the equation.

When all the independent variables, including the transformation variables had an equal chance of being entered into the equation, the analysis entered blmean, shearwale, and thickshearcourse. The R^2 value was 0.91 and the standard error of the estimate was 5.29.

Multiple linear regression analysis indicated that several variable combinations could predict the drape coefficient equally as well as blmean-thickness. They were: blmean2-thick2, blmean2-thick, and blmean-thick2. On the other hand, blmean2-blmeanthick-thick2, blmean-blmeanthick-thick, blmean2-blmeanthick-thick, blmean-blmeanthick-thick2 were not good predictor combinations.

Warp Knit Subgroup

The same stepwise procedure was performed on the blmean-thickness combination for the warp knit subgroup as for the all knit group. The analysis entered blmean, thickness, and thick2 into the equation. The R^2 value was 0.99 and the standard error of the estimate was 2.10. With blmean and thickness, only, the R^2 value was 0.97 and the standard error of the estimate was 3.15. The transformation variable did not improve prediction.

When the analysis was repeated on the best three-variable combination (blmean-extmean-thickness) and the related transformation variables (blmean2, extmean2, thick2, blmeanextmean, blmeanthick, and thick-extmean) some transformation variables were entered in addition to the original three variables. However, the transformation variables did not increase the R^2 value and decrease the standard error of the estimate enough to warrant using them in the equation.

When all the independent variables, including the transformation variables had an equal chance for entry into the equation, the analysis entered blmean and thickextmean. The R^2 value was 0.99 and the standard error of the estimate was 1.49.

Multiple linear regression analysis indicated that the following variable combinations could predict the drape coefficient equally as well as blmean-thickness: blmean2-thick2, blmean2-thick, blmean-thick2, blmean2-blmeanthick-thick2, and blmean-blmeanthick-thick2. On the other hand, blmean2-blmeanthick, and blmean-blmeanthick-thick were poor predictor combinations.

Weft Knit Subgroup

The same stepwise procedure was performed for the best two-variable combination (blcoursein-shearmean) and the related transformation variables (blcoursein2, shearmean2, and blcourseinshearmean) for the weft knit subgroup as for the all knit group. The analysis entered some of the transformation variables into the equation but the variables did not increase the R^2 value or decrease the standard error of the estimate enough to warrant using them in the equation.

The analysis was repeated, but in addition, thickness and the related thickness transformation variables were allowed entry into the equation after the analysis entered the original two variables. The analysis entered blcoursein, shearmean, and thickness into the equation.

When the nine bending length variables were allowed entry into the equation before the other independent variables, including the transformation variables, the analysis entered blcoursein and shearmean2 into the equation. The R^2 value was 0.97 and the standard error of the estimate was 3.31.

Multiple linear regression analysis indicated that several variable combinations could predict the drape coefficient equally as well as blcoursein-shearmean. They were: blcoursein2-shearmean2, blcoursein-shearmean2, and blcoursein2-shearmean. However, the addition of blcourseinshearmean into these combinations decreased the R^2 values appreciably.

For the all knit group and the warp and weft knit subgroups, transformation of the variables permitted development of variable combinations that predicted the drape coefficient as well as or better than those previously developed. The most useful of these were:

1. blmean-shearcourse-thickness-thickshearcourse-thick2 (all knit group)
2. blmean-shearwale-thickshearcourse (all knit group)
3. blmean-thickness-thick2 (warp knit subgroup)
4. blmean-thickextmean (warp knit subgroup)
5. blcoursein-shearmean2 (weft knit subgroup)

THE PREDICTOR EQUATIONS

The regression equations selected to describe the relationships between the mean drape coefficient and the relevant predictor variables include one best equation and several other good equations for each knit group. The R^2 values, standard errors of the estimates, and multiple regression line constants are recorded in Table 13. The multiple regression line constants include the intercept, a, and the partial regression coefficients, b_p. The best simple equations are indicated with asterisks. An example of the equation format is:

$$Y = -21.435 + 40.701X_1 + 119.005X_2,$$

where Y is the mean drape coefficient, X_1 is the mean bending length, and X_2 is the thickness for the all knit group.

The predictor equations have been kept as simple as possible in order to allow a reasonable number of degrees of freedom remaining for error and so that a minimum amount of testing and calculation have to be done to predict the drape coefficient. However, there were two instances where the R^2 value was extremely high when five or six independent variables were included in the regression equation. The R^2 values, standard errors of the estimates, and multiple regression constants for these equations are presented in Table 14. The blmean-shearcourse-thickness-thickshearcourse-thick2 combination is actually the best predictor equation for the all knit group. However, because several property measurements and calculations are required, a simpler combination such as blmean-thickness may be more useful. The warp knit combination in Table

14 involves six independent variables, but is not as useful because the warp knit sample size was ten and therefore only three degrees of freedom remain for error. In addition to these predictor equations, four equations have been developed in order that the drape coefficient may be predicted with one independent variable. The R^2 values, standard errors of the estimates, and multiple regression constants for these equations are presented in Table 15. These equations are not as good for prediction, but measurements of only one property are required.

Table 13

Multiple Regression Constants to Predict the Mean Drape Coefficient With Two and Three Independent Variables

Knit Group	Independent Variables			Y intercept	Regression Coefficients			Coefficient of Multiple Determination	Standard Error of the Est.
	X_1	X_2	X_3	a	b_1	b_2	b_3	R^2	
ALL KNIT	* blmean	thick	--	-21.453	40.701	119.005	--	.839	6.708
	blmean	shear mean	density	- 4.052	40.482	0.011	-0.058	.844	6.797
	blmean	shear mean	thick	-21.611	37.643	0.007	129.414	.854	6.584
	blmean	weight	density	-10.184	40.052	0.060	-0.049	.847	6.748
	blmean	shear course	thick	-21.789	36.858	0.009	133.351	.861	6.422
	blmean	thick shear course	shear wale	-13.113	36.686	0.420	-0.020	.906	5.287
WARP KNIT	blmean	thick	---	-25.968	46.070	93.993	--	.969	3.147
	blmean	density	---	-14.677	48.725	-0.036	--	.964	3.414
	blmean	thick	density	-18.149	45.985	74.812	-0.027	.988	2.169
	* blmean	extmean	thick	-34.459	49.477	0.357	102.047	.991	1.869

Table 13 (continued)

Knit Group	Independent Variables			Y intercept	Regression Coefficients			Coefficient of Multiple Determination	Standard Error of the Est.
	X_1	X_2	X_3	a	b_1	b_2	b_3	R^2	
WARP KNIT	blmean	weight	density	-13.960	45.787	0.043	-0.050	.984	2.402
	blmean	weight	thick	-23.253	46.525	- 0.049	153.467	.986	2.263
	blmean	thick extmean	---	-32.115	51.465	8.901	--	.993	1.489
	blmean	thick	thick2	-17.711	46.446	-183.150	1700.602	.988	2.105
WEFT KNIT	blmean	shear mean	---	-23.692	34.862	0.048	--	.898	6.010
	* blcourse in	shear mean	---	-24.349	35.307	0.051	--	.953	4.065
	blcourse in	shear mean	thick	-22.197	49.566	0.067	-308.724	.974	3.248
	** blcourse in	shear mean2	---	-15.531	35.747	0.001	--	.969	3.314

* Best simple predictor equations

** Shearmean2 = shearmean/1000

Table 14

Multiple Regression Constants to Predict the Mean Drape Coefficient With More Than Three Independent Variables

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<u>ALL KNIT GROUP</u>

X_1 - blmean	$b_1 = 34.123$	a	$= 11.411$
X_2 - shearcourse	$b_2 = -0.035$	R^2	$= 0.930$
X_3 - thickness	$b_3 = -584.668$	* S	$= 0.964$
X_4 - thickshearcourse	$b_4 = 0.693$		
X_5 - thick2	$b_5 = 3092.255$		

<u>WARP KNIT GROUP</u>

X_1 - blmean	$b_1 = 48.963$	a	$= -49.149$
X_2 - shearmean	$b_2 = 0.006$	R^2	$= 0.999$
X_3 - extmean	$b_3 = 0.517$	* S	$= 0.733$
X_4 - weight	$b_4 = -0.145$		
X_5 - thickness	$b_5 = 339.760$		
X_6 - density	$b_6 = 0.069$		

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* Standard error of the estimate

Table 15

Multiple Regression Constants to Predict the Mean Drape Coefficient With One Independent Variable

Knit Group	Independent Variable X	Y Intercept a	Regression Coefficient b	Coefficient of Multiple Determination R^2	Standard Error of the Estimate
All Knit	blmean	-19.686	46.325	0.797	7.327
Warp Knit	blmean	-24.776	49.873	0.929	4.493
Weft Knit	blcoursein	-12.777	42.246	0.711	9.454
Weft Knit	thickness	-17.279	668.732	0.722	9.275

The predictors of the drape coefficient have been influenced by the knit structure. The best simple equation for the all knit group includes blmean and thickness. Blmean, extmean, and thickness are the best predictor variables for the warp knit subgroup, while blcoursein and shearmean are the best predictor variables for the weft knit subgroup. For the conditions of test used, the regression equations describe these relationships quantitatively.

Needless to say, not all of the possible combinations of variables and their related transformations have been analyzed because of the numerous possibilities. However, the variables which are the most reliable predictors of the drape coefficient have been determined and transformations of these to the second power and multiplication of these variables in pairs have been performed.

The equations developed could not be compared directly to those by other researchers (Cusick, 1965; Morooka and Niwa, 1976) because of the different measurements involved. However, the variables in Cusick's equations were bending and shear measurements; the same as the best predictor variables found for the weft knit subgroup in the present research.

THE FABRIC PROPERTIES AS PREDICTORS OF THE DRAPE COEFFICIENT

The bending length, secondary shear modulus, extension, and thickness variables were included in at least one of the best predictor equations. Weight and density were included in some of the additional good predictor equations.

The results of this research project are compared to the findings of previous researchers where possible. However, this is limited on two accounts. The past research dealt primarily with woven fabrics and simple linear correlation statistical analysis rather than multiple linear regression analysis was utilized.

The Deformation Properties

Bending Length

Bending length was expected to be an accurate predictor of the drape coefficient because past research indicated that for wovens, nonwoven, and knits, stiffness measurements were highly correlated with the drape coefficient both in simple and multiple linear correlations (Peirce, 1930; Cusick, 1965; Sudnik, 1972, 1978; Kim and Vaughn, 1974; Morooka and Niwa, 1976). Hearle, Grosberg, and Backer (1969) stated that bending is the major mode of fabric deformation in draping. All of the best and good predictor equations developed in the present research included a bending length variable. However, one or two additional independent variables were necessary for high correlation (R^2 increased from approximately 0.70 to 0.90).

There were no significant differences between the face and back and between the directional components of the bending length data. These findings do not agree with the findings of Knapton and Lo (1975) who stated that structurally unbalanced knitted fabrics have different directional and/or face and back bending characteristics. The similarities in the face and back components of bending length in the present research may be due to the fact that the fabrics were screened in order to obtain similar face and back drape coefficients. In the present research there were dissimilarities in the simple linear correlation coefficients between the drape coefficient and the bending length variables. In addition, the best bending length predictor variable was different for the various knit groups. For the all knit group and the warp knit subgroup the blmean variable was the best, while for the weft knit subgroup, blcoursein was the best.

Secondary Shear Modulus

The secondary shear modulus was expected to be an accurate predictor of the drape coefficient for all three knit groups because past research indicated that for wovens, nonwovens, and knits, shear measurements were moderately to highly correlated with the drape coefficient in simple and multiple linear correlations (Cusick, 1965; Kim and Vaughn, 1974; Morooka and Niwa, 1976; Sudnik, 1978). In this research, the secondary shear modulus was included in the best predictor equation for the weft knit group (blcoursein-shearmean) and the best three-variable equation for the all knit group (blmean-shearcourse-thickness). It was also included in some of the good predictor equations.

The walewise and coursewise directions of the secondary shear modulus univariate statistics were not significantly different. In addition, there was little difference between the correlations of the drape coefficient with shearwale and the drape coefficient with shearcourse. The fabric direction was not important in the predictor equations. This is in agreement with Gibson and Postle (1978) who found that bending length was dependent on fabric direction, but shear was not.

Extension

Since controversy existed in the literature concerning the degree of association between the drape coefficient and extension for wovens (Peirce, 1930; Chu et al, 1963; Kim and Vaughn, 1974; Morooka and Niwa, 1976), it was uncertain whether extension would be a good predictor of the drape coefficient for knitted fabrics. The present research indicated that the simple linear correlation between the drape coefficient and extension was poor for all three knit groups. However, extension was included in the best predictor equation for the warp knit subgroup (blmean-extension-thickness). This may be related to the findings of Cook and Grosberg (1961) who reported that for warp knits, yarn stiffness influenced extensibility.

The literature stated that fabric direction was an important factor in the extension of knitted fabrics (Doyle, 1953; Cook and Grosberg, 1961; Knapton and Lo, 1975). In this research project there were differences in the data depending on the fabric direction, especially for the warp knit subgroup. In addition, the simple linear correlations were dependent on fabric direction for both knit groups. However, the direction of extension was not an important factor with respect to the predictor equations.

The Structural Characteristics

Fabric Weight

Fabric weight was expected to be an accurate predictor of the drape coefficient because it was an important variable in the equations developed by Morooka and Niwa (1976) for woven fabrics and because past research indicated that the stiffness of knitted fabrics was influenced by fabric weight (Knapton, 1973, 1974; Knapton and Lo, 1975). On the other hand, some question existed, since Kim and Vaughn (1974) indicated that weight and the drape coefficient were not highly related. In addition, Morooka and Niwa (1976) found weight and the drape coefficient were negatively related, while Kim and Vaughn (1974) found a positive relationship. In the present research the simple linear correlation between weight and the drape coefficient was low. Weight was not included in any of the best predictor equations, but was an important variable in three of the good predictor equations for the warp knit group. They were: blmean-weight-density, blmean-weight-thickness, and blmean-shearmean-extension-thickness-weight-density.

Fabric Thickness

Since past research indicated that fabric thickness has an influence on knitted fabric stiffness (Knapton, 1973, 1974; Knapton and Lo, 1975) it was expected that thickness would be a good predictor of the drape coefficient. On the other hand, Kim and Vaughn (1974) and Morooka and Niwa (1976)found correlation was poor between thickness and the drape coefficient. In the present research project the simple linear correlation was generally higher than that reported in the literature, especially for the weft knit subgroup. Blmean and thickness formulated the best predictor equation for the all knit group and blmean, thickness, and extension formulated the best predictor equation for the warp knit subrgroup. Thickness, therefore, was an important variable with respect to all three knit groups.

Fabric Density

Since past results were not available for comparison, it was uncertain whether a relationship between density and the drape coefficient existed. However, since weight and thickness influenced the drape of wovens (Chu et al, 1963; Kim and Vaughn, 1974; Morooka and Niwa, 1976) it was felt density would influence drape as well. Fabric density was found to be poorly correlated with the drape coefficient in simple linear correlation and was not included in any of the best equations. However, it was an important predictor variable in two of the good equations. They were: the blmean-shearmean-density combination for the all knit group and the blmean-density combination for the warp knit subgroup.

Chapter 5

SUMMARY AND RECOMMENDATIONS

SUMMARY

The present research project investigated certain deformation properties and structural characteristics to determine their reliability as predictors of the drape coefficient in knitted fabrics. The deformation properties included stiffness, shear, and extension, while the structural charateristics included weight, thickness, and density. The study also investigated the reliability of these predictors for the two main types of knitted constructions-- warp knits and weft knits. Predictor equations were developed in order to enable prediction of the drape of a knitted fabric if one or more of the property measurements are known.

Twenty fabrics were selected for the study, including ten warp knits and ten weft knits. The warp knits included tricot and raschel knits, while the weft knits included single jersey, rib, interlock, and double knits. The fabrics selected had similar face and back draping properties. The measurements of the fabric properties were made according to standard test methods, except for shear, where no standard test method for textiles exists. All of the directional and face and back components of the deformation properties were measured. To assess drape, the British Standard Method BS:5058-1973 was used. The Cusick Drape Tester enabled calculation of the drape coefficient. Stiffness was quantitatively expressed by the bending length. The Heart Loop Method specified in the American Society for Testing and Materials 1975 Designation D1388-64 was followed. The apparatus used to measure shear was based on the one developed by S.M. Spivak for woven fabrics. This appears to be the first time this apparatus has been used successfully to measure the shearing properties of knitted fabrics. The secondary shear modulus was the measurement taken from the stress-strain curve. Extensibility was measured with reference to ASTM 1975 Designation D1682-64. The Instron tensile tester was employed to measure the percent extension at a load of 100 grams. To measure fabric weight, the Canadian National Standard CAN2-4.2-M77 Method 5.A-1977 was followed. The assessment of fabric thickness was made according to the standard CGSB 4-GP-2-1957 using a Frazier Compressometer. Fabric density was calculated from the measurements of weight and thickness.

The most reliable predictors of the drape coefficient in knitted fabrics were established using regression analysis. Multiple linear, stepwise, and all possible subsets analyses were performed. In addition, some of the independent variables were multiplied in pairs and squared in order to obtain transformation variables. It was proposed that improved equations would result. Predictor equations were developed for the entire group of knitted fabrics (all knit group) as well as for the warp and weft knit subgroups.

The regression analyses resulted in one best predictor equation as well as several other good predictor equations for the all knit group and for the warp and weft knit subgroups. Some of the transformation variables were included in some of the good predictor equations.

In meeting the objectives of the present research several conclusions have been drawn. For the twenty fabrics the most reliable predictor variables were bending length, thickness, secondary shear modulus, and transformations of these three variables. Weight and density were included in some of the good predictor equations, but extension was not.

The mean bending length component was a better predictor than the coursewise, which was a better predictor than the walewise. The face-in and face-out components were equally good predictors and followed the tendancies mentioned for the mean, walewise, and coursewise components. The walewise, coursewise, and mean secondary shear modulus components were equally good for prediction.

The equations for the warp and weft knit subgroups differed from those for the all knit group. The best equation for the warp knit subgroup included bending length, thickness, and extension. Weight and density were included in some of the good equations but the secondary modulus shear was not. The mean component of bending length was the best variable component for prediction. This was followed by the coursewise component. The mean, walewise, and coursewise components of extension were equally good. For the weft knit subgroup the bending length and secondary shear modulus variables were the best for prediction. Thickness was the only other variable that was included in a good predictor equation. The coursewise direction was the best component of bending length, followed by the mean, while all the secondary shear modulus components were equally good predictors. For both the warp and weft knit subgroups the bending length face-in and face-out variables were equally good predictors and followed the the trends mentioned for the mean, walewise, and coursewise components.

The best predictor equation for the all knit group was:

$$Y = 11.411 + 34.123\ X_1 - 0.035\ X_2 - 584.668\ X_3 + 0.693\ X_2X_3 + 3092.225\ X_2^2$$

where Y is the mean drape coefficient, X_1 is the mean bending length, X_2 is the coursewise secondary shear modulus, and X_3 is the fabric thickness.

The best simple predictor equation for this knit group was:

$$Y = -\ 21.485 + 40.701\ X_1 + 119.005\ X_2$$

where Y is the mean drape coefficient, X_1 is the mean bending length, and X_2 is the fabric thickness.

The best predictor equation for the warp knit subgroup was:

$$Y = -\ 34.459 + 49.477\ X_1 + 0.357\ X_2 + 102.047\ X_3$$

where Y is the mean drape coefficient, X_1 is the mean bending length, X_2 is the mean extension, and X_3 is the fabric thickness.

The best predictor equation for the weft knit subgroup was:

$$Y = -\ 24.349 + 35.307\ X_1 + 0.051\ X_2$$

where Y is the mean drape coefficient, X_1 is the coursewise face-in bending length, and X_2 is the mean secondary shear modulus.

IMPLICATIONS OF THE RESEARCH PROJECT

The present research project has provided a better understanding of the physical properties that influence the drape of knitted fabrics, and therefore has filled a void in the current literature. Additional insight into the shearing properties of knitted fabrics has also been accomplished.

Several predictor equations have been developed. The equations would be of particular interest to knitted fabric and garment manufacturers, as knitted fabrics with similar face and back draping properties can be designed, modified, or selected to give the drape desired. The drape coefficient can be predicted with one variable or several different combinations of variables, allowing flexibility in the types of physical properties measured. In addition to predicting the drape coefficient, a deformation property or structural characteristic might be predicted if measurements of the drape coefficient and other relevent independent variables are known.

RECOMMENDATIONS FOR FURTHER STUDY

The research project led to several recommendations for further study and analysis. This research project was limited to a sample size of twenty fabrics for the all knit group and sample sizes of ten for the warp and weft knit subgroups. A recommendation for further study is to incorporate a larger sample size in order to obtain a more precise estimate of the variability. A different group of fabrics could be studied to check the validity of the results of the present research. In addition, the study of a different group of fabrics may extend the present research results to a wider range of fabrics. The fabrics chosen for study could include both warp and weft knits or the fabric sample could be limited to one basic type of knitted fabric, ie. either warp knits or weft knits. In addition, since past research indicates that single and double knits vary in several properties (Doyle, 1953; Knapton and Lo, 1975; Hamilton and Postle, 1977; Gibson and Postle, 1978), it may be worth studying different stitch structures, for example, tricot, raschel, milanese, double, or single. Rib knits and/or pile knits could be studied as they were eliminated from this research project due to their directional and face and back draping properties, respectively.

The fabrics incorporated in this research were limited to those suitable for apparel. Examination of knitted fabrics with other end uses is recommended.

The physical properties measured in this research project were limited to those which influence the drape of woven fabrics as suggested by the literature. In addition, the high residuals in this research indicate that with some fabrics, other factors may be influencing drape. Consideration of other properties would be useful, for example, compressive and surface properties.

The measurements taken in this research were limited to one type for each physical property. Additional study could be conducted, altering the testing methods and/or equipment used and/or the types of measurements taken to determine if better correlation could be obtained. For example, flexural rigidity rather than bending length could be calculated as a measure of stiffness.

Re-entrant folding in the draping of very limp fabrics was encountered in this study. In extreme cases the results from the Cusick drape tester may be limited. The extent of this limitation and alternative methods of measuring the draping properties of very limp fabrics could be derived.

Further regression analysis could be conducted to include the development of additional linear regression equations and quadratic equations. More extensive analysis might be worthwhile utilizing the transformation variables formulated in this research project as well as developing additional transformation variables. Further statistical analysis of the various face and back components of the measurements would also be useful.

Further understanding of the relationships between drape and other properties of knitted fabrics could be achieved through an alternative theoretical approach. A theoretical model based on the elements of the knit structure could be developed using the variables identified as reliable predictors of the drape coefficient in the present research.

The present research has resulted in additional knowledge concerning the shearing properties of knitted fabrics. A shearing apparatus based on the one developed by S.M. Spivak has been used to measure the shearing properties of knitted fabrics successfully. A suggestion for further study is additional research on the shearing properties of knitted fabrics utilizing Spivak's shearing apparatus and/or other apparatuses.

Throughout the present study several equations have been developed in order that the drape coefficients of knitted fabrics could be predicted if measurements of one or more physical properties are known. The two basic types of knitted fabrics- warp knits and weft knits, have been studied separately, as well as the entire group of knitted fabrics. The recommendations for further study are expected to provide additional information into the drape of knitted fabrics and their related physical properties.

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APPENDIX A

Statistics Tables

Table 16a

R^2 Values, F-Ratios, t-statistics, and Standard Error of the Estimate Values For the Variable Combinations Which Include Bending Length - All Knit Group

Variable Combinations	R^2	F-Ratio	Standard Error of Estimate	t-statistics
blmean-shearmean	.81	35.14	7.38	7.43, 0.86
blmean-density	.81	37.14	7.22	7.32, -1.25
blmean-extmean	.80	34.19	7.46	7.14, 0.60
blmean-weight	.81	37.18	7.21	7.14, 1.26
blmean-thickness	.84	44.30	6.71	7.13, 2.12
blmean-shearmean-extmean	.81	23.08	7.47	6.88, 0.99, 0.78
blmean-shearmean-thickness	.85	31.26	6.58	6.19, 1.29, 2.32
blmean-shearmean-density	.84	28.96	6.80	6.93, 1.78, -2.01
blmean-shearmean-weight	.82	23.93	7.36	6.63, 0.58, 1.05
blmean-extmean-thickness	.84	28.80	6.81	6.51, 0.70. 2.10
blmean-extmean-weight	.83	26.04	7.11	7.15, 1.23, 1.66
blmean-extmean-density	.81	23.43	7.42	5.63, -0.27, -1.09

Table 16a (continued)

Variable Combinations	R^2	F-Ratio	Standard Error of Estimate	t-statistics
blmean-density-weight	.85	29.46	6.75	6.83, -1.85, -1.09
blmean-density-thickness	.84	28.75	6.82	7.03, -0.68, 1.75
blmean-weight-thickness	.84	28.06	6.89	6.94, -0.36, 1.63
blmean-shearmean-extmean-weight	.84	19.08	7.21	6.77, 0.72, 1.28, 1.46
blmean-shearmean-extmean-thickness	.86	23.66	6.58	6.08, 1.46, 0.99, 2.36
blmean-shearmean-extmean-density	.85	20.98	6.93	4.52, 1.83, -0.62, -1.89
blmean-shearmean-weight-density	.87	25.28	6.40	6.04, 1.67, 1.75, -2.48
blmean-shearmean-thickness-density	.87	25.89	6.33	6.07, 1.86, 1.85, -1.51
blmean-extmean-weight-density	.85	20.78	6.96	5.46, 0.19, 1.79, -1.80
blmean-extmean-weight-thickness	.84	20.25	7.04	6.17, 0.58, 0.05, 1.15

Table 16a (continued)

Variable Combinations	R^2	F-Ratio	Standard Error of Estimate	t-statistics
blmean-extmean-thickness-density	.84	20.35	7.02	5.66, 0.30, 1.70, -0.26
blmean-weight-thickness-density	.85	20.72	6.97	6.59, 0.56, -0.02, -0.79
blmean-shearmean-weight-thickness	.87	24.94	6.44	6.12, 1.82, -1.31, 2.43
blmean-shearmean-weight-thickness-density	.87	19.33	6.55	5.23, 1.69, -0.31, -0.87 1.93
blmean-shearmean-extmean-weight-thickness	.87	18.77	6.64	5.86, 1.71, -0.03. 0.55 -0.68
blmean-shearmean-extmean-weight-density	.87	18.92	6.62	4.50, 1.61, -0.17, 1.57, -1.96
blmean-shearmean-extmean-thickness density	.87	19.34	6.55	4.61, 1.79, -0.05, 0.04, -0.55
blmean-extmean-weight-thickness-density	.85	15.51	7.20	5.14, 0.19, 0.50, 0.04, -0.55
blmean-shearmean-extmean-weight-thickness-density	.87	14.96	7.03	4.41, 1.65, -0.05, -0.03, 0.50, -0.59

Table 16b

R^2 Values, F Ratios, t-statistics and Standard Error of the Estimate Values For the Variable Combinations Which Include Bending Length - Warp Knit Subgroup

Variable Combinations	R^2	F-ratio	Standard Error of Estimate	t-statistics
blmean-shearmean	.93	49.87	4.60	9.24, -0.79
blmean-density	.96	93.50	3.41	13.02, -2.62,
blmean-extmean	.94	58.31	4.28	10.22, 1.35,
blmean-weight	.93	47.14	4.73	9.14, 0.48
blmean-thickness	.97	110.70	3.15	12.64, 3.05
blmean-shearmean-extmean	.94	34.14	4.57	9.22, -0.37 1.05
blmean-shearmean-thickness	.97	67.37	3.30	10.90, -0.62, 2.77
blmean-shearmean-density	.97	55.17	3.63	9.88, 0.43, -2.30
blmean-shearmean-weight	.94	31.94	4.71	8.88, -1.20, 0.82
blmean-extmean-thickness	.99	213.77	1.87	21.05, 3.72, 5.54
blmean-extmean-weight	.96	55.02	3.64	11.98, 2.41, 1.92
blmean-extmean-density	.97	55.93	3.61	8.72, -0.52, 1.96

Table 16b (continued)

Variable Combinations	R^2	F-ratio	Standard Error of Estimate	t-statistics
blmean-density-weight	.98	128.69	2.40	16.20. -4.59, 2.85
blmean-density-thickness	.99	158.25	2.17	18.31, -2.96, 3.37
blmean-weight-thickness	.99	145.30	2.26	17.72, -2.75, 4.95
blmean-shearmean-extmean-weight	.97	40.03	3.70	11.47, -0.89 2.18, 2.03
blmean-shearmean-extmean-thickness	.99	136.39	2.03	18.03, 0.32, 3.30, 5.05
blmean-shearmean-extmean-density	.97	36.68	3.86	6.70, 0.49, -0.55, -1.84
blmean-shearmean-weight-density	.98	80.83	2.62	12.74, 0.16, 2.55, -3.79
blmean-shearmean-thickness-density	.99	109.57	2.26	14.36, 0.73, 3.24, -2.79
blmean-extmean-weight-density	.99	84.24	2.57	12.25, 0.48, 2.61, -2.65
blmean-extmean-weight-thickness	.99	158.63	1.88	19.70, 1.92, -0.96, 4.18

Table 16b (continued)

Variable Combinations	R^2	F-ratio	Standard Error of Estimate	t-statistics
blmean-extmean-thickness-density	.99	138.88	2.01	16.07, 1.41, 3.79, -0.44
blmean-weight-thickness-density	.99	100.17	2.36	16.50, -0.25, 1.10, -0.71
blmean-shearmean-weight-thickness	.99	134.51	2.04	15.31, 1.54, -3.26, 5.20
blmean-shearmean-weight-thickness-density	.99	86.43	2.28	13.66, 1.17, -0.96, 1.63, -0.13
blmean-shearmean-extmean-weight-thickness	.99	151.06	1.73	16.52, 1.39 1.73, -1.70, 4.36
blmean-shearmean-extmean-weight-density	.99	53.93	2.88	9.22, 0.03, 0.41, 2.24, -2.07
blmean-shearmean-extmean-thickness density	.99	95.26	2.17	12.35, 0.53, 1.19, 3.44, -0.60
blmean-extmean-weight-thickness-density	.99	123.12	1.91	15.30, 1.91, -1.24, 2.25, 0.92
blmean-shearmean-extmean-weight-thickness-density	.99	701.48	0.73	36.99, 4.92, 6.00, -5.66, 7.65, 4.38

Table 16c

R^2 Values, F Ratios, t-statistics, and Standard Error of the Estimate Values For the Variable Combinations Which Include Bending Length - Weft Knit Subgroup

Variable Combinations	R^2	F-ratio	Standard Error of Estimate	t-statistics
blmean-shearmean	.90	30.74	6.01	5.26, 3.81
blmean-density	.69	7.67	10.52	3.74, -0.07
blmean-extmean	.69	7.69	10.52	3.04, -0.06
blmean-weight	.79	13.15	8.62	1.99, 1.86
blmean-thickness	.79	12.95	8.67	1.47, 1.82
blmean-shearmean-extmean	.90	18.55	6.33	3.57, 3.65, -0.55
blmean-shearmean-thickness	.90	17.93	6.43	2.73, 2.59, 0.34
blmean-shearmean-density	.90	17.66	6.48	4.66, 3.53, -0.17
blmean-shearmean-weight	.90	17.65	6.48	3.30, 2.53, 0.16
blmean-extmean-thickness	.80	7.92	9.12	0.78, -0.58, 1.83
blmean-extmean-weight	.80	7.54	9.29	1.73, 0.14, 1.73
blmean-extmean-density	.69	4.39	11.36	2.39, -0.09, -0.10

Table 16c (continued)

Variable Combinations	R^2	F-ratio	Standard Error of Estimate	t-statistics
blmean-density-weight	.81	8.47	8.88	1.39, -0.78, 1.96
blmean-density-thickness	.80	7.90	9.13	1.33, 0.56, 1.82
blmean-weight-thickness	.80	8.19	8.99	1.36, 0.71, 0.65
blmean-shearmean-extmean-weight	.90	11.59	6.94	2.71, 2.40, -0.48. 0.02
blmean-shearmean-extmean-thickness	.91	12.16	6.79	1.74, 2.41, -0.62, 0.47
blmean-shearmean-extmean-density	.91	12.12	6.80	2.66, 3.43, -0.66, -0.45
blmean-shearmean-weight-density	.90	11.19	7.05	2.47, 2.12, 0.25, -0.25
blmean-shearmean-thickness-density	.90	7.04	7.04	2.44, 2.25, 0.26, -0.02
blmean-extmean-weight-density	.81	5.35	9.68	0.93, -0.21, 1.81, -0.73
blmean-extmean-weight-thickness	.81	5.19	9.80	0.82, -0.24, 0.44, 0.63

Table 16c (continued)

Variable Combinations	R^2	F-ratio	Standard Error of Estimate	t-statistics
blmean-extmean-thickness-density	.80	5.09	9.88	0.77, -0.36, 1.71, 0.33
blmean-weight-thickness-density	.80	8.19	8.99	1.36, 0.71, 0.65, redundant
blmean-shearmean-weight-thickness	.90	11.21	7.04	2.44, 2.19, -0.03, 0.27
blmean-shearmean-weight-thickness-density	.90	11.21	7.04	2.44, 2.19, -0.03, 0.27, redundant
blmean-shearmean-extmean-weight-thickness	.91	8.09	7.46	1.51, 2.15, -0.68, -0.38, 0.57
blmean-shearmean-extmean-weight-density	.91	7.83	7.57	1.71, 2.04, -0.58, 0.19, -0.45
blmean-shearmean-extmean-thickness density	.91	7.93	7.53	1.55, 2.15, -0.62, 0.29, -0.26
blmean-extmean-weight-thickness-density	.81	5.19	9.80	0.82, -0.24, 0.44, 0.63, redundant
blmean-shearmean-extmean-weight-thickness-density	.91	8.09	7.46	1.51, 2.15, -0.68, -0.38, 0.57, redundant

APPENDIX B1

Computer Printout

Multiple Linear Regression

```
BMDP1R - MULTIPLE LINEAR REGRESSICN                                 PROGRAM REVISED NOVEMBER, 1978
HEALTH SCIENCES COMPUTING FACILITY                                  MANUAL DATE  -- 1977
UNIVERSITY OF CALIFORNIA, LOS ANGELES
COPYRIGHT (C) 1977, REGENTS OF UNIVERSITY OF CALIFORNIA

IN THIS VERSION OF BMDP1R

   -- NEW OPTION - TO PRINT THE CORRELATICN OF THE REGRESSION COEFFICIENTS, SPECIFY RREG IN THE PRINT PARAGRAPH.
      IF LESS THAN TWO VARIABLES ENTERED THE EQUATION, THE CORRELATION OF THE REGRESSION COEFFICIENTS IS NOT PRINTED.

   -- NEW OPTION - SPECIFY NORM IN THE PLCT PARAGRAPH TO PRINT THE NORMAL PROBABILITY PLOT OF RESIDUALS.

   -- NEW OPTION - SPECIFY DNORM IN THE PLOT PARAGRAPH TO PRINT THE DETRENDED NORMAL PROBABILITY PLOT OF RESIDUALS.


  PROGRAM CONTROL INFORMATION

         /PROBLEM                   TITLE IS 'REGRESSICN TO PREDICT DRAPE COEFFICIENT'.
         /INPUT                     VARIABLES ARE 24.
                                FORMAT IS '(3(1X,F6.3),F3.0,3(1X,F5.2),
                                    3(1X,F8.3),2X,A1/9(1X,F5.3)/1X,F8.4,1X,
                                    F5.4,1X,F8.4,2X,A1)'.
         /VARIABLE           NAMES ARE DCFACE,DCBACK,DCMEAN,IDENT,EXTWALE,EXTCOURS,
                               EXTMEAN,SHEARWAL,SHEARCOU,SHEARMEA,FABRIC1,
                              BLWALEIN,BLWALEOU,BLCOURIN,BLCOUROU,BLMEANIN,
                              BLMEANOU,BLMEAN,BWALEME,BLCOURME,
                                    WEIGHT,THICKNES,DENSITY,FABRIC2,
                              BLMEAN2,THICK2,SHEARCO2,BLTHICK,EXTMEAN2,
                              BLSHEACO,BLEXTMEA,THEXTMEA,BLCOUIN2,
                                SHEACOTH,SHEARME2,BLCOISHM,THBLCOUI,
                               THSHEARM.
                                    BLANKS ARE MISSING.
                                    LABELS ARE FABRIC1,FABRIC2.
                             ADD IS 14.
         /TRANSFORM                   BLMEAN2=BLMEAN*BLMEAN.
                                    THICK2=THICKNES*THICKNES.
                              SHEARCO2=SHEARCOU*SHEARCOU.
                                    BLTHICK=BLMEAN*THICKNES.
                                EXTMEAN2=EXTMEAN*EXTMEAN.
                              BLSHEACO=BLMEAN*SHEARCOU.
                                  THEXTMEA=THICKNES*EXTMEAN.
                                  BLEXTMEA=BLMEAN*EXTMEAN.
                              SHEACOTH=SHEARCOU*THICKNES.
                                BLCOUIN2=BLCOURIN*BLCOURIN.
                              SHEARME2=SHEARMEA*SHEARMEA.
                               BLCOISHM=BLCOURIN*SHEARMEA.
                              THBLCOUI=BLCOURIN*THICKNES.
                              THSHEARM=SHEARMEA*THICKNES.
```

```
        /REGRESS          DEPENDENT IS DCMEAN.
                            INDEPENDENT ARE BLMEAN,THICKNES.
        /PRINT              DATA.
                            CORRELATION.
                             COVARIANCE.
                            RREG.
        /PLOT               RESIDUALS.
                            VARIABLES ARE BLMEAN,THICKNES.
                            PREP ARE BLMEAN,THICKNES.
                            NORMAL.
        /END

    PROBLEM TITLE . . . . . . .REGRESSION TO PREDICT DRAPE COEFFICIENT

    NUMBER OF VARIABLES TO READ IN. . . . . . . . .      24


  NUMBER OF VARIABLES ADDED BY TRANSFORMATIONS. .      14
  TOTAL NUMBER OF VARIABLES . . . . . . . . . . .      38
  NUMBER OF CASES TO READ IN. . . . . . . . . . . 1000000
  CASE LABELING VARIABLES . . . . . . . . . . . .  FABRIC1    FABRIC2
  LIMITS AND MISSING VALUE CHECKED BEFORE TRANSFORMATIONS
  BLANKS ARE. . . . . . . . . . . . . . . . . . . MISSING
  INPUT UNIT NUMBER . . . . . . . . . . . . . . .       5
  REWIND INPUT UNIT PRIOR TO READING. . DATA. . .      NO

  INPUT FORMAT
        (3(1X,F6.3),F3.0,3(1X,F5.2), 3(1X,F8.3),2X,A1/9(1X,F5.3)/1X,F8.4,1X, F5.4,1X,F8.
        4,2X,A1)

*** CONTROL LANGUAGE TRANSFORMATIONS ARE PERFORMED ***


  VARIABLES TO BE USED
               1  DCFACE        2  DCBACK        3  DCMEAN        4  IDENT         5  EXTWALE
               6  EXTCOURS      7  EXTMEAN       8  SHEARWAL      9  SHEARCOU     10  SHEARMEA
              12  BLWALEIN     13  BLWALECU     14  BLCOURIN     15  BLCOUROU     16  BLMEANIN
              17  BLMEANOU     18  BLMEAN       19  BWALEME      20  BLCOURME     21  WEIGHT
              22  THICKNES     23  DENSITY      25  BLMEAN2      26  THICK2       27  SHEARCO2
              28  BLTHICK      29  EXTMEAN2     30  BLSHEACO     31  BLEXTMEA     32  THEXTMEA
              33  BLCOUIN2     34  SHEACOTH     35  SHEARME2     36  BLCOISHM     37  THBLCOUI
              38  THSHEARM
  REGRESSION INTERCEPT. . . . . . . . . . . . . . .NON-ZERO
  GROUPING VARIABLE . . . . . . . . . . . . . . .
  WEIGHT VARIABLE . . . . . . . . . . . . . . . .
  PRINT COVARIANCE MATRIX . . . . . . . . . . . .      YES
  PRINT CORRELATION MATRIX. . . . . . . . . . . .      YES
  PRINT CORRELATION OF REGRESSION COEFFICIENTS. .      YES
  PRINT RESIDUALS . . . . . . . . . . . . . . . .      YES
  PRINT NORMAL PROBABILITY PLOT . . . . . . . . .      YES
  PRINT DETRENDED NORMAL PROBABILITY PLOT . . . .       NO

  NUMBER OF CASES READ. . . . . . . . . . . . . .       20
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VARIABLE              MEAN STANDARD DEVIATION COEFFICIENT     MINIMUM       MAXIMUM
                                               OF VARIATION
  1 DCFACE        39.23392         15.89880     0.40523     17.52399      67.10799
  2 DCBACK        38.15736         15.83948     0.41511     17.86099      65.86899
  3 DCMEAN        38.69566         15.81520     0.40871     17.69199      66.21599
  4 IDENT          0.00000          1.02598 ************    -1.00000       1.00000
  5 EXTWALE        7.88250          5.64504     0.71615      1.48000      26.67000
  6 EXTCOURS      12.94598         10.05527     0.77671      1.72000      46.42000
  7 EXTMEAN       10.41599          6.85744     0.65836      2.09000      27.64999
  8 SHEARWAL     448.52002        312.41211     0.69654    141.42899    1288.57080
  9 SHEARCOU     460.10596        286.45313     0.62258    162.85699    1327.14282
 10 SHEARMEA     454.31323        295.89673     0.65131    152.14299    1307.85693
 12 BLWALEIN       1.20509          0.33326     0.27654      0.77600       1.99800
 13 BLWALEOU       1.35994          0.29921     0.22001      0.91800       1.98400
 14 BLCOURIN       1.26145          0.37247     0.29527      0.83000       2.14500
 15 BLCOUROU       1.21385          0.37925     0.31244      0.82200       1.93800
 16 BLMEANIN       1.23355          0.32089     0.26013      0.84400       1.90000
 17 BLMEANOU       1.30465          0.30045     0.23029      0.91700       1.92800
 18 BLMEAN         1.26025          0.30472     0.24179      0.88900       1.89400
 19 BWALEME        1.28275          0.28901     0.22531      0.91500       1.89000
 20 BLCCURME       1.23790          0.36735     0.29675      0.82600       2.00900
 21 WEIGHT       164.58859         56.41321     0.34192     24.46259     252.46939
 22 THICKNES       0.07425          0.03091     0.41621      0.02060       0.14020
 23 DENSITY      230.87523         61.68460     0.26718    118.75240     335.18774
 25 BLMEAN2        1.67643          0.84150     0.50196      0.79032       3.58723
 26 THICK2         0.00642          0.00497     0.77340      0.00042       0.01966
 27 SHEARCO2  289651.37500     401676.56250     1.38676  26522.39844 ************



  28 BLTHICK        0.09775          0.05638     0.57683      0.02464       0.20665
  29 EXTMEAN2     153.16629        215.87447     1.40941      4.36810     764.52197
  30 BLSHEACO     610.93433        518.82080     0.84923    155.92816    2513.60718
  31 BLEXTMEA      12.07849          7.11683     0.58922      3.73079      33.06937
  32 THEXTMEA       0.72109          0.50184     0.69595      0.10755       2.26458
  33 BLCOUIN2       1.72304          1.04408     0.60595      0.68890       4.60102
  34 SHEACOTH      34.49948         23.87660     0.69209      3.35485      92.76724
  35 SHEARME2  289578.87500     419835.62500     1.44636  23147.48828 ************
  36 BLCOISHM     619.69312        584.00488     0.94241    134.19011    2805.35229
  37 THBLCOUI       0.09855          0.05835     0.59208      0.01817       0.22334
  38 THSHEARM      34.19569         24.26886     0.70971      3.13414      91.41916
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COVARIANCE MATRIX

              DCFACE     DCBACK     DCMEAN     IDENT      EXTWALE    EXTCOURS   EXTMEAN    SHEARWAL   SHEARCOU   SHEARMEA
                   1          2          3          4          5          6          7          8          9         10

DCFACE     1   252.7720
DCBACK     2   248.4077   250.8892
DCMEAN     3   250.5909   249.6492   250.1207
IDENT      4    -1.2523    -0.6858    -0.9692     1.0526
EXTWALE    5   -34.5918   -31.9160   -33.2532    -1.2816    31.8665
EXTCOURS   6   -56.8545   -57.2292   -57.0417     1.2452    27.5552   101.1086
EXTMEAN    7   -45.7157   -44.5660   -45.1405    -0.0189    29.7093    64.3365    47.0245
SHEARWAL   8  1748.1548  2037.7104  1892.9407    70.0219  -246.6558 -1256.3721  -751.4875 97601.3125
SHEARCOU   9  1900.0046  2079.7922  1989.9124    45.3000  -171.9411 -1124.8594  -648.3870 85281.4375 82055.4375
SHEARMEA  10  1824.0798  2058.7520  1941.4268    57.6610  -209.2982 -1190.6155  -699.9380 91441.3125 83668.3125 87554.9375
BLWALEIN  12     3.9236     4.1721     4.0478    -0.0364    -0.8237    -1.1301    -0.9768    28.8174    21.8384    25.3279
BLWALEOU  13     3.3448     3.1638     3.2543    -0.0494    -0.8618    -0.4972    -0.6791    24.1100    26.1072    25.1086
BLCOURIN  14     4.9455     4.9870     4.9662     0.0224    -0.8439    -2.1941    -1.5189    47.6165    50.4875    49.0520
BLCOUROU  15     4.8763     4.9839     4.9301     0.0383    -0.8554    -1.6208    -1.2381    34.4204    32.4101    33.4152
BLMEANIN  16     4.4355     4.5806     4.5081    -0.0071    -0.8335    -1.6619    -1.2476    38.2459    36.1959    37.2209
BLMEANOU  17     3.9415     3.9047     3.9231     0.0128    -0.8176    -0.9564    -0.8867    26.8859    26.8576    26.8718
BLMEAN    18     4.2744     4.3284     4.3014    -0.0064    -0.8463    -1.3609    -1.1034    33.7431    32.7216    33.2323
BWALEME   19     3.6336     3.6673     3.6505    -0.0430    -0.8423    -0.8127    -0.8273    26.4683    23.9730    25.2206
BLCOURME  20     4.9118     4.9861     4.9490     0.0302    -0.8496    -1.9078    -1.3786    41.0338    41.4734    41.2536
WEIGHT    21   448.1377   455.3372   451.7395   -22.6320   -43.3861  -367.2813  -205.3271  6727.9375  5509.4766  6118.7070
THICKNES  22     0.2937     0.2908     0.2923    -0.0114     0.0002    -0.1104    -0.0551     0.6179     0.3519     0.4849
DENSITY   23  -269.1362  -240.4243  -254.7843     9.1396   -85.0940  -318.3115  -201.7783  7386.6328  6537.6094  6962.1211
BLMEAN2   25    11.4935    11.7165    11.6050    -0.0200    -2.2715    -3.8314    -3.0510   101.4312    96.8383    99.1347
THICK2    26     0.0488     0.0485     0.0487    -0.0013    -0.0012    -0.0125    -0.0068    -0.0081    -0.0534    -0.0307
SHEARCO2  27 ********** ********** ********** 90741.5625 ********** ********** ********** ********** ********** **********
BLTHICK   28     0.7036     0.7065     0.7051    -0.0156    -0.0696    -0.2413    -0.1554     2.7725     2.1530     2.4628
EXTMEAN2  29  -974.4080  -938.8518  -956.6157     2.9327   867.9153  1986.8345  1427.4316 ********** ********** **********
BLSHEACO  30  4979.4531  5184.9375  5082.2148    77.1238  -820.3562 -2276.9792 -1548.5083 ********** ********** **********
BLEXTMEA  31   -22.9866   -21.8988   -22.4422     0.0825    26.4360    67.1880    46.8150  -807.8035  -699.9836  -753.8931
THEXTMEA  32    -0.6096    -0.4503    -0.5299    -0.1272     2.2740     2.1055     2.1897   -32.5764   -24.0931   -28.3347
BLCOUIN2  33    13.4601    13.7072    13.5837     0.0910    -2.4575    -5.9281    -4.1925   149.3868   155.0280   152.2074
SHEACOTH  34   248.9611   257.8770   253.4208    -2.8987    -5.9780  -100.2661   -53.1113  6177.4219  5930.5195  6053.9727
SHEARME2  35 ********** ********** ********** ********** ********** ********** ********** ********** ********** **********
BLCOISHM  36  5433.3242  5683.1211  5558.2383   116.4783  -962.3997 -2670.3958 -1816.1914 ********** ********** **********
THBLCOUI  37     0.7475     0.7507     0.7491    -0.0129    -0.0667    -0.2647    -0.1656     3.3479     3.0159     3.1819
THSHEARM  38   243.6277   256.4336   250.0325    -1.8358   -10.7642  -106.0965   -58.4189  6584.7695  5990.7500  6287.7539
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              BLWALEIN   BLWALEOU   BLCOURIN   BLCOUROU   BLMEANIN   BLMEANOU     BLMEAN    BWALEME   BLCOURME     WEIGHT
                    12         13         14         15         16         17         18         19         20         21

BLWALEIN 12     0.1111
BLWALEOU 13     0.0668     0.0895
BLCOURIN 14     0.0810     0.0662     0.1387
BLCOUROU 15     0.0962     0.0618     0.1286     0.1438
BLMEANIN 16     0.0960     0.0665     0.1099     0.1124     0.1030
BLMEANOU 17     0.0764     0.0747     0.0946     0.0987     0.0855     0.0903
BLMEAN   18     0.0888     0.0711     0.1037     0.1077     0.0962     0.0862     0.0929
BWALEME  19     0.0889     0.0781     0.0736     0.0790     0.0813     0.0756     0.0799     0.0835
BLCOURME 20     0.0886     0.0640     0.1337     0.1362     0.1111     0.0967     0.1057     0.0763     0.1349
WEIGHT   21     8.6872     4.2145     9.7075     7.2823     9.1996     4.0895     7.4747     6.4532     8.4965  3182.4497
THICKNES 22     0.0052     0.0024     0.0051     0.0047     0.0052     0.0031     0.0044     0.0038     0.0049     1.3982
DENSITY  23    -3.6852    -4.2008     0.0488    -3.2834    -1.8190    -5.1438    -2.7786    -3.9413    -1.6192   750.8142
BLMEAN2  25     0.2442     0.1965     0.2865     0.2934     0.2653     0.2357     0.2552     0.2203     0.2899    21.1097
THICK2   26     0.0009     0.0004     0.0008     0.0008     0.0008     0.0005     0.0007     0.0006     0.0008     0.1999
SHEARCO2 27 32250.4570 42744.5586 73856.1250 51231.0547 53093.5234 43642.0820 50029.0391 37494.8320 62570.8945 **********
BLTHICK  28     0.0140     0.0090     0.0145     0.0143     0.0143     0.0108     0.0130     0.0115     0.0144     2.4210
EXTMEAN2 29   -22.2655   -12.2828   -35.3268   -25.9071   -28.7845   -18.1424   -23.9410   -17.2527   -30.6195 -6413.5234
BLSHEACO 30    74.8126    81.6604   131.6268   104.8468   103.3678    88.5817    98.3224    78.2220   118.3787 10399.0508
BLEXTMEA 31    -0.5412    -0.3168    -1.1584    -0.7564    -0.8495    -0.4729    -0.6933    -0.4284    -0.9575  -194.5937
THEXTMEA 32    -0.0253    -0.0510    -0.0426    -0.0421    -0.0339    -0.0470    -0.0402    -0.0381    -0.0423     3.9124
BLCOUIN2 33     0.2320     0.1915     0.3851     0.3575     0.3086     0.2655     0.2917     0.2116     0.3714    25.5331
SHEACOTH 34     3.3798     3.0214     4.9383     3.5713     4.1620     2.9552     3.7286     3.2012     4.2571   898.4807
SHEARME2 35 33333.3320 36366.3945 67563.1250 48703.5195 50488.2969 39124.1797 46491.5391 34851.2656 58153.5781 **********
BLCOISHM 36    79.5992    87.5477   153.3576   121.6862   116.5264    99.8376   110.5851    83.5509   137.5609 11678.9023
THBLCOUI 37     0.0134     0.0087     0.0164     0.0156     0.0149     0.0113     0.0135     0.0110     0.0160     2.4623
THSHEARM 38     3.7020     3.0289     4.9067     3.7409     4.3071     3.0445     3.8453     3.3662     4.3257   939.1377


              THICKNES    DENSITY    BLMEAN2     THICK2   SHEARCO2    BLTHICK   EXTMEAN2   BLSHEACO   BLEXTMEA   THEXTMEA
                    22         23         25         26         27         28         29         30         31         32

THICKNES 22     0.0010
DENSITY  23    -0.6766  3804.9900
BLMEAN2  25     0.0116    -5.3989     0.7081
THICK2   26     0.0001    -0.1309     0.0019     0.0000
SHEARCO2 27    -0.6116 ********** **********  -134.8473 **********
BLTHICK  28     0.0016    -1.1188     0.0352     0.0003  2775.6213     0.0032
EXTMEAN2 29    -1.8761 -6231.4492   -66.0704    -0.2361 **********    -4.3625 46601.7852
BLSHEACO 30     1.7423  8896.6758   284.2651     0.1273 **********     8.5908 ********** **********
BLEXTMEA 31    -0.0278  -280.9465    -2.0026    -0.0013 **********    -0.0850  1454.7886 -1445.7019    50.6493
THEXTMEA 32     0.0072   -14.8574    -0.1147     0.0012 **********     0.0062    61.4777   -70.7373     2.2292     0.2518
BLCOUIN2 33     0.0126     2.6058     0.8142     0.0020 **********     0.0382   -95.2881   400.0601    -3.2573    -0.1379
SHEACOTH 34     0.3599   158.0882    10.5715     0.0481 **********     0.7069 -1223.0508 10392.5156   -45.6441     1.0875
SHEARME2 35     6.6513 ********** **********  -137.4395 **********  2595.9548 ********** ********** ********** **********
BLCOISHM 36     1.8760 10715.3516   321.5042     0.1393 **********     9.6116 ********** ********** -1724.6367   -85.5422
THBLCOUI 37     0.0016    -1.0707     0.0367     0.0003  4112.3203     0.0032    -4.5737    10.3321    -0.0950     0.0065
THSHEARM 38     0.3672   192.1966    10.9593     0.0496 **********     0.7346 -1432.5264 10396.4258   -50.7825     0.5969
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               BLCOUIN2   SHEACOTH   SHEARME2   BLCOISHM   THBLCOUI   THSHEARM
                     33         34         35         36         37         38

BLCOUIN2  33     1.0901
SHEACOTH  34    14.1724   570.0923
SHEARME2  35 ********** ********** **********
BLCOISHM  36   465.0415 11370.7227 ********** **********
THBLCOUI  37     0.0434     C.7641  3741.CC98    11.9050     0.0034
THSHEARM  38    14.1710   572.6707 ********** 11476.2188     0.7804   588.9775
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CORRELATION MATRIX

                  DCFACE    DCBACK    DCMEAN    IDENT     EXTWALE   EXTCOURS  EXTMEAN   SHEARWAL  SHEARCOU  SHEARMEA
                       1         2         3         4         5         6         7         8         9        10

DCFACE      1     1.0000
DCBACK      2     0.9864    1.0000
DCMEAN      3     0.9966    0.9966    1.0000
IDENT       4    -0.0768   -0.0422   -0.0597    1.0000
EXTWALE     5    -0.3854   -0.3569   -0.3725   -0.2213    1.0000
EXTCOURS    6    -0.3556   -0.3593   -0.3587    0.1207    0.4854    1.0000
EXTMEAN     7    -0.4193   -0.4103   -0.4162   -0.0027    0.7675    0.9330    1.0000
SHEARWAL    8     0.3520    0.4118    0.3831    0.2185   -0.1399   -0.3999   -0.3508    1.0000
SHEARCOU    9     0.4172    0.4584    0.4392    0.1541   -0.1063   -0.3905   -0.3301    0.9530    1.0000
SHEARMEA   10     0.3877    0.4393    0.4149    0.1899   -0.1253   -0.4002   -0.3450    0.9892    0.9871    1.0000
BLWALEIN   12     0.7405    0.7904    0.7680   -0.1065   -0.4378   -0.3373   -0.4274    0.2768    0.2288    0.2569
BLWALEOU   13     0.7031    0.6676    0.6877   -0.1610   -0.5102   -0.1653   -0.3310    0.2579    0.3046    0.2836
BLCOURIN   14     0.8351    0.8453    0.8431    0.0585   -0.4014   -0.5858   -0.5947    0.4092    0.4732    0.4451
BLCOUROU   15     0.8087    0.8297    0.8220    0.0983   -0.3995   -0.4250   -0.4761    0.2905    0.2983    0.2978
BLMEANIN   16     0.8694    0.9012    0.8883   -0.0216   -0.4601   -0.5151   -0.5670    0.3815    0.3938    0.3920
BLMEANOU   17     0.8251    0.8205    0.8256    0.0415   -0.4820   -0.3166   -0.4304    0.2864    0.3121    0.3023
BLMEAN     18     0.8823    0.8968    0.8926   -0.0204   -0.4920   -0.4442   -0.5281    0.3545    0.3749    0.3686
BWALEME    19     0.7908    0.8011    0.7987   -0.1450   -0.5163   -0.2797   -0.4174    0.2931    0.2896    0.2949
BLCOURME   20     0.8410    0.8569    0.8518    0.0802   -0.4097   -0.5165   -0.5473    0.3575    0.3941    0.3795
WEIGHT     21     0.4997    0.5096    0.5063   -0.3910   -0.1362   -0.6475   -0.5308    0.3817    0.3409    0.3666
THICKNES   22     0.5978    0.5941    0.5980   -0.3594    0.0011   -0.3553   -0.2600    0.0640    0.0398    0.0530
DENSITY    23    -0.2744   -0.2461   -0.2612    0.1444   -0.2444   -0.5132   -0.4770    0.3833    0.3700    0.3814
BLMEAN2    25     0.8591    0.8790    0.8720   -0.0231   -0.4782   -0.4528   -0.5287    0.3858    0.4017    0.3981
THICK2     26     0.6185    0.6164    0.6196   -0.2513   -0.0423   -0.2498   -0.2005   -0.0052   -0.0375   -0.0209
SHEARCO2   27     0.4116    0.4481    0.4313    0.2202   -0.1481   -0.3299   -0.3028    0.9210    0.9604    0.9511
BLTHICK    28     0.7849    0.7911    0.7907   -0.2689   -0.2186   -0.4255   -0.4019    0.1574    0.1333    0.1476
EXTMEAN2   29    -0.2839   -0.2746   -0.2802    0.0132    0.7122    0.9153    0.9643   -0.2712   -0.2188   -0.2491
BLSHEACO   30     0.6037    0.6309    0.6194    0.1449   -0.2801   -0.4365   -0.4352    0.8618    0.9311    0.9057
BLEXTMEA   31    -0.2032   -0.1943   -0.1994    0.0113    0.6580    0.9389    0.9593   -0.3633   -0.3434   -0.3580
THEXTMEA   32    -0.0764   -0.0566   -0.0668   -0.2471    0.8027    0.4172    0.6363   -0.2078   -0.1676   -0.1908
BLCOUIN2   33     0.8109    0.8288    0.8226    0.0849   -0.4170   -0.5647   -0.5856    0.4580    0.5183    0.4927
SHEACOTH   34     0.6558    0.6819    0.6711   -0.1183   -0.0444   -0.4176   -0.3244    0.8281    0.8671    0.8569
SHEARME2   35     0.3505    0.4013    0.3771    0.2562   -0.1290   -0.3271   -0.2929    0.9620    0.9482    0.9668
BLCOISHM   36     0.5852    0.6144    0.6018    0.1944   -0.2919   -0.4547   -0.4535    0.8635    0.9199    0.9012
THBLCOUI   37     0.8058    0.8122    0.8117   -0.2148   -0.2024   -0.4511   -0.4139    0.1836    0.1804    0.1843
THSHEARM   38     0.6314    0.6671    0.6514   -0.0737   -0.0786   -0.4348   -0.3510    0.8685    0.8617    0.8756
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                 BLWALEIN    BLWALEOU    BLCOURIN    BLCOUROU    BLMEANIN    BLMEANOU    BLMEAN      BWALEME     BLCOURME    WEIGHT
                    12          13          14          15          16          17          18          19          20          21

BLWALEIN  12     1.0000
BLWALEOU  13     0.6657      1.0000
BLCOURIN  14     0.6526      0.5941      1.0000
BLCOUROU  15     0.7610      0.5448      0.9103      1.0000
BLMEANIN  16     0.8981      0.6927      0.9193      0.9235      1.0000
BLMEANOU  17     0.7635      0.8313      0.8457      0.8658      0.8873      1.0000
BLMEAN    18     0.8743      0.7800      0.9135      0.9316      0.9843      0.9410      1.0000
BWALEME   19     0.9232      0.9037      0.6834      0.7204      0.8761      0.8702      0.9076      1.0000
BLCOURME  20     0.7236      0.5827      0.9770      0.9777      0.9428      0.8758      0.9441      0.7185      1.0000
WEIGHT    21     0.4621      0.2497      0.4620      0.3404      0.5082      0.2413      0.4348      0.3958      0.4100      1.0000
THICKNES  22     0.5090      0.2632      0.4468      0.4037      0.5236      0.3347      0.4660      0.4297      0.4350      0.8020
DENSITY   23    -0.1793     -0.2276      0.0021     -0.1404     -0.0919     -0.2775     -0.1478     -0.2211     -0.0715      0.2158
BLMEAN2   25     0.8706      0.7803      0.9140      0.9193      0.9826      0.9323      0.9954      0.9057      0.9379      0.4447
THICK2    26     0.5227      0.2754      0.4423      0.4394      0.5281      0.3640      0.4824      0.4439      0.4511      0.7135
SHEARCO2  27     0.2409      0.3557      0.4937      0.3363      0.4119      0.3616      0.4087      0.3230      0.4240      0.2781
BLTHICK   28     0.7472      0.5363      0.6886      0.6692      0.7877      0.6402      0.7548      0.7083      0.6946      0.7611
EXTMEAN2  29    -0.3095     -0.1902     -0.4394     -0.3164     -0.4155     -0.2797     -0.3640     -0.2765     -0.3861     -0.5266
BLSHEACO  30     0.4327      0.5260      0.6822      0.5329      0.6209      0.5683      0.6219      0.5217      0.6211      0.3553
BLEXTMEA  31    -0.2282     -0.1488     -0.4370     -0.2802     -0.3720     -0.2211     -0.3197     -0.2083     -0.3663     -0.4847
THEXTMEA  32    -0.1512     -0.3396     -0.2277     -0.2212     -0.2106     -0.3120     -0.2632     -0.2627     -0.2296      0.1382
BLCOUIN2  33     0.6667      0.6130      0.9904      0.9029      0.9211      0.8464      0.9168      0.7013      0.9682      0.4335
SHEACOTH  34     0.4248      0.4229      0.5553      0.3944      0.5432      0.4119      0.5125      0.4639      0.4854      0.6670
SHEARME2  35     0.2388      0.2902      0.4331      0.3066      0.3757      0.3109      0.3643      0.2879      0.3780      0.2920
BLCOISHM  36     0.4090      0.5010      0.7050      0.5494      0.6218      0.5690      0.6214      0.4950      0.6412      0.3545
THBLCOUI  37     0.6893      0.4982      0.7537      0.7031      0.7954      0.6448      0.7601      0.6551      0.7451      0.7480
THSHEARM  38     0.4577      0.4171      0.5428      0.4064      0.5531      0.4175      0.5200      0.4799      0.4852      0.6860


                 THICKNES    DENSITY     BLMEAN2     THICK2      SHEARCO2    BLTHICK     EXTMEAN2    BLSHEACO    BLEXTMEA    THEXTMEA
                    22          23          25          26          27          28          29          30          31          32

THICKNES  22     1.0000
DENSITY   23    -0.3549      1.0000
BLMEAN2   25     0.4462     -0.1040      1.0000
THICK2    26     0.9773     -0.4274      0.4560      1.0000
SHEARCO2  27    -0.0000      0.3290      0.4465     -0.0676      1.0000
BLTHICK   28     0.9227     -0.3217      0.7413      0.9241      0.1226      1.0000
EXTMEAN2  29    -0.2812     -0.4680     -0.3637     -0.2202     -0.1895     -0.3584      1.0000
BLSHEACO  30     0.1087      0.2780      0.6511      0.0494      0.9578      0.2937     -0.2877      1.0000
BLEXTMEA  31    -0.1262     -0.6400     -0.3344     -0.0355     -0.3101     -0.2119      0.9469     -0.3915      1.0000
THEXTMEA  32     0.4649     -0.4800     -0.2717      0.4664     -0.2121      0.2188      0.5675     -0.2717      0.6241      1.0000
BLCOUIN2  33     0.3894      0.0405      0.9267      0.3824      0.5637      0.6481     -0.4228      0.7385     -0.4384     -0.2631
SHEACOTH  34     0.4878      0.1073      0.5262      0.4055      0.8168      0.5251     -0.2373      0.8389     -0.2686      0.0908
SHEARME2  35     0.0005      0.3434      0.4033     -0.0661      0.9828      0.1099     -0.2014      0.9128     -0.3062     -0.2135
BLCOISHM  36     0.1039      0.2974      0.6542      0.0480      0.9587      0.2919     -0.3071      0.9936     -0.4149     -0.2919
THBLCOUI  37     0.9100     -0.2975      0.7477      0.9138      0.1755      0.9862     -0.3631      0.3413     -0.2288      0.2234
THSHEARM  38     0.4896      0.1284      0.5366      0.4114      0.8158      0.5369     -0.2734      0.8257     -0.2940      0.0490
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                    BLCOUIN2    SHEACOTH    SHEARME2    BLCOISHM    THBLCOUI    THSHEARM
                       33          34          35          36          37          38

   BLCOUIN2  33       1.0000
   SHEACOTH  34       0.5685      1.0000
   SHEARME2  35       0.5033      0.8014      1.0000
   BLCOISHM  36       0.7627      0.8155      0.9195      1.0000
   THBLCOUI  37       0.7120      0.5484      0.1531      0.3493      1.0000
   THSHEARM  38       0.5593      0.9883      0.8256      0.8097      0.5511      1.0000


   REGRESSION TITLE. . . . . . . . . . . . . . . . .REGRESSION TO PREDICT DRAPE COEFFICIENT
   DEPENDENT VARIABLE. . . . . . . . . . . . . . . .          3 DCMEAN
   TOLERANCE . . . . . . . . . . . . . . . . . . . .   0.0100
 ALL DATA CONSIDERED AS A SINGLE GROUP

 MULTIPLE R             0.9160            STD. ERROR OF EST.          6.7084
 MULTIPLE R-SQUARE      0.8390

 ANALYSIS OF VARIANCE
                        SUM OF SQUARES      DF     MEAN SQUARE        F RATIO     P(TAIL)
         REGRESSION          3987.250        2        1993.625         44.300     0.00000
         RESIDUAL             765.043       17          45.003

                                                    STD. REG
   VARIABLE         COEFFICIENT    STD. ERROR         COEFF            T    P(2 TAIL) TOLERANCE

 INTERCEPT            -21.43451
 BLMEAN       18       40.70119        5.708           0.784       7.130      0.000     0.782873
 THICKNES     22      119.00529       56.280           0.233       2.115      0.050     0.782873



    CORRELATION MATRIX OF REGRESSION COEFFICIENTS


                      BLMEAN     THICKNES
                         18           22

    BLMEAN    18       1.0000
    THICKNES  22      -0.4660       1.0000
```

```
LIST OF PREDICTED VALUES, RESIDUALS, AND VARIABLES
         NOTE - NEGATIVE CASE NUMBER DENOTES A CASE WITH MISSING VALUES.
                THE NUMBER OF STANDARD DEVIATIONS FROM THE MEAN IS DENOTED BY UP TO 3 ASTERISKS TO THE RIGHT
                   OF EACH RESIDUAL OR VARIABLE.
                MISSING VALUES ARE DENOTED BY MORE THAN THREE ASTERISKS.

   CASE          RESIDUAL      PREDICTED      VARIABLES
  LABEL   NO.                    VALUE         1 DCFACE      2 DCBACK      3 DCMEAN      4 IDENT       5 EXTWALE     6 EXTCOURS
                                               7 EXTMEAN     8 SHEARWAL    9 SHEARCOU   10 SHEARMEA   12 BLWALEIN   13 BLWALEOU
                                              14 BLCOURIN   15 BLCOUROU   16 BLMEANIN   17 BLMEANOU   18 BLMEAN     19 BWALEME
                                              20 BLCOURME   21 WEIGHT     22 THICKNES   23 DENSITY    25 BLMEAN2    26 THICK2
                                              27 SHEARCO2   28 BLTHICK    29 EXTMEAN2   30 BLSHEACO   31 BLEXTMEA   32 THEXTMEA
                                              33 BLCOUIN2   34 SHEACOTH   35 SHEARME2   36 BLCOISHM   37 THBLCOUI   38 THSHEARM


A  A      1      -0.4187       26.6947        23.6980       28.8540       26.2760        1.0000      13.9300*      11.3700
                                              12.6500     1225.7139**   914.2859*    1070.0000**     1.1130        0.9180*
                                               0.9180        0.9680        1.0160        0.9430*       0.9790        1.0160
                                               0.9430      200.2245        0.0696      287.6794        0.9584        0.0048
                                          ***********        0.0681      160.0225      895.0857       12.3843        0.8804
                                               0.8427       63.6343*   ************    982.2598        0.0639       74.4720*
B  B      2       1.0183       28.5387        30.0970       29.0170       29.5570        1.0000       10.1000       18.5100
                                              14.3100      320.0000      330.0000      325.0000        0.9330        1.3090
                                               1.1130        0.9900        1.0230        1.5000        1.0860        1.1210
                                               1.0520       74.9456*       0.0485      154.5278*       1.1794        0.0024
                                          **********         0.0527      204.7761      358.3796       15.5407        0.6940
                                               1.2388       16.0050    **********      361.7249        0.0540       15.7625
C  C      3       6.5254       29.6956        37.0900       35.3520       36.2210        1.0000        8.8700       46.4200***
                                              27.6500**    141.4290      162.8570*     152.1430*       1.1470        1.5740
                                               0.8820*       1.1800        1.0150        1.3770        1.1960        1.3610
                                               1.0310       24.4626**      0.0206*     118.7524*       1.4304        0.0004*
                                           26522.3984        0.0246*     764.5220**    194.7768       33.0694**      0.5696
                                               0.7779        3.3549*   23147.4883      134.1901        0.0182*       3.1341*
D  D      4      -2.6965       29.2275        27.1230       25.9390       26.5310        1.0000        5.5500        7.0700
                                               6.3100      434.2859      517.8569      476.0718        0.7760*       1.2320
                                               1.3790        1.0110        1.0780        1.1220        1.1000        1.0040
                                               1.1950      165.9184        0.0495      335.1877*       1.2100        0.0025
                                          **********         0.0544       39.8161      569.6421        6.9410        0.3123
                                               1.9016       25.6339    **********      656.5027        0.0683       23.5656
```

```
E  E    5    3.1414      55.2436        57.6580*      59.1120*      58.3850*      1.0000      7.2500      16.0500
                                        11.6500      265.7139      268.5708     267.1428      1.4490       1.1990
                                         1.5930        1.6550*       1.5210       1.4270      1.4740       1.3240
                                         1.6240*     207.2789        0.1402**   147.8452*     2.1727       0.0197**
                                     72130.2500        0.2067*     135.7225     395.8733     17.1721       1.6333*
                                         2.5376       37.6536    71365.2500     425.5583      0.2233**    37.4534

F  F    6    2.2440      63.9720        66.5630*      65.8690*      66.2160*      1.0000      1.4800*      2.6900*
                                         2.0900*    1288.5708**   1327.1428***  1307.8569**   1.5740*      1.9840**
                                         2.1450**      1.8720*       1.8600*      1.9280**    1.8940**     1.7790*
                                         2.0090**    194.4150        0.0699     278.1328      3.5872**     0.0049
                                     *************     0.1324        4.3681    2513.6072***   3.9585*      0.1461*
                                         4.6010**     92.7672**  *************  2805.3523***  0.1499      91.4192**

G  G    7    1.4295      24.0955.       26.7200       24.3290       25.5250       1.0000      4.0200      13.4600
                                         8.7400      480.0000      504.2859     492.1428      0.8670*      1.3730
                                         1.0110        0.8600        0.9390       1.1170      1.0280       1.1200
                                         0.9360       88.8751*       0.0310*    286.6348      1.0568       0.0010*
                                     **********        0.0319*      76.3876     518.4058      8.9847       0.2709
                                         1.0221       15.6329    **********     497.5562      0.0313*     15.2564

H  H    8   -4.6271      22.3190        17.5240*      17.8610*      17.6920*      1.0000      7.9500      12.5900
```

```
                                               10.2700     164.0000     168.5710*    166.2860       1.0380      1.0110*
                                                0.8300*      0.8220*      0.9340       0.9170*      0.9250*     1.0250
                                                0.8260*    167.1633       0.0513     325.8538*      0.8556      0.0026
                                            28416.1797       0.0475     105.4729     155.9282       9.4997      0.5269
                                                0.6889       8.6477*  27651.0313     138.0174       0.0426      8.5305*

I  I    9   -1.9872       44.3722          45.3420      39.4290      42.3850       1.0000       4.4300     11.4100
                                                7.9200     287.8569     257.8569     272.8569       1.3220      1.4300
                                                1.2380       1.2060       1.2800       1.3180       1.2990      1.3760
                                                1.2220     177.7483       0.1087*    163.5216*      1.6874      0.0118*
                                            66490.1875       0.1412      62.7264     334.9561      10.2881      0.8609
                                                1.5326      28.0290   74450.8750     337.7966       0.1346     29.6595

J  J   10    1.5077       47.4553          48.6290      49.2980      48.9630       1.0000       3.0700      1.7200*
                                                2.3900*    542.8569     580.0000     561.4290       1.4860      1.1000
                                                1.7180*      1.9380*      1.6020*      1.5190       1.5610      1.2930
                                                1.8280*    133.8503       0.0450     297.4443*      2.4367      0.0020
                                            **********       0.0702       5.7121     905.3799       3.7308*     0.1075*
                                                2.9515*     26.1000   **********     964.5344       0.0773     25.2643

K  K   11   -1.6333       35.4563          34.9930      32.6530      33.8230      -1.0000      11.9400     12.4700
                                               12.2100     347.1428     414.2859     380.7148       1.0110      1.2510
                                                1.1600       1.0590       1.0860       1.1550       1.1200      1.1310
                                                1.1100     192.2653       0.0950     202.5974       1.2544      0.0090
                                            **********       0.1064     149.0841     464.0000      13.6752      1.1599
                                                1.3456      39.3571   **********     441.6292       0.1102     36.1679

L  L   12   -1.6185       21.3655          21.3770*     18.1170*     19.7470*     -1.0000      12.1300     18.6700
                                               15.4000     202.8570     188.5710     195.7140       0.7840*     1.0450*
                                                0.9040       0.8220*      0.8440*      0.9340*      0.8890*     0.9150*
                                                0.8630*    159.7551       0.0556     287.3289       0.7903*     0.0031
                                            35559.0195       0.0494     237.1600     167.6396      13.6906      0.8562
                                                0.8172      10.4845*  38303.9648     176.9254       0.0503     10.8817

M  M   13   15.2603 **    37.1626          54.5200      50.3260      52.4230      -1.0000       4.3200      7.3700
                                                5.8500     591.4290     655.0000     623.2148       0.9830      1.3920
                                                1.2640       0.9970       1.1240       1.1950       1.1590      1.1880
                                                1.1310     227.0068*      0.0960     236.4656       1.3433      0.0092
                                            **********       0.1113      34.2225     759.1445       6.7801      0.5616
                                                1.5977      62.8800*  **********     787.7434       0.1213     59.8286*

N  N   14   -7.1520 *     25.9500          18.9930*     18.6030*     18.7980*     -1.0000       6.5200     12.6300
                                                9.5800     230.0000     244.2860     237.1430       1.0380      1.1400
                                                0.8630*      0.8820       0.9490       1.0110       0.9800      1.0890
                                                0.8710     137.0204       0.0630     217.8378       0.9604      0.0040
                                            59675.6445       0.0617      91.7764     239.4003       9.3884      0.6035
                                                0.7396      15.3900   56236.7969     203.9429       0.0542     14.9400

O  O   15   -1.2197       38.8957          39.4760      35.8750      37.6760      -1.0000      10.9000      5.8800
                                                8.3900     154.2860     245.7140     200.0000       0.9830      1.2510
                                                1.4280       1.4170       1.2060       1.3340       1.2700      1.1170
                                                1.4230     138.7687       0.0726     191.1419       1.6139      0.0053
                                            60375.3633       0.0922      70.3923     312.0566      10.6553      0.6091
                                                2.0392      17.8388   40000.0000     285.5999       0.1137     14.5200
```

```
P   P     16     0.6229        28.8761        29.3900      29.6070      29.4990      -1.0000      26.6700***   28.0300*
                                              27.3500**   381.4290     560.0000     470.7148       0.9470       1.1000
                                               1.0380       0.8890       0.9930       0.9950*      0.9940       1.0240
                                               0.9640     152.1156       0.0828     183.7149       0.9880       0.0069
                                            **********      0.0823     748.0220**   556.6399      27.1859**     2.2646***
                                               1.0774      46.3680    **********    488.6016       0.0859      38.9752

Q   Q     17   -13.8711 **     61.7561        49.4580      46.3110      47.8850      -1.0000       3.9400       5.0300
                                               4.4900     447.1428     347.1428     397.1428       1.6050*      1.8720*
                                               1.6370*      1.7440*      1.6210*      1.8080*      1.7150*      1.7390*
                                               1.6910*    252.4694*      0.1125*    224.4169       2.9412*      0.0127*



                                            **********      0.1929*     20.1601     595.3496       7.7003       0.5051
                                               2.6798      39.0535    **********    650.1223       0.1842*     44.6785

R   R     18    12.1553 *      53.5116        67.1080*     64.2250*     65.6670*     -1.0000       7.1000       8.1400
                                               7.6230     668.5708     731.4290     700.0000       1.5930*      1.7120*
                                               1.4360       1.4050       1.5150       1.5590       1.5370       1.6530*
                                               1.4210     237.2721*      0.1041     227.9269       2.3624       0.0108
                                            **********      0.1600*     58.0644    1124.2061      11.7119       0.7932
                                               2.0621      76.1417*   **********   1005.1997       0.1495      72.8700*

S   S     19    -4.7605        33.8165        29.0750      29.0380      29.0560      -1.0000       2.2300*     14.2100
                                               8.2200     385.7139     420.0000     402.8569       1.4550       1.5240
                                               0.8740*      0.8670       1.1650       1.1960       1.1800       1.4900
                                               0.8710     153.1088       0.0607     252.2389       1.3924       0.0037
                                            **********      0.0716      67.5684     495.5996       9.6996       0.4990
                                               0.7639      25.4940    **********    352.0969       0.0531      24.4534

T   T     20    -3.9230        65.5130        59.8460*     63.3340*     61.5900*     -1.0000       5.2500       5.2000
                                               5.2300     411.4290     364.2859     387.8579       1.9980**     1.7820*
                                               1.8010*      1.6930*      1.9000**     1.7380*      1.8190*      1.8900**
                                               1.7470*    215.1088       0.1085*    198.2571       3.3088*      0.0118*
                                            **********      0.1974*     27.3529     662.6357       9.5134       0.5675
                                               3.2436*      39.5250    **********    698.5317       0.1954*     42.0826


SERIAL CORRELATION OF RESIDUALS = -0.4650
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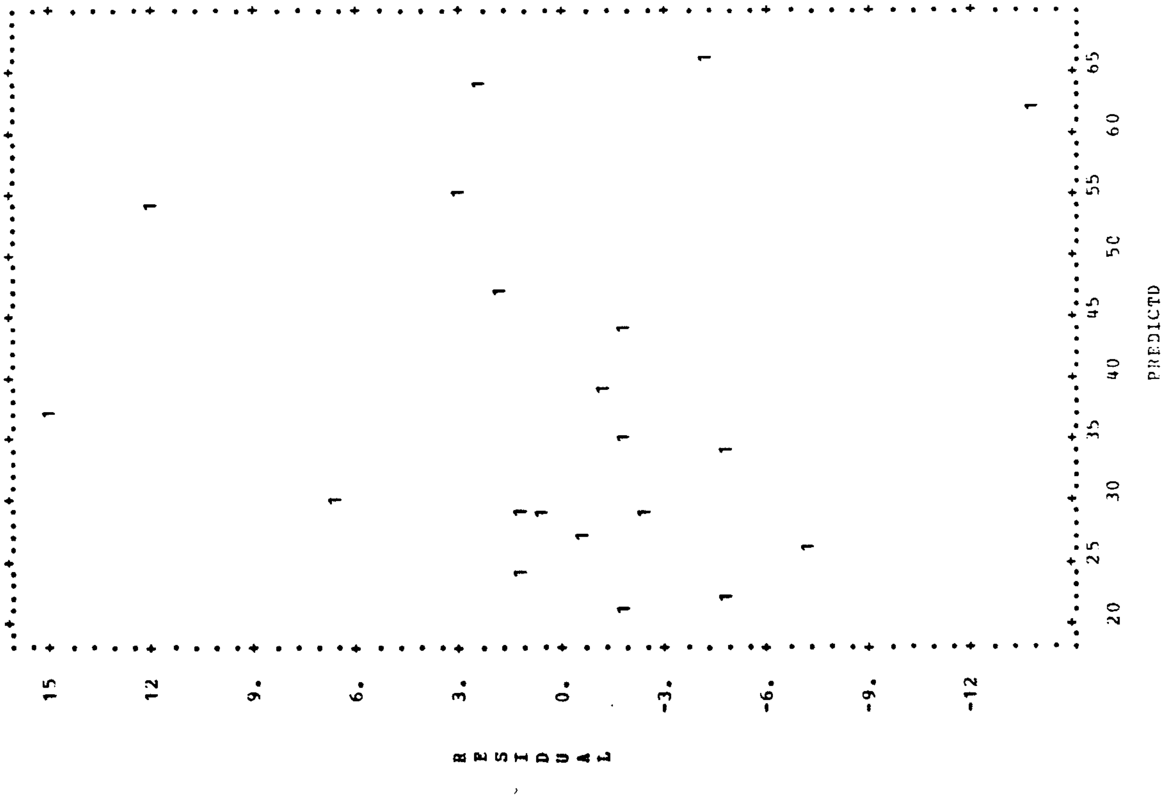
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6.
3.
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-6.
-9.
-12
20
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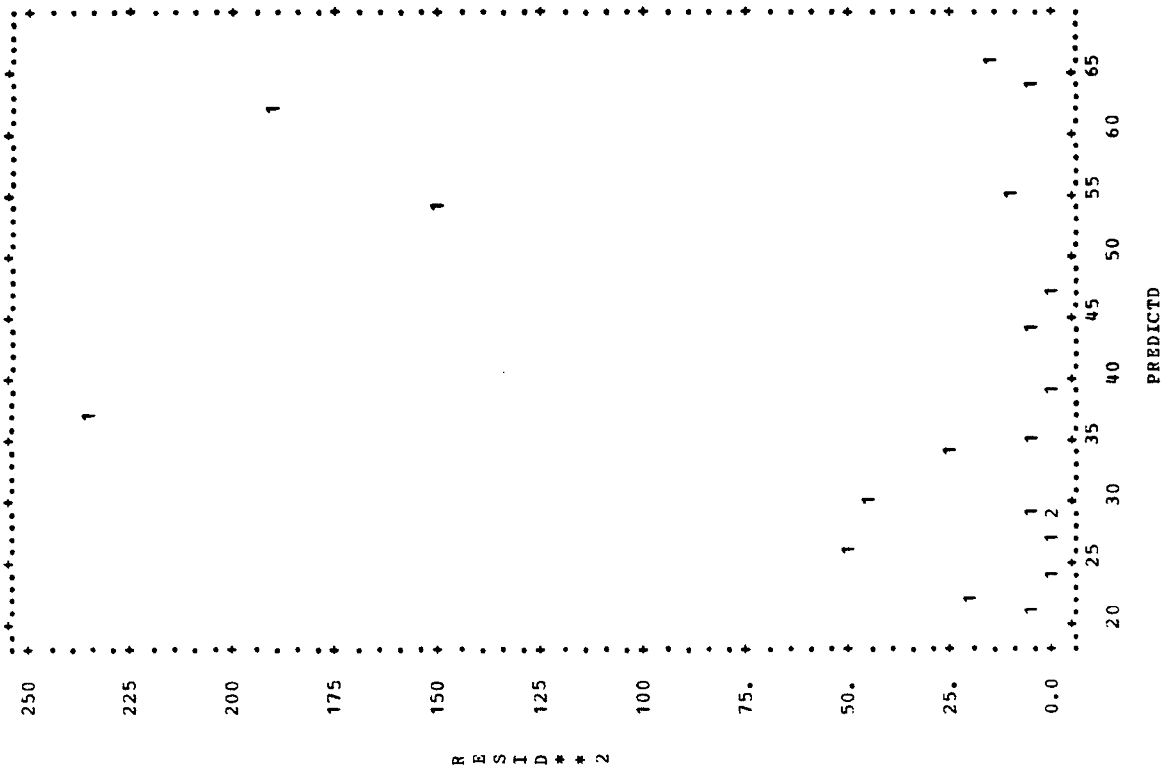
35
40
45
50
55
60
65
PREDICTD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40
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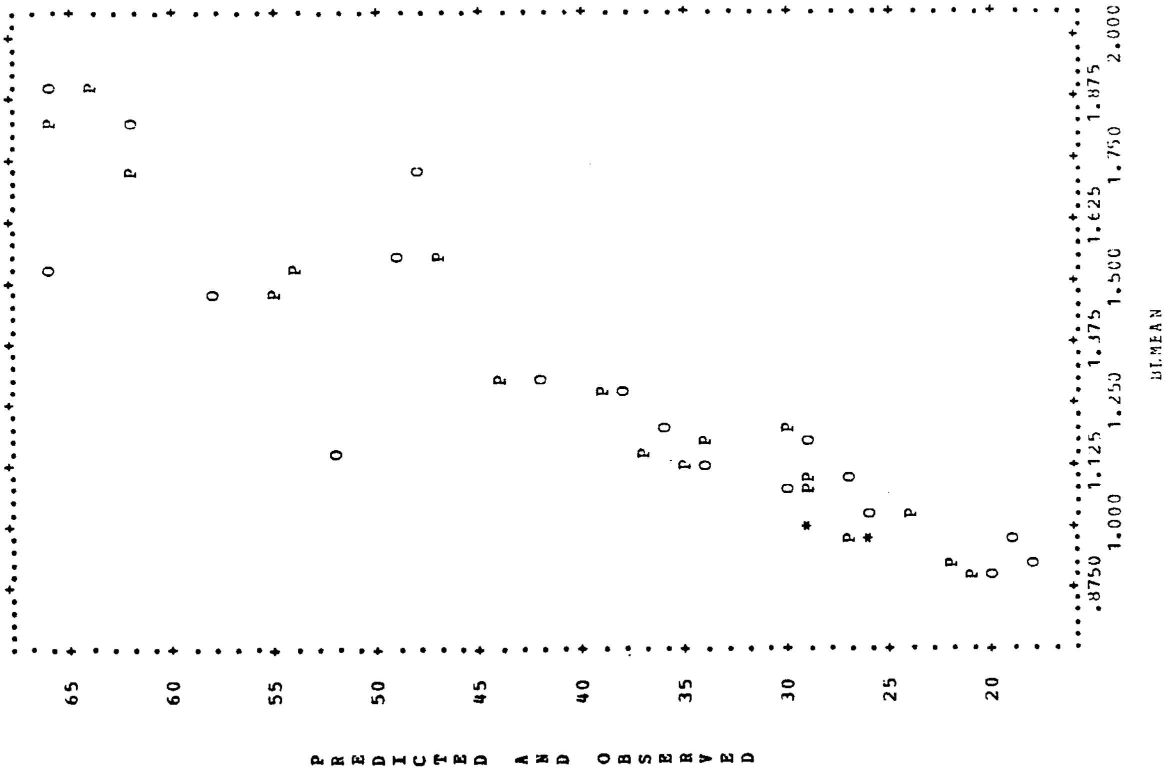
50
55
60
65
PREDICTD


PREDICTED AND OBSERVED
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55
50
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40
35
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25
20
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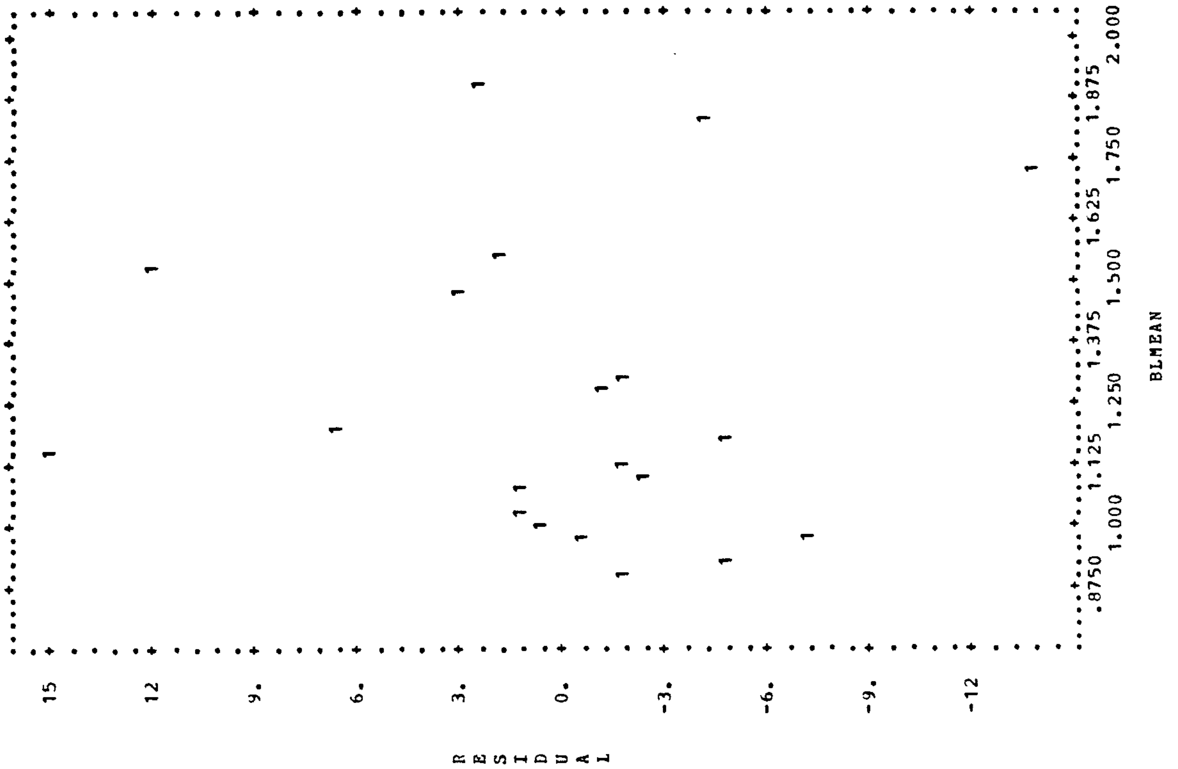
1.375
1.500
1.625
1.750
1.875
2.000
BLMEAN
P
O
*


RESIDUAL
15
12
9.
6.
3.
0.
-3.
-6.
-9.
-12
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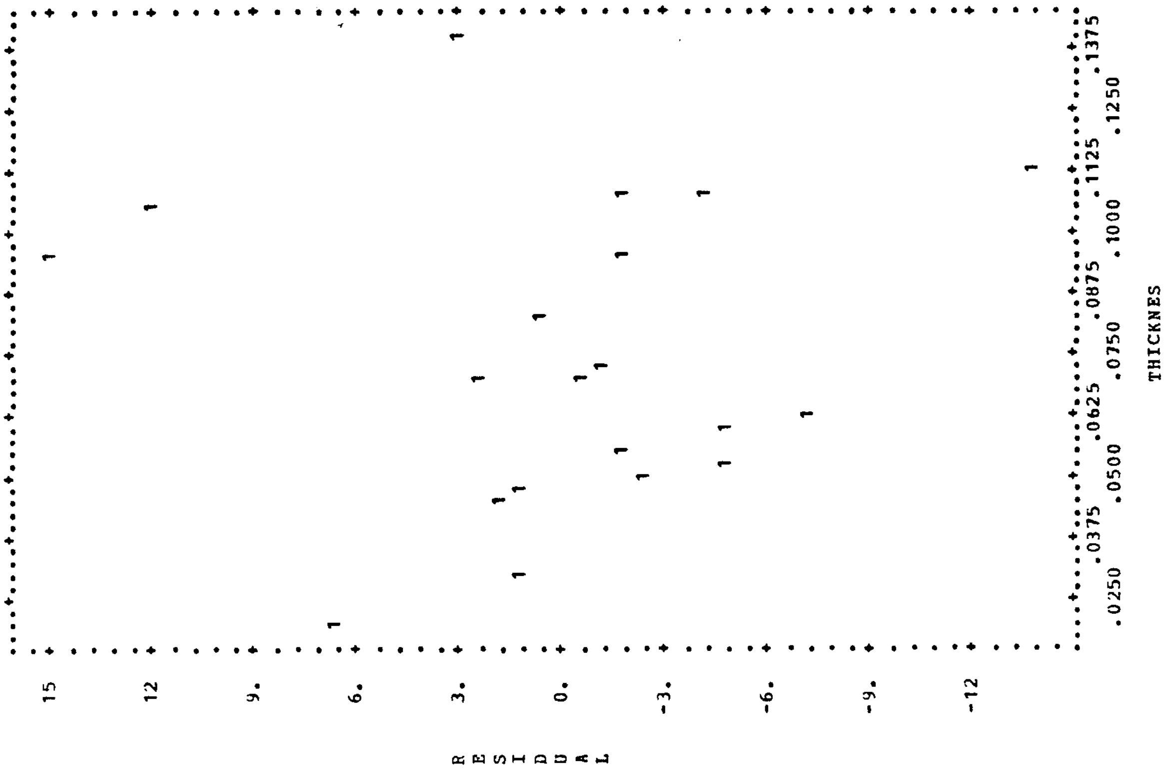
1.875
2.000
BLMEAN
1


RESIDUAL
15
12
9.
6.
3.
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-9.
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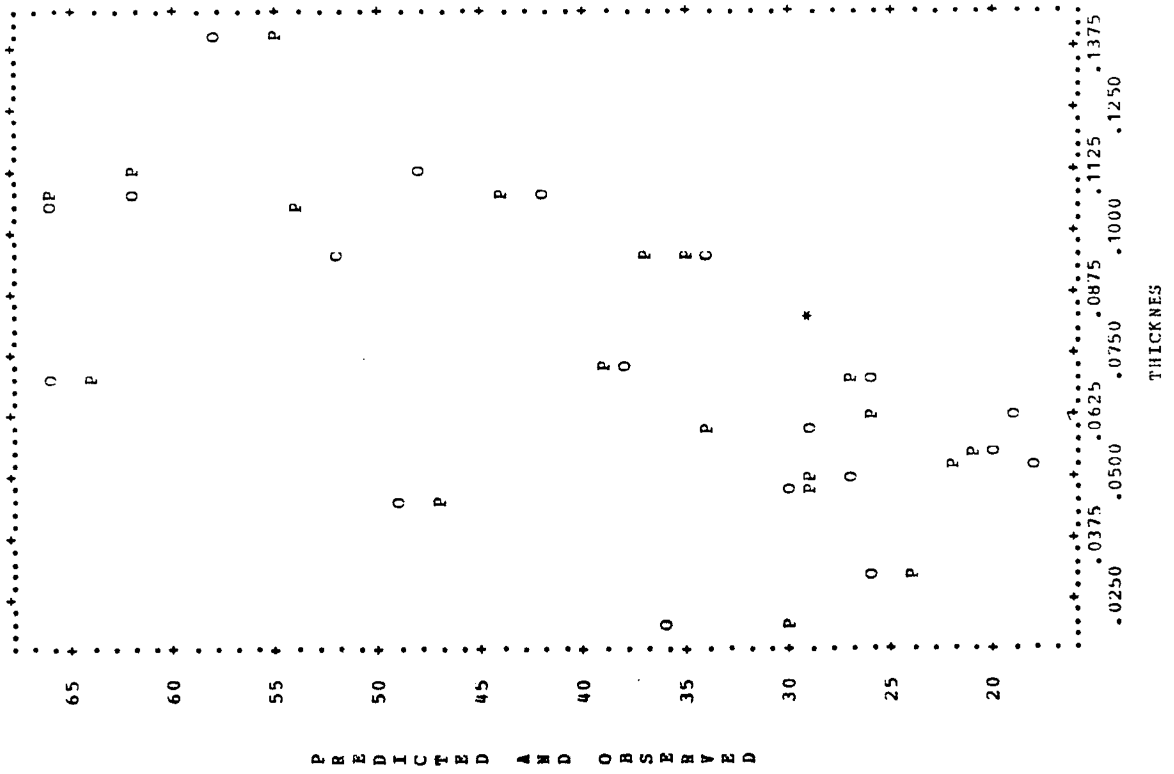
.1375
THICKNES


PREDICTED AND OBSERVED
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60
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45
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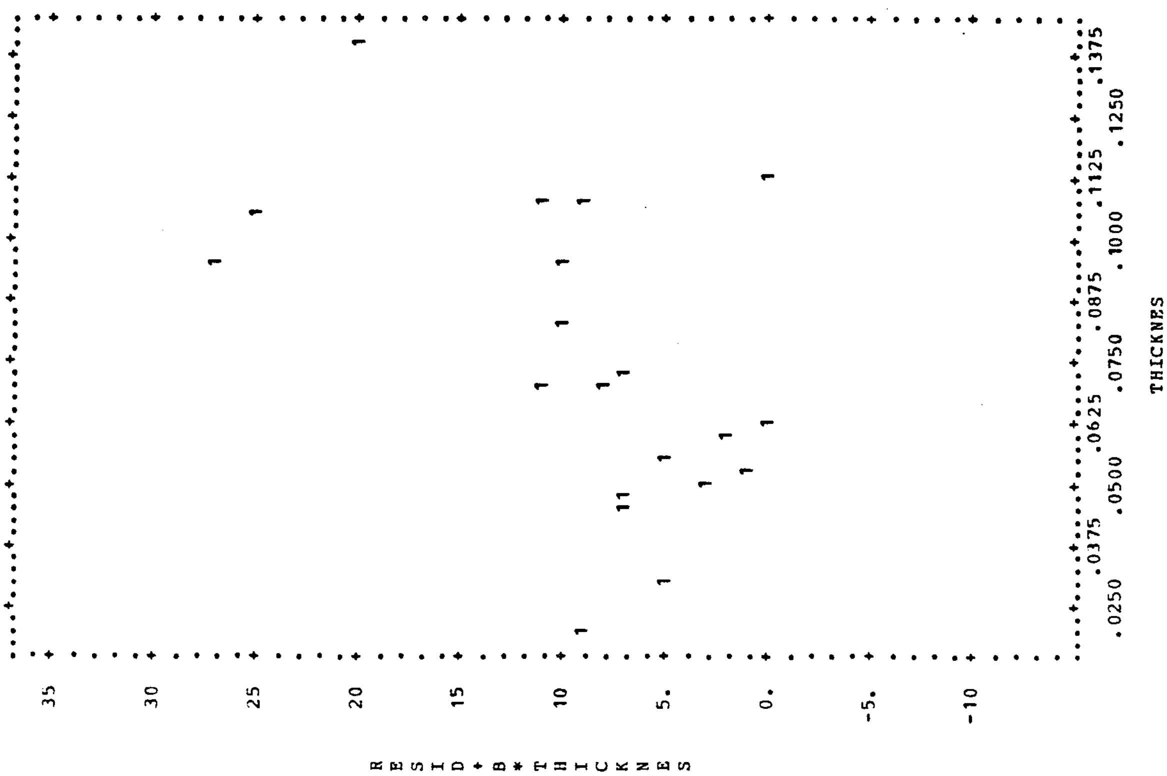
THICKNES


RESID+B*THICKNESS
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30
25
20
15
10
5.
0.
-5.
-10
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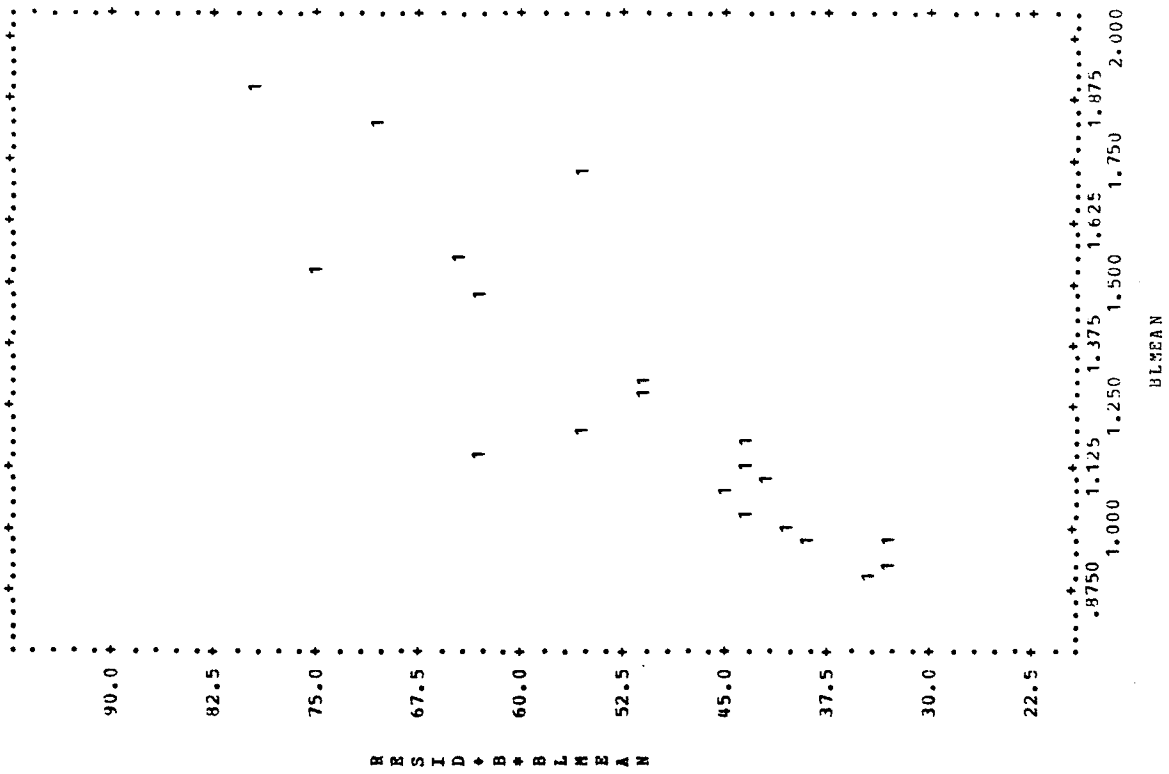
.0500
.0625
.0750
.0875
.1000
.1125
.1250
.1375
THICKNES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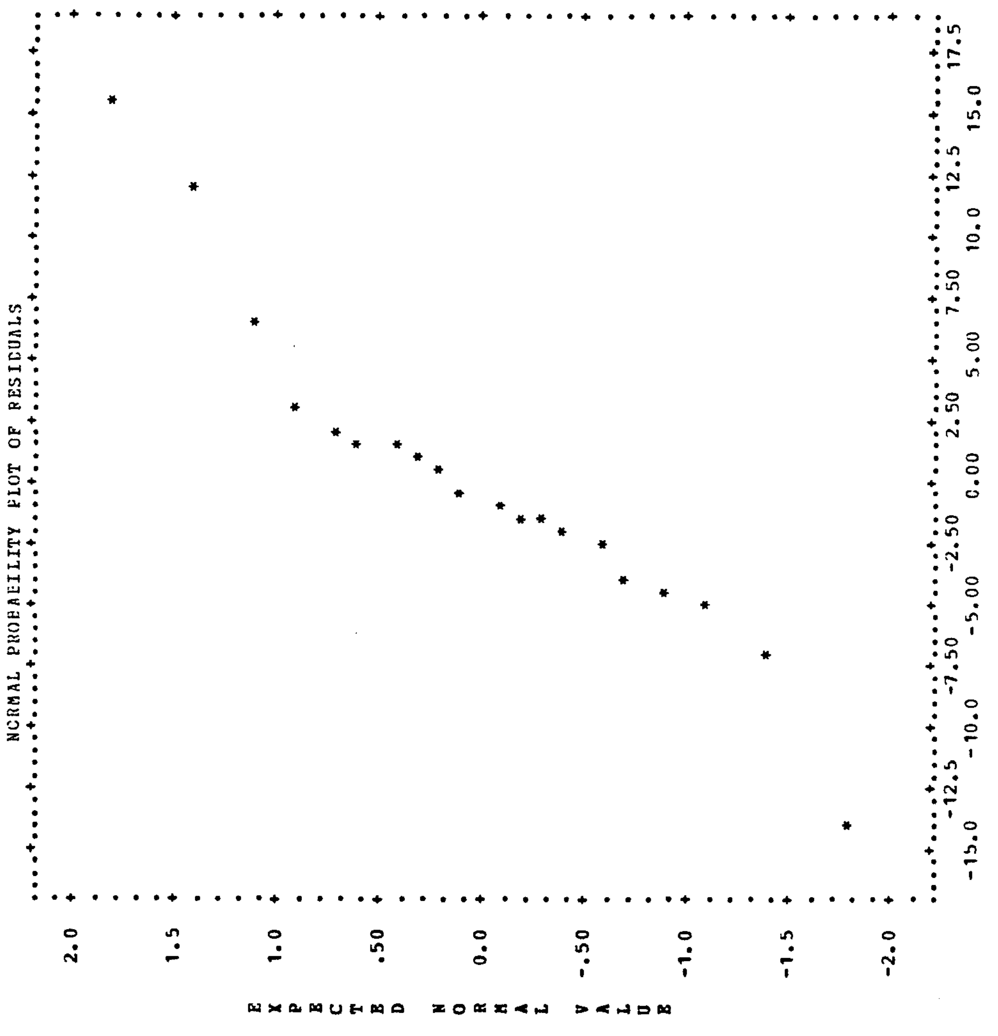
82.5
75.0
67.5
60.0
52.5
45.0
37.5
30.0
22.5
.8750
1.000
1.125
1.250
1.375
1.500
1.625
1.750
1.875
2.000
BLMEAN


NORMAL PROBABILITY PLOT OF RESIDUALS
EXPECTED NORMAL VALUE
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1.0
.50
0.0
-.50
-1.0
-1.5
-2.0
-15.0
-12.5
-10.0
-7.50
-5.00
-2.50
0.00
2.50
5.00
7.50
10.0
12.5
15.0
17.5

APPENDIX B2

Computer Printout

Stepwise Regression

```
BMDP2R - STEPWISE REGRESSION                                     PROGRAM REVISED NOVEMBER, 1978
HEALTH SCIENCES COMPUTING FACILITY                               MANUAL DATE  --  1977
UNIVERSITY OF CALIFORNIA, LOS ANGELES 90024
COPYRIGHT (C) 1977, REGENTS OF UNIVERSITY OF CALIFORNIA


IN THIS VERSION OF BMDP2R

  -- NEW OPTION - TO PRINT THE CORRELATION OF THE REGRESSION COEFFICIENTS, SPECIFY RREG IN THE PRINT PARAGRAPH.
     IF LESS THAN TWO VARIABLES ENTERED THE EQUATION, THE CORRELATION OF THE REGRESSION COEFFICIENTS IS NOT PRINTED.

  -- THE INTLEV OPTION IS NOT AVAILABLE.

  -- NEW OPTION - SPECIFY NORMAL IN THE PLOT PARAGRAPH TO PRINT THE NORMAL PROBABILITY PLOT OF RESIDUALS.

  -- NEW OPTION - SPECIFY DNORMAL IN THE PLOT PARAGRAPH TO PRINT THE DETRENDED NORMAL PROBABILITY PLOT OF RESIDUALS.

  -- NEW OPTION - TO SPECIFY INDEPENDENT VARIABLES IN THE REGRESSION PARAGRAPH, STATE INDEP=VARIABLE LIST.
     THE LEVELS OPTION STILL MAY BE USED TO SPECIFY THE INDEPENDENT VARIABLES IF AN INDEP= STATEMENT IS NOT SPECIFIED.


 PROGRAM CONTROL INFORMATION

        /PROBLEM           TITLE IS 'REGRESSION TO PREDICT DRAPE COEFFICIENT'.
        /INPUT             VARIABLES ARE 24.
                         FORMAT IS '(3(1X,F6.3),F3.0,3(1X,F5.2),
                           3(1X,F8.3),2X,A1/9(1X,F5.3)/1X,F8.4,1X,
                           F5.4,1X,F8.4,2X,A1)'.
        /VARIABLE   NAMES ARE DCFACE,DCBACK,DCMEAN,IDENT,EXTWALE,EXTCOURS,
                      EXTMEAN,SHEARWAL,SHEARCOU,SHEARMEA,FABRIC1,
                    BLWALEIN,BLWALEOU,BLCOURIN,BLCOUROU,BLMEANIN,
                    BLMEANOU,BLMEAN,BWALEME,BLCOURME,
                           WEIGHT,THICKNES,DENSITY,FABRIC2,
                    BLMEAN2,THICK2,SHEARCO2,BLTHICK,EXTMEAN2,
                    BLSHEACO,BLEXTMEA,THEXTMEA,BLCOUIN2,
                      SHEACOTH,SHEARME2,BLCOISHM,THBICOUI,
                     THSHEARM.
                           BLANKS ARE MISSING.
                           LABELS ARE FABRIC1,FABRIC2.
                   ADD IS 14.
        /TRANSFORM       BLMEAN2=BLMEAN*BLMEAN.
                           THICK2=THICKNES*THICKNES.
                    SHEARCO2=SHEARCOU*SHEARCOU.
                           BLTHICK=BLMEAN*THICKNES.
                      EXTMEAN2=EXTMEAN*EXTMEAN.
                    BLSHEACO=BLMEAN*SHEARCOU.
                         THEXTMEA=THICKNES*EXTMEAN.
                         BLEXTMEA=BLMEAN*EXTMEAN.
                    SHEACOTH=SHEARCOU*THICKNES.
                      BLCOUIN2=BLCOURIN*BLCOURIN.
                    SHEARME2=SHEARMEA*SHEARMEA.
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                      BLCOISHM=BLCOURIN*SHEARMEA.
                     THBLCOUI=BLCOURIN*THICKNES.
                     THSHEARM=SHEARMEA*THICKNES.
       /REGRESS         DEPENDENT IS DCMEAN.
                       TITLE IS 'SPECIFYING ORDER OF ENTRY
                                OF VARIABLES INTO EQUATION'.
                        METHOD IS F.
                     LEVELS ARE 4*0,6*1,0,12*1,13*0.
       /END


    PROBLEM TITLE . . . . . . .REGRESSION TO PREDICT DRAPE COEFFICIENT


  NUMBER OF VARIABLES TO READ IN. . . . . . . . .        24
  NUMBER OF VARIABLES ADDED BY TRANSFORMATIONS. .        14
  TOTAL NUMBER OF VARIABLES . . . . . . . . . . .        38
  NUMBER OF CASES TO READ IN. . . . . . . . . . . 1000000
  CASE LABELING VARIABLES . . . . . . . . . . . .   FABRIC1     FABRIC2
  LIMITS AND MISSING VALUE CHECKED BEFORE TRANSFORMATIONS
  BLANKS ARE. . . . . . . . . . . . . . . . . . .  MISSING
  INPUT UNIT NUMBER . . . . . . . . . . . . . . .         5
  REWIND INPUT UNIT PRIOR TO READING. . DATA. . .        NO

  INPUT FORMAT
        (3(1X,F6.3),F3.0,3(1X,F5.2), 3(1X,F8.3),2X,A1/9(1X,F5.3)/1X,F8.4,1X, F5.4,1X,F8.
        4,2X,A1)

*** CONTROL LANGUAGE TRANSFORMATIONS ARE PERFORMED ***


  VARIABLES TO BE USED
             1  DCFACE         2  DCBACK         3  DCMEAN         4  IDENT          5  EXTWALE
             6  EXTCOURS       7  EXTMEAN        8  SHEARWAL       9  SHEARCOU      10  SHEARMEA
            12  BLWALEIN      13  BLWALEOU      14  BLCOURIN      15  BLCOUROU      16  BLMEANIN
            17  BLMEANOU      18  BLMEAN        19  BWALEME       20  BLCOURME      21  WEIGHT
            22  THICKNES      23  DENSITY       25  BLMEAN2       26  THICK2        27  SHEARCO2
            28  BLTHICK       29  EXTMEAN2      30  BLSHEACO      31  BLEXTMEA      32  THEXTMEA
            33  BLCOUIN2      34  SHEACOTH      35  SHEARME2      36  BLCOISHM      37  THBLCOUI
            38  THSHEARM


  REGRESSION INTERCEPT. . . . . . . . . . . . . . .NON ZERO
  WEIGHT VARIABLE . . . . . . . . . . . . . . . .
  PRINT COVARIANCE MATRIX . . . . . . . . . . . .        NO
  PRINT CORRELATION MATRIX. . . . . . . . . . . .        NO
  PRINT ANOVA AT EACH STEP. . . . . . . . . . . .       YES
  PRINT STEP OUTPUT . . . . . . . . . . . . . . .       YES
  PRINT REGRESSION COEFFICIENT SUMMARY TABLE. . .       YES
  PRINT PARTIAL CORRELATION SUMMARY TABLE . . . .        NO
  PRINT F-RATIO SUMMARY TABLE . . . . . . . . . .        NO
  PRINT SUMMARY TABLE . . . . . . . . . . . . . .       YES
  PRINT RESIDUALS AND DATA. . . . . . . . . . . .        NO
  PRINT CORRELATION OF REGRESSION COEFFICIENTS. .        NO
  PRINT NORMAL PROBABILITY PLOT . . . . . . . . .        NO
  PRINT DETRENDED NORMAL PROBABILITY PLOT . . . .        NO

  NUMBER OF CASES READ. . . . . . . . . . . . . .        20
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  VARIABLE                   STANDARD    COEFFICIENT                                 SMALLEST      LARGEST      SMALLEST    LARGEST
NO.   NAME        MEAN       DEVIATION   OF VARIATION    SKEWNESS      KURTOSIS       VALUE         VALUE       STD SCORE   STD SCORE
  1  DCFACE      39.2339      15.8988       0.4052        0.3511       -1.3134       17.5240       67.1080     -1.3655      1.7532
  2  DCBACK      38.1574      15.8395       0.4151        0.4576       -1.2115       17.8610       65.8690     -1.2814      1.7495
  3  DCMEAN      38.6957      15.8152       0.4087        0.4054       -1.2727       17.6920       66.2160     -1.3281      1.7401
  4  IDENT        0.0000       1.0260 2648160.0000       -0.0000       -2.0975       -1.0000        1.0000     -0.9747      0.9747
  5  EXTWALE      7.8825       5.6450       0.7161        1.7348        3.4362        1.4800       26.6700     -1.1342      3.3281
  6  EXTCOURS    12.9460      10.0553       0.7767        1.8211        3.5984        1.7200       46.4200     -1.1164      3.3290
  7  EXTMEAN     10.4160       6.6574       0.6584        1.3193        1.1403        2.0900       27.6500     -1.2142      2.5132
  8  SHEARWAL   448.5200     312.4121       0.6965        1.5741        1.7068      141.4290     1288.5708     -0.9830      2.6889
  9  SHEARCOU   460.1060     286.4531       0.6226        1.4144        1.7762      162.8570     1327.1428     -1.0377      3.0268
 10  SHEARMEA   454.3132     295.8967       0.6513        1.4764        1.6166      152.1430     1307.8569     -1.0212      2.8846
 12  BLWALEIN     1.2051       0.3333       0.2765        0.6156       -0.6808        0.7760        1.9980     -1.2876      2.3793
 13  BLWALEOU     1.3599       0.2992       0.2200        0.5523       -0.8423        0.9180        1.9840     -1.4771      2.0857
 14  BLCOURIN     1.2614       0.3725       0.2953        0.6462       -0.6290        0.8300        2.1450     -1.1583      2.3722
 15  BLCOUROU     1.2138       0.3793       0.3124        0.6412       -1.1959        0.8220        1.9380     -1.0332      1.9094
 16  BLMEANIN     1.2335       0.3209       0.2601        0.7702       -0.8232        0.8440        1.9000     -1.2140      2.0769
 17  BLMEANOU     1.3046       0.3004       0.2303        0.4738       -0.9335        0.9170        1.9280     -1.2902      2.0747
 18  BLMEAN       1.2602       0.3047       0.2418        0.7117       -0.8437        0.8890        1.8940     -1.2183      2.0798
 19  BWALEME      1.2827       0.2890       0.2253        0.7303       -0.8273        0.9150        1.8900     -1.2724      2.1012
 20  BLCOUBME     1.2379       0.3673       0.2968        0.6508       -1.0276        0.8260        2.0090     -1.1213      2.0991
 21  WEIGHT     164.9886      56.4132       0.3419       -0.6799       -0.0163       24.4626      252.4694     -2.4910      1.5507
 22  THICKNES     0.0743       0.0309       0.4162        0.2622       -0.8721        0.0206        0.1402     -1.7361      2.1338
 23  DENSITY    230.8752      61.6846       0.2672       -0.0045       -1.1896      118.7524      335.1877     -1.8177      1.6911
 25  BLMEAN2      1.6764       0.8415       0.5020        0.9489       -0.4334        0.7903        3.5872     -1.0530      2.2707
 26  THICK2       0.0064       0.0050       0.7734        0.9256        0.1122        0.0004        0.0197     -1.2075      2.6650
 27  SHEARCO2 289651.3750  401676.5625       1.3868        2.5090        6.2393    26522.3984 1761308.0000     -0.6551      3.6638
 28  BLTHICK      0.0977       0.0564       0.5768        0.6432       -0.9631        0.0246        0.2067     -1.2967      1.9315
 29  EXTMEAN2   153.1663     215.8744       1.4094        2.0981        3.1508        4.3681      764.5220     -0.6893      2.8320
 30  BLSHEACO   610.9343     518.8208       0.8492        2.3955        6.2062      155.9282     2513.6072     -0.8770      3.6673
 31  BLEXTMEA    12.0785       7.1168       0.5892        1.5658        2.0363        3.7308       33.0694     -1.1730      2.9495
 32  THEXTMEA     0.7211       0.5018       0.6959        1.5457        2.3090        0.1075        2.2646     -1.2226      3.0756
 33  BLCOUIN2     1.7230       1.0441       0.6060        1.0851        0.4931        0.6889        4.6010     -0.9905      2.7565
 34  SHEACOTH    34.4995      23.8766       0.6921        0.8500       -0.2126        3.3549       92.7672     -1.3044      2.4404
 35  SHEARME2 289578.8750  418835.6250       1.4464        2.3038        4.5402    23147.4883 1710489.0000     -0.6361      3.3925
 36  BLCOISHM   619.6931     584.0049       0.9424        2.5340        6.9223      134.1901     2805.3523     -0.8313      3.7425
 37  THBLCOUI     0.0986       0.0584       0.5921        0.5901       -0.8787        0.0182        0.2233     -1.3776      2.1385
 38  THSHEARM    34.1957      24.2689       0.7097        0.8357       -0.3682        3.1341       91.4192     -1.2799      2.3579
          NOTE - KURTOSIS VALUES GREATER THAN ZERO INDICATE A DISTRIBUTION WITH HEAVIER TAILS THAN NORMAL DISTRIBUTION
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REGRESSION TITLE. . . . . . . . . . . . . . . . . .SPECIFYING ORDER OF ENTRY OF VARIABLES INTO EQUATION
STEPPING ALGORITHM. . . . . . . . . . . . . . . . .F
MAXIMUM NUMBER OF STEPS . . . . . . . . . . . . .      76
DEPENDENT VARIABLE. . . . . . . . . . . . . . . .       3 DCMEAN
MINIMUM ACCEPTABLE F TO ENTER . . . . . . . . . .   4.000,    4.000
MAXIMUM ACCEPTABLE F TO REMOVE. . . . . . . . . .   3.900,    3.900
MINIMUM ACCEPTABLE TOLERANCE. . . . . . . . . . . 0.01000
SUBSCRIPTS OF THE INDEPENDENT VARIABLES . . . .       1     2     4     5     6     7     8     9    10    12    13    14    15    16    17    18
                                                     19    20    21    22    23    25    26    27    28    29    30    31    32    33    34    35
                                                     36    37    38


 STEP NO.    0

STD. ERROR OF EST.     15.8152

ANALYSIS OF VARIANCE
                     SUM OF SQUARES      DF    MEAN SQUARE
        RESIDUAL     4752.2891           19   250.1205

                          VARIABLES IN EQUATION                                         .                  VARIABLES NOT IN EQUATION
                                    STD. ERROR  STD REG                   F TO          .                PARTIAL                F TO
   VARIABLE         COEFFICIENT     OF COEFF     COEFF     TOLERANCE     REMOVE    LEVEL.    VARIABLE       CORR.   TOLERANCE   ENTER  LEVEL
(Y-INTERCEPT            38.696 )                                                        .
                                                                                        . DCPACE      1  0.99661  1.00000   2642.80    0
                                                                                        . DCBACK      2  0.99659  1.00000   2622.26    0
                                                                                        . IDENT       4 -0.05973  1.00000      0.06    0
                                                                                        . EXTWALE     5 -0.37247  1.00000      2.90    1
                                                                                        . EXTCOURS    6 -0.35869  1.00000      2.66    1
                                                                                        . EXTMEAN     7 -0.41623  1.00000      3.77    1
                                                                                        . SHEARWAL    8  0.38312  1.00000      3.10    1
                                                                                        . SHEARCOU    9  0.43924  1.00000      4.30    1
                                                                                        . SHEARMEA   10  0.41486  1.00000      3.74    1
                                                                                        . BLWALEIN   12  0.76802  1.00000     25.89    1
                                                                                        . BLWALEOU   13  0.68773  1.00000     16.15    1
                                                                                        . BLCOURIN   14  0.84308  1.00000     44.24    1
                                                                                        . BLCOUROU   15  0.82198  1.00000     37.49    1
                                                                                        . BLMEANIN   16  0.88831  1.00000     67.35    1
                                                                                        . BLMEANOU   17  0.82563  1.00000     38.54    1
                                                                                        . BLMEAN     18  0.89257  1.00000     70.53    1
                                                                                        . BWALEME    19  0.79866  1.00000     31.70    1
                                                                                        . BLCOURME   20  0.85185  1.00000     47.61    1
                                                                                        . WEIGHT     21  0.50633  1.00000      6.21    1
                                                                                        . THICKNES   22  0.59797  1.00000     10.02    1
                                                                                        . DENSITY    23 -0.26117  1.00000      1.32    1
                                                                                        . BLMEAN2    25  0.87201  1.00000     57.12    0
                                                                                        . THICK2     26  0.61956  1.00000     11.21    0
                                                                                        . SHEARCO2   27  0.43132  1.00000      4.11    0
                                                                                        . BLTHICK    28  0.79068  1.00000     30.02    0
                                                                                        . EXTMEAN2   29 -0.28020  1.00000      1.53    0
                                                                                        . BLSHEACO   30  0.61939  1.00000     11.20    0
                                                                                        . BLEXTMEA   31 -0.19939  1.00000      0.75    0
                                                                                        . THEXTMEA   32 -0.06676  1.00000      0.08    0
                                                                                        . BLCOUIN2   33  0.82264  1.00000     37.68    0
                                                                                        . SHEACOTH   34  0.67111  1.00000     14.75    0
                                                                                        . SHEARME2   35  0.37715  1.00000      2.98    0
                                                                                        . BLCOISHM   36  0.60179  1.00000     10.22    0
                                                                                        . THBLCOUI   37  0.81175  1.00000     34.78    2
                                                                                        . THSHEARM   38  0.65144  1.00000     13.27    2
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VARIABLE ENTERED   18 BLMEAN

MULTIPLE R             0.8926
MULTIPLE R-SQUARE      0.7967
ADJUSTED R-SQUARE      0.7854
STD. ERROR OF EST.     7.3267

ANALYSIS OF VARIANCE
                      SUM OF SQUARES     DF    MEAN SQUARE      F RATIO
         REGRESSION   3786.0342            1   3786.034           70.53
         RESIDUAL     966.25586           18   53.68088

                         VARIABLES IN EQUATION                                .           VARIABLES NOT IN EQUATION
                              STD. ERROR  STD REG                 F TO        .            PARTIAL                  F TO
    VARIABLE     COEFFICIENT   OF COEFF    COEFF    TOLERANCE   REMOVE    LEVEL.  VARIABLE     CORR.   TOLERANCE    ENTER  LEVEL
(Y-INTERCEPT        -19.686 )                                                 .
BLMEAN     18        46.325        5.516     0.893  1.00000      70.53       1 . DCFACE     1  0.98521  0.22156    561.90   0
                                                                              . DCBACK     2  0.98311  0.19575    490.52   0
                                                                              . IDENT      4 -0.09214  0.99958      0.15   0
                                                                              . EXTWALE    5  0.16979  0.75795      0.50   1
                                                                              . EXTCOURS   6  0.09343  0.80273      0.15   1
                                                                              . EXTMEAN    7  0.14391  0.72115      0.36   1
                                                                              . SHEARWAL   8  0.15830  0.87436      0.44   1
                                                                              . SHEARCOU   9  0.25033  0.85947      1.14   1
                                                                              . SHEARMEA  10  0.20490  0.86415      0.74   1
                                                                              . BLWALEIN  12 -0.05648  0.23559      0.05   1
                                                                              . BLWALEOU  13 -0.03007  0.39158      0.02   1
                                                                              . BLCOURIN  14  0.15093  0.16545      0.40   1
                                                                              . BLCOUROU  15 -0.05795  0.13220      0.06   1
                                                                              . BLMEANIN  16  0.12263  0.03116      0.26   1
                                                                              . BLMEANOU  17 -0.09369  0.11448      0.15   1
                                                                              . BWALEME   19 -0.06049  0.17623      0.06   1
                                                                              . BLCOURME  20  0.06179  0.10870      0.07   1
                                                                              . WEIGHT    21  0.29113  0.81092      1.57   1
                                                                              . THICKNES  22  0.45633  0.78287      4.47   1
                                                                              . DENSITY   23 -0.28977  0.97815      1.56   1
                                                                              . BLMEAN2   25 -0.37916  0.00923      2.85   0
                                                                              . THICK2    26  0.47840  0.76726      5.05   0
                                                                              . SHEARCO2  27  0.16157  0.83293      0.46   0
                                                                              . BLTHICK   28  0.39543  0.43024      3.15   0
                                                                              . EXTMEAN2  29  0.10633  0.86754      0.19   0
                                                                              . BLSHEACO  30  0.18203  0.61321      0.58   0
                                                                              . BLEXTMEA  31  0.20116  0.89780      0.72   0
                                                                              . THEXTMEA  32  0.38651  0.93074      2.99   0
                                                                              . BLCOUIN2  33  0.02425  0.15955      0.01   0
                                                                              . SHEACOTH  34  0.55188  0.73736      7.45   0
                                                                              . SHEARME2  35  0.12384  0.86730      0.26   0
                                                                              . BLCOISHM  36  0.13342  0.61384      0.31   0
                                                                              . THBLCOUI  37  0.45502  0.42229      4.44   2
                                                                              . THSHEARM  38  0.48635  0.72963      5.27   2
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 STEP NO.     2
VARIABLE ENTERED   22 THICKNES

MULTIPLE R              0.9160
MULTIPLE R-SQUARE       0.8390
ADJUSTED R-SQUARE       0.8201
STD. ERROR OF EST.      6.7084

ANALYSIS OF VARIANCE
                     SUM OF SQUARES      DF     MEAN SQUARE        F RATIO
         REGRESSION  3987.2471            2    1993.624             44.30
         RESIDUAL    765.04297           17    45.00252



                               VARIABLES IN EQUATION                                        .                     VARIABLES NOT IN EQUATION
                                    STD. ERROR   STD REG                    F TO            .                       PARTIAL               F TO
     VARIABLE         COEFFICIENT   OF COEFF     COEFF      TOLERANCE     REMOVE     LEVEL.      VARIABLE         CORR.    TOLERANCE     ENTER  LEVEL
 (Y-INTERCEPT          -21.434 )                                                            .
 BLMEAN       18        40.701       5.708       0.784     0.78287       50.84        1    . DCFACE       1   0.98146   0.17705      419.42    0
 THICKNES     22       119.005      56.280       0.233     0.78287        4.47        1    . DCBACK       2   0.97877   0.15610      364.94    0
                                                                                            . IDENT        4   0.10809   0.84323        0.19    0
                                                                                            . EXTWALE      5   0.03924   0.69016        0.02    1
                                                                                            . EXTCOURS     6   0.20459   0.77461        0.70    1
                                                                                            . EXTMEAN      7   0.17127   0.72090        0.48    1
                                                                                            . SHEARWAL     8   0.24243   0.86129        1.00    1
                                                                                            . SHEARCOU     9   0.37073   0.83621        2.55    1
                                                                                            . SHEARMEA    10   0.30752   0.84615        1.67    1
                                                                                            . BLWALEIN    12  -0.19017   0.22241        0.60    1
                                                                                            . BLWALEOU    13   0.06002   0.37875        0.06    1
                                                                                            . BLCOURIN    14   0.13982   0.16488        0.32    1
                                                                                            . BLCOUROU    15  -0.01686   0.13103        0.00    1
                                                                                            . BLMEANIN    16  -0.08306   0.02576        0.11    1
                                                                                            . BLMEANOU    17   0.07738   0.10071        0.10    1
                                                                                            . BWALEME     19  -0.07732   0.17617        0.10    1
                                                                                            . BLCOURME    20   0.07813   0.10867        0.10    1
                                                                                            . WEIGHT      21  -0.08891   0.35208        0.13    1
                                                                                            . DENSITY     23  -0.16721   0.87364        0.46    1
                                                                                            . BLMEAN2     25  -0.32694   0.00884        1.91    0
                                                                                            . THICK2      26   0.16588   0.04396        0.45    0
                                                                                            . SHEARCO2    27   0.31136   0.78657        1.72    0
                                                                                            . BLTHICK     28  -0.33655   0.01376        2.04    0
                                                                                            . EXTMEAN2    29   0.19070   0.85163        0.60    0
                                                                                            . BLSHEACO    30   0.35084   0.57130        2.25    0
                                                                                            . BLEXTMEA    31   0.21221   0.89714        0.75    0
                                                                                            . THEXTMEA    32   0.11216   0.48973        0.20    0
                                                                                            . BLCOUIN2    33   0.08250   0.15772        0.11    0
                                                                                            . SHEACOTH    34   0.47859   0.65818        4.75    0
                                                                                            . SHEARME2    35   0.24982   0.83072        1.07    0
                                                                                            . BLCOISHM    36   0.29815   0.56983        1.56    0
                                                                                            . THBLCOUI    37   0.06098   0.02766        0.06    2
                                                                                            . THSHEARM    38   0.40085   0.65153        3.06    2

* * * * * F-LEVELS(   4.000,    3.900) OR TOLERANCE INSUFFICIENT FOR FURTHER STEPPING
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                        STEPWISE REGRESSICN COEFFICIENTS

 VARIABLES    0 Y-INTCPT   1 DCFACE     2 DCBACK     4 IDENT      5 EXTWALE    6 EXTCOURS   7 EXTMEAN    8 SHEARWAL   9 SHEARCOU  10 SHEARMEA
STEP
  0             38.6957*     0.9914       0.9951      -0.9207      -1.0435      -0.5642      -0.9599       0.0194       0.0243       0.0222
  1            -19.6858*     0.9388       1.0004      -0.6406       0.2464       0.0740       0.1762       0.0039       0.0067       0.0053
  2            -21.4345*     0.9309       0.9924       0.7280       0.0531       0.1467       0.1867       0.0053       0.0090       0.0072

NOTE-
  1)   REGRESSION COEFFICIENTS FOR VARIABLES IN THE EQUATION ARE INDICATED BY AN ASTERISK
  2)   THE REMAINING COEFFICIENTS ARE THOSE WHICH WOULD BE OBTAINED IF THAT VARIABLE WERE TO ENTER IN THE NEXT STEP


                        STEPWISE REGRESSICN COEFFICIENTS

 VARIABLES   12 BLWALEIN  13 BLWALEOU  14 BLCOURIN  15 BLCOUROU  16 BLMEANIN  17 BLMEANOU  18 BLMEAN    19 BWALEME   20 BLCOURME  21 WEIGHT
STEP
  0             36.4474      36.3513      35.7978      34.2774      43.7814      43.4600      46.3255      43.7042      36.6739       0.1419
  1             -2.4900      -1.1455       7.1047      -2.9970      15.4399      -6.5723      46.3255*     -3.5557       3.6384       0.0409
  2             -7.6782       2.0682       5.8662      -0.7791     -10.2323       5.1501      40.7012*     -4.0446       4.0943      -0.0169

NOTE-
  1)   REGRESSION COEFFICIENTS FOR VARIABLES IN THE EQUATION ARE INDICATED BY AN ASTERISK
  2)   THE REMAINING COEFFICIENTS ARE THOSE WHICH WOULD BE OBTAINED IF THAT VARIABLE WERE TO ENTER IN THE NEXT STEP


                        STEPWISE REGRESSICN COEFFICIENTS

 VARIABLES   22 THICKNES  23 DENSITY   25 BLMEAN2   26 THICK2    27 SHEARCO2  28 BLTHICK   29 EXTMEAN2  30 BLSHEACO  31 BLEXTMEA  32 THEXTMEA
STEP
  0            305.9963      -0.0670      16.3886    1973.0391       0.0000     221.7801      -0.0205       0.0189      -0.4431      -2.1040
  1            119.0053      -0.0339     -33.4381     784.2725       0.0000      76.2473       0.0038       0.0032       0.2127       5.6931
  2            119.0053*     -0.0184     -26.2248    1010.9082       0.0000    -322.9155       0.0061       0.0057       0.1998       2.0266

NOTE-
  1)   REGRESSION COEFFICIENTS FOR VARIABLES IN THE EQUATION ARE INDICATED BY AN ASTERISK
  2)   THE REMAINING COEFFICIENTS ARE THOSE WHICH WOULD BE OBTAINED IF THAT VARIABLE WERE TO ENTER IN THE NEXT STEP
```

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                         STEPWISE REGRESSION COEFFICIENTS

 VARIABLES  33 BLCOUIN2 34 SHEACOTH 35 SHEARME2 36 BLCOISHM 37 THBLCOUI 38 THSHEARM
STEP
   0           12.4609     0.4445     0.0000     0.0163   220.0095     0.4245
   1            0.4146     0.1920     0.0000     0.0021    85.5741     0.1673
   2            1.2626     0.1568     0.0000     0.0043    39.8734     0.1298

NOTE-
   1)   REGRESSION COEFFICIENTS FOR VARIABLES IN THE EQUATION ARE INDICATED BY AN ASTERISK
   2)   THE REMAINING COEFFICIENTS ARE THOSE WHICH WOULD BE OBTAINED IF THAT VARIABLE WERE TO ENTER IN THE NEXT STEP




  SUMMARY TABLE
  STEP          VARIABLE                         MULTIPLE       INCREASE        F-TO-        F-TO-  NUMBER OF INDEPENDENT
   NO.     ENTERED       REMOVED              R         RSQ       IN RSQ         ENTER        REMOVE   VARIABLES INCLUDED
    1    18 BLMEAN                         0.8926    0.7967    0.7967       70.5285                        1
    2    22 THICKNES                       0.9160    0.8390    0.0423        4.4711                        2
```

APPENDIX B3

Computer Printout

All Possible Subsets Regression

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BMDP9R - ALL POSSIBLE SUBSETS REGRESSION      PROGRAM REVISED NOVEMBER, 1978
HEALTH SCIENCES COMPUTING FACILITY            MANUAL DATE  --   1977
UNIVERSITY OF CALIFORNIA, LOS ANGELES, CA 90024
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-- IF THERE ARE FEWER THAN THREE INDEPENDENT VARIABLES, THEN
   METHOD=NONE. WILL BE USED.
-- IF STATISTICS. IS STATED IN THE PLOT PARAGRAPH, THEN
   STATISTICS AS IN BMDP6D WILL ACCOMPANY EACH PLOT.
-- TO LIMIT THE NUMBER OF VARIABLES IN THE REPORTED SUBSETS,
   IN THE PRINT PARAGRAPH STATE MAXVAR=THE MAXIMUM NUMBER OF
   VARIABLES THAT YOU DESIRE.  A SUBSET WITH GREATER THAN
   MAXVAR VARIABLES WILL NOT BE REPORTED UNLESS IT IS ONE
   OF THE BEST SUBSETS BY THE CP OR ADJUSTED R-SQUARED
   CRITERIA.
-- TO OBTAIN THE COVARIANCE MATRIX OF THE REGRESSION
   COEFFICIENTS, INCLUDE CREG IN THE MATRIX STATEMENT OF
   THE PRINT PARAGRAPH, E.G.,
           MATRIX=CORR,RESID,CREG.
-- IF RESIDUALS ARE COMPUTED OR IF YOU STATE HISTOGRAM. IN
   THE PLOT PARAGRAPH, A HISTOGRAM OF THE STANDARDIZED
   (STUDENTIZED) RESIDUALS WILL BE MADE.


  PROGRAM CONTROL INFORMATION

         /PROBLEM              TITLE IS 'REGRESSION TO PREDICT DRAPE COEFFICIENT'.
         /INPUT                VARIABLES ARE 24.
                            FORMAT IS '(3(1X,F6.3),F3.0,3(1X,F5.2),
                               3(1X,F8.3),2X,A1/9(1X,F5.3)/1X,F8.4,1X,
                               F5.4,1X,F8.4,2X,A1)'.
         /VARIABLE    NAMES ARE DCFACE,DCBACK,DCMEAN,IDENT,EXTWALE,EXTCOURS,
                        EXTMEAN,SHEARWAL,SHEARCOU,SHEARMEA,FABRIC1,
                       BLWALEIN,BLWALEOU,BLCOURIN,BLCOUROU,BLMEANIN,
                       BLMEANOU,BLMEAN,BWALEME,BLCOURME,
                               WEIGHT,THICKNES,DENSITY,FABRIC2,
                       BLMEAN2,THICK2,SHEARCO2,BLTHICK,EXTMEAN2,
                       BLSHEACO,BLEXTMEA,THEXTMEA,BLCOUIN2,
                          SHEACOTH,SHEARME2,BLCOISHM,THBLCOUI,
                        THSHEARM.
                               BLANKS ARE MISSING.
                               LABELS ARE FABRIC1,FABRIC2.
                      ADD IS 14.
         /TRANSFORM          BLMEAN2=BLMEAN*BLMEAN.
                               THICK2=THICKNES*THICKNES.
                       SHEARCO2=SHEARCOU*SHEARCOU.
                               BLTHICK=BLMEAN*THICKNES.
                          EXTMEAN2=EXTMEAN*EXTMEAN.
                       BLSHEACO=BLMEAN*SHEARCOU.
                            THEXTMEA=THICKNES*EXTMEAN.
                            BLEXTMEA=BLMEAN*EXTMEAN.
                       SHEACOTH=SHEARCOU*THICKNES.
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                   BLCOUIN2=BLCOURIN*BLCOURIN.
                  SHEARME2=SHEARMEA*SHEARMEA.
                   BLCOISHM=BLCOURIN*SHEARMEA.
                  THBLCOUI=BLCOURIN*THICKNES.
                  THSHEARM=SHEARMEA*THICKNES.
     /REGRESS          DEPENDENT IS DCMEAN.
                   METHOD=RSQ.
                  NUMBER=5.
                   INDEPENDENT ARE 6,7,9,10,17,18,20 TO 23,
                  25 TO 28,30,34.
     /END

 PROBLEM TITLE . . . . . . .REGRESSION TO PREDICT DRAPE COEFFICIENT



 NUMBER OF VARIABLES TO READ IN. . . . . . . . .      24
 NUMBER OF VARIABLES ADDED BY TRANSFORMATIONS. .      14
 TOTAL NUMBER OF VARIABLES . . . . . . . . . . .      38
 NUMBER OF CASES TO READ IN. . . . . . . . . . . 1000000
 CASE LABELING VARIABLES . . . . . . . . . . .   FABRIC1    FABRIC2
 LIMITS AND MISSING VALUE CHECKED BEFORE TRANSFORMATIONS
 BLANKS ARE. . . . . . . . . . . . . . . . . .  MISSING
 INPUT UNIT NUMBER . . . . . . . . . . . . . . .       5
 REWIND INPUT UNIT PRIOR TO READING. . DATA. . .      NO

 INPUT FORMAT
        (3(1X,F6.3),F3.0,3(1X,F5.2), 3(1X,F8.3),2X,A1/9(1X,F5.3)/1X,F8.4,1X, F5.4,1X,F8.
        4,2X,A1)

*** CONTROL LANGUAGE TRANSFORMATIONS ARE PERFORMED ***

 VARIABLES TO BE USED
              1  DCFACE        2  DCBACK        3  DCMEAN        4  IDENT         5  EXTWALE
              6  EXTCOURS      7  EXTMEAN       8  SHEARWAL      9  SHEARCOU     10  SHEARMEA
             12  BLWALEIN     13  BLWALEOU     14  BLCOURIN     15  BLCOUROU     16  BLMEANIN
             17  BLMEANOU     18  BLMEAN       19  BWALEME      20  BLCOURME     21  WEIGHT
             22  THICKNES     23  DENSITY      25  BLMEAN2      26  THICK2       27  SHEARCO2
             28  BLTHICK      29  EXTMEAN2     30  BLSHEACO     31  BLEXTMEA     32  THEXTMEA
             33  BLCOUIN2     34  SHEACOTH     35  SHEARME2     36  BLCOISHM     37  THBLCOUI
             38  THSHEARM

 INDEPENDENT VARIABLES ARE
              6  EXTCOURS      7  EXTMEAN       9  SHEARCOU     10  SHEARMEA     17  BLMEANOU
             18  BLMEAN       20  BLCOURME     21  WEIGHT       22  THICKNES     23  DENSITY
             25  BLMEAN2      26  THICK2       27  SHEARCO2     28  BLTHICK      30  BLSHEACO
             34  SHEACOTH

 DEPENDENT VARIABLE. . . . . . . . . . . . . . .       3 DCMEAN
 NUMBER OF 'BEST' REGRESSIONS. . . . . . . . . .        5
 SELECTION CRITERION . . . . . . . . . . . . . .  RSQ
 WEIGHT VARIABLE . . . . . . . . . . . . . . . .
 PRECISION . . . . . . . . . . . . . . . . . . .  DOUBLE
 TOLERANCE FOR MATRIX INVERSION. . . . . . . . . 0.0001000
```

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PRINT CORRELATION MATRIX. . . . . . . . . . . . . YES
PRINT COVARIANCE MATRIX . . . . . . . . . . . .  NO
PRINT RESIDUALS . . . . . . . . . . . . . . . .  NO
PRINT COVARIANCE MATRIX FOR REGRESSION COEFS. .  NO
PRINT CORRELATION MATRIX FOR REGRESSION COEFS .  NO
MAX. NO. OF VARS. IN ANY REPORTED SUBSET  . . .   16




DATA AFTER TRANSFORMATIONS FOR FIRST    5 CASES
CASES WITH ZERO WEIGHTS AND MISSING DATA NOT INCLUDED.

 CASE      CASE            CASE
LABEL     NUMBER          WEIGHT    6 EXTCOURS    7 EXTMEAN      9 SHEARCOU   10 SHEARMEA   17 BLMEANOU    18 BLMEAN      20 BLCOURME
                     21 WEIGHT     22 THICKNES   23 DENSITY     25 BLMEAN2    26 THICK2     27 SHEARCO2    28 BLTHICK     30 BLSHEACO
                     34 SHEACCTH    3 DCMEAN
A    A        1          1.00000      11.37000      12.65000      914.28589    1070.00000       0.94300        0.97900        0.94300
                       200.22449       0.06960     287.67944        0.95844       0.00484  835918.62500        0.06814      895.08569
                        63.63428      26.27599
B    B        2          1.00000      18.50999      14.31000      330.00000     325.00000       1.50000        1.08600        1.05200
                        74.94559       0.04850     154.52779        1.17939       0.00235  108900.00000        0.05267      358.37964
                        16.00499      29.55699
C    C        3          1.00000      46.42000      27.64999      162.65699     152.14299       1.37700        1.19600        1.03100
                        24.46259       0.02060     118.75240        1.43041       0.00042   26522.39844        0.02464      194.77682
                         3.35485      36.22099
D    D        4          1.00000       7.07000       6.31000      517.85693     476.07178       1.12200        1.10000        1.19500
                       165.91840       0.04950     335.18774        1.21000       0.00245  268175.75000        0.05445      569.64209
                        25.63391      26.53099
E    E        5          1.00000      16.04999      11.65000      268.57080     267.14282       1.42700        1.47400        1.62400
                       207.27888       0.14020     147.84520        2.17268       0.01966   72130.25000        0.20665      395.87329
                        37.65361      58.38499

  NUMBER OF CASES READ. . . . . . . . . . . . . .       20
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UNIVARIATE SUMMARY STATISTICS
                                                                                 SMALLEST  LARGEST
                                      STANDARD   COEFFICIENT     SMALLEST    LARGEST  STANDARD  STANDARD
   VARIABLE           MEAN           DEVIATION   OF VARIATION       VALUE       VALUE     SCORE     SCORE  SKEWNESS  KURTOSIS

  6 EXTCOURS       12.94600          10.05529       0.776710      1.72000    46.42000     -1.12      3.33      1.82      3.60
  7 EXTMEAN        10.41600           6.85745       0.658358      2.09000    27.64999     -1.21      2.51      1.32      1.14
  9 SHEARCOU      460.10709         286.45416       0.622581    162.85699  1327.14282     -1.04      3.03      1.41      1.78
 10 SHEARMEA      454.31442         295.89762       0.651306    152.14299  1307.85693     -1.02      2.88      1.48      1.62
 17 BLMEANOU        1.30465           0.30045       0.230291      0.91700     1.92800     -1.29      2.07      0.47     -0.93
 18 BLMEAN          1.26025           0.30472       0.241790      0.88900     1.89400     -1.22      2.08      0.71     -0.84
 20 BLCOURME        1.23790           0.36735       0.296753      0.82600     2.00900     -1.12      2.10      0.65     -1.03
 21 WEIGHT        164.98864          56.41321       0.341922     24.46259   252.46939     -2.49      1.55     -0.68     -0.02
 22 THICKNES        0.07425           0.03091       0.416211      0.02060     0.14020     -1.74      2.13      0.26     -0.87
 23 DENSITY       230.87530          61.68469       0.267178    118.75240   335.18774     -1.82      1.69     -0.00     -1.19
 25 BLMEAN2         1.67644           0.84150       0.501955      0.79032     3.58723     -1.05      2.27      0.95     -0.43
 26 THICK2          0.00642           0.00497       0.773401      0.00042     0.01966     -1.21      2.66      0.93      0.11
 27 SHEARCO2   289651.70215      401677.36616       1.386760  26522.398441761308.00000     -0.66      3.66      2.51      6.24
 28 BLTHICK         0.09775           0.05638       0.576825      0.02464     0.20665     -1.30      1.93      0.64     -0.96
 30 BLSHEACO      610.93533         518.82118       0.849224    155.92816  2513.60718     -0.88      3.67      2.40      6.21
 34 SHEACOTH       34.49956          23.87663       0.692085      3.35485    92.76724     -1.30      2.44      0.85     -0.21
  3 DCMEAN         38.69574          15.81521       0.408707     17.69199    66.21599     -1.33      1.74      0.41     -1.27

VALUES FOR KURTOSIS GREATER THAN ZERO INDICATE DISTRIBUTIONS
WITH HEAVIER TAILS THAN THE NORMAL DISTRIBUTION.
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CORRELATIONS


                EXTCOURS   EXTMEAN  SHEARCOU  SHEARMEA  BLMEANOU    BLMEAN  BLCOURME    WEIGHT  THICKNES   DENSITY   BLMEAN2    THICK2  SHEARCO2
                       6         7         9        10        17        18        20        21        22        23        25        26        27

EXTCOURS    6      1.000
EXTMEAN     7      0.933     1.000
SHEARCOU    9     -0.391    -0.330     1.000
SHEARMEA   10     -0.400    -0.345     0.987     1.000
BLMEANOU   17     -0.317    -0.430     0.312     0.302     1.000
BLMEAN     18     -0.444    -0.528     0.375     0.369     0.941     1.000
BLCOURME   20     -0.516    -0.547     0.394     0.380     0.876     0.944     1.000
WEIGHT     21     -0.647    -0.531     0.341     0.367     0.241     0.435     0.410     1.000
THICKNES   22     -0.355    -0.260     0.040     0.053     0.335     0.466     0.435     0.802     1.000
DENSITY    23     -0.513    -0.477     0.370     0.381    -0.278    -0.148    -0.071     0.216    -0.355     1.000
BLMEAN2    25     -0.453    -0.529     0.402     0.398     0.932     0.995     0.938     0.445     0.446    -0.104     1.000
THICK2     26     -0.250    -0.201    -0.038    -0.021     0.364     0.482     0.451     0.713     0.977    -0.427     0.456     1.000
SHEARCO2   27     -0.330    -0.303     0.960     0.951     0.362     0.409     0.424     0.278    -0.000     0.329     0.447    -0.068     1.000
BLTHICK    28     -0.426    -0.402     0.133     0.148     0.640     0.755     0.695     0.761     0.923    -0.322     0.741     0.924     0.123
BLSHEACO   30     -0.436    -0.435     0.931     0.906     0.568     0.622     0.621     0.355     0.109     0.278     0.651     0.049     0.958
SHEACOTH   34     -0.418    -0.324     0.867     0.857     0.412     0.512     0.485     0.667     0.488     0.107     0.526     0.405     0.817
DCMEAN      3     -0.359    -0.416     0.439     0.415     0.826     0.893     0.852     0.506     0.598    -0.261     0.872     0.620     0.431


                 BLTHICK  BLSHEACO  SHEACOTH    DCMEAN
                      28        30        34         3

BLTHICK    28      1.000
BLSHEACO   30      0.294     1.000
SHEACOTH   34      0.525     0.839     1.000
DCMEAN      3      0.791     0.619     0.671     1.000
```

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FOR EACH SUBSET SELECTED BY YOUR CRITERION, THE R-SQUARED,
ADJUSTED R-SQUARED, MALLOWS' CP, AND THE VARIABLE NAMES ARE
PRINTED.  THE REGRESSION COEFFICIENTS AND T-STATISTICS ARE
PRINTED TO THE RIGHT OF THE VARIABLE NAMES.

MANY OTHER SUBSETS MAY ALSO BE REPORTED THAT ARE NOT
ACCOMPANIED BY REGRESSION COEFFICIENTS AND T-STATISTICS.
SOME OF THESE SUBSETS MAY BE QUITE GOOD ALTHOUGH THEY ARE
NOT NECESSARILY BETTER THAN ANY SUBSET THAT HAS NOT BEEN
PRINTED.


                                        ****  SUBSETS WITH    1 VARIABLES  ****
              ADJUSTED
  R-SQUARED  R-SQUARED         CP

   0.796675   0.785379      51.77  VARIABLE        COEFFICIENT  T-STATISTIC
                                  18 BLMEAN          46.3255       8.40
                                     INTERCEPT      -19.6859

   0.760394   0.747083      63.86  VARIABLE        COEFFICIENT  T-STATISTIC
                                  25 BLMEAN2         16.3886       7.56
                                     INTERCEPT       11.2212

   0.725642   0.710400      75.44  VARIABLE        COEFFICIENT  T-STATISTIC
                                  20 BLCOURME       36.6738       6.90
                                     INTERCEPT      -6.70276

   0.681660   0.663974      90.10  VARIABLE        COEFFICIENT  T-STATISTIC
                                  17 BLMEANOU       43.4599       6.21
                                     INTERCEPT      -18.0042

   0.625179   0.604356     108.93  VARIABLE        COEFFICIENT  T-STATISTIC
                                  28 BLTHICK        221.780       5.48
                                     INTERCEPT      17.0171

   0.450391   0.419857     167.19  SHEACOTH

   0.383848   0.349618     189.37  THICK2

   0.383639   0.349397     189.44  BLSHEACO

   0.357568   0.321877     198.12  THICKNES

   0.256368   0.215055     231.86  WEIGHT
```

```
                                   ****  SUBSETS WITH    2 VARIABLES  ****
                 ADJUSTED
 R-SQUARED      R-SQUARED          CP

  0.858602      0.841967      33.13  VARIABLE        COEFFICIENT  T-STATISTIC
                                     18 BLMEAN          38.6172       7.01
                                     34 SHEACOTH        0.191957      2.73
                                       INTERCEPT       -16.5940

  0.843208      0.824762      38.26  VARIABLE        COEFFICIENT  T-STATISTIC
                                     18 BLMEAN          40.1592       7.06
                                     26 THICK2          784.270       2.25
                                       INTERCEPT       -16.9508

  0.839015      0.820076      39.66  VARIABLE        COEFFICIENT  T-STATISTIC
                                     18 BLMEAN          40.7012       7.11
                                     22 THICKNES        119.006       2.11
                                       INTERCEPT       [illegible]


0.828467    C.808287      43.17  VARIABLE        COEFFICIENT  T-STATISTIC
                                 18 BLMEAN          35.6760      4.49
                                 28 BLTHICK         76.2474      1.78
                                   INTERCEPT       -13.7180

0.825905    C.805424      44.03  VARIABLE        COEFFICIENT  T-STATISTIC
                                 18 BLMEAN          138.239      2.53
                                 25 BLMEAN2        -33.4378     -1.69
                                   INTERCEPT       -79.4637

0.822721    0.801865      45.09  BLMEAN2     SHEACOTH

0.822586    0.801714      45.13  BLMEAN2     THICK2

0.814875    0.793095      47.70  THICKNES    BLMEAN2

0.813908    0.792015      48.02  BLMEAN      WEIGHT

0.813747    0.791835      48.08  BLMEAN      DENSITY

                              ****  SUBSETS WITH    3 VARIABLES  ****
              ADJUSTED
R-SQUARED    R-SQUARED          CP

0.908611     0.891476      18.46  VARIABLE        COEFFICIENT  T-STATISTIC
                                  18 BLMEAN          159.805      3.88
                                  25 BLMEAN2        -44.5873     -2.96
                                  34 SHEACOTH       0.226151      3.81
                                    INTERCEPT       -95.7532

0.903394     0.885281      20.20  VARIABLE        COEFFICIENT  T-STATISTIC
                                  10 SHEARMEA     -0.0222282     -2.72
                                  18 BLMEAN          36.5516      7.68
                                  34 SHEACOTH       0.441514      4.03
                                    INTERCEPT       -12.5018
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```
0.894650    0.874897      23.11  VARIABLE        COEFFICIENT  T-STATISTIC
                                18 BLMEAN           38.3891       7.83
                                27 SHEARCO2    -0.0000129600     -2.34
                                34 SHEACOTH         0.371532      3.75
                                  INTERCEPT        -18.7479

0.894229    0.874397      23.25  VARIABLE        COEFFICIENT  T-STATISTIC
                                18 BLMEAN           35.8269       7.08
                                23 DENSITY        -0.0501094     -2.32
                                34 SHEACOTH         0.224102      3.49
                                  INTERCEPT        -2.61748

0.892854    0.872764      23.71  VARIABLE        COEFFICIENT  T-STATISTIC
                                 9 SHEARCOU       -0.0207879     -2.26
                                18 BLMEAN           36.7755       7.34
                                34 SHEACOTH         0.420254      3.53
                                  INTERCEPT        -12.5844

0.888984    0.868168      25.00  BLMEAN    BLSHEACO  SHEACOTH

0.886526    0.865250      25.82  BLMEAN    THICK2    SHEACOTH

0.876082    0.852848      29.30  BLCOURME  DENSITY   SHEACOTH

0.875889    0.852618      29.37  BLMEAN    THICKNES  SHEACOTH

0.874973    0.851531      29.67  SHEARCOU  BLCOURME  SHEACOTH




STATISTICS FOR 'BEST' SUBSET
MALLOWS' CP                         17.00
SQUARED MULTIPLE CORRELATION      0.99100
MULTIPLE CORRELATION              0.99549
ADJUSTED SQUARED MULT. CORR.      0.94299
RESIDUAL MEAN SQUARE            14.258177
STANDARD ERROR OF EST.           3.776000
F-STATISTIC                         20.64
NUMERATOR DEGREES OF FREEDOM           16
DENOMINATOR DEGREES OF FREEDOM          3
SIGNIFICANCE                       0.0146
```

```
 VARIABLE      REGRESSION         STANDARD   STAND.     T-   2TAIL        TOL-  CONTRIBUTION
NO.   NAME     COEFFICIENT           ERROR    COEF.  STAT.    SIG.      ERANCE  TO R-SQUARED

   INTERCEPT      -43.2923         70.0599   -2.737  -0.62   0.580
  6 EXTCOURS       1.57754         1.29528    1.003   1.22   0.310    0.004424      0.004450
  7 EXTMEAN       -2.29552         1.39269   -0.995  -1.65   0.198    0.008228      0.008151
  9 SHEARCOU    -0.0572940       0.0650874   -1.038  -0.88   0.444    0.002159      0.002325
 10 SHEARMEA    -0.0176923       0.0490370   -0.331  -0.36   0.742    0.003564      0.000391
 17 BLMEANOU       13.4202         22.6023    0.255   0.59   0.594    0.016273      0.001058
 18 BLMEAN        -33.0761         69.6438   -0.637  -0.47   0.667    0.001666      0.000677
 20 BLCOURME       28.4602         25.4241    0.661   1.12   0.345    0.008603      0.003760
 21 WEIGHT       -0.574638        0.247814   -2.050  -2.32   0.103    0.003840      0.016132
 22 THICKNES       1144.77         928.871    2.237   1.23   0.306    0.000911      0.004557
 23 DENSITY       0.292573        0.163228    1.141   1.79   0.171    0.007402      0.009639
 25 BLMEAN2        27.8990         32.9615    1.484   0.85   0.459    0.000975      0.002149
 26 THICK2        -2309.58         5097.15   -0.725  -0.45   0.681    0.001171      0.000616
 27 SHEARCO2  0.0000134208    0.0000375189    0.341   0.36   0.744    0.003304      0.000384
 28 BLTHICK       -255.818         523.650   -0.912  -0.49   0.659    0.000861      0.000716
 30 BLSHEACO    -0.0547689       0.0492269   -1.797  -1.11   0.347    0.001150      0.003714
 34 SHEACOTH       2.13664        0.567571    3.226   3.76   0.033    0.004086      0.042519

THE CONTRIBUTION TO R-SQUARED FOR EACH VARIABLE IS THE AMOUNT
BY WHICH R-SQUARED WOULD BE REDUCED IF THAT VARIABLE WERE
REMOVED FROM THE REGRESSION EQUATION.


PROBLEM NUMBER  1 COMPLETED.
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