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Evaluation of the capabilities of commercially available Computer Aided Design (CAD) systems for made-to-measure on Army and Air Force Men's Dress Coats. This report reviews the characteristics of commercially available CAD systems applicability to special measure programs. The results showed that all the objectives of computerized patterns were achievable: correct patterns could be generated quickly; cut files could be generated and garments cut; and the sewing staff could produce the garments without any additional problems.

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Computer Aided Design Made-to-Measure System Evaluation

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EXECUTIVE SUMMARY

The DDFG-T1-P5 Phase 0 Short Term Project conducted at Southern Polytechnic State University evaluated the capabilities of commercially available Computer Aided Design (CAD) systems from Gerber Garment Technology, Polygon Software & Technology, and Lectra Systems Inc. The garments used during the evaluation were the Air Force and Army Men's Dress Coat. This report reviews the characteristics of commercially available CAD systems and the applicability of those systems to special measure programs.

Southern Polytechnic staff received training on the made-to-measure software provided by each of the vendors. Patterns were introduced into each system through digitizing, copying, or importing as appropriate. Alteration rules or actions were developed on each system based on a method of distribution developed by the Defense Apparel Manufacture (DAM) partners and SPSU staff. The rules were then linked to the appropriate pattern pieces and orders were processed. Each rule was tested by itself and in combination with others. Test coats were manufactured to test sewability and were determined to process in the manufacturing facility without difficulty.

The results showed that all the objectives of computerized patterns were achievable: correct patterns could be generated quickly; cut files could be generated and garments cut; and the sewing staff could produce the garments without any additional problems. The process of producing made-to-measure patterns and cut parts was analyzed based on manual and computer assisted methods. The manual process was determined to require 100 minutes verses 35 for the CAD method. This resulted in an estimated savings of approximately $30.00 per unit produced.

COMMERCIAL COMPUTER AIDED DESIGN MADE-TO-MEASURE PATTERN SYSTEMS

1. Introduction

1.1 Purpose, Scope and Objectives

The DDFG-T1-P5 Phase 0 Short Term Project conducted at Southern Polytechnic State University evaluated the capabilities of commercially available Computer Aided Design (CAD) systems from Gerber Garment Technology, Polygon Software & Technology, and Lectra Systems Inc. Each system was evaluated on its capability to provide accurate made-to-measure (MTM) patterns and markers. The objective of the evaluation was to determine the ability of Defense Apparel Manufacturers (DAMs) to utilize these CAD systems to provide this vital component of a successful special measure program.

1.2 Sources and Method of Evaluation

The garments used during the evaluation were the Air Force and Army Men's Dress Coat. Patterns were obtained through the Defense Personnel Support Center (DPSC) and DAMs producing the special order program. The patterns were imported or digitized into each of the systems to be evaluated. A sample of orders were obtained from the DPSC and the DAMs. These orders were reviewed to determine the types of measure changes that were needed for the alteration tables. Research personnel with training and assistance from applications specialists developed the appropriate files to generate altered patterns.

1.3 Report Organization

This report reviews the characteristics of commercially available CAD systems and the applicability of those systems to special measure programs. The implementation process defines the steps that are required to utilize these systems in creating special measure garments. The evaluation section explores the advantages and

disadvantages of specific capability on each system. Data management, marker making, and integratability are important to the efficiency of the process and are reviewed. The final section gives the conclusions and the benefits of CAD to DPSC and the DAMs.

2. Computer Pattern System Description

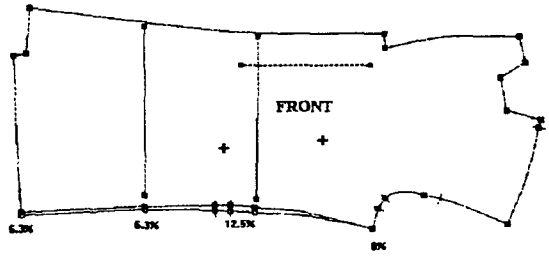
Pattern sets are entered into the CAD system through digitizing or imported from another system. Special points on the base pattern are identified as grading points, each with a unique x and y coordinate. Grading, the term used to indicate changing the base pattern into larger and smaller sizes, is accomplished by creating on the system a table of rules that can be applied to points on the pattern. These rules indicate a set amount of movement that will be applied to a specified point on the pattern as each new size is generated. The pattern with rules applied is referred to as a graded nest. Any single or combination of the sizes incorporated into the rule set can be used to plot patterns and create a lay of pattern pieces for cutting referred to as a marker.

These graded patterns can be manipulated by an additional set of rules to create a subset of patterns for other body types such as short or tall. These altered pattern sets are unique and can be used to plot patterns and create markers. This set of rules remains with the stored set of patterns and will consistently generate this predetermined modified base pattern.

Made-to-measure pattern alterations can be applied to either of the previously discussed pattern sets. These rules are written with movement based on a percentage of change rather than an exact mathematical number. The changes are applied through the input of a MTM order. *The change can be predetermined by entering the amount of change or it can be calculated by the difference between the standard pattern and the requested pattern.* However the change is determined, it is applied to specific points on the pattern based on the distribution dictated in the MTM table. This

software system creates a unique pattern from either the base or the subset of the base for each order.

For example, if the waist of a coat pattern is designed to fit a 34 inch person but the waist body measurement taken is 36 inches, then the pattern must be changed by a 2 inch increase. The CAD system would take the 2 inch increase and distribute that change on the appropriate pieces based on the distribution dictated in the rule. The following is an illustration of one way of distributing those changes. (Figure 1)



Example:

Increase the waist of the garment 2 inches.

Percentage increase at the front waist: 12.5

.125 x 2.0 = 4/16

Percentage increase at the sidebody: 18.7

.187 x 2.0 = 6/16

Percentage increase at the back waist: 18.7

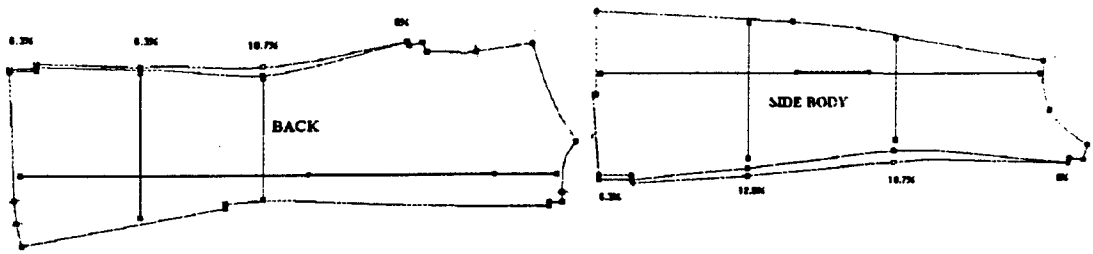
.187 x 2.0 = 6/16

Total 1.0 inch

There are two pieces of each for a garment.

Therefore the total increase is 2 inches.

Any measurement change entered as an alteration would distribute by these same proportions.



3. Implementation: Process Flow

3.1 Software installation and training

The made-to-measure software is an additional module to the existing pattern grading and marking system supplied by the vendors. If the manufacturer has a CAD system in place, the addition of the MTM software is a standard installation and can be done by the user or a vendor software technician. Three to five days of training are usually included in the purchase price. If the user of the MTM software has previously worked on the existing system, this training should be adequate. The person responsible for entering the orders and entering the information into the MTM database would better maximize the training time if they have the following level of experience before attending training offered by the vendor:

- basic understanding of Windows and/or Windows 95
- use of the mouse and keyboard
- knowledge of the x and y coordinate system
- experience with any CAD (drawing) software is a plus

The interpretation of manually pivoting patterns to create altered patterns must be represented in the alteration table using the x and y system of movement. To fully maximize the capability of the system the following personnel should have a basic understanding of the software and attend the training session if possible: the designer/pattern person who will decide the alteration distribution; the person responsible for software support; the person who will create the database on the system; and the person who will be responsible for entering orders and creating the marker output. These responsibilities may belong to several people or there may be only one person who performs all of these functions depending on the company size and diversity. The level of expertise of the order entry person is minimal if the persons responsible for creating the database information document their decisions appropriately. The existing system hardware recommendations are included in the appendix, Table A1.

3.2 Pattern input and preparation

Patterns can be digitized into the system or can be imported from another system. The digitizing table is usually purchased with the CAD system. The user enters points on the pattern piece perimeter with a hand-held cursor, including grade rule numbers if appropriate. Pattern pieces can be copied from the storage media (disk) onto the system if they are generated by the same CAD system. Non-compatible files are imported from a disk through conversion software. The vendors will provide this service, if requested, at a charge dependent on the quantity of patterns to be converted (Appendix, Table A3). Pattern file compatibility is discussed in section 7.1 of this report. Software can be purchased but would not be the most cost effective for a one-time use.

The grading of patterns is usually performed by manipulating predetermined points by a standard used in the industry. If the graded patterns have been previously input into a cad system, they may not have all the grade points necessary to manipulate line segments in the way required for the MTM alterations. The patterns can be modified in

the module of software referred to as pattern design software (PDS). As the patterns are tested it may be necessary to modify the first trial by moving or adding additional points to obtain an acceptable line segment.

3.3 Alteration rule generation

Alteration rules are created and applied to the patterns in two different ways. A special unique numbering system or coding system can be used to identify the points of alteration on the pattern. These special points are identified in the alteration rule with a distribution of change for a specified body measurement. The second method allows the user to retrieve a graphic of the pattern piece on the screen where points are selected with the mouse as the rules are being written. This method does not require special point number identification.

3.4 Base measurements

A base measurement table is created on the system for the specific garment to be modified. The measurements are the body measurements that were used to create the base pattern for each size. Patterns are created with an additional amount for comfort and serviceability. This ease is the difference between the body measurement and the sew line on the pattern. These measurements can be obtained by utilizing the pattern design software. The sew lines can be generated automatically on the pattern graphic on screen. The measurement function can be used to determine the finished garment dimensions. The amount of ease allowed is subtracted and the final number should correlate to the body measurement.

3.5 Order entry

The order entry form has a field predetermined for each of the alteration rule sets that are created for that specific garment. This list can include measurements such as chest, waist, hip, length, etc. There is a field for the user to enter the measurements taken for the special order or the amount of change requested.

3.6 Testing the rules

Alteration sets in development may require several revisions. The first test is usually on screen. The order for each of the rules can be processed and displayed on-screen. The on-screen graphic will display the base pattern with the altered pattern superimposed. From this display the user may identify errors that distort the pattern due to incorrect data entry in a measurement table, alterations rule, or at order entry. An application of each rule in the alteration set should be plotted out next. The altered pattern should be compared to the base pattern and verified correct. If the user has determined an upper and lower limit allowed on a specific measurement, this would be a good alteration for the test. For example, if it is determined that the waist measurement change range is +/- 3 inches, a good test of the rule would be a change of + 3 inches and a change of -3 inches. These two end limits should verify the range in between.

3.7 Plotting patterns

The new pattern can be sent to the plotter or to the marking system. In some systems this can be done automatically by making selections in a parameter table.

4. Evaluation: MTM Pattern Systems

4.1 Pattern Preparation

Patterns for the Air Force and Army Men's Coat provided by DPSC were imported into the Gerber system. The Air Force pattern pieces provided by HAAS were compatible files and were copied into the Gerber system. The Army coat patterns used by Maryland Clothing were digitized into the Polygon system. The Air Force patterns previously copied to the Gerber system were imported into the Lectra system. Each cad system was evaluated for functions in the PDS software that may be necessary to prepare patterns for alteration or to do clean-up on the patterns after importing them from a different cad system. This was accomplished as a test exercise on some functions, but others were actually used to prepare patterns for the MTM evaluation.

One of the most useful functions allowed the user to enter grade points on the perimeter of the piece with proportional grading automatic. This function automatically wrote the grading for this newly created grade point based on the movement distribution between the existing grade points. A list of these functions and the availability of them on each system is included in the appendix, Table A2.

4.2 Alteration Rules

An alteration table was written on the Gerber system for the Army and Air Force coat. The Gerber system uses special point numbers for alterations. When patterns are digitized the system numbers the graded points sequentially. Each new pattern piece starts with number 1. The special point number system required all pieces be brought into the PDS software and modified at each grade point. This can be done quickly but is not automatic. The point to be modified must be selected and the new number keyed in and applied. There cannot be duplicate numbers anywhere in the pattern set if that point is being used differently during the alteration of the pattern. A table is generated with alteration sets. An alteration set is all the rules necessary to change the pattern set for a specific measurement. For example, the waist rule set would require each point number that is altered with the rule be identified with a percentage change in the x and y. Each point movement is an additional line entry. Each pattern piece affected, in this case the front, sidebody, and back, would have points of movement.

Alteration rules were written on the Polygon system for the Army coat. The Polygon system uses the second method of setting up the alteration table. It utilizes the graphic of the pattern on screen. Rules or actions are written in a similar way but the points are selected on the graphic display of the pattern piece with the mouse. This method does not require special point numbers and reduces the amount of preparation time. It is visually assisting in correctly assigning changes.

Lectra alteration rules were developed with the graphic of the Air Force pattern piece on screen. The alteration changes were entered and the point "label", similar to special

point numbers, was linked to the appropriate points on the pattern piece. Rules were written in the same way as Gerber and Polygon, utilizing rules of change distribution applied to the appropriate points. Lectra utilizes a combination of special point labels and pattern graphics on screen when creating the alteration set.

Each method has advantages. The special rule system allows the user to apply the alteration rule table to multiple styles utilizing a system for digitizing the patterns with a predetermined point number. Also, the table can be renamed and modified to fit another garment for alterations reducing the amount of data entry.

The pattern graphic system allows the user to see which pattern pieces and at what point on that pattern piece they are applying the change. The set-up of the rules is more efficient but they are unique to the particular pattern set. New rules would be written for each new garment being prepared for alteration.

The special point labels and pattern graphics combined supplied the visual aid and could easily be applied to other styles. All systems evaluated provided the capability to meet the needs of the military manufacturer.

4.3 Alteration Limitation Capability

A base measurement chart was generated in the Gerber and Polygon system. This information was generated using the PDS software. The changes requested in the MTM order are compared to the base measurement to calculate the change. There are limits that the designer/pattern maker will determine on some measurements. These decisions are made at the manual blue pencil step. When the decisions are made manually for alterations, it is referred to as blue penciling. The computer software can be designed to allow the user to dictate the limit of change for a specific measurement to a positive limit, negative limit, or a positive/negative range. When the change falls outside the limit the order can be aborted or another pattern option can be prompted.

For example, a sub-option on the coat pattern could be an athletic cut that is selected if the acrossback request falls outside the limits.

The Gerber system gives the user the opportunity to dictate or not dictate limits on measurements. The Gerber system also allows the user to write rules that will assist in selecting the base pattern size, replace a pattern piece, or activate another alteration. For example, two rules may be written for the waist. One which is used if the alteration is within the limit and another if outside. The rule could dictate that if the waist rule limit is exceeded that waist alteration rule 2 be used which may distribute the increase in a different proportion on the pattern pieces. These rules reduce the amount of blue pencil required previous to order entry.

The Polygon system does not at this time have limitation capability. The system of manual blue pencil decisions prior to pattern order will facilitate the decision making. The user can utilize the functions of software spreadsheets to prepare order information and facilitate some checks and balances at this step. Other pattern options such as a stout model can be created as styles and utilize the same alteration sets as the regular base. The person performing the blue pencil information would also note on the order if other styles are to be used such as the stout pattern. The MTM order entry technician would choose that alteration base file and enter the appropriate measurement changes as would be done on any order.

The Lectra system allows input of change on each alteration at order entry. The method of entering the body measurement chart is not fully implemented at this time. It is currently under development. The Lectra system does allow the user to input limits on the individual alterations. When these limits are exceeded the order is aborted. This function reduces the amount of errors that go forward due to data entry errors or inappropriate measure taking methods. The system also allows the order entry technician to select model options such as stout, based on the blue pencil interpretation or order information.

4.4 Order entry

The Gerber order entry form includes fields for the information pertaining to the request, order, and shipping of the order. The measurement fields are dictated by the measurement alterations created in the alteration table. The form can be customized to fit the users needs. Fields can be created that when selected activate specific alterations. For example, if the slope shoulder field is checked the pattern will be automatically altered for this fit. The order is saved as a record and can be deleted at the user request. Test orders were created to evaluate the limit capability and were successful.

The Polygon system entry form includes fields for the information pertaining to measurement data and other pattern changes such as slope shoulder that were defined in the alteration table. When the order is exported the name of the altered pattern can indicate the order, customer name, or any other identification system that the user prefers. This identification system should tie the pattern and marker to the special measure order form for future reference.

The Lectra system order form has exact blue pencil change capabilities. The measurement change fields are dictated by the alteration table created. For example, if the appropriate alteration rules are written, the left shoulder can be altered a specific amount of 1/8 inch in addition to the slope shoulder rule which drops both shoulders 1/4 inch. Test orders were processed. The system created a unique pattern set for each order.

At present the type of information to do some of the more complex changes is not provided by the DPSC special measurement order. The example used previously for a person who has slope shoulders with an additional drop on one shoulder would be more custom than what is possible with the information being gathered at the measurement stage now. With scan data information many additional fit and form functions can be addressed. All systems evaluated have or will have in the near future

the capability to provide alterations from measurements and from blue pencil changes of an exact amount of change. Each of the systems has the specific information fields available for the processing of the special measure program. Users of the system for commercial use would utilize the additional capabilities more often.

4.5 Testing the rules

Orders were created and processed on each system to evaluate the alteration rules written. Simulation orders were processed to test multiple alterations on one pattern set. A sample of these orders are included in the appendix. The patterns were compared to the base to verify that the requested changes were made properly. The altered patterns were superimposed on the base pattern on a lighted drafting table. The modified lines were evaluated on smoothness and correct change in measurement. The test patterns were approved as acceptable patterns for garment manufacturing. A sample of these orders was processed into markers successfully on all systems.

4.6 Plotting patterns

Preferences can be set on the Gerber system to automatically plot out the placement of patterns or wait until approval. The patterns can be sent to AutoMark where the pieces are automatically laid or the user can lay all pieces from an unplaced marker. Made-to-measure patterns generated on the Gerber system were drawn out on the plotter for the rule verification.

Pattern orders were placed on the Polygon system and exported. The system generates a set of pattern files unique to the order. These pattern pieces were processed to the plotter. The patterns are placed on the plot paper in a fashion to best utilize the paper with a predetermined amount of space between each. The patterns were used to verify the alteration rules. Marker order can be placed and automatic marking performed. At the present, the system does not process the pattern directly through marking to the plotter. This function is currently in development.

Lectra orders can be processed through marker order, automatic marker making and plotting. Parameters can be set to send orders directly to the plotter without intervention. The use of this function will reduce throughput time but does not allow the marking technician to try to improve the marker utilization. Experience with the system and styles would provide data that management could use to determine the best through-put for the incoming orders.

4.7 Computer vs hand made patterns

Made-to-measure pattern sets were processed on each system for a sample of each body measurement alterations created in the alteration table. Upper and lower limits for changes were determined by Southern Polytechnic staff, an industry expert in dress coats, and representatives of the DAMs. The distribution of change and the limits may vary among designers and pattern makers. The numbers used for this project were determined to be acceptable to test the systems.

A pattern was processed for each of the upper and lower limits for each measurement. (Table 1) The industry pattern maker drafted from the base a hand made pattern by manipulating and pivoting the pattern as appropriate to create acceptable lines on the newly created draft. The hand drawn patterns were compared to the computer patterns by Southern Polytechnic and the pattern maker. The patterns were compared based on the direction and amount of movement at altered grade points and on the smoothness of the line segments between these alteration points. It was determined that all the altered patterns created by the computer simulated the hand drawn patterns within an acceptable limit for the apparel industry.

Table 1 Alteration Measurements and Limits for Rule Testing

Measurement	*Inch*	*Measurement*	*Inch*
Waist	+ / - 3	Crossback (half)	+ 3/4
Hip	+ / - 1 1/2	Biceps	+ / - 2
Center back length	+ / - 2	Slope shoulder	1/4
Sleeve length	+ / - 2	Square shoulder	1/4

4.8 Test coats

Markers were created on each of the systems for test orders. These orders are included in the appendix. Maryland Clothing manufactured the Army test coats and HAAS Tailoring manufactured the Air Force. There were a total of five test coats. It was determined by the manufacturing staff that the garments made from the MTM patterns performed in the sewing area no differently than the standard production. This indicates that garments produced from patterns and markers created with the MTM cad system should process through the sewing floor simultaneously with regular production.

5. Data management

5.1 Orders and Patterns

The Gerber system retains the MTM order as a record. This record when processed automatically created the pattern and/or marker as requested. It does not create a stored pattern file set on the computer system. To use the pattern again the user would simply process the record again. A system of purging the record folder after a predetermined time would facilitate deletion of out of date information. The system has import capability of MTM orders. Depending on the source of the orders, additional code can be written to translate the measurement data into the appropriate order form fields.

The Polygon system generates a unique pattern set upon exporting from MTM input information. Once the patterns are processed the order no longer exits. A pattern file set is stored on the computer system. The pattern pieces are selected and processed to the plotter or marking system. A folder for only MTM patterns was created. All MTM patterns were exported to this folder for which a system of purging after a predetermined date would be necessary.

The Lectra system saves a record of the MTM order. This record can be processed at a later date for repeat orders. This can be of value to companies doing commercial

MTM garments. The orders processed for special measurement, under normal circumstances would only be processed one time. The records would be deleted based on some schedule of purging the system at some date after conformation that the customer was satisfied with the purchase. The system has the capability of importing orders on-line with additional setup of software. This would allow orders to come directly from the measurement stage to the plotter without intervention.

5.2 Output information

The order form can be printed from the Gerber system. This customizable form can be used to track and record special measurement orders. Screen prints are available for output of patterns graphically displayed on screen.

The order information is not stored on the Polygon system at present. This is a feature that is in development at present. A form was generated in Excel to use for recording data entered on the system for special measure. A software program for screen capture was utilized to capture the patterns graphically displayed on the screen for this project.

The order information on the Lectra system can be printed and used for a hard copy record of MTM orders. Screen prints are available for output of patterns graphically displayed on screen.

6. Marker Making

Markers can be processed with unplaced pieces on the Gerber system or the user can set the parameters for the system to automatically process through the automatic marker making, AutoMark. Parameters can be predetermined such as the maximum effort for each marker. Other parameters such as replacement of existing marker upon request are available. Gerber will be offering an additional automatic marking software,

Nester, which will be an optional software purchase. It was not used during this project.

Polygon has an automatic marking function as part of their PolyNest software. They are introducing their latest version of interactive marker making, SuperLay. The unplaced marker was created by processing an order for a marker. The new unplaced marker was then processed through SuperLay. Parameters can be set in SuperLay such as the maximum time to perform before accepting the best placement that has been generated. After processing the marker through SuperLay it can be viewed in the marking portion of the Polygon software. The SuperLay software was used to process orders for this project and is an optional purchase.

Lectra offers an automatic marking function as part of their system. They also offer, Expert, which is an additional software purchase. Markers were processed on Lectra's automatic marking system, Expert. Constraints are available such as number of tries, time limit of effort, and efficiency. The system will document which of the parameters it achieved first to complete the marker.

Data collected for this project is only a small sample of the number of combinations and sizes processed by a manufacturer. This data is being used to demonstrate the ability of automatic marking software to reduce costs and turn around time for product. The speed of automatically laying a marker varies with pattern shapes, garment sizes, and fabric widths. The optional production automatic marking software provided by each vendor evaluated many times meets or exceeds the marker efficiency provided by a totally human-made marker.

Sample markers were processed for a group of sizes on each system in a quantity of two garments and single garments.(Appendix, Table A5-7) A sample of these markers were then modified for improvement by an experienced marker cad technician,

Table 2 below. The average run time for a marker was 9.08 minutes with an efficiency of 77.61%. With an additional average time of 6.13 minutes the average marker efficiency was improved to 79.74% by the cad technician. This is an improvement of 2.13% in material utilization at a cost of 6.13 minutes of technician time. The software can be run in the back ground or during off-hours. The estimated time for placing a 2 garment marker on the cad system without utilizing automatic marking is 15-30 minutes. This data indicates a reduction of turn-around time of approximately 50-75%. This is very significant in an environment where many small and variable size markers are necessary for quick response.

Table 2 Sample Data: Marker % and Time for Improvement

SIZE	*No. of Coats*	*Run Time / minutes*	*Efficiency %*	*Revise Time / minutes*	*Efficiency %*
41	2	12.27	80.02	6.00	80.94
40	2	5.00	78.53	9.00	81.73
37	2	8.50	80.05	5.00	81.48
42L	2	15.00	81.60	6.00	82.76
36L	2	12.50	79.88	8.00	83.22
36	1	10.00	76.03	5.00	79.43
44	1	4.00	74.25	5.00	76.94
48	1	5.36	70.53	5.00	71.41
		9.08	77.61	6.13	79.74

Made-to-measure and regular stock can be processed through the auto-marking software on all systems. The single garment marker, such as the MTM, is traditionally not the most efficient marker. At present these garments are not being combined in markers for reasons of tracking in the production area. The single garment markers can be attached and processed through automatic marking for fabric maximization. It was determined through testing that the majority of markers can be improved with additional modification from a technician. The auto-marking does reduce the amount of

time spent generating the marker lay if allowed to run in off-time for the computer technician.

7. Integratability

7.1 Pattern file

Pattern files were generated on each of the systems. They were exported in the individual system format and also in AAMA format. The ANSI/AAMA standard is designed to facilitate communication between CAD systems which represent two dimensional flat pattern pieces. The file format defined by this standard complies with the DXF format. The following table details the files generated.

Table 3 File Formats

CAD SYSTEM	FILE FORMATS	
Gerber	Gerber	AAMA
Lectra	Lectra	AAMA
Polygon	Polygon	AAMA

The pattern files created in each of the formats were imported into the remaining test CAD systems. Gerber and Lectra each have direct conversion software for import of the other's pattern files. Graded nests were only successfully transferred between Gerber and Lectra by the direct conversion. Grade tables were not converted to AAMA standards for this project. This is being done by the vendors with success in most cases. If grade tables are not converted, grading data must be entered into a rule table and linked to the ungraded base pattern pieces transferred to obtain a graded nest on the non-compatible systems. The grading information and a step-by-step procedure is supplied by DPSC upon request. Table 4 shows the results of these pattern transfers.

Table 4 Pattern File Transfer Results

FILE TRANSFER		
Gerber	Direct Import of Lectra File	The Lectra file imported into the Gerber system successfully. The graded nest transferred correctly.
	Import of Polygon AAMA	The Polygon base file was imported into the Gerber system successfully. The graded nest did not transfer.
Lectra	Direct Import of Gerber File	The Gerber file imported into the Lectra system successfully. The graded nest transferred correctly.
	Import of Polygon AAMA	The Polygon pattern base file imported into the Lectra system successfully. The graded nest did not transfer.
Polygon	Import of Gerber AAMA	Imported Gerber base pattern file successfully. The graded nest did not transfer.
	Import of Lectra AAMA	Imported Lectra base pattern file successfully with some line distortion. End points came through as curve, required cleanup in PDS. The graded nest did not transfer.

Some inconsistencies in pattern accuracy can occur when transferring files from cad system to system between vendors using the ANSI/AAMA-292 standard. Each vendor writes algorithms whose calculations may result in different output. For this reason, the AAMA has commissioned a committee to develop an amendment to the standard which is an implementation guide. The guide will assist vendors in writing algorithms

whose calculations will produce consistent results in pattern accuracy and grade information. For example, vendor A may use a certain algorithm to calculate the curve of the armscye and vendor B will use another. The data from the standard is sufficient for each but the results may be different. The implementation guide stipulates a more exact format for curve data to be exported so that each vendor can adjust the algorithm to produce similar results when output A is compared to output B. Table A1 in the appendix lists the cad vendors, their import and export capabilities and a sample of plotters that each can drive.

7.2 Cut file

Each of the tested cad systems have the ability to output data files that will operate the most widely used cutters. These outputs consist of data organized according to one or more of the following formats: RS274D, ANSI/AAMA, Gerber, NC-CUT. The output tested was ANSI/AAMA. The cut tests were performed on single and low ply cutters listed in the following table. Cut files generated were imported into each of the systems and processed for cut tests. The technician importing the files can make changes when necessary due to file translation differences. For example, the internal lines were not indicated to be no-cut lines previous to file output on one system. The technician selected the internal lines and labeled them no-cut upon import. Once these differences are documented the translation software can be edited to match the incoming file in the future. The tests were performed on the Gerber Cutter 3200, Lectra Vector 2500, GGT Cutting Edge 2500, and Eastman M9000. Polygon has introduced a single ply cutter, LogiCut, to the market that was not available during the project period for cut tests.

Table 5 Cut File Test Results

System	Cut File	
Gerber Cutter 3200	Polygon	AAMA cut file imported successfully.
Low ply cutter		2 ply cut - cut quality approved.
	Lectra	Lectra cut file direct conversion successfully
		4 ply cut - cut quality approved.
Lectra Vector 2500	Gerber	Gerber cut file direct conversion successfully.
Low ply cutter		4 ply cut - cut quality approved.
	Polygon	AAMA cut file imported successfully.
		4 ply cut - cut quality approved.
		1 ply cut - cut quality approved.
GGT Cutting Edge 2500	Gerber	Gerber cut file imported successfully.
Single ply cutter		1 ply cut - cut quality approved.
		2 ply cut - cut quality approved.
	Polygon	AAMA cut file imported successfully.
		2 ply cut - cut quality approved.
	Lectra	AAMA cut file imported successfully.
		Cut test was not performed.
Eastman M9000	Gerber	Gerber cut file imported successfully.
Single ply cutter		2 ply cut - cut quality approved.
		1 ply cut - cut quality approved.
	Polygon	AAMA cut file imported successfully.
		2 ply cut - cut quality approved.
	Lectra	Did not import, did not determine problem.

The criteria used for evaluation of cut file exchange analysis was import abilities and cut quality. The file exchange success is noted in Table 5. All system cutting was evaluated for quality of cut lines and was determined acceptable. The vendors of the single ply cutters were tested on single and double ply. When creating single garment

markers better fabric utilization can be achieved by doubling the fabric in half which is called bookfold and cutting some of the pattern pieces on the folded edge. For this reason, tests were performed with double ply even though the systems are designated single ply. Each of the single ply vendors can cut double ply fabric with minor adjustments to the cutting equipment.

Table 6 Approximate Time Required to Cut MTM Garment- Automatic Cutter

Cut speed	45 - 65 inches/sec	Dress coat perimeter inches	2000 inches
Cut speed with dryhaul (reposition time)	30 inches / sec	Cut speed	15 inches/sec
Cut speed including all functions for estimates	15 inches / sec	Approx. time to cut coat	2.25 minutes

The vendors of low ply cutters can cut approximately 1 - 1 1/2 inch compressed heights of fabric. These cutters are used to facilitate stock cutting in smaller order quantities for quick response and single ply cutting for special orders. Single and multiply ply cutting quality was determined acceptable. Cutters are a substantial capital investment for the manufacturer and are selected based on the overall objectives of the company. The technology is available and can be utilized by defense apparel manufactures as well as producers of commercial items to meet the needs of the customer and to become more competitive in the marketplace.

8. Present vs Future System

8.1 Present System

Upon receipt of the order, the authorized personnel would "blue pencil" or identify the alterations required to create a custom pattern from the body measurements and posture data. The order would then be passed onto the pattern/cutter technician who would identify and retrieve the correct set of hard paper patterns from a storage rack

and the fabric which would be placed on the table for marking. The technician would trace around the pattern pivoting at the appropriate points to change the dimensions of a specific measurement as the order required. The order information must be interpreted by the pattern/cutter technician correctly combining measurement changes. This takes special training and skills.

This technician is performing three separate functions simultaneously. He/she is creating a unique pattern set, determining the best fit of the pattern pieces on the fabric for maximum utilization, and manually cutting intricate pattern components that have been chalked onto soft goods fabrics. The process of the technician interpreting blue pencil information, hand making patterns and markers, and cutting the fabric correctly has too much human interaction to obtain consistent quality and to be totally efficient.

8.2 Future System

Basic changes in stature, or other height or width adjustments, can be made directly to the pattern upon request utilizing off-the-shelf cad systems with marker making capabilities. How complex the alterations can be is dependent upon how the software is utilized. Rules can be written for more complex alterations such as enlarging or reducing the armhole, left or right shoulder drop, and increased or decreased biceps if the personnel who set up the made-to-measure software system have design/pattern training. The alteration rules are written for each new garment type introduced only one time. The theory of alteration and the alteration rules can be copied or duplicated with similar products.

After receiving the order, the "blue pencil" is handled quite differently if the state-of-the-art cad system is being utilized. The measurement information from the order would be entered into the computerized order form provided by the made-to-measure software. Parameters can be set to automatically generate the marker lay of the pattern pieces and send it directly to the plotter and/or generate a cut file for computerized cutting. The amount of human intervention is minimized. The order entry technician does not

need training or skills in pattern making, marker making, or cutting. The quality of the pattern output is consistent and the overall efficiency of the made-to-measure process is improved substantially. The process can be further automated by using the on-line import order capabilities which would eliminate the manual data entry of orders. For this analysis manual entry is being described.

9. Benefits

Table 7 Present vs Future Time Comparison for MTM

Present/Manual System	Time/ minutes	Future/Computer System	Time/ minutes
"Blue pencil" to determine base pattern size to use and alterations to be made	5	"Blue pencil" automatically performed by made-to-measure software	0
Select and retrieve correct base paper pattern and fabric	5	Enter measurement data into computer order form and process to plotter	3
Trace pattern pieces creating alterations as necessary	60	Visually check pattern marker for errors as plotting. (not necessary after history using the system)	2
Manually cut fabric on traced pattern lines	30	Process cut file to computerized cutter with fabric roll feed and cut garment	5
Total time to process manually	**100 minutes**	**Total time to process with computer technology**	**10 minutes**

9.1 Quality

Creating custom patterns from body measurements requires special training and skills. Fewer personnel are being trained in this area. The amount of man hours required to perform the manual process is not always available from the limited staff with extensive training in this area. Therefore, less experienced personnel are given the responsibility

of manually creating the made-to-measure pattern. This reduces the accuracy of the pattern generation and therefore, the appropriate fit. Inconsistency of fit is derived from multiple personnel creating the patterns with different interpretations of the necessary pattern manipulations to obtain the body measurement fit required by the order.

The one time creation of the alteration set on the made-to-measure computer system should be performed by qualified personnel. The pattern makers role of pattern drafting for each individual order has been eliminated and that skilled personnel can now concentrate on other activities. The use of the same alteration set will provide accurate and consistent patterns and therefore, fit.

The cut quality from manually drawn patterns can be inconsistent and produce sewing deviations during the manufacturing process. The accuracy of computerized cutting presents a better quality garment component for the manufacturing process and will facilitate a better sewn end product.

9.2 Cost

There is an initial capital investment in the software system and cutting equipment. Range estimates are included in the appendix, Table A3. This investment can usually be justified by the fabric utilization alone. Therefore, the initial purchase is not being considered in this analysis. As indicated in Table 8, the use of computer technology in the made-to-measure process can reduce the cost of producing one unit by approximately $39.16 assuming a fully automated system. ($41.66-$2.50)

Table 8 Present vs Future Cost to Process MTM with Cutter

Present/ Manual		Future/Computer	
Process	100 minutes	Process	10 minutes
Cost/hour	$25.00	Cost/hour	$15.00
Total Cost Per Unit	$41.66	Total Cost Per Unit	$2.50

As indicated in Table 9, the use of the computer system only and manually cutting would reduce the cost of producing one unit by approximately $30.00. ($41.66-$11.66)

Table 9 Present vs Future Cost to Process MTM without Cutter

Present/ Manual		Future/Computer	
Process	100 minutes	Process	5 + 30 minutes *
Cost/hour	$25.00	Cost/hour	$20.00
Total Cost Per Unit	$41.66	Total Cost Per Unit	$11.66

* From Table 7 reduce by 5 minutes auto cut and add 30 minutes for manual cutting

9.3 Time

The production requirement of 80 units per day used for the example detailed in Table 10 indicates the need for a large number of staff to produce MTM garments. This example indicates that only 2 people would be required to run the computer system and automatic cutting verses 20 to perform the process manually. Not only does this indicate the problems of training and/or hiring 20 qualified personnel but meeting the requirements of quick response with a fluctuating pool of qualified applicants.

Table 10 Present vs Future Staff Requirements

Manual System		Computer System	
Units per day	80	Units per day	80
Man minutes/person	400	Man minutes/person	400
Man minutes/unit	100	Man minutes/unit	10
Output /person	400/100=4	Output/person	400/10=40
Total staff required	80/4=20	Total staff required	80/40=2

10. Conclusions and Recommendations

The computer-aided-design systems evaluated are at different levels of development. The Gerber Garment software is available at this time as a add-on module to the AccuMark Marking and Grading System. The Polygon alteration software is in the beta test stage and is being updated for improvements suggested during the process of this project. It is an add-on module for Polygon's pattern system, PolyNest. The Lectra alteration software is being alpha tested at this date. The previous software was developed for a platform that is no longer available on the Lectra pattern system, Modaris. The functionality has evolved into a comprehensive made-to-measure system that will be offered on the Unix platform currently utilized.

The results showed that all the objectives of computerized patterns were achievable: correct patterns could be generated quickly; cut files could be generated and garments cut; and the sewing staff could produce the garments without any additional problems. The computer programs were user friendly- orders could be processed easily and efficiently. The systems address the needs of the Defense-Apparel-Manufacturer of special measurement garments.

The made-to-measure systems, while having capability of producing accurate patterns which fit well, leave the responsibility on the company to achieve this. The base size pattern set of each style must reflect exactly the base size measurements in the size chart. The measurements taken from the customers must be taken with a consistent, repeatable method.

The base measurement chart created on each style must have correct measurements throughout the whole size range. This can be achieved using the grade tables provided by DPSC. In addition to the grade tables, to achieve the best results and accurate fit, the body measurements for the base need to be provided to the company utilizing the made-to-measure software. This will promote consistency of fit between manufactures.

The Blue Pencil decision making must still be performed by qualified design -pattern personnel, as well as the determination of alteration distribution. The cad system is capable given the appropriate information in base measurements, alteration distribution, and order measurement data.

All of the systems evaluated had their strengths and weaknesses, but each was capable of producing an acceptable made-to-measure pattern. The choice of which system best fits the needs of the individual company is dependent on many factors. The made-to-measure software module resides on the cad system that provides such functions as marking, grading, auto-marking, and also drives the cutting systems. These areas are of major importance in the complete process. Only if made- to-measure is the majority of the product would it be the determining factor in system selection.

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Polygon Software and Technology

Lectra Systems, Inc.

ARN Partners

ARN Related Projects

Standardize Anthropometric Measurements (T1P1)

Interpret ANSUR data (T1P1)

Electronic Order Form (T1P2)

Expert System Evaluation (T1P5)

TABLE A1

DDFG-T1-P5 PHASE O EVALUATION

File import/export Formats	Gerber	Lectra	Polygon
ANSI/AAMA	Optional Import / Export	Optional Import/Export	Optional Import/Export
DXF	Optional Import/Export	Optional Import/ Export	Standard Import / Optional Export
HPGL	Standard Export	Standard Export	
GERBER	Standard	Optional Direct Conversion	Optional Import AAMA
LECTRA	Optional Direct Conversion	Standard	Optional Import AAMA
Plotters	**Gerber**	**Lectra**	**Polygon**
Hewlett Packard	yes	yes	yes
Gerber	yes	yes	yes
Microdynamics	yes	yes	yes
Lectra	yes	yes	yes
Polygon	yes	yes	yes
Minimum Hardware	**Requirement**		
CPU	Pentium processor		
Hard Drive	High capacity hard disk		
Monitor	Color graphics display		
Ram Memory	16 MB RAM		
Standard Backup Device	3 1/2" floppy drive		
Keyboard	101-key enhanced style		
Mouse	Dedicated mouse		

TABLE A2

DDFG-T1-P5 PHASE O EVALUATION

Pattern Design Functions	Gerber	Lectra	Polygon
Measure distance 2 points	X	X	X
Measure line	X	X	X
Measure angle	X	X	X
Add point grade/proportional	X	X	X
Point add	X	X	X
Point delete	X	X	X
Point move	X	X	X
Point move smooth	X	X	X
Line move	X	X	X
Line move parallel	X	X	X
Line pivot	X	X	X
Split line	X	X	X
Merge line	X	X	X
Blend line	X	X	X
Smooth line	X	X	X
Add a seam	X	X	

TABLE A3

DDFG-T1-P5 PHASE O EVALUATION

Software / Hardware	Gerber	Lectra	Polygon
System Software Name			
Grading and Marking	AccuMark	Modaris/Diamino	PolyNest
Pattern Design	AccuMark PDS	Modaris	PolyNest
Standard Alterations	YES	YES	YES
MTM Alterations	AccuMark MTM	FITNET	Alter Program
AAMA Conversion Software - Optional	YES	YES	YES
Automatic Marking -Standard	AutoMark	Flash	AutoMarker
Production Automatic Marking - Optional	Nester	Expert	SuperLay
Software Platforms Tested	**Gerber**	**Lectra**	**Polygon**
Windows 95	YES		YES
Unix		YES	
System and/or Software	**Range of Price**		
Marking and Grading Software Only	$10,000 - $15,000		
Marking and Grading System w/ digitizer	$17,000 - $25,000		
Made-to-Measure Software	$3,000 - $5,000		
Plotters	$15,000 - $40,000		
Single Ply Cutters	$50,000 - $65,000		
Low Ply Cutters	$150,000 - $200,000		
Commercial Training Services	$600 - $750 /day		
Commercial Pattern Digitizing and Grading	$6.50 - $7.50 /piece		
Pattern Piece Conversion to AAMA	$0.25 /piece		

Table A4

Sample Orders Reviewed

DDFG T1-P5 Test Data

Height	Weight	Coat Length	Waist Length	CrossBack	Slve Length	Chest	Waist	Seat	Rec. Size
6ft 9in	195	42	21	8	38 1/2	39	32 1/2	39 1/2	39XL
6ft 5in	225	34	21	9	40 1/2	41	35 1/2	40 1/2	42XL
6ft 6in	220	40	38 1/2	10	37	41	38 1/2	46	46XXL
6ft 2in	180	31 1/2	12	9 1/2	35	42	34	38	42L
6ft 4in	205	34	N/A	10	38	42	36	N/A	
5ft 9in	208	N/A	21	9 1/2	20	42 1/2	40	N/A	52R
5ft 4in	165	27	18 3/4	9 1/4	31	43	40	43 1/2	43XS
6ft 6in	238	36 1/2	22	9 1/2	40	44	37	42	50L
6ft 2in	242	N/A	32	10	38	44	39	N/A	46L
5ft 7in	215	22 1/2		9	31	45	41	N/A	
6ft 7in	230	36	21	10	40	45	40	47 1/2	48L
6ft 1in	235	34	20	10	36	45	42	46	
6ft 4in	225	36	21	11	35	45	38	N/A	50R
6ft 4in	245	33	N/A	10 1/2	36	45	47	44	48L
5ft 7in	190	30	17	9	33	46	40	43	
6ft 9in	240	35	12	10	39	46	38	45	48L
6ft 8in	230	35	14	10	37	46	38	44	48L
		35	20	10 1/2	38	47	39	46 1/2	
6ft 8in	260	37	23 1/2	11	38	47	41	49 1/2	
6ft 5in	300	36	24	9	37	48	47	49	
6ft 5in	235	21	31	9 1/2	38	48	42	46	
5ft 9in	250	32	22	9 1/2	35 1/2	48	43	47 1/2	48R
6ft 6in	240	35	21 1/2	10	37 1/2	48	38 1/2	42	48XL
5ft 7in	210	30 3/4	19	11	32	48	36	48	
6ft 2in	260	32	20 1/2	11	39 1/2	48	44 1/2	N/A	50L
6ft	260	35	N/A	10 1/2	36	48 1/2	47	N/A	50L
6ft 6in	235	33 1/2	23 1/2	11	36 1/2	49	46 1/2	48 1/2	48XL
5ft	212	31	11 1/2	12	34	49	37	49	
5ft 11in	261	30	20	9	34	49 1/2	45 1/4	49 1/2	50R
6ft 2in	262	31	24	9	36 1/2	50	43	N/A	
5ft 7in	210	30	50	9	29	50	50	49	48R
6ft	240	30	22	10	32	50	47	48	48R
6ft 3in	261	34	22	10 1/4	36 1/4	50	43	48	48XL
6ft 3in	260	33 1/2	N/A	11	38	50	42	N/A	48L
5ft 11in	260	33	N/A	13	35	50	44	N/A	
5ft 5in	249	27	18 1/2	9	28 1/2	50 1/2	53 1/2	53	48R
6ft 2in	265	35 1/2	21 3/4	11 3/4	37 3/4	51 1/2	44		48L
5ft 7in	268	36	21	11	36	52	48	48	48L
6ft 2in	279	36		10	35 1/2	53	51	46	53L
5ft 7in	336	N/A	N/A	12	32	55	60	60	48R

DDFG T1P5 TEST DATA **Table A5** **AUTOMATIC MARKING DATA** SuperLay-Optional

MARKER	SIZE		QUANTITY		LENGTH		RUN TIME		EFFICIENCY
AR37R	37REG		2		2YD 06IN		8.5MIN		80.05%
					MANUAL IMPROVEMENT		5MIN		81.48%
AR38R	38REG		2		2YD .40IN		7.37MIN		80.49%
					MANUAL IMPROVEMENT		5MIN		81.10%
AR40R	40REG		2		2YD 2.66IN		8.29MIN		81.20%
					MANUAL IMPROVEMENT		5MIN		83.18%
AR48L	48LONG		2		2YD 16.3IN		8.02MIN		80.74%
					MANUAL IMPROVEMENT		5MIN		81.26%
AR43S	43SHORT		2		2YD .06IN		6.54MIN		79.29%
					MANUAL IMPROVEMENT		5MIN		81.18%

DDFG T1P5 TEST DATA

Table A6 AUTOMATIC MARKING DATA

Gerber Automark-Standard

MARKER	SIZE	QUANTITY	LENGTH	RUN TIME	EFFICIENCY
AR36LSHELL	36LONG	2	2YD 4.2IN	1.06 MIN	76.14%
			MANUAL IMPROVEMENT	4 MIN	77.60%
AR40 SHELL	40REG	2	2YD 7.08IN	1.00MIN	76.00%
			MANUAL IMPROVEMENT	10MIN	79.29%
AR41SHELL	41REG	2	2YD 2.88IN	1.05MIN	75.42%
			MANUAL IMPROVEMENT	7MIN	77.67%
AFSHELL40	40REG	2	2YD .72IN	.20MIN	74.58%
			MANUAL IMPROVEMENT	4MIN	79.30%
AFSHELL41	41REG	2	2YD 4.96IN	.15MIN	71.58%
			MANUAL IMPROVEMENT	3MIN	79.35%

DDFG T1P5 TEST DATA **Table A7** **AUTOMATIC MARKING DATA** Lectra Expert-Optional

MARKER	SIZE		QUANTITY		LENGTH		RUN TIME		EFFICIENCY
AFSHELL32	32REG		2		1YD 22.10IN		2MIN		73.49%
AFSHELL36	36REG		2		1YD 23.05IN		2MIN		77.88%
AFSHELL40	40REG		2		1YD 25.02IN		2MIN		80.82%
AFSHELL44	44REG		2		1YD 32.12IN		2MIN		76.87%
AFSHELL48	48REG		2		1YD 32.23IN		2MIN		81.04%

Table A8

Date: Army Test **MADE TO MEASURE ORDER FORM**

ORDER NAME Order 36

BASE 36 **SLOPE** **SQUARE** **System Calculation for Alteration Amount**

MEASUREMENT		Alteration Base Table	-	ORDER	=	
waist		30.0		29.0		-1
hip		36.0		35.0		-1
cross back						
bicep		14.5		15.5		1
sleeve length						
cb sleeve length						
cb length						

Note: Enter measurements only where you wish to make changes

Date: Army Test **MADE TO MEASURE ORDER FORM**

ORDER NAME Order 44

BASE 44 **SLOPE** X **SQUARE** **System Calculation for Alteration Amount**

MEASUREMENT		Alteration Base Table	-	ORDER	=	
waist						
hip						
cross back						
bicep						
sleeve length		17		18		1
cb sleeve length						
cb length		31.75		32.75		1

Note: Enter measurements only where you wish to make changes

Date: Army Test **MADE TO MEASURE ORDER FORM**

ORDER NAME Order 48

BASE 48 **SLOPE** **SQUARE** X **System Calculation for Alteration Amount**

MEASUREMENT		Alteration Base Table	-	ORDER	=	
waist						
hip						
cross back		9.62		10.37		0.75
bicep						
sleeve length						
cb sleeve length						
cb length						

Note: Enter measurements only where you wish to make changes

DDFG T1-P5 TEST DATA

Table A8-1

ARMY FINISHED DIMENTIONS

(PATTERN MEASUREMENTS)

ARMY -SIZE	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
WAIST	28.00	29.00	30.00	31.00	32.00	33.00	34.00	35.00	36.00	37.00	**38.00**	39.00	40.00	41.00	42.00	43.00	44.00	45.00	46.00	47.00	48.00	49.00	50.00
SEAT (HIP)	33.50	34.50	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50	54.50	55.50
CROSS BACK	7.37	7.50	7.62	7.75	7.87	8.00	8.12	8.25	8.37	8.50	**8.62**	8.75	8.87	9.00	9.12	9.25	9.37	9.50	9.62	9.75	9.87	10.00	10.12
BICEP	15.00	15.25	15.50	15.75	16.00	16.25	16.50	16.75	17.00	17.25	**17.50**	17.75	18.00	18.25	18.50	18.75	19.00	19.25	19.50	19.75	20.00	20.25	20.50
P.P.	7.88	8.00	8.13	8.25	8.38	8.50	8.63	8.75	8.88	9.00	**9.13**	9.25	9.38	9.50	9.63	9.75	9.88	10.00	10.13	10.25	10.38	10.50	10.63
REGULAR	30	31	32	33	34	35	36	37	38	39	**40**	41	42	43	44	45	46	47	48	49	50	51	52
CHEST FULL	33.50	34.50	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50	54.50	55.50
SLEEVE ARM	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	**17.00**	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
CB LENGTH	30.00	30.13	30.25	30.38	30.50	30.63	30.75	30.88	31.00	31.13	**31.25**	31.38	31.50	31.63	31.75	31.88	32.00	32.13	32.25	32.38	32.50	32.63	32.75

DDFG T1-P5 TEST DATA
(BODY MEASUREMENT)

ARMY BODY MEASUREMENTS

Table A8-2

ARMY -SIZE	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
WAIST	24.00	25.00	26.00	27.00	28.00	29.00	30.00	31.00	32.00	33.00	**34.00**	35.00	36.00	37.00	38.00	39.00	40.00	41.00	42.00	43.00	44.00	45.00	46.00
ease 4"																							
SEAT (HIP)	30.00	31.00	32.00	33.00	34.00	35.00	36.00	37.00	38.00	39.00	**40.00**	41.00	42.00	43.00	44.00	45.00	46.00	47.00	48.00	49.00	50.00	51.00	52.00
ease 3.5"																							
CROSS BACK	7.37	7.50	7.62	7.75	7.87	8.00	8.12	8.25	8.37	8.50	**8.62**	8.75	8.87	9.00	9.12	9.25	9.37	9.50	9.62	9.75	9.87	10.00	10.12
ease 0"																							
BICEP	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	**15.50**	15.75	16.00	16.25	16.50	16.75	17.00	17.25	17.50	17.75	18.00	18.25	18.50
ease 2"																							
P.P.	7.88	8.01	8.13	8.26	8.38	8.51	8.63	8.76	8.88	9.01	**9.13**	9.26	9.38	9.51	9.63	9.76	9.88	10.01	10.13	10.26	10.38	10.51	10.63
ease 0"																							
REGULAR	30	31	32	33	34	35	36	37	38	39	**40**	41	42	43	44	45	46	47	48	49	50	49	50
CHEST FULL	30.00	31.00	32.00	33.00	34.00	35.00	36.00	37.00	38.00	39.00	**40.00**	41.00	42.00	43.00	44.00	45.00	46.00	47.00	48.00	49.00	50.00	51.00	52.00
ease 3.5"																							
SLEEVE ARM	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	**17.00**	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
ease 0"																							
CB LENGTH	30.00	30.13	30.25	30.38	30.50	30.63	30.75	30.88	31.00	31.13	**31.25**	31.38	31.50	31.63	31.75	31.88	32.00	32.13	32.25	32.38	32.50	32.63	32.75
ease 0"																							
CB SLEEVE	35.75	35.88	36.00	36.13	36.25	36.38	36.50	36.63	36.75	36.88	**37.00**	37.13	37.25	37.38	37.50	37.63	37.75	37.88	38.00	38.13	38.25	38.38	38.50
ease 0"																							

ARMY MIL-C-44211B

DDFG T1-P5 TEST DATA
(LENGTH DATA)

X-SHORT	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
CHEST FULL	33.50	34.50	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50	54.50	55.50
SLEEVE ARM	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	**15.00**	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
CB LENGTH	27.00	27.13	27.25	27.38	27.50	27.63	27.75	27.88	28.00	28.13	**28.25**	28.38	28.50	28.63	28.75	28.81	28.88	28.94	29.00	29.06	29.13	29.19	29.25

SHORT	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
CHEST FULL	33.50	34.50	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50	54.50	55.50
SLEEVE ARM	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	**16.00**	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
CB LENGTH	28.50	28.63	28.75	28.88	29.00	29.13	29.25	29.38	29.50	29.63	**29.75**	29.88	30.00	30.13	30.25	30.38	30.50	30.63	30.75	30.88	31.00	31.13	31.25

REGULAR	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
CHEST FULL	33.50	34.50	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50	54.50	55.50
SLEEVE ARM	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	**17.00**	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
CB LENGTH	29.75	29.88	30.00	30.13	30.25	30.38	30.50	30.63	30.75	30.88	**31.00**	31.13	31.25	31.38	31.50	31.63	31.75	31.88	32.00	32.13	32.25	32.38	32.50

LONG	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
CHEST FULL	33.50	34.50	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50	54.50	55.50
SLEEVE ARM	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25	**18.25**	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25
CB LENGTH	31.25	31.38	31.50	31.63	31.75	31.88	32.00	32.13	32.25	32.38	**32.50**	32.63	32.75	32.88	33.00	33.13	33.25	33.38	33.50	33.63	33.75	33.88	34.00

X-LONG	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
CHEST FULL	33.50	34.50	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50	54.50	55.50
SLEEVE ARM	19.75	19.75	19.75	19.75	19.75	19.75	19.75	19.75	19.75	19.75	**19.75**	19.75	19.75	19.75	19.75	19.75	19.75	19.75	19.75	19.75	19.75	19.75	19.75
CB LENGTH	33.00	33.13	33.25	33.38	33.50	33.63	33.75	33.88	34.00	34.13	**34.25**	34.38	34.50	34.63	34.75	34.88	35.00	35.13	35.25	35.38	35.50	35.63	35.75

Table A9

Date: Air Force Test **MADE TO MEASURE ORDER FORM**

ORDER NAME Order 36

BASE 36 **SLOPE** **SQUARE**

MEASUREMENT		Alteration Base Table	-	ORDER	=	System Calculation for Alteration Amount
waist		30.00		29.00		-1.000
hip						
cross back		8.63		9.00		0.375
bicep						
sleeve length		17.50		17.00		-0.500
cb sleeve length						
cb length		30.87		29.87		-1.000

Note: Enter measurements only where you wish to make changes

Date: Air Force Test **MADE TO MEASURE ORDER FORM**

ORDER NAME Order 44

BASE 44 **SLOPE** **SQUARE**

MEASUREMENT		Alteration Base Table	-	ORDER	=	System Calculation for Alteration Amount
waist		38.00		40.00		2.00
hip		44.00		45.50		1.50
cross back						
bicep						
sleeve length		17.50		19.00		1.50
cb sleeve length						
cb length		31.38		33.38		2.00

Note: Enter measurements only where you wish to make changes

Date: Air Force Test **MADE TO MEASURE ORDER FORM**

ORDER NAME Order 48

BASE 48 **SLOPE** **SQUARE**

MEASUREMENT		Alteration Base Table	-	ORDER	=	System Calculation for Alteration Amount
waist						
hip						
cross back						
bicep						
sleeve length		17.50		20.50		3.00
cb sleeve length						
cb length		31.63		34.63		3.00

Note: Enter measurements only where you wish to make changes

DDFG T1-P5 Test Data
(PATTERN MEASUREMENTS)

Table A9-1

AIRFORCE FINISHED DIMENTIONS
BASE

AIRFORCE - SIZE	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
WAIST	31.00	32.00	33.00	34.00	35.00	36.00	37.00	38.00	**39.00**	40.00	41.00	42.00	43.00	44.00	45.00	46.00	47.00	48.00	49.00
SEAT (HIP)	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50
CROSS BACK	8.13	8.25	8.38	8.50	8.63	8.75	8.88	9.00	**9.13**	9.25	9.38	9.50	9.63	9.75	9.88	10.00	10.13	10.25	10.38
BICEP	16.16	16.31	16.47	16.63	16.78	16.94	17.09	17.25	**17.50**	17.75	17.91	18.06	18.22	18.38	18.53	18.69	18.84	19.00	19.16
P.P.	8.75	8.88	9.00	9.13	9.25	9.38	9.50	9.63	**9.75**	9.88	10.00	10.13	10.25	10.38	10.50	10.63	10.75	10.88	11.00
REGULAR	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
CHEST FULL	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50
SLEEVE UNDER ARM	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	**17.50**	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
LENGTH CB REGULAR	30.62	30.68	30.75	30.81	30.87	30.94	31.00	31.06	**31.13**	31.19	31.25	31.31	31.38	31.44	31.50	31.57	31.63	31.69	31.76

DDFG T1-P5 TEST DATA
(BODY MEASUREMENTS)

Table A9-2

AIR FORCE BODY MEASUREMENTS
BASE

AIRFORCE - SIZE	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
WAIST	26.00	27.00	28.00	29.00	30.00	31.00	32.00	33.00	**34.00**	35.00	36.00	37.00	38.00	39.00	40.00	41.00	42.00	43.00	44.00
5" ease																			
SEAT (HIP)	32.00	33.00	34.00	35.00	36.00	37.00	38.00	39.00	**40.00**	41.00	42.00	43.00	44.00	45.00	46.00	47.00	48.00	49.00	50.00
3 1/2" ease																			
CROSS BACK	8.13	8.25	8.38	8.50	8.63	8.75	8.88	9.00	**9.13**	9.25	9.38	9.50	9.63	9.75	9.88	10.00	10.13	10.25	10.38
0 ease																			
BICEP	14.16	14.31	14.47	14.63	14.78	14.94	15.09	15.25	**15.50**	15.75	15.91	16.06	16.22	16.38	16.53	16.69	16.84	17.00	17.16
2" ease																			
P.P.	8.75	8.88	9.00	9.13	9.25	9.38	9.50	9.63	**9.75**	9.88	10.00	10.13	10.25	10.38	10.50	10.63	10.75	10.88	11.00
0 ease																			
REGULAR	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
CHEST FULL	32.00	33.00	34.00	35.00	36.00	37.00	38.00	39.00	**40.00**	41.00	42.00	43.00	44.00	45.00	46.00	47.00	48.00	49.00	50.00
3 1/2" ease																			
SLEEVE UNDER ARM	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	**17.50**	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
0 ease																			
LENGTH CB REGULAR	30.62	30.68	30.75	30.81	30.87	30.94	31.00	31.06	**31.13**	31.19	31.25	31.31	31.38	31.44	31.50	31.57	31.63	31.69	31.76
0 ease																			

DDFG T1-P5 TEST DATA

AIR FORCE MIL -C-31006

(LENGTH DATA) Table A9-3

X-SHORT	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
CHEST FULL	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50
SLEEVE UNDER ARM	15.50	15.50	15.50	15.50	15.50	15.50	15.50	15.50	**15.50**	15.50	15.50	15.50	15.50	15.50	15.50	15.50	15.50	15.50	15.50
LENGTH CB X-SHORT	28.62	28.68	28.75	28.81	28.87	28.94	29.00	29.06	**29.13**	29.19	29.25	29.31	29.38	29.44	29.50	29.57	29.63	29.69	29.76
SHORT	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
CHEST FULL	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50
SLEEVE UNDER ARM	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50	**16.50**	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50
LENGTH CB SHORT	29.62	29.68	29.75	29.81	29.87	29.94	30.00	30.06	**30.13**	30.19	30.25	30.31	30.38	30.44	30.50	30.57	30.63	30.69	30.76
REGULAR	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
CHEST FULL	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50
SLEEVE UNDER ARM	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	**17.50**	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
LENGTH CB REGULAR	30.62	30.68	30.75	30.81	30.87	30.94	31.00	31.06	**31.13**	31.19	31.25	31.31	31.38	31.44	31.50	31.57	31.63	31.69	31.76
LONG	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
CHEST FULL	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50
SLEEVE UNDER ARM	18.50	18.50	18.50	18.50	18.50	18.50	18.50	18.50	**18.50**	18.50	18.50	18.50	18.50	18.50	18.50	18.50	18.50	18.50	18.50
LENGTH CB REGULAR	31.62	31.68	31.75	31.81	31.87	31.94	32.00	32.06	**32.13**	32.19	32.25	32.31	32.38	32.44	32.50	32.57	32.63	32.69	32.76
X-LONG	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
CHEST FULL	35.50	36.50	37.50	38.50	39.50	40.50	41.50	42.50	**43.50**	44.50	45.50	46.50	47.50	48.50	49.50	50.50	51.50	52.50	53.50
SLEEVE UNDER ARM	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	**19.50**	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50
LENGTH CB REGULAR	32.62	32.68	32.75	32.81	32.87	32.94	33.00	33.06	**33.13**	33.19	33.25	33.31	33.38	33.44	33.50	33.57	33.63	33.69	33.76

BICEP PATTERN ALTERATIONS

Front

Back

Side Body

Under Sleeve Shell

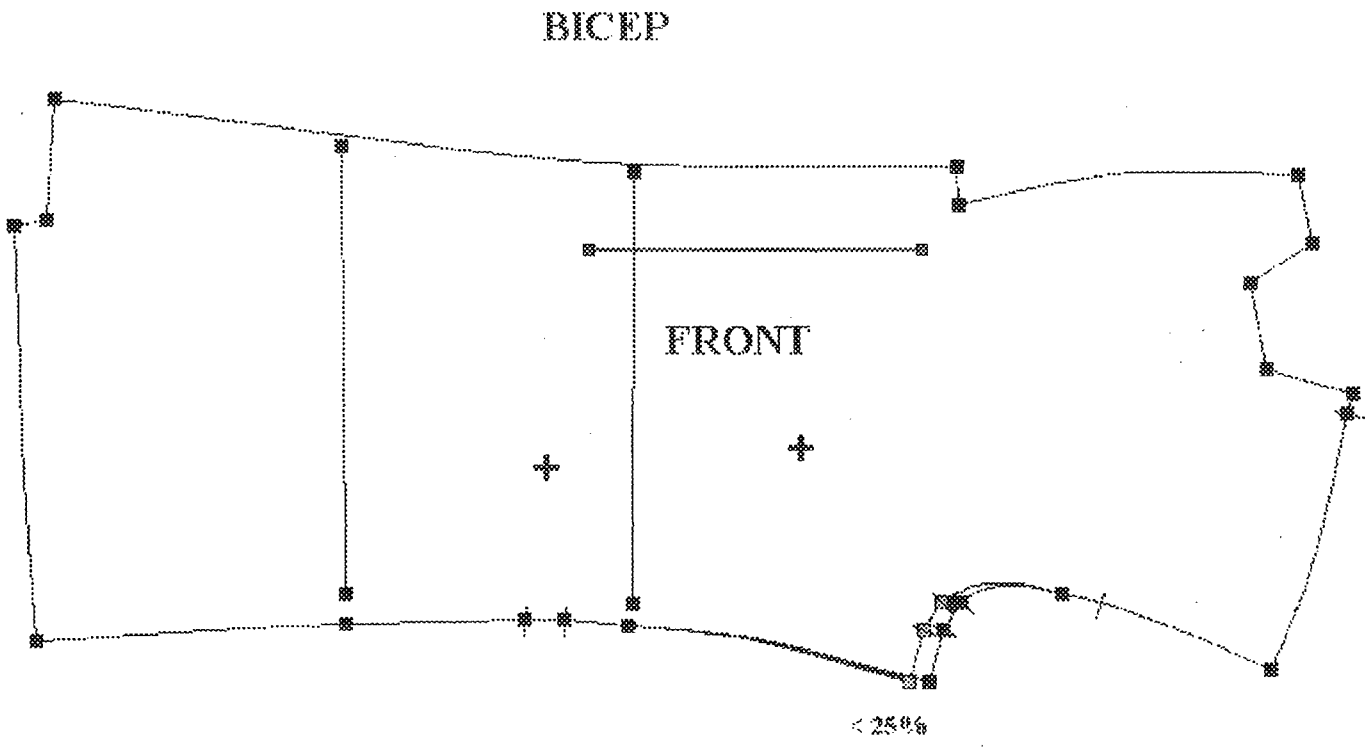
Under Sleeve Lining

Side Body Lining

Front Lining

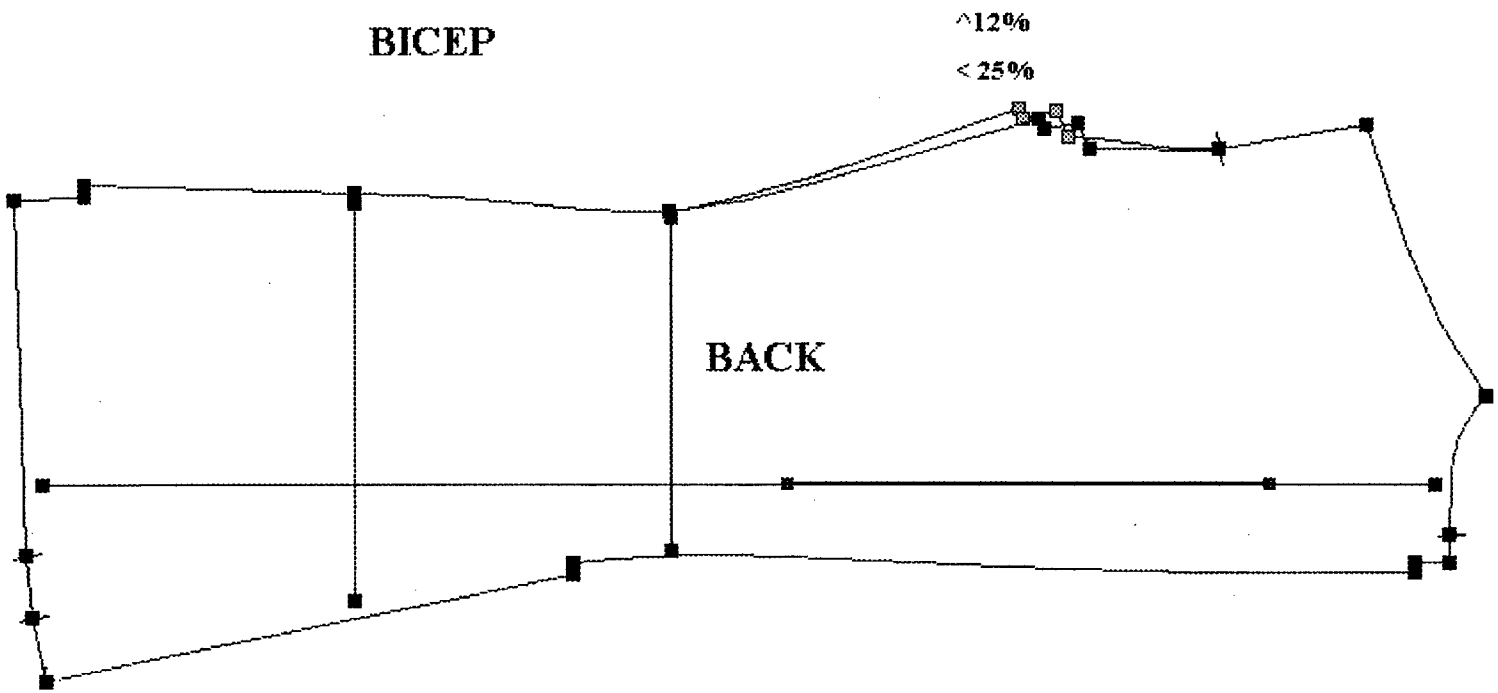
Back Yoke

SPSU DDFG T1-P5 ALTERATION DISTRIBUTION

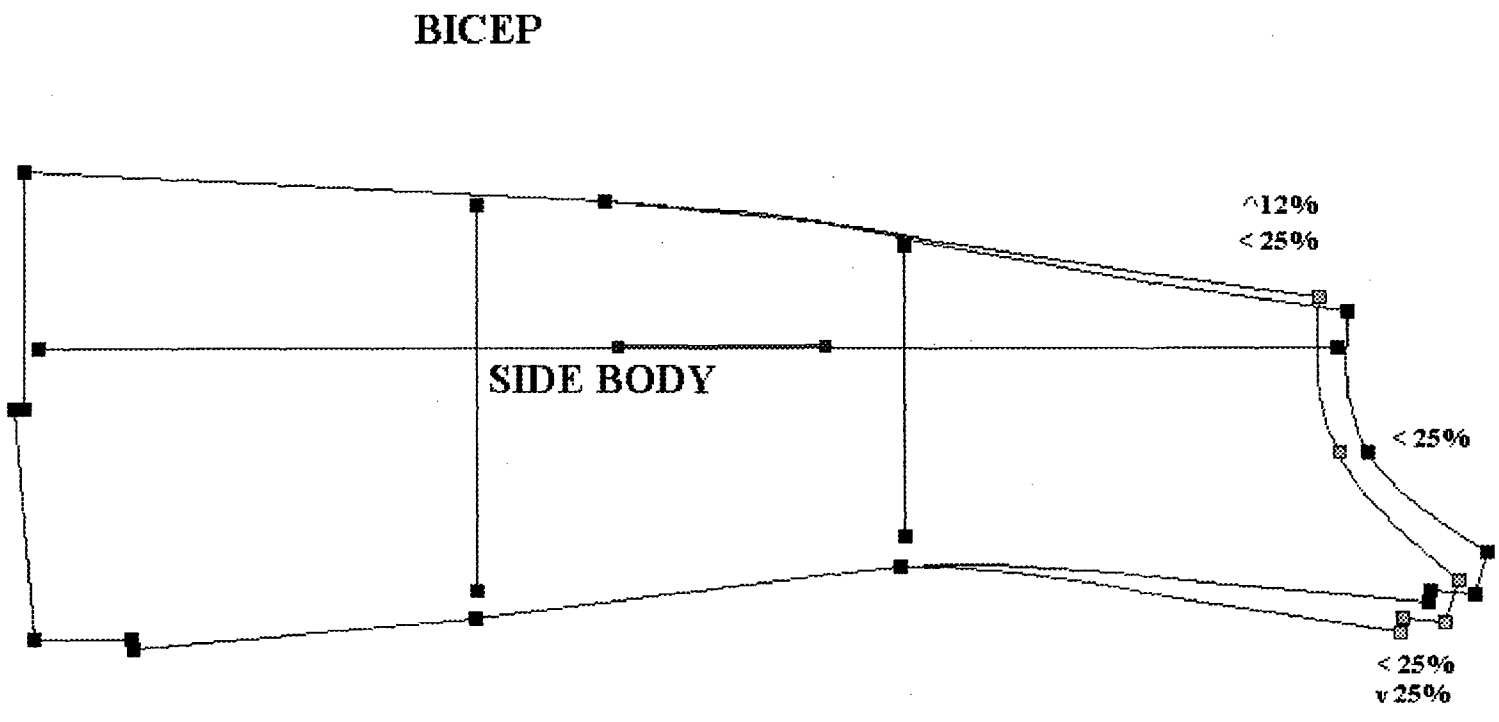


Appendix A10

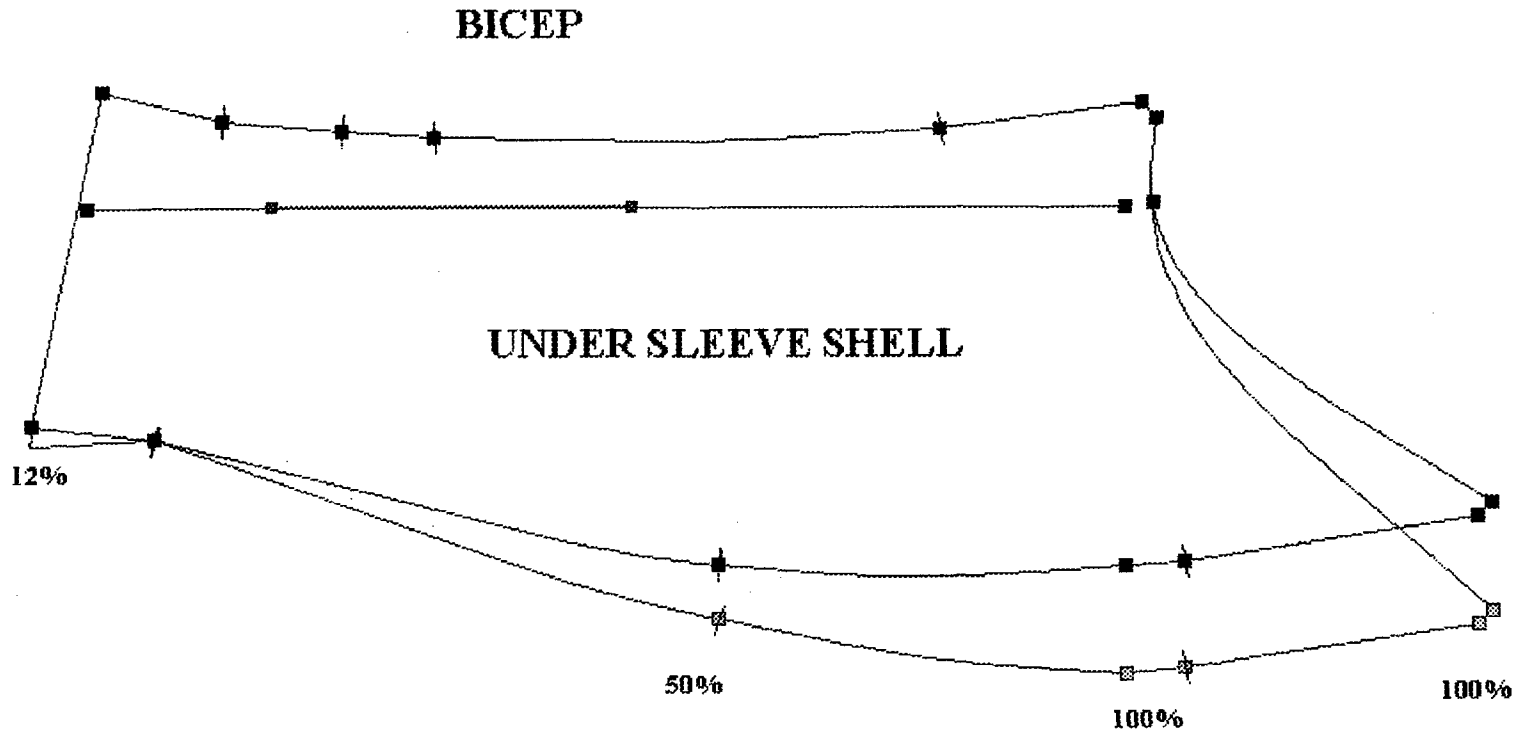
SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



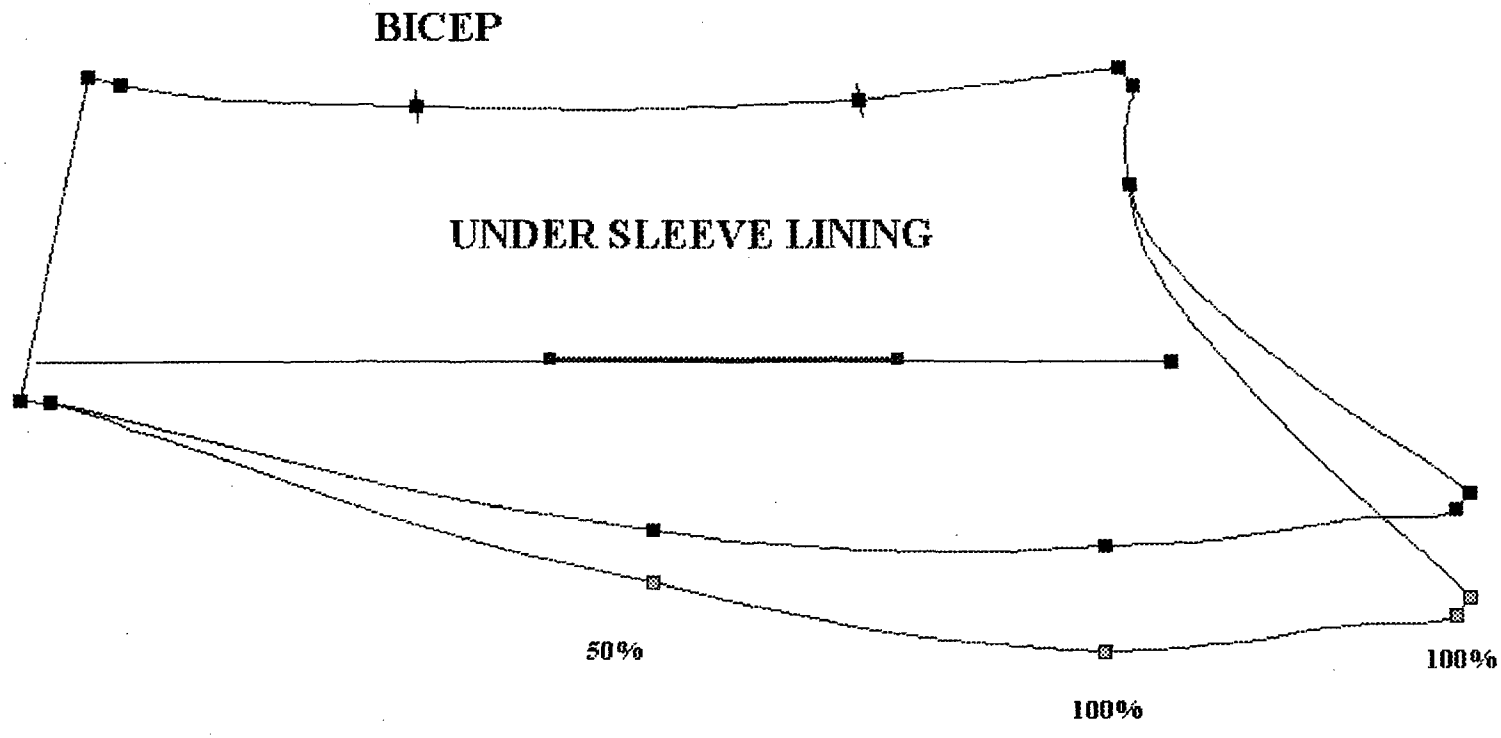
SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



SPSU DDFG T1-P5 ALTERATION DISTRIBUTION

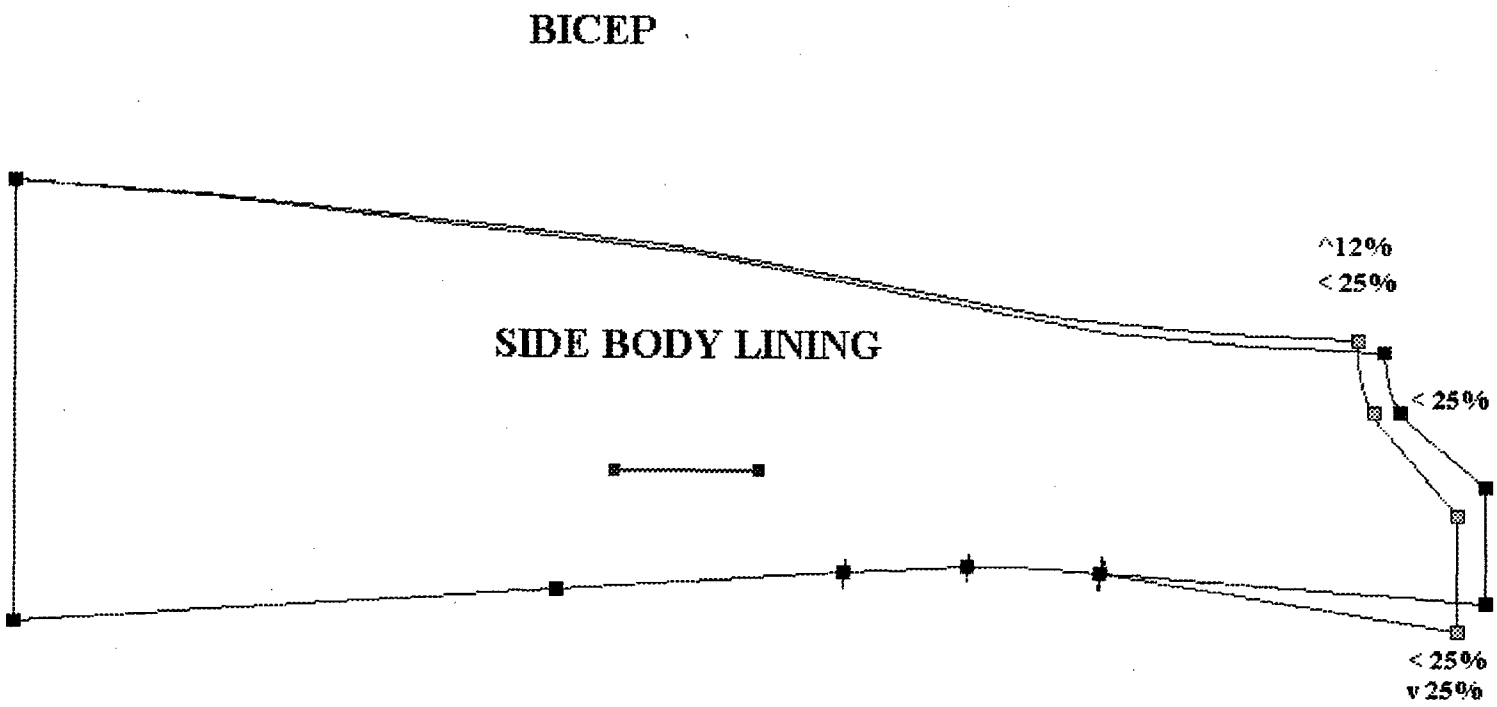


SPSU DDFG T1-P5 ALTERATION DISTRIBUTION

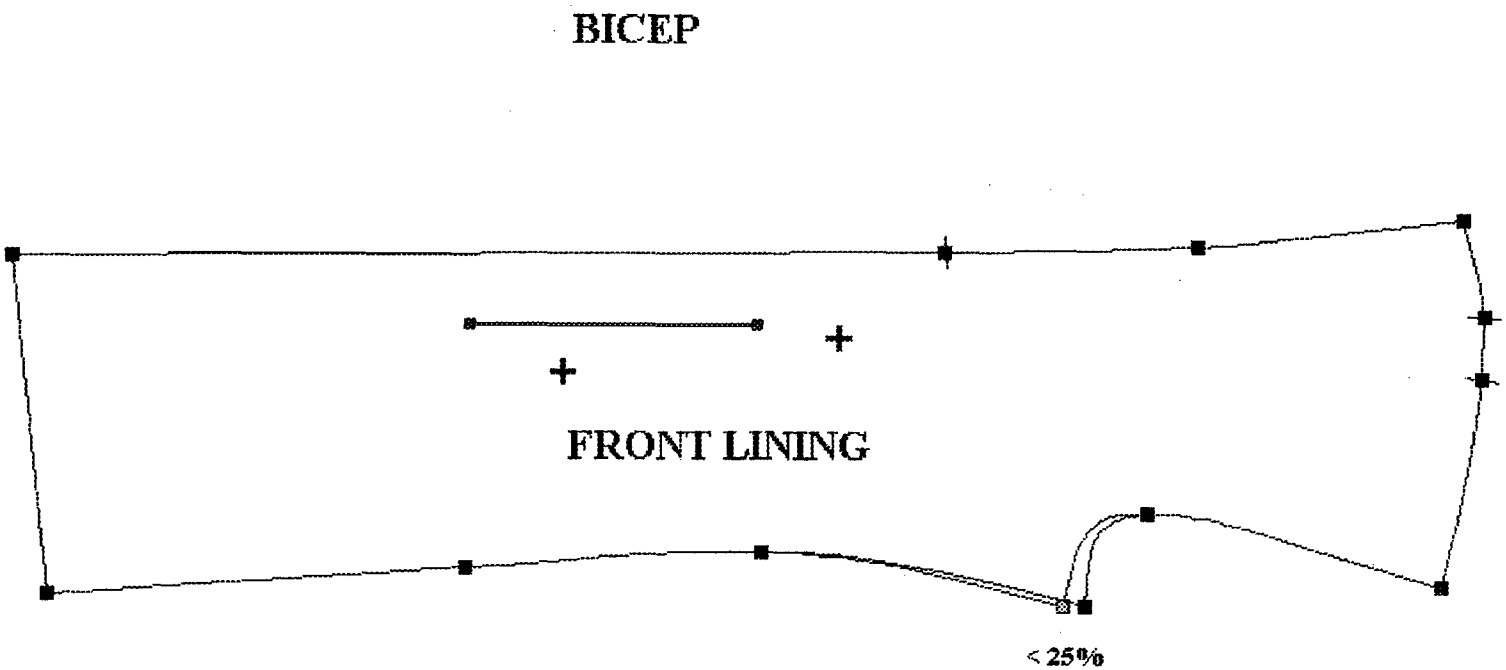


Appendix A10

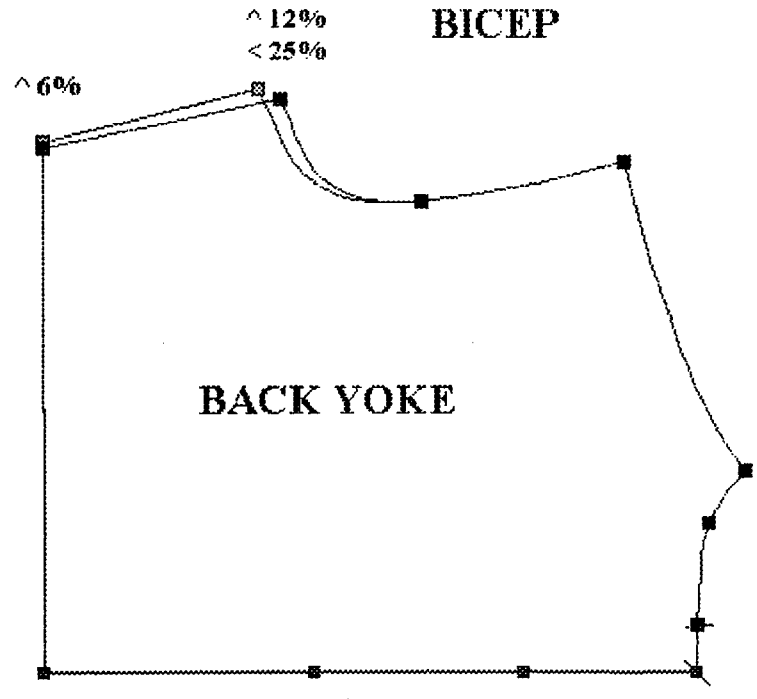
SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



WAIST PATTERN ALTERATIONS

Front

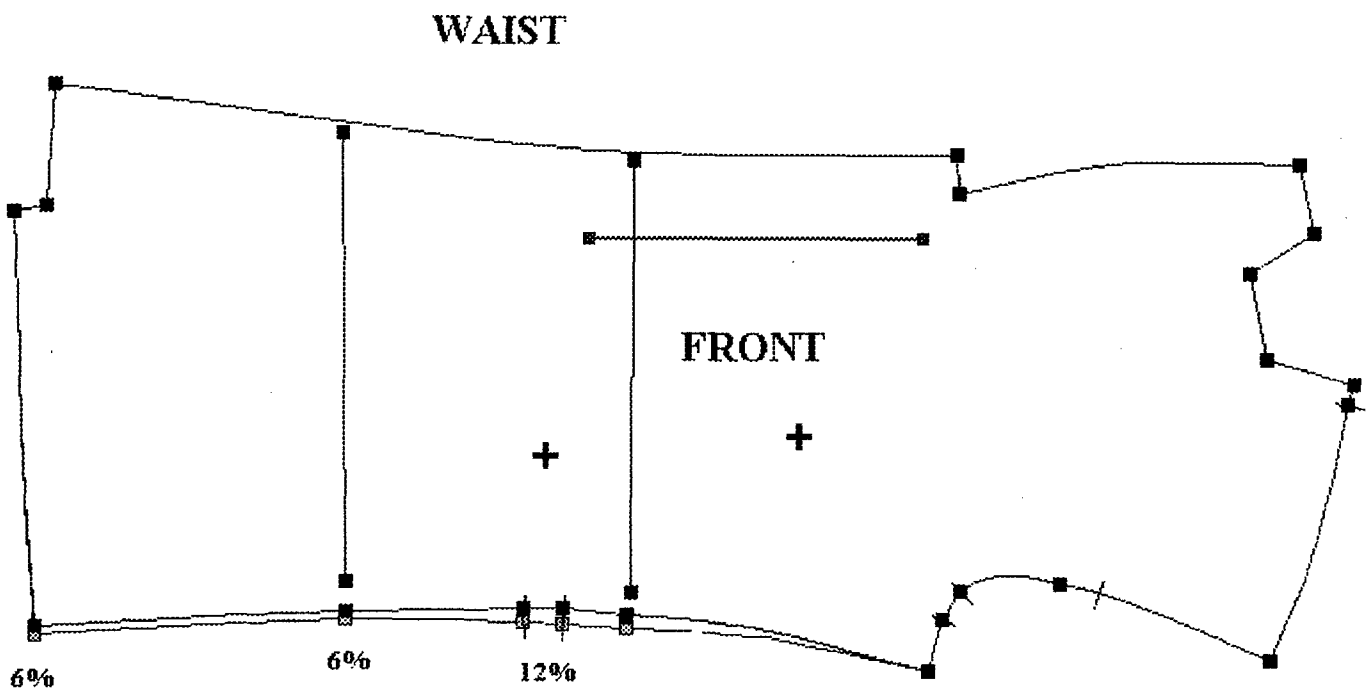
Back

Side Body

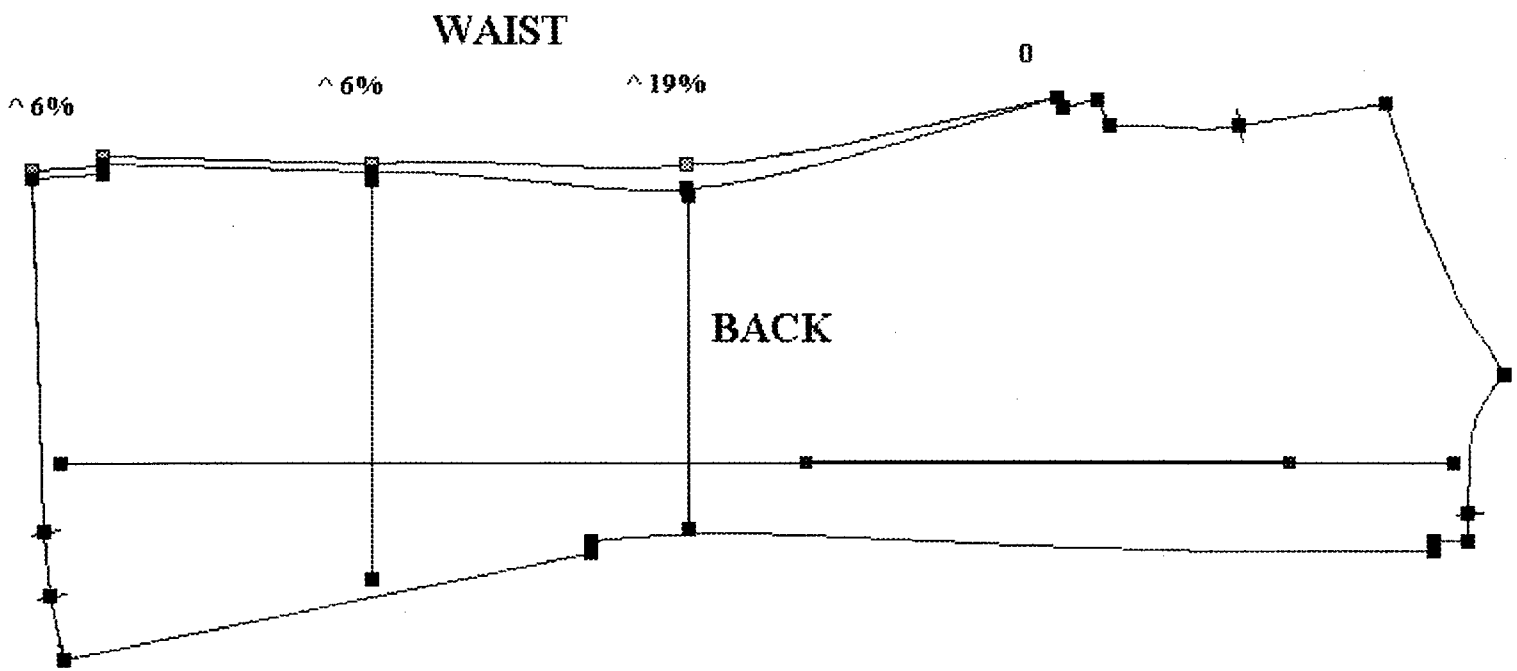
Side Body Lining

Front Lining

SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



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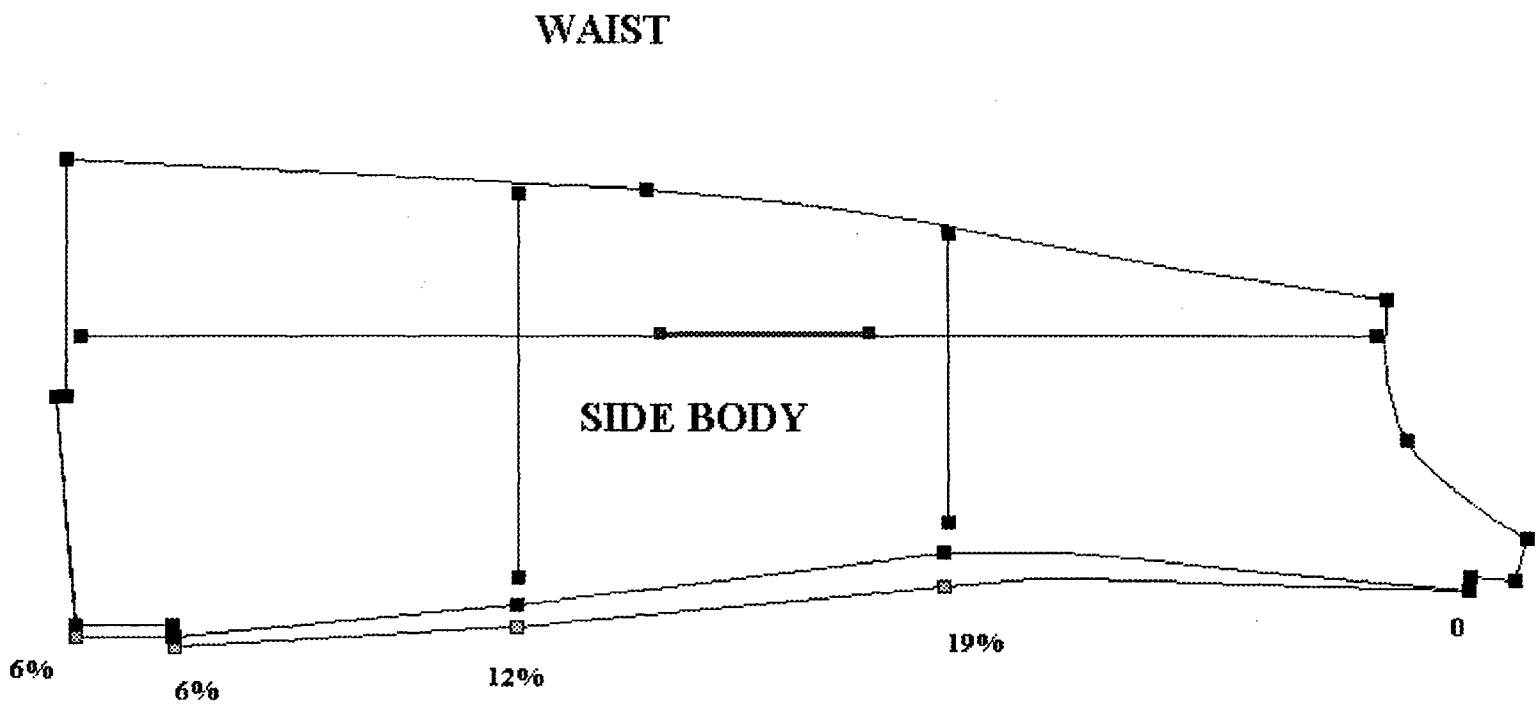

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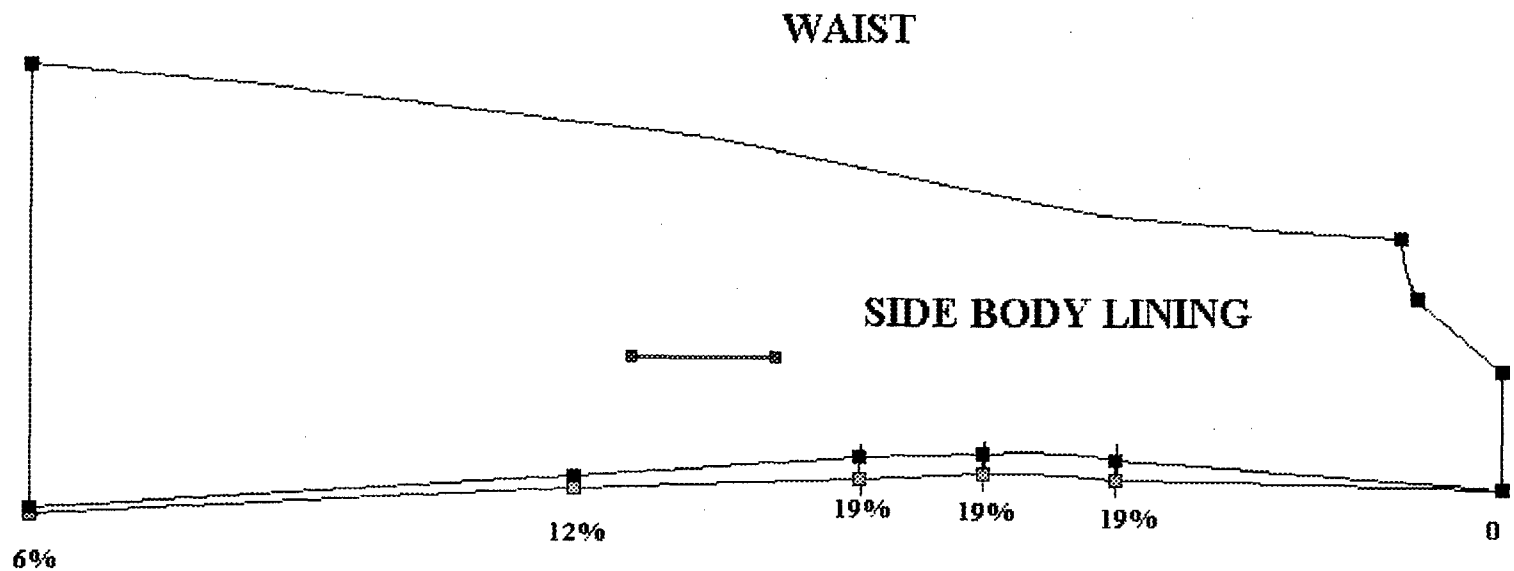

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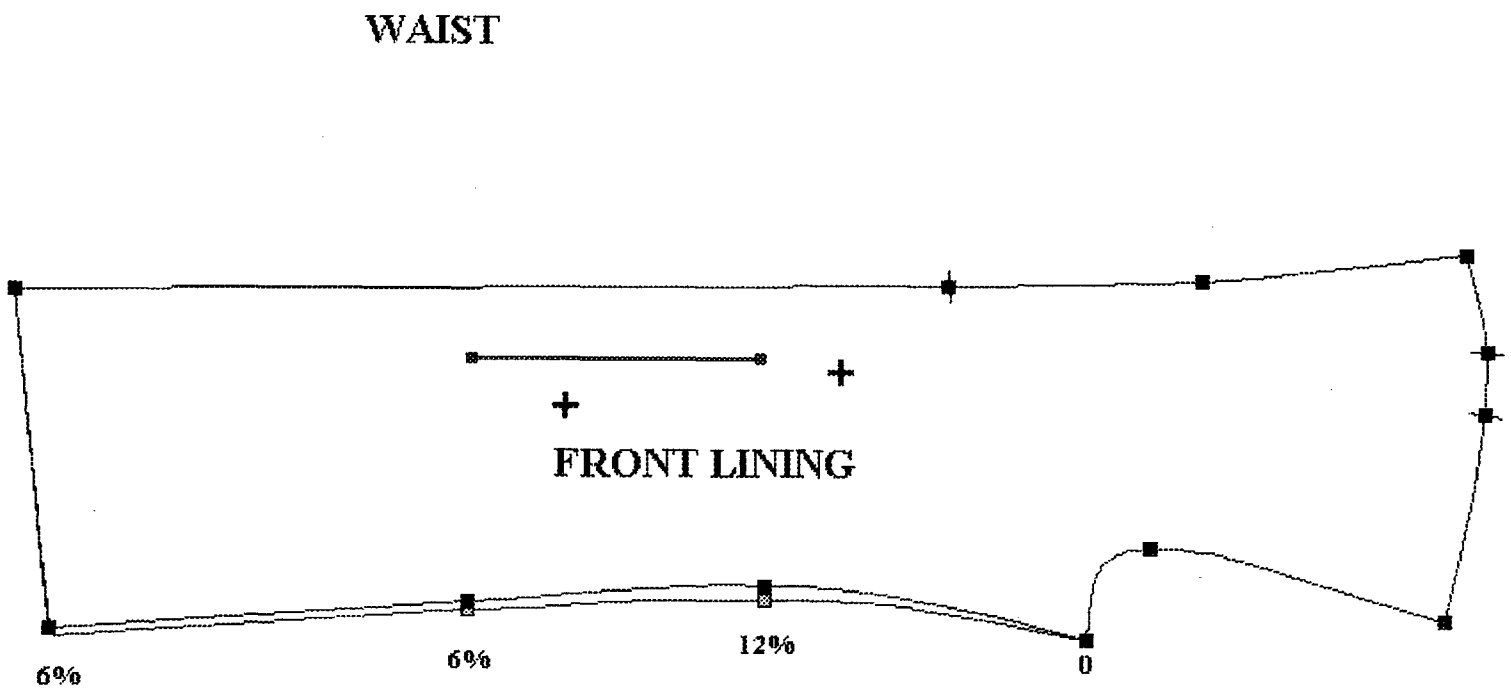


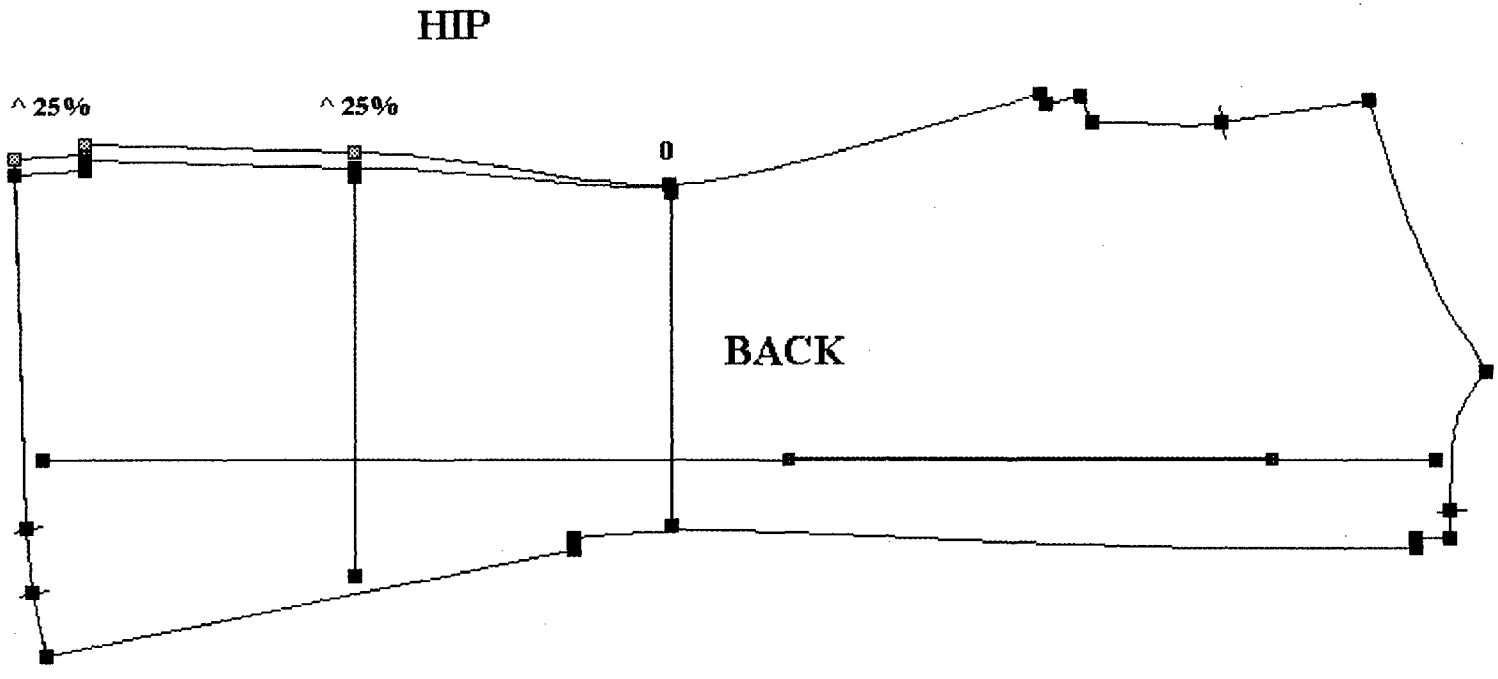
HIP PATTERN ALTERATIONS

Back

Side Body

Side Body Lining

SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



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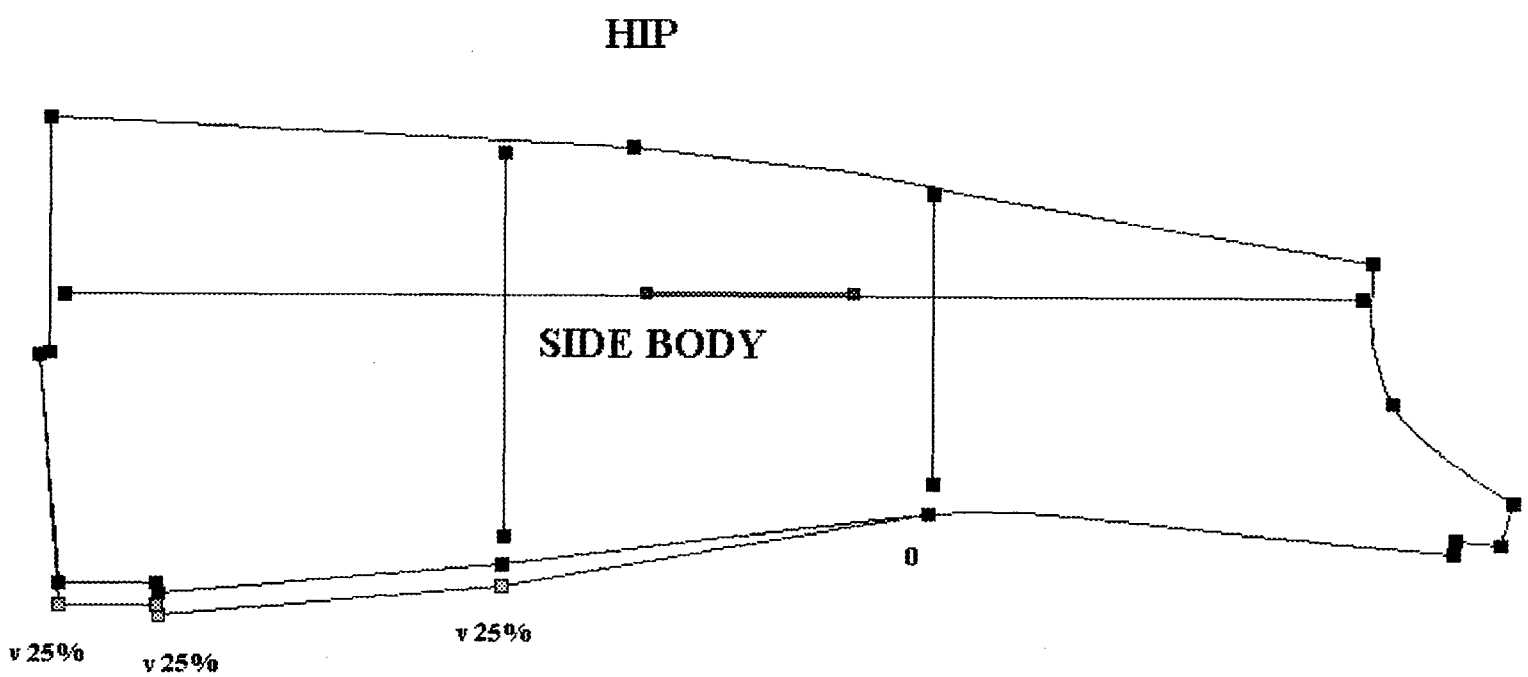


CROSSBACK PATTERN ALTERATIONS

Front

Back

Side Body

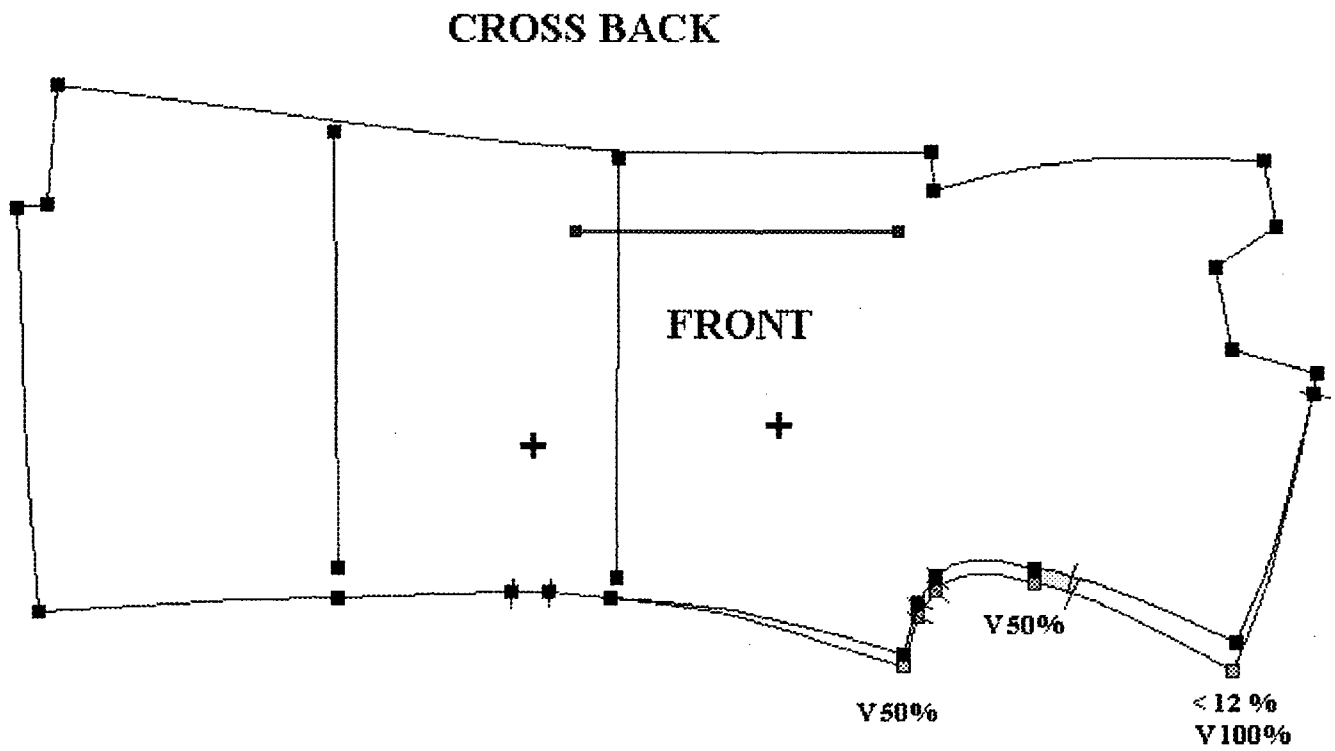
Front Lining

Side Body Lining

Shoulder Loop

Back Yoke

SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



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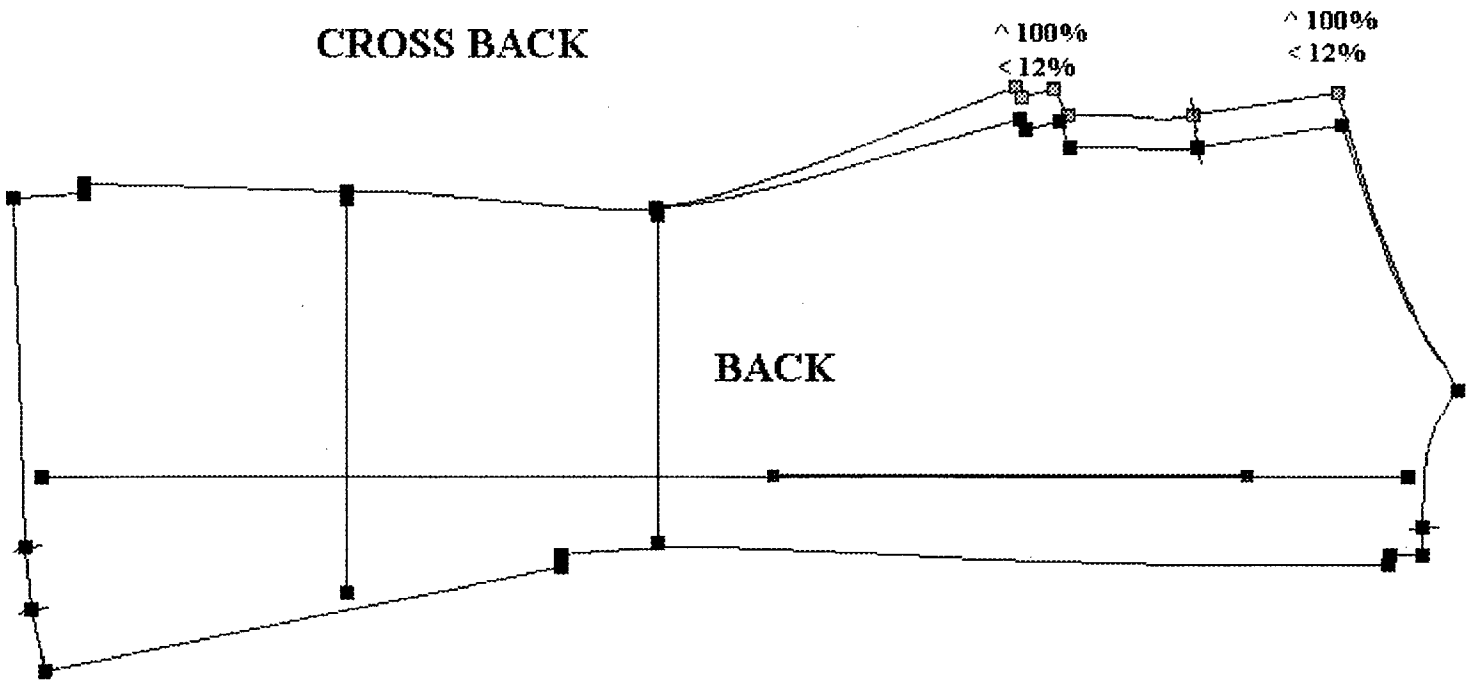

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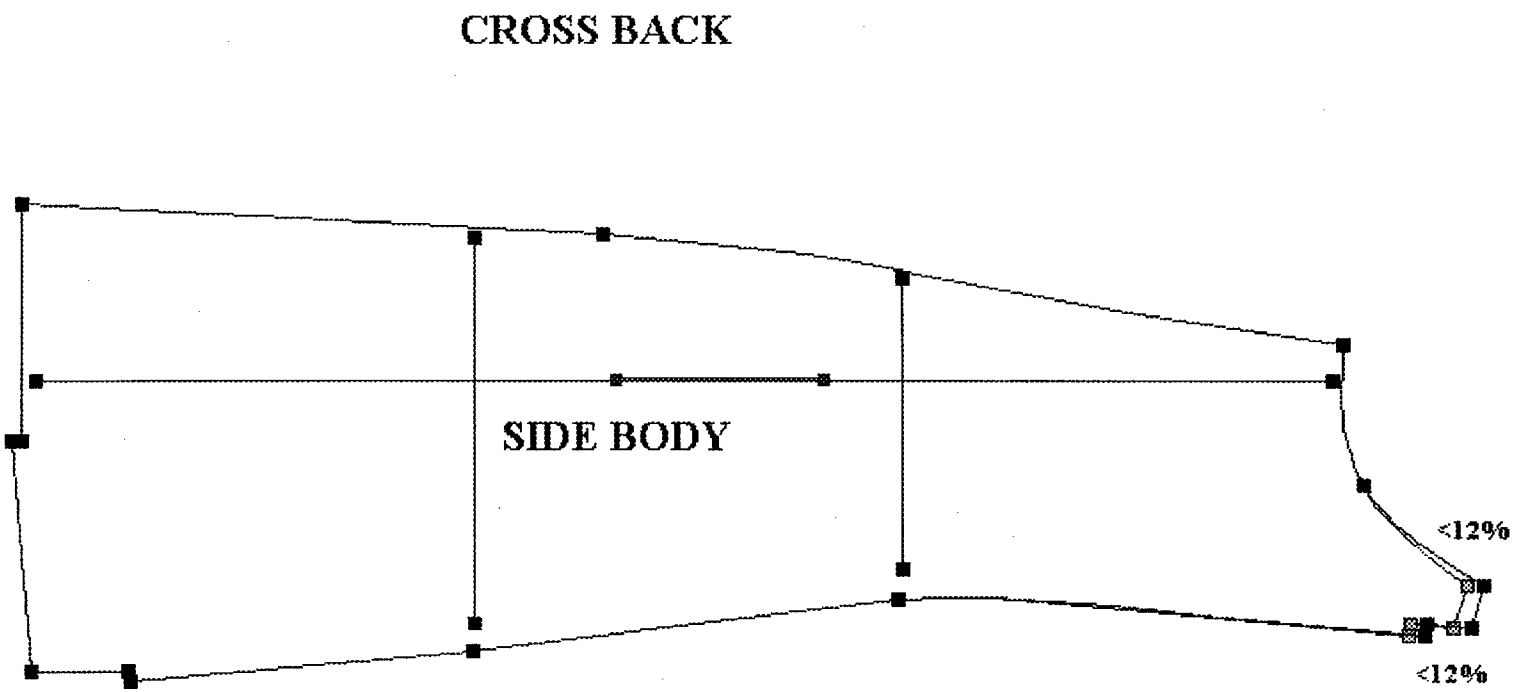

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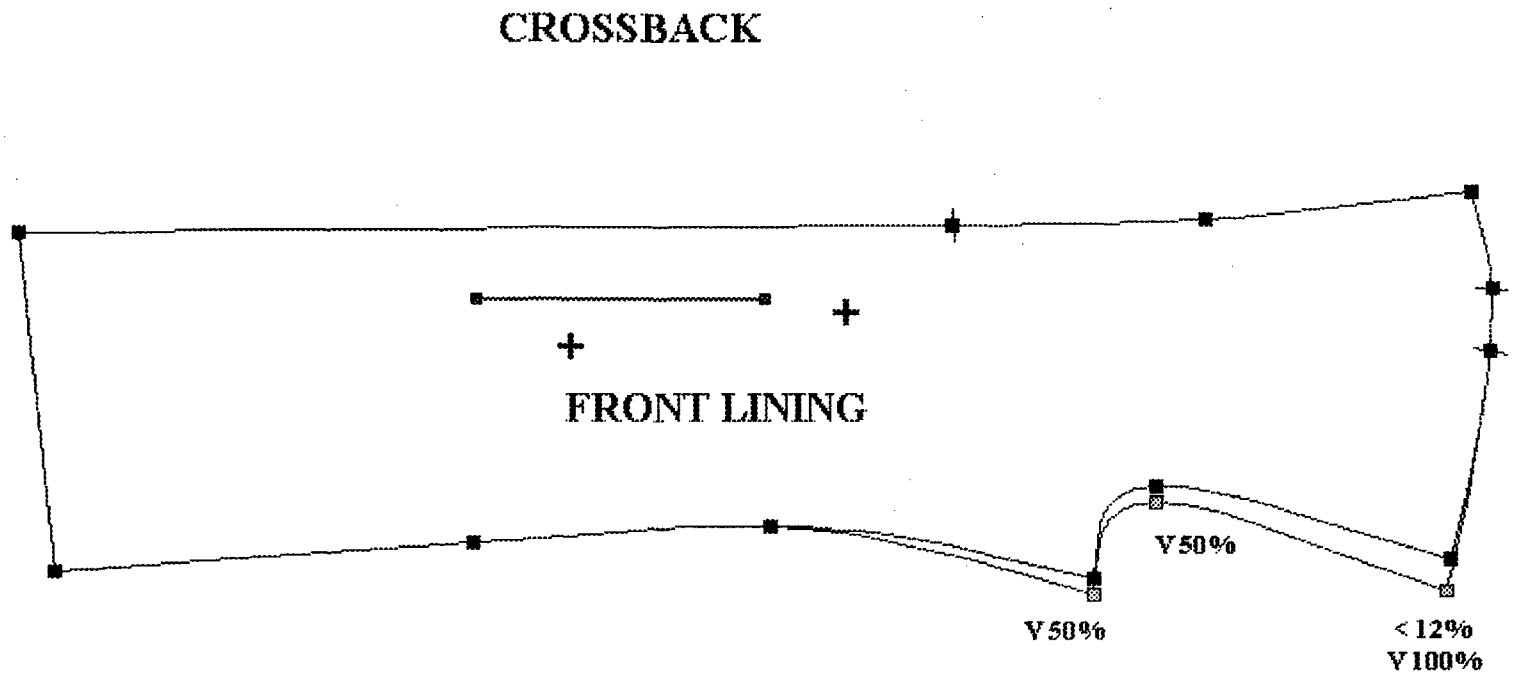

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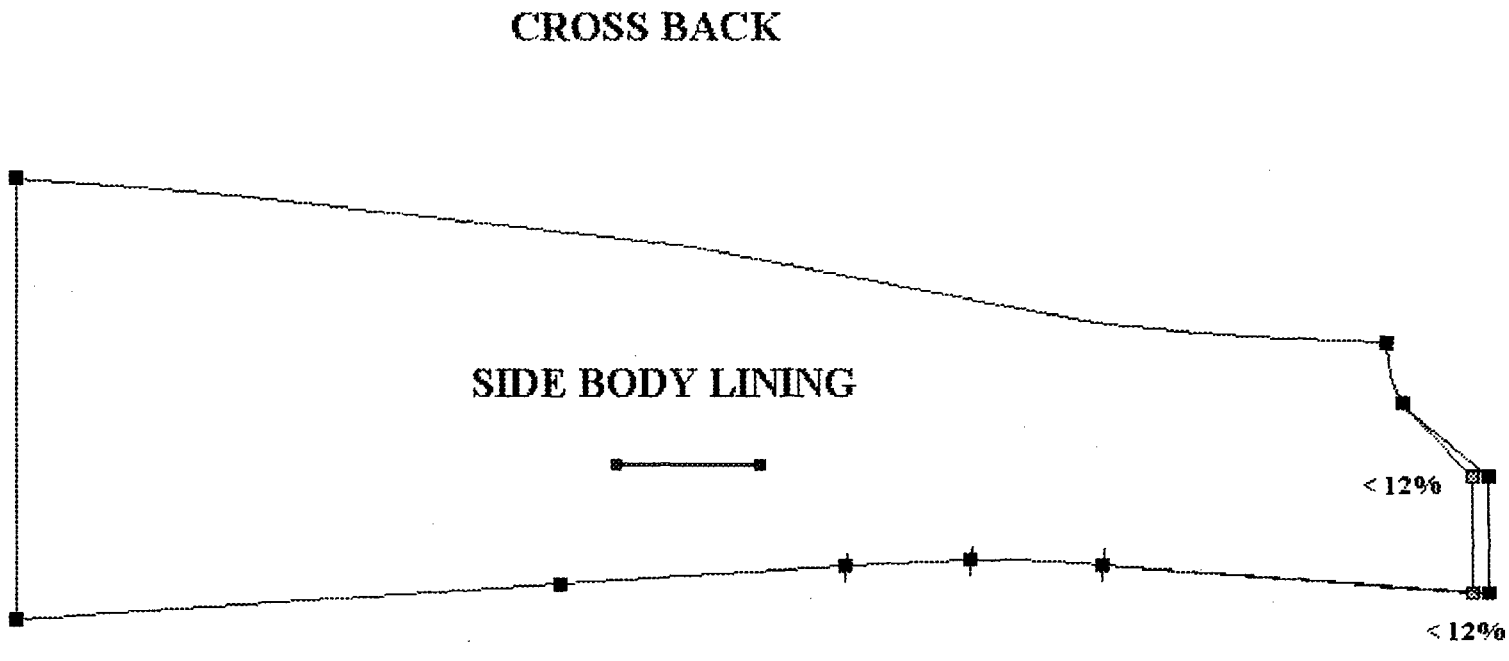

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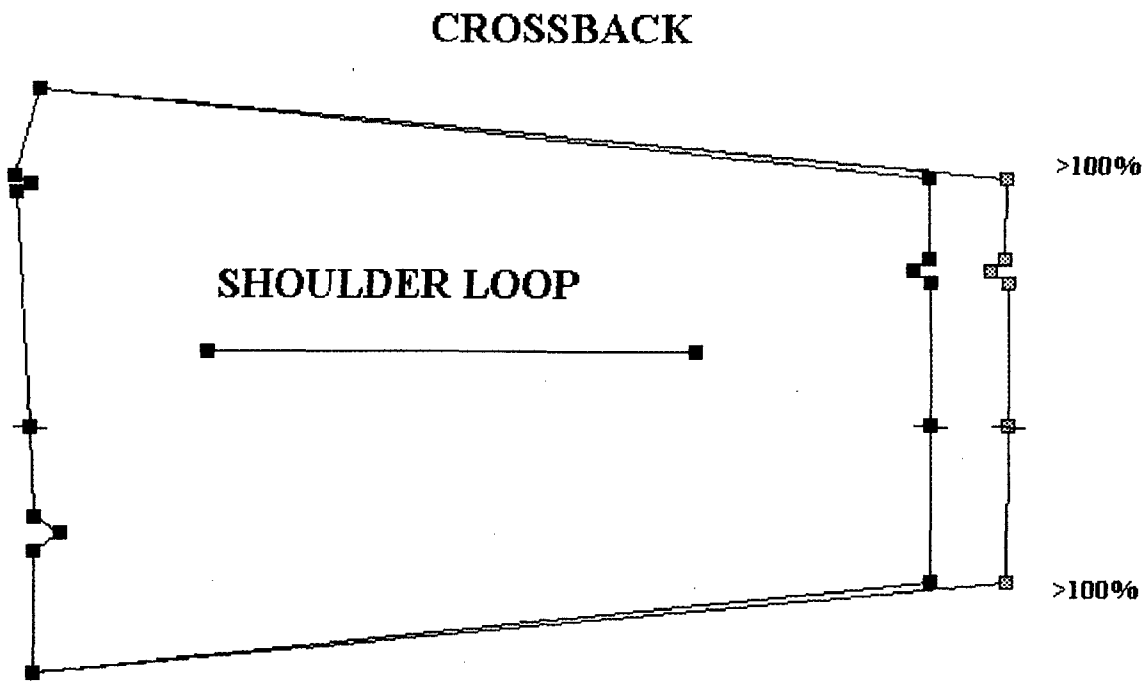

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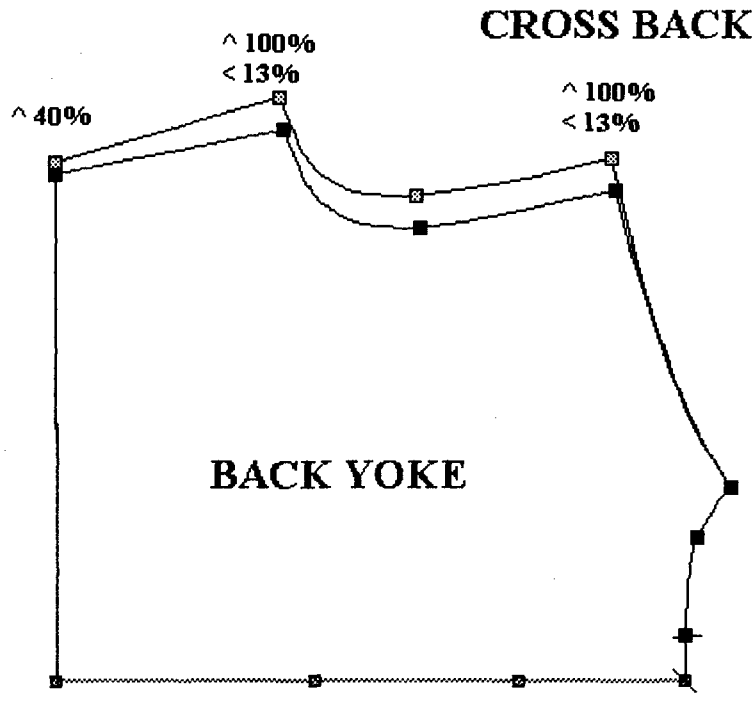


SLEEVE LENGTH PATTERN ALTERATIONS

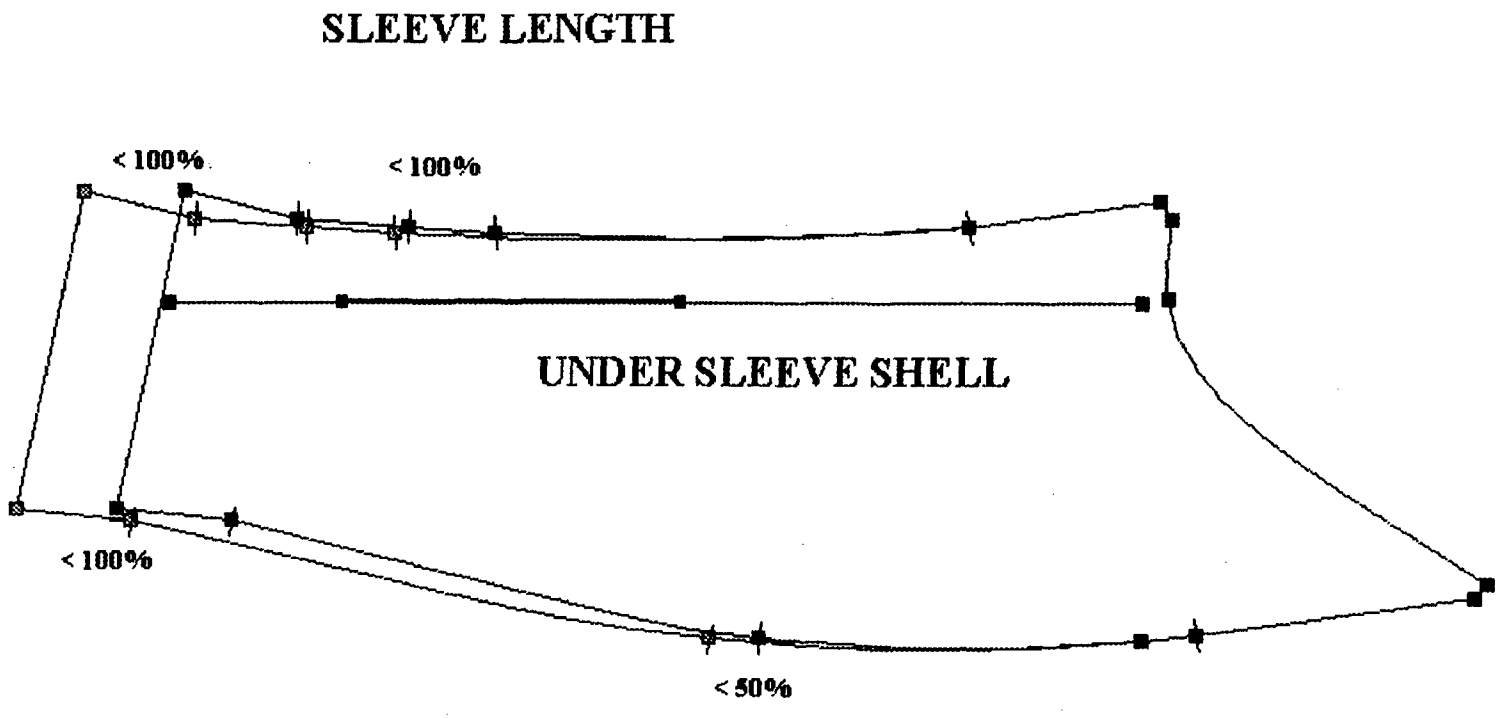
Under Sleeve

Top Sleeve

Under Sleeve Lining

Top Sleeve Lining

SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



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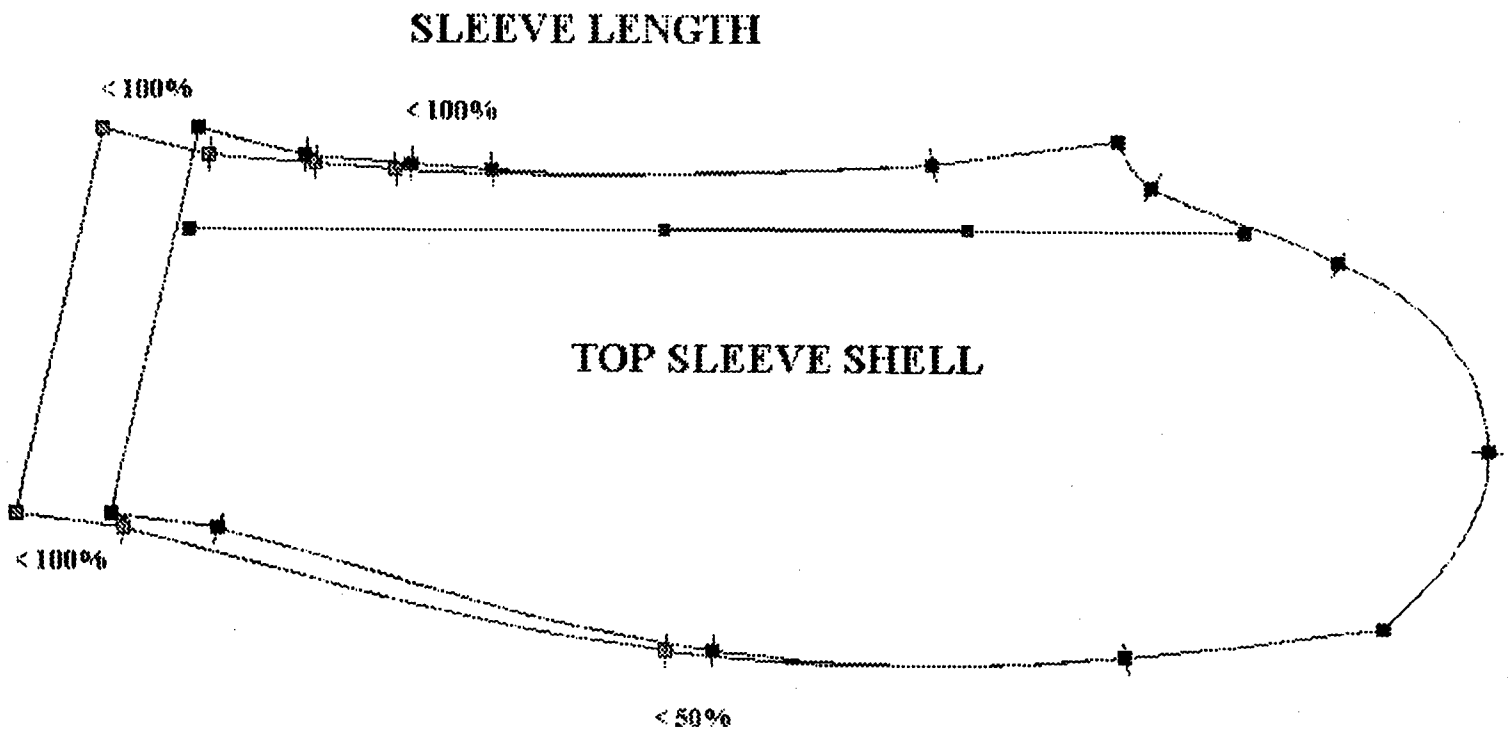

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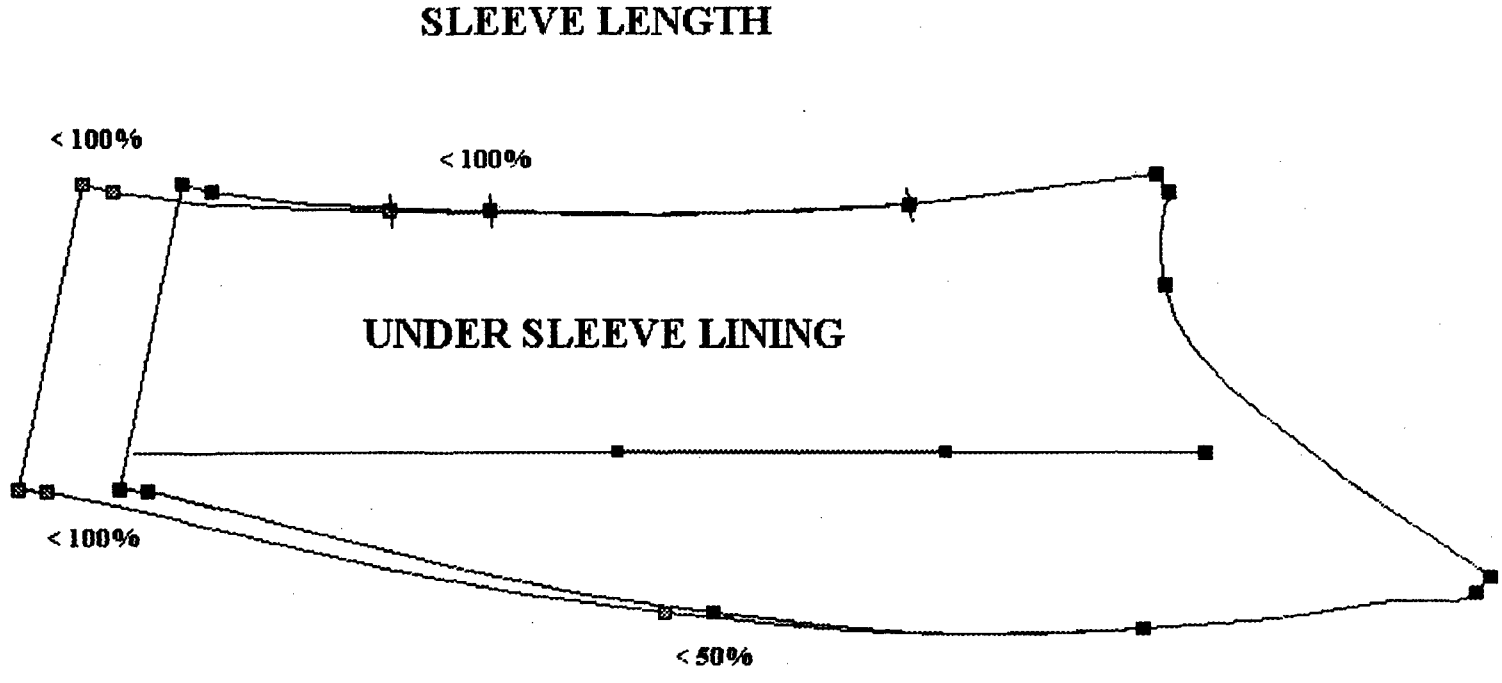

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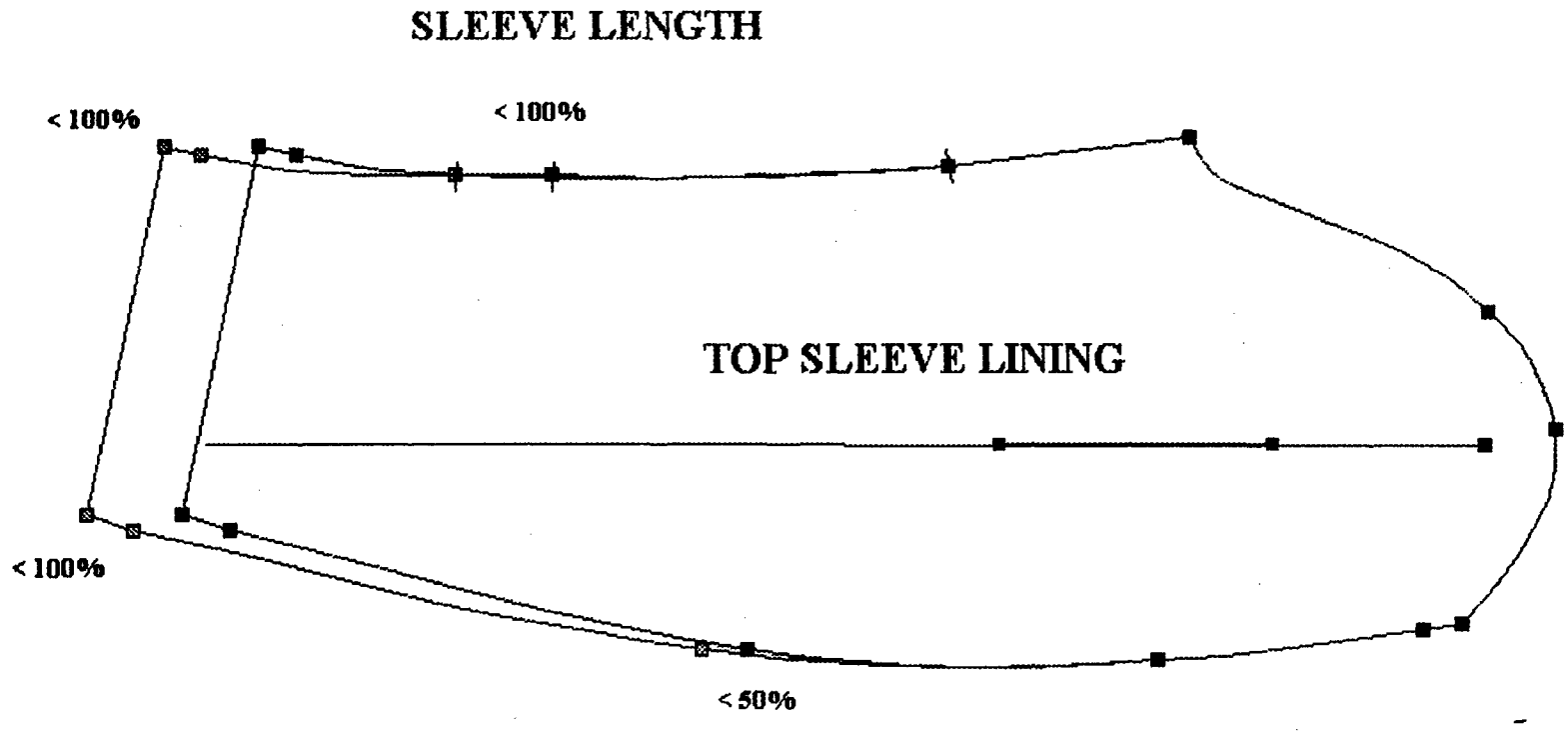


CENTER BACK LENGTH PATTERN ALTERATIONS

Front

Back

Side Body

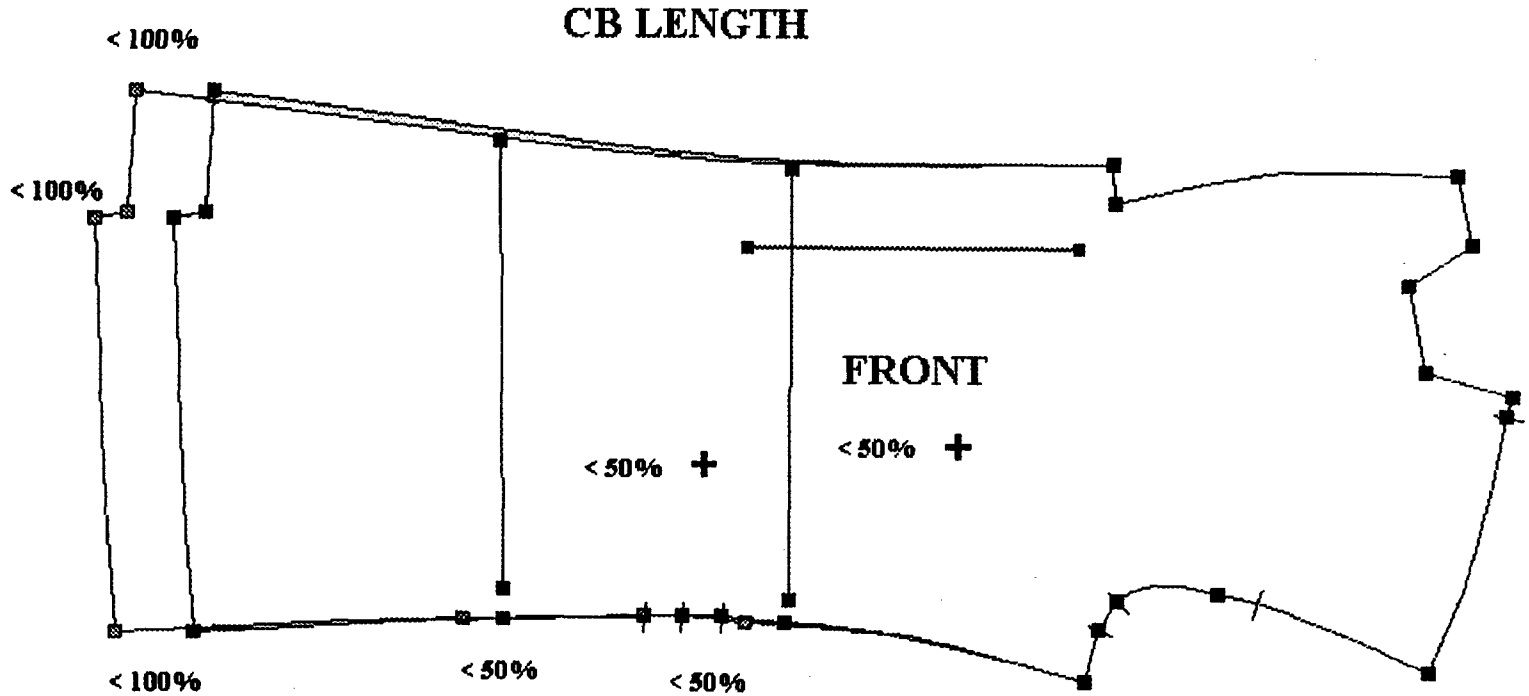
Front Facing

Front Lining

Side Body Lining

Back Vent

SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



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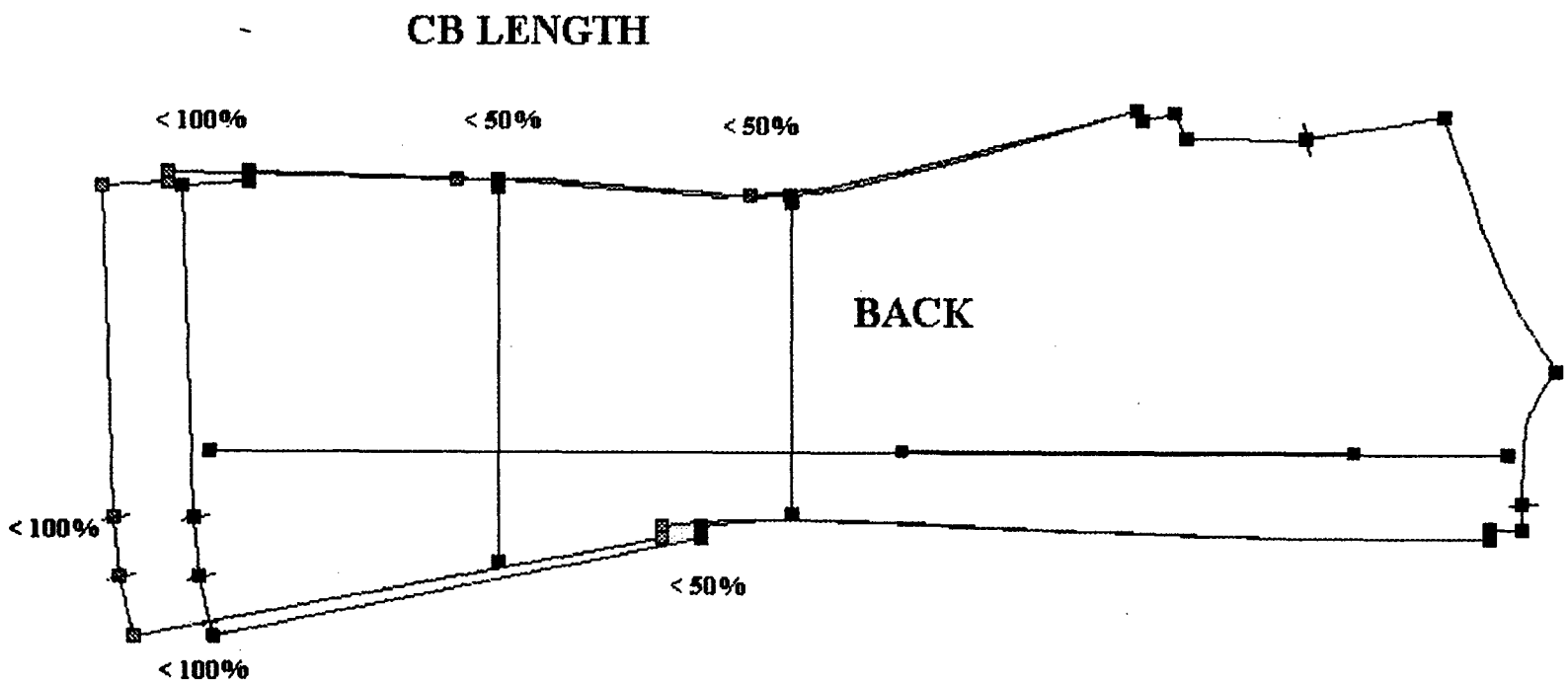

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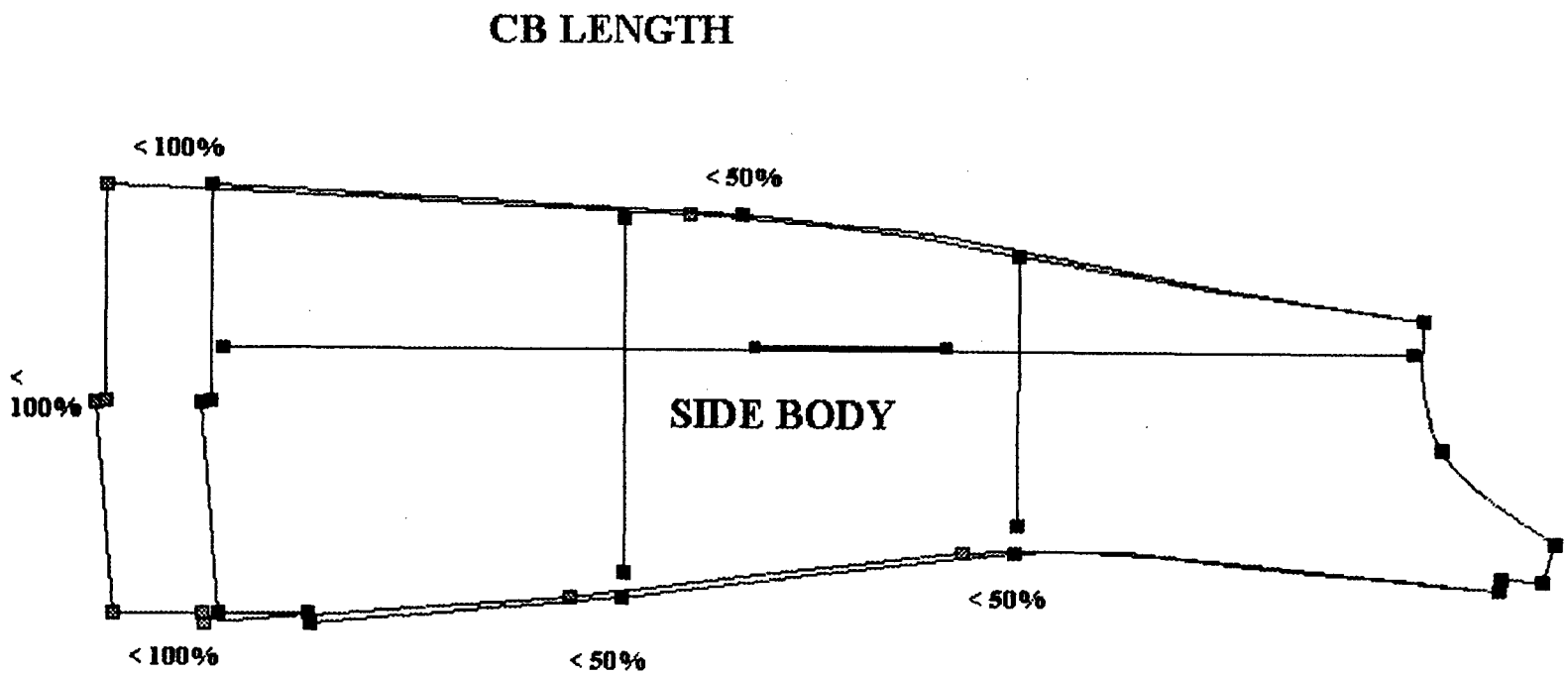

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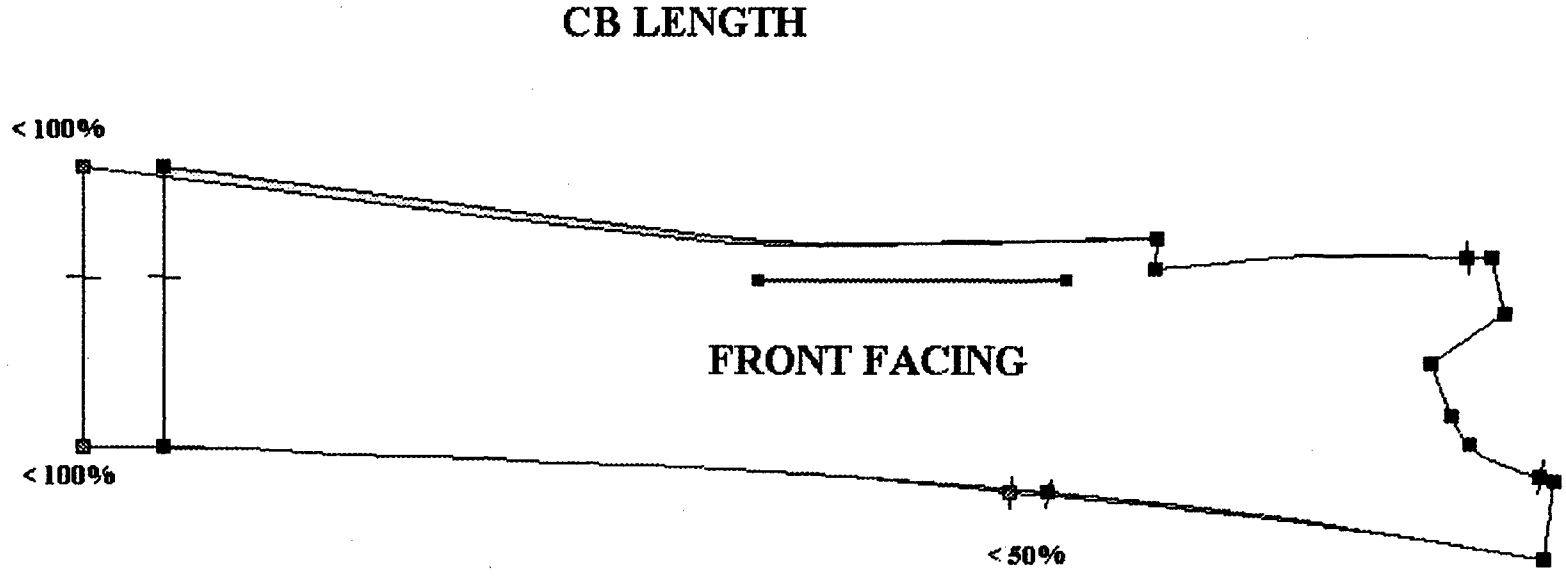

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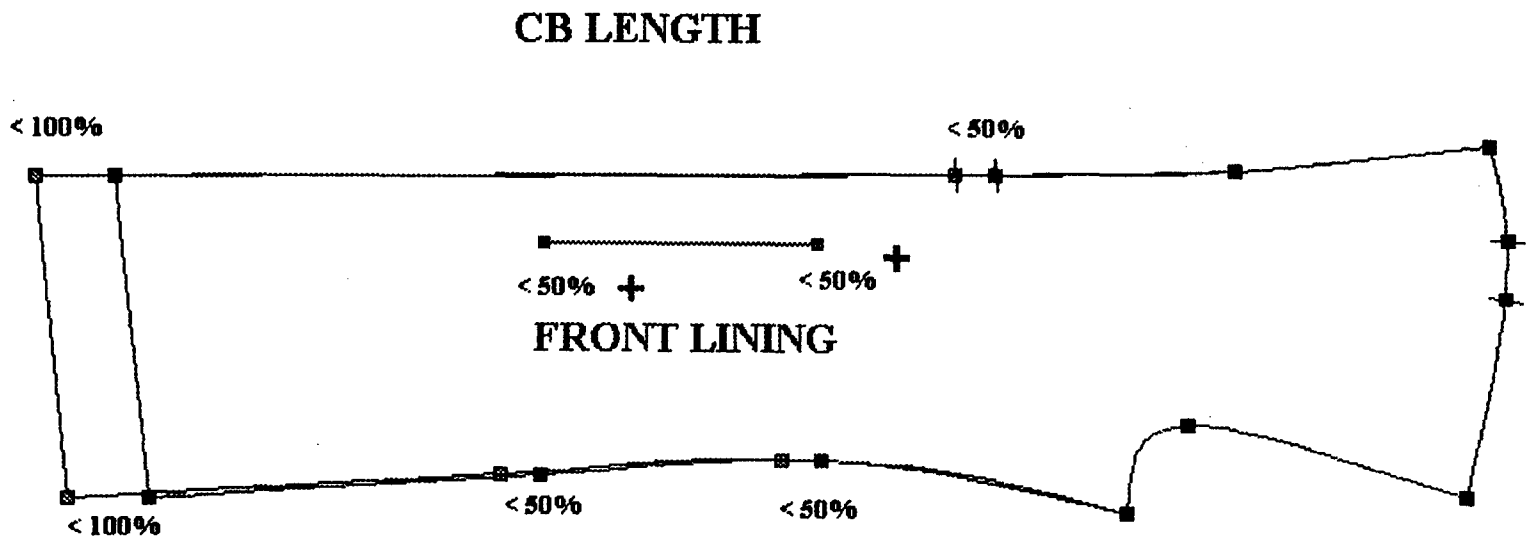

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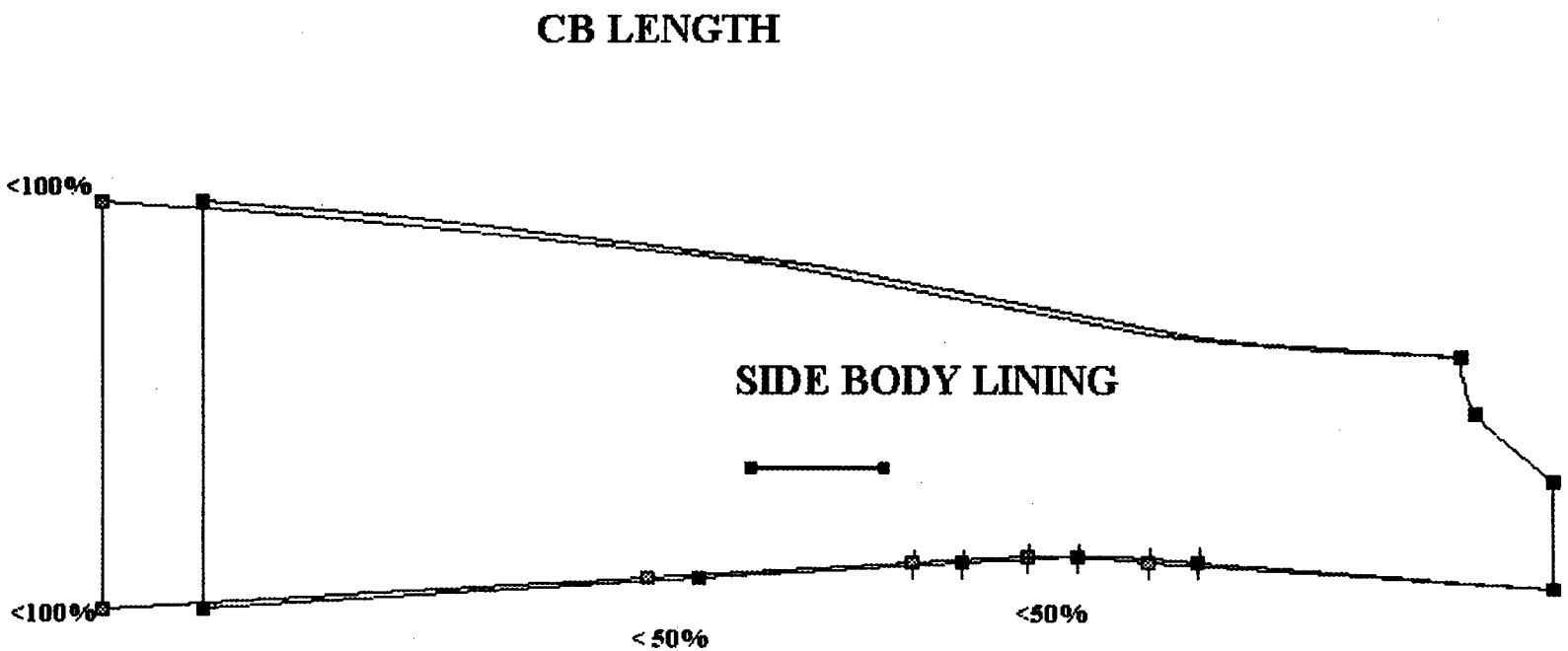

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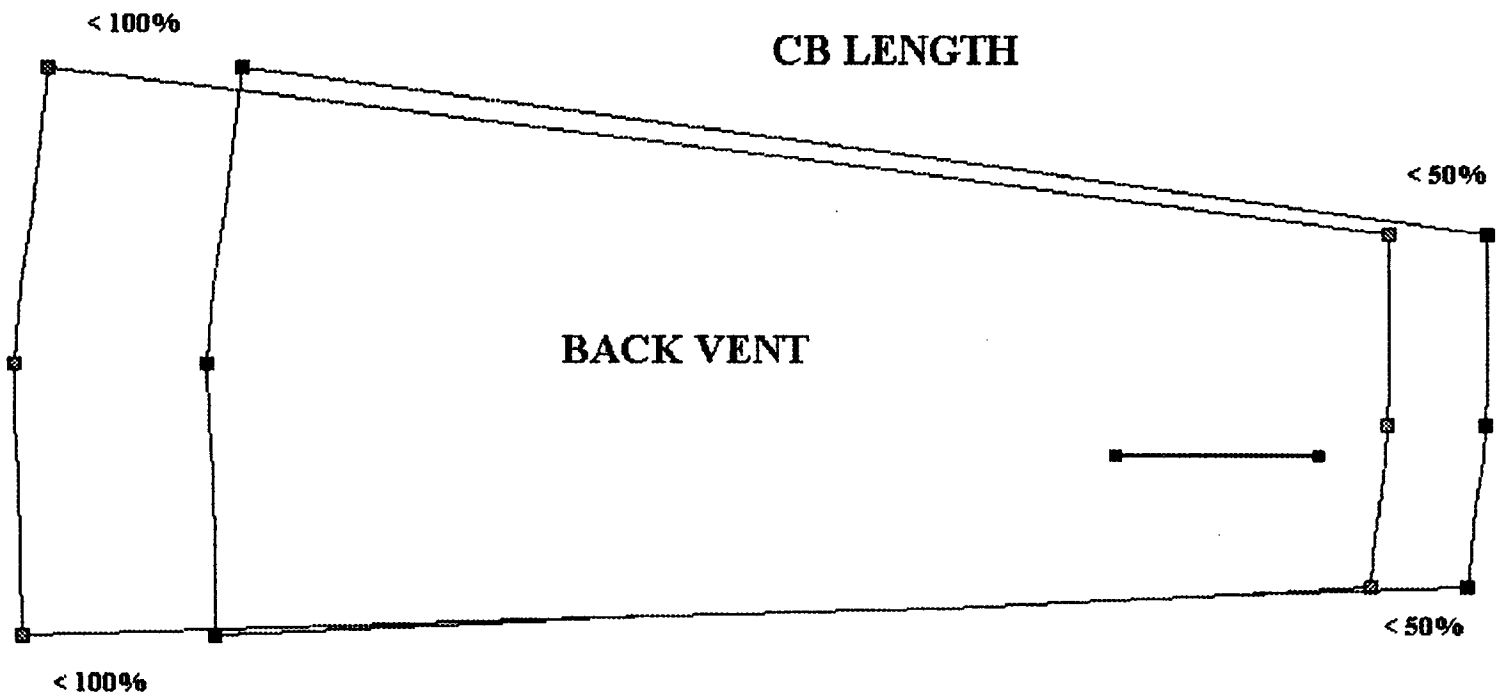


SLOPE SHOULDER PATTERN ALTERATIONS

Front

Back

Side Body

Front Lining

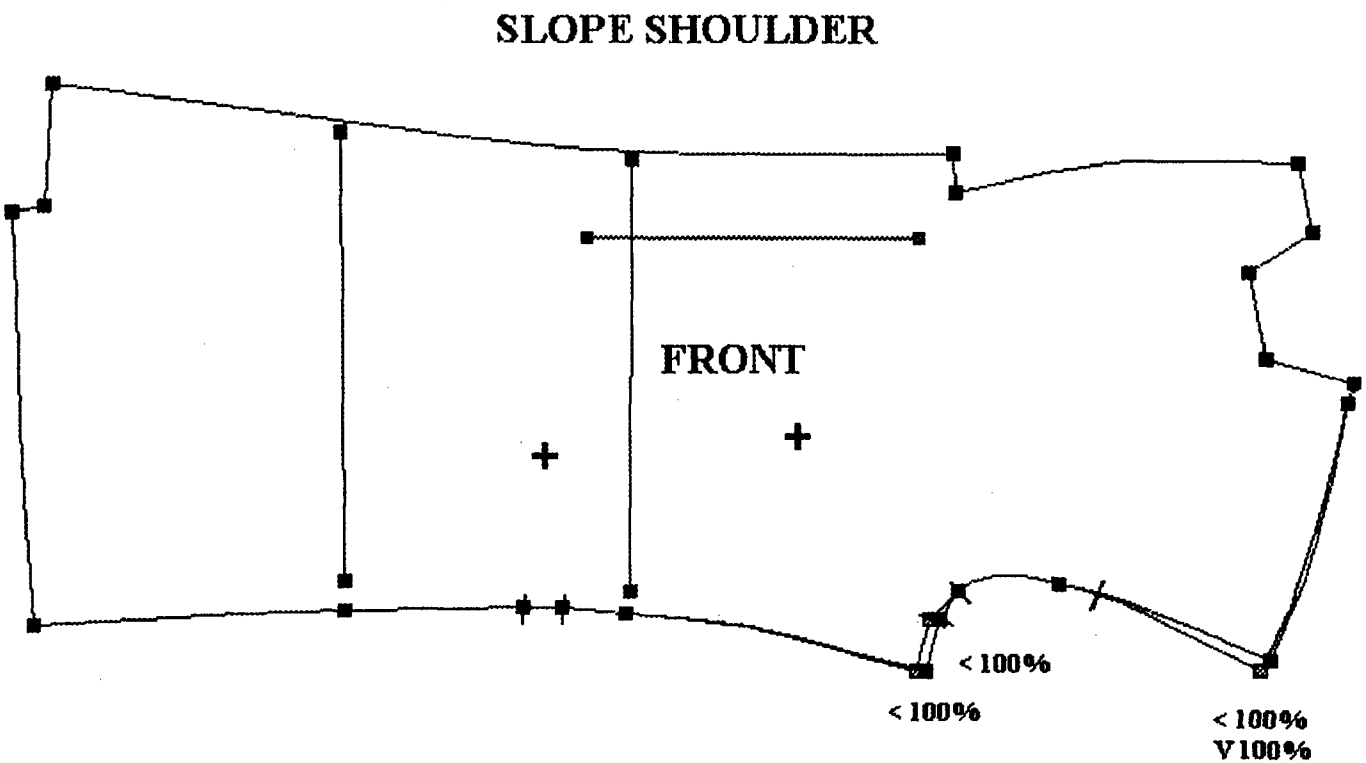
Front Facing

Side Body Lining

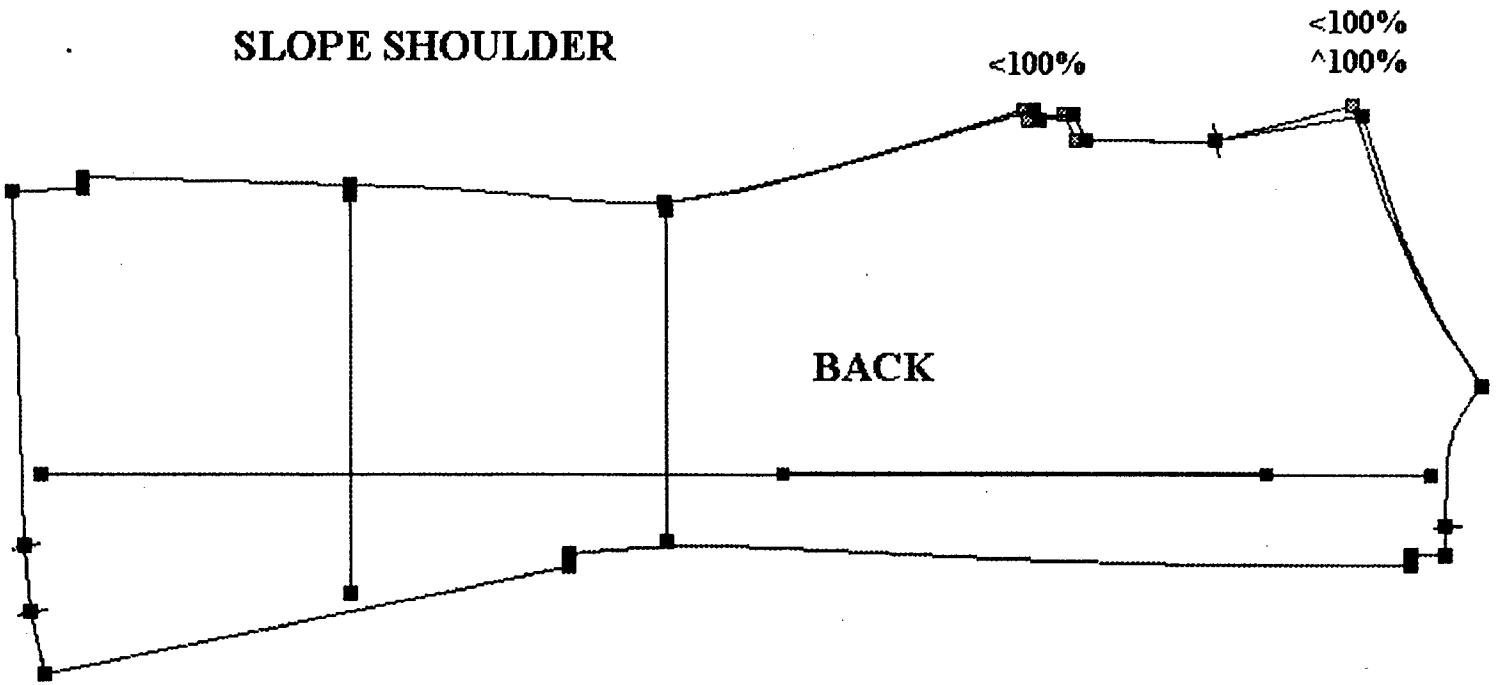
Back Yoke

Shoulder Loop

SPSU DDFG T1-P5 ALTERATION DISTRIBUTION

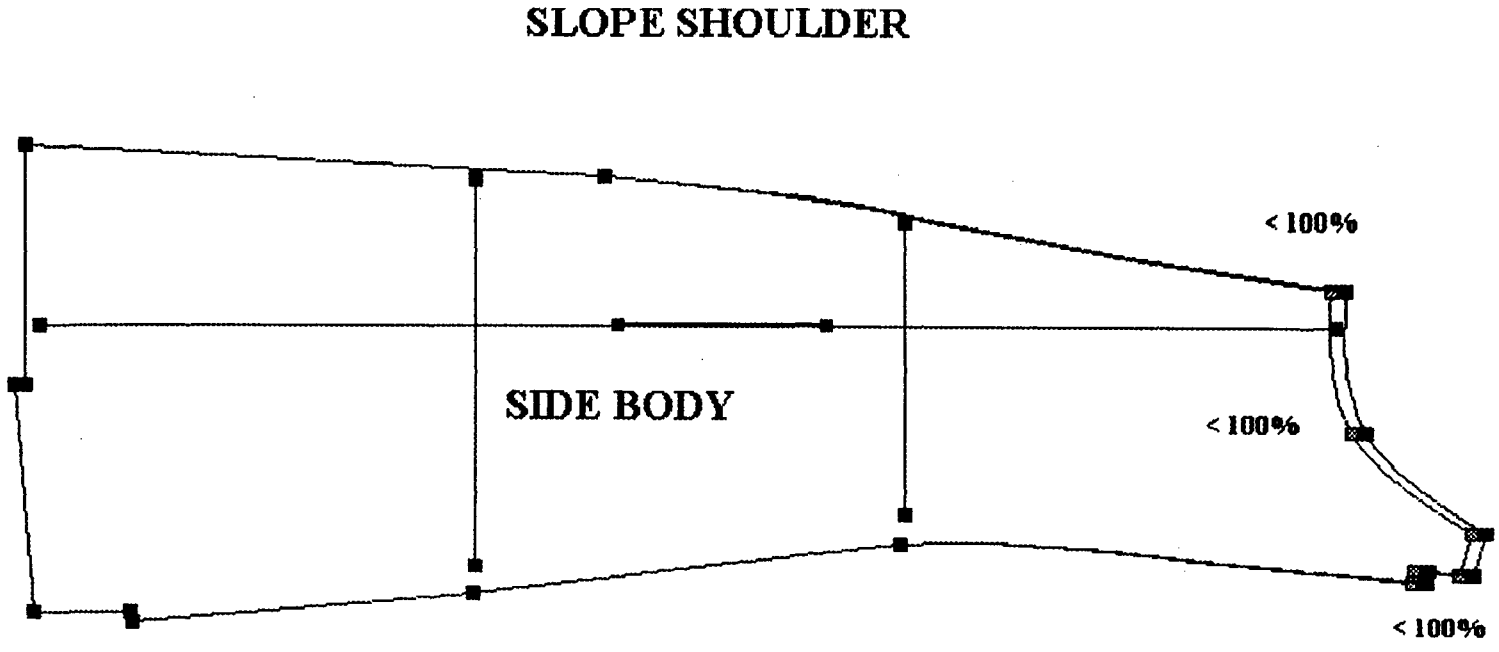


SPSU DDFG T1-P5 ALTERATION DISTRIBUTION

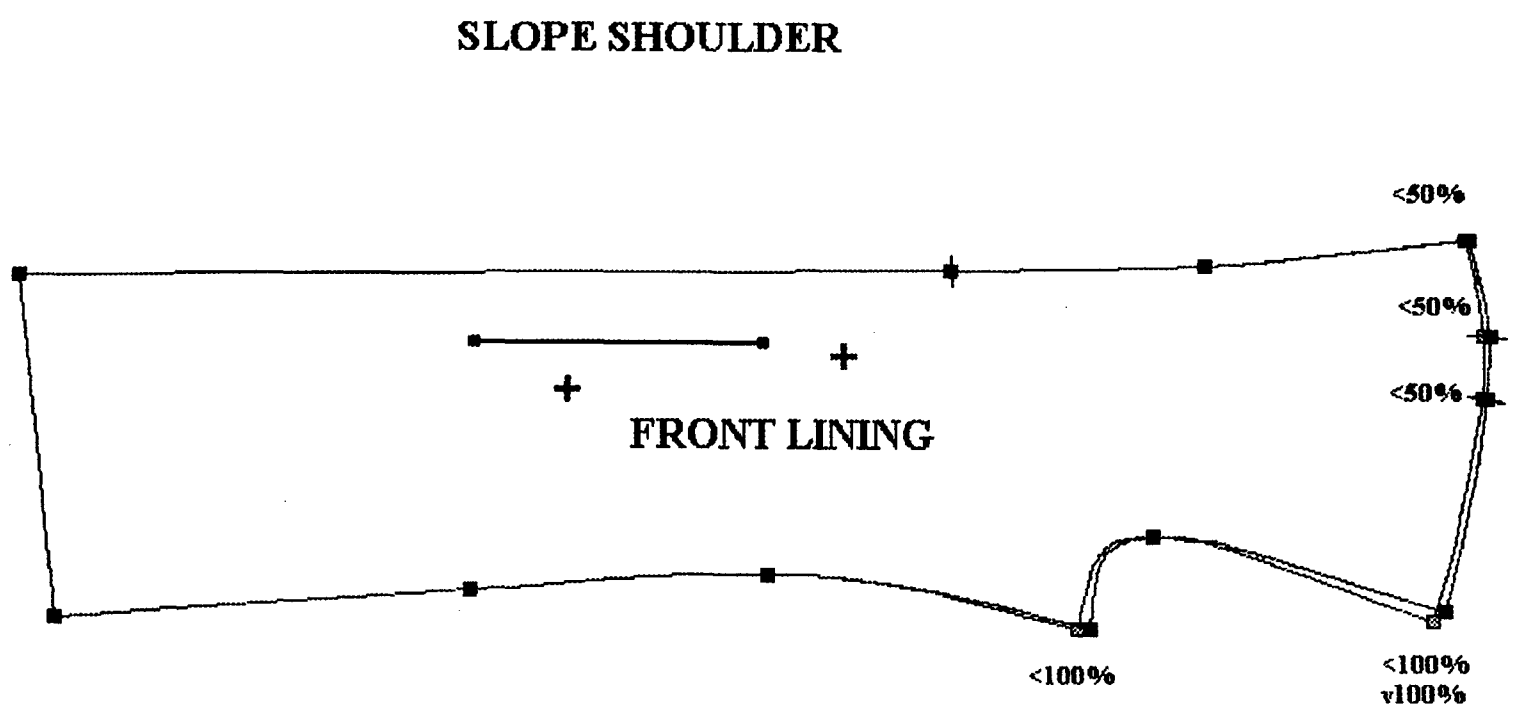


Appendix A10

SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



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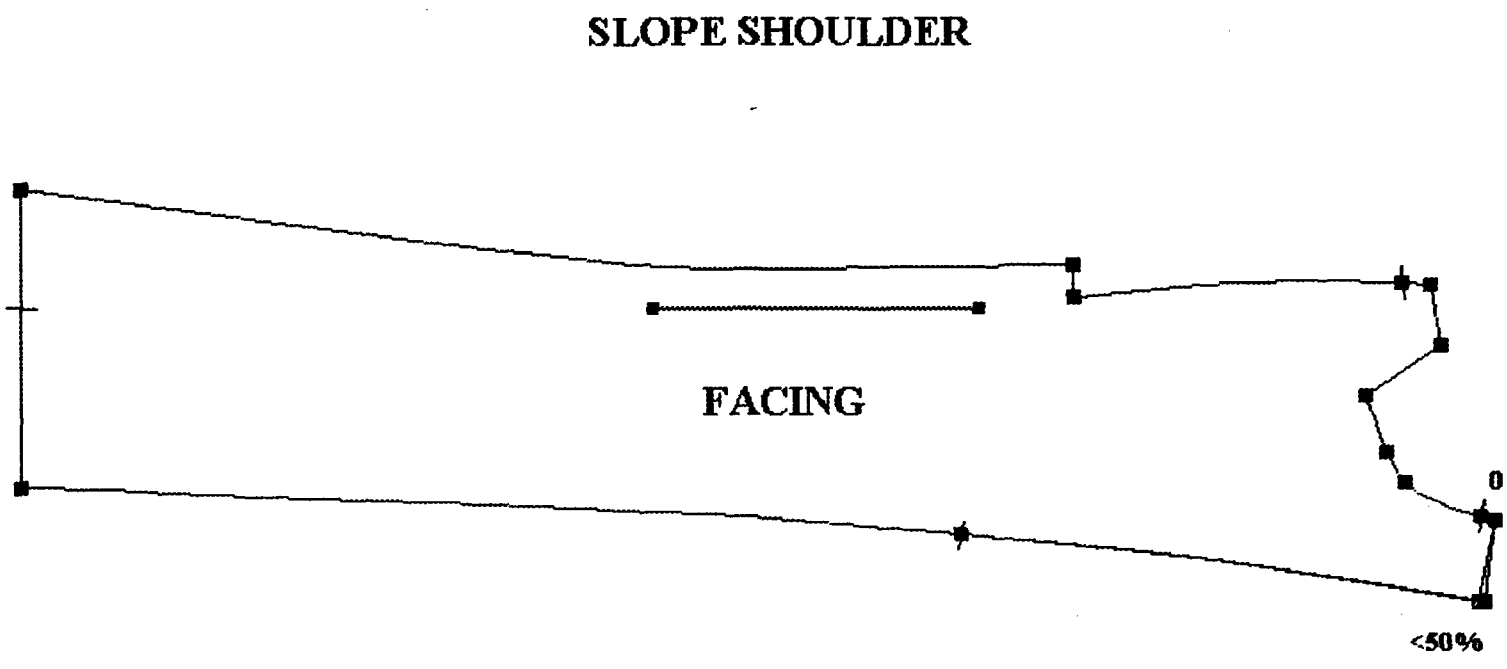

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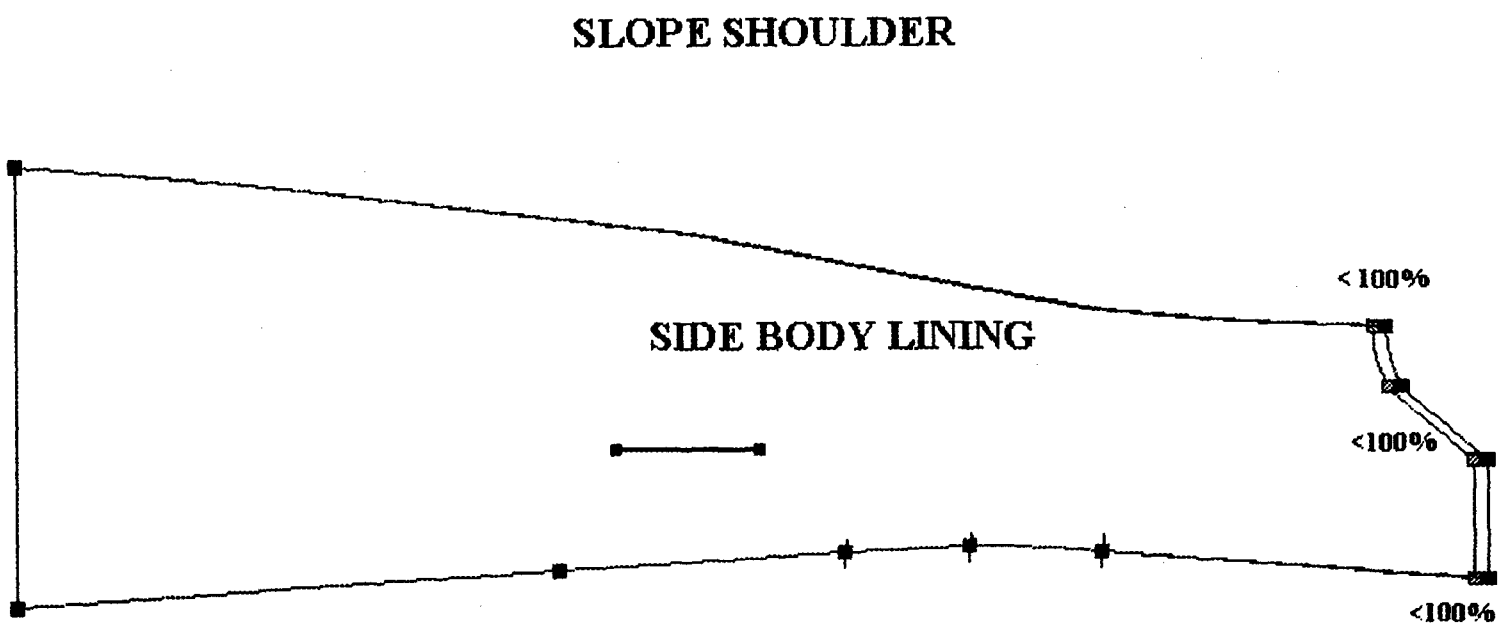

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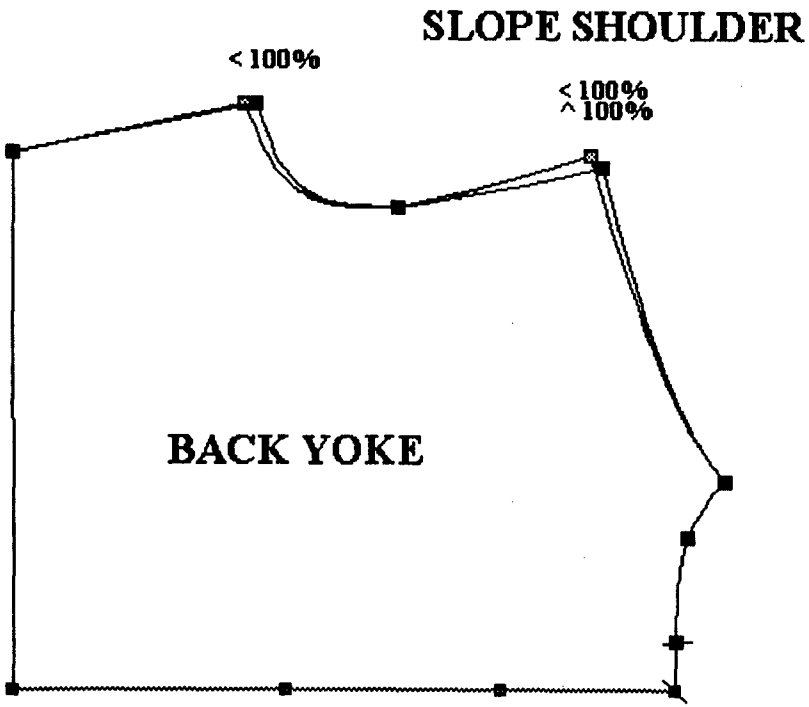

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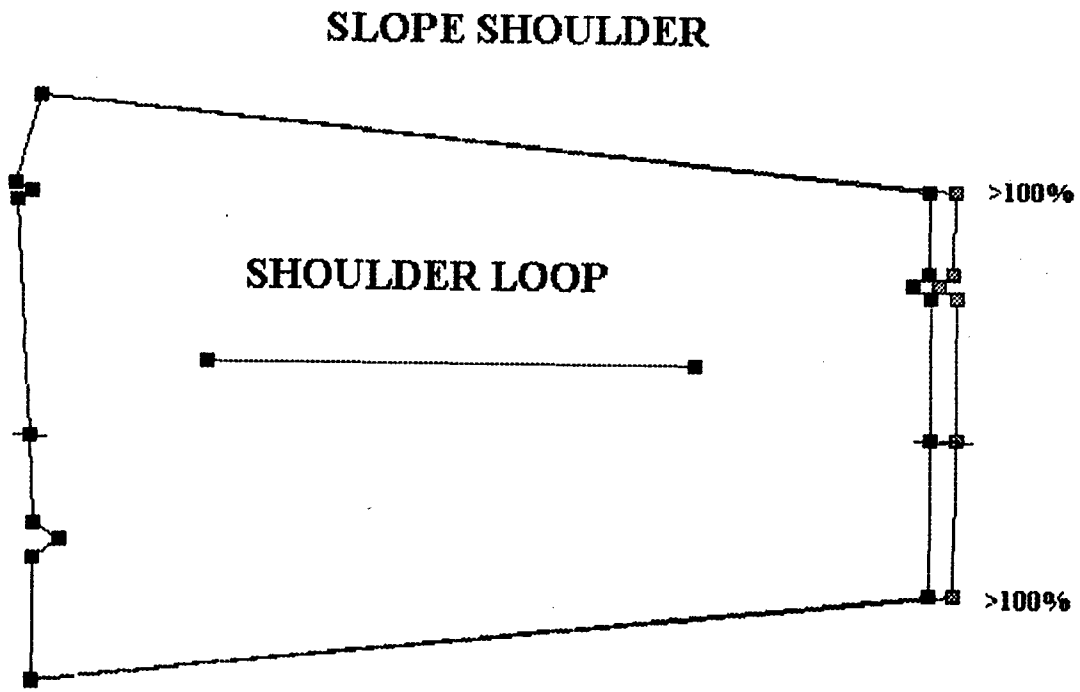


SQUARE SHOULDER PATTERN ALTERATIONS

Front

Back

Side Body

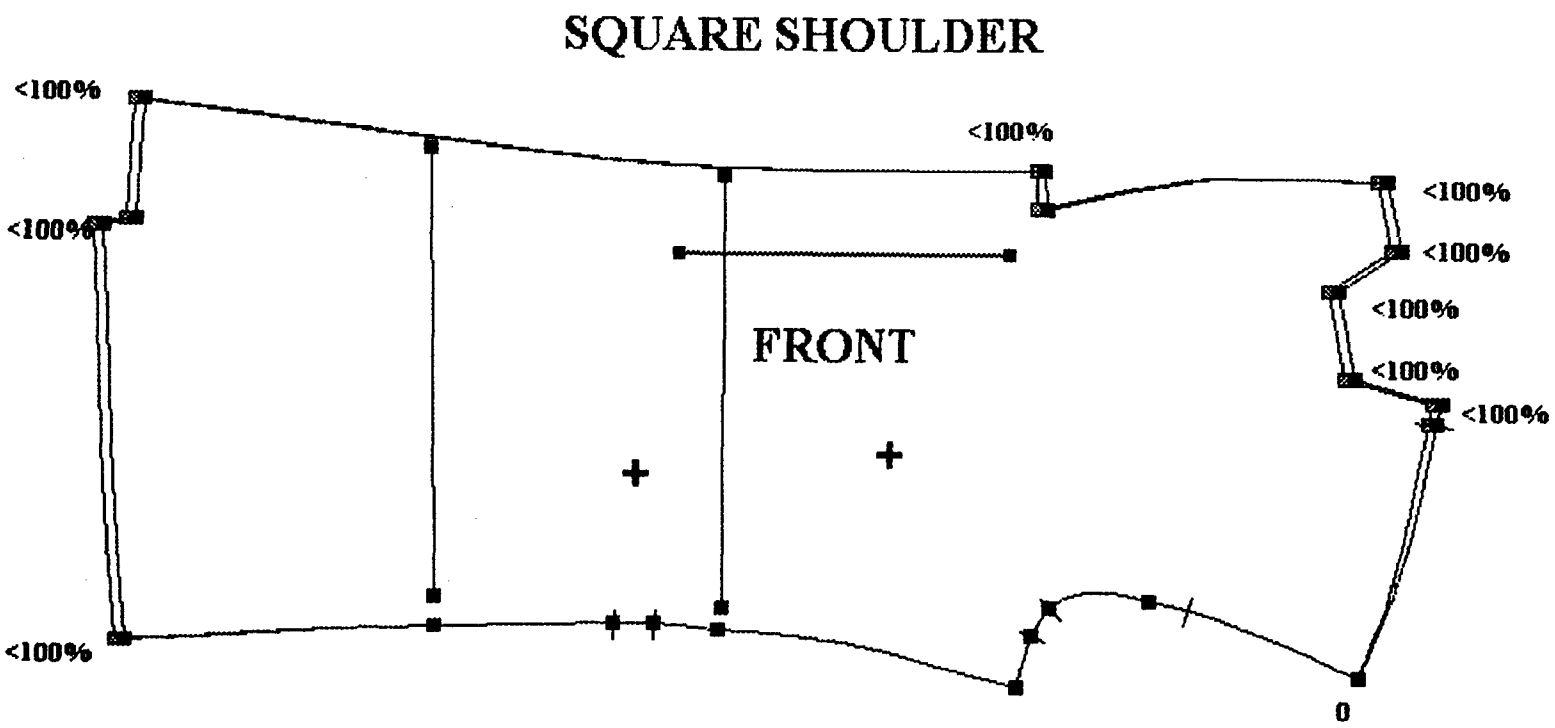
Front Lining

Front Facing

Back Yoke

Side Body Lining

SPSU DDFG T1-P5 ALTERATION DISTRIBUTION



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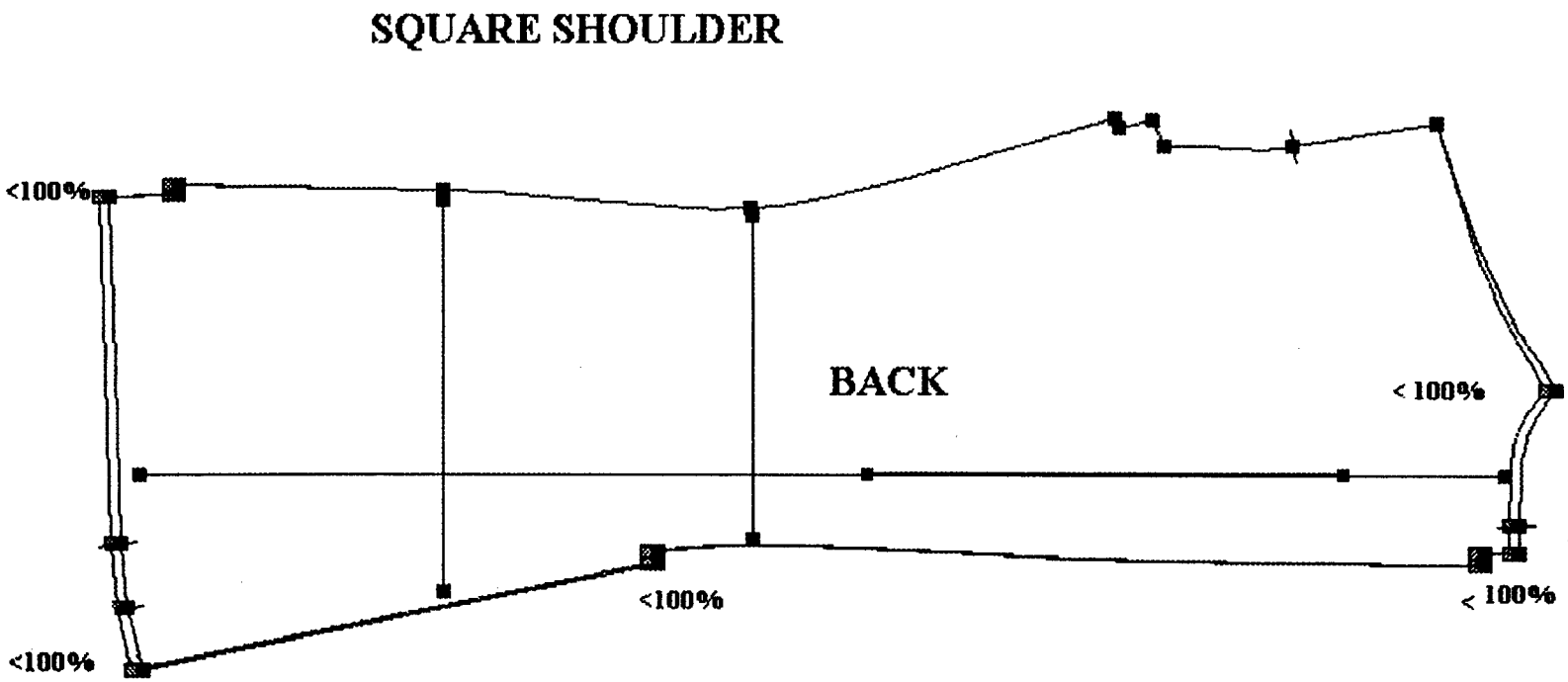

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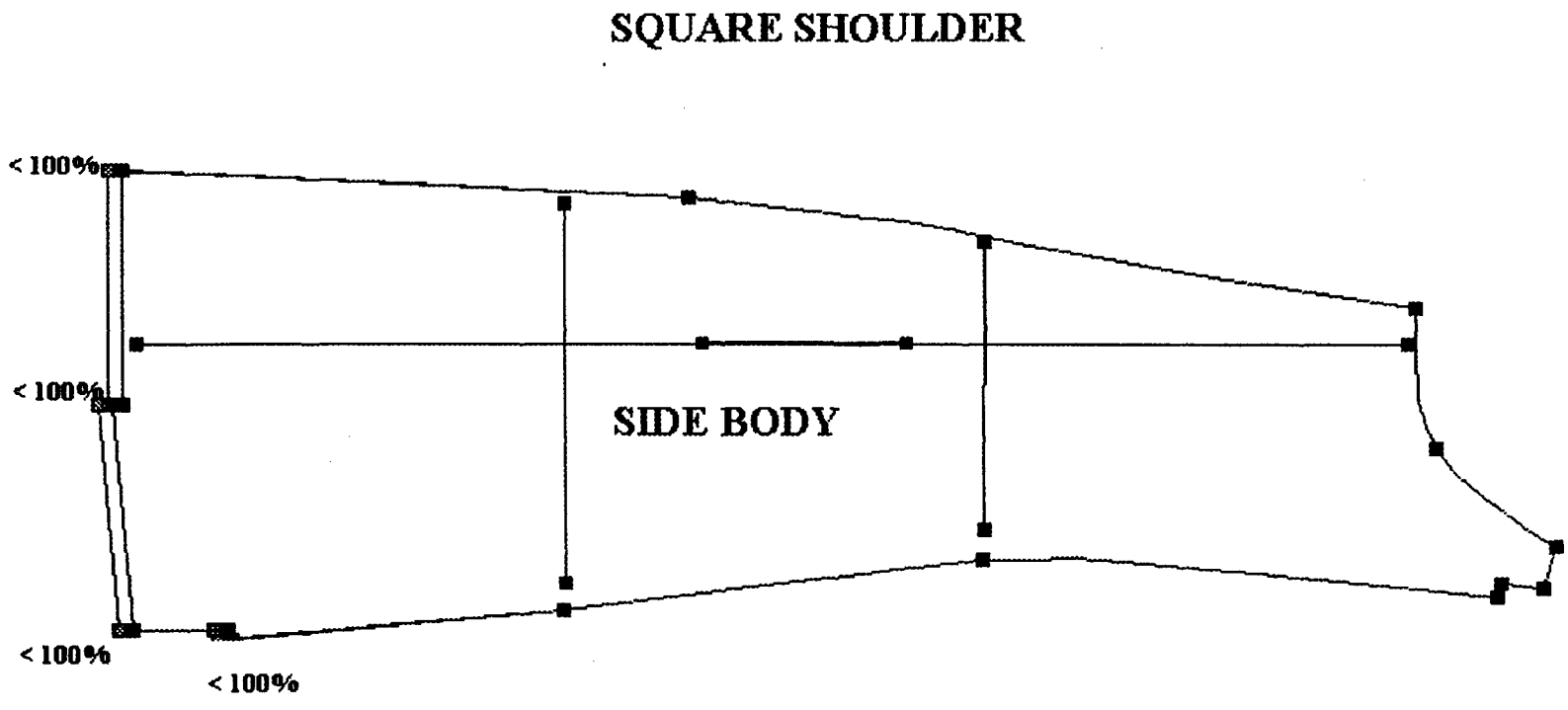
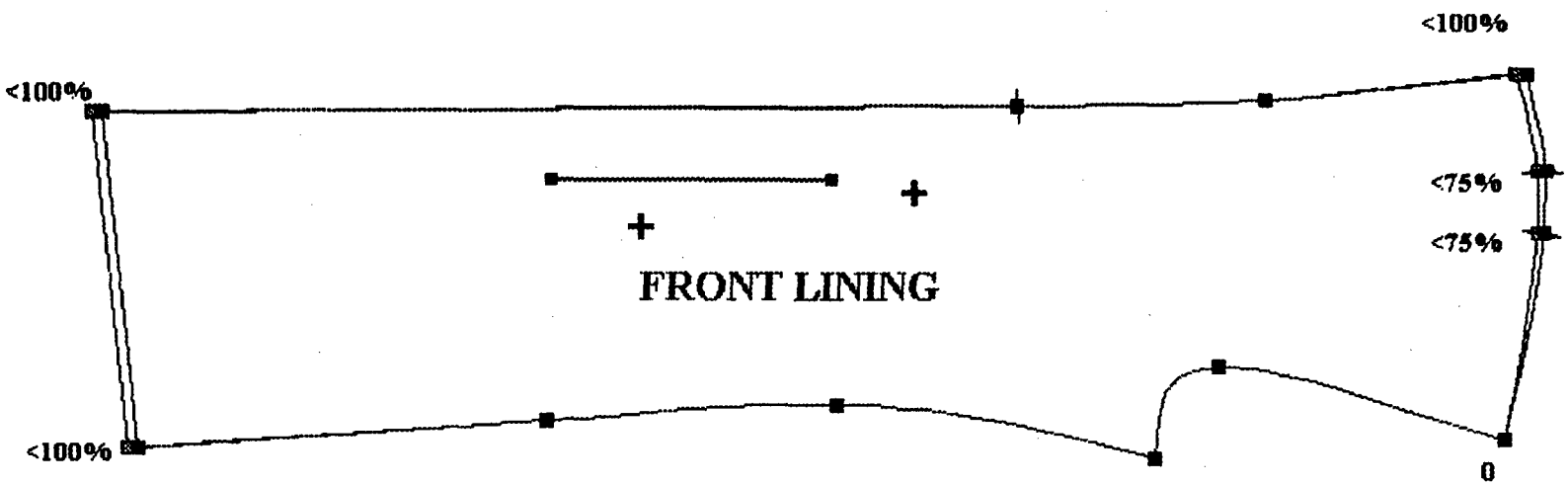


SPSU DDFG T1-P5 ALTERATION DISTRIBUTION

SQUARE SHOULDER



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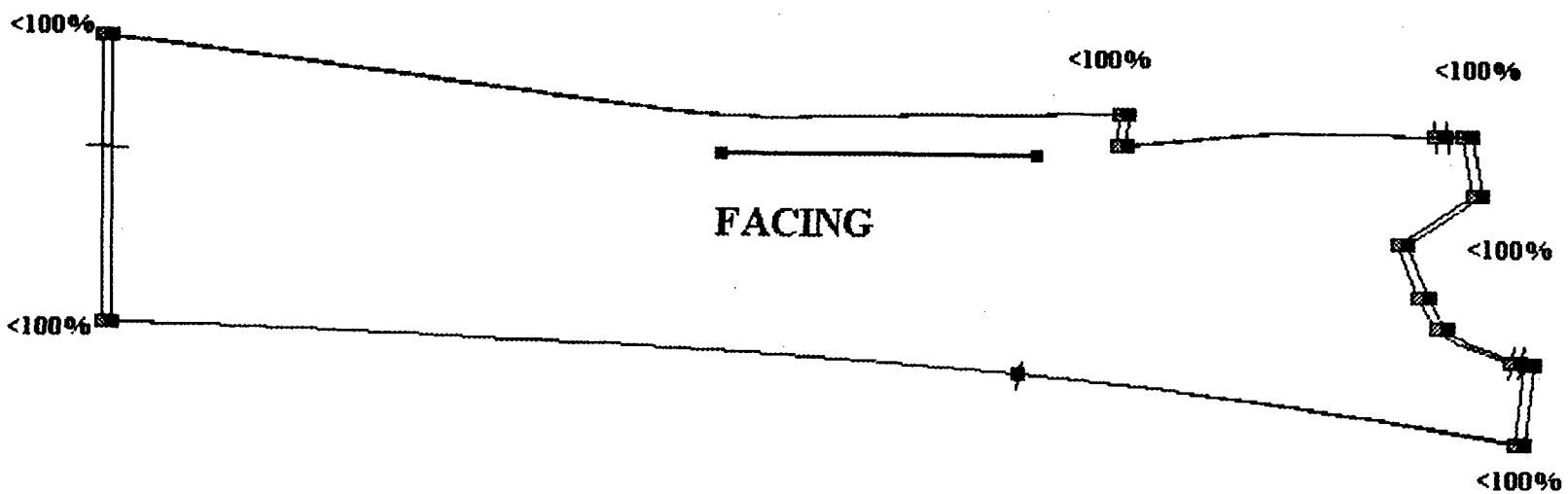
SQUARE SHOULDER



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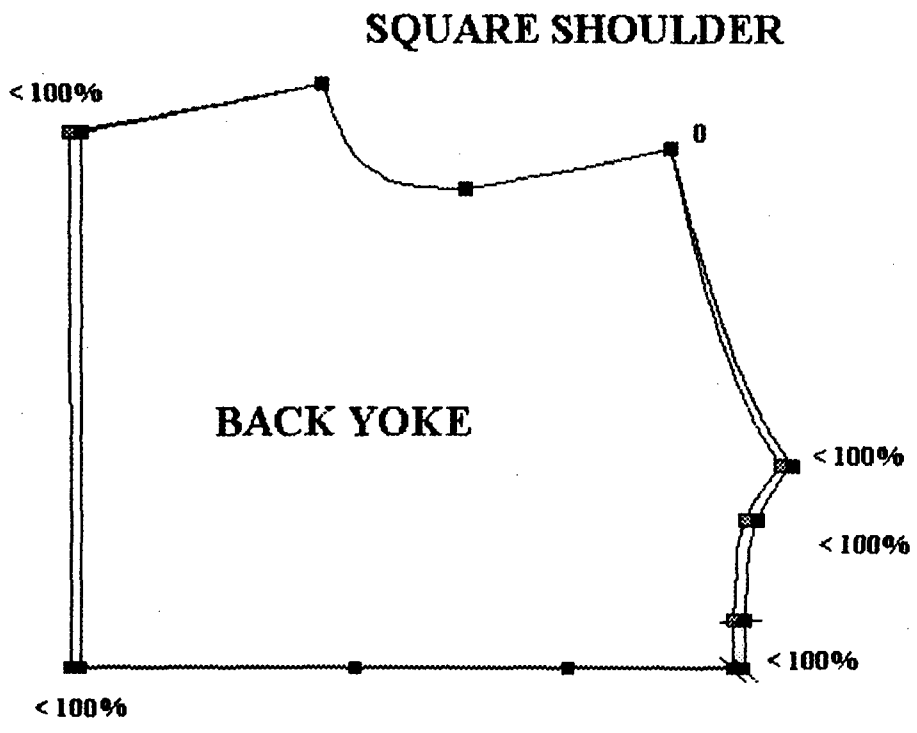

SPSU DDFG T1-P5 ALTERATION DISTRIBUTION

SQUARE SHOULDER