MEASUREMENT FOR PATTERN SHAPE:

TESTING A CONIC MODEL

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INTRODUCTION

Background

Inconsistency in sizing and fit is widespread in the American apparel industry (Orzechowski and Forney, 1988). The use of sizing standards is voluntary, but the data upon which they are based are 50 years old (O'Brien and Shelton, 1941) and have been found to be inaccurate for current consumers in almost every size category (Delk and Cassill, 1989; Giddings and Boles, 1990; Orzechowski and Forney, 1988; Patterson, 1982; Salusso-Deonier, DeLong, Martin and Krohn, 1986; Woodson and Horridge, 1990). The original survey was of Caucasians only; some areas of the country were not surveyed. In addition, the data have been manipulated in a variety of ways since collection.

Problems associated with poor fit in apparel range from annoying to dangerous. Delk and Cassill (1989) found that a size 10 female subject needed to try on 28 pairs of jeans before finding two pairs that fit well enough to purchase. Individuals who work do not have time for the extended shopping implied in Delk and Cassill's study; individuals who handle dangerous substances face more serious problems due to poor fit.

Clothing and personal equipment are key elements in safety programs designed to minimize worker contact with potential toxins (Raheel, 1988), but workers are reluctant to wear protective garments because they are uncomfortable, in part due to poor fit (Goldstein, 1989). Accidental rips in too-small protective clothing may result in exposure to toxic materials; too-large clothing may impede worker performance. Despite the inherent danger in poorly fitted protective wear, size standards for such apparel are minimal and their use is voluntary.

Production of good fitting apparel depends on accurate data about the distribution of body forms and sizes within the target population (Salusso-Deonier et al., 1986). Although the apparel industry is considering collection of new data, it will be several years before studies are complete. With new data, fitting problems might still occur because there is no theory relating human figure shape to pattern shape used in garment construction. Pattern drafting procedures are empirical in origin (Hutchinson, 1977); the intent of most patternmakers is to produce a garment that fits, not to explain how or why it fits (Gazzuolo, 1985). Garment manufacturers often use fit as a means of differentiating their product from that of their competitors so information about their methods is proprietary. Only a few explicit statements about the process of making patterns exist (Heisey, Brown and Johnson, 1988).

It seems unlikely that a single pattern shape could fit all of the possible shapes of human bodies. Without an explanation of the relationship between body form variance and pattern shape variance it is not even possible to be sure that body measurements are taken in the proper manner or location.

Significance

Poor fit in ready-to-wear clothing has widespread consequences. The retail apparel industry suffers markdown losses that total millions of dollars each year. McVey (1983) said that 70% of garments on markdown racks are there due to poor workmanship and/or fit. Curry (1983) called incorrect size the primary reason for retailer returns.

Voluntary Product Standard PS 42-70, currently in use in the U.S., has been shown to be inaccurate for almost every size category. Solinger (1988) considered the body measurements in PS 42-70 insufficient for drafting a closely fitted pattern.

Poor fit in protective garments for individuals involved in handling hazardous substances such as pesticides has serious consequences because it contributes to garment stress. Rips and tears in high stress garment areas may result in increased wearer exposure to pesticides, since occlusion (covering) of a substance accidentally admitted under fabric increases its absorption (Wester and Maibach, 1985). Clothing that is too large may be caught in equipment. Poorly fitted protective clothing offers little real protection.

Pesticide exposure has been linked to human illnesses: non-Hodgkins's lymphoma and leukemia (Alavanja, Blair, Merkle, Teske, Eaton, and Reed, 1989). Males residing on farms are most at risk; increased risk is associated with increased age (Stehr-Green, 1989).

As with other types of apparel, there are voluntary sizing standards for protective garments. The American National Standards Institute (ANSI) established minimum size requirements in 1985 as ANSI/ISEA 101-1985. These standards were seen by manufacturers as a first step. Consumer complaints have led to reevaluation of ANSI/ISEA 101-1985 (Prevatt and Keeble,1991).

Research has been conducted to improve the design of protective clothing (Ashdown and Watkins, 1991; Prevatt and Keeble, 1991, Van Schoor, 1989). Research is in progress to improve sizing standards for protective garments (Prevatt and Keeble, 1991). Glock and Kunz (1991) noted, however, that size is not fit. While research into more appropriate sizing standards is necessary, of equal importance is the need for research into the "cut" of clothing: the shape of the pattern as it relates to the form of the human body.

Theoretical Framework

There is no comprehensive theoretical framework which relates body form variance to pattern shape variation. A few explicit statements of theory are found in instructions for dart manipulation in the flat pattern method of patternmaking. The proposed theoretical framework for this study is based on those instructions combined with morphometric methodologies used in anthropology and evolutionary biology.

Morphometrics shares common goals with fitting and patternmaking; it attempts to find ways to compare biological forms for the discrimination of groups and the description of change. It is also concerned with collection and manipulation of data on form differences (Bookstein, Chernoff, Elder, Humphries, Smith and Strauss, 1985).

It is proposed that the front bodice (upper body from waist to shoulder) be modelled as a cone with the bust point as its apex. The pattern which fits the bodice is then a circle with the bust point as its center. The gap which occurs when the cone is flattened to a circle represents the dart which is required to fit the breast.

Based on a morphometric technique developed by Yasui (1986), the shape of the front bodice pattern for a particular figure would be determined by measurements taken from the bust point to body landmarks representing the neck-shoulder point, the shoulder-armhole point, armhole break point, underarm-side seam point, side seam-waist point, center front-waist point, and center front-neck point. The length of each radius from bust point to body landmark would be recorded, and the angles between each pair of radii measured at the bust circle, 1 1/2" from bust point.

The proposed model combines the conic model implied in flat pattern dart manipulation and Yasui's (1986) technique of measurement from a figure centroid, thus joining an empirically tested method of pattern design with a measurement technique capable of statistical analysis which relates directly to the design method.

Purpose

The overall purpose of this study is to test the validity and reliability of a conic model which relates body form variance to pattern shape variation by describing the front bodice area (upper body from waist to shoulders) as a cone with the bust point as its apex. If the conic model is valid, then the pattern is a cone flattened to a circle with the bust point as its center. The gap which occurs when the cone is flattened to a circle becomes the dart which is necessary to fit the breast.

The proposed conic model was selected because it is implicit in the techniques of flat pattern design and because a measurement technique that relates directly to the model exists (Yasui, 1986). The front bodice area of the figure was chosen because in females this area represents the most complete application of the cone-flattened-to-circle model. The same model is assumed to apply to the chest area of men's patterns: Solinger (1988) said that the only difference in fitting the front upper body of men and women is that for women the most prominent bulge is the bust while for men it may be the chest or the waist. If the conic model is valid, it should be valid for both male and female figures.

Yasui's (1986) study described a method for measuring any form by measuring the length of lines radiating from a central point to specified points on the form's perimeter. Yasui measured skulls from a centroid to their periphery using lines at one degree intervals with computer digitizing techniques. Yasui's work is based in part on a study by Ramaekers (1975) which used a similar technique with lines from a central point to selected body landmarks, measuring the angles between the defined lines. Ramaekers chose a particular central point based on its relationship to the peripheral points he wished to use as landmarks. Yasui used the figure centroid because it was independent of the figure outline. Measurements may be taken from lines radiating from the center at predetermined angle increments as Yasui did with skulls. It is also possible to measure the length of lines radiating from the central point to specified points on the form's perimeter, then to measure the size of angles between adjacent lines. The latter method will be used for this study because of equipment limitations.

Most sets of measurements taken to describe body form involve body circumferences, lengths and widths; the measurements are difficult to relate to pattern drafting techniques. Yasui's methodology was chosen for this study because measurements taken according to his techniques may be related directly to the pattern.

Yasui's measurement technique provided data about body form that is possible to analyze statistically. He recommended constructing an averaged outline from mean radius lengths for each group analyzed. Proportions of adjacent line lengths may be calculated to describe figure shape, for instance, shoulder slope, in a precise manner. The range and average length of various line measures could provide data of use to pattern graders.

Objectives

The specific objectives for this study are as follows:

1. To test the proposed conic model by
   a) measuring the front bodice area of female body forms by measuring the length of lines from the bust point to selected body landmarks and by measuring the angles between the lines,
   b) drafting a front bodice pattern for each body form using the line and angle measurements, and
   c) evaluating the fit of the drafted front bodice patterns on the body forms.

2. To refine a measurement technique for determining both the length of lines from the bust point to body landmarks and the size of the angles between those lines.

3. To analyze the line and angle data collected from body forms using the refined measurement technique for similarities and differences within front bodice patterns which fit female body forms.

4. To test and refine the proposed conic model by
   a) measuring the front upper body of male subjects by measuring the length of lines from the bust point (nipple) to selected body landmarks and by measuring the angles between the lines,

b) drafting a front bodice pattern for each subject from the line and angle measurements.

5. To analyze the line and angle data collected using the refined measurement technique for similarities and differences within front bodice patterns for male subjects.

CHAPTER II

LITERATURE REVIEW

Introduction

Garment fit is a very complex concept for which there is no single definition. The term "fit" serves as a general heading for many interrelated topics. In the most general terms fit concerns the relationship between a garment and the body on which it is worn.

Garments are constructed from fabric which is two dimensional to be worn on a body which is three dimensional; a pattern provides the transition. Fitting theory should provide guidance for the way in which the transition from two-dimensional to three-dimensional is made. Any discussion of fit must include the ways in which the body is classified, described and measured for the development of a pattern. One might begin the discussion from either the body or the pattern. This discussion begins with the pattern. The fit of protective clothing is considered as an illustration.

Pattern Development

Patternmaking and fitting developed as a skilled craft rather than as a science (Brackelsberg, Farrell-Beck and Winakor, 1986). A wide variety of pattern drafting systems were developed and patented from the latter part of the eighteenth century to the 1920s (Heisey, Brown and Johnson, 1988). These systems were used as the basis for ready-to-wear sizing as the industry developed. Patternmaking procedures have changed very little to the present day although computers are now used to perform some of the repetitive tasks (Salusso-Deonier et al., 1986).

The process of making clothing to fit the body involves the transformation of flat fabric into a three-dimensional garment which conforms (more or less) to the shape of the human body while allowing for some degree of movement. A pattern is a flat piece of paper which determines how cloth will be cut and provides direction for sewing techniques which complete the transformation of fabric into three-dimensional clothing.

Patternmakers have historically used three different methods to create patterns: drafting, draping, and standard sloper (Martell, 1990). Drafting is the process of drawing patterns using body measurement data as reference. Draping involves cutting and manipulating fabric directly on a body form. The cut pieces of fabric are then used to develop paper patterns. A standard sloper is a set of reference patterns drafted according to selected body measurements with a minimum amount of ease added. Ease is additional room added to the pattern to allow for basic body movement during garment wear. It is, in patternmaking terms, the difference between body measure and pattern measure. A standard sloper is manipulated according to the rules of flat pattern design to produce any desired garment style. None of the three methods is inherently superior to any other. Most designers use flat pattern techniques, but the choice of method is determined by personal preference.

Drafting systems are classified based on the number of measurements used to derive a pattern. Most attempts to improve pattern drafting have concentrated on ways to improve the specification of body form by increasing the number of two-dimensional measurements (Heisey, Brown and Johnson, 1988). Thirty to fifty measurements of body circumference, width and length are not uncommon. However, as Heisey, Brown and Johnson noted, more measurements are not necessarily better; as the number of measures increases, the distances measured decrease, while measurement error increases.

Drafting systems may also be classified as direct or proportional. Direct drafting systems rely on complete sets of measurements often from government standards. However, "measurements taken for standard sizing are body measurements only and cannot predict even major dimensions of pattern shape without making unsubstantiated assumptions about the body forms of those being fitted" (Gazzuolo, 1985, p.13). Measurements are subject to interpretation when applied to pattern shapes. Major commercial pattern companies use identical measurements but their finished patterns are not identical. Proportional drafting systems use a single key measurement such as bust or chest size. The remaining measurements are assumed to vary in the same fashion as the key measurement.

Draping relies on body forms which are also based on government body standards. Forms like patterns are interpretations of measurements and vary by manufacturer (Jay, 1969). The forms are modified yearly but there is no scientific basis for the changes made (Gazzuolo, 1985). Jay (1969) also stated that dress forms for higher priced garments are as much as 1 1/2" larger in circumference than normal forms of the same size category. The customer who pays more for a garment is rewarded with a smaller size number designation for a garment that is actually larger than a less expensive garment of the same size number.

Fit models, individuals who represent the manufacturer's target customer, are often used to test drafted or draped patterns. Workman (1991) examined classified employment advertisements seeking size 8 and size 10 fit models for the years 1976 to 1986. She recorded the advertised body measurements for each size and compared them to determine if a size 8 fit model had a distinctly different set of measurements than a size 10 fit model. Workman found that the advertised body measurements for the two size categories were the same except for the hip measures: the size 10 was larger in that dimension.

Whether drafted or draped, reference sets of slopers used by manufacturers to establish fit are based on a designer's interpretation of body shape. The shape of the sloper represents essentially one figure or body form which the manufacturer hopes is representative of his customer. Heisey, Brown and Johnson (1988) stated that no completely accurate method exists for creating individually fitted patterns because no theoretical framework for modelling the fitting process has been developed. If this is true, it follows that there are no accurately developed patterns; if a pattern fits an individual it is a happy accident.

Body Form Classification

An almost infinite number of body forms exist. Attempts to classify them are numerous also. One of the earliest in this country by Wampen in 1864 is a description of a normal or proportionate form based on classical concepts of human perfection. He constructed a standard pattern draft for that form. Many authors still define body forms in terms of deviation from a standard. Berry (1970) defined a normal figure as one which fit the standard pattern.

Gazzuolo (1985) noted that normal/deviant classifications make several assumptions. They assume that such a single standard form exists and that it represents a typical or average form. They also assume that variations from average occur one at a time.

A scientific theory of body form classification was developed in 1926 by W. H. Sheldon. He identified three extreme body forms which he reasoned to represent factors in the structure of any individual. He called the system somatotyping and the three factors endomorphy (the fat component), mesomorphy (the muscle and bone component), and ectomorphy (the skin and nervous component). (Sheldon, Dupertuis and McDermott, 1954; Sheldon, Stevens and Tucker, 1970).

Sheldon assigned a scale of numbers from 1 to 7 to each component, with 7 representing the most extreme. Any human body could be typed using three numbers, in order, representing the endomorphic, mesomorphic and ectomorphic components. An extreme endomorph, for example, would be rated 7-1-1.

Croney (1981) stated that Sheldon's system requires practice and knowledge of anatomy, but there is a high level of rating agreement among practiced users. Parnell (1964) also noted that somatotyping required skill and added that the method took too long: about one hour per subject. Parnell modified Sheldon's technique so that it could be accomplished more quickly.

Somatotyping as originally proposed was also found to be inadequate for the description of body extremes such as obesity (Seltzer and Mayer, 1964) and muscular development of Olympic athletes (Tanner, 1964). Heath and Carter (1967) modified the system to include component ratings higher than 7.

Heath and Carter discussed the notion that an individual's somatotype might not be a lifetime constant. Children's body types change as they age (Heath, 1963; Parizkova and Carter, 1976), as do body types of aging adults.

Hunt (1949) stated that somatotype is less related to type or origin of tissue than it is to developmental stage and age. He considered most infants to be endomorphs and children to be increasingly ectomorphic until puberty when they became more mesomorphic.

Somatotyping is descriptive of how the body appears; somatotypes do not correlate well with all aspects of actual body composition. Slaughter and Lohman (1974) found per cent body fat closely related to endomorphy, but lean body mass determinations were not correlated with mesomorphy.

Although many research studies about fitting make reference to Sheldon, none make use of his somatotyping system. There is no single system of body form classification mentioned in clothing research. Farrell-Beck and Pouliot (1983) used five body variations: round, pear-shaped, weight-in-front, weight-in-back, and average, to describe women's hip shapes. The Douty Body Build Scale (Douty, 1968) uses categories called thin, slender, average, stocky, and heavy. Gazzuolo (1985) used categories based on body balance (comparison of front body length to back body length) and body differences (comparison of body circumferences).

If the number of body forms is infinite, the causes for variety are almost as numerous. Age, weight loss, sex, skeletal differences, body use, nutritive status, and socio-economic status have all been found to influence body shape. (Salusso-Deonier et al., 1986; Takamura, Ohyama, Yamada and Ishinishi, 1988). Gazzuolo (1985) said that "Throughout the growth process and continuing through the aging process, innumerable genetic and environmental influences interact to produce a continuous series of changes on the form of the body. Each occasion for change is also an occasion for variation among individuals." (p.286).

Body Measurement

Precision in body measurement is difficult because the living body is always in motion even when apparently standing still. The act of measuring produces further complications: People assume unnatural poses, flinch when touched, become fatigued, shrink over a day's time in height, and expand in circumference (Gazzuolo, 1985). With all its difficulties, it is still better to measure subjects than to rely on their own reported measurements. Boldsen, Mascie-Taylor and Madsen (1985) found that subjects' mean self-reported height increased with time.

Gazzuolo (1985) felt that assessment of body form variance should include both anthropometry (body measurement) and anthroposcopy (visual and verbal description). Tanner and Weiner (1949) stated that measurements taken from photographs are in general as accurate as measurements taken on living persons.

In 1954, Douty published the first of a long series of research studies using photographic methodology in body assessment. The process, called graphic somatometry, involves photography of a backlit body silhouetted against a gridded screen. It is used to show body proportion and measure body angles and generally accompanies more traditional measuring techniques. Graphic somatometry has been refined and tested in a number of studies (Brinson, 1977; Farrell-Beck and Pouliot, 1980; Lesko, 1982; Pouliot, 1980).

Traditionally, body measurements have been taken with steel measuring tapes, calipers, and other specially developed instruments. No matter how they are taken, body measurements vary in reliability. Tanner and Weiner (1949) felt that it was the dimension measured not the means for measuring that determined reliability. More recent studies such as Martorell's (1975) suggested that measurement reliability was not the same for all parts of the body.

Soft body tissue is difficult to measure without compressing it. The chest, due to breathing motion, varies in girth. Carr, Rempel and Ross (1987) found that it was harder to take consistent replicated measurements of fat individuals than lean ones. Gavan (1950) found the highest consistency (smallest standard deviation for any given mean) for measurements of bony prominences.

Opinions differ on which side of the body to measure. The dominant side, determined by which hand an individual prefers to use, is usually the larger. The non-dominant side is sometimes seen as being the "natural" shape of the body. Damon (1965) stated that neither side is intrinsically better; the researcher needs to state which side is used.

The same body measures on a subject may differ when taken by two different researchers, when taken on two separate occasions, or when taken with different instruments. For these reasons anthropometric techniques are carefully standardized and instruments are calibrated daily. Croney (1977) listed three major causes of measurement error: variation in tape tension, failure to accurately locate body landmarks, and postural changes of subject during measurement.

Measurements are routinely replicated with the mean value of the replications used in evaluation and analysis (Croney, 1977; Himes, 1989; Johnson, 1984); two or three measures may be averaged. A certain amount of error is inevitable even with standardized methods and instruments (Kemper and Pieters, 1974). The correlation between the replicated measures, however, should be high.

Multivariate statistical techniques are used to analyze anthropometric data. Factor analysis, for instance, has been used with whole body anthropometry to determine key dimensions (Croney, 1977), although the results have often been replaced by more commonly recognized measures. Principal components analysis is used in assessment of subcutaneous fat patterning (Mueller and Wohlleb, 1981).

Gazzuolo (1985) suggested that pinpoint accuracy in obtaining a series of linear body measurements may not be as important as rapidly determining body shape. Validity of the measurements taken may be more important than absolute accuracy. Croney (1977) suggested practicing the measurement routine beforehand to expedite the measurement process during research.

Accuracy of body measurement is complicated by the fact that the human body is a whole, not composed of segmented parts. For measurement to take place, landmarks on the body must be clearly defined and clearly marked on the skin. If valid as well as reliable measurements are to be taken, body landmarks must be chosen for their ability to define form. There is a need for a theoretical construct to determine what information is needed and how it can be applied to pattern shape (Gazzuolo, 1985).

The most recent developments in anthropometry involve three-dimensional specification of body form (Heisey, Brown and Johnson, 1988). Without a clear theory for the application of body measurement to pattern shape there is no reason to suppose that three-dimensional data will be more useful than two-dimensional.

Sizing

French (1975) identified three aspects of sizing: (a) the relationship between one dimension and another in a particular garment, (b) the size intervals by which one garment is larger that the next larger garment, and (c) what identifying name the size will be given. Proportions, the relationship between one dimension and another in a garment, are determined in the drafting or draping of the pattern.

Sizing standards such as those upon which body forms and slopers are based make use of principal measurements called control or key dimensions (Brunn, 1983; French, 1975). The measures control pattern size since all other body measures are assumed to be dependent dimensions which change with the key measure proportionally. The number of key dimensions is purposely kept to a minimum in hopes that simplicity will promote the use of the standard. The group determining international sizing standards, for instance, agreed to use only 3 to designate each size category (French, 1975).

Key or control dimensions are rather arbitrarily chosen, often from a desire to use body measurements easily understood and accessed by the consumer. The American standard for women's clothing, PS 42-70, uses bust girth and height as controls even though bust girth is a poor predictor of other measurements such as hip girth (Gazzuolo, 1985). Salusso-Deonier et al. (1986) found that PS 42-70 misfit over 50% of the young women in their sample. The German system for sizing men's clothing uses half-chest measure, drop (the difference between chest and waist circumferences) and height (Brunn, 1983).

Research has shown that height and weight are the two measurements that correlate most closely with a large number of body dimensions (Aplin, 1984; McConville and Tebbetts, 1979; Morant, 1948). Lengths of different segments of the body correlate with height; body girths correlate with weight. At the present time, only children's apparel and women's hosiery are sized according to height and weight. New size standards for protective clothing will also be based on these two measures (Prevatt and Keeble, 1991).

Size intervals are determined by pattern grading; the grading process does not carry out a body measurement-based change. Grading is the process of taking a given pattern configuration and changing its absolute size incrementally (Gazzuolo, 1985). Changes are made in equal steps between sizes and calibrated in mathematically convenient fractions of inches to make the grading process easier to accomplish and to facilitate computer use (Brunn, 1983; Salusso-Deonier et al., 1986). It is assumed that the same pattern shape is appropriate for all sizes. Gaetan (1989), however, stated that "although a set of standard graded patterns may be correct for one body form, the set is incomplete if it does not allow for different shapes" (p.31).

The study of size and its consequences, called allometry, is the subject of debate in fields other than patternmaking. Discussion in allometry is focused on whether to consider size and shape together or independently (Corruccini, 1987). In garment patterns the relationship between size and shape is unknown.

Identification labels for garment size categories have been based on height, age, weight and sex of the supposed wearer. Consumer acceptance of size labels is important to clothing sales. Height designations such as Petite or Tall are rather neutral descriptive terms, but weight related designations such as Portly or Chubby are less likely to promote sales.

There is a need for body measurement labelling to indicate the body proportions or shape a garment is intended to fit (Salusso-Deonier et al., 1986). Gazzuolo (1985) stated that fit could be assisted in a practical manner by a construct which links visually perceptible traits to pattern shape.

Sizing Standards in Protective Clothing

There is no single accepted definition for protective clothing. The Federal Register in 1974 carried the following definition for protective clothing: "at least a clean hat with a brim, a clean long-sleeved shirt and long-legged trouser or a coverall type garment, all of a closely woven fabric" (pp. 16888-16891). York and Grey (1986) said that chemical protective clothing is "that clothing designed to afford a known amount of protection against a known type, concentration and length of exposure to a hazardous substance" (p.28). There are many levels of protection afforded by the various styles of protective clothing.

There are also many problems associated with the design and fit of protective garments.

Although the wearing of protective garments during pesticide application has been mandated (Federal Register, 1974) farmers are reluctant to use them. Keeble (1984) found that most Virginia fruit growers wore their usual work shirts and pants for pesticide application. DeJonge, Vredegvood and Henry (1983-84) suggested that protective garments resembling the blue shirt, pants and hat similar to farmers' everyday wear would increase acceptance of protective clothing. They also found comfort to be a very important aspect of protective garments.

Sizing standards for protective garments were established in 1985. Protective clothing standards are one responsibility of American Society for Testing and Materials committee F23 on protective clothing; subcommittee F23.5 is specifically concerned with human factors such as clothing sizing, comfort and stress (Henry, 1988).

Sizing standards "contain sizing systems which are developed by applying a body form classification method to an appropriate data base" (Salusso-Deonier, et al., 1986, p.38). The authors also commented that the adequacy of the standard depends upon the appropriateness of both the classification method and the data base.

Body forms are classified according to chest circumference and inseam length in protective clothing standard ANSI/ISEA 101-1985. No source could be found which listed the data base used.

Because of consumer complaints, protective clothing standard ANSI/ISEA 101-1985 has been subject to revision. The proposed classification method is based on weight and height to cover seven sizes from XS to XXXL; the data base is not stated. An evaluation of the fit of garments made according to the new classification method is in progress (Prevatt and Keeble, 1991).

As Goldstein (1989) noted, standards do not insure good fit. The use of a sizing standard for protective clothing is voluntary so there is a wide variety of garments on the market which do not conform to ANSI/ISEA 101-1985. Eiser (1988) felt that fitting problems will become more complex as both men and women use the available protective garments.

Protective garments have been found to have problems associated with design as well as fit. McGary (1986) listed problems with donning and doffing garments and with zipper locations, especially critical when fast garment removal is necessary. He suggested that performance standards are also desirable.

Van Schoor (1989) used a movement protocol of activities typical of pesticide application to test new coverall designs. She found the use of elastic at waist, ankle and wrist helpful in allowing extra ease for movement while controlling the bulk of excess fabric.

Ashdown (1991) used movement analysis based on techniques described by Crowe and Dewar (1986) to identify the location, direction and amount of stress on protective coveralls used by asbestos abatement workers. She identified the shoulder/armhole area as especially critical and redesigned the underarm of coveralls to include a gusset for extra mobility. McGary (1986) suggested a similar idea, accordion joints, as a desirable design feature.

The Concept of Fit

Although garment fit is an important part of clothing comfort and personal appearance, there is no universally accepted definition for it. Berry (1970) noted that what is considered to be good garment fit changes with the type of garment and the occasion for which it is worn. Gazzuolo (1985) said that individuals bring a perceptual frame of reference to judgements of "good fit". Standards of good fit vary over time, with cultural context and according to personal preference.

LaBat (1987) said that in a broad sense the fit of clothing is the relationship of clothing to the body combining visual analysis and comfort. Damhorst (1989) simply called fit a part of garment/body interaction. Berry (1970) offered a broader explanation of the interaction: "Fit is a correspondence in dimensional form or shape and in placement of detail between the outer covering and the figure to provide for physical structure and for activity of the wearer, to suit the purpose of the garment, and to fulfill the intended style without distortion . . ." (p.6). One of the few constants in literature about fit is the desirability of what Erwin and Kinchen (1969) called smooth set: the lack of wrinkles caused by body distortion of fabric grain and seam lines.

Berry chose the term correspondence to define fit because most garments are not exact duplications of body form. Gazzuolo (1985) preferred abstraction as a general descriptor because, as in abstract art, the design of a garment duplicates the shape of some body parts (the slope of shoulder, the curve of hipline) but exaggerates or ignores others. Gazzuolo considered every garment to be an abstraction of the body to some degree: the looser the fit, the more "abstract" the garment.

Gazzuolo (1985) used the term abstraction to encompass all of the various elements of fit. Erwin and Kinchen (1969) identified five elements of fit: ease, line, grain, set and balance. In an examination of the fitting literature, Gazzuolo found that these five elements were frequently listed a part of fit along with a sixth element, aesthetic considerations. Gazzuolo's 1985 thesis listed five elements of fit also. They are ease, suspension, balance, division, reduction and correspondence. Gazzuolo's elements of fit included most of the elements identified by Erwin and Kinchen. A brief discussion of the elements follows.

Ease

Berry (1970) defined ease as "the perpendicular distance between any point on the pattern (or the finished garment) and the figure directly inside" (p.6). There are essentially two types of ease: minimum wearing ease and design ease. Minimum wearing ease provides room for comfort and movement; design ease provides enough fullness to achieve a desired style.

The amount of ease in garments varies considerably. Berry (1970) felt that ease was determined by type of fabric, garment style, wearer's figure and activity, and wearer's preference. Erwin and Kinchen (1969) listed the following as reasons for variation in amounts of ease: fashion, body build, personality, age, fabric, activity and occasion.

In a more technical discussion of ease, Gazzuolo (1985) stated that "ease at any given level of a garment may reflect the surface measurements of a prominence at a different level" (p.77). Since a single garment, such as a dress, may fit many different areas of a figure, it must be large enough to cover the largest part of that figure. The amount of fabric needed to cover a large figure area will help to determine the amount of ease in smaller figure areas. Gazzuolo also noted that fabric usually spans the hollows between body prominences creating areas where the garment does not lie along the body surface.

Suspension

The suspension of a garment is the manner in which it is supported by the body. A "stabile" garment is built upward from a base resting on a bony prominence (a strapless dress, for instance), while a "mobile" garment hangs from above and falls in free drape below (Berry, 1970). Gazzuolo (1985) noted that garment suspension is often achieved in "mobile" garments by constriction of fabric into a circumference smaller that the largest body prominence. A waistline, for instance, is constricted by means of fasteners or elastic so that a skirt or pants cannot fall down over the hips.

Reduction

Reduction refers to contouring devices such as darts and dart equivalents (gathers or pleats) which remove fabric so the garment conforms to body contours. Reduction techniques may be used to assist in constricting a garment near areas of suspension (Gazzuolo, 1985).

Balance

Balance refers to the relative lengths of the front and back of the body which determine fabric grain alignment with the midline of the body (Gazzuolo, 1985). Erwin and Kinchen (1969) also considered balance as the comparative size of left and right sides of the figure; this would also determine fabric grain alignment with the body's midline.

Grain

For both Gazzuolo (1985) and Erwin and Kinchen (1969), the position of the lengthwise and crosswise threads in woven fabric (grain) was a clue to the balance of the garment. When woven fabric is constructed into garments, the lengthwise grain is usually placed parallel to the vertical axis of the body; the crosswise grain is perpendicular to the lengthwise.

Division

Division, according to Gazzuolo (1985), is location and position of garment seamlines. Erwin and Kinchen (1969) referred to the same idea as "line". Of particular interest is the location and position of the garment side seam. Most authors agree that the side seam should be plumb, but the location at which the plumbline is held varies. Berry (1970) and Erwin and Kinchen (1969) felt that a side seam should bisect the lateral view of the body from front to back. Since body bulges are not uniform as viewed from the side, Gazzuolo (1985) noted that there may be considerable variation in side seam position depending upon which body area is bisected. Gazzuolo preferred to use the most lateral extension of the thigh at the level of the greater trochanter to determine side seam location.

Correspondence

In Gazzuolo's (1985) context, correspondence is the matching of major pattern points to anatomical landmarks when the assembled garment is worn. The closer a garment fits, the more points of correspondence.

Theory Development in Fitting

Interest in a theoretical basis for fitting is of fairly recent date, probably prompted by the increased use of computers in the manufacture of clothing. As previously mentioned, no comprehensive theory which relates pattern shape variance to body form variance exists. There is no widely accepted model for the physical process of fitting.

Gazzuolo (1985) proposed a theoretical framework as a means of examining all of the various aspects of garment fitting. Her proposed components, given in order, are as follows:

1. The Analytical Component composed of a detailed verbal description of garment abstraction, an operational definition of garment-to-body relationship, and a methodological design for application of measurement data to pattern development.
2. The Dimensional Component composed of anthropometric data collection, determination of size categories and grading increments.
3. The visual Component which takes visually apparent body traits that identify body forms in a size range to make a composite image for size identification.
4. The Physiological Component which provides a vocabulary for description of body form variables and their causes.

Gazzuolo's framework formed the basis for her own research in fitting so it has been tested to some extent, though it has not been replicated by anyone else to date. Other theory development in fitting has been concerned with modeling the process of making pattern shape match body form.

Statements of rules for the manipulation of standard slopers in the formation of various garment styles are found in instructions for the flat pattern method of patternmaking (Armstrong, 1987; Brockman, 1965; Hollen, 1972). These rules contain implicit assumptions and a few explicit statements about the geometric basis of patternmaking.

A major component of flat pattern technique is dart manipulation. Fitting darts, triangular folds in cloth that fit flat fabric to body curves, are a necessary part of every pattern and every garment. The bust point (nipple) is the focal point of dart manipulation in the front bodice. The front bodice of women's patterns is traditionally used to illustrate dart manipulation because it represents the most complete application of darts to figure; the same technique can be used (with a few modifications) to the back bodice and skirt patterns.

The area surrounding the bust point is described as a full circle (360^0) when the pattern is flat. Fitting darts radiate from the bust point, their wedge shapes describing arcs of the circle. Dart size is measured by the angle of the dart at the tip. The larger the body bulge, the larger the angle of the fitting dart. Fitting darts may be rotated around the bust point to any position without changing fit as long as the dart angle is unchanged. As the dart is stitched during garment construction, a cone shaped bulge is created in fabric to fit around the bulge in the figure.

Recently attempts have been made to model the process of fitting pattern shape to body form using geometric relationships as their basis. Although the geometric basis has been assumed, the mathematics of the assumption has not been examined. Heisey, Brown and Johnson (1988) stated that the lack of mathematical analysis has resulted in failure to develop scientific methodology for fitting garments.

Three geometric models of the fitting process have been presented. Gazzuolo (1985) modeled the garment as a cylinder. Heisey, Brown and Johnson (1988) and Winakor, Beck and Park (1990) used truncated cone models.

Gazzuolo did not examine the mathematics of her model. She visualized the garment as a cylinder of woven fabric large enough to surround the largest body circumference, then reduced by darts and seams to fit body concavities. The method emphasizes fabric grain as a pre-existing set of coordinates for a two-dimensional surface upon which pattern points may be plotted. Identifying straight grain with the plumbline of gravity provides the connection between three-dimensional body form and two-dimensional pattern shape.

Heisey et al. (1988) developed the idea that the physical process of fitting a garment can be modelled with mathematical mapping and projection techniques. Three-dimensional coordinates for points on the body must be transformed into two-dimensional coordinates for points on the pattern in a systematic manner using functional relationships.

Mapping and projection techniques provide the systematic element in the Heisey et al. model, but projection techniques involve some distortion as coordinates are mapped. Distortion may not be conducive to good fit. The authors suggest that the mapper must choose a distortion which reflects the way specific fabrics distort when worn. They do not suggest how this might be accomplished. Their model has not been tested.

The functional relationship in Heisey et al. is the geometry of a cone. Heisey (1984) said that for any portion of a garment that can be modeled as a cone, a direct geometric relationship exists. An advantage of conic models according to Winakor et al. (1990) is that conic surfaces can be unrolled to form flat surfaces without loss of information.

Heisey et al. (1988) modeled the bodice from bust to waist as a series of upright right circular cones. Reductions (darts and seams) are determined by graphic somatometry. Winakor, Beck and Park (1990) modeled the bodice from bust to waist as an upside-down truncated cone with a hyperelliptical base that represents the cross section of the body through the bustline. This model was tested with some success but not to the authors' complete satisfaction.

Neither conic model attempted to fit the chest, neck or shoulders; a vertically oriented cone simply does not apply to the shape of those areas. Both models were thought to be applicable to the lower body from waist to hip although modelling the side hip curve has proved to be a problem.

Solinger (1988) described the female figure from neck to bust as a truncated elliptical cone section which rests on the base of an inverted truncated oblique cone representing the figure from bust to waist. Solinger, however, generated the pattern for the female front bodice as follows:

> "The entire surface can be generated in one movement of the straight edge by fixing one end of the straight edge at the bust point and then rotating the straight edge around the fixed point; the revolving straight edge can then generate the surface" (p.74).

Solinger's pattern development method is based on the conic model implicit in flat pattern methodology. His measurement techniques do not relate directly to either conic model.

Two other geometric models are briefly mentioned in the fitting literature, but less is known about the methodology. Appel and Stein (1972, 1978) used three-dimensional data and projection techniques to form a pattern composed of 31 three-and-four sided facets. Efrat (1982) defined a basic bodice composed of 30 three-sided facets, 15 for the front and 15 for the back. All facets are triangles which share a common vertex (bust point in front bodice) with other vertices on the perimeter. The Efrat model was tested with apparent success.

The Efrat and Appel and Stein models have been criticized on two major points (Heisey et al., 1988). First, body landmarks were thought to have been chosen so that body specification, garment approximation and flattening to pattern shape could be accomplished simultaneously. It was also felt that the models forced the form of the garment to be approximated by facets when the garment is actually a continuous curve. Continuous measurement-to-drafting process may be efficient and not necessarily lacking in strict methodology. It is also not easy to see how a triangle differs conspicuously from a three-sided facet.

A paper pattern almost always approximates body form in a different manner than flexible cloth does. All of the geometric models have some difficulty interpreting smooth curves. Some of the success of the pattern depends upon the skill of the sewer.

At the present time no single model has been accepted as the best representation of the fitting process. The geometric models represent a beginning in what appears to be the right direction, although there is still the need for more theoretical work.

Morphometrics

It is sometimes profitable to look to other areas of study to gain insight into new approaches or methodologies. Morphometrics in evolutionary biology and anthropology shares common goals with fitting and patternmaking. Morphometrics attempts to find ways to compare biological forms for the discrimination of groups and the description of change. It is also concerned with collection and manipulation of data on form differences (Bookstein, Chernoff, Elder, Humphries, Smith and Strauss, 1985).

Morphometrics, like patternmaking, studies biological questions using geometric information. Bookstein, Chernoff, Elder, Humphries, Smith and Strauss (1985) said that the idea of a simple and recognizable geometrical pattern of explanation for shape change has long fascinated biologists. Cheverud, Lewis, Bachrach and Lew (1983) called the concept anatomical geometry. The concept of shape in morphometrics is made operational using ratios of measured distance. Geometric data may be recorded as collections of measured distances, coordinates of landmark points, landmarks supplemented by information about the curving of form between them, or information about curving of form with no landmarks.

A landmark in morphometrics is an identifiable point with a reliable anatomical definition (Bookstein et al., 1985). For biological forms to be comparable, their landmarks must be homologous: having the same relative position, proportion, value or structure. Body landmarks in fitting share these properties.

Bookstein et al. (1985) stressed flexibility of morphometric methods. In their opinion, no methodology can be wrong in all contexts and no method is universally applicable. It is necessary to match morphometric machinery to biological context.

A morphometric method proposed by Yasui (1986) seemed especially applicable to patternmaking. Yasui began with the premise that illustrations of forms are helpful in understanding those forms but are not capable of being statistically analyzed. In his view, if visual image and quantitative treatment could be merged, the combination would be a powerful tool in morphometric analysis.

Yasui stated that comparison of two-dimensional images needs at least one reference point and a common orientation. His choice of reference point was the figure centroid of the area enclosed by the figure outline because it has no dependence on any point on the outline and includes all information about it. Measurements are taken from the centroid to the outline. Yasui preferred measurement from the centroid using it as the center of rotation for radii at specified angle increments. Ramaekers (1975) proposed a similar method of measuring from centroid to specific landmarks.

CHAPTER III

MANUSCRIPT I

Measurement from Pattern Centroid: An Application of the Flat Pattern Conic Model

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Abstract

This study investigated the use of the flat pattern conic model for body form implicit in the flat pattern method of patternmaking combined with a morphometric measurement technique for drafting individually fitted patterns. Measurements of 24 female body forms were taken. Lengths of lines from bust point to body landmarks and sizes of angles between the lines were determined. A pattern was drafted for each form and an average pattern based on measurement means was drawn for five forms with bust size 37. Individual patterns showed great variability in shape due to variable angle sizes; line measurements were more consistent. The average pattern fit only one of five size 37 forms. Results suggest that accurate pattern drafting requires assessment of angles between linear measurements to capture body shape.

Measurement from Pattern Centroid: An Application of the Flat Pattern Conic Model

Problems with fit are common in the American apparel industry. Sizing standards and the data upon which they are based are of limited usefulness for many categories of apparel (Delk and Cassill, 1989; Giddings and Boles, 1990; Orzechowski and Forney, 1988; Patterson, 1982; Salusso-Deonier, DeLong, Martin and Krohn, 1986; Woodson and Horridge, 1990). Garment sizing, however, is only one portion of the fit problem. Of equal importance is the "cut" of clothing: the shape of a pattern as it relates to the form of the human body.

There is no commonly accepted comprehensive theoretical framework which relates body form variance to pattern shape variation. A few statements of a theoretical nature exist in instructions for dart manipulation used in the flat pattern method of pattern development. Research in fitting theory has been stimulated by the use of computers in patternmaking; the geometry of producing a two-dimensional pattern which corresponds to a three-dimensional form has been of particular interest. An adjunct to any theoretical approach to fitting is the measurement technique which provides necessary data.

Recent research in the geometry of fitting includes studies by Gazzuolo (1985), Heisey, Brown and Johnson (1988), and Winakor, Beck and Park (1990). Gazzuolo modeled the body as a cylinder; a planar measurement technique was used to assess body dimensions. Studies by Heisey et al.(1988) and Winakor et al.(1990) modeled portions of the bodice as truncated cones. Heisey et al. (1988) modeled the lower bodice as a series of upright circular cones. Positions and angles for darts and seams were determined by graphic somatometry. Graphic somatometry requires a photograph of body silhouette to provide information about body angles, but some angles cannot be analyzed in this fashion because detail is lost with silhouette photography. Winakor, Beck and Park (1990) also used graphic somatometry to assess body angles. They modeled the bodice from bust to waist as an upside-down truncated cone with a hyperelliptical base representing the cross section of the body through the bustline.

The flat pattern method of pattern development assumes a conic model: the front bodice area (shoulder to waistline) is modeled as a cone with the bust point as its apex (Armstrong, 1987; Brockman, 1965; Hollen, 1972). When the bust cone is flattened to a circle to form the pattern, the open wedge created in the process becomes the bust fitting dart. Dart size is measured by the angle of the dart at the tip: the larger the body bulge, the larger the angle of the fitting dart. Fitting darts may be rotated around the bust point to any position without changing fit as long as the dart angle is unchanged. As the dart is stitched during garment construction, a cone shaped bulge is created in fabric to fit around the bulge in the figure. Solinger (1988) referred to this model when he discussed generating a bodice pattern by fixing one end of a straight edge at the bust point, then rotating the straight edge around the fixed point to produce the pattern surface; Efrat (1982) used a similar model with apparent success.

One major problem with any geometric model for fit is that the human body is not a collection of regularly shaped geometric components. The cylinder and truncated cone models described above do not attempt to fit the shoulder, neck and armscye. The flat pattern conic model assumes a bust circle, but in fact the completed bodice pattern has an irregular outline. An additional problem lies with the collection of measurements relevant to pattern drafting. Solinger (1988) stated that the measurements found in Voluntary Product Standard PS 42-70 are insufficient for drafting a closely fitted pattern. These standard measurements, as is customary for any fitting-related work, are composed of body length, width and circumference measures.

It is often informative to investigate other areas of study for solutions to familiar problems. Morphometrics, the quantification of shape, is used in evolutionary biology and anthropology for purposes common to fitting and patternmaking. Cheverud, Lewis, Bachrach and Lew (1983) called the concept anatomical geometry. Morphometrics attempts to find ways to compare biological forms for the discrimination of groups and the description of change. It is also concerned with collection and manipulation of data on form differences (Bookstein, Chernoff, Elder, Humphries, Smith and Strauss, 1985).

The concept of shape in morphometrics is made operational using ratios of measured distance. Geometric data may be recorded as collections of measured distances, coordinates of landmark points, landmarks supplemented by information about the curving of form between them, or information about curving of form with no landmarks. A landmark in morphometrics is an identifiable point with a reliable anatomical definition (Bookstein et al., 1985). For biological forms to be comparable, their landmarks must be <u>homologous</u>: having the same relative position, proportion, value or structure. Bookstein et al. (1985) stressed flexibility of morphometric methods, and the necessity of matching morphometric method with biological context: a single way of measuring need not work in all instances. A morphometric method proposed by Yasui (1986) seems especially applicable to patternmaking.

Yasui felt that two-dimensional illustrations were helpful in understanding forms but illustrations could not be statistically analyzed. Measurements alone provide little information about shape. However, if visual image and statistical analysis were merged, the combination would be a powerful morphometric tool. Yasui stated that comparison of two-dimensional images needed one common reference point and a common orientation. The preferred reference point was the centroid of the area enclosed by the figure outline because it had no dependence on any point on the outline and included all information about it. Lines which radiated from the centroid to the outline were measured; the centroid served as the point of rotation for the lines. Yasui measured skull outlines using a radius every one degree around the circle. Yasui's methodology may be combined with the flat pattern conic model by using the bust point as figure centroid for radial measurement.

Very little quantitative information about body form variance exists. Measurement data taken using Yasui's methodology may provide useful details about body form that can be analyzed in a variety of ways. The range and standard deviation of line measures provides information about the variability of individuals within a group, data of use to pattern graders. The ratio of one line length to an adjacent line length may be calculated to describe figure shape. Shoulder slope, for example, could be specified in this manner. Yasui constructed an averaged outline from mean radius lengths for each group analyzed. In a similar manner, mean line lengths and angle sizes may be used to construct an "average" pattern for a group. Average patterns may be compared to determine differences between the shapes of various groups, and individual pattern outlines may be compared to examine the differences from the average group pattern.

The overall purpose of this study was to test the reliability and validity of the conic model implicit in the techniques of flat pattern design, combined with the measurement and data analysis technique described by Yasui (1986). The overall purpose was addressed by: 1) measuring the front bodice of female body forms by determining the lengths of radii from bust point to selected body landmarks and the size of angles between the radii, 2) drafting a front bodice pattern for each form based on the line and angle measurements, 3) evaluating the fit of the patterns on the body forms, and statistically analyzing the line and angle data collected.

The front bodice area of the figure was chosen because in females this area represents the most complete application of the conic model. The same model is assumed to apply to the chest area of men's patterns: the only difference in men's patterns is that the most prominent bulge may be either the chest or waist (Solinger, 1988).

The conic model is also assumed to apply, with modifications, to other figure prominences.

Method

Subjects

Twenty-four standard commercial and individualized female body forms were available in the Apparel Design Laboratory at Oklahoma State University. Body form bust circumferences ranged from 31 inches to 39 inches with the sizes distributed as follows: two size 31, three size 33, 6 size 34, five size 35, three size 36, four size 37, and one size 39. These forms constituted a convenience sample that provided some variety of shape and size. Since the measurement technique was not refined, body forms were a more forgiving sample for experimentation than human subjects would be.

Preliminary Measurement and Pattern Draft Trials

Prior to measuring the forms, preliminary measurement trials were conducted using a form not included in the sample. Changes were made in measurement and pattern drafting methodologies based on the experience gained during these trials. First, it seemed that large errors might be associated with the measurement of large angles. Two areas, the shoulder seam and the side seam, were particularly troublesome. As a result, an additional point was added at the midpoint of each of the two seamlines to divide each pattern segment into two smaller angles. The addition of those two points, however, made it possible for the shoulder seam and side seam to be curved lines rather than straight lines. It was decided at that time to retain the additional points in an attempt to take more accurate angle measurements, but not to use the line measurements to the two seam midpoints in drawing the seam lines. Shoulder seams and side seams were drawn as straight lines: the actual shape of the shoulder and side seams may be a topic for future study.

It also seemed useful to draw the center front of the pattern as a straight line. If each angle between radial lines around the bust point is measured directly, the center front of the pattern is not necessarily a straight line. Yasui's comparison of two-dimensional images required a common point of reference and a common orientation. The bust point is the common point of reference for bodice patterns; aligning the straight center front line of patterns provides a common orientation. It is difficult, however, to directly measure the two angles that contain the area from bust point to center front line when center front is kept straight: some ease or space is included. If the line from the bust point to the center front line is drawn perpendicular to center front, two right triangles are formed: bust point-to-center-front-to-neck-center, and bust-point-to-center-front-to-waist-center. With the measured lengths of lines from bust point to neck center and waist center, it is possible to derive the two angles at bust point since a right triangle may be constructed from only two other parts, at least one of which is a side.

Drawing the center front as a straight line introduced some ease into the pattern, however, no design ease was added. Fitting ease was limited to that included by measuring from one body prominence to another, spanning body hollows rather than measuring the depressions: essentially the same effect as keeping the center front of the pattern straight rather than fitting into the hollow between the breasts.

Angle measurements were initially taken with a protractor held against the marked body form, but this method was awkward and its accuracy questionable. An adjustable metal compass which could be fixed on an angle setting was used instead, and its measurement compared to angle measurements on the protractor.

Marking the Forms

Points representing real body landmarks were marked on one side of each form. Since there is no universally preferred side of the body to measure, the left side was chosen arbitrarily. Body forms usually have seams at traditional pattern seamline locations so landmarks were defined in terms of pattern seam locations. Points were marked with a straight pin inserted so the pin head designated the intersection of two seams. Figure 1 shows the points marked including: bust point (B), center front neckline (D), shoulder seam at neckline (E), shoulder seam midpoint (F), shoulder seam at armhole (G), armhole breakpoint (H), armhole at side seam (I), side seam midpoint (J), side seam at waistline (K), bust dart location at waistline (L and M), and waistline seam at center front (N). The shoulder seam midpoint (F) and side seam midpoint (J) were added to produce smaller angles. The length of the lines from bust point to F and J were not used to create the shoulder and side seam lines as previously noted.

Insert Figure 1 about here

Point C was not marked as the other points; it was determined during the measuring process.

Measuring the Forms

Two strands of non-stretch braid were used to mark the lines from bust point to body landmarks as shown in Figure 2. Each strand was 36" long; each was marked with indelible ink at its midpoint (18") and at two points 1 1/2" in each direction from the midpoint.

The two strands were placed one on top of the other with midpoints matched and pinned in place at the bust point of each body form. Only two strands of braid were used

Insert Figure 2 about here

because it seemed possible that an individual strand for each line to be measured would be unnecessarily bulky at the bust point and might distort length and angle measurements.

Line BC was established first. One strand of braid attached to the bust point on the measured side of the form was stretched across and pinned to the bust point on the unmeasured side. The length of BC equals half of that measured distance from bust point to bust point (Minott, 1988; Brinson, 1977; Brockman, 1965). Line BD was pinned in place and its length measured with a non-stretch measuring tape. Angle CBD was not measured, but was determined in pattern drafting as previously discussed.

The braid forming the line from bust point to bust point was detached from right side bust point; its opposite end was pivoted, stretched taut, and pinned to point E. Line BE was measured. Angle DBE was measured as the distance between the two marked points 1 1/2" from the bust point with a protractor and compass. The remaining lines and angles were marked and measured in the same manner, moving clockwise around the bust circle. Exceptions to this procedure included lines BL and BM which form two sides of the dart and are equal, requiring only one length measurement, and angle LBM which was developed as the pattern was drafted. Line BN and angle CBN were measured in the same manner as BD and CBD.

All measurements were recorded on a measurement form, along with information identifying the body form measured, the bust circumference of the form, and the date. In addition, the length of the shoulder line (EG) and the side seam line (IK) were measured and recorded. Measurement of a single form took about 25 minutes to accomplish.

<u>Pattern Drafting</u>

A front bodice pattern was drafted for each body form using the measurements obtained by the methods described above. First, as shown in Figure 3, a vertical line approximately 24" in length was drawn on pattern tissue. Point C was marked halfway along its length. Line CB was drawn at a right angle to the original line; the length of CB was half of the bust point to bust point measure taken on the body form.

Insert Figure 3 about here

Lines BD and BN were drawn to their measured lengths so that they intersected with the original base line. Line BM was drawn to the appropriate measured length using the measured angle NBM for placement in relationship to line BN. Line BE was drawn in the same manner using angle DBE to place it in relationship to line BD. The remaining lines were drawn to their measured lengths in a similar fashion, working in a clockwise direction around the bust circle. Angle LBM was formed as the "gap" remaining in the circle after all other measured angles were drawn; its size was determined from the drafted pattern and recorded on the measurement sheet. Shoulder seam line EG and side seam line IK were drawn as straight lines. Neckline DE, armscye GHI, and waistline segments KL and MN were drawn using standard curved pattern rulers.

Evaluating Pattern Fit

As a preliminary step in evaluating pattern fit, recorded measurements for shoulder seam and side seam lengths were compared to the lengths of the drafted pattern lines. To evaluate the fit of each bodice pattern, the paper pattern was placed on the appropriate body form by first pinning the bust point in place, then matching pattern points to the appropriate landmarks on the form. Pin fitting a paper pattern has been determined to produce the best means of evaluating pattern fit (Androsko, 1957).

Pattern paper should lie smoothly over the surface of the body form without wrinkles; pattern points should match body landmarks. Pattern fit was evaluated by the researcher.

Pattern Corrections

Pattern corrections were made as the pattern was evaluated on the body form. Excess paper was folded or the pattern slashed to allow extra space so that pattern points coincided with body landmarks. The amount and placement of pattern corrections was recorded, with the correction denoted by a dotted line.

Statistical Analysis

Sample means, ranges, variances and standard deviations were calculated for each measured line and angle. As recommended by Yasui (1986), an averaged pattern outline was constructed for one size group within the sample using the mean values for lines and angles. Yasui used the averaged outline as a summary of the characteristic shape of the sample as a whole. The sample of individual patterns was compared to the averaged outline to establish the variation within this group of body forms.

Pearson correlation matrices were calculated for both the line and angle data. Anthropometric data are often reduced using Principal Components Analysis or Factor

Analysis techniques to determine the measurements which are most useful in predicting the size of other body areas. Height, for instance, is a good predictor of other body lengths. If the line or angle data showed sufficient intercorrelation, it might be possible to take fewer measurements without loss of information.

Morphometrics uses ratios of measured distances to explain shape. To investigate the usefulness of ratios for describing pattern shape, the ratio of shoulder line BE to BG was calculated as a means of determining shoulder slope.

Results

Pattern Drafting and Evaluation

Only one line length error in line BE, and a total of 43 angle errors were discovered when individual drafted patterns were placed on the body forms. Twenty-six of the 43 errors were overestimations of angle size. Table 1 shows, for instance, that for form number 2, angle DBE was one degree larger than it should have been for the pattern to fit smoothly and correspond with body landmarks. Combined side seam angles IBJ and JBK contained a total of 16 errors. Three pattern areas accounted for 34 of 43 errors: the neck, shoulder and side seam.

Although there was error in measurement on 20 of the 24 forms, most of the errors were very small. Forms 12 and 19 were both customized body forms padded with cotton: a very soft surface compared with the papier mache or foam used in the remainder of the forms. Research has shown that soft body tissue is more difficult to measure accurately than bone (Gavan, 1950; Carr, Rempel and Ross,1989). The same may be true of body forms with soft surfaces. Measurements of forms 21 through 24 differ from the others in that they are underestimations of angle size. These four forms are similar in that they have large dart angles indicating a prominent bustline.

Insert Table 1 about here

Since the dart angle should equal the difference between 360^0 and the sum of the remaining angles, corrected angle measurements were summed for each pattern and the total subtracted from 360^0 as a way of checking the method. Differences between measured dart angles and the dart angle required to make a complete circle ranged from one degree to fourteen degrees. Twenty-one of twenty-four patterns (88%) had some dart error, with 17 of the 21 being underestimations of the dart angle. Most of the errors were of five degrees or less. Four patterns had significant errors of 8, 8, 10 and 14 degrees respectively; two were underestimations (8 and 10) and two were overestimations (8 and 14).

Comparative Analysis of Line and Angle Data

Minimum size, maximum size, range and standard deviation of each line is shown in Table 2. Range and standard deviations for all lines except line BC are about 2 to 2.5" and .5 respectively.

Insert Table 2 about here

Table 3 lists the minimum size, maximum size, range and standard deviations for all angles. Angle sizes were more

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Insert Table 3 about here

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variable than line lengths. The dart angle, LBM, showed the greatest variability with a range and standard deviation almost twice that of any other angle. Side seam angle IBJ also is more variable than the remaining angles.

Averaged Pattern Outline and Comparison of Pattern Outlines

Yasui used an outline drawn from mean sample measurements as a way to summarize the characteristic shape of the group. For this study, one group within the sample was selected and an averaged outline drafted for that group to assess the value of an averaged bodice pattern. A group of five forms with bust circumferences of 37 inches (bust circumferences from 36.5 inches to 37.5 inches) was selected. Figure 4 shows the averaged outline for forms with bust size 37 compared to the five pattern outlines for individual forms.

Insert Figure 4 about here

Pearson Correlations for Line and Angle Data

The Pearson correlation matrix for line data shown in Table 4 indicates that all lines are positively correlated with adjacent lines; nine of the ten possible correlations

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Insert Table 4 about here

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are greater than .50. Line BF, bust to mid-shoulder, appears to be a good predictor of pattern length above the bustpoint: correlation between BF and BE is .83, between BF and BG is .94.

The Pearson correlation matrix for angle data (Table 5) shows that the angle sizes are much less interrelated than

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Insert Table 5 about here

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the line lengths. Only two correlations are greater than .50: angles EBF and FBG have a positive correlation of .69, angles HBI and GBH show a negative correlation of .57. No angle is a very reliable predictor of the size of any of the other angles.

Analysis of Pattern Ratios

Table 6 gives a comparison of the two lines between the bust point (B) and points E and G which mark the neck and armscye ends of the shoulder seam. The differences in line

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Insert Table 6 about here

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lengths range from .5" to 1.625"; ratios of measured distances (BG divided by BE) range from .85 to .95. The average difference between the two lines for this sample is 1.05"; thirteen of the twenty-four forms have a ratio of .88 to .91.

Discussion and Conclusions

Measurement of body angles is recognized as an important element of garment fit but has been attempted only indirectly through graphic somatometry; direct measurement of angles between measured lines is a new approach. Current pattern drafting and grading methods are dependent upon measurement data alone; information about body shape is seldom considered. Research in graphic somatometry has indicated, however, that use of body angle measurements plus body shape information can improve garment fit (Douty and Ziegler, 1980; Pouliot and Farrell, 1980). Graphic somatometry provides visual information about body proportions, contours and posture through silhouette photographs. Some exterior body angles can be assessed by this method also.

Researchers using graphic somatometry do not attempt to replace measurement data with visual information but to supplement it. Yasui (1986) also felt that the combination of visual information about shape plus measurement data provided the most complete assessment of a figure. The results of the current study indicate that both linear measurement of figure length, width, and circumference, plus measurement of the angles between the lines are necessary to produce a pattern that accurately reflects the form it is drafted to fit.

Line data for this sample of body forms are remarkably consistent. Although the size range of forms is not wide, the figures represent several brands, ages, and types of body forms. In addition, some forms were customized with supplemental padding. Despite these differences, the table illustrating variability in line data could serve as a specification sheet for a standard pattern grade.

Angle data exhibited more variability than line data. It was anticipated that the dart angle would be variable; this angle should reflect the differences in bust shapes. The side seam area was quite variable also. Winakor et al. (1990) had difficulty fitting the side seam with computer drafted patterns based on a conic model. One possible explanation is that the dart angle is measured at the bust point, but the bulge of the bustline rarely extends to the side seam; the figure is usually flatter at the side. The measured angle is therefore too large as it reaches the side seam, making that seam too long. When clothing is constructed, the sewn dart is the so-called "dressmaker" dart which is not stitched to the bust point, thus releasing extra fabric to fit the bustline bulge. This allows the sewn bust dart to be somewhat smaller than the drafted dart would measure at the bust point.

Contrasts between line data and angle data are apparent in correlations within each type of data also. The Pearson correlation matrix for line data shows sufficiently high correlations between lines to make data reduction seem possible. It would seem reasonable to use a very few "key" measures to predict the remaining lengths and widths of the figure. The angle data, however, does not exhibit many significant correlations. Each of the angles appears to be unique, making any data reduction a loss of necessary information.

A further confirmation of the importance of both line and angle methods is demonstrated by drafting an averaged pattern for the sample. Yasui suggested this method as a way of classifying forms (male vs.female forms in his study) for both intergroup and intragroup comparisons. The sample of patterns for forms with bust measurements of 37 inches differ dramatically in shape from the averaged pattern for that group. Even in a small sample, most of the individuals would be misfit by the averaged pattern. Since the line lengths are consistent, the angles between the line lengths are the source of the shape differences. The averaged pattern outline combined with only linear measurements might lead one to expect a homogeneous sample of standard body forms rather than the variety exhibited by the patterns drafted using angle measurements also.

As Yasui (1986) suggested, analysis of line ratios may be a source of shape information. For this study, the relationship of the lines that extend from bust point to the ends of the shoulder seam was examined. The ratios obtained when line BG is compared to line BE indicate that the most common "drop" in shoulder slope for this sample is about 10%. Ratios for the sample range from .85 to .95. These results may be due to the use of body forms for this study. Although data from a larger sample of human subjects is necessary before any definitive statement can be made, results of this study suggest that ratio analysis is a simple, effective way to describe shoulder slope.

The conic model implicit in the flat pattern method of patternmaking appears to have distinct advantages in capturing pattern shape when combined with a measurement technique that allows for an irregular pattern outline. This study treated the shape of the pattern in a traditional fashion, maintaining straight lines in center front, shoulder and side seam areas. Although the methodology could be used to obtain a far more precise and detailed picture of body shape, a few carefully selected body landmarks provide adequate information for a pattern draft. Most clothing would include more ease and be less closely-fitted to the body than the basic patterns drafted for this study.

The combination of flat-pattern conic model with line and angle measurements facilitated pattern drafting and made pattern alterations easy to accomplish. Errors were more prevalent in angle than line measurements, but were small and easy to correct. Location of a misfit was obvious when the pattern was placed on the form and matched with body landmarks, so the location for necessary pattern alterations was obvious also. Alteration of the pattern was most easily accomplished by increasing or decreasing the affected pattern angle.

Yasui (1986) indicated that "overshoot" errors were a common occurrence with his method, even using computer digitizing techniques. Many of the errors found in patterns for this sample of body forms involved overestimation of angle sizes. In consequence, errors in dart angle size were underestimations. Overestimation may occur because angle measurements were taken in progression around the bust circle. An error in measurement of one angle might be carried forward to the next angle and so on around the circle, potentially magnifying the original error. One solution to the problem might be to measure the bodice angles in two half-circle segments, starting at line BE and progressing first clockwise to the dart line (BLM) then counter-clockwise to the same location.

The method for taking measurements needs improvement in speed as well as accuracy. As used in this study, measurement techniques were slow and tedious, taking about 25 minutes per form. Measurement of live subjects needs to be faster to avoid fatigue and the movement that results from impatience. Other areas of the body such as the back bodice and hipline need to be measured also, but may require variation in measurement technique or an adaptation of the conic model.

The overall purpose of this study was to test the reliability and validity of the conic model implicit in flat pattern design, combined with a measurement and data analysis technique described by Yasui (1986) both for pattern drafting and description of body shape. The model reliably described the front bodice of twenty-four female forms. The measurement technique requires refinement and further testing to establish reliability. Both model and measurement technique seem valid for the front bodice of female body forms. Measurement of body lengths from bust point to selected body landmarks provides data that may be unambiguously applied to the task of drafting a front bodice pattern for a female figure. Measurement of angles between linear measures provides a way to capture the shape of pattern necessary to fit an individual figure. Since information about body angles is incomplete with graphic somatometry, direct measurement is needed. Using both line and angle data it is possible to produce a good fit for individual patterns and to quantify aspects of body form variation.

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Table 1

Amount and Direction of Errors in Angle Measurements.

Form	DBE	EBF	FBG	GBH	HBI	IBJ	JBK	KBL	MBN
2	+1				−3			+3	
4	+4		−3				−2	−3	
5			+2				+4	+7	+4
6	+4						−2		
7						+3			
8	−3	+5							
9	+6			+4		+6			
10	+5				+6				
11			+1				−1		
12	+4					+11	−5		
13							+3		
15	+3				−2				
17			+3						
18						+6			
19						+10	+8		
20	+4		+2						
21			−3				−5		
22			−4				−4		
23			−5				−1		
24			−6				−4		
Total No. of Errors	9	1	9	1	3	5	11	3	1

Note. Sizes of errors in degrees.

Table 2.

Variation in Line Data for Body Form Sample.

Line	Minimum	Maximum	Range	Standard Deviation
BC	3.25"	4.63"	1.40"	0.33
BD	7.50"	10.00"	2.50"	0.56
BE	9.00"	11.50"	2.50"	0.52
BF	8.25"	10.25"	2.00"	0.47
BG	8.13"	10.25"	2.13"	0.48
BH	4.00"	6.13"	2.13"	0.54
BI	4.88"	7.00"	2.13"	0.46
BJ	5.13"	7.25"	2.13"	0.50
BK	7.50"	9.75"	2.25"	0.59
BL-BM	6.00"	8.25"	2.25"	0.55
BN	6.75"	9.00"	2.25"	0.56"

Table 3.

Variation in Angle Data for Body Form Sample.

Angle	Minimum	Maximum	Range	Standard Deviation
CBD	60	66	6	1.68
DBE	16	25	9	2.37
EBF	8	18	10	2.70
FBG	10	20	10	2.80
GBH	10	25	15	3.90
HBI	16	37	21	5.70
IBJ	21	46	25	7.50
JBK	16	30	14	3.90
KBL	22	42	20	4.20
LBM	12	55	42	11.60
MBN	17	37	20	4.50
NBC	57	66	9	2.60

Note. All figures given in degrees.

Table 4.

Pearson Correlation Matrix for Body Form Line Measurements.

Line	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BLM	BN
BC	1										
BD	.71	1									
BE	.51	.75	1								
BF	.38	.56	.83	1							
BG	.24	.44	.78	.94	1						
BH	.35	.56	.42	.45	.46	1					
BI	.27	.51	.42	.52	.56	.80	1				
BJ	.21	.42	.29	.57	.55	.64	.66	1			
BK	.20	.27	.13	.32	.29	.17	.14	.65	1		
BLM	.24	.07	−.10	.01	−.07	−.22	−.30	.22	.80	1	
BN	.39	.16	.02	.03	−.07	−.19	−.29	.18	.75	.95	1

Table 5.

Pearson Correlation Matrix for Body Form Angle Measurements.

Angle	CBD	DBE	EBF	FBG	GBH	HBI	IBJ	JBK	KBL	LBM	MBN	NBC
CBD	1											
DBE	-.14	1										
EBF	.05	-.41	1									
FBG	-.24	.34	-.69	1								
GBH	.05	-.11	-.12	.04	1							
HBI	.08	.17	.31	-.26	-.57	1						
IBJ	-.27	.10	.10	.04	.09	.09	1					
JBK	.10	-.23	-.24	.04	-.05	-.30	-.49	1				
KBL	.15	-.29	-.14	-.15	.35	-.18	.11	.11	1			
LBM	-.18	-.18	-.07	.09	-.24	-.22	-.62	.10	-.43	1		
MBN	-.03	.02	.03	-.19	.23	-.23	.00	.36	.28	-.43	1	
NBC	.45	.13	.13	.02	.05	.22	.00	-.22	-.35	-.12	-.49	1

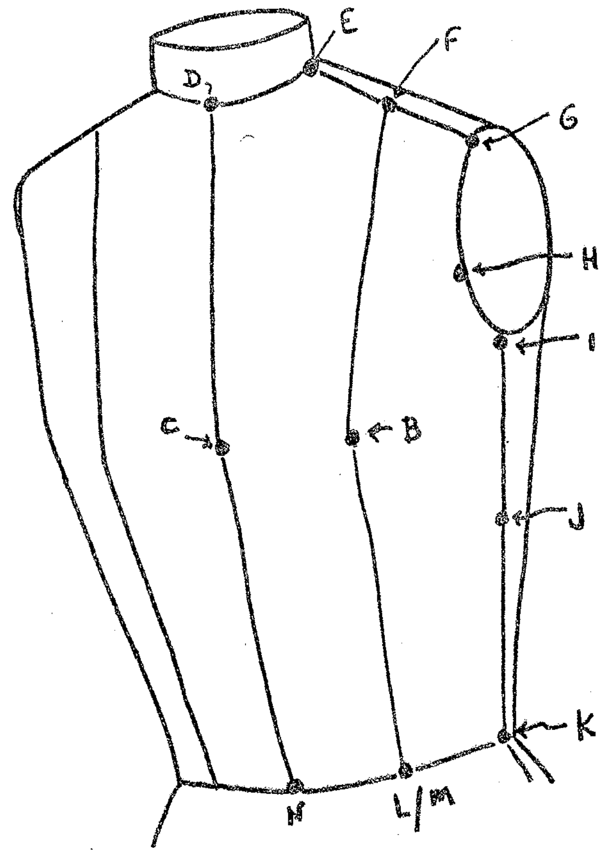
Table 6.

Comparison of Lines BE and BG Measured on Body Forms.

Form	Length of BE	Length of BG	Difference: BE - BG	Ratio BG/BE
1	10.125	9.125	1.00	.90
2	10.50	9.375	1.125	.89
3	9.00	8.125	.875	.90
4	10.25	9.75	.50	.95
5	11.50	10.00	1.50	.87
6	10.375	9.50	.875	.92
7	10.50	9.375	1.125	.89
8	10.75	9.125	1.625	.85
9	10.75	10.25	.50	.95
10	9.75	8.375	1.375	.86
11	10.125	9.375	.75	.93
12	10.125	9.25	.875	.91
13	10.50	9.25	1.25	.88
14	9.50	8.75	.75	.92
15	10.50	9.375	1.125	.89
16	10.25	9.00	1.25	.88
17	9.875	8.875	1.00	.90
18	10.75	9.25	1.50	.86
19	10.00	9.00	1.00	.90
20	10.375	9.50	.875	.92
21	10.25	9.375	.875	.92
22	11.25	9.625	1.625	.86
23	10.25	9.00	1.25	.88
24	10.50	10.00	.50	.95

Note. Line lengths in inches.

Figure Captions



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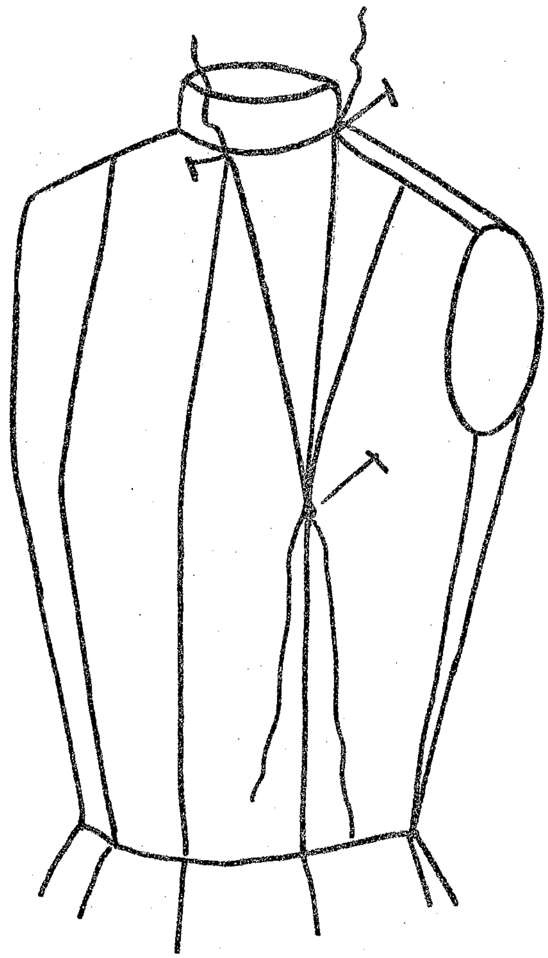

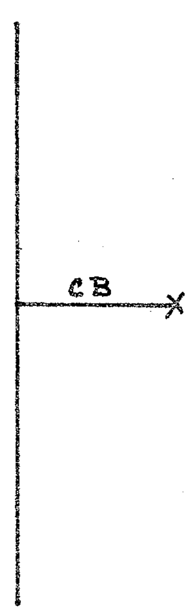
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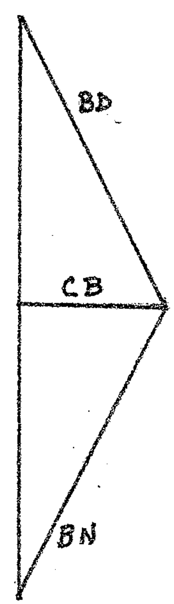
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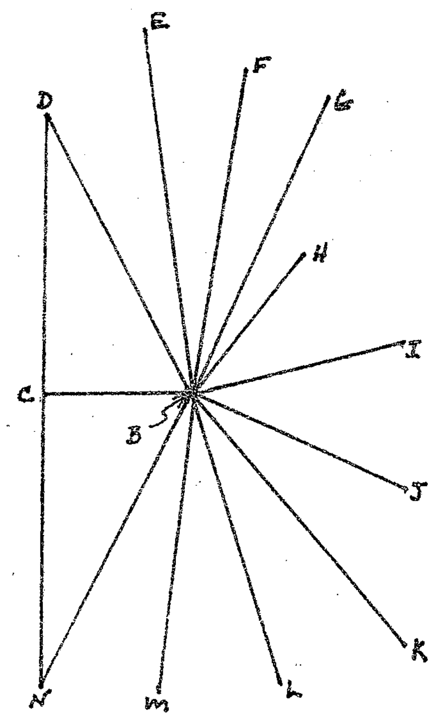
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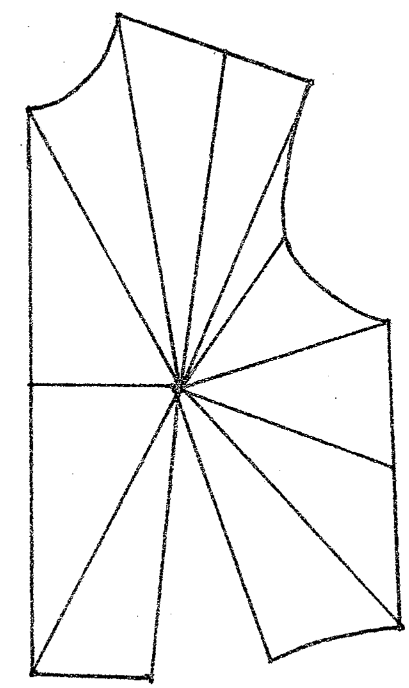

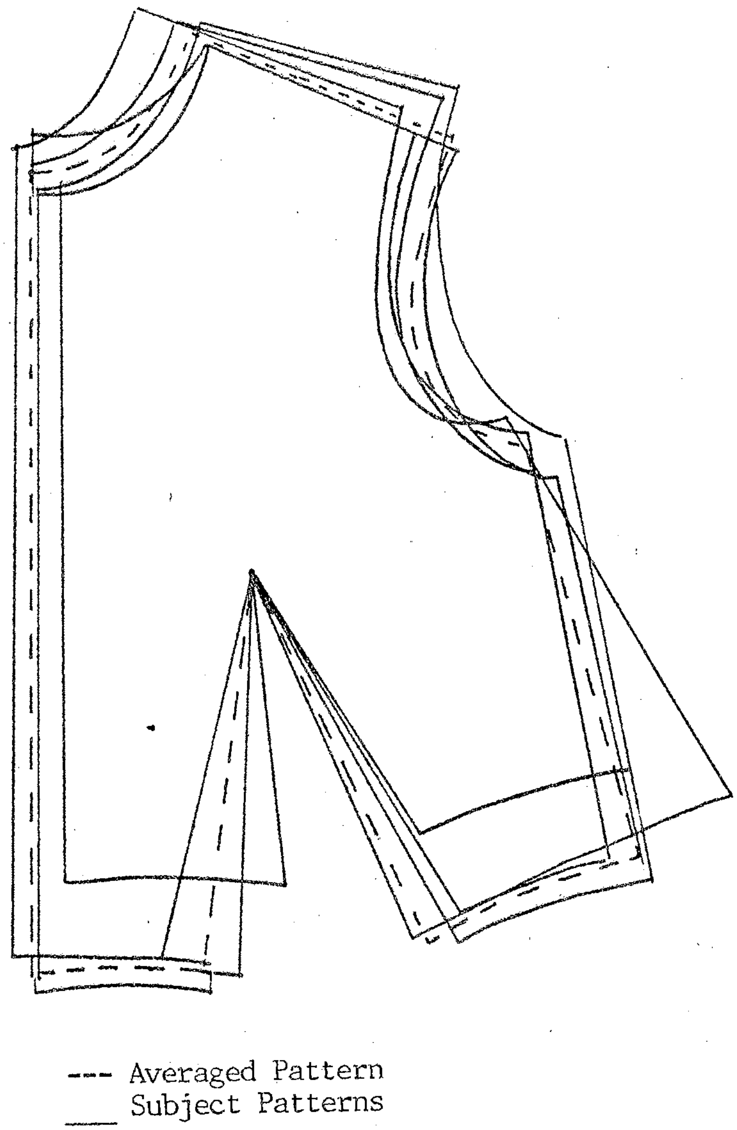

CHAPTER IV

MANUSCRIPT II

Planar Measurement of Body Shape: An Application of the Flat Pattern Conic Model

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Abstract

This study applied a conic model implicit in the flat pattern method of patternmaking with a morphometric measurement concept to measurement of human subjects. Planar-type measurement instruments were used to assess the front bodice of 50 male subjects selected to conform to size categories for protective garments. Findings suggest that increases in chest circumference are not predictive of proportional increases in shoulder length. Subject armscye and waistline shapes varied with the presence of fat versus muscle tissue. A noticeable drop in the waistline seam at center front for subjects in all size categories indicates the desirability of additional front opening length in protective garments.

Planar Measurement of Body Shape: An Application of the Flat Pattern Conic Model

Poor fit in protective garments for individuals who handle hazardous substances has serious consequences when it interferes with the protective function of the clothing. Clothing and personal equipment are key elements in programs designed to minimize worker contact with potential toxins (Raheel, 1988). When poorly fitted garments are stressed, resulting rips and tears may increase wearer exposure to substances such as pesticides and occlusion (covering) of a substance accidentally admitted under fabric increases its absorption (Wester and Maibach, 1985).

To address the problem of poor fit, voluntary size standards with minimum garment size requirements were established for protective garments in 1985 by the American National Standards Institute (ANSI) as ANSI/ISEA 101-1985. The standard provides minimum chest and inseam garment measurements for protective coveralls in five sizes: Small, Medium, Large, Extra-Large, and Extra-Extra-Large. Research is in progress to improve the minimum size standards (Prevatt and Keeble, 1991). Garment size, however, is only a part of garment fit (Goldstein, 1989; Glock and Kunz, 1990). Also of importance is the "cut" of clothing: the shape of the pattern as it relates to the form of the human body. At the present time there is no consistent approach to relate pattern shape to body form.

Research into the theoretical relationship between pattern shape and body form has been stimulated by the use of computers in patternmaking. The geometric model used to translate a three-dimensional form into a two-dimensional pattern has been of particular interest. Closely allied to the geometric model is the measurement technique used to assess the body form and provide data for pattern development. Recent research in the geometry of fitting includes studies by Gazzuolo (1985) who modeled the body as a cylinder using a planar measurement technique to determine body dimensions, and Heisey, Brown and Johnson (1986) and Winakor, Beck and Park (1990) who developed conic models using graphic somatometry to assess body angles. These proposed geometric models were helpful in fitting the body from bust to waist, but none addressed the entire upper body. The neck and shoulder areas are not readily defined by an upright cone.

The flat pattern method of pattern development also assumes a conic model: the front bodice area (shoulder to waistline) is modeled as a cone with the bust point as its apex (Armstrong, 1987; Brockman, 1965; Hollen, 1972). When the bust cone is flattened to a circle to form the pattern, the open wedge created in the process becomes the bust fitting dart. Dart size is measured by the angle of the dart at the tip: the larger the body bulge, the larger the angle of the fitting dart. The relationship of dart angle size to body bulge size suggests that pattern angles may be an important part of proper fit.

A recent study by King and Branson (1993) combined the flat pattern conic model with a morphometric measuring technique that provided a means of determining figure shape. Length measurements taken along radii from the bust point to selected body landmarks made it possible to maintain the circular nature of the flattened cone while providing information about the shape of pattern outline appropriate to a particular body. Angle sizes between measured lines were also determined; the sum of measured angles subtracted from the 360^0 in a full circle provided the size of dart necessary to fit the figure. Angle sizes were determined to be critical to development of a pattern which reflected body form. Line and angle information supplied by the radial measurement technique could also be analyzed statistically for information about the shape of the sample group as a whole.

While the measurement technique used by King and Branson (1993) provided valuable information about body form, the methodology was used to measure dress forms only and was judged too slow to be used on live subjects. Gazzuolo (1985) developed a system of "planar measurement":

measuring the human form using pieces of nonwoven interfacing marked with a one-centimeter grid. Measurement over the surface of the body was thought to be more relevant to patternmaking than linear measurements. Planar measurement was also faster than a series of linear measurements so subject fatigue was less. Gazzuolo suggested that pinpoint accuracy in obtaining a series of linear body measurements may not be as important as rapidly determining body shape.

The purpose of this study was to apply the flat pattern conic model combined with radial measurement from the bust point to selected body landmarks as proposed by King and Branson (1993) to measurement of male subjects using a modification of Gazzuolo's planar technique. Since the need for improved fit is so great in protective clothing, the ANSI size standards for protective garments were used to determine the study sample.

Method

Subjects

Fifty male volunteer subjects were measured. Qualified subjects were determined through assessment of chest circumference and inseam length. Subjects were given a baseball-style cap for their participation. Ten subjects were chosen for each of the five size categories of

ANSI/ISEA 101-1985 sizing standard for protective clothing: Small, Medium, Large, Extra-Large, and Extra-Extra-Large. The measurements given in the sizing standard are garment measures. Because no body measurements were available from protective clothing sources, major catalogue company size charts were consulted for appropriate body measurements. These were: small, chest 34-36", inseam 26.5-27.5"; medium, chest 38-40", inseam 27-28"; large, chest 42-44", inseam 28-29"; extra-large, chest 46-48", inseam 28.5-29.5"; extra-extra-large, chest 50-52", inseam 29-30".

Marking Body Landmarks

Body measurements were taken over a knit undershirt which served both as a surface on which to mark body landmarks and a place to attach the measuring device. Subjects also wore sweatpants or shorts with elastic waistbands. Body landmarks were marked with small adhesive-backed paper dots on the left side of the body. Body landmark locations approximating those marked by King and Branson (1993) were marked with the exception of points F and J, the shoulder and side seam midpoints, as shown in Figure 5. The change in measuring technique makes those

Insert Figure 5 about here

points unnecessary. The following body landmarks were located:

B. Breast point or nipple marked on left and right sides

D. Center front at neckline: the midpoint between the sterno-cleido mastoid tendons at the attachment to the sternum

E. Shoulder seam at neckline: the point where the trapezius muscle and the sterno-cleido mastoid separate

G. Shoulder seam at armscye: the intersection of the ridge of the scapular spine with the trapezius ridge at the acromion process

H. Front break point: the pectoral attachment of the arm to the trunk

I. Side seam at armscye: a point in the axillary space midway between the front break point and the back break point (latissimus dorsi attachment of the arm to the trunk)

K. Side seam at waistline: waistline was located using the elastic waistband as a guideline; side seam position was located plumb from the side seam at armscye point

L/M. Dart position: a point at which a line from the bust point forms a right angle with the waistline

N. Center front at waistline: a point at the waistline plumb from the center-front-at-neckline.

Measurement Instrument

A variation of Gazzuolo's technique was used to measure male subjects. A 25" wide by 30" long rectangle of nonwoven polyester interfacing (shown as A in Figure 6) was marked with a point located 12.5" from either side and 13" from the

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Insert Figure 6 about here

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top. Two lines, one horizontal marked H, H' and one vertical marked V, V', were drawn through the center point, dividing the rectangle into 4 segments. Additional radii were marked from the center in five-degree increments in a circular fashion.

All lines were screen printed on the nonwoven interfacing in black ink. Since the heat used to set the ink caused some distortion of lines and angles, it was decided to also use a second instrument. A second 25" wide by 30" long rectangle of nonwoven polyester interfacing, designated as B in Figure 6, was marked in indelible ink with the same bust point, horizontal (H, H') and vertical (V,V') lines as the previous instrument; radii were omitted on the second instrument. Measurements were taken with both instruments and the data were averaged for analysis. Correlations between the two sets of measurements were calculated. Each measuring device was pinned to the subject's undershirt with the center point over the marked breast point. The portion of line H, H' from the breast point to the center of the figure was levelled to reach from breast point to breast point.

The remainder of the body landmark locations were transferred to the interfacing using an indelible marking pen (laundry marker). Some pinning was necessary to hold the measuring device in position. Excess fabric within the circle was pinned as a dart in the breast point to mid-waistline location.

Measuring devices were removed from the subjects and the adhesive markings and waistline marker removed. Each measuring device was coded for subject and dated. Lines and angles were measured and the length of each line and size of each angle recorded on a data sheet. The measuring technique essentially formed the pattern as the data was collected; it was only necessary to "connect the dots".

Results

Fifty male volunteer subjects who conformed to the five ANSI categories for protective coverall sizing, ten subjects per category, were measured for this study. Subjects were selected by measuring chest circumferences and inseam lengths of volunteers. Those whose combination of chest and inseam sizes corresponded to one of the five ANSI/ISEA 101-1985 size categories were asked to participate in the study. Participants were given a baseball-style cap in thanks for their cooperation.

Subjects ranged in age from 14 to 62 years. Mean subject ages for each size category were as follows: Small, 26 years; Medium, 31 years; Large, 36.7 years; Extra-Large, 40.3 years; Extra-Extra-Large, 34.1 years. Chest size tended to increase with age from size Small through size Extra-Large; subjects in the Extra-Extra-Large category, however, were younger on average than those in the Large or Extra-Large categories.

Traditional body measurements including chest circumference, shoulder length, side seam length, center front length and inseam length were taken for each subject using a tape measure. Average measurements for each group are given in Table 7. In general, average length

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Insert Table 7 about here

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measurements increased with chest circumference with the exception of side seam length which showed no discernible pattern. Average side seam length for the size Medium group was the shortest, followed in ascending order by those of the Extra-Large, Small, Large and Extra-Extra-Large groups.

Average center front lengths increased with chest circumference except for the Medium group which had the shortest center front measure. Specific measurements for each subject may be found in Appendix G.

Average shoulder seam lengths did increase with average chest circumference but the range of the increases was small. Mean lengths ranged from 5.52 inches for the size Small group to 5.8 inches for the Extra-Extra-Large group. Three-tenths of an inch is a minor amount of change when compared to mean chest circumferences which increased fifteen inches from Small to Extra-Extra-Large. A standard grade increase for men's shoulder seams is 1/16 inch (.063") of shoulder length for each inch of chest circumference; the expected range for this sample would be .94 inches (Kawashima, 1986). The range of individual shoulder seam lengths was 2.25 inches, the sample mean 5.64 inches, and the standard deviation .596 inches. The smallest shoulder length of 4.4 inches was found on subjects in sizes Small, Large and Extra-Large categories. The longest shoulder seam, 6.75 inches in length, was found on one Extra-Large subject.

Inseam lengths specified for the ANSI size categories generally increase with chest circumference, but the size groups are not mutually exclusive. For instance, size Small lists inseam lengths from 26 1/2" to 27 1/2", while size Medium lists inseam lengths from 27" to 28"; a 27 1/2" inseam length may be found in both categories. Average inseam lengths for subjects in this study increased with chest size with the exception of the Extra-Large group which had an average inseam length of 28.9"; that inseam length was second in order of increasing length.

The remaining line and angle measurements were taken with the two nonwoven interfacing instruments labelled A and B as previously described. When two or more measurement instruments are used it is customary to calculate the mean of the instrument readings for each measurement and use the mean value of the replications in evaluation and analysis (Croney, 1977; Himes, 1989; Johnson, 1984). A certain amount of error is expected (Kemper and Pieters, 1974), but the correlation between the replicated measures should be high. The results of the two instruments were compared using two-tailed t-tests for differences in paired data (Ott, 1988). Results of t-tests for line data are shown in Table 8 and for angle data in Table 9.

Insert Table 8 about here

Insert Table 9 about here

Paired t-tests indicate that there are significant differences in the results obtained from the two measuring devices for all measured lines and angles (p–value $<.005$). The signs of the differences were not predominantly positive or negative so it does not appear that one instrument is more accurate than the other. It is possible that the differences were due to shifting of fabric layers as the sheets of interfacing were pinned and unpinned from t–shirts; the t–shirts were rarely skin tight. More accurate measurements might be taken without a shirt, but there is a risk of less subject cooperation.

Group average lengths of all radial lines were calculated by adding the averaged line measures for each subject in the group and dividing that sum by ten. Mean line lengths are given in Table 10. For most of

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Insert Table 10 about here

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the measured radial lines, the tendency is for line length to increase with chest size. The subjects in the Medium size category, however, have less length in the lower torso than the Small subjects. Extra–Large subjects have shorter average distances from bust point to shoulder and armscye than the Large subjects. Extra–Extra–Large subjects measured slightly less from bust point to neck and from bust point to armscye than did large subjects.

Group average sizes of all measured angles were calculated by adding the averaged angle measures for each subject in the group and dividing that sum by ten. Table 11 lists average angle sizes for each size category.

Insert Table 11 about here

Some general trends may be seen: angle CBD, the upper center front, decreases with chest size; angle DBE, the neck angle, increases with chest size; both angle IBJ and KBL, the waistline angles, increase with chest size. There is also a slight tendency for the shoulder angle, EBG, to decrease as the neck angle, DBE, increases. Observation of the subjects suggests that muscular development such as that due to weight lifting which changes the definition and size of the trapezius muscle would give this result.

Mean line and angle sizes were used to draft an average pattern outline for each size group. Average pattern outlines, although they may not accurately fit many individuals within the group, are useful for intergroup comparisons and identification of trends. Average pattern outlines for the five size groups are shown in Figure 7.

Insert Figure 7 about here

As King and Branson (1993) found, the average pattern for even a small group does not reflect the shape differences that may be seen in individual pattern outlines.

Observations of the front armscye and the front waistline of subjects were of particular interest. Pattern A in Figure 8 shows the typical armscye for the sample. Forty-one of fifty sample patterns (82%) were of this shape. Pattern B with a deeply indented armscye curve is typical of patterns for 4 subjects (8%). The indented armscye shape was associated with noticeable muscular development of the shoulder, chest and arm. Pattern C was typical of patterns for 5 of 50 subjects who had more soft body tissue in the armscye area.

Insert Figure 8 about here

Differences due to fat versus muscle tissue could be seen at the waistline also. As individual patterns were evaluated it became apparent that several in each size category exhibited a noticeable drop in the waistline seam from side seam to center front. Some of the patterns with a long center front were drafted for subjects with visceral ptosis (potbelly), but others appeared to be due to posture. Some subjects stood with the abdomen pushed forward and a pronounced curve to the lower back. Pattern A in Figure 9 illustrates waist seam shape as it is commonly drafted for men's patterns, a straight line from side seam forming a right angle with the center front line. Eight of fifty subjects (16%) were fit by patterns with a straight waist seam. Pattern B in Figure 9 illustrates the waistline configuration found in the remaining 42 of 50 patterns. The waistline seam drops from point K at side seam to the dart position; on some patterns it continues to drop to the center front.

Insert Figure 9 about here

It also appeared that the shape of the lower bodice pattern from chest to waistline at the side seam for the sample formed three groups: patterns that narrowed from chest to waist as shown by Pattern A in Figure 10, patterns that formed a straight line from chest to waist as shown in Pattern B, and patterns that widened from chest to waist as seen in Pattern C. The drop from side seam to center front occurred in members of all three shape-groups.

Insert Figure 10 about here

King and Branson (1993) introduced the concept of an index, a ratio of two measured lines, to provide information about shoulder slope. The same technique is useful for this sample to describe the waistline drop as well as slope of the shoulder. The ratio of line BN to BK was used to describe the waistline drop. Ratios ranged from .80 indicating the most extreme center front drop, to 1.12

indicating an almost straight waistline seam. Average waistline drop index for each size group is as follows: small, .96; medium, .93; large, .95; extra-large, .94; extra-extra-large, .91. These numbers may suggest that the distribution of waistline shapes is similar for the size groups, or may be the result of small sample size which allows one extreme measurement to unduly impact the mean.

Shoulder slope for female body forms was calculated by dividing line lengths from bust point to side neck into length from bust point to shoulder at armscye (King and Branson, 1993). Similarly, for this sample shoulder slope was described by the ratio of line BE to line BG. Shoulder slope ratios for female body forms ranged from .85 to .95 with a mean of .90. Shoulder slope ratios for this sample of males ranged from .79 to 1.0, with a mean of .88. Although the larger range of ratios for the male sample may be due to larger sample size, observation of the subjects indicates that development of the trapezius muscle appears to increase shoulder slope.

Discussion and Conclusions

The conic model for body form when combined with a morphometric measurement technique that relates directly to the model may be used successfully to describe the pattern shape which fits the front bodice area of male subjects.

The data collected suggest that current assumptions about the shape of men's garment patterns and the scales used to grade them may not be appropriate.

Sizing systems for men's clothes, including ANSI/ISEA 101-1985 for protective coveralls, assume that increased body circumferences are associated with increased body lengths. A further assumption carried out in pattern grading is that length in one body area is associated with length in others, and that width in one body area assumes width in others. Average line and angle measurements and average pattern outlines for the five size-groups analyzed for this study indicate that subjects' body proportions were not that consistent. Subjects with chest measurements in the Extra-Large category had average inseam lengths longer only than the Small group. Subjects in the Medium group with short measurements from bust point to waistline did not have inseam measurements indicating that the Medium group was shorter than expected; subject selection based on the size standard eliminated potential subjects of much-less-than-expected height.

The two largest size categories exhibited very short lengths above the bust point, an area that includes the front of the armscye. Individual patterns for subjects indicate that the armscye shape was inconsistent as well, with variation apparently due to the presence of fat versus muscle tissue. The size and shape of the pattern armscye is critical for adequate arm movement when a garment is worn. Contrary to expectation, extra length in the armscye does not provide extra room for movement. When combined with a shoulder seam that is also long, an armscye designed with excess fabric in the underarm area may actually make it difficult for the wearer to raise his arm, a safety concern for protective clothing wearers.

Shoulder length measurements from the smallest group to the largest did not increase in the same increments that are used to grade men's patterns (Kawashima, 1986). Average angle measurements illustrated the variability of the upper chest area also. The angle encompassing the upper center front area decreased with increasing chest size while a large neck angle was often associated with a decrease in shoulder length. Patterns are graded on the assumption that the two measurements increase proportionally.

Results of this study suggest that individuals with extreme muscular development may have problems with garment fit. Muscular development may increase the size of some parts of the body; it certainly changes their shape. Development of the trapezius muscle in particular seemed to alter the shape of the shoulder and neck, resulting in a larger neck, and a more sloped, but not necessarily wider, shoulder. Patterns for some of the more muscular subjects for this study had a large neck, very sloped shoulders, deeply curved short armscyes, and a tapered waist. Men's shirts are routinely made with different waistline shapes such as tapered, regular, or full fit. Men's suits, however, have similar waistline variations for the jacket, but the trouser waistline is apt to grow with chest circumference.

The drop in waistline seam from the side seam to center front found in subjects in all five size categories is a finding with serious implications for garment fit. One piece garments such as protective coveralls would be greatly improved by an increase in length of zipper opening to make the garment easier to don and doff. A too-short opening makes a one-piece protective garment nearly impossible to don quickly. Likewise, a contaminated garment without adequate opening length would require far too much handling for safe removal.

Further research on pattern shape variation as related to body form variance is needed. The flat pattern conic model used in this study was helpful in capturing front bodice shape and size. Measurement from the bust point to selected landmarks had the advantage of determining body size and shape with a few pertinent measurements. The measurement technique, however, still needs work. Yasui used computer digitizing techniques and anyone attempting a large body measurement effort would no doubt do likewise, but an individual patternmaker might not have access to computer equipment. A simple measurement instrument would be helpful. Gazzuolo's planar measurement concept has promise as it is much faster to use than a traditional measuring tape. If further research in the area of garment fit confirms the results suggested by this study, the impact on the apparel industry could be profound.

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Table 7

Average Subject Measurements for Men in Each Protective Clothing Size Group

Measurement	S	M	L	XL	XXL
Chest Circumference	35.35	38.88	42.65	46.5	50.5
Shoulder Length	5.52	5.57	5.6	5.68	5.8
Side Seam Length	10.39	9.9	10.7	10.31	10.98
Center Front Length	18.22	17.78	19.26	19.33	19.78
Inseam Length	28.3	29.7	29.9	28.9	30.2

Note. Measurements given in inches.

Table 8

Results of Paired t-tests Comparing Line Data from Measurement Instruments A and B.

	BC	BD	BE	BG	BH	BI	BK	BLM	BN
Mean Difference	.19	.21	.17	.18	.19	.24	.19	.21	.22
Standard Deviation	.20	.23	.19	.20	.25	.31	.24	.22	.26
t-calc.*	6.5	6.6	6.4	6.3	5.4	5.7	5.6	7.0	6.0

Note. Mean differences in inches.
*P-value in all cases <.005

Table 9

Results of Paired t-tests Comparing Angle Data from Measurement Instruments A and B.

	CBD	DBE	EBG	GBH	HBI	SIDE	KBL	DART	MBN	NBC
Mean Difference	1.6	1.2	1.3	1.9	2.7	2.1	1.9	.6	1.8	1.9
Standard Deviation	1.5	1.7	1.3	1.7	2.9	2.2	1.8	1.0	1.8	2.2
t-calc.*	7.3	5.1	6.8	7.8	6.6	6.6	7.2	4.4	6.7	6.3

Note. Mean differences given in degrees.
*P-Value in all cases <.005

Table 10

Mean Lengths of Radial Lines Measured on Male Subjects

	Size Groups				
Line	Sm.	Med.	Lg.	X-Lg.	XX-Lg.
BC	3.62	4.26	4.77	4.97	5.19
BD	7.70	8.35	8.97	9.02	8.96
BE	10.33	10.92	11.53	11.63	11.72
BF	8.99	9.77	10.36	10.23	10.54
BG	4.63	5.07	5.65	5.55	5.63
BH	6.00	6.23	7.43	7.50	8.04
BI	11.43	10.69	11.98	12.07	12.23
DART	11.26	10.30	11.40	11.78	12.31
BL	11.93	11.48	12.64	12.93	13.62

Note. Line lengths in inches.

Table 11

Mean Sizes of Bodice Angles Measured on Male Subjects

	Size Groups				
Angle	Sm.	Med.	Lg.	X-Lg.	XX-Lg.
CBD	62.25	59.15	58.98	57.30	54.75
DBE	26.65	27.63	27.63	28.35	30.90
EBF	31.85	29.95	28.37	28.50	28.90
FBG	22.90	19.35	23.28	24.60	21.90
GBH	33.55	36.40	34.92	35.15	33.40
HBI	64.65	64.75	62.55	57.05	61.05
IBJ	24.95	28.48	30.20	34.45	35.40
DART	3.65	5.10	5.80	4.60	3.55
KBL	17.25	21.15	21.78	22.10	22.30
LBC	72.75	67.35	67.30	67.50	67.00

Note. Angle sizes in degrees.

Figure Captions

Figure 5. Body landmarks as marked on male versus female subjects

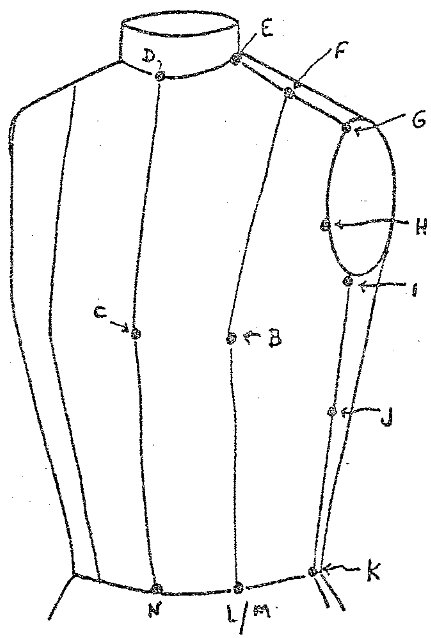
Figure 6. Planar measuring devices A and B

Figure 7. Average pattern outlines for five size groups

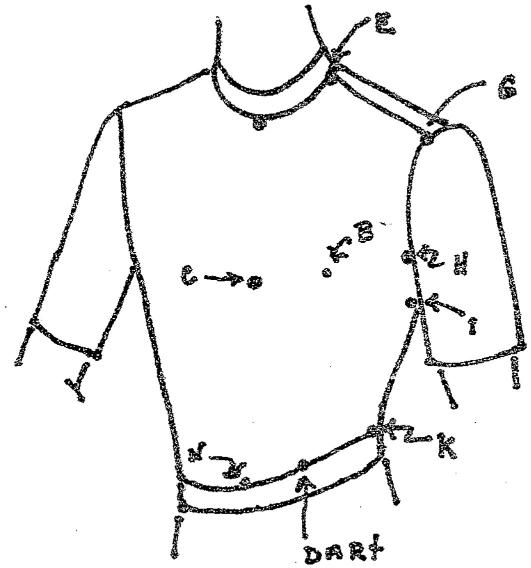
Figure 8. Variation in pattern armscye shapes

Figure 9. Commonly drafted waistline seam versus waist seam drop found in the sample

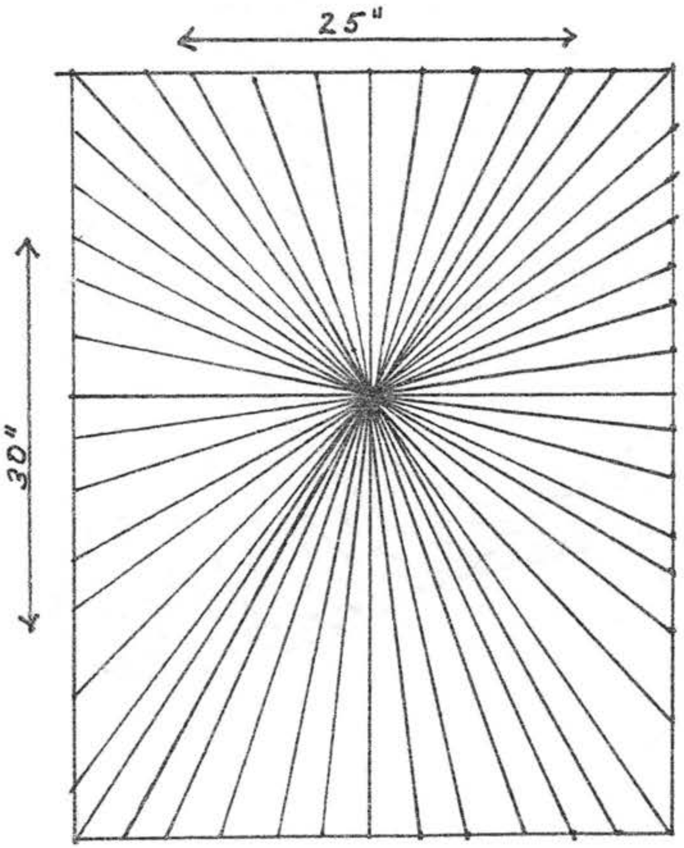
Figure 10. Lower bodice shapes found for male subjects



FEMALE BODY FORMS



MALE SUBJECTS



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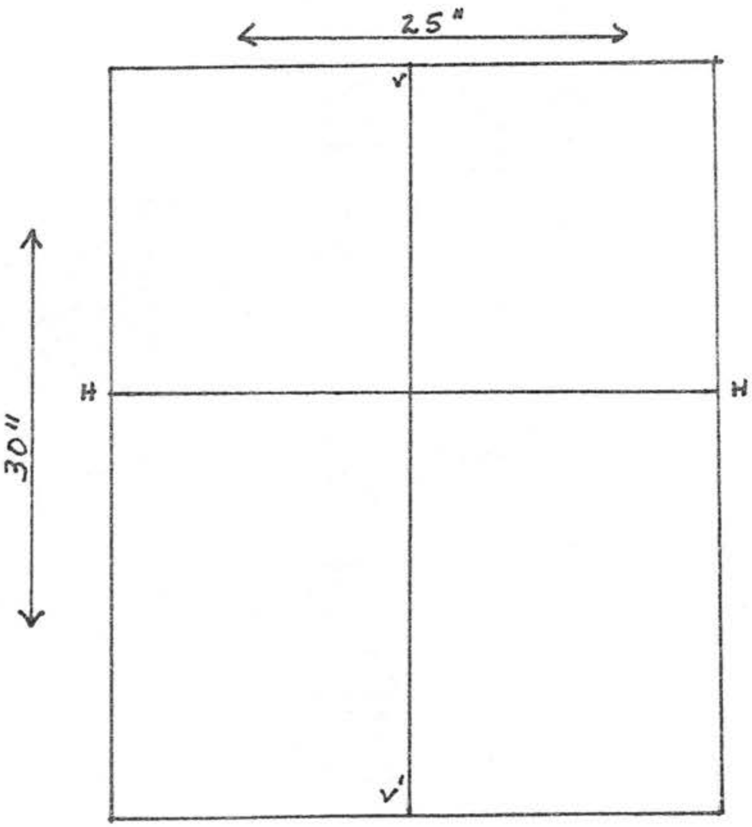

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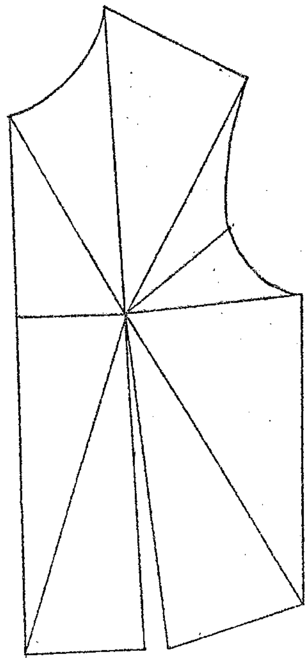

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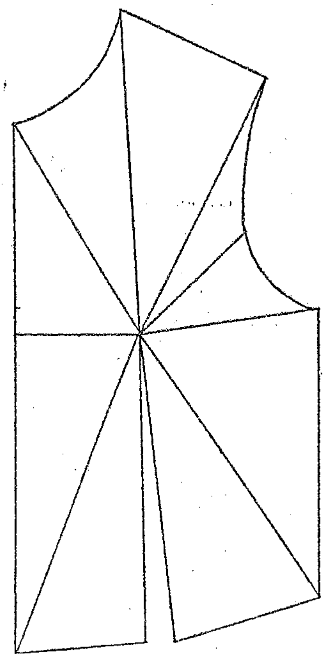

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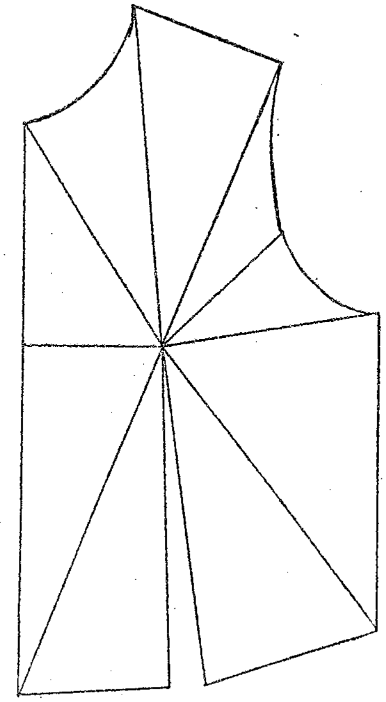
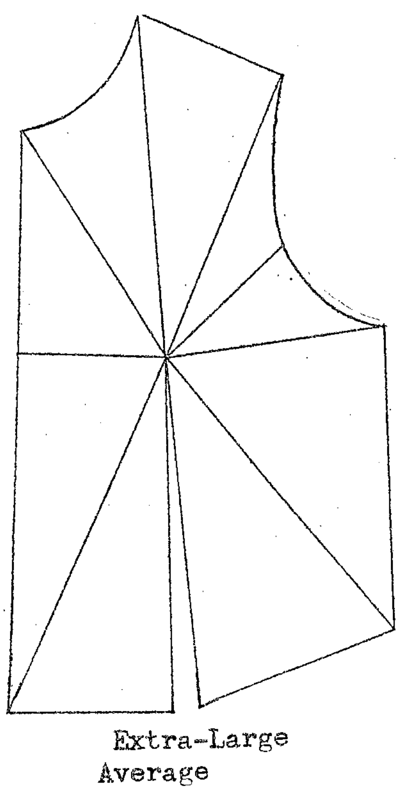
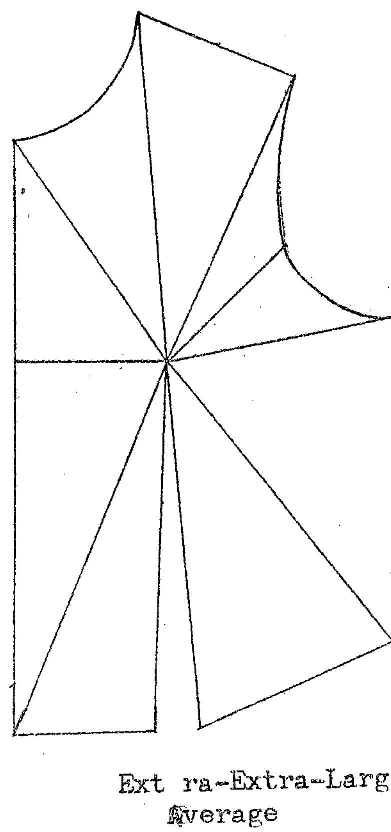


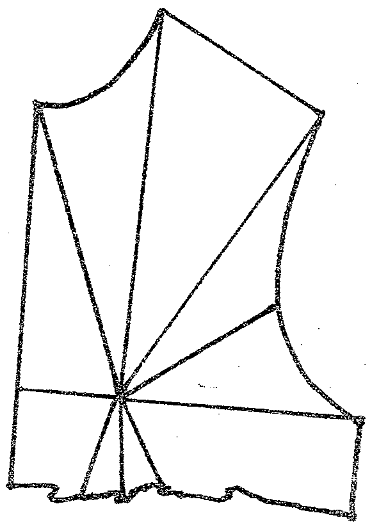
Large
Average



Extra-Large
Average



Ext ra-Extra-Large
Average



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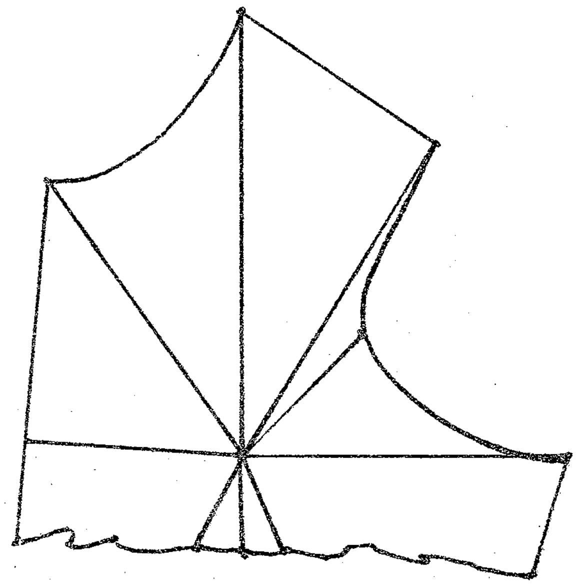

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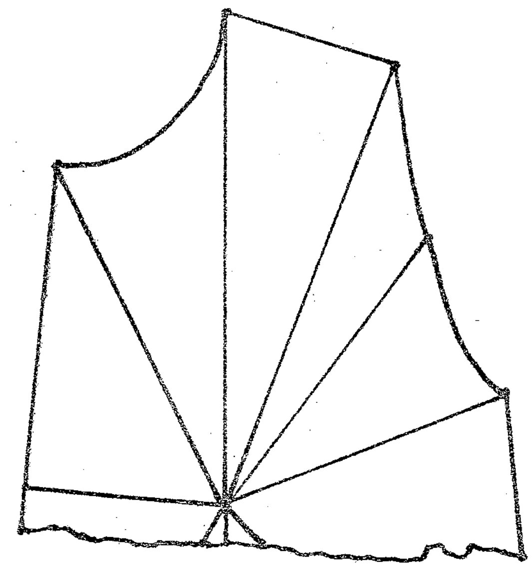

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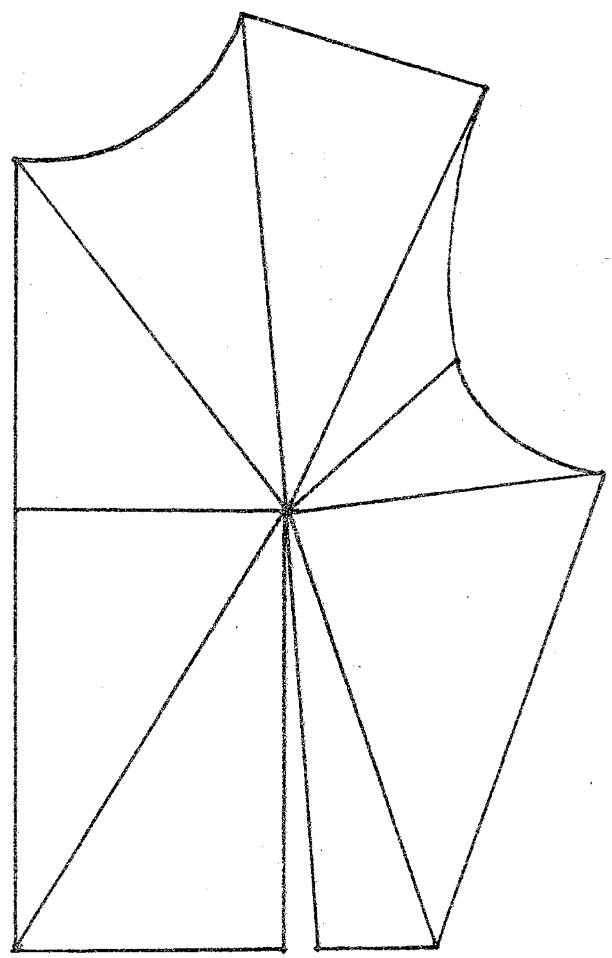

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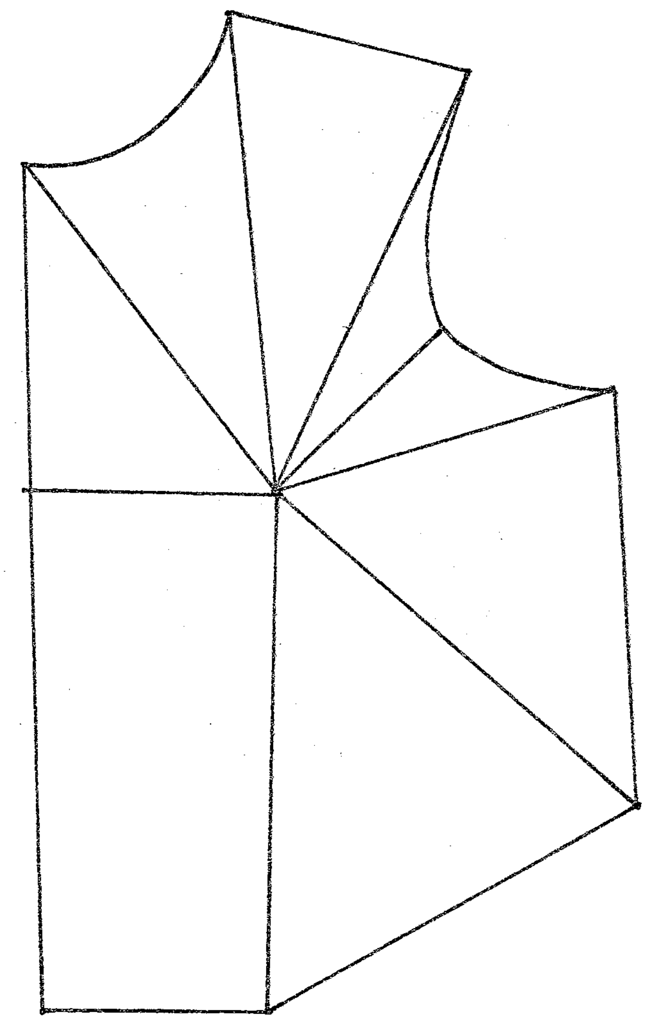

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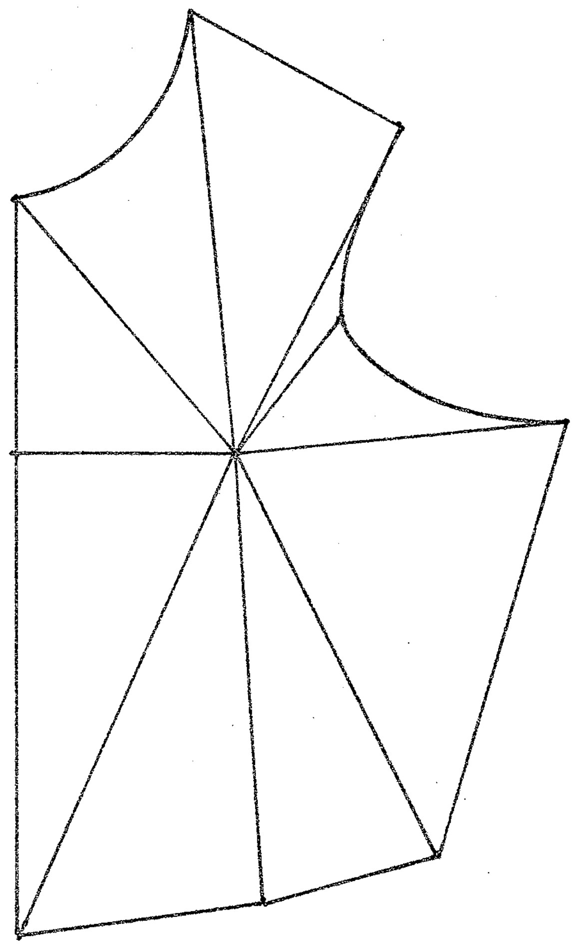

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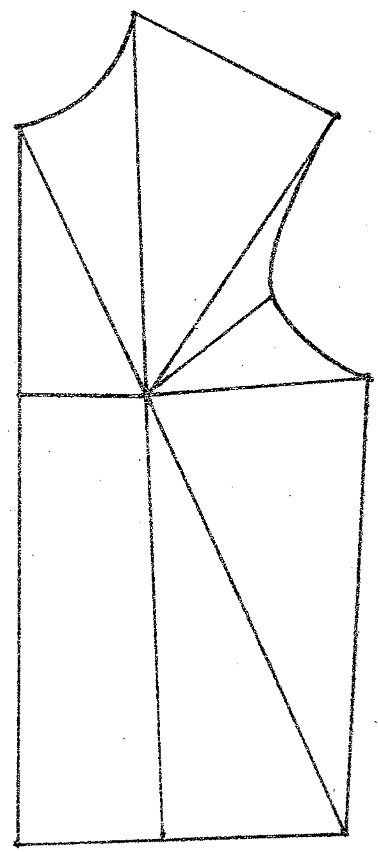

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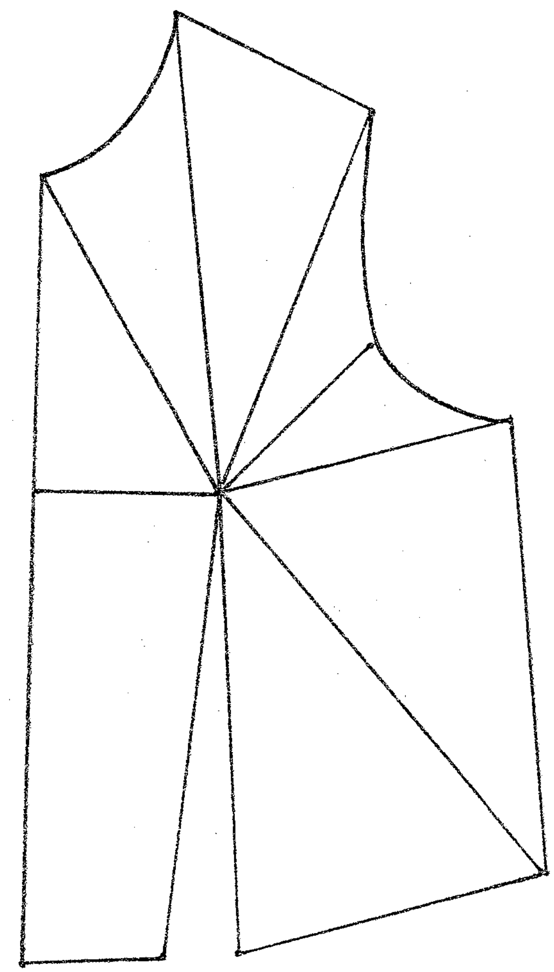

PATTERN C

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Introduction

The numerous problems with fit in all types of manufactured garments has spurred research into proposed theoretical models for garment fit. As more women enter the workforce the time they can spend searching for good-fitting clothing decreases. Manufacturers and retailers lose money on lines of clothing that are rejected by consumers due to poor fit. Concerns about worker safety, particularly around hazardous materials have increased production of protective garments. Poorly fitted protective garments interfere with worker activities or increase worker exposure to dangerous materials if torn, resulting in little real protection.

Because the use of computers in patternmaking for the ready-to-wear industry has increased, most of the theoretical work in fitting has concentrated on the use of geometric models to describe human body form. Geometric models for fitting include cylinder and cone models which are used to describe portions of the human body. Since the body is not composed of regular geometric forms, many areas are difficult to model. Research in fitting also includes information about the measurements needed to describe the body and the way(s) in which they are taken. At the present time there is no universally accepted theoretical framework for garment fit. Body measurement is accomplished primarily through assessment of body lengths widths and circumferences, with additional information about exterior angles provided by graphic somatometry.

Both linear measures and somatographs provide limited information that is difficult to apply directly to patternmaking. Most patterns are drafted with linear measurements alone. Voluntary size standards for the industry, including PS 42-70 for ready-to-wear and ANSI/ISEA 101-1985 for protective garments, are based on chest circumference and height or inseam length. Size alone, however, is not fit. Fitting research that included information about body shape through graphic somatometry indicated that size information plus shape information improved garment fit. Data about body angles obtained through graphic somatometry is limited to external angles only.

The overall purposes of this study were to determine the usefulness of: a geometric model implicit in flat pattern dart manipulation instructions and a measurement concept from morphometrics. The flat pattern model is a conic one. The bust is assumed to be a cone with the bust point as its apex. When the cone is flattened to a circle the open wedge created becomes a dart which, when sewn, fits the bustline bulge. Dart size is determined by measuring the angle of the dart at the tip: the larger the body bulge, the larger the dart angle. The relationship between size of dart angle and size of body bulge suggests that knowledge of body angles is important to fit.

Morphometrics addresses the problem of quantifying shape for the discrimination of groups and description of shape change. Often used in evolutionary biology and physical anthropology, morphometric techniques are matched to task or context; one measurement method is not expected to be useful in all instances. Shape is operationalized using ratios of measured distance between defined anatomical points called landmarks. Data collection and statistical analysis are also stressed.

A morphometric method proposed by Yasui (1986) seemed especially applicable to a patternmaking context since it involved measurement of the lengths of lines and the sizes of angles between them working from a figure centroid to an irregular outline. Lines radiating from either the centroid to selected body landmarks or from centroid to points at pre-determined angle increments are measured. For this study, Yasui's morphometric method was combined with the flat pattern conic model with bust point as the figure centroid. Yasui also used an averaged figure outline constructed from the mean line measurements for a sample as a way of assessing group differences. The combined measurement method and conic model provides a means of collecting data about body form variance through both a visual assessment of pattern shape and numeric data which may be statistically analyzed.

Methods

Testing the usefulness of the flat pattern conic model as combined with Yasui's (1986) measurement and data analysis method was addressed in two phases. The first portion of the study involved: 1) measuring the front bodice of female body forms by determining the lengths of radii from bust point to selected body landmarks and the size of angles between the radii, 2) drafting a front bodice pattern for each form based on the line and angle measurements, 3) evaluating the fit of patterns on the body forms, and 4) statistically analyzing the line and angle data collected. The front bodice area of female forms was selected for measure because traditionally this area is the most complete test of dart fit. Body forms were measured because the process of developing a measurement technique is apt to be too slow for the comfort of human subjects. A convenience sample of 24 standard and personalized forms with bust sizes 31 to 39 inches was measured.

Male subjects were measured for the second phase of the study after the measurement technique had been developed and modified. Male subjects were chosen for this phase because men are the primary wearers of protective garments, a type of garment for which good fit is critical. Fifty male volunteer subjects whose chest and inseam measurements corresponded to those listed for the five size categories of ANSI/ISEA 101-1985 were measured, ten subjects per category. Size categories ranged from Small to Extra-Extra-Large.

Members of both samples were measured from bust point to selected body landmarks. For female body forms, body landmarks are indicated by seam positions. These positions were marked with pins on the left side of the form. Preliminary measurement trials indicated that two areas of the figure, represented by shoulder seam and side seam, might be difficult to measure accurately because of large angles. Two additional landmarks were added at the midpoints of these seams. Other body landmarks included: bust point, center front neckline, shoulder seam at neckline, shoulder seam at armscye, armscye breakpoint, armscye at side seam, side seam at waistline, bust dart location at waistline, and waistline seam at center front. The bust point level at center front was determined during measurement.

Angle measurements were taken using a metal compass while lines were marked with strands of braid pinned taut from bust point to body landmark and measured with a non-stretch tape. Lines and angles were marked and measured starting from center front at bust point level and working clockwise around the bust circle. The dart angles were not measured on the body but were developed during pattern drafting and measured from it. The only ease allowed was incorporated by measuring from one body prominence to another, spanning body hollows rather than measuring the depressions.

Patterns were drafted for each form from the line and angle measurements. Center front, shoulder and side seam lines on the patterns were drawn as straight lines. Necklines, armscyes, and waistlines were drawn using standard curved rulers. Paper patterns were pin fitted on the appropriate forms, evaluated by the researcher, and corrected as necessary

Line and angle measurements collected from each form provided data which was used to draft front bodice patterns as described above. Angle measurements were subject to more error than line measurements, but misfit areas were easy to locate and correct through pin fitting. Soft surfaced customized forms and forms with proportionately large bustlines were most difficult to measure. Corrected angle measures were summed for each pattern and subtracted from 360^0 as a check on the accuracy of drafted dart angles.

The measuring process for body forms took about twenty-five minutes per form to accomplish. Because this seemed like a long time for a human subject to stand without moving, alternative methods were investigated. A planar technique devised by Gazzuolo (1985) to measure the body surface in imitation of the way clothing fabric drapes provided a speedier approach. Planar measurement involves the use of a piece of non-woven interfacing fabric marked with measurement guidelines. The measurement instrument is used to record the position of body landmarks as a pattern for the measured area is being developed. Subject fatigue is lessened and body shape as well as size is captured during measurement.

Two planar-type measurement instruments were devised for the second phase of the study. One rectangle of nonwoven interfacing was marked with radial lines originating from a central point and placed every 5^0 in a circle; a second rectangle was marked with one horizontal and one vertical line which crossing at a central point and dividing the rectangle into four segments. Averaged measurements from the two instruments were used in analyses, and correlations between the two sets of measurements were calculated.

Male subjects wore a knit undershirt on which body landmarks were marked with adhesive dots, and sweatpants or shorts with elastic waistbands to indicate waistline location. The following body landmarks were located:

1. Breast point or nipple marked on left and right sides
2. Center front at neckline: the midpoint between the sterno-cleido mastoid tendons at the attachment to

sternum

3. Shoulder seam at neckline: the point where the trapezius muscle and the sterno-cleido mastoid separate
4. Shoulder seam at armscye: the intersection of the ridge of the scapular spine with the trapezius ridge at the acromion process
5. Front break point: the pectoral attachment of the arm to the trunk
6. Side seam at armscye: a point in the axillary space midway between the front break point and the back break point (latissimus dorsi attachment of the arm to the trunk)
7. Side seam at waistline: waistline was located using the elastic waistband as a guideline; side seam position was located plumb from the side seam at armscye point
8. Dart position: a point at which a line from the bust point forms a right angle with the waistline
9. Center front at waistline: a point at the waistline plumb from the center-front-at-neckline

The center of each instrument was pinned to bust point, the horizontal line from bust point to center front levelled, and body landmark positions recorded on the fabric.

Data were analyzed using both statistical and visual methods. Sample means, ranges, variances and standard deviations were calculated for each measured radial line and angle for the female body form sample. Radial measurements plus traditional measurements including chest circumference, shoulder length, side seam length, center front length and inseam length, were collected for male subjects. The same summary statistics were calculated for each size group of male subjects using the average of measurements taken using the two instruments. As recommended by Yasui (1986), an averaged pattern outline was constructed from mean line and angle values for a subset of the female body form sample and for each size group of the male sample. An index (a ratio of two lines) was calculated to describe shoulder slope for the female body form group and the five size groups of male subjects. An index was also used to describe the waistline shape of the male subjects.

Results

Analysis of line and angle measurements as well as visual examination of group and individual patterns for both samples indicated a clear need for information about body shape as well as size for patternmaking. Length and width measurements without information about the relative positions of measurement locations give a false impression of the homogeneity of a group. For this study, the sizes of angles between radial lines from bust point to body landmarks provided data about the relative position of measured lines. Correlations calculated for line and angle data from both body form and human subjects revealed that while line measures were strongly correlated, angle measurements were not. Although it might be possible to a few line measurements and use them as predictors of other lengths and widths, all of the angle measurements were necessary to determine shape.

For female body forms, sample line measurements were more consistent than angle measurements in range and standard deviation. The dart angle which directly reflects variation in bust size and shape was the most variable with a range and standard deviation of almost twice that of any other angle. The side seam angle was variable also. This angle, while measured near the bust point, actually fits a flatter portion of the rib cage. An averaged pattern outline drafted from mean line and angle values for the subset of sample forms with bust circumference of 37 inches emphasized the importance of angle measurements. When compared to individual pattern outlines for that group, the average pattern actually corresponded in shape and size to only one of the individuals within the group. Since the line measurements were similar, differences in angle values contributed greatly to differences in shape.

Because morphometric methods often involve ratios of measured distances to describe shape, a ratio of the two lines marking each end of the shoulder seam area was calculated for each form. Ratios for the body form sample ranged from .85 to .95 with a mean of about .90. The small amount of difference in ratios may reflect the use of body forms and may not be an accurate description of female shoulder shapes.

Analysis of measurement data collected from male subjects also emphasized the desirability of including body angles when measurements are taken for patternmaking. Average pattern outlines were drafted for each of the five size groups. Although these patterns revealed general trends in size and shape for this sample, they did not reflect the diversity that exists among individual patterns. In comparison to female forms, patterns for male subjects were less variable as to dart size but did exhibit some variability in side seam length. Angle data indicated that the upper chest, shoulder and armscye were variable in shape. Observation of the subjects suggested that the presence of fat versus muscle tissue made a difference in pattern shape.

Patterns for male subjects showed that waistline shape was variable also. Solinger (1988) noted that the most prominent bulge in the front upper torso for men may be either the chest or the waist. The presence of fat or muscle tissue as well as posture may have accounted for differences in waistline shape. There appeared to be three distinct waistline shapes represented in the sample patterns: waist narrower than chest, waist about the same width as chest, waist wider than chest.

A distinct drop in waistline seam from side to center front was noted on subjects in all size categories. As mentioned previously, fat versus muscle tissue accounted for extra length at center front for some subjects, but others with no evidence of visceral ptosis (potbelly) also required a pattern with a drop from side to center front at waistline. These subjects were observed to stand with an exaggerated curve to the lower back: a sort of stomach-forward posture. A ratio of lines from bust point to waist at side seam and center front was calculated to describe the drop in waistline seams for the sample. Ratios ranged from 1.12 for a straight seam with no drop to .80 the most extreme center front drop.

An index was calculated to describe shoulder slope for male subjects in the same manner as for female forms. Male subjects exhibited a wider range of shoulder slope ratios than did female forms with amounts ranging from .79 to 1.0 with a mean of .88. The wider range may be due to the use of human subjects for this phase of the study or to the larger sample with more size variation.

Using a sample that varied in size and age allowed the investigation of some possible shape/size and age/size relationships. Although the data are not definitive, the information is interesting. Average age and age range data showed a tendency for chest size to increase with age although the subjects in the Extra-Extra-Large category reversed the trend. In general, length of radial lines and seam lengths increased as chest size increased; there were, however, exceptions to this trend for specific measurements in all size groups. Average inseam lengths, for instance, increased with chest size except for that of the Extra-Large group. The size Medium group, while having an expected average inseam length, was proportionally short in the lower chest on average.

The most unexpected measurement result occurred in shoulder seam length for male subjects. Average shoulder seam length increased with chest size within a range of .28 inches from size Small to size Extra-Extra-Large, a smaller than expected increase. The range of individual shoulder seam lengths was 2.35 inches, with the shortest length of 4.4 inches occurring in small, large and extra-large subjects; the longest measure of 6.75 inches occurred in one extra-large subject.

Conclusions

Measurement of body angles is recognized as important to good fit because it provides information about body proportions, contours and posture, but has been assessed only indirectly through graphic somatometry. Research in graphic somatometry indicates that a combination of linear measurements of body size should be supplemented with angle measurements which describe body shape. The conic model implicit in flat pattern data manipulation techniques plus measurement from a figure centroid to body landmarks provides a way to capture body form with a few measurements directly related to pattern development.

Results of this study indicate that measurement of body lengths and widths and use of average pattern outlines for a group of individuals, essentially what is now used to create patterns, give an erroneous impression of shape variation within even small groups. Both line and angle data appear to be necessary to draft an accurate front bodice pattern. Line data alone suggest less shape variability than is actually present. Averaged pattern outlines, although useful for assessing trends within and between groups, do not actually fit many individuals within a sample.

Limitations of the Study

The results of this study and the conclusions based upon them are limited by the type of geometric model assumed, the area of the body measured, the measurements taken, and the specific subjects measured. The model for body form variation is a cone with the bust point as its apex and an irregular outline at the base. The left front bodice area of male and female figures was measured from waist to shoulder, center front to armscye and side seam area. Measurements were taken from the bust point to selected body landmarks only. Landmarks were selected for their appropriateness for patternmaking purposes.

Measurements for female bodice patterns were taken from body forms only, not from human subjects. Measurements for male bodice patterns were taken from volunteer subjects whose chest size and inseam length corresponded to the sizes specified in ANSI/ISEA 105-1985 standard for protective garments.

Implications for Future Research

The results of this study plus its limitations suggest several areas for future research. The flat pattern conic model needs to be tested on female human subjects in general. In particular, two areas need investigation: the bust/side seam area, and the shoulder/armscye. The bust/side seam has proved difficult to model in other studies. The shoulder/armscye appeared to be rather standard in shape over the sample for this study, but that regularity may have been a function of using a sample of body forms.

The flat pattern conic model needs to be tested on other areas of the human body. Solinger (1988) was of the opinion that a pattern for the back bodice could not be drafted from measurements taken from a single center point. The model may require modification when applied to the bodice back, front hip, back hip, and sleeve. Research into instrumentation for measurement from a figure centroid needs to be undertaken both for mechanical and computer applications of the technique.

Results of this study suggested but did not define relationships between body size and age of individual, body shape and age of individual, and type of body tissue (fat versus muscle) and body shape. Many assumptions are made about the existence of such relationships, but no data are available.

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APPENDIXES

APPENDIX A

IRB FORM

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
FOR HUMAN SUBJECTS RESEARCH

Proposal Title: Measurement for Pattern Shape: Testing a Conic Model

Principal Investigator: Donna Branson / Paula King

Date: 5-20-92 IRB # HE-92-57

This application has been reviewed by the IRB and

Processed as: Exempt [ ] Expedite [x] Full Board Review [ ]

Renewal or Continuation [ ]

Approval Status Recommended by Reviewer(s):

Approved [X] Deferred for Revision [ ]

Approved with Provision [ ] Disapproved [ ]

Approval status subject to review by full Institutional Review Board at next meeting, 2nd and 4th Thursday of each month.

Comments, Modifications/Conditions for Approval or Reason for Deferral or Disapproval:

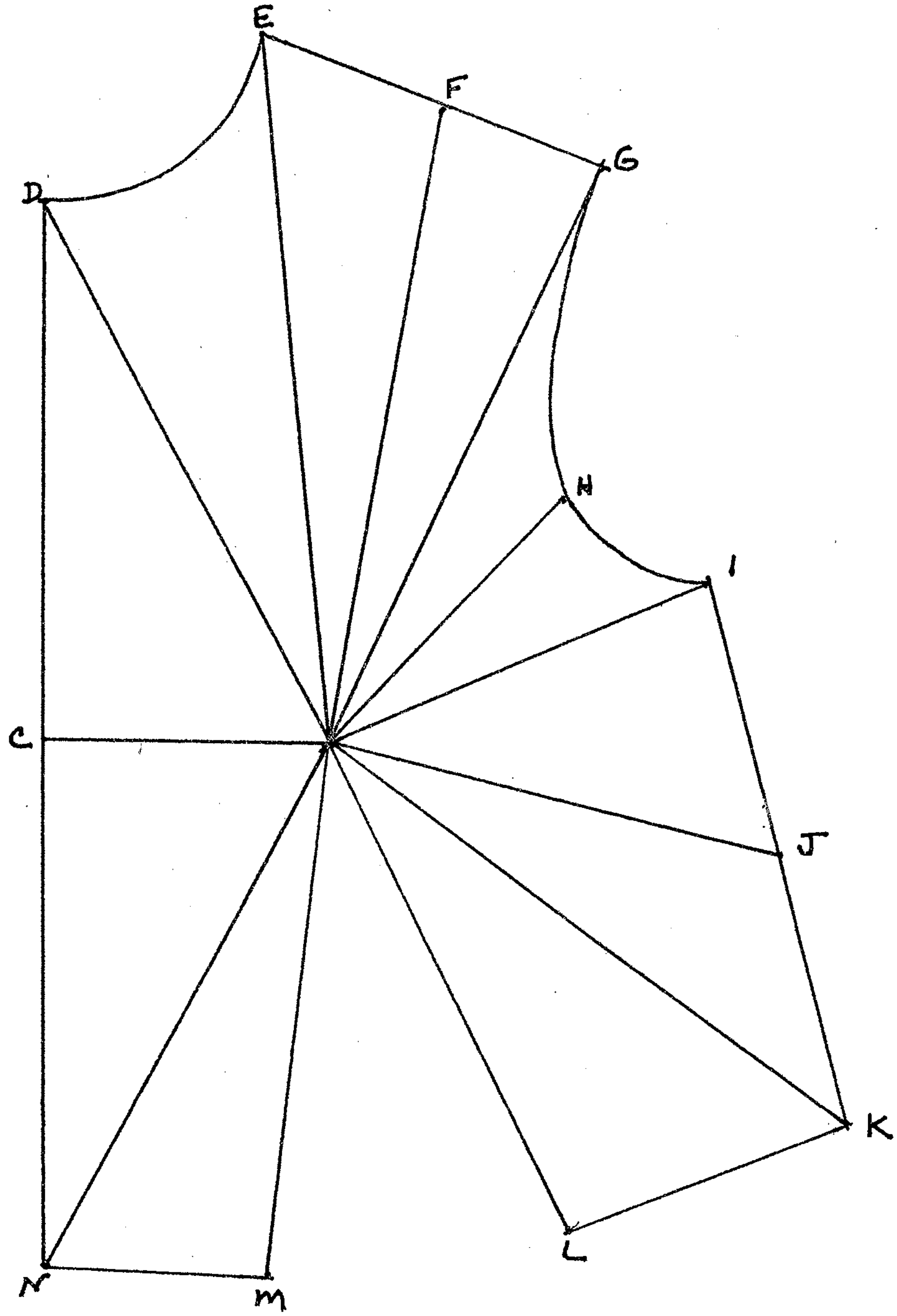
Signature: Marcia L. Tilley Date: 5-28-92
Chair of Institutional Review Board

APPENDIX B

SAMPLE DATA SHEET FOR FEMALE

BODY FORMS

FORM______________________ DATE______________



SHOULDER LENGTH______________

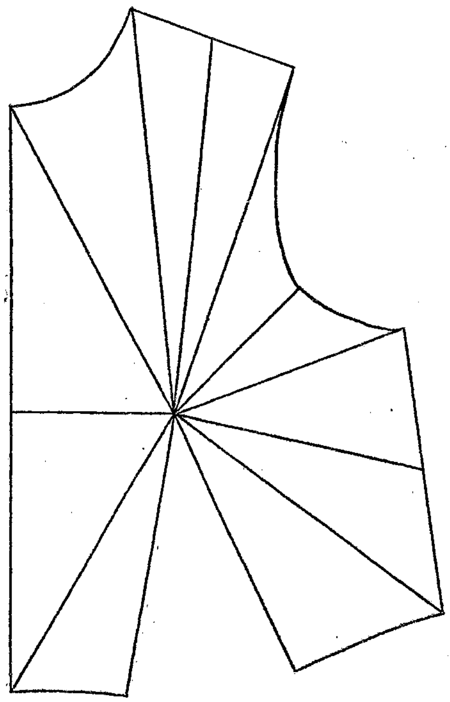
SIDE SEAM LENGTH____________

BUST CIRCUMFERENCE__________

APPENDIX C

INDIVIDUAL PATTERNS FOR FEMALE

BODY FORMS



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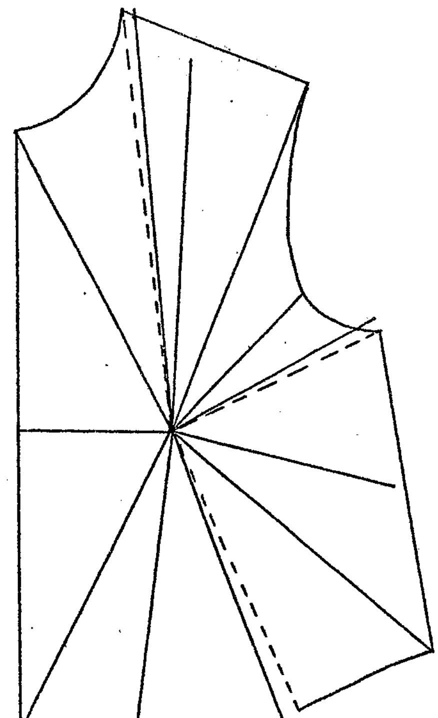

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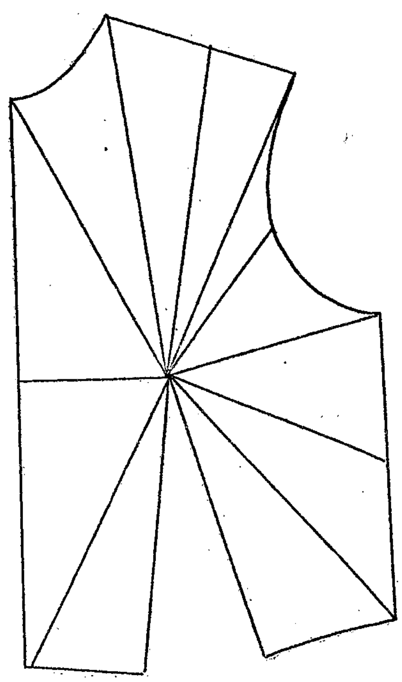

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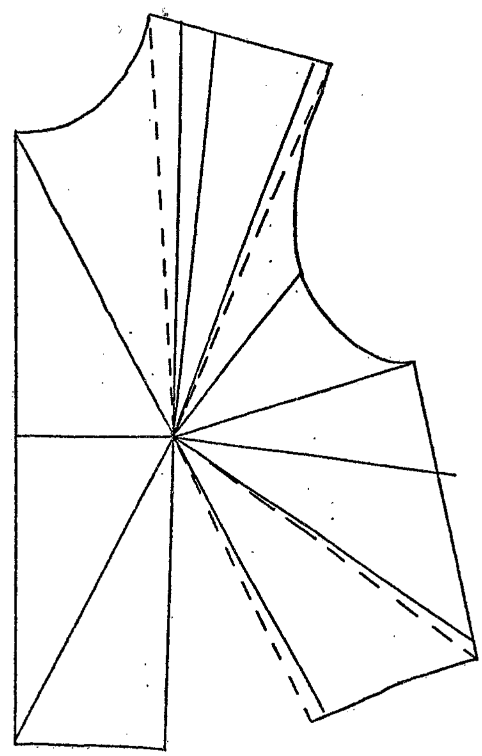

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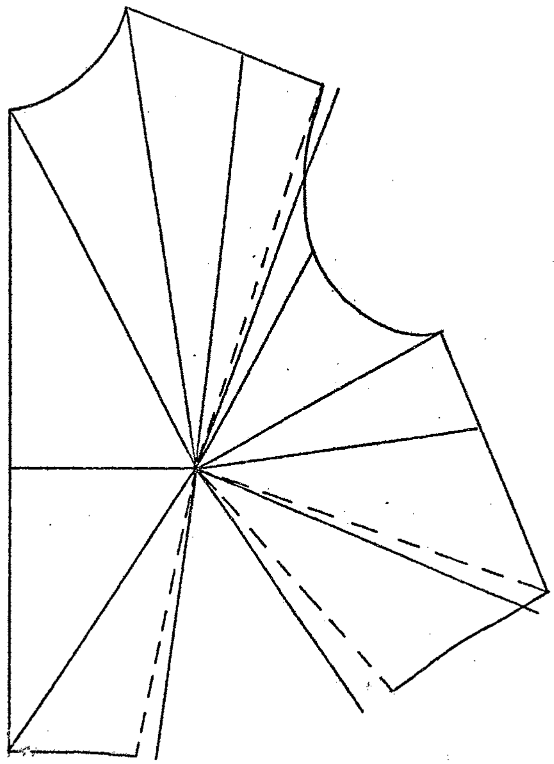

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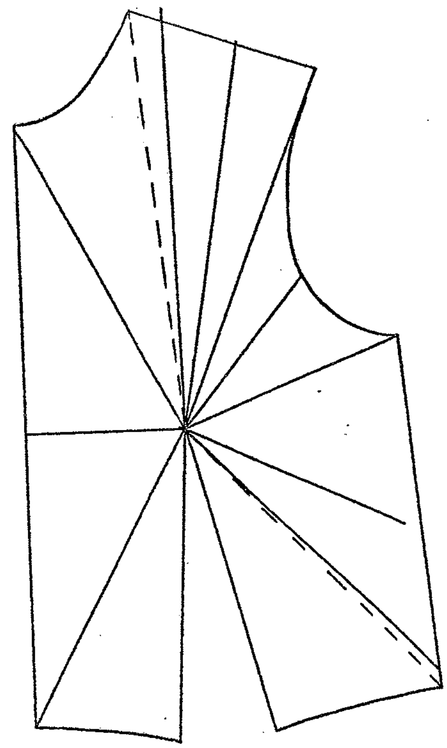

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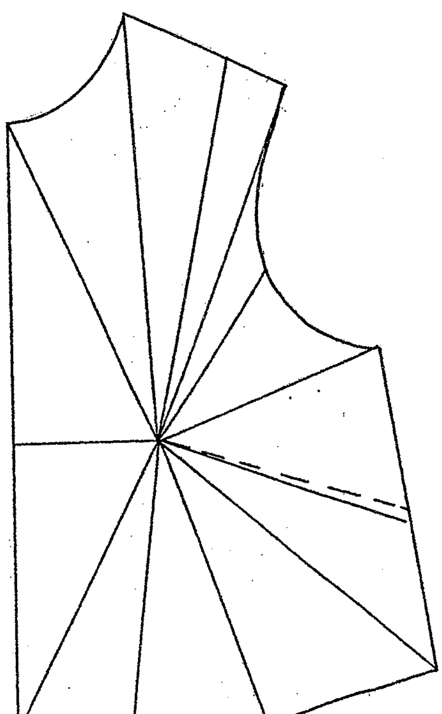

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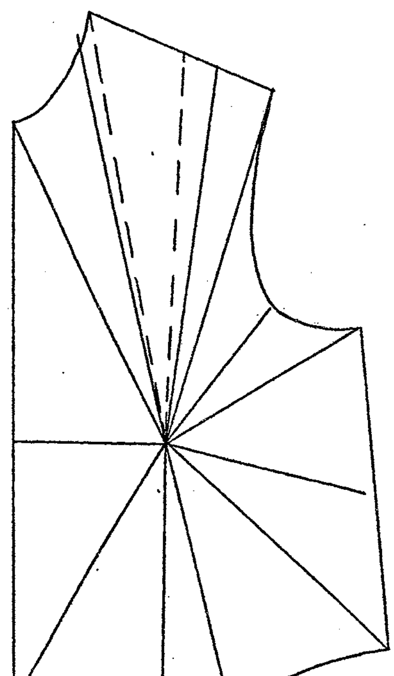

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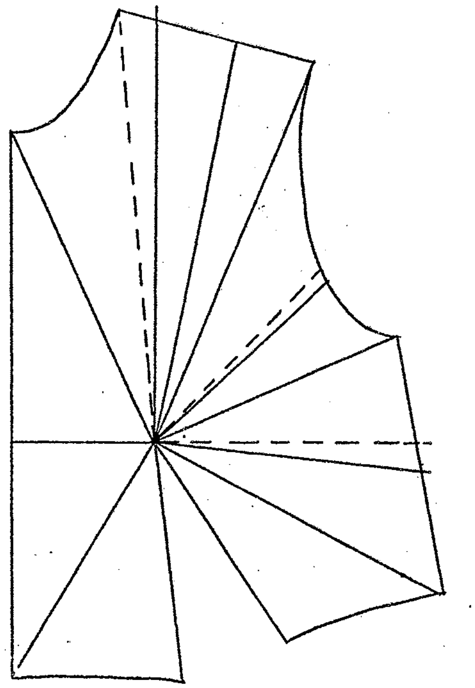

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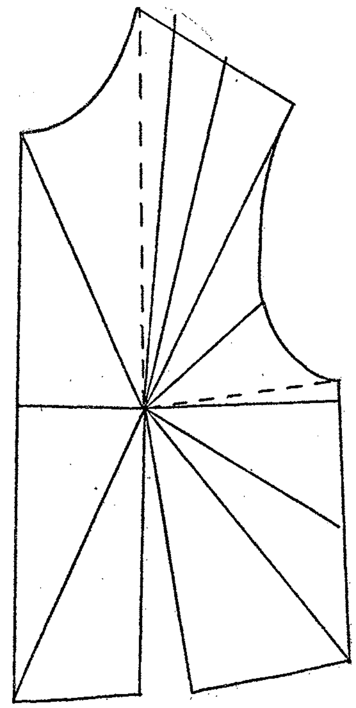

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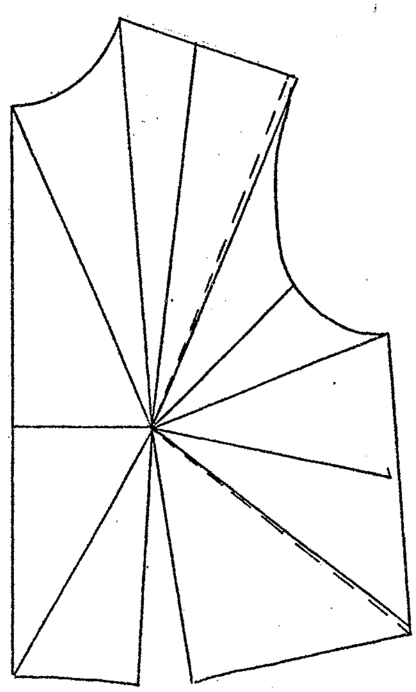

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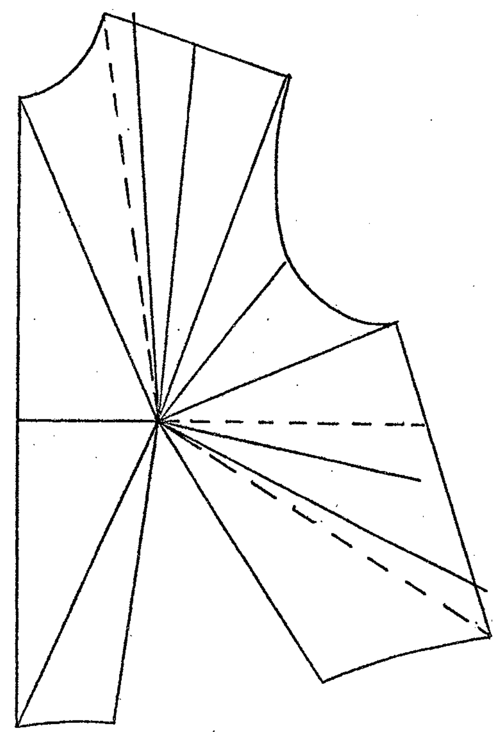

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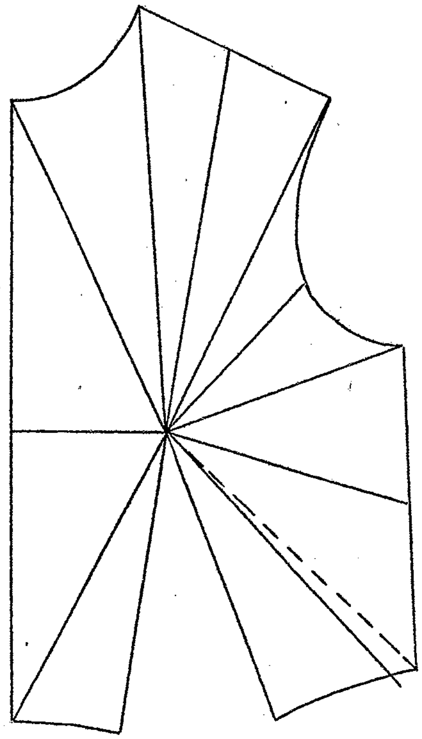

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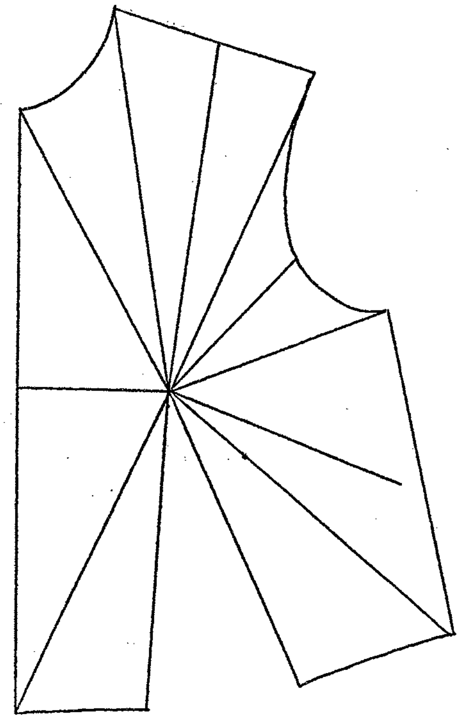

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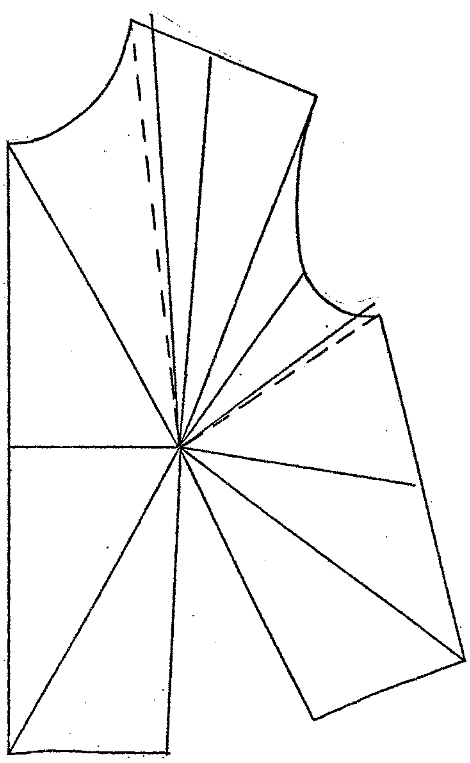

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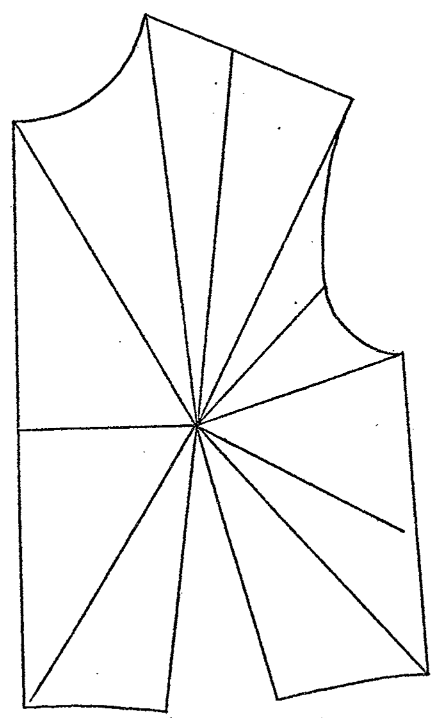

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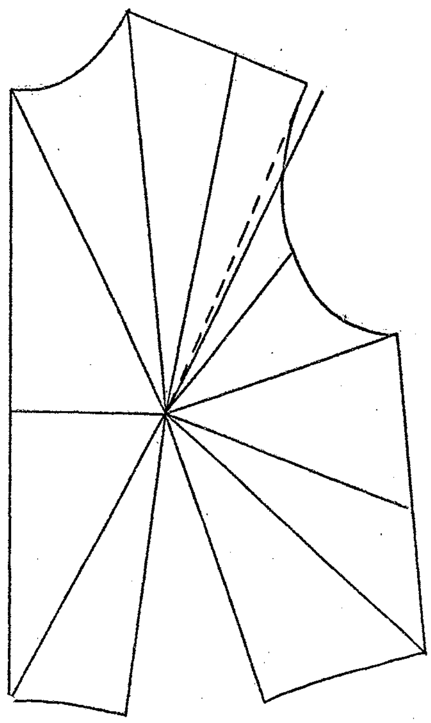

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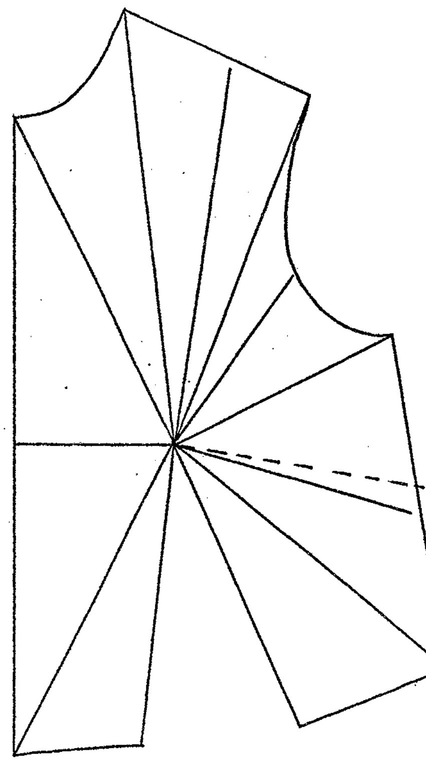

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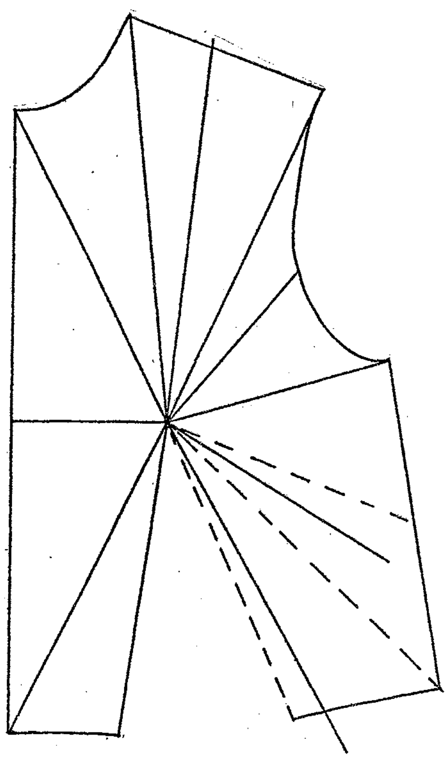

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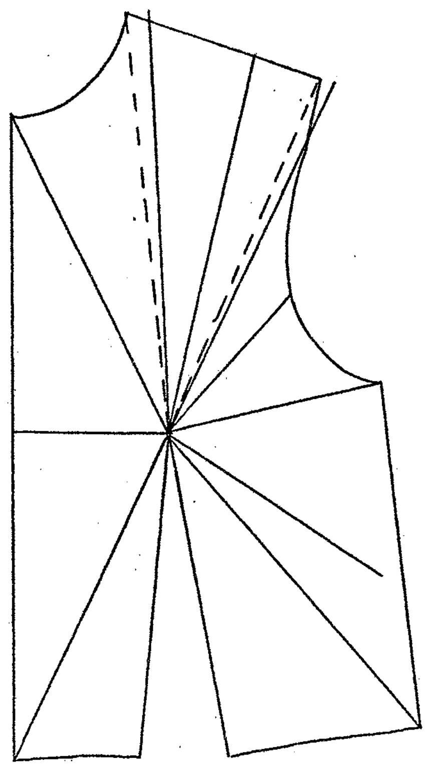

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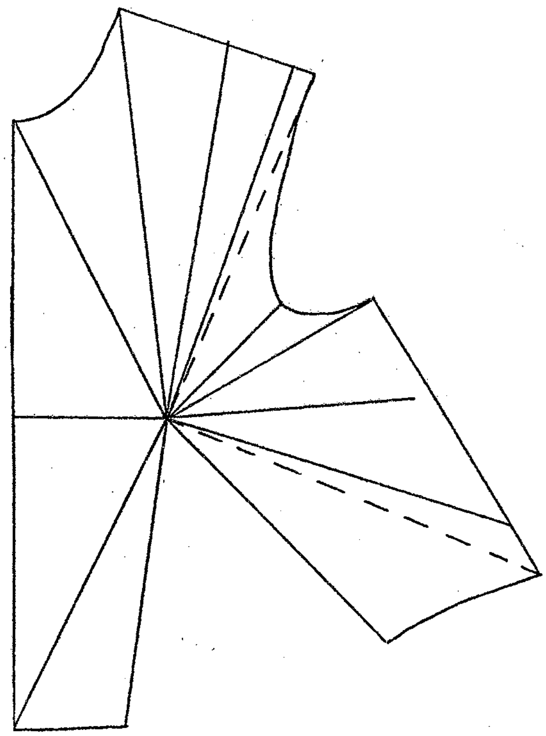

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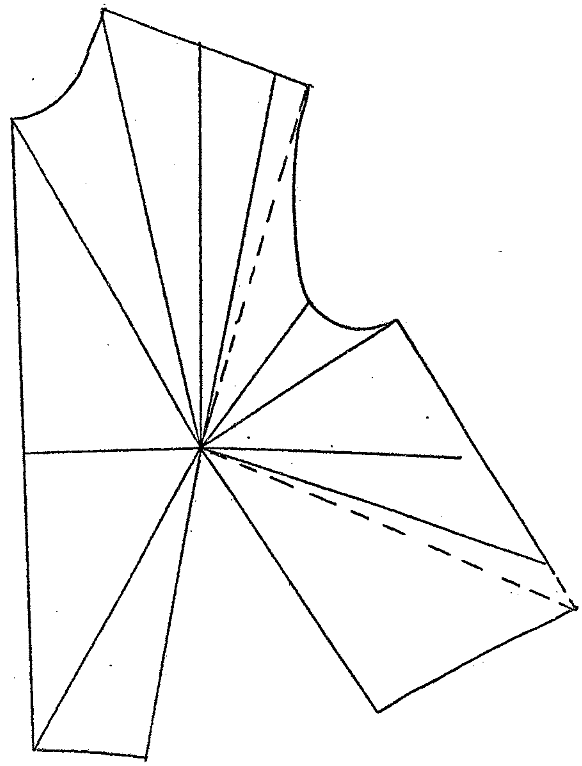

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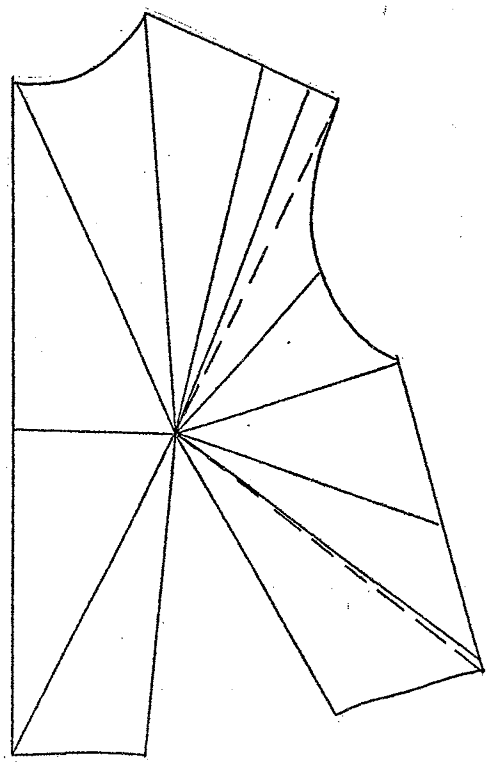

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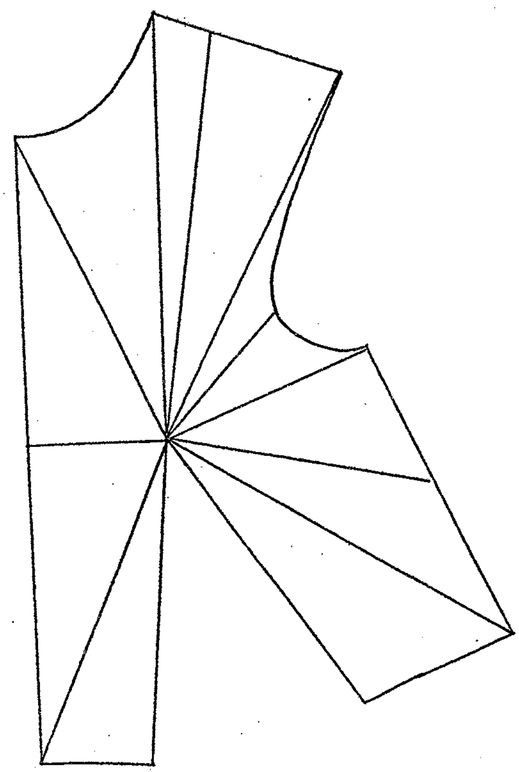


24

APPENDIX D

SAMPLE SOLICITATION FORM FOR MALE VOLUNTEER SUBJECTS

If you fit into one of the following size categories, we could use your help.

Chest Circumference		Pants Inseam Length
1. 34 - 36	and	26 1/2 - 27 1/2
2. 38 - 40	and	27 - 28
3. 42 - 44	and	28 - 29
4. 46 - 48	and	28 1/2 - 29 1/2
5. 50 - 52	and	29 - 30

Protective coveralls don't fit very well, but we need "real life" measurements to make them fit better. If your chest and pants inseam length measurements match one of the categories listed we would appreciate 15 minutes of your time to take some chest measurements.

Here's what you'd have to do:

1. Wear a T-shirt (your own undershirt is fine) and sweat pants (furnished).
2. Stand while a researcher places removable adhesive "dots" on the neck, shoulder, armhole, side and waist of the T-shirt.
3. Keep standing while a researcher pins a piece of fabric to the T-shirt, marks dot positions on the fabric, unpins the fabric, then repeats the process with a second fabric piece.
4. Let the researcher unpin the fabric and remove the dots.

If you have 15 minutes to spare your help would be appreciated. We'll give you a ball cap for your time and trouble.

APPENDIX E

SAMPLE DATA SHEET FOR MALE SUBJECTS

SIZE GROUP____________ SUBJECT NO.__________

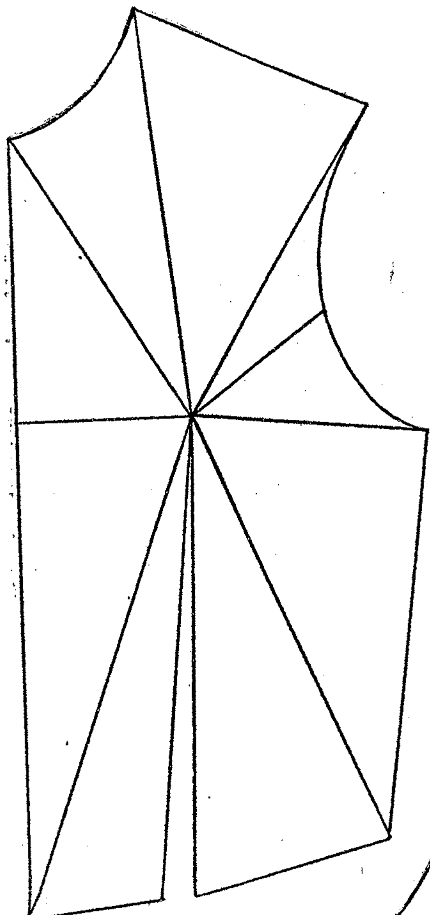
CHEST CIRCUMFERENCE______ INSEAM______ AGE_____________

SEAM	1	2	AVERAGE
SHOULDER			
SIDE			
CF			

LINE	1	2	AVG	ANGLE	1	2	AVG
BC				CBD			
BD				DBE			
BE				EBG			
BG				GBH			
BH				HBI			
BI				IBK			
BK				KBL			
BL/M				DART			
BN				MBN			
				NBC			

APPENDIX F

INDIVIDUAL PATTERNS FOR MALE SUBJECTS



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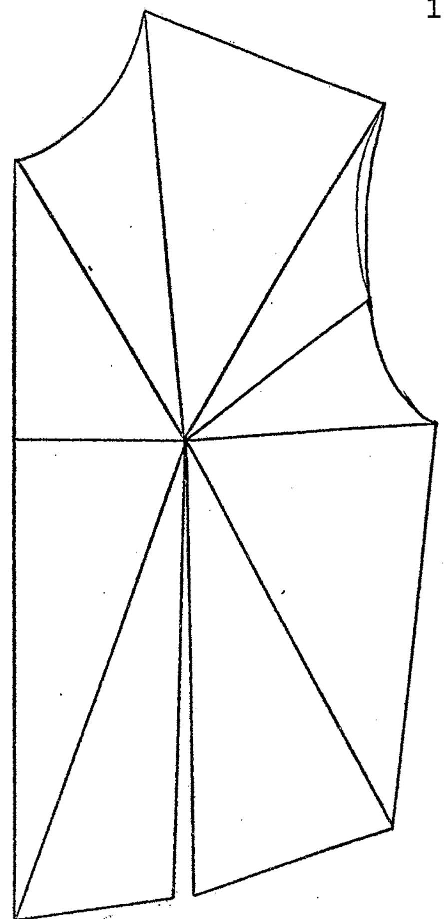

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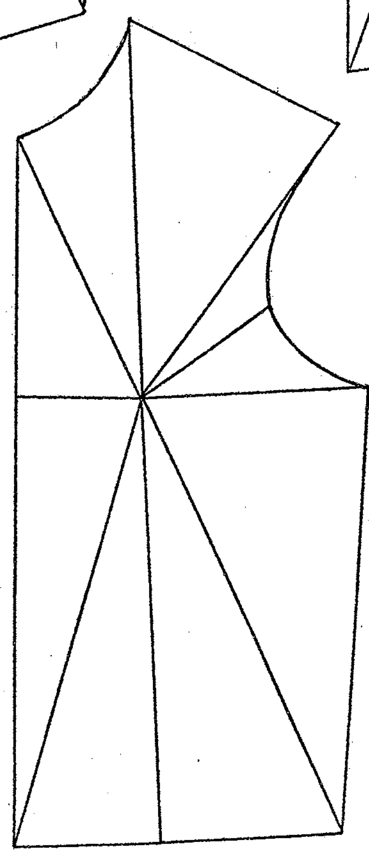

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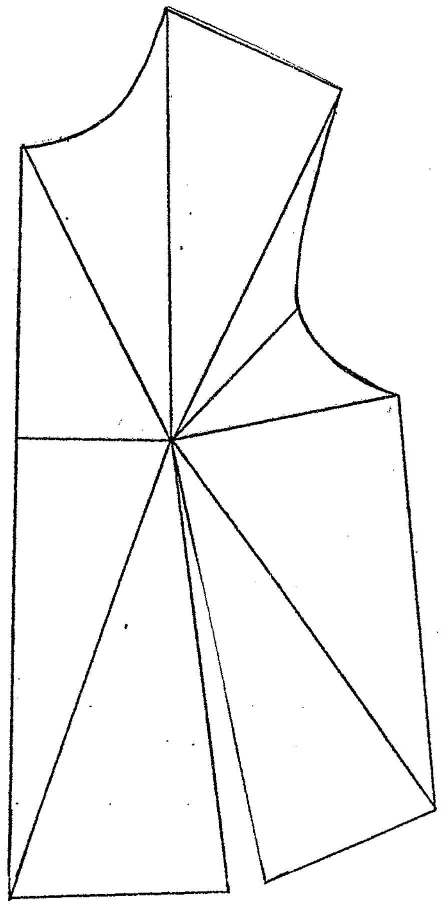

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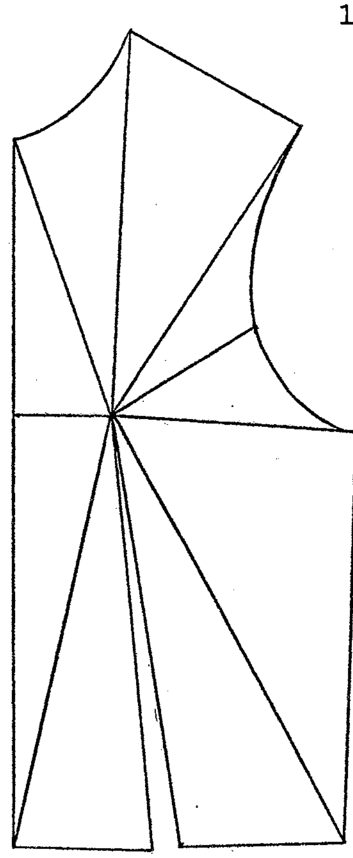

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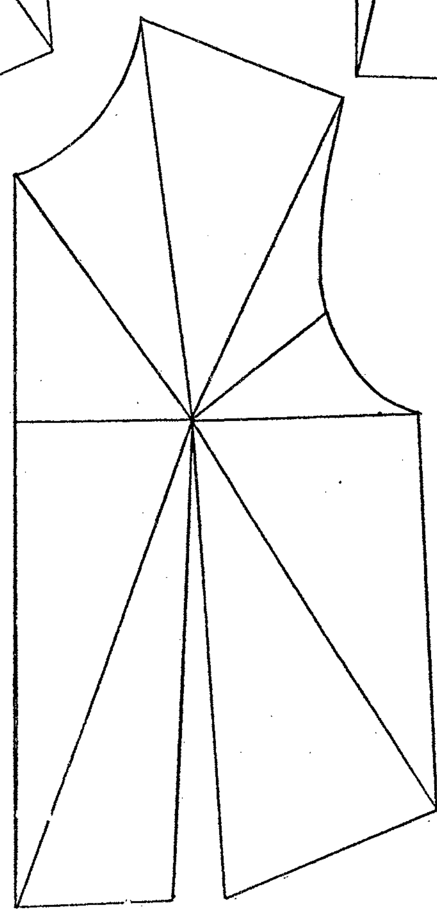

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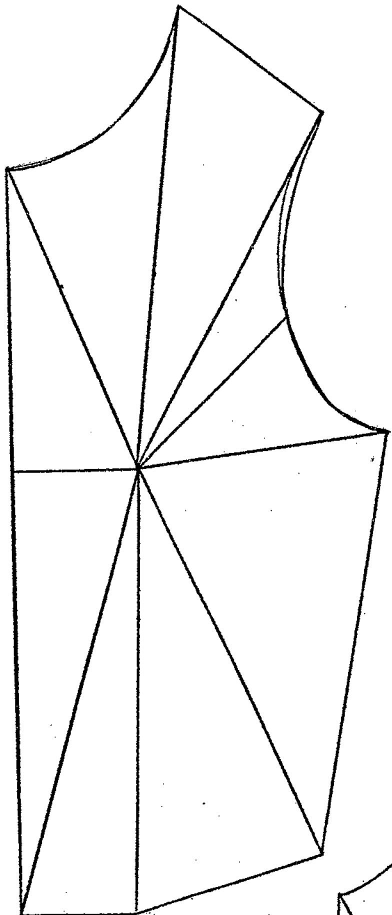

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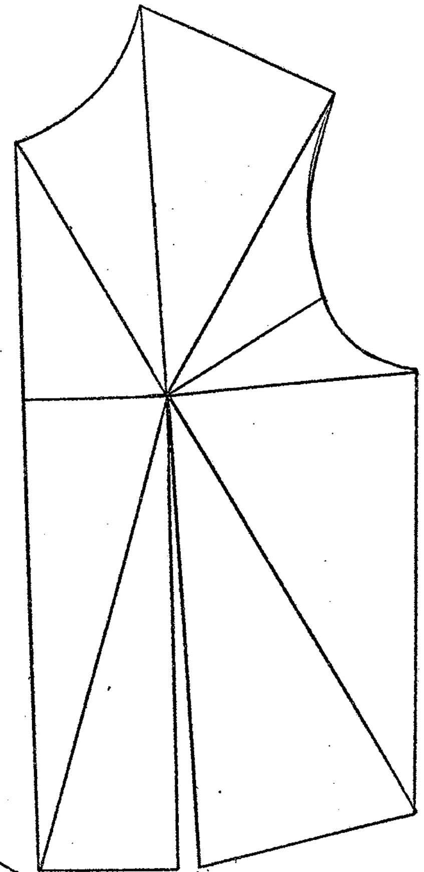

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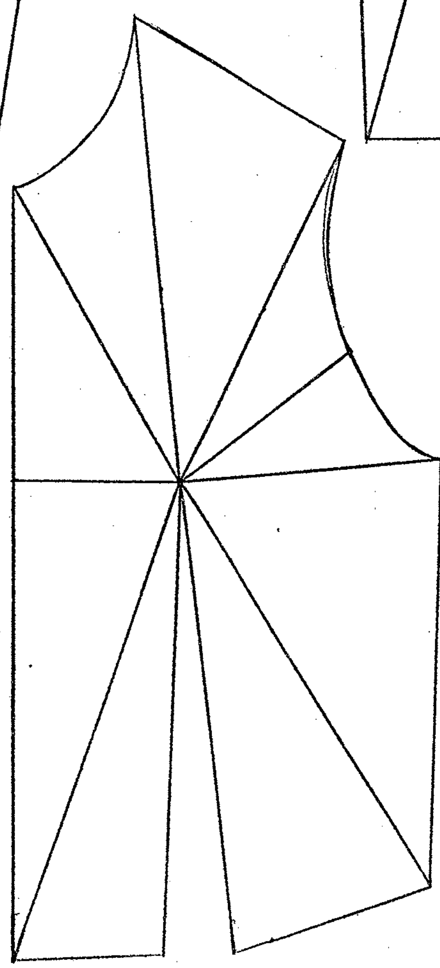

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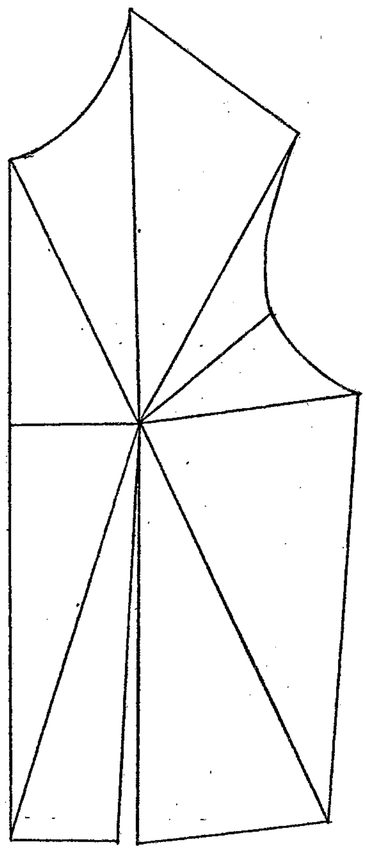

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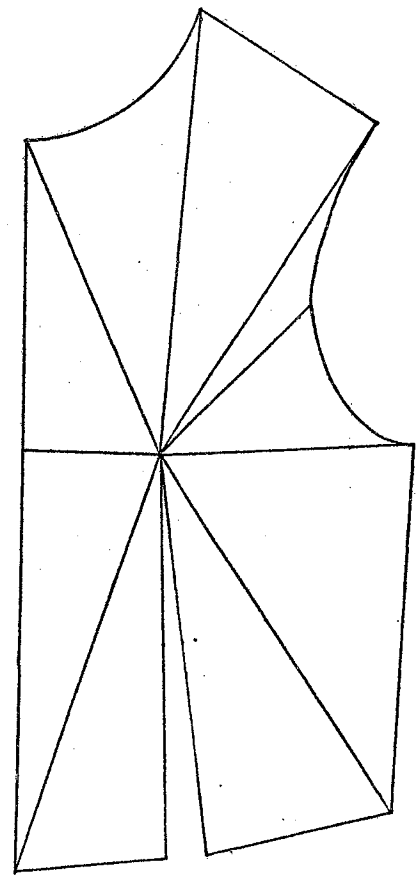

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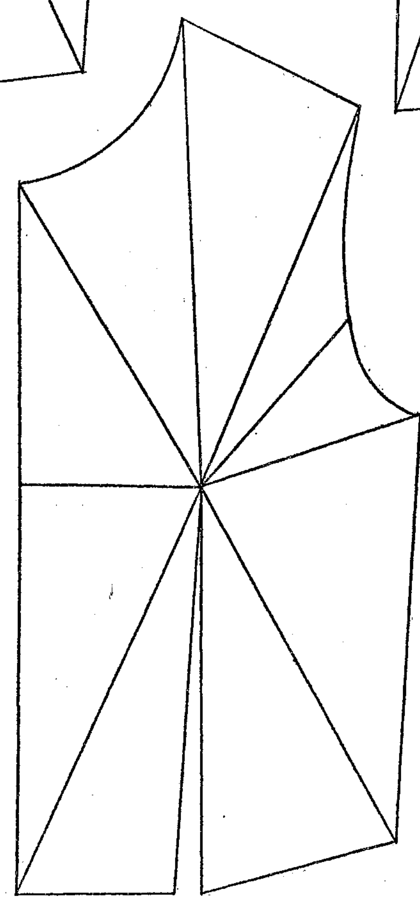

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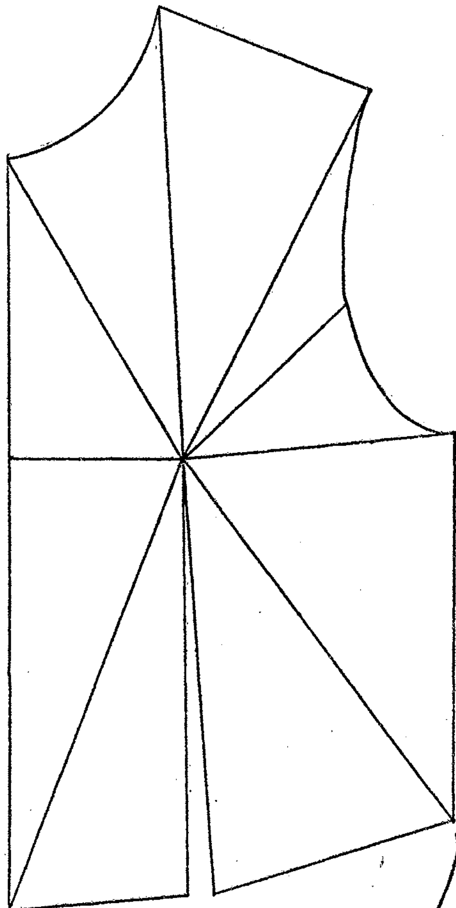

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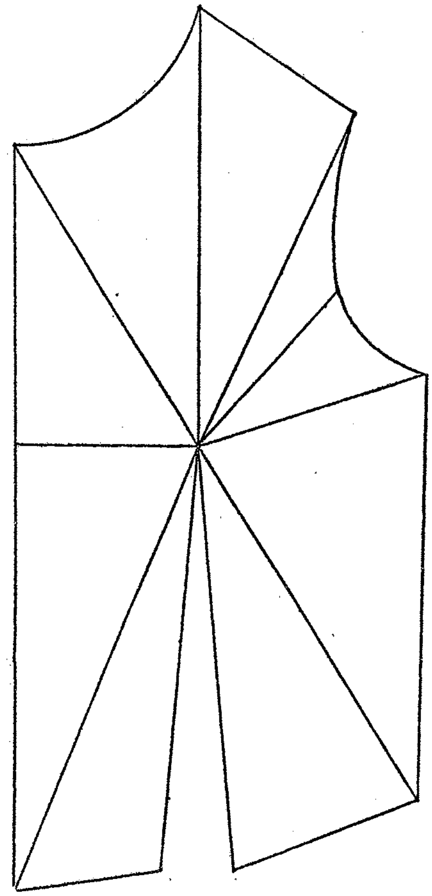

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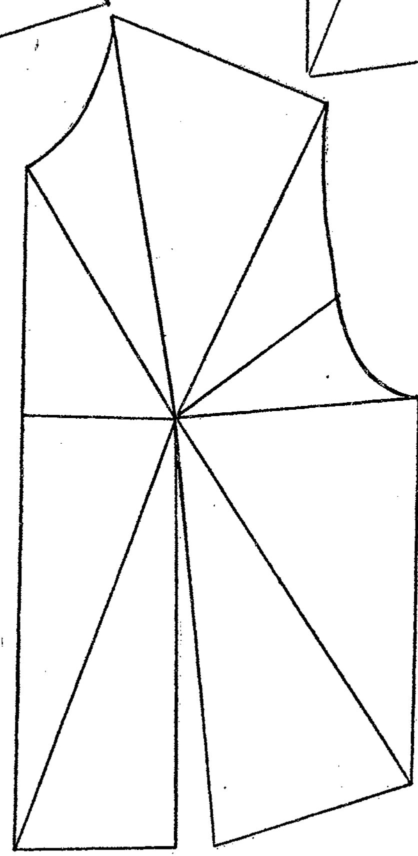

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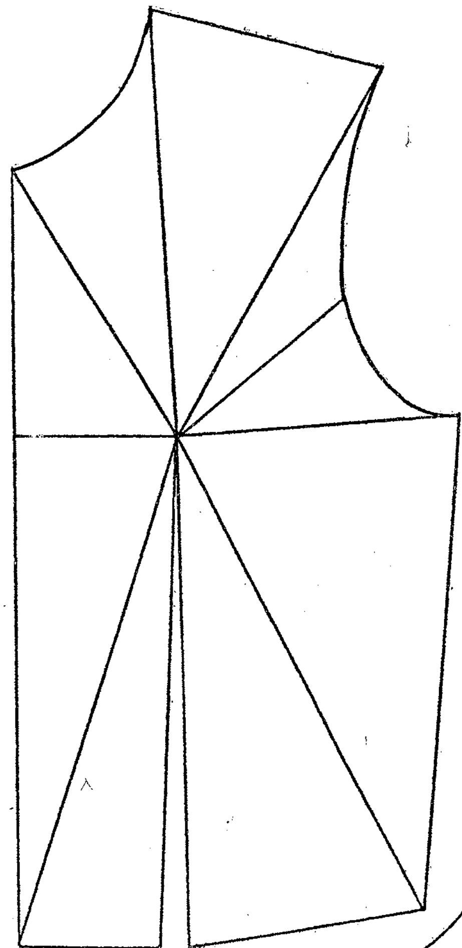

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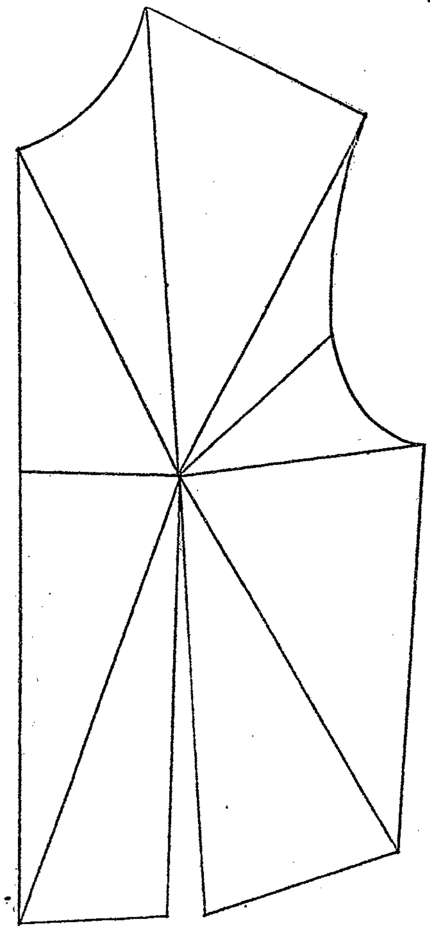

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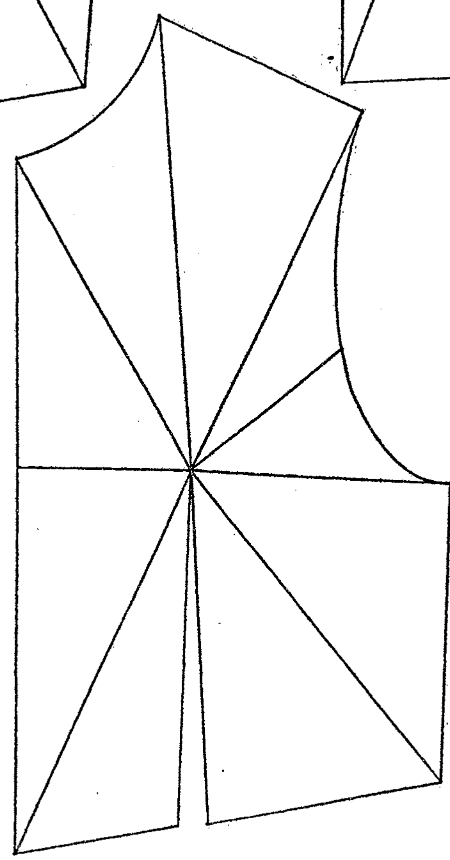

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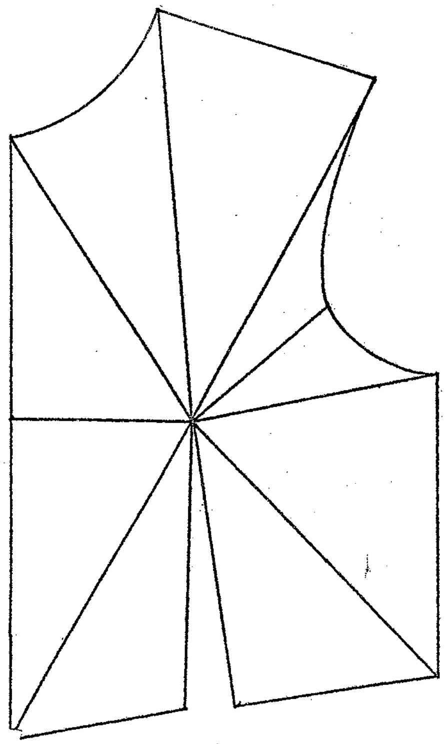

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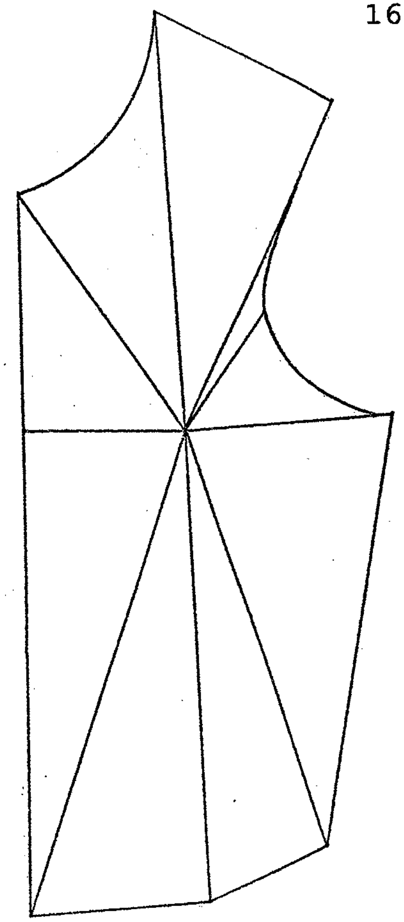

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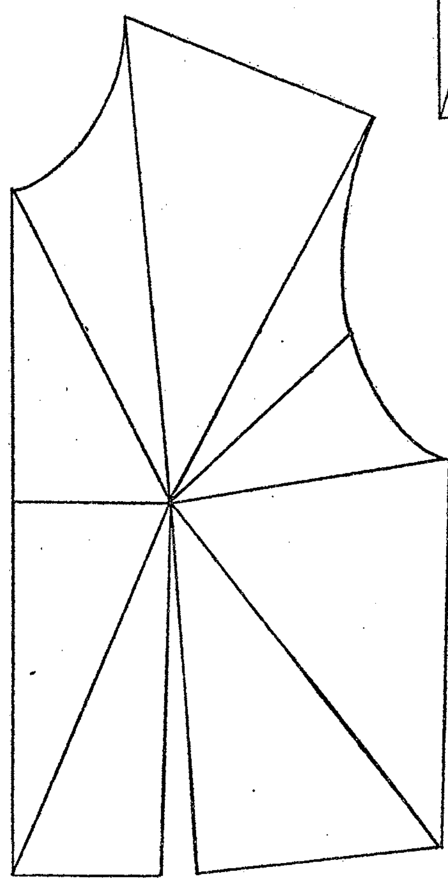

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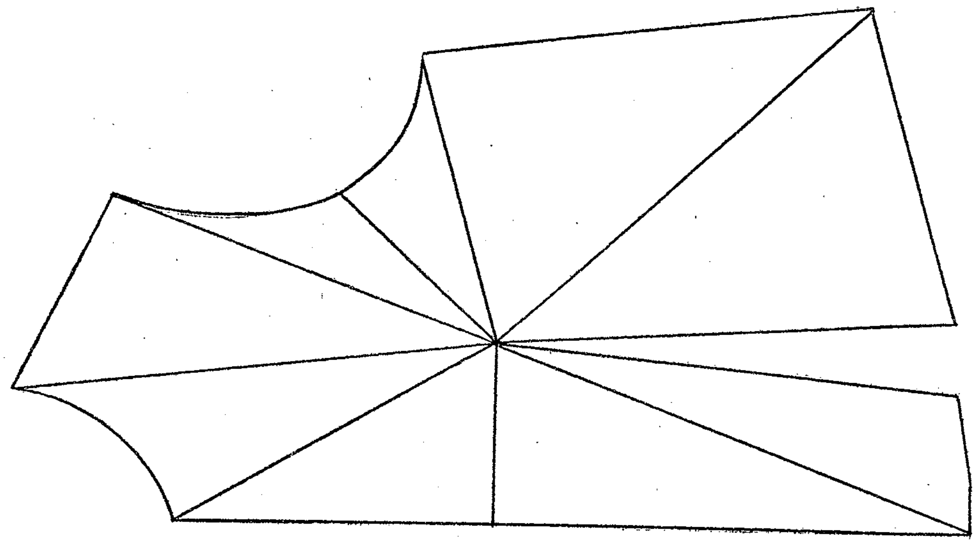

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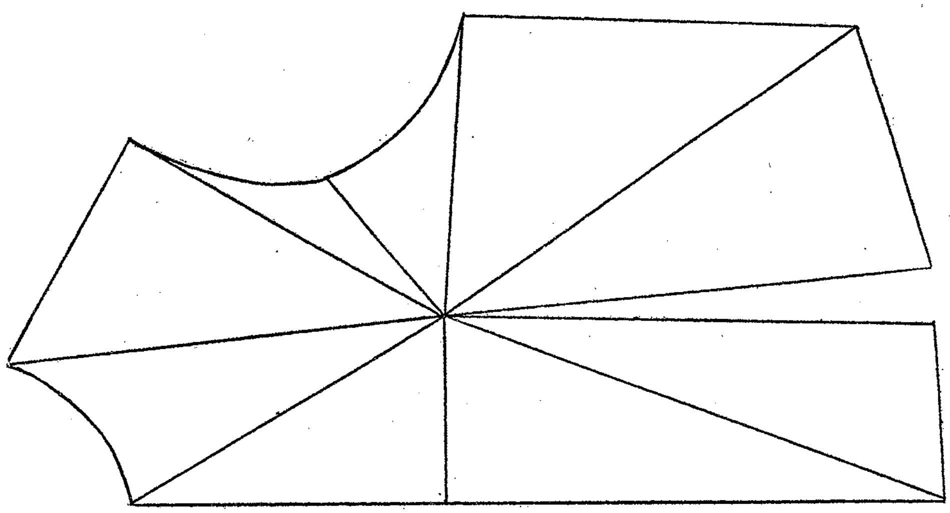

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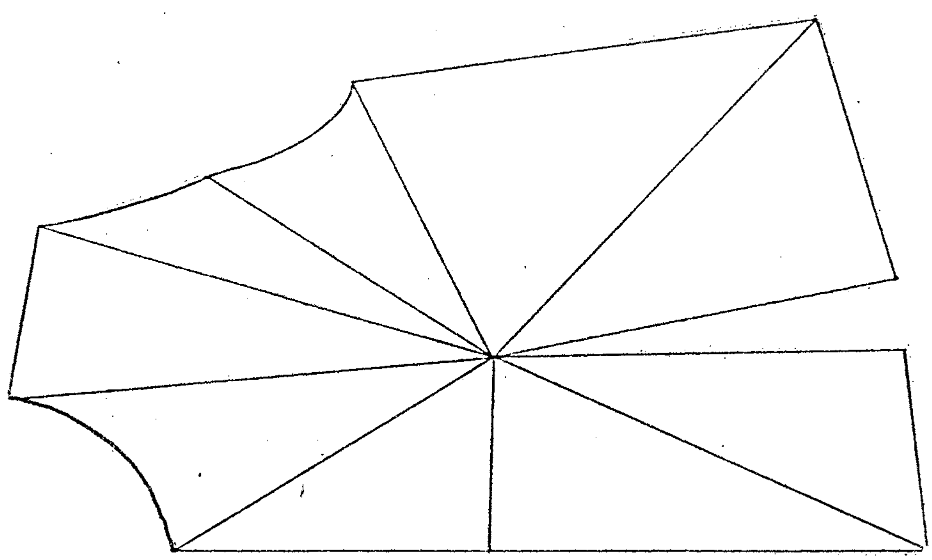

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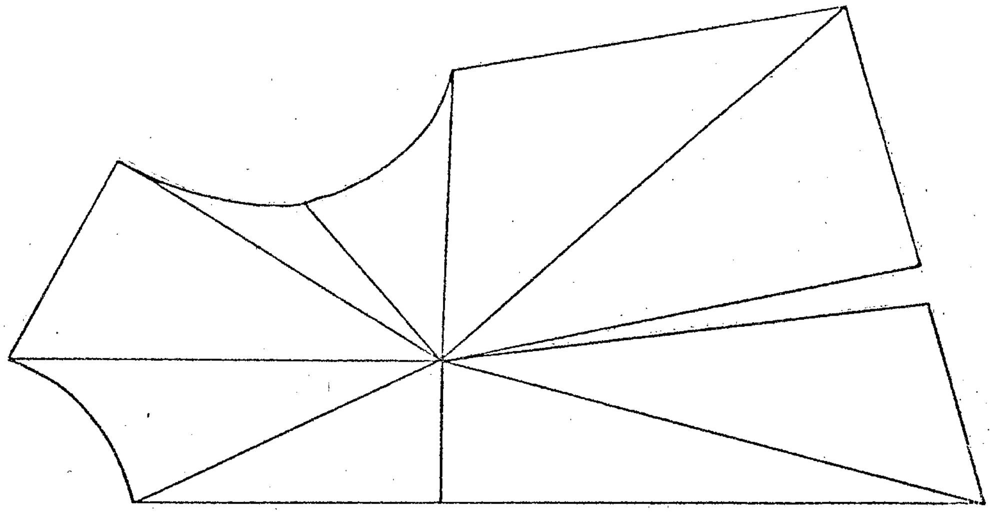

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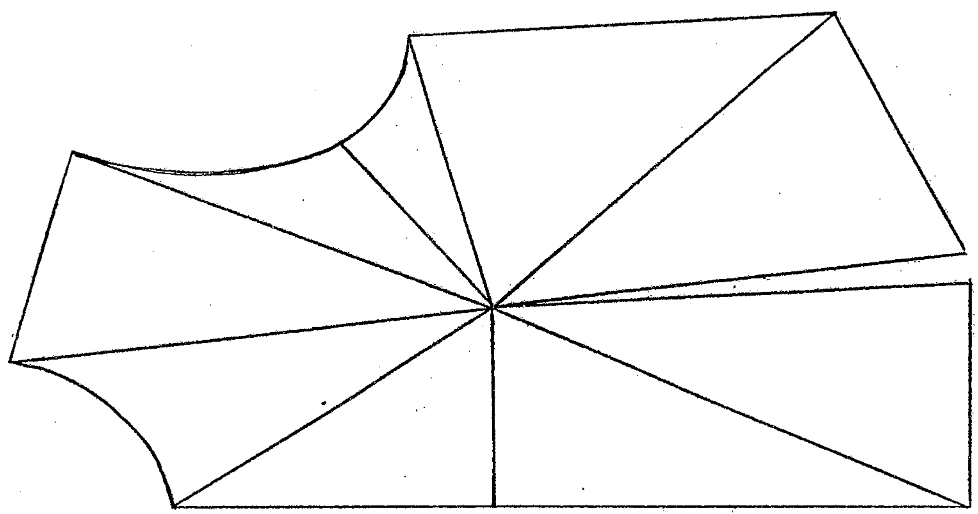

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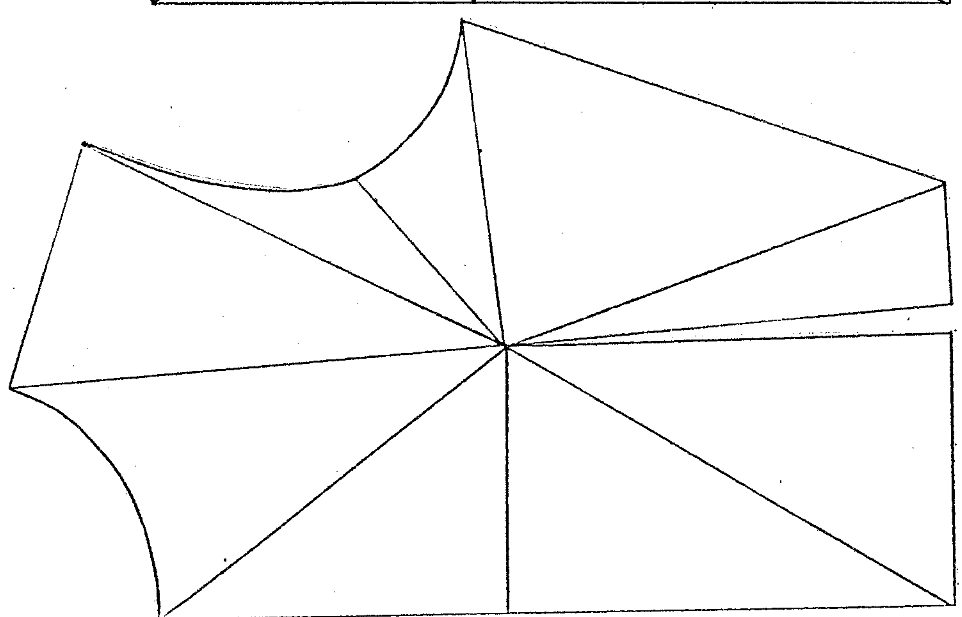

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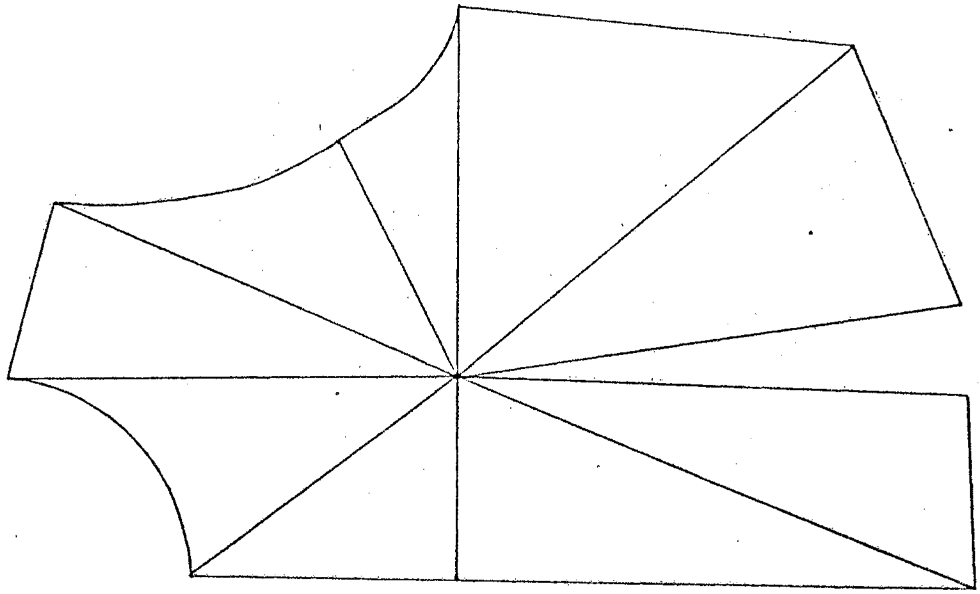

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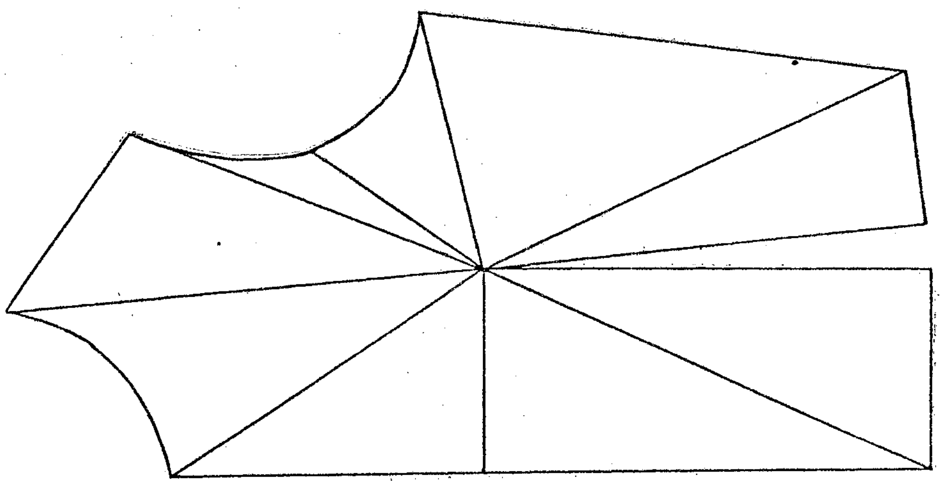

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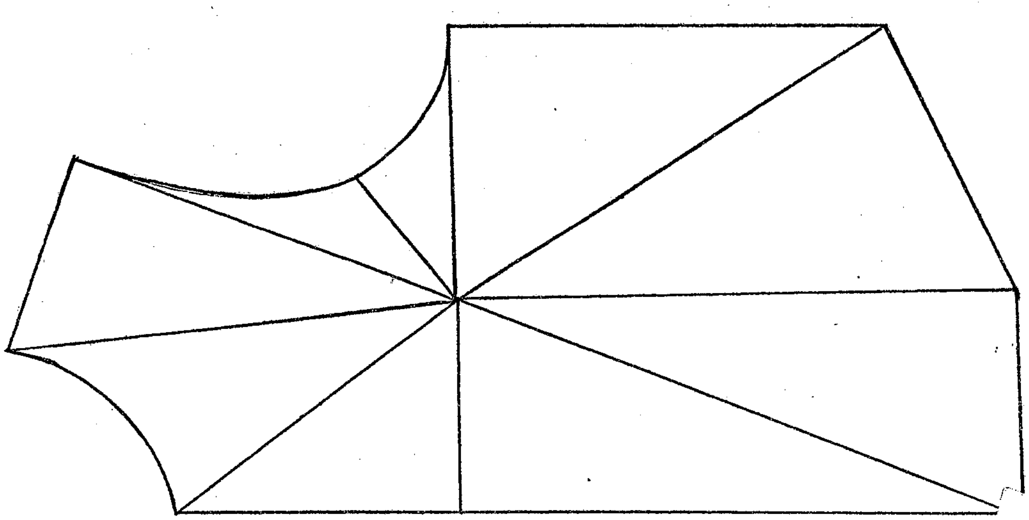

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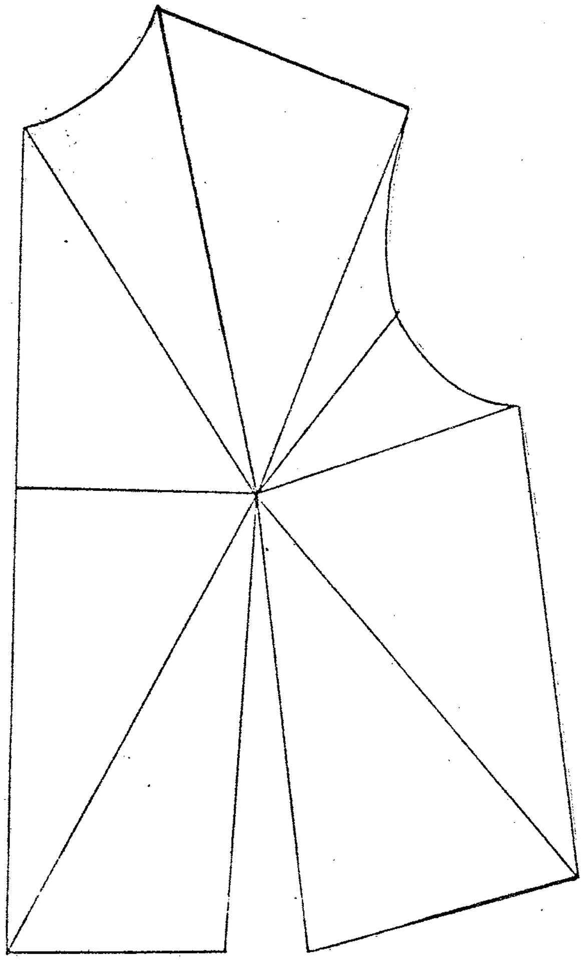

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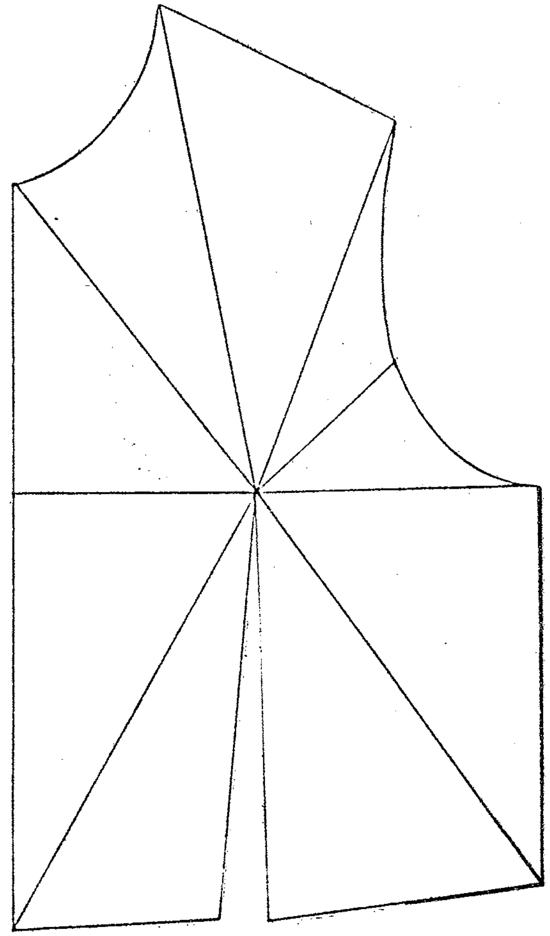

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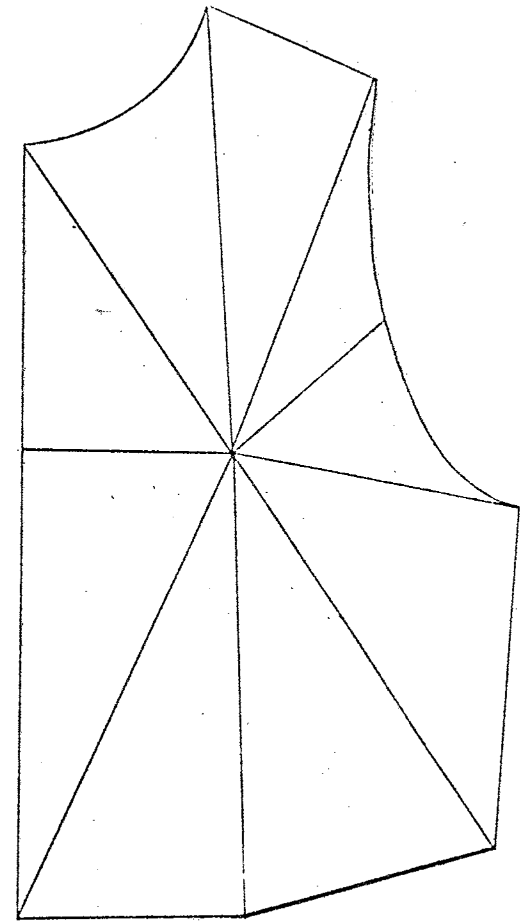

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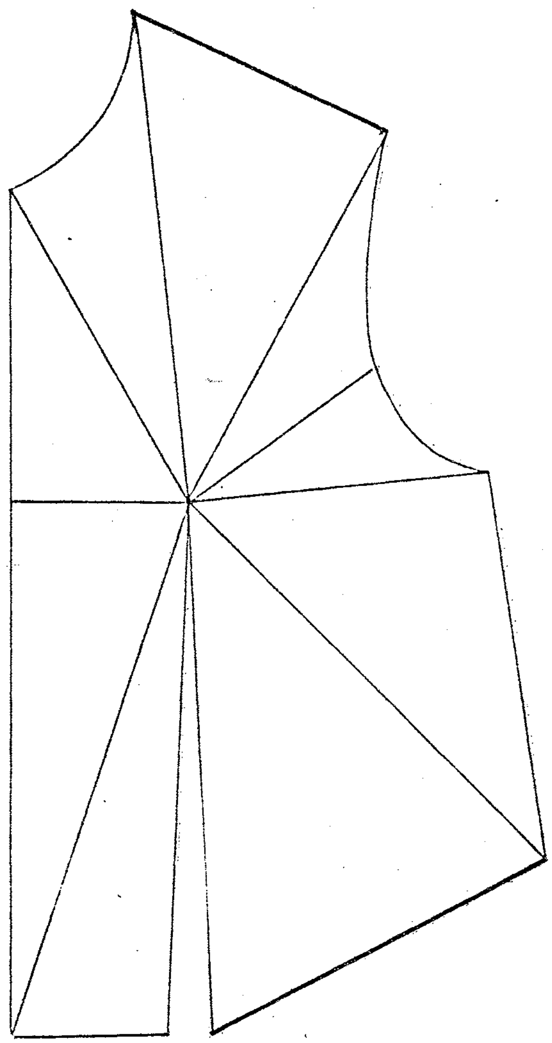

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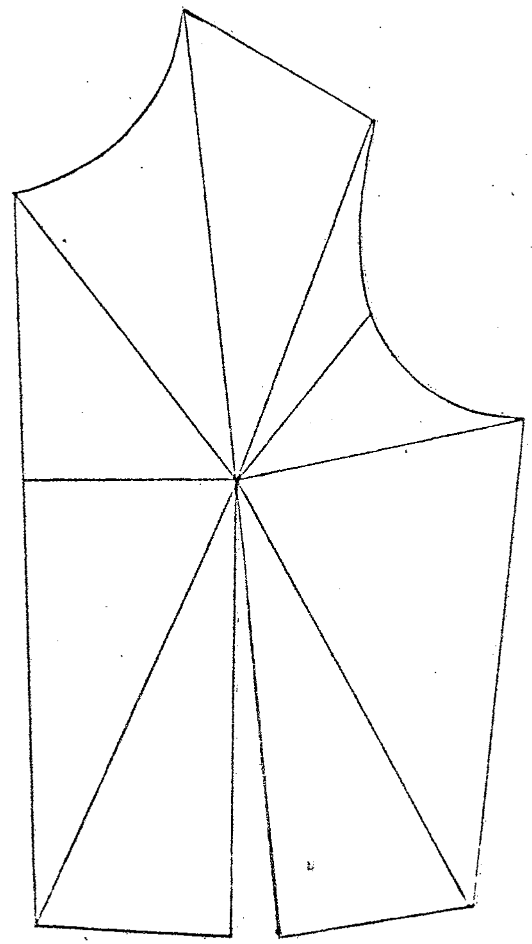

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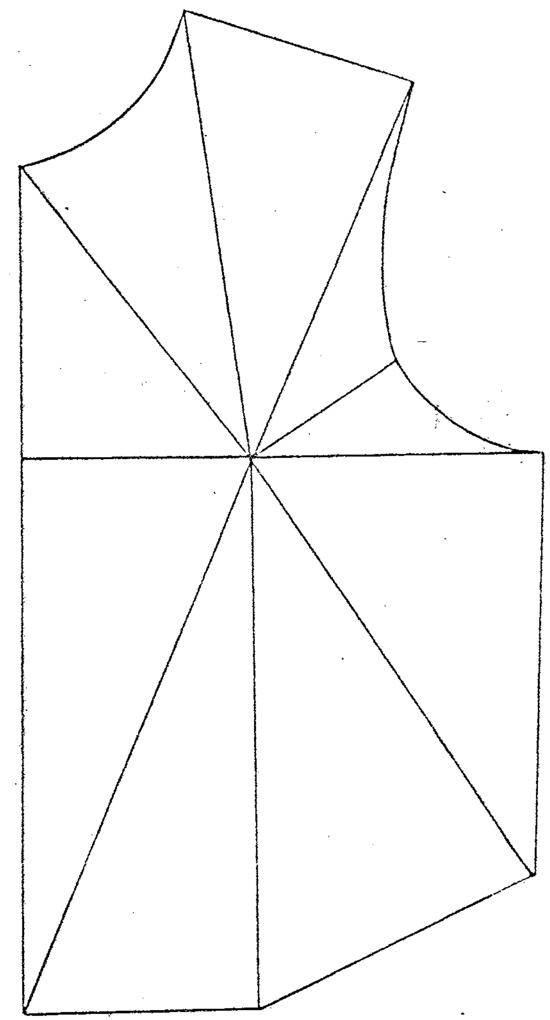

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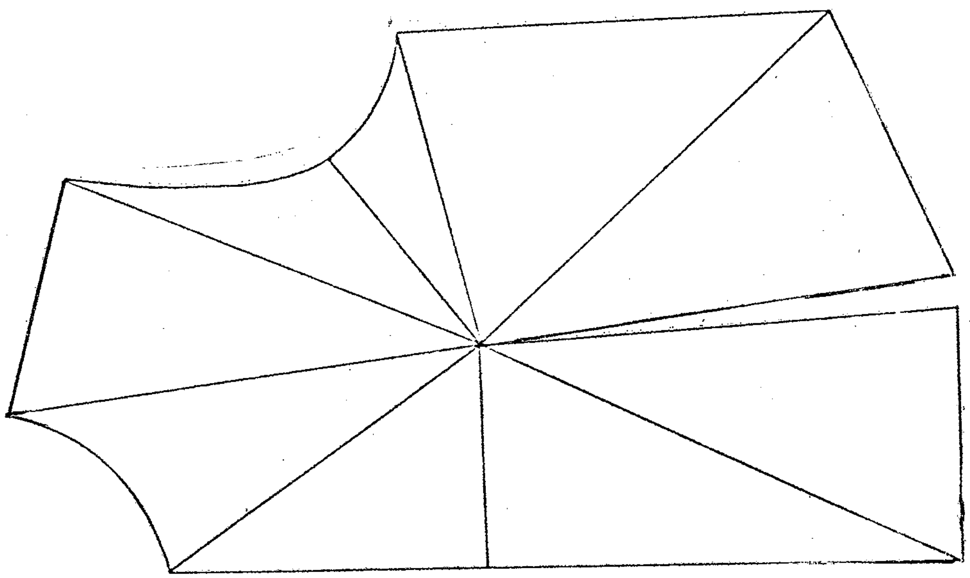

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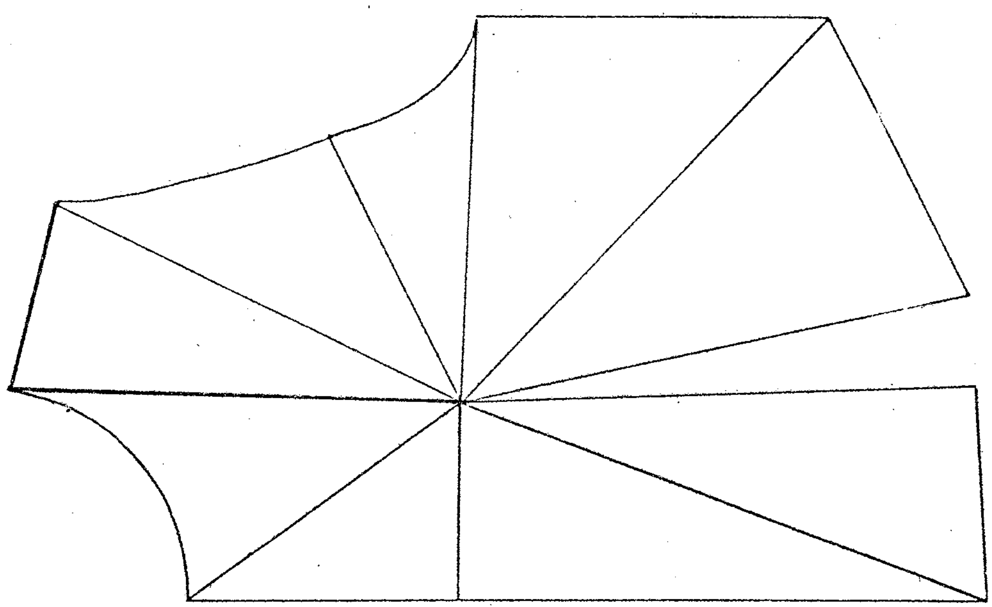

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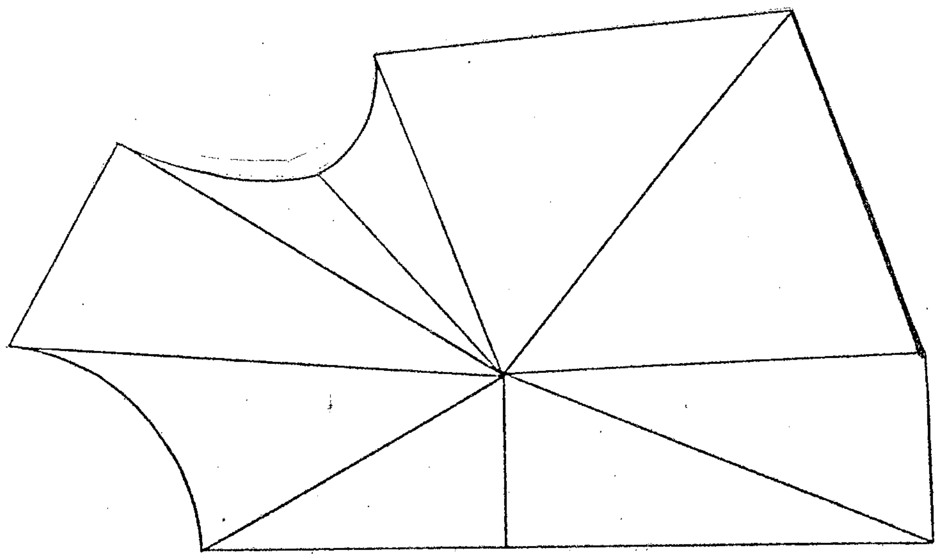

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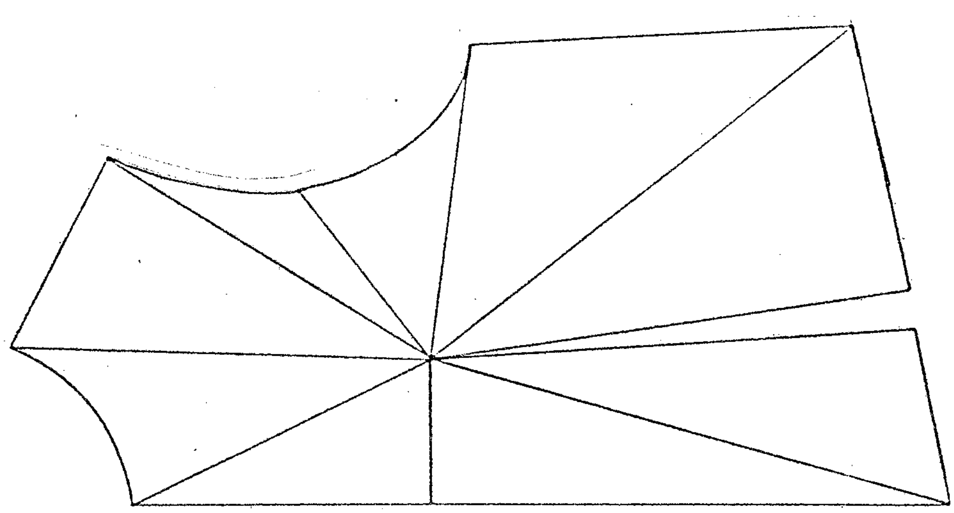

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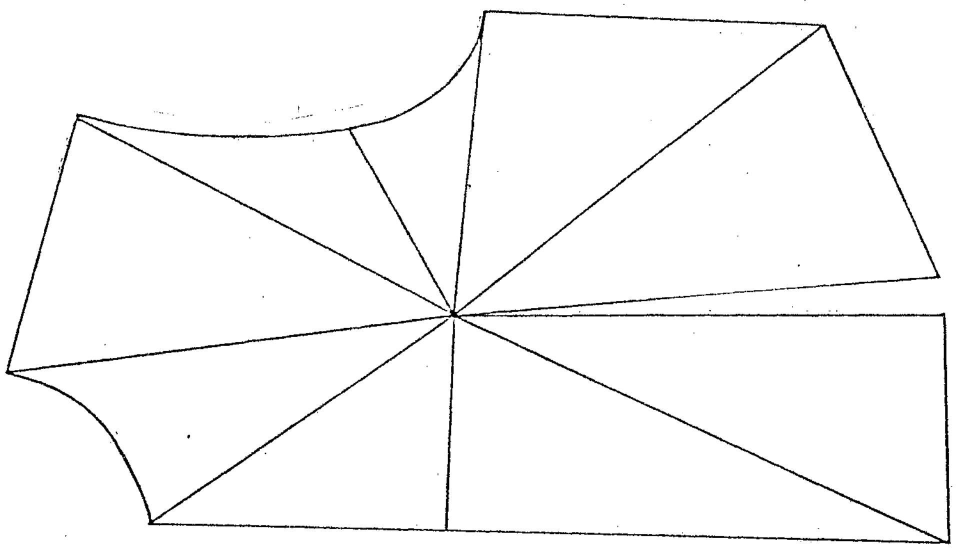

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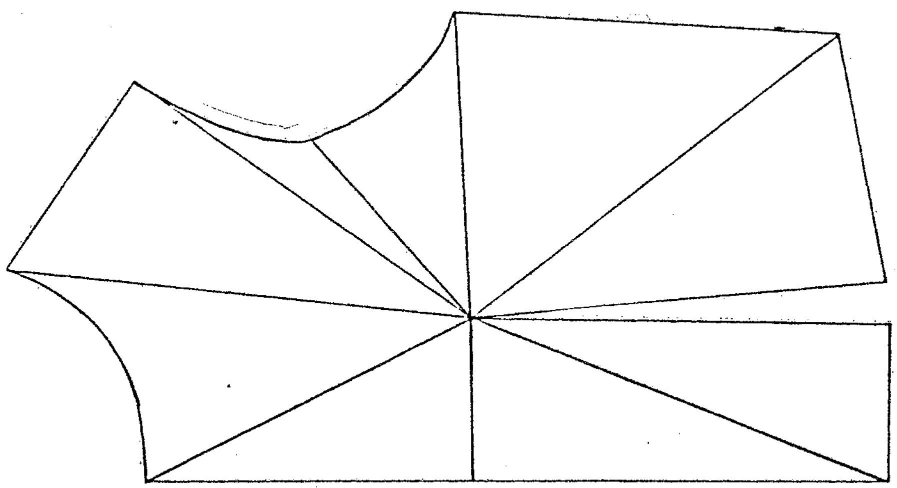

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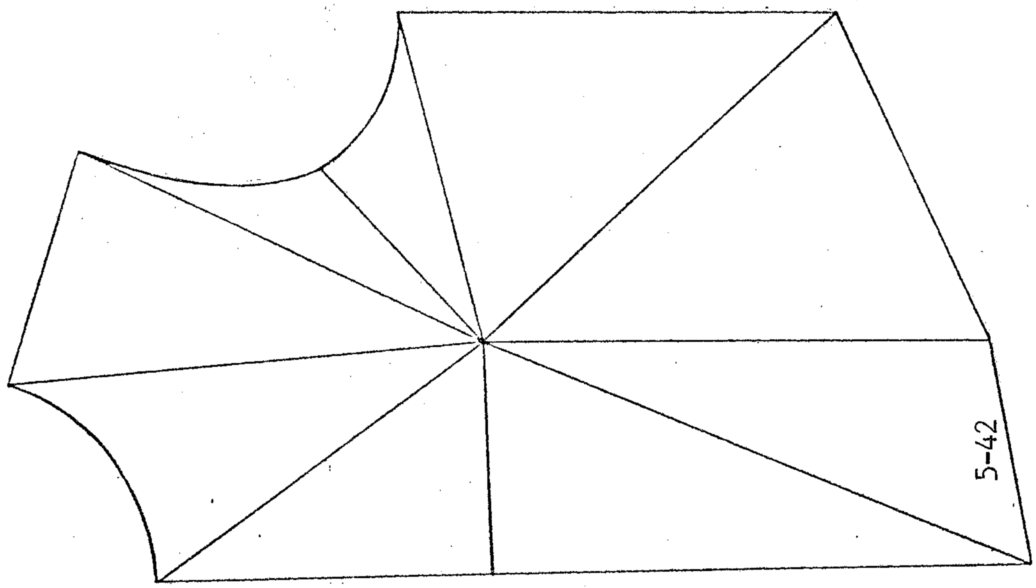

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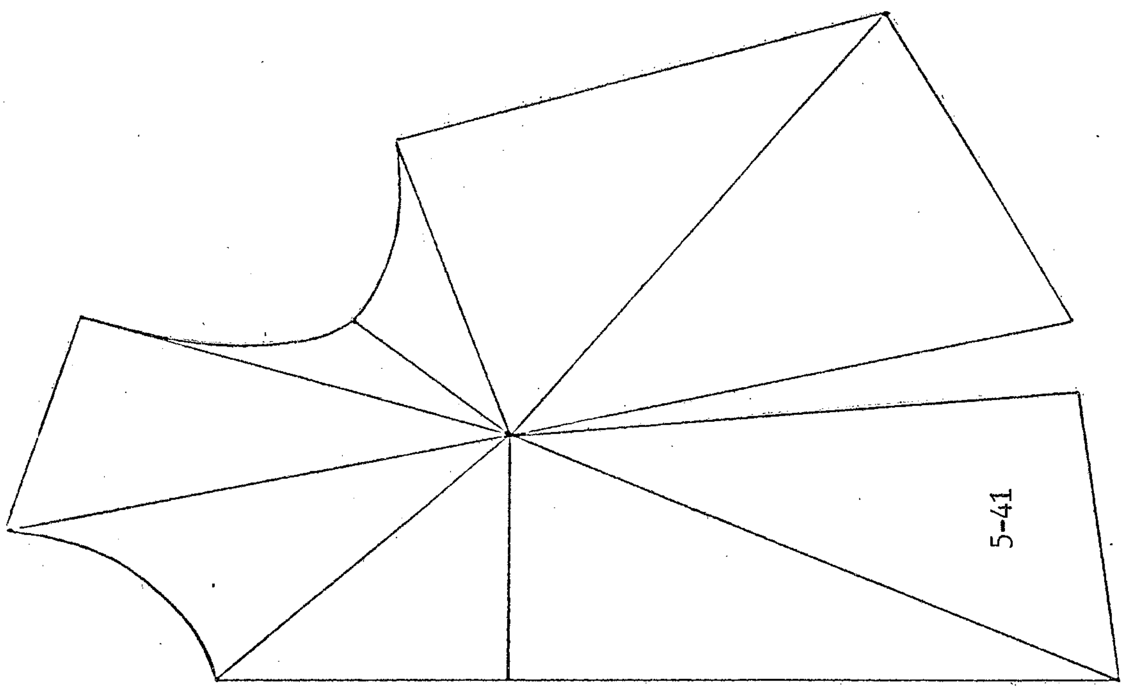

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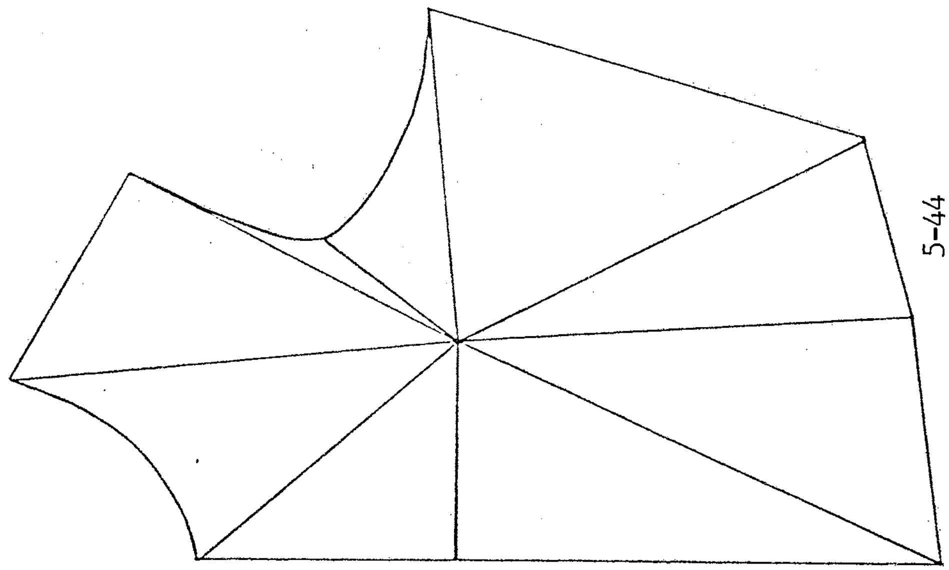
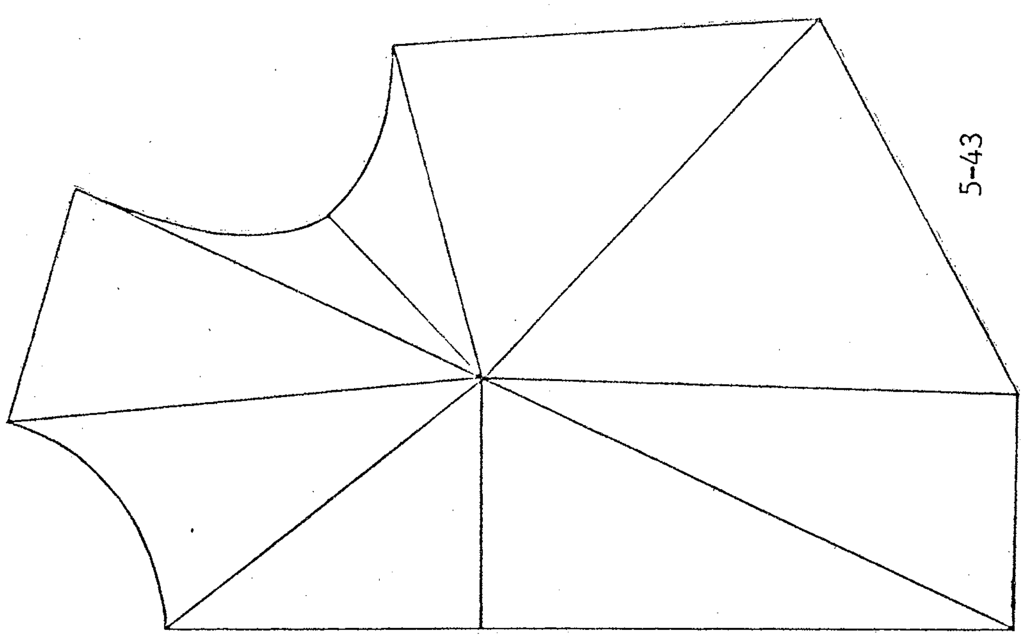
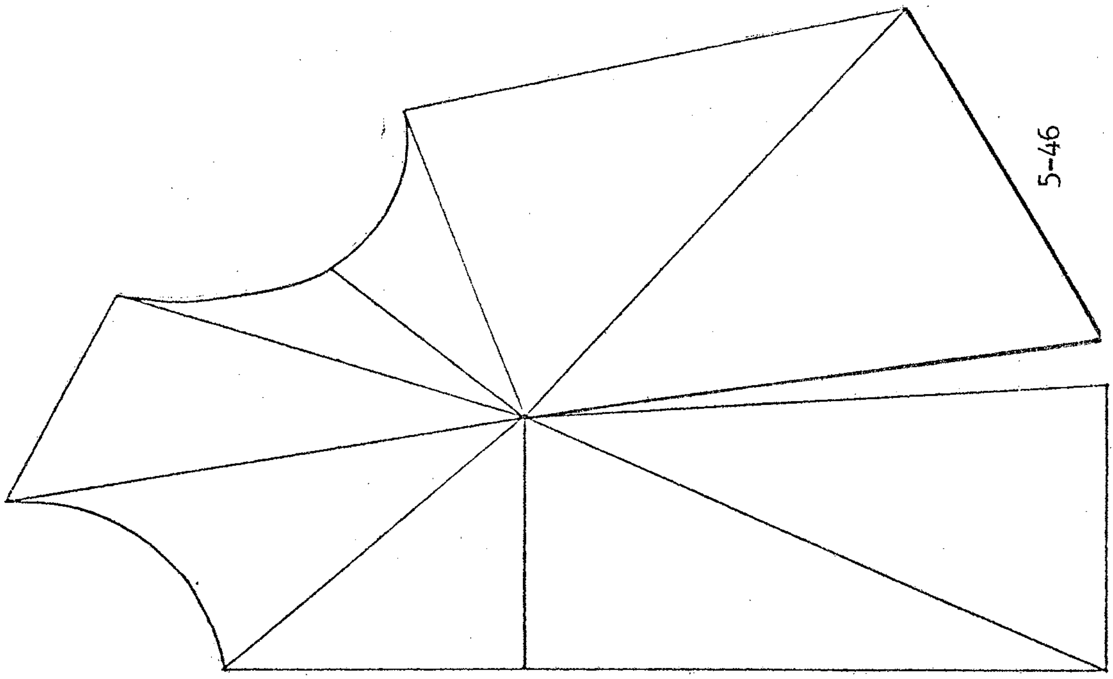


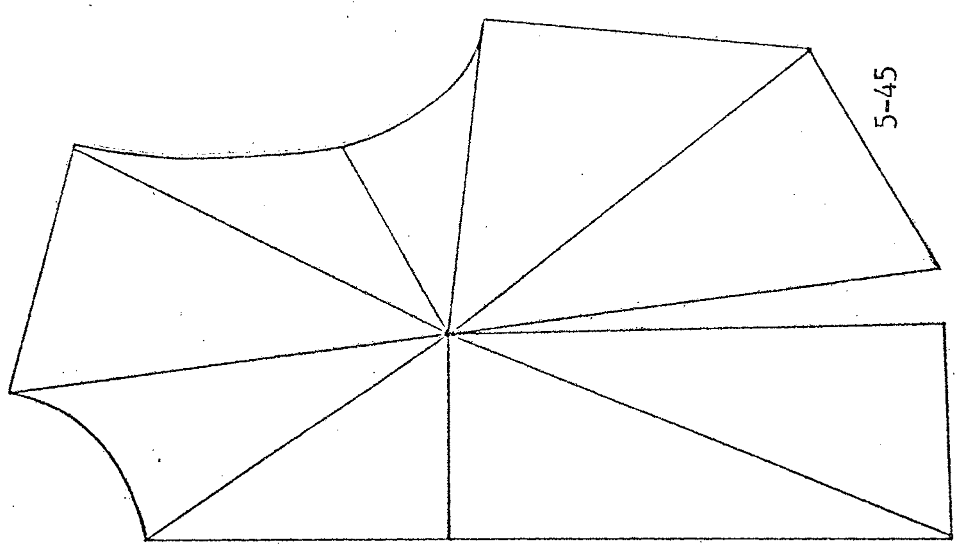
5-44



5-43



5-46



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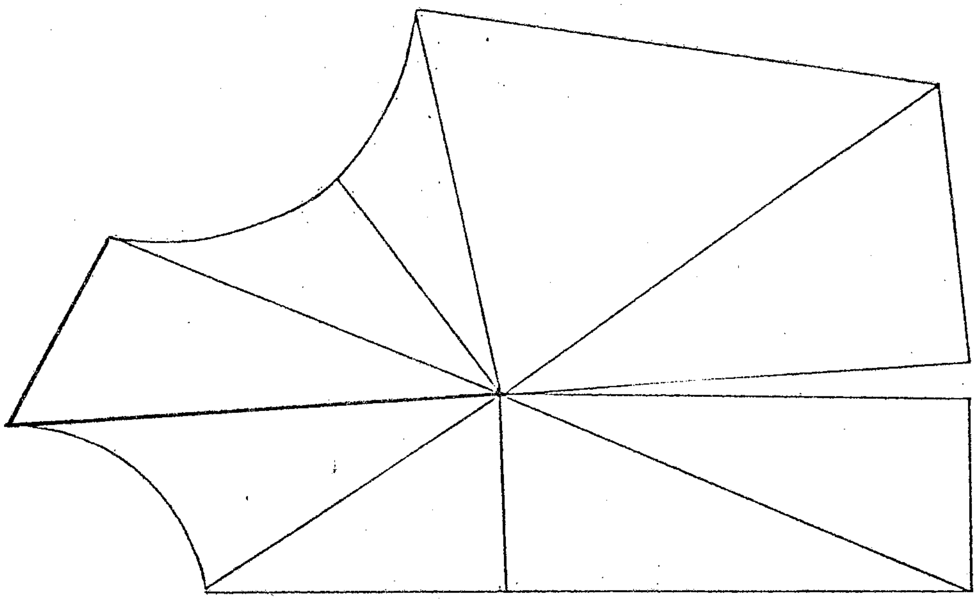
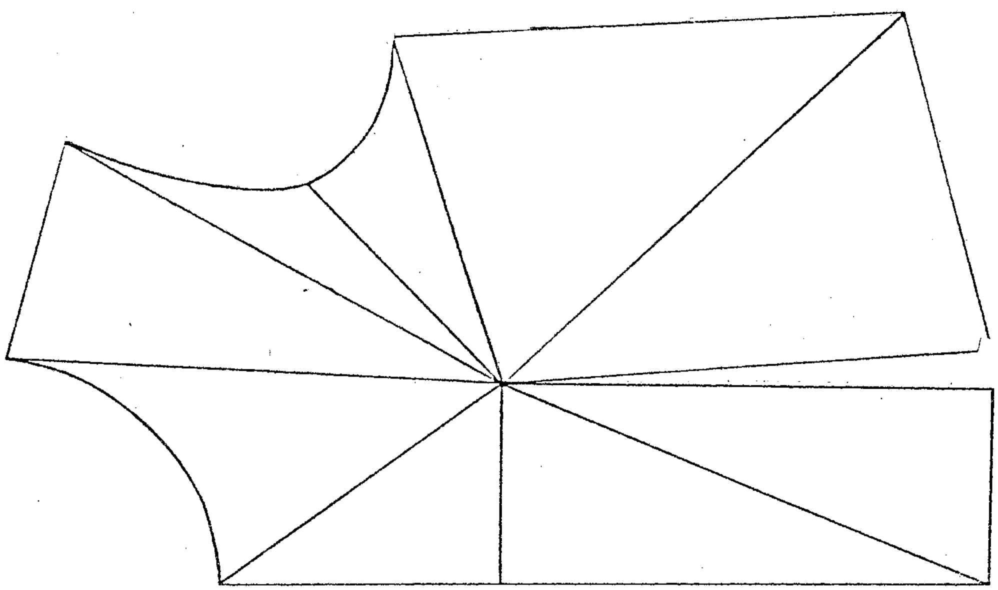


5-50



5-49

APPENDIX G

DATA FORMS FOR MALE SUBJECTS

SIZE GROUP: 1 SUBJECT NUMBER: 3

CHEST: 36 INSEAM: 28 AGE: 25

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.1875
SIDE SEAM: 10.0
CENTER FRONT LENGTH: 18.875

LINES		ANGLES	
BC 4.125	BI 6.25	CBD 60	IBK 65.5
BD 7.9	BK 10.97	DBE 26	KBL 26.5
BE 10.625	BL/M 11.375	EBG 34.5	DART 3.0
BG 9.625	BN 12.69	GBH 22.5	MBN 19.5
BH 5.75		HBI 33.0	NBC 72.03

SIZE GROUP: 1 SUBJECT NUMBER: 26

CHEST: 36.25 INSEAM: 27.5 AGE: 24

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.25
SIDE SEAM: 10.63
CENTER FRONT LENGTH: 19.19

LINES		ANGLES	
BC 4.13	BI 6.56	CBD 59.5	IBK 62.5
BD 8.44	BK 11.81	DBE 24.5	KBL 25.5
BE 11.63	BL/M 11.75	EBG 32.5	DART 9.0
BG 9.44	BN 12.44	GBH 27.0	MBN 15.0
BH 5.44		HBI 31.5	NBC 70.5

SIZE GROUP: 1 SUBJECT NUMBER: 25

CHEST: 36 INSEAM: 28 AGE: 14

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.25
SIDE SEAM: 10.94
CENTER FRONT LENGTH: 18.0

LINES				ANGLES			
BC	3.56	BI	6.25	CBD	61	IBK	64
BD	7.25	BK	11.94	DBE	27.5	KBL	27
BE	9.44	BL/M	11.63	EBG	33	DART	3
BG	8.63	BN	12.01	GBH	29	MBN	14.5
BH	4.56			HBI	26	NBC	73.5

SIZE GROUP: 1 SUBJECT NUMBER: 24

CHEST: 35.75 INSEAM: 30.5 AGE: 55

AVERAGED MEASUREMENTS

SHOULDER SEAM: 4.38
SIDE SEAM:10.75
CENTER FRONT LENGTH: 18.5

LINES				ANGLES			
BC	3.06	BI	6.25	CBD	68.5	IBK	72.5
BD	7.94	BK	10.56	DBE	29	KBL	25.5
BE	11.44	BL/M	11.01	EBG	22	DART	0
BG	9.88	BN	11.13	GBH	17.5	MBN	16
BH	5.25			HBI	36.5	NBC	74.5

SIZE GROUP: 1 SUBJECT NUMBER: 21

CHEST: 35 INSEAM: 27.5 AGE: 36

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.01
SIDE SEAM: 9.81
CENTER FRONT LENGTH: 18.56

LINES				ANGLES			
BC	3.69	BI	5.94	CBD	64	IBK	65
BD	8.0	BK	11.25	DBE	30	KBL	24
BE	10.69	BL/M	11.31	EBG	27	DART	4.5
BG	9.63	BN	12.0	GBH	17.5	MBN	21
BH	4.44			HBI	34.0	NBC	72

SIZE GROUP: 1 SUBJECT NUMBER: 47

CHEST: 34 INSEAM: 27 AGE: 19

AVERAGED MEASUREMENTS

SHOULDER SEAM:
SIDE SEAM:
CENTER FRONT LENGTH:

LINES				ANGLES			
BC	3.19	BI	5.5	CBD	63	IBK	72
BD	7.13	BK	11.0	DBE	27	KBL	26
BE	10.25	BL/M	10.38	EBG	30	DART	3
BG	8.13	BN	10.82	GBH	22	MBN	16
BH	4.25			HBI	31.5	NBC	73

SIZE GROUP: 1 SUBJECT NUMBER: 17

CHEST: 35 INSEAM: 32 AGE: 14

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.94
SIDE SEAM: 10.94
CENTER FRONT LENGTH: 17.5

LINES				ANGLES			
BC	3.13	BI	5.75	CBD	64	IBK	68
BD	7.19	BK	11.81	DBE	24.5	KBL	22.5
BE	9.38	BL/M	11.0	EBG	38	DART	0
BG	8.44	BN	11.5	GBH	18.5	MBN	18.5
BH	4.0			HBI	32	NBC	74

SIZE GROUP: 1 SUBJECT NUMBER:2

CHEST: 36 INSEAM: 28 AGE: 22

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.25
SIDE SEAM: 10.19
CENTER FRONT LENGTH: 19.19

LINES				ANGLES			
BC	4.44	BI	5.88	CBD	56.5	IBK	61
BD	8.25	BK	11.56	DBE	26	KBL	25
BE	10.13	BL/M	11.75	EBG	37.5	DART	4
BG	8.81	BN	13.12	GBH	22.5	MBN	16
BH	4.19			HBI	41	NBC	70.5

SIZE GROUP: 1 SUBJECT NUMBER: 23

CHEST: 35.5 INSEAM: 27.5 AGE: 36

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.75
SIDE SEAM: 9.88
CENTER FRONT LENGTH: 18.31

LINES				ANGLES			
BC	4.44	BI	5.69	CBD	55	IBK	59
BD	7.56	BK	11.44	DBE	29	KBL	28
BE	10.0	BL/M	11.75	EBG	33	DART	6.5
BG	8.88	BN	12.88	GBH	27	MBN	18
BH	4.25			HBI	35.5	NBC	69.5

SIZE GROUP: 1 SUBJECT NUMBER: 22

CHEST: 34 INSEAM: 27 AGE: 15

AVERAGED MEASUREMENTS

SHOULDER SEAM: 4.94
SIDE SEAM: 10.13
CENTER FRONT LENGTH: 17.31

LINES				ANGLES			
BC	3.44	BI	6.01	CBD	71	IBK	57
BD	7.38	BK	12.0	DBE	23	KBL	19.5
BE	9.75	BL/M	10.69	EBG	31	DART	3.5
BG	8.5	BN	10.69	GBH	25.5	MBN	18.0
BH	4.19			HBI	34.5	NBC	78.0

SIZE GROUP: 2 SUBJECT NUMBER: 16

CHEST: 40 INSEAM: 36 AGE: 21

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6
SIDE SEAM: 11
CENTER FRONT LENGTH: 19.38

LINES				ANGLES			
BC	4.07	BI	6.19	CBD	63.5	IBK	67.0
BD	9.0	BK	10.75	DBE	22.5	KBL	27.0
BE	11.72	BL/M	10.88	EBG	31.5	DART	5.0
BG	10.19	BN	11.94	GBH	20.0	MBN	17.5
BH	5.31			HBI	35.0	NBC	70.5

SIZE GROUP: 2 SUBJECT NUMBER: 18

CHEST: 40 INSEAM: 30 AGE: 14

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.68
SIDE SEAM: 7.44
CENTER FRONT LENGTH: 17.25

LINES				ANGLES			
BC	4.44	BI	6.56	CBD	60	IBK	48
BD	8.88	BK	10.01	DBE	26	KBL	36
BE	11.38	BL/M	8.88	EBG	30	DART	5
BG	9.94	BN	10.56	GBH	25.5	MBN	24
BH	4.88			HBI	41.5	NBC	64.5

SIZE GROUP: 2 SUBJECT NUMBER: 1

CHEST: 38 INSEAM: 27.5 AGE: 21

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.25
SIDE SEAM: 9.25
CENTER FRONT LENGTH: 17.94

LINES				ANGLES			
BC	3.5	BI	6.31	CBD	67	IBK	59.5
BD	8.44	BK	10.63	DBE	29	KBL	25.5
BE	11.0	BL/M	10.0	EBG	28	DART	6.0
BG	9.88	BN	10.94	GBH	13	MBN	17.5
BH	5.32			HBI	42.5	NBC	71.0

SIZE GROUP: 2 SUBJECT NUMBER: 20

CHEST: 38 INSEAM: 34 AGE: 18

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.13
SIDE SEAM: 10.94
CENTER FRONT LENGTH: 18.0

LINES				ANGLES			
BC	4.13	BI	5.25	CBD	55	IBK	75.5
BD	7.25	BK	10.88	DBE	31	KBL	16.5
BE	10.38	BL/M	11.63	EBG	28.5	DART	0
BG	9.0	BN	12.63	GBH	9.0	MBN	19.5
BH	3.56			HBI	52.0	NBC	71.0

SIZE GROUP: 2 SUBJECT NUMBER: 13

CHEST: 38 INSEAM: 27.5 AGE: 25

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.88
SIDE SEAM: 9.81
CENTER FRONT LENGTH: 16.88

LINES				ANGLES			
BC	3.94	BI	6.13	CBD	58	IBK	62
BD	7.34	BK	10.94	DBE	23	KBL	28
BE	10.03	BL/M	10.63	EBG	35	DART	5
BG	8.66	BN	11.44	GBH	28	MBN	19
BH	5.19			HBI	31	NBC	69

SIZE GROUP: 2 SUBJECT NUMBER: 12

CHEST: 38 INSEAM: 28 AGE: 29

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.01
SIDE SEAM: 12.22
CENTER FRONT LENGTH: 19.5

LINES				ANGLES			
BC	4.03	BI	7.01	CBD	58	IBK	67
BD	7.88	BK	13.28	DBE	28	KBL	26
BE	10.63	BL/M	12.63	EBG	33	DART	3
BG	10.5	BN	13.19	GBH	22	MBN	16
BH	5.56			HBI	35	NBC	72

SIZE GROUP: 2 SUBJECT NUMBER: 19

CHEST: 40.25 INSEAM: 30 AGE: 50

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.82
SIDE SEAM: 7.56
CENTER FRONT LENGTH: 14.63

LINES				ANGLES			
BC	4.75	BI	6.19	CBD	55	IBK	57
BD	8.44	BK	8.88	DBE	28	KBL	36
BE	10.28	BL/M	7.13	EBG	33	DART	11
BG	9.69	BN	9.0	GBH	22	MBN	32
BH	4.44			HBI	30	NBC	58

SIZE GROUP: 2 SUBJECT NUMBER: 11

CHEST: 38 INSEAM: 28.5 AGE: 39

AVERAGED MEASUREMENTS

SHOULDER SEAM: 4.94
SIDE SEAM: 10.5
CENTER FRONT LENGTH: 18

LINES				ANGLES			
BC	4.69	BI	6.0	CBD	57	IBK	76
BD	8.84	BK	10.25	DBE	32	KBL	28
BE	10.94	BL/M	10.53	GBG	26	DART	10
BG	9.31	BN	12.01	GBH	17	MBN	25
BH	5.25			HBI	30	NBC	66

SIZE GROUP: 2 SUBJECT NUMBER: 8

CHEST: 38 INSEAM: 28 AGE: 52

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.0
SIDE SEAM: 9.69
CENTER FRONT LENGTH: 18.63

LINES				ANGLES			
BC	4.47	BI	6.81	CBD	60	IBK	58
BD	8.63	BK	11.25	DBE	28	KBL	33
BE	11.31	BL/M	10.75	EBG	30	DART	3
BG	10.31	BN	12.01	GBH	20	MBN	20
BH	5.63			HBI	38	NBC	68

SIZE GROUP: 2 SUBJECT NUMBER: 6

CHEST: 40.5 INSEAM: 27 AGE: 50

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.01
SIDE SEAM: 10.56
CENTER FRONT LENGTH: 17.63

LINES				ANGLES			
BC	4.56	BI	5.81	CBD	59	IBK	79
BD	8.81	BK	10.0	DBE	29	KBL	30
BE	11.56	BL/M	10.0	EBG	25	DART	4
BG	10.25	BN	11.13	GBH	19	MBN	22
BH	5.56			HBI	30	NBC	62

SIZE GROUP: 3 SUBJECT NUMBER: 5

CHEST: 44 INSEAM: 28.5 AGE: 41

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.5
SIDE SEAM: 9.94
CENTER FRONT LENGTH: 20.19

LINES				ANGLES			
BC	4.65	BI	7.72	CBD	59	IBK	51
BD	8.97	BK	12.53	DBE	26	KBL	30
BE	10.75	BL/M	12.0	EBG	37	DART	7
BG	8.94	BN	13.25	GBH	21	MBN	17
BH	4.47			HBI	43	NBC	70

SIZE GROUP: 3 SUBJECT NUMBER: 7

CHEST: 42 INSEAM: 29 AGE: 37

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.56
SIDE SEAM: 11.13
CENTER FRONT LENGTH: 19.75

LINES				ANGLES			
BC	4.66	BI	7.63	CBD	60	IBK	61
BD	9.19	BK	12.65	DBE	24	KBL	40
BE	11.81	BL/M	11.34	EBG	28	DART	10
BG	10.19	BN	12.63	GBH	23	MBN	17
BH	5.56			HBI	31	NBC	64

SIZE GROUP: 3 SUBJECT NUMBER: 28

CHEST: 42 INSEAM: 28.5 AGE: 54

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.63
SIDE SEAM: 10.63
CENTER FRONT LENGTH: 19.69

LINES				ANGLES			
BC	5.0	BI	7.31	CBD	60	IBK	66
BD	9.25	BK	11.31	DBE	26	KBL	35
BE	11.94	BL/M	11.75	EBG	28	DART	4
BG	11.01	BN	12.88	GBH	28	MBN	24
BH	5.56			HBI	25	NBC	67

SIZE GROUP: 3 SUBJECT NUMBER: 30

CHEST: 44.5 INSEAM: 32 AGE: 39

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.75
SIDE SEAM: 10.88
CENTER FRONT LENGTH: 21.19

LINES				ANGLES			
BC	5.25	BI	7.0	CBD	54	IBK	59
BD	8.69	BK	12.69	DBE	31	KBL	32
BE	11.06	BL/M	13.88	EBG	28	DART	0
BG	10.0	BN	15.25	GBH	31	MBN	21
BH	4.0			HBI	37	NBC	70

SIZE GROUP: 3 SUBJECT NUMBER: 29

CHEST: 41.5 INSEAM: 29.5 AGE: 40

AVERAGED MEASUREMENTS

SHOULDER SEAM: 4.44
SIDE SEAM: 9.88
CENTER FRONT LENGTH: 19.38

LINES				ANGLES			
BC	4.94	BI	8.81	CBD	55	IBK	51
BD	8.19	BK	12.5	DBE	36	KBL	32
BE	11.13	BL/M	12.44	EBG	23	DART	10
BG	10.94	BN	13.75	GBH	40	MBN	19
BH	6.44			HBI	28	NBC	70

SIZE GROUP: 3 SUBJECT NUMBER: 27

CHEST: 42 INSEAM: 27 AGE: 15

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.31
SIDE SEAM: 9.75
CENTER FRONT LENGTH: 19.38

LINES				ANGLES			
BC	3.31	BI	7.0	CBD	67	IBK	47
BD	8.19	BK	13.01	DBE	25	KBL	31
BE	10.69	BL/M	11.63	EBG	31	DART	4
BG	9.31	BN	12.38	GBH	18	MBN	21
BH	5.0			HBI	45	NBC	75

SIZE GROUP: 3 SUBJECT NUMBER: 10

CHEST: 42 INSEAM: 30 AGE: 37

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.31
SIDE SEAM: 12.5
CENTER FRONT LENGTH: 19.31

LINES		ANGLES	
BC 6.38	BI 7.78	CBD 53	IBK 79
BD 10.56	BK 11.44	DBE 34	KBL 15
BE 12.25	BL/M 10.91	EBG 30	DART 4
BG 11.5	BN 12.56	GBH 23	MBN 29
BH 5.63		HBI 35	NBC 60

SIZE GROUP: 3 SUBJECT NUMBER: 31

CHEST: 43.5 INSEAM: 34 AGE: 26

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.5
SIDE SEAM: 11.94
CENTER FRONT LENGTH: 18.25

LINES		ANGLES	
BC 4.94	BI 6.5	CBD 58	IBK 79
BD 9.0	BK 11.44	DBE 28	KBL 20
BE 11.75	BL/M 10.81	EBG 27	DART 6
BG 9.25	BN 11.88	GBH 14	MBN 24
BH 5.19		HBI 43	NBC 67

SIZE GROUP: 3 SUBJECT NUMBER: 4

CHEST: 42 INSEAM: 28 AGE: 36

AVERAGED MEASUREMENTS

SHOULDER SEAM: 4.44
SIDE SEAM: 11.56
CENTER FRONT LENGTH: 18.58

LINES				ANGLES			
BC	4.63	BI	7.44	CBD	60	IBK	73
BD	8.94	BK	11.25	DBE	26	KBL	35
BE	11.94	BL/M	10.13	EBG	21	DART	10
BG	11.56	BN	11.69	GBH	16	MBN	24
BH	8.54			HBI	30	NBC	67

SIZE GROUP: 3 SUBJECT NUMBER: 15

CHEST: 43 INSEAM: 32 AGE: 42

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.56
SIDE SEAM: 9.44
CENTER FRONT LENGTH: 16.94

LINES				ANGLES			
BC	3.94	BI	7.13	CBD	64	IBK	61
BD	8.56	BK	10.94	DBE	22	KBL	35
BE	12.01	BL/M	9.13	EBG	34	DART	6
BG	10.94	BN	10.19	GBH	20	MBN	23
BH	6.13			HBI	34	NBC	66

SIZE GROUP: 4 SUBJECT NUMBER: 36

CHEST: 46.5 INSEAM: 29.5 AGE: 40

AVERAGED MEASUREMENTS

SHOULDER SEAM: 4.75
SIDE SEAM: 9.19
CENTER FRONT LENGTH: 19.56

LINES				ANGLES			
BC	4.88	BI	9.25	CBD	55	IBK	44
BD	8.25	BK	12.88	DBE	37	KBL	34
BE	11.25	BL/M	12.63	EBG	24	DART	11
BG	11.0	BN	13.84	GBH	37	MBN	20
BH	7.25			HBI	29	NBC	70

SIZE GROUP: 4 SUBJECT NUMBER: 35

CHEST: 46.5 INSEAM: 28 AGE: 33

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.88
SIDE SEAM: 10.5
CENTER FRONT LENGTH: 20.5

LINES				ANGLES			
BC	5.53	BI	7.01	CBD	53	IBK	58
BD	8.88	BK	12.19	DBE	29	KBL	33
BE	11.13	BL/M	13.44	EBG	31	DART	0
BG	10.19	BN	14.63	GBH	33	MBN	23
BH	4.31			HBI	33	NBC	68

SIZE GROUP: 4 SUBJECT NUMBER: 38

CHEST: 46 INSEAM: 29.5 AGE: 18

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.31
SIDE SEAM: 9.69
CENTER FRONT LENGTH: 19.31

LINES				ANGLES			
BC	3.59	BI	7.56	CBD	64	IBK	45
BD	8.13	BK	13.06	DBE	27	KBL	30
BE	10.38	BL/M	11.81	EBG	30	DART	5
BG	9.38	BN	13.19	GBH	20	MBN	24
BH	5.19			HBI	46	NBC	74

SIZE GROUP: 4 SUBJECT NUMBER: 37

CHEST: 47 INSEAM: 27 AGE: 46

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.88
SIDE SEAM: 10.88
CENTER FRONT LENGTH: 19.5

LINES				ANGLES			
BC	5.34	BI	7.78	CBD	56	IBK	63
BD	9.38	BK	11.75	DBE	27	KBL	36
BE	11.82	BL/M	11.68	EBG	29	DART	4
BG	11.01	BN	12.88	GBH	29	MBN	27
BH	5.78			HBI	24	NBC	66

SIZE GROUP: 4 SUBJECT NUMBER: 9

CHEST: 46 INSEAM: 30 AGE: 60

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.38
SIDE SEAM: 11.81
CENTER FRONT LENGTH: 20.19

LINES		ANGLES	
BC 5.88	BI 6.69	CBD 58	IBK 72
BD 10.63	BK 12.0	DBE 21	KBL 33
BE 12.38	BL/M 11.38	EBG 32	DART 10
BG 10.18	BN 12.88	GBH 16	MBN 22
BH 5.63		HBI 34	NBC 63

SIZE GROUP: 4 SUBJECT NUMBER: 14

CHEST: 46.5 INSEAM: 29 AGE: 31

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.43
SIDE SEAM: 9.94
CENTER FRONT LENGTH: 18.5

LINES		ANGLES	
BC 5.88	BI 6.88	CBD 53	IBK 55
BD 9.63	BK 11.88	DBE 26	KBL 35
BE 12.25	BL/M 10.5	EBG 31	DART 6
BG 9.81	BN 12.25	GBH 26	MBN 22
BH 4.63		HBI 43	NBC 62

SIZE GROUP: 4 SUBJECT NUMBER: 33

CHEST: 45.5 INSEAM: 28.5 AGE: 32

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.75
SIDE SEAM: 9.69
CENTER FRONT LENGTH: 20.75

LINES				ANGLES			
BC	4.31	BI	7.31	CBD	61	IBK	52
BD	8.81	BK	12.25	DBE	23	KBL	42
BE	12.13	BL/M	13.13	EBG	33	DART	5
BG	10.38	BN	13.88	GBH	26	MBN	17
BH	5.63			HBI	31	NBC	72

SIZE GROUP: 4 SUBJECT NUMBER: 32

CHEST: 47.5 INSEAM: 29 AGE: 62

AVERAGED MEASUREMENTS

SHOULDER SEAM: 4.375
SIDE SEAM: 8.75
CENTER FRONT LENGTH: 19.0

LINES				ANGLES			
BC	5.01	BI	7.0	CBD	57	IBK	47
BD	9.13	BK	11.56	DBE	30	KBL	31
BE	11.01	BL/M	11.5	EBG	23	DART	0
BG	9.94	BN	12.5	GBH	28	MBN	23
BH	5.31			HBI	52	NBC	67

SIZE GROUP: 4 SUBJECT NUMBER: 34

CHEST: 46.5 INSEAM: 30 AGE: 41

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.34
SIDE SEAM: 12.13
CENTER FRONT LENGTH: 18.13

LINES		ANGLES	
BC 5.13	BI 7.13	CBD 56	IBK 75
BD 8.88	BK 11.88	DBE 31	KBL 24
BE 11.69	BL/M 11.38	EBG 27	DART 6
BG 9.44	BN 12.0	GBH 18	MBN 24
BH 5.19		HBI 40	NBC 65

SIZE GROUP: 4 SUBJECT NUMBER: 48

CHEST: 47 INSEAM: 28 AGE: 40

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.75
SIDE SEAM: 10.5
CENTER FRONT LENGTH: 17.88

LINES		ANGLES	
BC 4.13	BI 8.34	CBD 61	IBK 62
BD 8.5	BK 11.25	DBE 33	KBL 48
BE 12.25	BL/M 10.38	EBG 27	DART 0
BG 11.0	BN 11.25	GBH 16	MBN 22
BH 6.63		HBI 21	NBC 69

SIZE GROUP: 5 SUBJECT NUMBER: 44

CHEST: 50.5 INSEAM: 30 AGE: 18

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.94
SIDE SEAM: 11.13
CENTER FRONT LENGTH: 18.13

LINES				ANGLES			
BC	5.25	BI	8.0	CBD	51	IBK	71
BD	8.13	BK	11.13	DBE	34	KBL	23
BE	11.0	BL/M	11.44	EBG	32	DART	0
BG	8.94	BN	13.0	GBH	10	MBN	25
BH	4.01			HBI	48	NBC	66

SIZE GROUP: 5 SUBJECT NUMBER: 42

CHEST: 50.5 INSEAM: 34 AGE: 21

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.81
SIDE SEAM: 10.56
CENTER FRONT LENGTH: 20.69

LINES				ANGLES			
BC	5.56	BI	8.19	CBD	56	IBK	63
BD	9.69	BK	11.63	DBE	32	KBL	43
BE	11.56	BL/M	12.38	EBG	29	DART	0
BG	10.94	BN	14.5	GBH	21	MBN	24
BH	5.75			HBI	29	NBC	66

SIZE GROUP: 5 SUBJECT NUMBER: 49

CHEST: 50 INSEAM: 30.5 AGE: 37

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.75
SIDE SEAM: 12.75
CENTER FRONT LENGTH: 18.88

LINES				ANGLES			
BC	4.75	BI	8.63	CBD	55	IBK	67
BD	8.5	BK	13.25	DBE	38	KBL	38
BE	12.13	BL/M	12.0	EBG	26	DART	4
BG	12.13	BN	12.88	GBH	17	MBN	20
BH	6.75			HBI	27	NBC	68

SIZE GROUP: 5 SUBJECT NUMBER: 50

CHEST: 52 INSEAM: 31 AGE: 27

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.13
SIDE SEAM: 13.0
CENTER FRONT LENGTH: 18.88

LINES				ANGLES			
BC	4.63	BI	9.5	CBD	58	IBK	69
BD	8.5	BK	13.0	DBE	29	KBL	31
BE	12.13	BL/M	11.5	EBG	25	DART	4
BG	10.38	BN	12.5	GBH	31	MBN	19
BH	6.5			HBI	25	NBC	69

SIZE GROUP: 5 SUBJECT NUMBER: 46

CHEST: 50 INSEAM: 29.5 AGE: 47

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.81
SIDE SEAM: 12.75
CENTER FRONT LENGTH: 21.5

LINES				ANGLES			
BC	6.01	BI	7.94	CBD	51	IBK	66
BD	9.5	BK	13.5	DBE	31	KBL	40
BE	12.88	BL/M	14.13	EBG	26	DART	4
BG	10.44	BN	15.56	GBH	21	MBN	26
BH	5.81			HBI	31	NBC	66

SIZE GROUP: 5 SUBJECT NUMBER: 39

CHEST: 50 INSEAM: 30 AGE: 30

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.25
SIDE SEAM: 8.44
CENTER FRONT LENGTH: 19.56

LINES				ANGLES			
BC	4.88	BI	7.5	CBD	56	IBK	47
BD	8.63	BK	11.25	DBE	27	KBL	30
BE	10.75	BL/M	12.31	EBG	34	DART	6
BG	10.19	BN	13.38	GBH	34	MBN	20
BH	5.19			HBI	37	NBC	67

SIZE GROUP: 5 SUBJECT NUMBER: 43

CHEST: 51 INSEAM: 30 AGE: 23

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.88
SIDE SEAM: 10.69
CENTER FRONT LENGTH: 20.63

LINES				ANGLES			
BC	6.0	BI	8.25	CBD	52	IBK	60
BD	9.69	BK	11.88	DBE	32	KBL	48
BE	11.63	BL/M	13.13	EBG	30	DART	0
BG	10.94	BN	14.31	GBH	21	MBN	22
BH	5.63			HBI	29	NBC	65

SIZE GROUP: 5 SUBJECT NUMBER: 41

CHEST: 50 INSEAM: 30 AGE: 57

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.63
SIDE SEAM: 12.56
CENTER FRONT LENGTH: 22.0

LINES				ANGLES			
BC	5.88	BI	7.56	CBD	50	IBK	65
BD	9.31	BK	13.69	DBE	29	KBL	37
BE	12.63	BL/M	14.0	EBG	26	DART	8
BG	10.94	BN	15.94	GBH	20	MBN	24
BH	5.69			HBI	32	NBC	68

SIZE GROUP: 5 SUBJECT NUMBER: 40

CHEST: 51 INSEAM: 29.5 AGE: 51

AVERAGED MEASUREMENTS

SHOULDER SEAM: 6.41
SIDE SEAM: 8.41
CENTER FRONT LENGTH: 19.31

LINES				ANGLES			
BC	5.16	BI	7.63	CBD	55	IBK	47
BD	8.88	BK	11.63	DBE	27	KBL	34
BE	11.01	BL/M	11.97	EBG	34	DART	5
BG	10.44	BN	13.19	GBH	32	MBN	24
BH	5.19			HBI	37	NBC	67

SIZE GROUP: 5 SUBJECT NUMBER: 45

CHEST: 50 INSEAM: 27.5 AGE: 30

AVERAGED MEASUREMENTS

SHOULDER SEAM: 5.5
SIDE SEAM: 9.56
CENTER FRONT LENGTH: 18.18

LINES				ANGLES			
BC	3.81	BI	7.25	CBD	65	IBK	57
BD	8.81	BK	11.38	DBE	32	KBL	32
BE	11.5	BL/M	10.25	EBG	29	DART	6
BG	10.01	BN	10.94	GBH	13	MBN	20
BH	5.81			HBI	40	NBC	69

VITA

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