THE DEVELOPMENT OF NORMAL STITCHING TIMES FOR THE MANUFACTURE OF EMBROIDERED EMBLEMS

by

RAJU JAIKRISHINDAS MUKHI

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Approved by:

L. E. Grosh

Major Professor

DEDICATED TO

SHRI. J. P. VASWANI

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CHAPTER 1

INTRODUCTION

1.1. Introduction

Embroidery is the art of ornamental needlework, the embellishment, decoration or ornamentation of any fabric (8). Emboridery, unlike other branches of textile manufacture, is something added to a fabric to enhance its value. Embroidery may be used for many purposes: bath accessories, decorative items, draperies, emblems, formal and casual wear, upholstery, bedding and bed spreads, blazers, bridals, costumes, insignia, laces, night wear, and tablecloths, to mention a few.

The art of embroidery can be traced to the beginning of recorded history. Machine made embroidery can be traced to its early innovators, Carl F. Weisenthal (1775) and Josua Heilman (1828) but Franz Rittmeyer (1846) invented the first practical embroidery machine. Before this time all embroideries were hand made. The original invention has undergone many changes through the years.

There are two kinds of embroidery machines in use today:

1) Multi-head embroidery machines

2) Shuttle or 'schiffli' embroidery machines. ('Schiffli' in colloquial German means a small boat, after the shape of the shuttles used in these machines).

Multi-head embroidery machines are smaller than schiffli machines and may have from 3 to 16 vertical sewing heads working on individual frames in the horizontal plane. Schiffli machines have several hundred

needles working in the horizontal plane and one large frame which moves in the vertical plane. The multi-head embroidery machines work at 300-350 rpm as compared to 120-150 rpm for the schiffli machines. Manufacturers of multi-head sewing machines include Wurker, Marco, Gross and Zangs.

Within the shuttle or schiffli embroidery machines there are two types:

1) Saurer (Switzerland)

2) Plauen (Metalmeccanica and Comerio Ercole (Italy), Hitatchi-Seiki and Hiraoka (Japan) and Zangs (Germany)).

The Saurer embroidery machine differs from the Plauen machines in two principal ways: Saurer has a left-hand threading system (the thread enters the needle from the right) and uses a different punched card control system not interchangeable with any other type of machine.

Both multi-head and schiffli machines are automatic and use punched cards to control the frame movement. Three card control systems are in use today. The Saurer card system is used on Saurer machines, the Zangs card system on the Plauen machines and the Wurker card system on multi-head embroidery machines.

The early embroidery machines were equipped with pantographs. A stitcher would trace the stitches on a pattern and the frame would respond in direct proportion to these movements. Pantographs have given way to automats over the years. An automat is a unit that reads the control card and translates the holes on the card into the movements of the frame and various other machine functions. A survey taken in 1919

showed that, of the 2000 schiffli machines in existence, 2/3 were equipped with pantographs and the rest with automats. A 1960 survey showed 4.5% of the 1530 machines as being pantograph machines (8). Pantograph machines are slow and require an additional person to operate them. Until World War II the embroidery trade was a cottage type industry, manned almost entirely with family labor. During the war, embroidery manufacturers saw some of their most profitable years. In 1947, entrepreneurs began expanding the schiffli industry and converted it from a home industry to a thriving business activity.

Most of the literature available on embroidery-making deals with hand-made embroideries. This is a different class of embroideries and is outside the scope of this research. The only published work dealing with the history and development of machine-made embroideries that has come to the author's notice is Schneider's work (8) published in 1968. Since then, until the present time, no work has appeared in the literature. Cottage type industries are usually labor-intensive in nature. Embroidery making is no exception. The embroidery process has a low ratio of machine running time to total time required to manufacture a design, and method studies could provide significant savings in manufacture.

The material that follows deals with the manufacture of emblems on the embroidery machine. The first emblems were made on the embroidery machine around 1900. Since then they have gained popularity and are now commonplace. Emblems are used as symbols of distinction by organizations. They are worn by people to show that they belong, to let others know about their job or function, or as achievement badges as members of a

group or organization.

The motivation for this research is the result of a summer's work with an emblem manufacturer. The author has had training with Metalmeccanica, Italy, and consequently, the analyses will refer to the Plauen class of machines. Machines are available in 10, 12, 15, and 16.4 yard lengths. As most of the machines used for emblem manufacture are capable of embroidering only 10 yard lengths of cloth, these have been used in the study. Similar analyses for other types and lengths of machines could be made.

1.2. Statement of the problem

While bidding on prospective jobs, an estimator must have an idea of manufacturing costs. A scheme is needed to enable an inexperienced estimator to make a good estimate of manufacturing costs even before the expensive task of making a punched card is undertaken. The apparent scarcity of work dealing with pricing policies instigated research into two principal areas:

1) The development of normal times for various operations in the emblem manufacturing process with a view of ultimately setting standard manufacturing costs. The Methods-Time-Measurement (MTM) procedure will be used to break down all the operations required for the emblem manufacturing process into the basic (elemental) motions required to perform the operations. Each elemental motion will be assigned a predetermined time standard from MTM or equivalent tables. Each elemental time is determined by the nature of the elemental motion and the conditions under which it is

performed (6) (Appendix C). A complete synthesis of the embroidery process with validations forms the core of this study. A micromotion film, made during an in-plant study, is the data source for analysis of operations constituting 80% of the manufacturing time. This film was analyzed for the motion content of the operations it represents and the results were compared to the synthesized times. Emphasis will always be on the method of manufacture; that is, the motions and sequence of motions required to perform a function.

2) The development of a mathematical model for estimating the stitch count, which in turn will be used to estimate the machine running time. There is no accepted procedure in the industry for estimating the stitch count. Actual counting of in-being samples consumes many man-hours and gives an estimate perhaps to within 20% of the true stitch count. In a great number of cases in-being samples are not available and an estimator must work with a sketch of the logotype to be embroidered. The proposed model should give an estimate as good as, or better than actual counting, but utilizing the artist's sketch. The model should be methodical and give quick, dependable results for estimation purposes.

CHAPTER 2

THE DEVELOPMENT OF STANDARDS

2.1. What is a standard:

2.1.1. Definition

A standard under modern scientific management is a carefully thought out method of performing a task, or a carefully drawn out specification covering an implement (3). The standard method for performing any task is the best method that can be devised at the time the standard is drawn. The best economic method is usually composed of motions which result in a minimum time for performing the task (1).

Physical standards of manufacture relate to (1) specification of the product and materials, (2) method of manufacture, and (3) equipment to be used. This study assumes that the standards for product and materials as well as the standards for the equipment have been established. The objective of this research is to develop a basis for establishing labor standards for the emblem manufacturing process.

2.1.2. How a standard is built

The steps involved in setting labor standards for an emblem are as follows:

2.1.2. (a) The methods engineer subdivides the manufacturing process into operations with clearly defined terminal points. For the emblem manufacturing process this starts with the goods cutting operation and continues through the removal of finished goods from the machine.

2.1.2. (b) Secondly, normal times for each operation in the sequence are determined. There are three methods by which normal times may be set (3).

(i) By time study: This involves the listing of elements of an operation, the order in which they occur, timing a trained "average" worker as he performs the given operation by the specified method and listing the times. Normal times are evolved by eliminating the outliers and averaging the observed time data. See (4).

(ii) By formulae: Predetermined, standardized motion-time systems have been developed which relate the elemental motions required to perform a series of operations to predetermined times for these motions. Methods-Time-Measurement (MTM) and Universal Standard Data (USD) are two such systems (6). The use of formulae involves identifying the elemental motions that compose the operations and combining the elements in proper sequence to determine the normal times of the operation.

(iii) By comparison: This method entails comparing a new product with an existing product with similar labor operations.

2.1.2. (c) The third step in setting labor standards is the application of allowances to the normal times established by one of the preceding methods. The standard time is then applied to the applicable labor rate to obtain a standard piece rate. The setting of actual standard times and piece rates will not be considered in this research.

2.1.3. The purposes of setting standards

One purpose, among others, of this research is to provide reliable estimates of normal times which are required to set time standards. The purposes of setting standards are:

(i) To systematically study the manufacturing process in order to secure economies in manufacture.

(ii) Where selling prices must be set in advance of manufacturing an item, to make it possible to estimate costs. In emblem manufacture selling prices must be set before production begins. Emblem manufacture is categorically a custom operation, and standard costs are of considerable use to the estimating department as a basis for bidding on jobs. This is the application of primary interest in this study.

(iii) To measure operating performance. Discrepancies between actual and standard times may be used to signal poor labor or machine utilization.

(iv) To value inventory. Standard costs, once set should remain constant for relatively long periods. They produce the same standard costs for physically identical products whereas actual costs may differ. The use of standard costs involves less clerical work in inventory estimation.

2.2. The manufacturing process

The technical features of the machine are listed in Table 2.1. The working of the embroidery machine will be described, followed by the process analyses required to set standards.

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Figure 2.1 shows a front view of the embroidery machine. The automat (a) is the heart of the machine. It houses the card reading mechanism (b), horizontal and vertical locks for the frame (c) and (d) and horizontal and vertical handwheels to move the frame manually (e) and (f). Also mounted on the automat is a hand lever (g) which enables hand stitches to be made when the machine is stopped. The automat reads a long punched card that controls the machine, called a "jacquard" (Figure 2.2.) and translates the punched holes into movements of the frame (h) and various controls. The terms "jacquard", "tape", or "pattern", may be used interchangeably to describe the punching made for use on the automat of the embroidery machine. The frame is constructed of aluminum alloy and is extremely well balanced by the spring at the machine stand (j) and various steel belts. The machine can be thought of as being divided into two identical halves; the top bank (k) and the bottom bank (l). Hence, two 10-yard lengths of cloth can be embroidered at one time. Each length of cloth is mounted on two rollers (m). Only the top roller of the top bank is visible in the picture. The cloth is tacked to a sharp comb along its length on the top and bottom rollers. These rollers may be tightened or loosened by operating a ratchet at the ends. To secure the cloth along its width, side combs (n) are provided at both ends. The stitching mechanism is mounted on foundation pillars (p) and walls (q). Spool holders house spools on the top and bottom banks (r). The yarn is threaded around the emery rollers (s) (to avoid slippage), under the small brass rod and over the large brass rod, to give it tension while the stitch is being

LEGEND

A Automat

B Card reading mechanism

C Horizontal frame lock

D Vertical frame lock

E Vertical handwheel

F Horizontal handwheel

G Hand stitching lever

H Frame

J Machine stand

K Top bank

L Bottom bank

M Goods roller

N Side combs

P Foundation pillars

Q Foundation walls

R Spool holders

S Emery roller

T Benches

U Starting lever

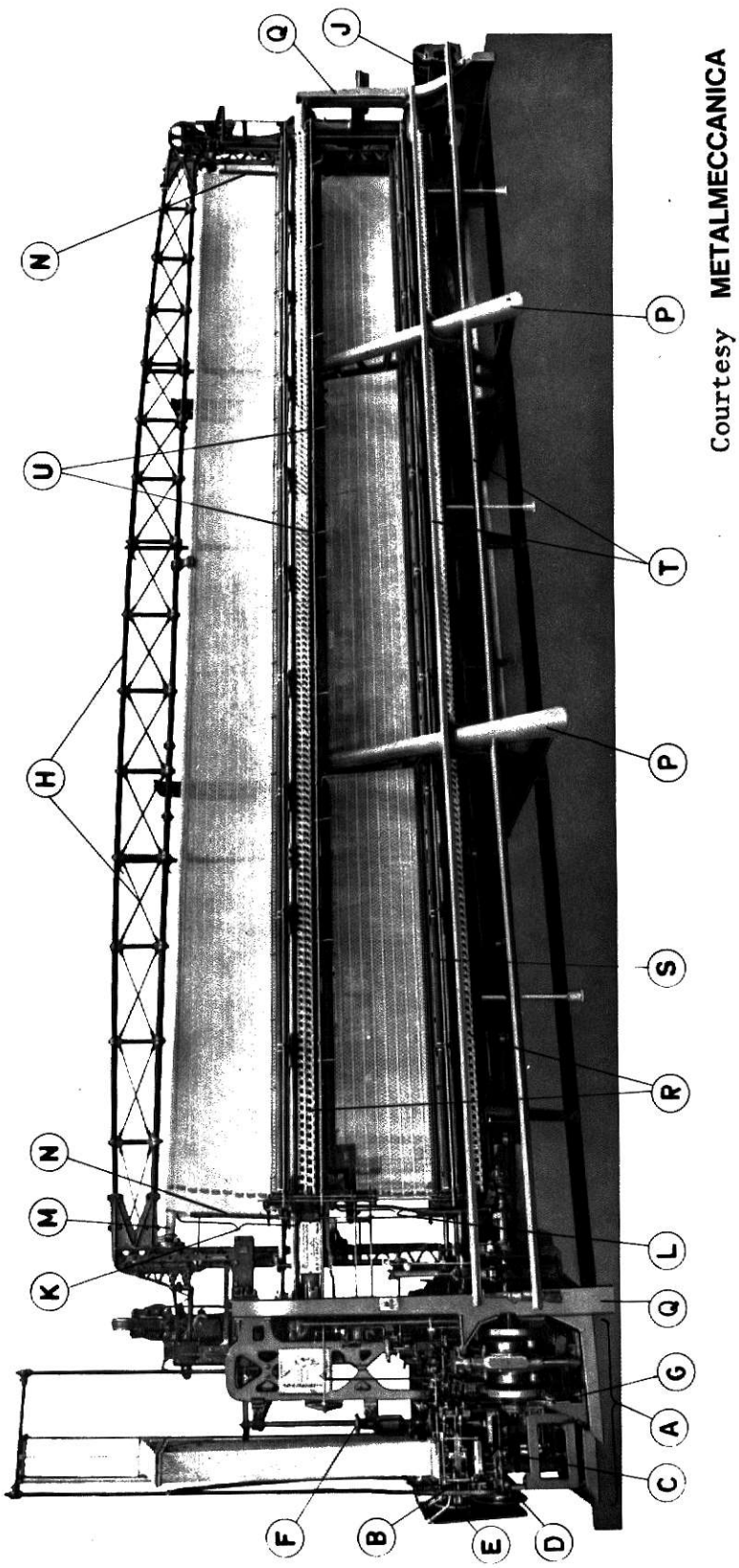

Figure 2.1 Front view of an embroidery machine

Table 2.1

Technical Data for the Embroidery Machine.

Specification	Value
Working speed	120 rpm.
Embroidery height	24"
Embroidery length	30 feet
Number of needles in 4/4	682
Shuttle	No. 4
Yarn content of bobbin (76/2)	165 yards
Diameter of (yarn) spool	2"
Diameter of empty cloth roller	3"
Capacity of driving motor	1.5 H.P.
Length of machine	40.8 feet
Height of machine from floor level	11.7 feet
Net weight approx.	11 tons.

formed. The thread is then guided through the needle eye entering on the left hand side. For every needle there is one spool holder and one shuttle box on the back of the machine. Benches (t) are provided at the back and front of the machine to permit working on the top bank. A starting lever (u) enables the operator to start or stop the machine anywhere along its length. Normally two people work on one machine; an operator and a helper. The operator usually works at the front of the machine and the helper at the back of the machine.

2.2.1. Outline of the working process

The process for making an emblem commences with the company logo-type. The first step is for an artist to sketch the design and get approval from the customer. This sketch is enlarged six times (6X) and a jacquard is punched for the design. The enlargement is called a "cartoon". Figure 2.2 shows a section of the jacquard. The jacquard is mounted on the machine along with the proper thread combinations. The fabric is spanned onto the machine along with the proper thread combinations and stitched.

After stitching, the cloth is removed from the machine for finishing. The first of the finishing steps is to cut the long threads deposited by the spring stitching, which connects the various embroidered segments of an emblem to starting points on the border of the emblem. Next the backing and the base cloth are bonded in a steam press, after which all regular shaped emblems are stamped out by special dies and irregular shapes handcut. The cut emblems are then surged in a special sewing

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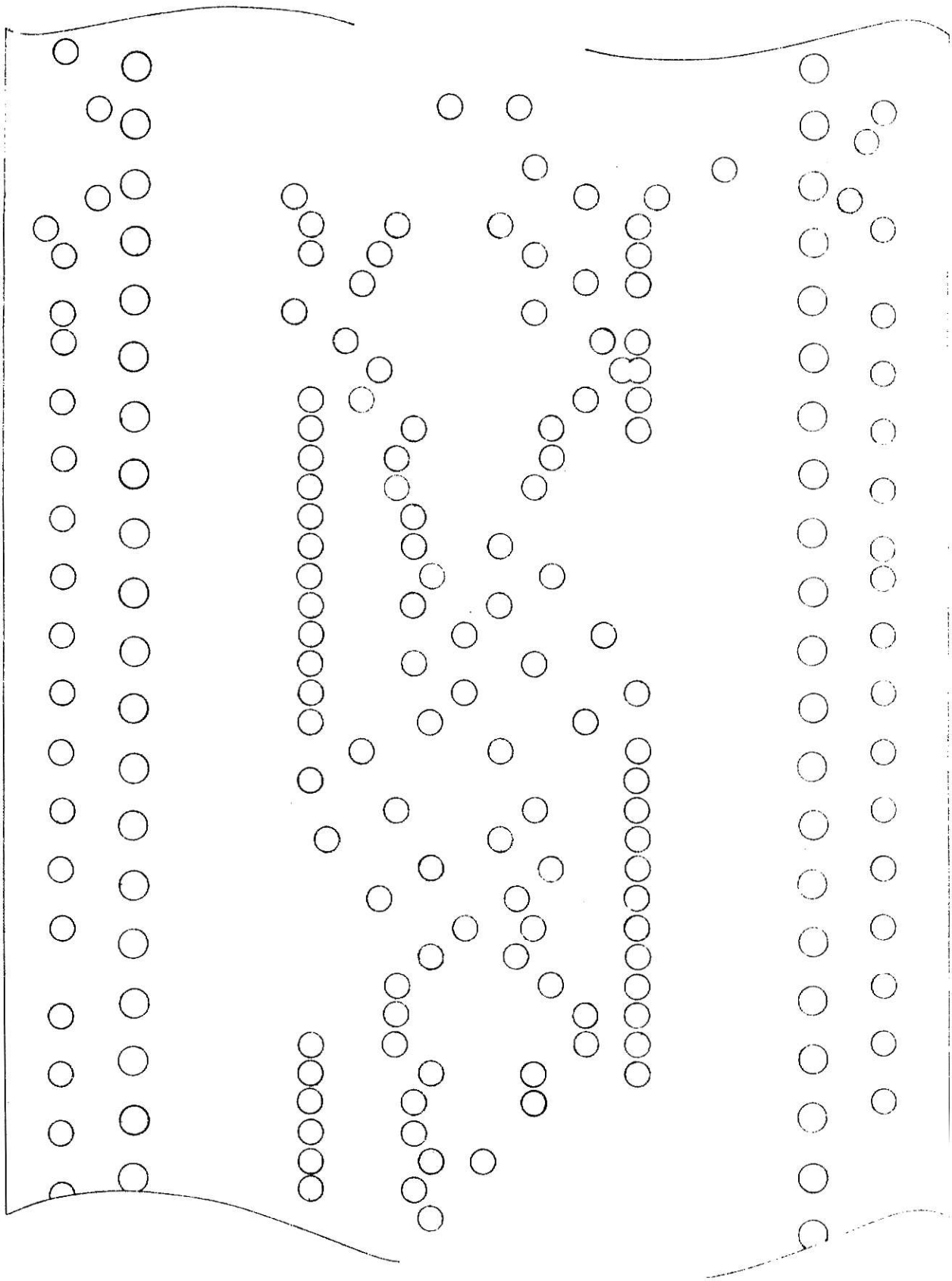
Fig. 2.2: Section of a jacquard used for schiffli machines. (Plauen)



machine with an overlocking stitch to give them a durable edge. This research is concerned only with the stitching phase of emblem manufacture. The finishing aspect is left for further investigation.

2.2.2. Process description

The process for emblem manufacture is flow charted in Figure 1A, Appendix A. The elements of the process chart are listed in Table 2.2 along with the times for each operation and the symbols used to represent the operations in the flowchart. There are twenty one distinct operations required to embroidered emblems. Each operation is described in turn as it occurs in the process. Initially, after a prior job has been completed, the machine has only a jacquard and shield boards mounted on it (to facilitate the mounting and removal of goods). Each batch of new emblems to be stitched will then be processed on the machine, after which the machine is returned to its latent state ready for the next job.

In the process chart certain non-conventional flowcharting symbols have also been used as well as descriptions. These will be introduced in sequence at the time their function is described.

The embroidery process begins thus:

Goods cutting operation. See Table C1. This involves the cutting of two pieces of "goods" and "backing" into 10 1/2 - yard lengths. Although the stitching length of the machine is 10 yards, the extra 1/2 yard is required to tack the goods onto the side combs on both sides. The "goods" are hand-waxed on the back side. Waxing of goods reduces thread breakage of the front yarn. As the threaded needle passes through

the cloth in the stitching process, the wax lubricates the thread thus making it less susceptible to fraying. The backing is required to stiffen the emblem which in turn makes it durable. In this process the backing is not glued onto the goods but is sewed with the base cloth as the emblem is stitched.

Goods spanning operation. Refer to Table C2. Here the goods are mounted onto the top and bottom banks of the machine at the required tension. This tension of approximately 60 lbs. is required to hold the cloth firm while being stitched. The operator and helper tack the top and bottom edge of the cloth onto the combs along the length of the machine. After positioning the cloth so that the top roller is bare, the cloth is tightened with the aid of a prybar and an extension tube (Table 2.3, Item 14). The cloth is then tacked onto the side combs to give it a horizontal anchor. Both lengths are mounted onto the top and bottom banks. It is important that the goods be tightened as they tend to sag while the machine is in operation and when the goods are left on the machine overnight. When the goods sag the yarn colors cannot be accurately superposed and quality of the finished emblem deteriorates.

Stiffener spanning operation. See Table C3. The stiffener or backing is mounted glued-side facing the waxed side of the goods. The backing is glued on one side so that it can be bonded firmly to the base cloth after the finished goods have been taken off the machine. The backing is tacked intermittently onto the top comb and firmly on the entire length of the side combs.

Loading operation ○ : This includes the mounting of the thread spools onto the machine in a specific manner. See Table 2.3, Item 1. The yarn is consistently threaded from the left hand side of the spool.

Depending on the size of the emblem there are different loading operations. The distance between two adjacent needle holders on the embroidery machine is 26.84 mm. In the arrangement where all the needle holders are active, that is, have needles mounted in them, the arrangement is called a "4/4 repeat." This corresponds to an emblem size of approximately 1 inch. Larger emblems require the omission of needles from certain needle holders. In an arrangement where every other needle holder is active, (that is, has needles mounted in it) the needles are spaced 53.68 mm apart. This arrangement is called an "8/4 repeat." Similarly, an arrangement where every third needle holder is active, the needles are spaced 80.52 mm apart and is called a "12/4 repeat." The 8/4 and 12/4 repeats on the embroidery machine are used to embroider emblems 2" and 3" in size respectively. It must be remembered that every active needle holder is threaded and stitches during the embroidery process. More than 95% of the emblems made today are 8/4 and 12/4 repeat emblems. Accordingly, the study is limited to these two arrangements.

Loading operation ① ② : See Table C4 and Loading operation ③ ④ : See Table C5. These are the loading operations for the 8/4 and 12/4 repeats. Figures 2.3 and 2.4 show the arrangement of spools for the 8/4 and 12/4 repeats. Loading operations ① ③ involve the loading of spools on the top row, for both the top and bottom banks

Figure 2.3: Schematic representation of an 8/4 repeat.

Rows (a) and (c) constitute the top bank of spools
Rows (b) and (d) constitute the bottom bank of spools
(a) and (c) are rows of spools of the same color
(b) and (d) are rows of spools of the same color

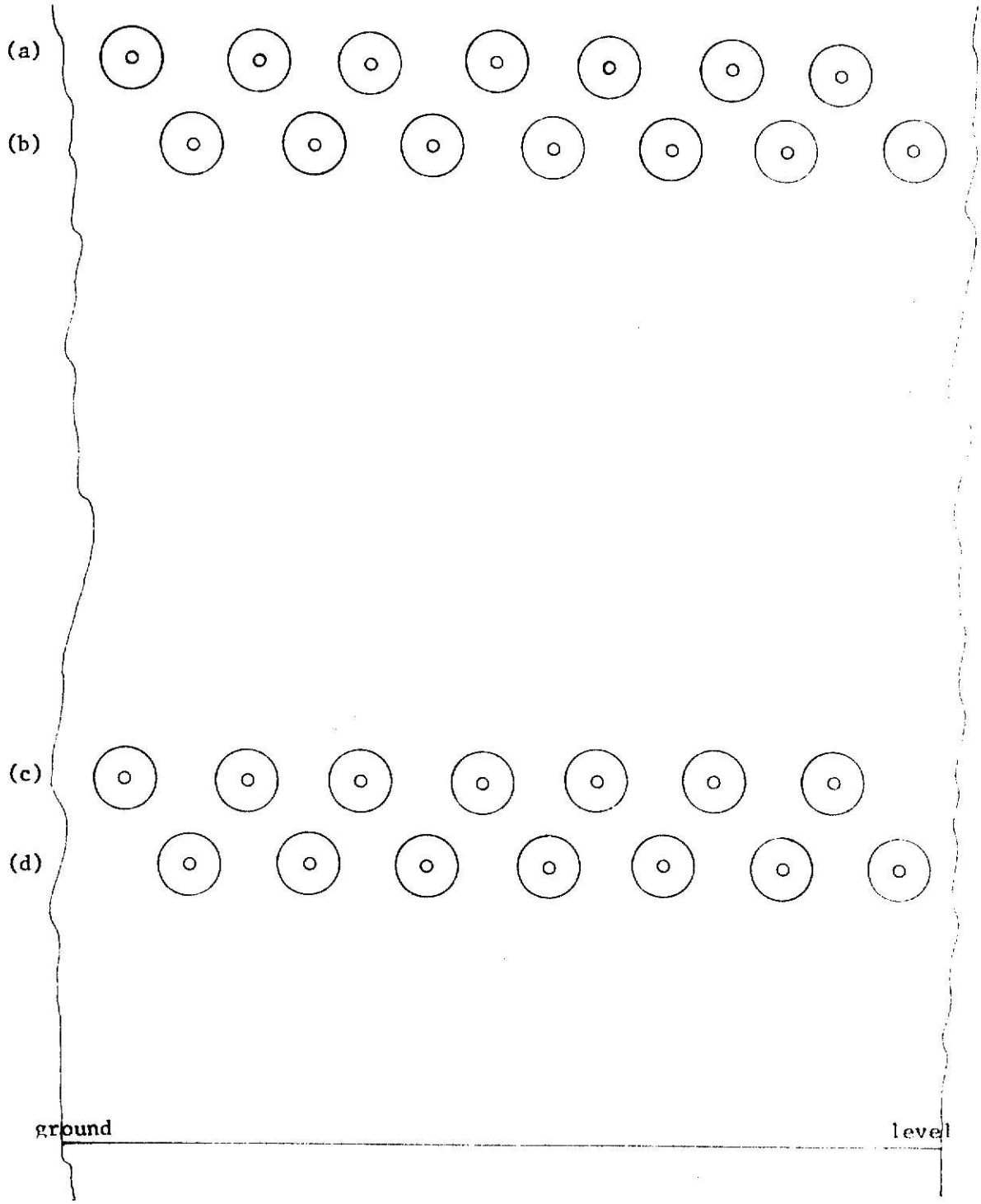
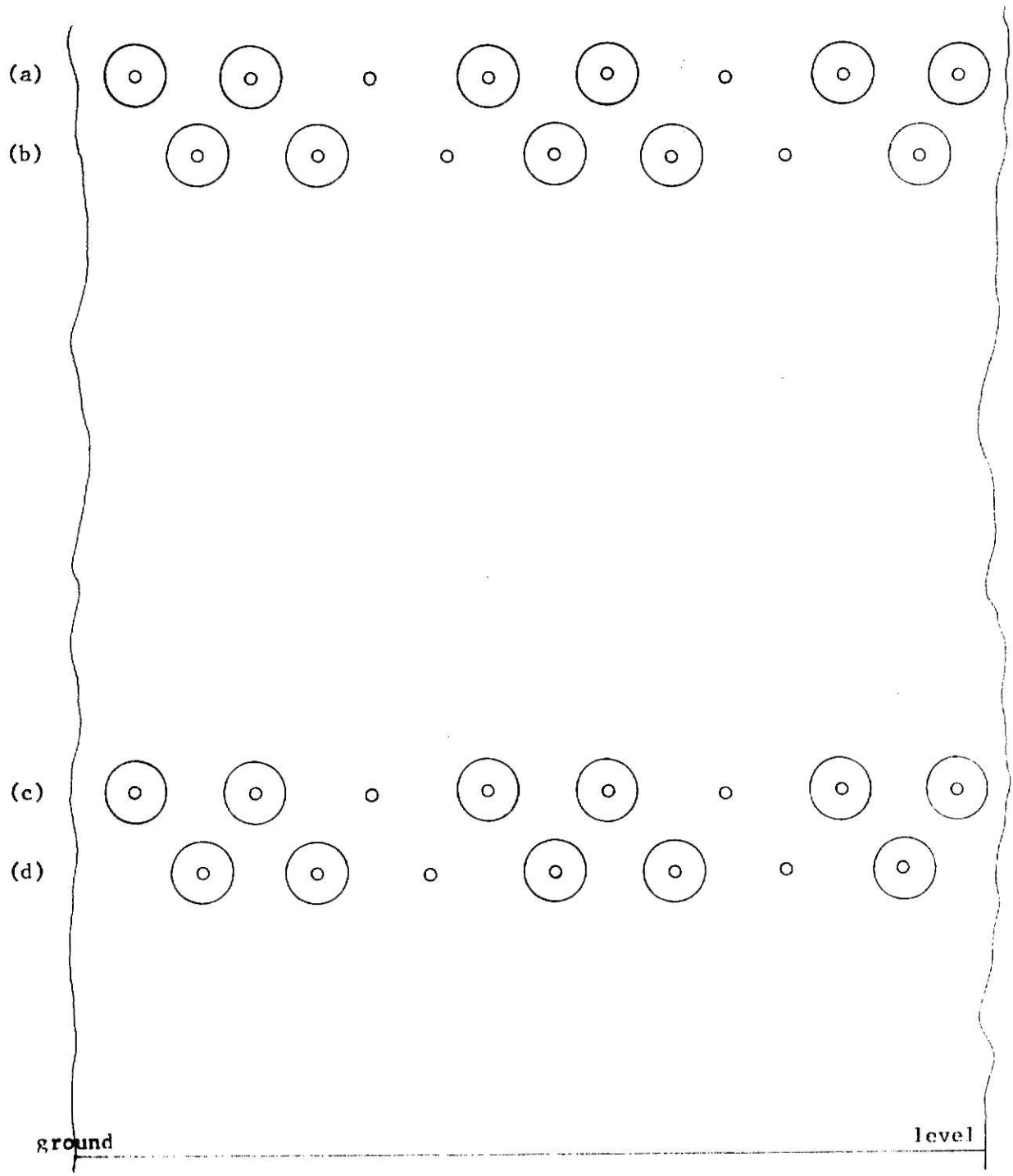


Figure 2.4: Schematic representation of a 12/4 repeat

Rows (a) and (c) constitute the top bank of spools
Rows (b) and (d) constitute the bottom bank of spools
(a) and (c) are rows of spools of the same color
(b) and (d) are rows of the spools of the same color



for the 8/4 and 12/4 repeats respectively. See (a) and (c) in Figures 2.3 and 2.4. Loading operations (2) (4) involve the loading of spools on the bottom row for the top and bottom banks for the 8/4 and 12/4 repeats respectively. See (b) and (d) in Figures 2.3 and 2.4.

Both loading operations are basically the same. The only difference between them is the number of spools loaded: 340 for the 8/4 repeat and 230 for the 12/4 repeat.

Threading operation (O) : This operation requires all the threads to be twisted around the emery roller once (to avoid slippage); under the small brass rod and over the large brass rod (to provide thread tension while forming the stitch). See Table 2.3, Items 2, 11. The yarn is then threaded (See Table 2.3, Items 4,12,13) through the needle eye from the left hand side. Figure 2.5 shows schematically how the yarn is threaded.

Threading operation (1) : See Table C6 and Threading operation (3) : See Table D7. This operation entails the twisting and the threading of spools for the 8/4 and 12/4 repeats respectively. For the 8/4 repeat two threads on either side of the roller bearings are to be guided through the guide-bar. In addition, one thread on each side of the foundation pillar on the bottom bank is to be guided through the guide-bar. In the 12/4 repeat no threads are guided through the guide-bars, as the needles are spaced approximately 3" apart and the threads are kept from entering the roller bearings.

Checking operation-1. See Inspection; Table C8. This operation requires the operator to check that all the spools have been correctly

Figure 2.5 Schematic threading of yarn

Legend

A. Needle

B. Needle holder

C. Small brass rod

D. Large brass rod

E. Front yarn

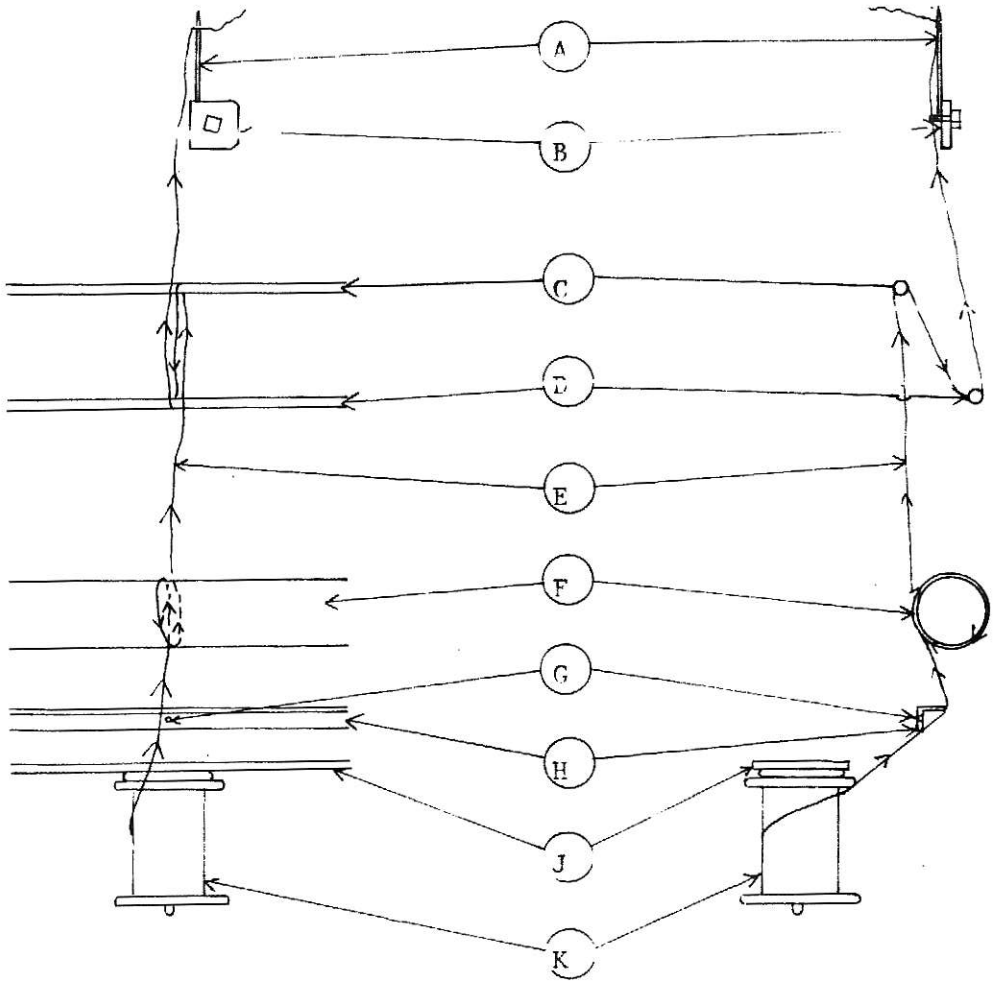
F. Emery roller

G. Guide hole

H. Guide-bar

J. Spool holder

K. Spool



twisted and threaded, and if not, to correct the defects. At the same time the helper also locks the machine. This is a useful check. The machine may be damaged if started with the frame unlocked and machine open. If some of the needles are not threaded correctly, the emblems produced by the improperly threaded needles may be defective and rejected.

Shuttle service operation. See Inspection/Operation; Table C9. The helper keeps the machine supplied with full shuttles in all shuttle boxes, making the change while the machine is running. At the outset all the shuttles are checked and the empty ones replaced so that the machine starts with full shuttles. The construction of the shuttle driving rail is such that the empty shuttles can be seen without having to open the shuttle boxes. A little opening on the side of the shuttle shows how full it is. The key to good quality work on an embroidery machine is to keep the shuttles full. Shuttles are also checked each time a row of emblems is stitched with each color.

Jacquard mounting operation. See Table C10. This requires the operator to mount a new control card, the correct one for the emblem to be embroidered, onto the machine. The previous control card is rolled and returned to a storage rack. (The card reading mechanism on the automat is never left without a tape, as accidental starting or hand stitching would result in certain damage to the automat. An interlock to prevent this could be provided, but is not standard equipment).

Checking operation-2. See Table C11. This involves a final check before starting the machine. The operator checks to see that the shuttle

rail is closed. Also, the frame is checked to see that it is in position vertically and centred horizontally. After the check is complete the automatic stop is reset and the switch is turned on.

Initialization operation. See Table C12. To avoid loose ends of yarn in the top row of emblems, the threads are anchored to the cloth with a few stitches (20 to 30) and the leads detatched manually. See Table 2.3, Item 5). The shuttles are checked again, to detect those that are not working. The helper first checks the shuttles and then helps the operator pull threads.

Stitching operation  : Here the emblems are stitched, one color at a time. Since most embroidery machines are not equipped with color change devices, only one color may be embroidered at a time. After each row of emblems is embroidered with a particular color, the control card is turned back to the starting point of that color, the frame is indexed to the next row of emblems, and a new row is embroidered. When the entire height of the stitching field has been embroidered, the color is changed and the second color is stitched row by row starting from the bottom. After the entire height of the frame has been stitched, the third color is loaded and stitched from the top to bottom. The stitching operation is entirely automatic and the operator watches for broken or frayed threads and rethreads them while the machine is running. The helper is responsible for keeping the machine full. The stitching operation has not been synthesized by MTM and USD, but a method to estimate machine running time is developed later in this section.

Preparation-1. See Table C13. After a color has been stitched and

before the next color is loaded on the machine a preparatory step is required. Preparation-1 includes the removal of threads on the machine. The machine is opened and the front yarn attached to the goods is cut at the cloth line with a knife. See Table 2.3, Item 6. The shuttle threads are left intact. The front yarn is then cut with a scissors at the guide-bar. See Table 2.3 Item 7. After this, the threads are removed manually and discarded. See Table 2.3 Item 8.

Switching operation  : This operation entails the switching of two entire top and bottom rows of spools, both on the top and on the bottom bank of the machine. This is done cyclically using both hands. For emblems having two or more colors, both the top and bottom rows are loaded with the first two colors to be used on the emblem, and then these are switched after the first color has been embroidered. See Table 2.3, Items 9,10.

Switching operation  . See Table C14. and Switching operation  : See Table D15. This operation requires switching an entire top row of spools with the bottom row, both on the top bank and on the bottom bank of the machine, for the 8/4 and 12/4 repeats respectively. In Figures 2.3 and 2.4, (a) is switched with (c) and (b) is switched with (d).

Unloading operation  : This operation involves the removal of spools from the machine and systematic replacement of the spools in the appropriate storage carton.

Unloading operation   . See Table C16 and Unloading operation   . See Table C17. These are the unloading

operations for the 8/4 and 12/4 repeats respectively. Unloading operations (1) (3) include the removal of spools on the top row for both the top and bottom banks for the 8/4 and 12/4 repeats respectively. See (a) and (c) in Figures 2.3 and 2.4. Unloading operations (2) (4) include the removal of spools on the bottom row for both the top and bottom banks. See (b) and (d) in Figures 2.3 and 2.4.

Rollover operation. See Table C18. When the total vertical height (24") of the potential stitching field has been stitched, the goods are "rolled over." This means the goods on the rollers are shifted after the stitching field has been used up, to reset the goods for the next field of stiching. This operation requires the finished goods to be rolled up on the top roller, while the unworked goods unroll from the bottom roller. If the cloth span consists of one 10-yard length of 42" width, one rollover is necessary. If two or more 10-yard lengths are used in the span the pieces are sewn together on the selvages. This is a disadvantageous procedure, since the turnaround time is increased because finished goods may remain on the machine for a long time awaiting the end of a span.

Preparation-2. See Table C19. Before the removal of finished goods from the machine, a preparatory operation is required. After stitching ends, the machine is opened, the frame raised to allow enough bobbin yarn length. Both the operator and the helper cut the front (needle) yarn with a knife at the cloth line, then at the guide-bar with a scissors. After the front yarn is cut with a knife at the cloth line, the helper then cuts the shuttle yarn with a knife. (If the shuttle

Table 2.2 Sequential Listing of all Operations in the Embroidery Process

No.	Operation Name		Time	Symbol	Table No. in Appendix C
1	Goods cutting operation		13.72		C1
2	Goods spanning operation		16.82		C2
3	Stiffener spanning operation		3.72		C3
4	Loading operation	(8/4)	5.71	 	C4
5	Loading operation	(12/4)	3.61	 	C5
6	Threading operation	(8/4)	22.36		C6
7	Threading operation	(12/4)	14.52		C7
8	Checking operation - 1		1.90		C8
9	Shuttle servicing operation		2.57		C9
10	Jacquard mounting operation		1.84		C10
11	Checking operation - 2		0.40		C11
12	Initialization		3.46		C12
13	Stitching operation				
14	Preparation - 1		3.37		C13
15	Switching operation	(8/4)	4.54		C14
16	Switching operation	(12/4)	2.86		C15
17	Unloading operation	(8/4)	4.67	 	C16
18	Unloading operation	(12/4)	3.65	 	C17
19	Roller operation		11.95		C18
20	Preparation - 2		4.22		C19
21	Goods removal operation		8.98		C20

yarn is cut first, the embroidery will start to rip off). The front yarn is removed for disposal.

Goods removal operation. See Table C20. Shield boards are first mounted on the machine over the brass rods, to facilitate removal of finished goods and spanning of goods onto the machine. The goods are then taken off the machine. The bottom rollers are loosened with a prybar. The cloth is first taken off the side combs and the bottom comb, then rolled up on the top roller. Then it is carefully unrolled from the top roller onto the shield boards and is bundled at the far end of the machine. The bundle is then taken to the finishing section of the plant. The present operation analysis stops here. Both the top and bottom spans are removed in an identical manner. The machine is now ready to process a new span.

2.2.3. Analyses

Each of the above operations is listed in Table 2.2. In the entire analysis only two persons are assumed working on the machine--an operator and a helper. All of the 20 operations in Section 2.2.2. (with the exception of the stitching operation) have been analyzed into MTM elemental motions, from which operation times have been synthesized. The time required for the performance of the 20 operations is obtained by table look-up (Appendix C). Throughout the study Methods-Time-Measurement (MTM) and Universal Standard Data (USD) systems have been used.

A brief explanation of how to read Tables C1 through C20 follows. (It is assumed the reader is familiar with the use of MTM and USD standard

data). There are three main columns in the table, headed HELPER, OPERATOR, and TOTAL. The HELPER and OPERATOR columns each have three sub-columns headed LEFT HAND, RIGHT HAND, AND BODY. The MTM elemental motions listed in each of these latter columns are the motions that these respective members perform. A horizontal line in either of the columns headed HELPER and OPERATOR is the beginning or the end of a simultaneous motion point for that person. Simultaneous motions are motions performed by two or more body members at the same time (7). Simultaneous motion points for the operator and helper together are indicated by a horizontal line through both columns. At such simultaneous motion points totals of elapsed time from the previous simultaneous motion point are carried foreward. The basic motions and the symbols used to represent them in the MTM and USD systems are listed in Appendix B.

2.2.4. Machine Running time

Next, the development of estimates for machine running time will be considered. Machine running time in embroidery manufacture is a function of the number of stitches in the design of the emblem. The number of stitches in an emblem will vary according to the complexity of the emblem and the quality standards expected by the customer.

The embroidery machine is not an infinitely variable-speed machine. The driving motor has an expansible pulley whereby the speed can be varied over a small range from about 115 rpm to 125 rpm (normally). Once the speed has been set at a particular value, it remains constant unless the pulley setting is changed. The type of machine dealt with here

runs best around 120 rpm. All Plauen-type machines have either a clutch mechanism or a two speed motor to enable the automat to run the machine at a 'slow' speed as well as at 'fast' (normal) speed. In the clutched machines a 2 to 1 reduction in the gearing provides the 'slow' speed of 60 rpm, compared to a 'fast' or normal speed of 120 rpm. The change of speeds is mechanical and is programmed into the jacquard. The two speed feature in embroidery machines is incorporated for:

1) Ease of automatic engagement and disengagement of various controls. The embroidery machine is mechanical in nature, with control residing primarily in levers, bearings and cams. The machine may in certain cases be damaged due to the engagement or disengagement of controls at the higher speed.
2) Stitching spring stitches to avoid bobbin yarn breakage resulting from fast speeds. Only spring stitches are stitched at slower speeds.

It must be remembered that the needles in an embroidery machine have only a rectilinear motion. The embroidered area is stitched by moving the frame on which the cloth is mounted. This frame moves on two axes perpendicular to the needle movement. This produces the relative movement between needle and cloth that is required to stitch a pattern. One forward and backward movement of the needle is counted as a half stitch by embroidery designers. Thus, in order to lay down one length of thread, commonly called a stitch, two such half-stitches are required. Hence, the embroidery machine, running at 120 rpm makes 60 stitches per minute when running fast and 30 statches per minute when running slow. Experience has shown that spring stitches are stitched at approximately 2 stitches

per inch. This will vary slightly among persons who punch jacquards. More than 2 stitches per inch indicates inefficient utilization of the machine while fewer stitches per inch risks bobbin yarn breakage.

For the purpose of this research, an estimate of the total number of stitches in the emblem is required in order to estimate the machine running time. Chapter 3 is devoted to developing an estimating equation for the stitch count of an emblem.

Machine running time may be estimated in the following manner. The total number of stitches is defined as

$$N = N_f + N_s \tag{2.1}$$

where

N = total number of stitches in the emblem,

N_f = number of stitches to be stitched at fast speed,

N_s = number of stitches to be stitched at slow speed.

Also, the number of stitches at slow speed is

$$N_s = k\ (LS) \tag{2.2}$$

where

LS = length of the spring stitches in inches,

k = an empirical constant, here taken as $k = 2$,

the approximate number of spring stitches per inch.

Substituting for N_s in (2.1) from (2.2)

$$N = N_f + 2\ (LS) \tag{2.3}$$

Then, the estimated machine running time in minutes is

$$T = \frac{N_f}{60} + \frac{2\ (LS)}{30} \ . \qquad (2.4)$$

2.2.5. Validation

In an effort to partially validate the analysis of some of the operations, an in-plant study was undertaken. A micromotion film, made during this study, provides raw motion-sampling data on operations covering more than 80% of the manufacturing time. The film was taken at 1000 frames per minute. Table 2.3 lists the operations studied by the micromotion film, along with the synthesized MTM times for cycles from these operations.

In this chapter the normal times for operations in the embroidery process have been developed. The normal times developed may be converted to standard times by the application of rating and allowance factors. These are subjective in nature and vary among embroidery manufacturers. Once standard times have been established, the applicable labor rate may be applied to obtain standard costs.

Table 2.3 Operations recorded on micro-motion film of the embroidery process (1000 frames per minute)

Film sequence no.	Frame count	Operation	Description of activity	MTM time in thousandths of a minute	Item no. on Table 2.2	Table no. in appendix C
1	0	Loading operation 1	(c) Loading of spools on top row of bottom bank - 8/4	151.00	4	C4
2	697	Threading operation 1	(a) Twisting of guided and unguided threads ... operator (a)	83.58, 112.00	6	C6
3	2483	Threading operation 1	(c) Twisting of guided threads - non standard method	*	6	C6
4	3181	Threading operation 1	(a) Pulling threads through needle eyes - 8/4	41.46	6	C6
5	3886	Initialization operation	(a) Pulling lead ends of thread after having stitched 20-30 stitches	87.92	12	C12
6	4335	Preparation - 1 and Preparation - 2	(d) Cutting threads with a knife at the cloth line	92.00	14, 20	C13,C19
7	4478	Preparation - 1 and Preparation - 2	(d) Cutting threads with a scissors at guide bar	62.22	14, 20	C13,C19
8	4694	Preparation - 1 and Preparation - 2	(b) Removing threads from machine for disposal	111.30	41, 30	C13,C19
9	5010	Switching operation 2	(b) Switching of spools on the top bank - 12/4	43.00	16	C15
10	5341	Switching operation 2	(b) Switching of spools on the bottom bank - 12/4	*	16	C15
11	5926	Threading operation 3	(b) Twisting of unguided threads - Operator (b)	79.38	7	C7
12	6670	Threading operation 3	(b) Pulling, threads through needle eyes - 12/4	42.24	7	C7
13	7364	Threading operation 3	(d) Pulling threads through needle eyes - untrained operator	*	7	C7
14	7619	Goods spanning operation Goods removal operation	Tightening of goods	2500.00	2, 21	C2,C20

Notes: 1. (a) and (b) are operators.
(c) and (d) are helpers.

2. Non-standard method *

CHAPTER 3

REGRESSION ANALYSIS FOR ESTIMATING THE STITCH COUNT OF AN EMBLEM

3.1. The problem

In Chapter 2 the need for an estimate of the emblem stitch count was stated, in order to estimate the machine stitching time for an emblem. The stitch count of an emblem is the total number of stitches in that emblem. The development of an estimating equation, based on estimates of the parameters of the emblem, forms the contents of Chapter 3.

The following paragraph describes a procedure that is quite common in the embroidery industry. Usually, the only information available to the estimator is the logotype or monogram (design) of the emblem to be produced. The designer must translate the logotype or monogram into the kind of emblem that works best on the embroidery machine. The first step is to sketch the design and get it approved by the customer. When the sketch is approved, the type of yarn and fabric are agreed upon. The next step is to make a six-fold enlarged technical drawing of the sketch, using an overhead projector. Lines representing stitches are then embossed into the technical drawing, using star-shaped wheels. The enlargement (or "cartoon") is the 6X technical drawing showing the stitches laid out on the outlines of the motifs to be embroidered. When the cartoon is complete, it is given to the stitcher (in the case of hand-controlled machines) or to the puncher (for punched-card controlled machines) for preparation of the jacquard. The puncher uses a separate punch pantograph to retrace the stitch lines on the cartoon. The movements

of the pantograph are registered by punching holes in a tape, which then forms the jacquard for the card controlled embroidery machines.

In order to quote a price to a customer, a supplier must have an estimate of the stitch count of an emblem, even before the enlarged cartoon or the jacquard is made. Although an exact stitch count would be desirable, it is never available until the jacquard is made in the manner described above. There is no accepted procedure in the industry for estimating the stitch count of an embroidery pattern before the jacquard is actually made. Even when in-being samples of stitched embroidery are available, counting stitches on a pattern is an expensive and inaccurate task. A designer must often spend several hours using a magnifying glass to retrace all of the movements of the puncher who first made the emblem. This procedure gives some sort of stitch count estimate, perhaps within 20% of the true stitch count. Different punchers use different techniques and it is difficult for one puncher to duplicate another's technique.

The present procedure proposes to estimate the stitch count with considerable precision by using only a sketch of the emblem, before the expensive task of making the jacquard is undertaken. The method is procedural and takes much less time than actual counting. The ratio of the machine running time to the total manufacturing time of an emblem is small, so a good estimate with a relative error of the order of 10 to 15% of the true value or less, arrived at quickly by a consistent method would give a reasonable basis for estimating machine running time.

One approach to the solution of this problem lies in using multiple

regression techniques (2). The development of a regression equation would provide management with an easy and dependable method to estimate the stitch count, and hence, the machine running time.

A linear relationship of the form

$$SC_j = \sum_{i=1}^{k} b_i X_{ij} + \sum_{i=k+1}^{m} b_i Y_{ij} + e_j \qquad (3.1)$$

where:

SC = the dependent variable, stitch count,

X_i = independent categorizing variables ($X_i = 0,1$),

Y_i = independent continuous variables ($0 \leq Y_i < \infty$),

e_j = the error term (NID $(0,\sigma^2)$),

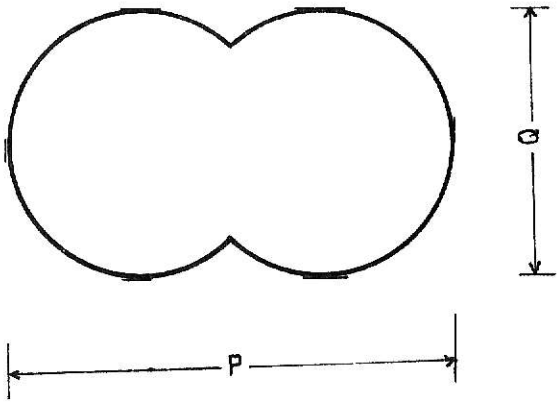
between the dependent variable stitch count and the independent variables X_i and Y_i, is assumed as the estimating equation. The coefficients b_i are determined by the multiple linear regression technique.

Emblems, in general, may be categorized in several ways. For example, emblems may be categorized by

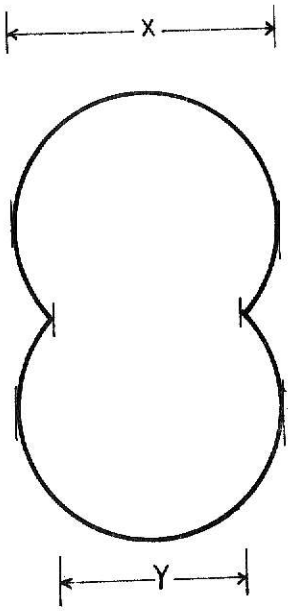
(i) Size: The size of an emblem is defined as its longest dimension on its shortest side, when the emblem is inscribed in a rectangle. Figure 3.1 demonstrates how the size of an emblem can be found. Size is important from the production viewpoint. An emblem is stitched as if it were standing vertically on its narrower side. (See Figure 2.1 (b)) This arrangement permits more emblems to be stitched in one row on the machine at any one time.

Figure 3.1 The size of an emblem

(a)



(b)



The size 'X' of an emblem is its longest dimension on its short side 'Q'

An emblem is stitched as though it were standing on its its narrower side (b)

(ii) Number of colors: Theoretically this could be very large number, but most emblems manufactured today rarely exceed five colors. Typically emblems have up to four colors.

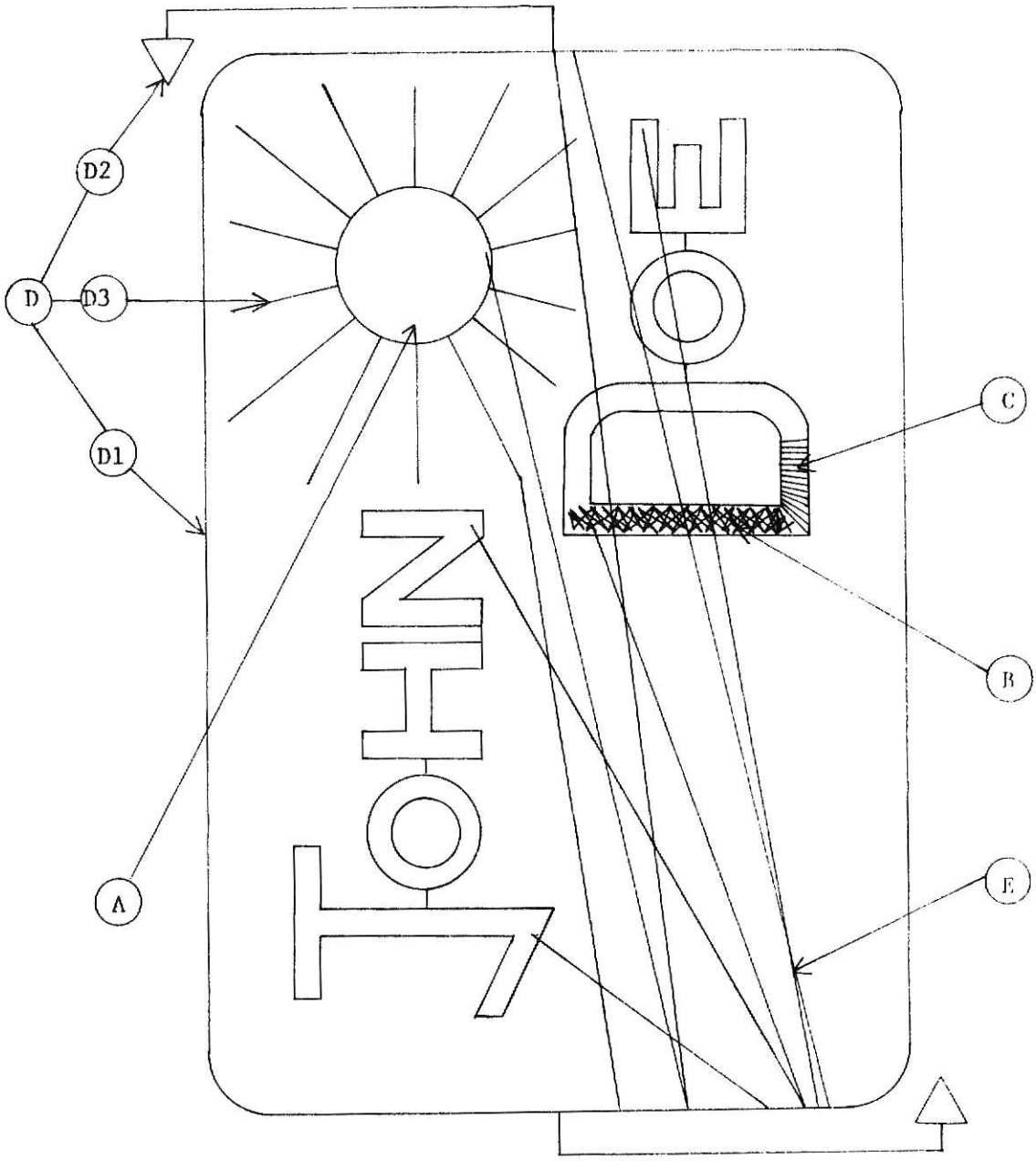
(iii) Yarn Size: In the emblem industry the most commonly used yarn counts are 150/2 and 100/2. The material used is rayon yarn. The count of a yarn for man-made fibres is the number of deniers (0.05 grams) that a 450 meter length of yarn weights. As the diameter of the yarn increases, this number increases (9). The 2 represents the number of strands that are twined to form the thread. The 150/2 yarn is often preferred to the 100/2 yarn because of economic reasons. Accordingly, the present model deals only the 150/2 count of yarn.

Emblems, in general, also vary in the number and types of stitches required: usually, one or more of five types of stitches may be required to stitch an emblem. The embroidery machine is designed for lock stitching. It produces five types of stitches, as illustrated in Figure 3.2 and described below:

(i) Background area stitches: A solid organized mass of stitches laid onto a desired outline on the base cloth. A background area stitch is made in a systematic way, with stitches side by side, very often horizontally or vertically. This is not a requirement of the background stitch, but this is the form in which it is most frequently encountered.

(ii) Fill-in area stitch: Embroidery patterns in general and

Figure 3.2: Various types of stiches



Legend:
A Background area stitches
B Fill-in area stitches
C cover stitches
D Linear stitches ---- D1 - Border stitches
D2 - Guide stitches
D3 - Linear stitches in body of emblem
E. Spring stitches

emblems in particular are three-dimensional in nature. To build up this three-dimensional effect, all areas on the emblem, with the exception of the background area, require a series of fill-in stitches, or an "underlay", as designers frequently call it. This is not a regular stitch and different punchers have different methods of providing fill-in while punching the jacquard. The designer merely lays out the cover stitches on a cartoon and it is up to the puncher to give an emblem its body or fill-in. The point here is that an area is to be underlayed in the form of a matte in order to give a three-dimensional effect to the area of interest.

(iii) Cover stitches: The underlay or fill-in stitch in an embroidery pattern will invariably be covered up using closely spaced finish stitches.

(iv) Linear stitches: This is the type of stitch one typically sees made by a domestic sewing machine. Linear stitches by the embroidery machine are used on emblems to stitch borders and guides. Border stitches are used to stitch the stiffener and base material together as well as reference the die while stamping out the emblems in the finishing process. Guide stitches are used to reference colors. Very few embroidery machines are equipped with automatic color change devices. In multicolored emblems, guide stitches are used to insure the correct superposition of colors.

(v) Spring stitches: These stitches are used as transport stitches to and from different areas of the emblem. They are made when the frame is intentionally moved with the needles not stitching. Spring stitches appear as long threads lying on top of the emblem and must be removed in the finishing process.

3.1.1. The Sample

The regression has been developed using a sample of 62 emblems supplied by an emblem manufacturer. Of these, 44 were 2" in size, 27 were 3" in size and 1 was 4" in size; this corresponds to the 8/4, 12/4 and 16/4 repeats respectively. There was no predetermined selection procedure followed in gathering the sample. All available emblems were used to gather as large a sample as possible.

3.2. Variables used in the development of the model

The information that a design sketch lacks as compared to an in-being sample is:

1) No spring stitches are present,

2) No guide stitches (linear stitches) are present for emblems with more than 1 color.

While estimating the stitch count, the estimator is required to know, among other things, the total length of the linear stitches and spring stitches. The layout of the spring stitches and guide stitches to reference colors can easily be taught to an unskilled estimator while the use of the estimating model is being explained to him.

Ten variables were considered as having a potential effect on the stitch count of an emblem (5). These 10 variables fall into two broad

groups: (a) categorizing variables and (b) continuous variables.

3.2.1. Categorizing variables

The variables considered in a regression equation can usually take values over a continuous range. Sometimes a variable may have two or more distinct levels. Data may represent emblems of two sizes, either of one to four colors, or the presence or absence of some other variable. In such cases levels are assigned to such variables as "size" and "number of colors" to account for the fact that various sizes or colors or the presence or absence of a variable may have separate deterministic effects on the stitch count. Variables of this sort are called dummy variables. Dummy variables group the data so that the data are more homogeneous within groups. Dummy variables are unrelated to any physical levels of the parameters themselves. The following are the categorizing variables chosen for consideration.

3.2.1. (a) Size of the emblem: S12/4

Sizes were classified into two groups. Emblems with the eight-quarter repeat formed one group and emblems with the twelve-quarter repeat formed the other group. The one sixteen-quarter emblem was lumped together with the twelve-quarter emblems as a matter of convenience. A 0-1 dummy variable was created to represent these two groups:

The variable S12/4 was assigned values:

S12/4 = 0 if the size of the emblem is 2"

S12/4 = 1 if the size of the emblem is 3"

3.2.1. (b) Background-No background area stitch: NBG

The dummy variable classifies the emblems into two groups: those with background area stitches and others without background area stitches. A 0-1 dummy variable was created to represent the presence or absence of background area stitches.

The variable NBG was assigned values:

NBG = 0 if background area stitches were present,

NBG = 1 if background area stitches were absent.

3.2.1. (c) Number of colors variable: C_1, C_2, C_3.

Three dummy variables C_1, C_2 and C_3, were created to represent emblems with two, three, and four or more colors, respectively, treating the one color case as the base.

This was accomplished in the following manner:

Dummy variables:	C_1	C_2	C_3
One color emblems	0	0	0
Two color emblems	1	0	0
Three color emblems	0	1	0
Four or more color emblems	0	0	1

This procedure allows treatment of r levels by the introduction of (r - 1) variables.

In the sample of 62 emblems there was one emblem that had five colors and this was lumped together with the four color emblems as a matter of convenience.

3.2.2. Continuous variables

This group of variables comprises the various types of stitches. These variables are considered to be independent variables in the regression analysis. These variables may take values over a continuous range and must be measured for each emblem.

3.2.2. (a) Area of the background stitch: AB

This variable is the most potent contributor to the stitch count. It is observed that background area occurs in significant amount in emblems. The mean for this variable for the 27 emblems having background area was 2.10 sq. inches, as compared to 0.92 square inches for the entire sample. The assumption made here is that the density of the background area stitch per unit area in different emblems and within different areas on the same emblem is constant. The area of the background stitch was measured using a polar planimeter. An experiment to determine the accuracy with which areas could be measured by a technically untrained group was made and the results (Section 3.3) showed that areas could be measured to 1% of their true values. The area was recorded in square inches to the nearest 0.01 square inch (the smallest division estimable by the vernier scale of the planimeter), from a 2X picture of the emblem. The actual area on the emblem, one-fourth the picture area, was used in building the model.

3.2.2. (b) Area of the fill-in stitch: AF

Fill-in stitches are required in an emblem to give it a raised, three-dimensional effect. Fill-in stitches are not present on the cartoon. The puncher thus has considerable latitude in the creation

of the underlay. Two punchers, working from the same cartoon, may produce entirely different effects on an emblem depending on how they provide for the fill-in stitches. Consequently, the resulting stitch count for the jacquard may vary considerably. This is one of the least understood areas in design punching. This "designer effect" could not be identified in the sample and was thus pooled with the error term. The consequent assumption made here is that number of stitches in an underlay is proportional to the area to be filled. This is a reasonable assumption because an underlay is invariably covered on an in-being sample and the only indication about its stitch count is the area which it covers. As the actual fill-in area could not be identified on the samples the area covered by the cover stitches was used in the calculations.

3.2.2. (c) Length of the cover stitches: LC

This variable was measured in inches using a map measurer, an instrument used to measure linear distances along curved paths. In this study the map measurer was used on the photos of the emblems. Its accuracy was determined by a method similar to that used to test the polar planimeter; the results (Section 3.3.) showed that lengths could be measured to 2% of their true values. The tracing wheel of the map measurer was run along all center lines of elemental areas of the motif having a constant width (i.e. constant length of cover stitch) beginning and ending with the extremes of such areas. For elemental areas of the motif with varying cover stitch length, the edge to edge distance measured perpendicular to the direction of the cover stitches was added.

A linear measure of the cover stitch was considered to be a reasonable characteristic as this is the manner in which the designer inserts cover stitches into an emblem. Here, half the length of the cover stitches on the 2X picture equals the corresponding length on the emblem.

The assumption made here is that the stitches per running inch are the same for all emblems stitched with the same count of yarn; also, the cover stitch density is the same for different parts of the same emblem. Although this is a simplification of the actual process it provides a repeatable method of estimating the number of cover stitches.

3.2.2. (d) Length of spring stitches: LS

Spring stitches appear as "strings" over the top of the stitched emblem and are not physically stitched onto the emblem. In a finished emblem, however, they are absent, having been removed in the finishing process. However, the samples used in this study had the spring stitches present (they were sampled before the finishing process). The assumption made here is that the length of the spring stitches is proportional to the number of such stitches. This is reasonable because once the emblem is stitched there is no way of telling exactly how many stitches were required to "spring" over a particular length, even on an in-being sample. It must be noted that, to avoid breakages of front and bobbin yarn, spring stitches are stitched at a slower speed than all other stitches. This was mentioned in Chapter 2 and a method to treat slower speeds was outlined. The map measurer was used on the 2X enlargement to give the length of spring stitches in inches.

3.2.2. (e) Length of linear stitches: LL

Linear stitches appear in an emblem as border stitches and guide stitches to reference colors. These may not be the only uses of linear stitches. They may be used with advantage in the body of the emblem; the length of the linear stitches in the body of the emblem is added to the length of linear stitches of the border and guides to give a value for this variable. Stitches which are used to link two letters of motifs may be considered as linear stitches. However, the length of such stitches is small as compared to the total length of the linear stitches and has been neglected.

The assumptions made here are that the number of linear stitches is proportional to the length stitched, and that this number is the same for different emblems and different areas on the same emblem. The map measurer was used on the 2X picture to measure this length in inches.

In building the model, actual lengths (half the lengths on the 2X picture) of the spring and linear stitches were used and not the values measured by the map measurer.

3.3. Implements used

In the course of the data reduction a polar planimeter and a map measurer were used to measure certain variables of the emblem.

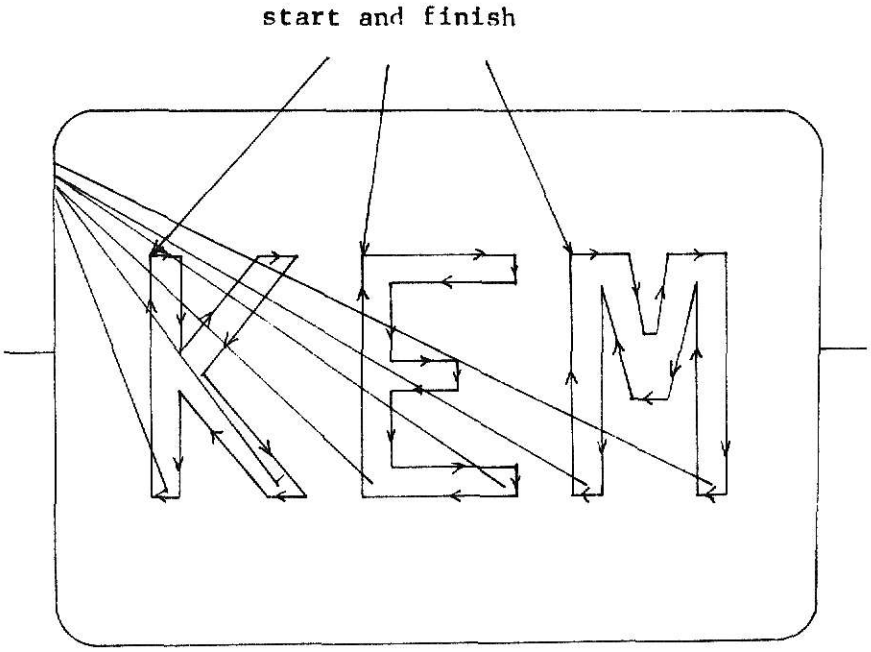
A polar planimeter (K & E 63-0000) was used to trace the area of the background stitching and the area of the fill-in stitching. The planimeter measured square inches, tenths, and hundredths of a square inch. Due to the uneven surface of an in-being sample and the presence of long threads representing spring stitches, it is difficult to use a

polar planimeter on an in-being emblem. In this study, double-sized black and white photographs were made of all the emblems constituting the sample. The planimeter was used on the photographic prints to find the areas of interest. One-fourth of the area on the enlarged photo is the actual area on the emblem. The area on the enlarged photo was traced ten times without resetting the planimeter in order to give a mean estimate of the area with reduced error.

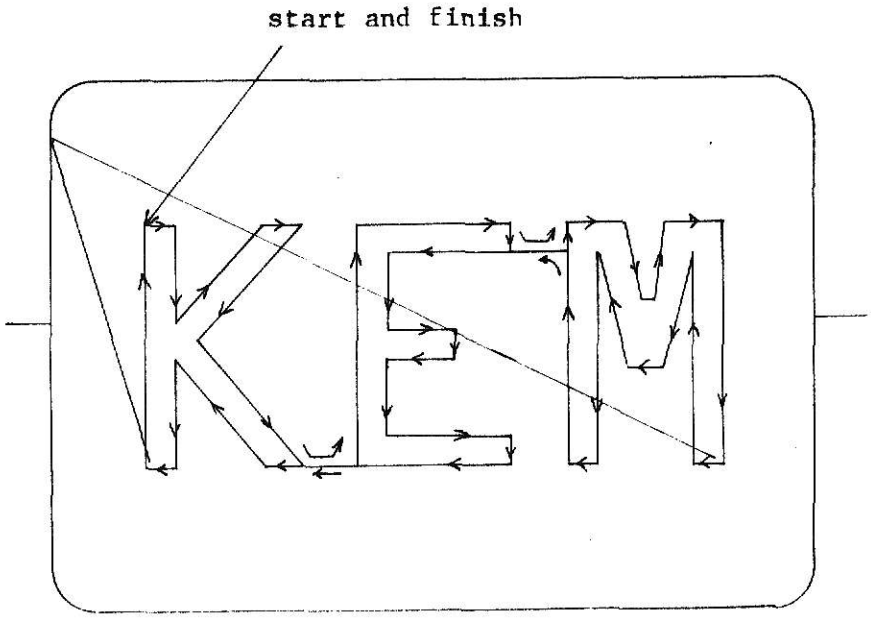
If certain letters of motifs on an emblem were stitched together, the area was found in one trial. If the letters were stitched separately, they were treated as such and the individual areas added to give the total figure area. Figure 3.3. illustrates this point. Two trials were needed to find the areas of letters with embedded blanks. See Figure 3.4. The embedded area was subtracted from the total area to give the net stitched area. The fill-in areas were found by tracing the letters or motifs along the periphery, although the fill-in stitches may not actually extend to the periphery. No allowance has been made for this discrepancy as there is no means of estimating this error on an in-being sample.

A map measurer (K & E 63-0300) was used to measure lengths of cover stitches, spring stitches and linear stitches. Cover stitches are used as finish stitches to cover the underlay required to give an emblem its three-dimensional effect. The tracing wheel on the map measurer was run along the center-line of the letter or motif in a direction perpendicular to the actual stitch direction (as defined in Section 3.2.2. (c)) on the 2X picture of the emblem, as shown in Figure 3.5. Half the length on the enlarged photo equals the corresponding length on the emblem. The length

Figure 3.3: Measurement of areas on joint and disjoint letters.

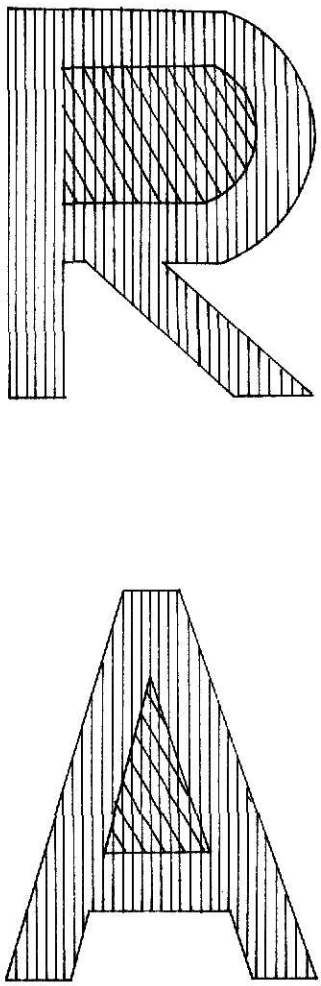


(a)



(b)

Figure 3.4: Finding areas of letters with embedded blanks

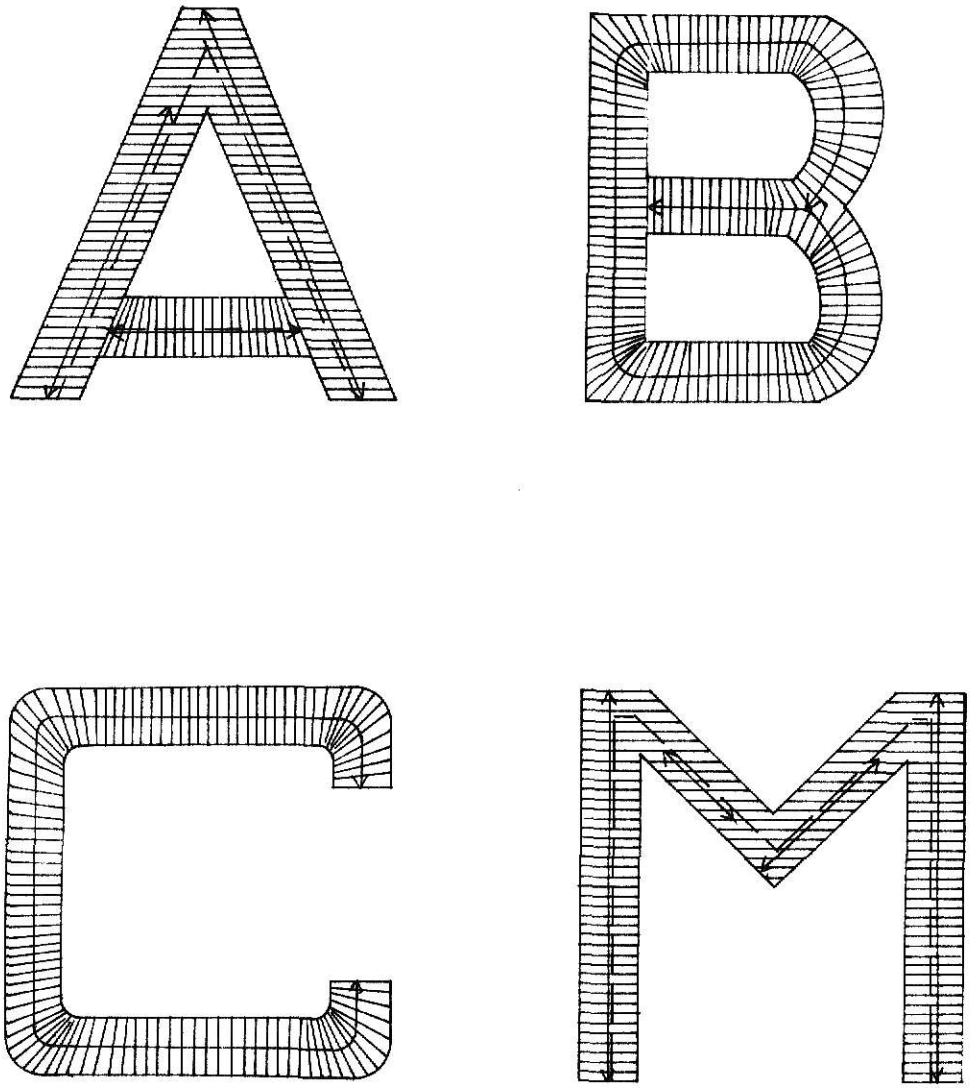


A_2 total area

A_1 embedded area

Net stitched area = $A_2 - A_1$

Figure 3.5: Measurement of the cover stitch length



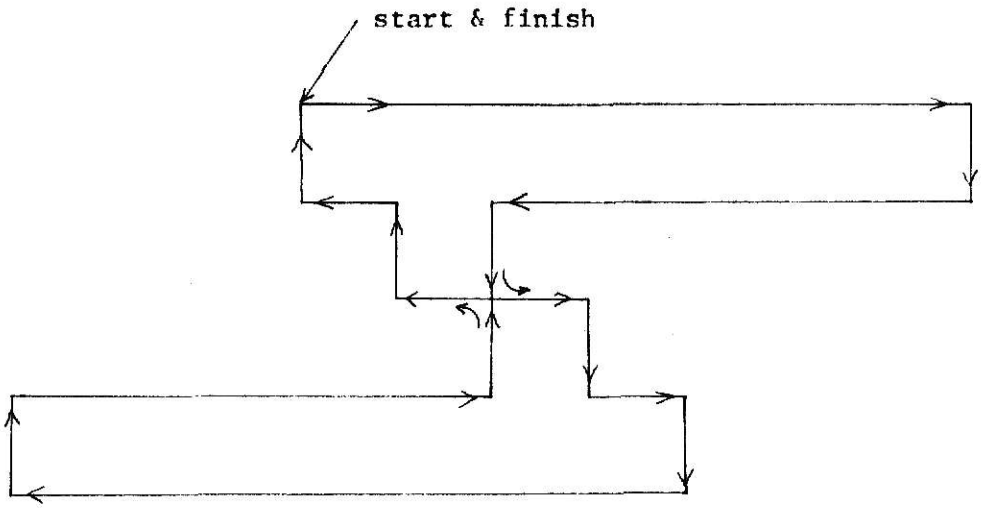
was traced five times and the mean value obtained to reduce the measurement error. The map measurer was calibrated in inches and half inches. This map measurer was provided with a swivel handle for easier negotiation of the curved paths.

In certain letters the actual stitch path differs slightly from the center-line of the letter or motif, as in the letters A and M Figure 3.5. In this study the actual stitch path was used as contrasted to the mean stitch path. The length of the spring stitches and linear stitches were also measured from the double-sized photographs. Measurements were halved to give the corresponding lengths on the actual emblem. In each case an average of five trials was taken. Lengths were recorded in inches and tenths of an inch. As the smallest division on the map measurer was one half inch, a 0.1 inch approximation was used on this smallest division.

An experiment was performed to determine the precision with which areas and lengths could be measured by a non-technical group of persons. The purpose of the experiment was to find the magnitude of error in the measurement of the independent variables used in the regression analysis. One of the assumptions of linear regression analysis is that the independent variables are measured without error.

Three male engineering students and three female social science students participated in the experiment. Each subject was asked to trace the area in Figure 3.6 ten times with the polar planimeter and the periphery of the same figure with the map measurer five times. Figure 3.6 is a test area of 4.00 square inches and a periphery of 18.0 inches. The

Figure 3.6: Test figure for determining accuracy of a polar planimeter and a map measurer



scale: 1" = 1"

Area = 4.00 square inches

Peripheral distance = 18.0 inches

results of three trials by each subject appear in Table 3.1.

The results of the experiments show that these techniques are capable of measuring areas to within 1% of their true values and lengths to within 2% of their true values. These errors are therefore neglected and it is assumed that the values obtained by measurement are the true values of the independent variables.

3.3.1. Results: Polar planimeter used to measure a nominal area of 4.00 sq. in.

Mean of the observations	4.0432 sq. inches
Standard deviation of the observations	0.0196 sq. inches
Maximum	4.0790 sq. inches
Minimum	3.990 sq. inches
Range of observations	0.0820 sq. inches

Limits on accuracy at 95% confidence interval ($\pm 2\sigma$) = 0.0392 sq. in.

Accuracy of the measurement of areas $\frac{0.0392}{4.0000} \times 100 = 0.975\%$

The results of statistical analysis of variance revealed no significant differences between groups, individuals within a group, or of observations for an individual. See Table 3.1.

Results: Map measurer used to measure a nominal length of 18 inches.

Mean of the observations	17.863 inches
Standard deviation of the observations	0.1088 inches
Maximum	18.95
Minimum	17.00
Range of observations	1.95

Limits of accuracy at 95% confidence interval ($\pm 2\sigma$) = 0.2176

Accuracy of length measurement $\frac{0.2176}{18.0000} \times 100 = 2.01\%$

Table 3.1 (a) Polar Planimeter-Results of experimental observations and ANOV

Group	Results of Successive Trials		
	Polar Planimeter		
Tech. Trained (m)	Trial # 1	Trial # 2	Trial # 3
Subject # 1	40.21	40.37	40.43
Subject # 2	40.58	40.37	40.28
Subject # 3	40.43	40.73	40.54
Tech. Untrained (F)			
Subject # 1	40.79	40.46	40.56
Subject # 2	40.40	40.45	40.38
Subject # 3	40.21	39.97	40.62

Mean of observations = 40.432 sq. in. Standard deviation of observations = 0.196 sq. in.

ANALYSIS OF VARIANCE

Source	Corrected SS	d_f	Mean S	F Calculated	F value from Tables (d_f, 0.05)
Between Groups	0.000555284	1	0.000555284	0.011	7.71
Within Groups	0.012979254	2	0.006489627	0.129	6.94
Within Persons	0.017814804	2	0.008907400	0.177	6.94
Between Gr x Within Gr	0.241110201	2	0.120555103	2.402	6.94
Between Gr x Within Persons	0.078882337	2	0.039441168	0.785	6.94
Within Gr x Within Perons	0.097819984	4	0.024454966	0.487	6.39
Error	0.200756848	4	0.050189212		
Total	0.649918795	17			

Table 3.1 (b) Map Measurer-Results of experimental observations and ANOV

Group	Results of successive trials		
	Map Measurer		
Tech. Trained (m)	Trial #1	Trial #2	Trial #3
Subject # 1	90.2	94.7	88.5
Subject # 2	85.0	85.4	86.6
Subject # 3	89.8	90.5	89.3
Tech. Untrained (f)			
Subject # 1	88.7	89.2	88.9
Subject # 2	89.5	91.8	92.4
Subject # 3	89.6	88.5	89.1

Mean of observations = 89.317 in standard deviation of observations = 0.544 in.

ANALYSIS OF VARIANCE

Source	Corrected ss	d_f	Mean s	F Calculated	F values from Tables (d_f,0.05)
Between groups	4.500000000	1	4.5000000000	2.526	7.71
Within groups	7.364725113	2	3.682362556	2.067	6.94
Within persons	3.134400368	2	1.567199707	0.879	6.94
Between Gr x Within Gr	50.040527344	2	25.020263672	14.045	6.94
Between Gr x Within Per	2.903440475	2	1.451720238	0.8149	6.94
Within Gr x Within Per	13.995481491	4	3.498869896	1.964	6.30
Error	7.125673294	4	1.781417847		
Total	89.064270020	17			

The results of the statistical analysis of variance revealed that the interaction (group x persons) was significant. Hence, care must be taken while training the non-technical group in the use of the map measurer.

3.4. Development of the model

A standard stepwise multiple regression program, "STEPWISE" was selected as a basis for the development of the model required to estimate the stitch count (2). This program utilizes the stepwise (step-up) technique to select variables to formulate a model.

At the outset only the various continuous (stitch) variables were used to build a linear model. The following model was tested:

$$SC = b_0 + b_1AB + b_2AF + b_3LC + b_4LS + b_5LL + e$$

where:

SC = the stitch count of the emblem

AB = the area of the background stitches

AF = the area of the fill-in stitches

LC = the length of the cover stitches

LS = the length of the spring stitches

LL = the length of the linear stitches

e = is the error term.

b_i = coefficients to be determined by MLR.

The original data for the 62 emblems are listed in Table 3.2. Columns 7 through 11 are the continuous variables used in this regression. The results of the "STEPWISE" (IBM supplied) appear in Table 3.3. The

Table 3.2 Data for 62 Emblems.

S	Dummy Variables					Continuous Variables					Dependent Variables
No.	S 12/4	NBG	C1	C2	C3	AB	AF	LC	LS	LL	SC
01	0	0	0	0	1	4140	1355	5100	2600	27400	3790
02	1	0	0	0	1	1270	1600	0700	33200	23000	2455
03	1	0	0	1	0	2635	2120	5500	24450	34000	3215
04	0	1	1	0	0	0000	1730	0550	32300	13600	1815
05	0	1	1	0	0	0000	2445	0100	22100	26600	2600
06	0	1	0	0	0	0000	0771	8000	02250	08800	0305
07	1	0	1	0	0	1720	1755	0000	18100	30550	2017
08	0	0	1	0	0	2500	1410	8750	60200	19000	2925
09	0	0	0	0	0	1560	1780	9100	08150	24750	2384
10	0	1	0	0	0	0000	1685	3300	81750	13500	1475
11	0	1	0	1	0	0000	2845	0130	19600	23750	1830
12	0	1	0	0	0	0000	0763	7250	07100	09300	0655
13	0	1	0	0	0	0000	0984	9050	07200	15000	0907
14	0	0	0	0	1	0520	1210	6700	24600	32500	1825
15	0	0	0	0	0	1716	0947	5300	00000	14100	1750
16	0	0	1	0	0	1048	1347	2050	13150	51400	2152
17	0	0	1	0	0	0460	0520	0700	13200	18750	2080
18	1	1	0	0	0	0000	1740	8825	20625	11850	1751
19	0	1	0	0	0	0000	1005	3300	10300	10500	1180
20	0	0	1	0	0	1610	0800	4500	15000	21200	1763
21	0	0	0	1	0	0724	2380	4000	22100	45750	2425
22	0	0	0	0	1	1516	1807	2170	30200	26500	3030
23	0	1	0	0	0	0000	1299	0700	08100	09300	1166
24	1	1	0	0	0	0000	1393	1550	27600	30000	1025
25	0	1	1	0	0	0000	1345	4000	09750	10150	0480
26	1	1	1	0	0	0000	2434	3150	23250	23000	2398
27	0	1	1	0	0	0000	1948	2150	25600	17350	1680
28	1	0	0	0	1	10440	0586	7050	34100	15750	6620
29	0	1	0	0	0	0000	0675	1650	22000	12200	1075
30	0	1	1	0	0	0000	1805	8100	07700	14200	1765
31	1	1	1	0	0	0000	1541	1700	29000	27500	2121
32	0	1	0	0	0	0000	1201	1700	09750	14800	1116
33	0	1	0	0	0	0000	2531	1200	27100	10800	1450
34	1	0	0	1	0	0685	1020	3250	39000	34800	1555
35	1	0	1	0	0	2790	0845	9000	19700	56700	3190
36	0	0	0	0	0	2145	1091	0850	00000	20850	2211
37	1	1	1	0	0	0000	1754	2300	21100	31600	1571
38	0	1	1	0	0	0000	1852	2500	12350	11250	1697
39	0	0	0	1	0	0735	1379	9500	35800	29600	1853
40	0	1	1	0	0	0000	1337	1420	22250	15500	1518
41	1	0	1	0	0	1825	1786	6900	31000	28750	2715
42	0	0	0	1	0	3380	1120	5600	15100	36270	2722
43	1	1	0	0	0	0000	1028	3380	29150	13500	1280
44	1	0	0	1	0	4900	0601	6600	19500	28700	3682
45	0	1	0	0	0	0000	1552	3200	10000	17100	1155
46	0	1	1	0	0	0000	1265	8150	23050	25850	1715
47	1	1	0	0	0	0000	2292	2400	18350	11050	2182
48	1	1	0	0	0	0000	1736	8100	18900	16000	1985
49	1	1	0	0	0	0000	0968	7100	24500	12500	0730
50	0	0	1	0	0	1010	1982	8150	28200	21200	2098
51	0	0	1	0	0	1270	0679	0350	11000	19800	1393
52	0	1	0	0	0	0000	1142	0600	21400	09100	0827
53	0	1	0	0	0	0000	1515	1900	40250	15000	1275
54	0	1	0	0	0	0000	0930	4250	12800	09700	0543
55	1	1	1	0	0	0000	2000	1800	24400	27550	1610
56	1	0	1	0	0	2898	1330	2000	16500	25700	3133
57	0	1	1	0	0	0000	1815	7600	24450	17600	2105
58	0	0	0	0	0	1622	0270	9600	27650	11950	1275
59	0	0	1	0	0	0694	1376	5600	20700	20380	1626
60	0	1	0	1	0	0000	2797	4820	09600	19600	1880
61	0	0	0	1	0	1032	0761	0900	16900	27600	1503
62	0	1	1	0	0	0000	2211	3700	06700	22400	1490

Table 3.3 Results for Model 1. Continuous variables

Number of observations = 62

FIN = 4.00 FOUT = 3.00

Mean of the response = 1899.09 Std deviation of the response = 973.40

Step #	Regression Equation	Std error of estimate for reg equation	Multiple corr coeff R x 100	d_f	Goodness of fit F	F comparison from Tables
1	$b_0 + b_1$ AB	503.53	85.78	(1,60)	167.20	4.00
2	$b_0 + b_1$ AB + b_2 AF	333.35	94.13	(2,59)	229.69	3.15
3	$b_0 + b_1$ AB + b_2 AF + b_3 LC	296.66	95.46	(3,58)	198.85	2.77
4	$b_0 + b_1$ AB + b_2 AF + b_3 LC + b_4 LS	287.24	95.83	(4,57)	160.29	2.53
5	$b_0 + b_1$ AB + b_2 AF + b_3 LC + b_4 LS + b_5 LL	279.73	96.12	(5,56)	136.03	2.37

Estimating equation:

= 66.45 + 468.57 (AB) + 317.41 (AF) + 38.82 (LC) + 6.00 (LS) + 8.34 (LL)

% Variation explained = $R^2 = (96.12)^2 = 92\%$

$$\frac{\text{Standard error}}{\text{Mean response}} \times 100 = \frac{279.73}{1899.09} \times 100 = 14.7\%$$

results gave a standard error to mean response ratio of 14.7% with 92% of the variation explained by the assumed model. An entering F level of 5 per cent has been used throughout the analysis to screen out the weak contributors to the regression equation.

Next, the inclusion of the interactions and powers of the continuous variables was considered in an effort to improve the quality of the forecast. The variables and transformations used are listed in Table 3.4. Variables X_7 through X_{16} are all first order interactions of the continuous variables. This was done with a view of not omitting any possible interaction which may contribute to the stitch count. X_{17} through X_{21} are the second order interaction terms for the five types of stitches. The 3/2 powers for the areas AB, AF were also included. Since areas were being regressed with lengths, higher order terms were thought of as being possible candidates for selection.

The data for the 62 emblems is the same as listed in Table 3.1. The results are shown in Table 3.5. Here the ratio of standard error to mean response is 15.22% with 92% of the variation about the mean explained. Also two interactions, (AF x LC) and (LS x LL), entered the regression equation, with no improvement in the forecast as compared to the linear model.

Examination of the mean and standard deviation of the stitch count for the sample revealed that the standard deviation (971.79) was 0.51 of the mean response (1899.09). This indicated that there was a great deal of variation in the raw data. Upon further investigation it was found that the ratio of standard deviation to mean response for emblems

Table 3.4 Variables for Model 2. Continuous independent variables and interactions

Variable no.	Variable	Description
		Original independent variable
x_1	AB	Area of the background stitch
x_2	AF	Area of the fill-in stitch
x_3	LC	Length of the cover stitches
x_4	LS	Length of the spring stitches
x_5	LL	Length of the linear stitches
		Dependent variable
		Stitch count - total number of stitches in an emblem
		Transformations used
x_7	AB. AF	Area of the background stitch X area of the fill-in stitch
x_8	AB. LC	Area of the background stitch X length of the cover stitches
x_9	AB. LS	Area of the background stitch X length of the spring stitches
x_{10}	AB. LL	Area of the background stitch X length of the linear stitches
x_{11}	AF. LC	Area of the fill-in stitch X length of the cover stitches
x_{12}	AF. LS	Area of the fill-in stitch X length of the spring stitches
x_{13}	AF. LL	Area of the fill-in stitch X length of the linear stitches
x_{14}	LC. LS	Length of the cover stitches X length of the spring stitches
x_{15}	LC. LL	Length of the cover stitches X length of the linear stitches
x_{16}	LS. LL	Length of the spring stitches X length of the linear stitches
x_{17}	$(AB)^2$	(Area of the background stitches)^2
x_{18}	$(AF)^2$	(Area of the fill-in stitch)^2
x_{19}	$(LC)^2$	(Length of the cover stitches)^2
x_{20}	$(LS)^2$	(Length of the spring stitches)^2
x_{21}	$(LL)^2$	(Length of the linear stitches)^2
x_{22}	$(AB)^{3/2}$	(Area of the background stitches)$^{3/2}$
x_{23}	$(AF)^{3/2}$	(Area of the fill-in stitches)$^{3/2}$

Table 3.5 Results for Model 2. Continuous independent variables and interactions

Number of reservations = 62

Fin = 4.00 FOUT = 3.00

Mean of the response = 1899.99 std. deviation of the response = 971.79

Step #	Regression equation	Std. error of estimate for reg eqn	Multiple corr coeff (R x 100)	d_f	Goodness of fit F	F value from Tables
1	$b_0 + b_1 \cdot AB$	503.53	85.78	(1,60)	167.20	4.00
2	$b_0 + b_1 \cdot AB + b_2 (AF \cdot LC)$	514.25	94.80	(2,59)	262.16	3.15
3	$b_0 + b_1 \cdot AB + b_2 (AF \cdot LC) + b_3 (LS \cdot LL)$	289.28	95.69	(3,58)	210.12	2.77

Estimating eqn:

SC = 703.55 + 495.31 (AB) + 21.59 (AF · LC) 10.40 (LS · LL)

% of variation explained = $R^2 = (95.69)^2 = 91.2\%$

$$\frac{\text{Std Error of Estimate}}{\text{Mean Response}} \times 100 = \frac{289.28}{1899.00} \times 100 = 15.22\%$$

with a background area stitch was 0.43 and for emblems without background area stitches was 0.39. This indicated that a breakdown of the emblems into two levels, representing the presence or absence of background area might lead to better results. Also at the same time the inclusion of dummy variables for size and color was considered. The data for the 62 emblems with five dummy variables, S12/4, NBG, C_1, C_2, C_3 and the five continuous variables is listed in Table 3.2. Table 3.6 lists the variables used in the program. All interactions have been dropped, except the following:

Length of the cover stitches x Area of the fill-in stitch (LC X AF)

Length of the spring stitches x Length of the linear stitches (LS X LL)

Length of the cover stitches / Area of the fill-in stitches (LC / AF)

The product terms were retained as they were known to have influenced the estimated stitch count in the previous regression equation (See Table 3.5). As most of the unknown designer effects are introduced in fill-in areas, it was felt that a quotient interaction, LC/AF, would be a possible candidate for selection by the stepwise regression program. Table 3.7 shows the results of the program. Here 92.2% of the variation has been explained by the assumed model. Also the ratio of standard error of estimate to mean response has improved from 15.22 to 14.6%. The linear model still remains the best fit to the given data, as the improvement is not worth the added complexity.

It was now established that background area did influence the stitch count, since this was the first variable to enter the regression equation. There is an appreciable number of stitches per square inch of background area. This indicated the possible building of two models for the two

Table 3.6 Variables for Model 3. Continuous variables, significant interactions and dummy variables

Variables used in the development of the estimating equation

Variable #	Variable	Description
		Independent variables
		Dummy independent variables
x_1	S 12/4	Size of the emblem. S 12/4 = for 2" S 12/4 = 1 for 3"
x_2	NBG	Background area - No background area NBG = 0 - emblems with BG NGB = 1 - emblems without BG
x_3	C_1	2 colors (C_1 C_2 C_3) = 1 0 0 for 2 colors
x_4	C_2	3 colors = 0 1 0 for 3 colors
x_5	C_3	4 or more colors = 0 0 1 for 4 or more colors
		= 0 0 0 for 1 color
		Continuous independent variables
x_6	AB	Area of the background stitch
x_7	AF	Area of the fill-in stitch
x_8	LC	Length of the cover stitches
x_9	LS	Length of the spring stitches
x_{10}	LL	Length of the linear stitches
		Dependent variable
x_{11}	SC	Stitch count - Number of stitches in an emblem
		Transformations used
x_{12}	LC·AF	Length of the cover stitches x area of the fill-in stitches
x_{13}	LC/AF	Length of the cover stitches/area of the fill-in stitches
x_{14}	LS·LL	Length of the spring stitches x length of the linear stitches

Table 3.7 Results for Model 3. Continuous variables, significant interactions and dummy variables

Fin = 4.00 FOUT = 3.00

Mean of the response = 1899.09 Standard deviation of the response = 971.79

Step #	Regression equation	Std error of estimate for regression eqn	Multiple correlation coeff. (R x 100)	d_f	Goodness of fit F	F Comparison from Tables
1	$b_0 + AB \cdot b_1$	503.53	85.78	(1,60)	167.20	4.00
2	$b_0 + AB \cdot b_1$ + $(AF \cdot LC)b_2$	314.25	94.80	(2,59)	262.17	3.15
3	$b_0 + AB \cdot b_1$ + $(AF \cdot LC)b_2$ + $(LS \cdot LL)b_3$	287.78	95.74	(3,58)	212.52	2.77
4	$b_0 + AB \cdot b_1$ + $(AF \cdot LC)b_2$ + $(LS \cdot LL)\, b_3$ + $c_2 \cdot b_4$	277.24	96.12	(4,57)	173.12	2.53

Estimating Equation:

$SC = 682.95 + 501.17\ (AB) + 22.05\ (AF \cdot LC) - 252.10\ (C_2)$.

Percent Variation Explained = $R^2 = (96.12)^2 = 92.2\%$

$$\frac{\text{Standard Error of Estimate}}{\text{Mean Response}} \times 100 = \frac{277.24}{1899.79} \times 100 = 14.60\%$$

categories of emblems: those with background area and those without background area. Of the 62 emblems that constituted the sample, 27 had background areas. Both dummy and continuous variables were used in the regression analysis for these two catagories of emblems. Emblems having no background area had no more than 3 colors and consequently, the dummy variable representing 4 or more colors, C_3, was dropped. For emblems with background area the variables used and the results of the program are shown in Tables 3.8 and 3.9. For emblems without background areas, the variables used and the results of the analysis are shown in Tables 3.10 and 3.11.

The ratio of standard error to mean response for emblems with background area was 13.28% with 91.2% of the variation explained and 13.9% for the emblems without background area with 88.2% of the variation explained. The standard error to mean response ratio for the linear model was 14.6%. This represents an improvement of less than 1%. Since the object of this analysis is a quick but reasonably good estimate, the linear model is favored over the two individual models.

Hence, the estimating equation for the stitch count of an emblem is:

$$SC = 66.45 + 468.57\ (AB) + 317.41\ (AF) + 38.82\ (LC) + 6.00\ (LS) + 8.34\ (LL) \qquad (3.2)$$

where:

SC = estimated stitch count of the emblem

AB = area of the background stitches, in square inches

AF = area of the fill-in stitches, in square inches

LC = length of the cover stitches, in inches

Table 3.8 Variables for Model 4-background area only

Variable #	Variable	Description
		Independent variables
		Dummy independent variables
x_1	S 12/4	Size of the emblem S 1214 = 0 for 2" = S 1214 = 1 for 3"
x_2	C_1	2 colors (C_1 C_2 C_3) = 1 0 0 for 2 colors
x_3	C_2	3 colors = 0 1 0 for 3 colors
x_4	C_3	4 or more colors = 0 0 1 for 4 or more colors
		= 0 0 0 for 1 color
		Continuous independent variables
x_5	AB	Area of the background stitch
x_6	AF	Area of the fill-in stitch
x_7	LC	Length of the cover stitches
x_8	LS	Length of the spring stitches
x_9	LL	Length of the linear stitches
		Dependent variable
x_{10}	SC	Stitch count - Number of stitches in the emblem
		Transformations used
x_{11}	LC·AF	Length of the cover stitches X Area of the fill-in stitches
x_{12}	LC/AF	Length of the cover stitches / Area of the fill in stitches
x_{13}	LS·LL	Length of the spring stitches X Length of the linear stitches

Table 3.9 Results for Model 4. Background area only

Number of observations = 27

Fin = 4.2 FOUT = 3.0

Mean of the response = 2495.81 Standard deviation of the response = 1076.5706

Step #	Regression equation	Standard error of estimate for regression eqn.	Multiple correlation coeff (R x 100)	d_f	Goodness of fit F	F Comparison from Tables
1	$b_0 + AB \cdot b_1$	436.59	91.74	(1,25)	133.01	4.24
2	$b_0 + AB \cdot b_1 + AF \cdot b_2$	331.64	95.52	(2,24)	124.98	3.40

Estimating Equation

SC = 668.77 + 535.13 (AB) + 558.53 (AF)

Percent Variation Explained = $(95.52\%)^2 = R^2 = 91.2\%$

$$\frac{\text{Standard error of estimate}}{\text{Mean response}} \times 100 = \frac{331.64}{2495.81} \times 100 = 13.28\%$$

Table 3.10 Variables for Model 5 - No background area

Variable #	Variable	Description
		Independent variables
		Dummy independent variables
x_1	S 12/4	Size of the emblem S 12/4 = 0 for 2" S 12/4 = 1 for 3"
x_2	C_1	2 colors (C_1 C_2) = 1 0 for 2 colors
x_3	C_2	3 colors = 0 1 for 3 colors
		= 0 0 for 1 color
		Continuous independent variable
x_4	AF	Area of the fill-in stitch
x_5	LC	Length of the cover stitches
x_6	LS	Length of the spring stitches
x_7	LL	Length of the linear stitches
		Dependent variable
x_8	SC	Stitch count - Number of stitches in the emblem
		Transformations Used
x_9	LC·AF	Length of cover stitcher X Area of the fill-in stitches
x_{10}	LC/AF	Length of the cover stitches / Area of the fill-in stitches
x_{11}	LS·LL	Length of the spring stitches X Length of the linear stitches

Table 3.11 Results for Model 5 - No background area

Number of observations = 35

Fin = 4.1 FOUT = 3.0

Mean of the response = 1438.77 Standard deviation of the response = 554.19

Step #	Regression equation	Standard error of estimate for regression equation	Multiple corr coefficient (R x 100)	d_f	Goodness of fit F	F Comparison from Tables
1	$b_0 + LCb_1$	262.14	88.47	(1,33)	118.96	4.14
2	$b_0 + LC \cdot b_1 + (LS \cdot LL)b_2$	227.53	91.72	(2,32)	84.84	3.30
3	$b_0 + LCb_1 + (LS \cdot LL)b_2 + (AF)b_3$	213.29	93.00	(3,31)	66.18	2.91
4	$b_0 + LC \cdot b_1 + (LS \cdot LL)\, b_2 + (AF)\, b_3 + (LC \cdot AF)b_4$	201.07	94.07	(4,30)	57.07	2.69

Estimating Equation

$$SC = -437.87 + 568.59\ (LC) + 99.46\ (LS \cdot LL) - 23.60\ (AF) + 0.3579\ (LC \cdot AF)$$

Percent Variation Explained = $R^2 = (94.07\%)^2 = 88.2\%$

$$\frac{\text{Standard error of estimate}}{\text{Mean response}} \times 100 = \frac{201.07}{1438.77} \times 100 = 13.91\%$$

LS = length of the spring stitches, in inches

LL = length of the linear stitches, in inches.

The results of the analysis for estimating the stitch count are summarized in Table 3.12.

In reviewing the regression work certain observations can be made. Variation in the techniques that designers and punchers use is an important factor and this breakdown would be desirable to account for the designer effect.

The interactions (AF X LC) and (LS X LL) have entered into some of the equations. The nature of the (AF X LC) interaction is not completely understood. An increase in the fill-in area (AF) does not in itself insure an increase or decrease in the length of the cover stitches (LC). An increase of the fill-in area may or may not increase the length of the cover stitches depending on how the area is disposed. The width of the embroidery stitch may vary from 0.166 mm to 16.67 mm and hence the uncertain relationship between the fill-in area and cover stitches.

The (LS X LL) interaction could be explained by the fact that the more the linear stitches there are, the closer the needle is to the point of stitching on the body and hence, the fewer the number of spring stitches required to get to the point. Practice, however, shows that the spring stitches are tied down to one judiciously chosen point for ease of picking. (Picking is the removal of the long threads deposited by spring stitching).

The linear model appears to have provided the best fit to the data. Although this could have been hypothesized at the outset the subsequent

Table 3.12 Summary of the regression analysis

Model No.	Description	Table No. of variables used	Table of results	Percentage of variation explained	$\frac{\text{Standard Error}}{\text{Mean Response}} \times 100$
1	Model using continuous variables	3.2	3.3	92.0	14.70
2	Model using continuous variables and interactions	3.4	3.5	91.2	15.22
3	Model using continuous variables, significant interactions and dummy variables	3.6	3.7	92.9	14.60
4	Model for emblems with background area using continuous variables, significant interactions and dummy variables	3.8	3.9	91.2	13.28
5	Model for emblems without background area using continuous variables, significant interactions and dummy variables	3.10	3.11	88.2	13.91

work with the other models helps substantiates the validity of the linear model. Although the problem needs more probing in the area of the relation between cover stitches and fill-in stitches, the procedure and model developed are suitable for estimation purposes.

CHAPTER 4

RESULTS AND CONCLUSIONS

The purpose of this chapter is to formulate an equation for estimating the normal stitching time for a batch of emblems. In Chapter two the normal operation times for the embroidery process were developed and a method for estimating the machine running time was outlined based on the stitch count of the emblem. Chapter three was devoted to the estimation of the stitch count using a sketch of the emblem. The present chapter uses these times to estimate the normal stitching time for a batch of emblems deriving the necessary information from the emblem sketch.

The method used to formulate the normal time equation involves the blocking of the flowchart (Figure A1) into segments or groups which are common in certain categories of emblems. Operations that are constant in nature, that is, occur in the stitching process of all emblems are grouped together. Operations that vary with the order quantity and characteristics of the emblem are grouped separately. Stitching operations which are used to estimate the machine running time form another group. The logical relationship between these groups forms the basis of an estimating equation for the normal stitching time for a batch of emblems.

4.1. Development of a normal time formula

When bidding on prospective jobs, a bidder has the company logotype and the desired order quantity available to him. After receiving

an artist's sketch of the logotype the bidder estimates:

1) the stitch count of the emblem,
2) the number of rows of the emblem desired to fill the order,
3) the normal time to stitch this batch which determines the cost to the bidder.

4.1.1 Estimation of the stitch count

In order to estimate the stitch count the size of the emblem is first determined as described in Section 3.1. Then the following independent variables are measured from the emblem in order to estimate the stitch count:

1) Area of the background stitch,
2) Area of the fill-in stitch,
3) Length of the cover stitching,
4) Length of the spring stitching,
5) Length of the linear stitching.

Generally, the sketch does not indicate all of the required guide, border and spring stitches. These must be added to the sketch before the measurements can be completed.

4.1.1.(a) Insertion of guide stitches and determination of emblem height

If the emblem border is machine embroidered or the emblem is irregular in shape, it is handcut in which case no border stitches are required. If, however, the border is to be surged, border stitches must be inserted on the entire periphery of the sketch. For multicolored emblems, guide stitches are required to reference these colors.

Guide stitches appear in the form of a regular figure (square, triangle, rectangle) at the top and bottom edge of the emblem as it stands on the goods. The guide stitches do not necessarily take the form of a regular figure, but this is the manner in which they are most frequently encountered. The only restriction on the placement of these guide stitches is that they should lie within the 2" stitching width of one needle in the 8/4 repeat or within the 3" stitching width of one needle in the 12/4 repeat. To save space vertically on the stitching field the guide stitches should be placed fairly close (about 1/8" to 3/16") to the edge of the emblem. The machine frame is centered horizontally before stitching commences and after stitching is completed. Each needle starts stitching at the point X (See Figure 4.3) on one side of the emblem, traces the guide stitch path, stitches the emblem segment to the stitched in that color, traces the guide path on the other side of the emblem and stops at the point X on the other side. These points X should lie on a vertical line so that the frame is automatically centered horizontally after each row of emblems has been stitched in each color. All colors must be made to trace the guide paths on both sides of the emblem. It is now apparant that the height (h) that each row of emblems occupies on the stitching field is the distance between the extreme guide stitches measured vertically.

4.1.1. (b) Insertion of spring stitches

Some thought must be given to the path of the required spring stitches before inserting lines representing these spring stitches on the sketch. Spring stitches will normally be required to go to and come

from any area to be stitched in the body of the emblem, for example disjoint letters, Figure 2.3. If the area to be stitched extends to the border of the emblem usually no spring stitches are required to stitch this area. Spring stitches are anchored to a judiciously chosen point such that:

1) the strings deposited by spring stitching are long enough to be accessible to the picker,
2) a minimum number of strokes of the picking knife are required to pick these strings from an emblem,
3) a minimum number of stitches are required to produce such produce such stitches.

In addition, the anchor point must lie either on the border or outside the body of the emblem but within the 2" stitching width of a needle in the 8/4 repeat or within the 3" stitching width of a needle in the 12/4 repeat.

4.1.2. Estimation of the machine running time

Now all the independent variables used in the regression equation 3.2 are measured using a polar planimeter and a map measurer as explained in Section 3.3. If a picture is used in the data reduction process, appropriate transformations are made on the measured values to give the actual values of the area and lengths on the emblem. The machine running time for a row of emblems may now be estimated from Equation (2.4) as:

$$R = N_f/60 + N_s/30$$

$$= N_f/60 + 2N_s/60$$

Substituting for N_s from Equation (2.2)

$$R = ((N_f + N_s) + 2\ LS)/60$$

$$= (SC + 2\ LS)/60 \qquad (4.1)$$

From Equation (3.2) the estimating equation for the stitch count of an emblem is:

$$SC = 66.45 + 468.57(AB) + 317.41(AF) + 38.82(LC) + 6.00(LS) + 8.34(LL) \qquad (4.2)$$

where:

AB = the area of the background stitch,

AF = the area of the fill-in stitch,

LC = the length of the cover stitch,

LS = the length of the spring stitch,

LL = the length of the linear stitch.

Hence the machine running time for a row of emblems, R, may be computed, knowing the variables in the estimating equations.

4.2. Batch size considerations

The next step is to decide on the number of rows of emblems required to fill the order. It is assumed that one span consists of one 42 inch width of goods. Not all 42 inches are available for stitching. Due to the physical disposition of the stitching elements, a 1 1/2 inch allowance is to be made on the top and bottom edges, leaving 39 inches for actual stitching. Thus 39 inches is the effective width of the span. Also, for a 24 inch machine the effective stitching height is 23 inches. This is to prevent the embroidery frame from touching its supports. Since all 39 inches cannot be stitched on one setting of a 24 inch machine, one rollover is necessary to stitch the entire span.

Let Q = the order quantity,

m_r = number of emblems per row,

$$= \begin{cases} 340 \text{ for an 8/4 repeat,} \\ 230 \text{ for a 12/4 repeat,} \end{cases}$$

n = the total number of stitching rows required to complete the order,

then,

n = smallest integer containing Q/m_r (since it is disadvantageous to stitch a fraction of a row).

Then, the number of stitching fields, f, required to stitch this number of rows, n, is to be calculated. A stitching field is defined as the height of goods embroidered on one setting of the fabric, that is, the height embroidered between the spanning operation and rollover operation, or between two rollover operations, or between the rollover operation and removal of finished goods from the machine. On a 24 inch machine, using 42 inch width of goods in a span, one rollover is necessary to stitch the entire 39 inches effective width of goods, hence there are two stitching fields.

Let,

n_s = the number of rows per span of 39 inch effective width of goods,

h = height that one row of emblems occupies on the stitching field (as defined in Section 4.1.1.(a)), in inches,

then,

n_s = largest integer contained in (39/h). (4.4)

Also, let n_i = number of rows in the ith stitching field, then n_i

shall have two values for a 42 inch wide span, corresponding to the two stitching fields: n_t corresponds to the number of rows of emblems on the first stitching field (on the top 1/2 span) and n_b corresponds to the number of rows of emblems on the second stitching field (on the bottom 1/2 span). Then,

$$n_s = n_t + n_b$$

Practice in the industry indicates that as much as possible of the 23 inch machine stitching height is stitched on the first stitching field, that is, on the top 1/2 span. Hence,

$$n_t = \text{largest integer contained in } (23/h), \quad \text{and} \quad n_b = n_s - n_t \tag{4.5}$$

Knowing n, the number of rows required to fill the order and n_i, the number of rows of emblems in the ith stitching field, the number of stitching fields, f, required to complete the order can be calculated. Assuming that every order starts with a fresh span,

$$f = 2(\text{LIC}(n/n_s)) + \begin{cases} 1 & \text{if } n_f \leq n_t \\ 2 & \text{if } n_{f-1} = n_t \text{ and } n_f \leq n_t, \end{cases} \tag{4.6}$$

where,

LIC(M) is the largest integer contained in M,

n_f is the number of rows in the fth stitching field.

Further, the fraction of each stitching field x_i that the order occupies is determined by,

$$x_i = 1 \quad \text{if } n_i = n_t \text{ or } n_b,$$

$$x_i = \begin{cases} n_f / n_t & \text{if the last field is a top field,} \\ n_f / n_b & \text{if the last field is a bottom field.} \end{cases} \qquad (4.7)$$

If the order does not start with a fresh span of goods necessary changes must be made to the values of f and x_i.

4.3 Macro flowchart

Figure 4.1 illustrates the flowchart for the embroidery process required to stitch a batch of emblems. This flowchart is essentially the same as Figure A1, where certain operations have been blocked into groups. This flowchart is a general chart for more than one span of goods whereas Figure A1 is a flowchart for a single 42 inch span.

The blocks used in the macro-flowchart are:

1) k- Jacquard mounting (See Table C10)

2) L-Load spools onto machine Depending on the repeat and whether the spools are loaded on the top row or bottom row, there are different types of loading operations. See Table C4 for the 8/4 repeat and Table C5 for the 12/4 repeat.

3) U-Unload spools from the machine Again depending on the repeat and whether the spools are loaded on the top row or bottom row, there are different types of unloading operations. See Table C17 for the 8/4 repeat and Table C18 for the 12/4 repeat.

4) I-Initialization This block consists of the following operations

	8/4 repeat	12/4 repeat
i) Threading operation (See Table C6 for 8/4 repeat and Table C7 for 12/4 repeat)	22.36 min.	14.52 min.
ii) Checking operation-1	1.90 min.	1.90 min.

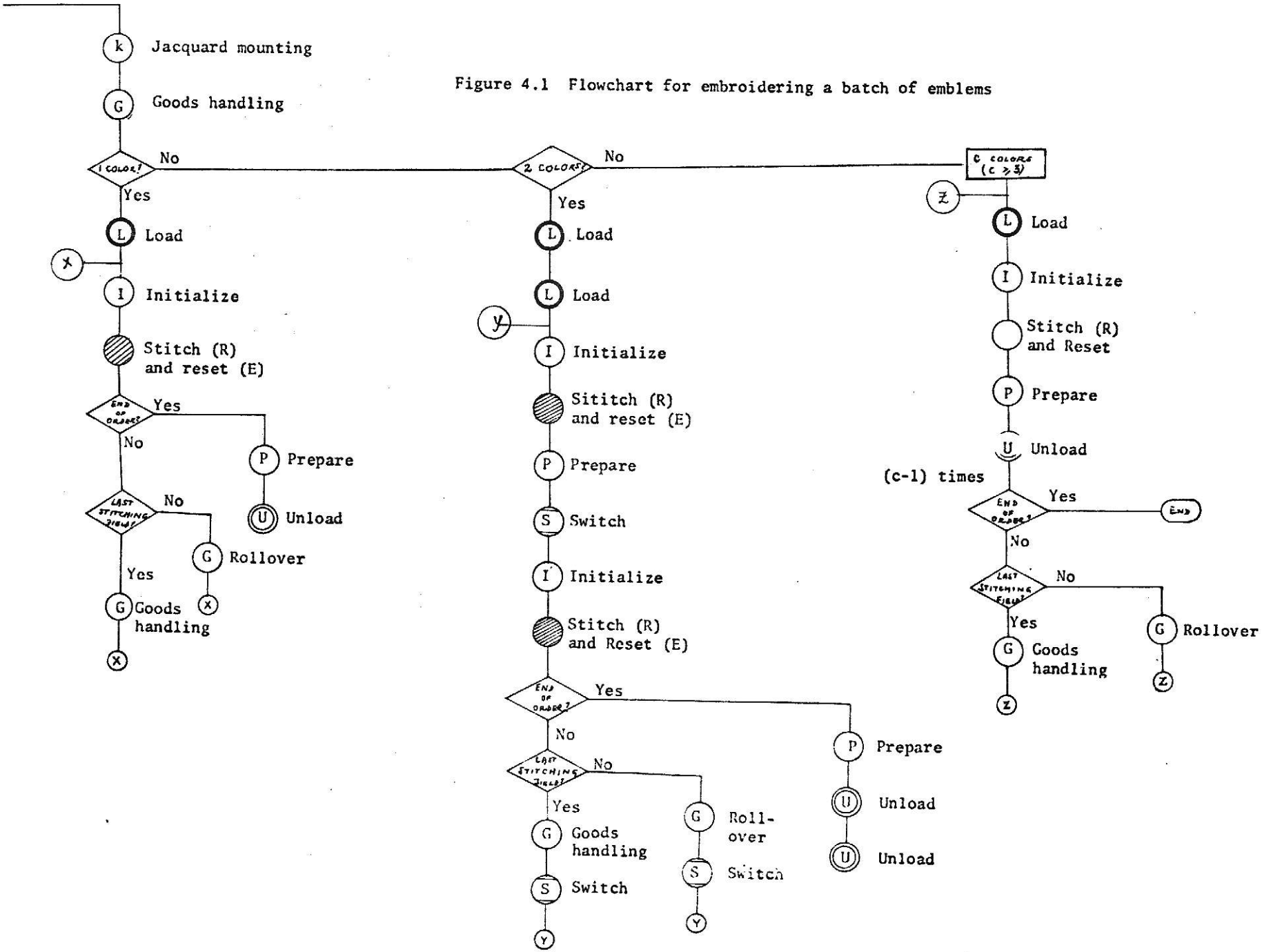


Figure 4.1 Flowchart for embroidering a batch of emblems

(iii)	Shuttle servicing operation (See Table C9)	2.57 min.	2.57 min.
(iv)	Checking operation-2 (See Table C11)	0.40 min.	0.40 min.
(v)	Initialization operation (See Table C12)	3.46 min.	3.46 min.
		30.69 min.	22.85 min.

Thus the time estimate for the I block for the 8/4 repeat is 30.69 min. and 22.85 min. for the 12/4 repeat.

5) G-Goods handling This block consists of the elements that are part of every order:

i)	Goods cutting operation (See Table C1)	13.72 min.
ii)	Goods spanning operation (See Table C2)	16.82 min.
iii)	Stiffener spanning operation (See Table C3)	3.72 min.
iv)	Rollover operation (See Table C18)	11.95 min.
v)	Preparation-2 (See Table C19)	4.22
vi)	Goods removal operation (See Table C20)	8.98 min.
		59.41 min.

Hence the value of the G block is 59.41 minutes.

6) Preparation-1 (See Table C13) This is an operation preparatory to the unloading of spools or the switching of spools.

7) S-Switching Depending on the repeat there are two different types of switching operations. See Table C14 for the 8/4 repeat and Table C15 for the 12/4 repeat.

The values for each of these blocks for the 8/4 repeat and 12/4 repeat are tabulated in Table 4.1.

4.4. Normal time formula

The total normal time, T, in minutes required to stitch a batch of emblems is thus:

$$T = k + \sum_{i=1}^{f} \left(\frac{G}{2} x_i + n_i R + cI + c(n_i - 1)E\right) + V(c) \qquad (4.8)$$

where:

k = time required to mount the jacquard,
= 1.84 minutes,

G/2 = the operational time required for the G block in minutes for one stitching field,

n_c = number of rows of emblems on the ith stitching field,

x_i = fraction of the vertical height of the ith stitching field that the emblem order occupies, $(0 \leq x_i \leq 1)$,

I = time required for the I block,

R = machine running time for stitching one row of emblems in minutes (as determined from Equation 4.1),

E = a constant representing the resetting time between rows, (from an actual time study the value of E (mean of 7 observations) was found to be 2.38 minutes),

c = number of colors in the emblem,

f = number of stitching fields required to fill the order.

V(c) = is a function of the number of colors c and

a) the Loading times L,

b) the Unloading times U,

c) the Preparation time P,

d) the Switching times S,

and $V(c) = 2(L+U) + (2f-1)(S+P)$ for $c = 2$,

$= 2f(L+U+P)$ for $c \neq 2$.

The values of the variables and constants required to evaluate the time T, from Equation 4.8 are tabulated in Table 4.1.

4.5 Numerical Example:

To illustrate the computations of the normal stitching time, Equation 4.8, let us consider the four color emblem depicted in Figure 4.2 and develop the normal stitching time for one lot of emblems to fill an order of 3000 emblems.

The first step is to find the size of the emblem. The size of the emblem (the longest dimension on its shorter side when inscribed in a rectangle) is 2.6 inches. Since 2.6 inches is greater than 2" but less than 3" the 12/4 repreat on the embroidery machine will be used. The center to center distance between two adjacent emblems is thus approximately 3". Figure 4.3 shows how the emblem is stitched.

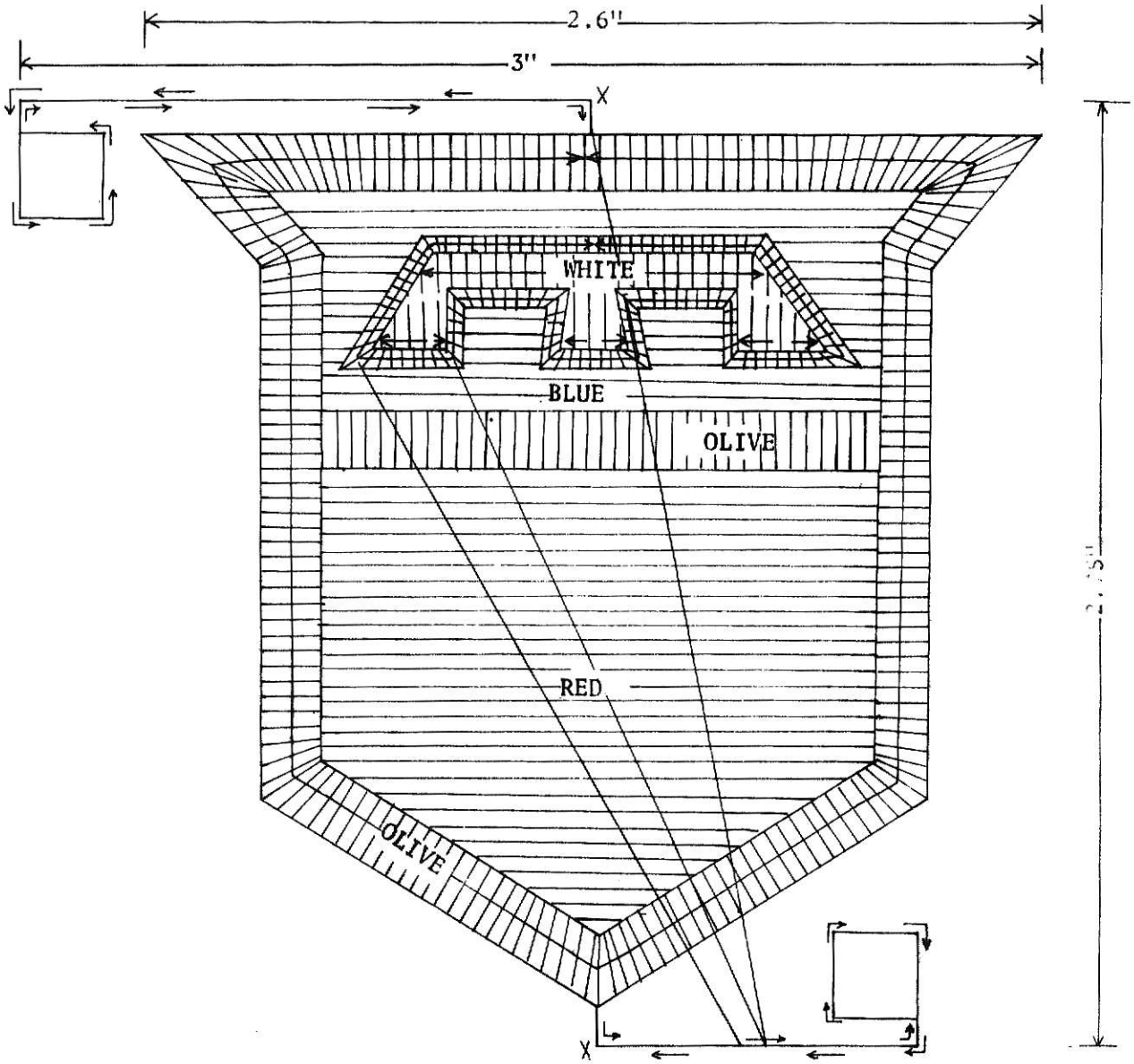
The next step is insert linear stitches (guides and border) and spring stitches onto the sketch. Since the border of the emblem is machine embroidered the emblem is handcut. Hence, no border stitches are required. However, since the emblem has more than 1 color, guide stitches are required to reference these colors. These appear at the top and bottom of the emblem as shown in Figure 4.2. Thus the height each row of emblems occupies on the stitching field is 2.75" as shown in Figure 4.2.

Table 4.1 Values of various constants (in minutes) used in Equation 4.8. for the 8/4 and 12/4 repeats.

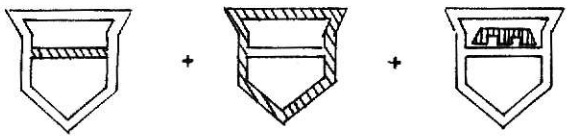
Constant	8/4	12/4
L	5.71	3.61
U	4.67	3.65
S	4.54	2.86
P	3.37	3.37
G	59.41	59.41
E	2.38	2.38
I	30.69	22.85
k	1.84	1.84

Fig. 4.2 Drawing of the Emblem

Scale 1" = 1/2"



AB =  = 7.29 + 4.47 - 1.57 = 10.19 sq. in.

AF =  = 5.22 + 0.98 + 1.57 = 7.77 sq. in.

LC =  = 30.00 in.

LS =  = 14.50 in.

LL = Sum of guide paths on both sides of the emblem for each color = 61.6 in.

Spring stitches are required for the white segment as this is to be stitched on the blue area. Red and blue colors are to be stitched first (which preceeds the other is the choice of the designer) followed by olive and finally the white color is stitched. Figure 4.3 shows in succession how the emblem appears after each color has been stitched. Since white is the fourth color, it is stitched from the bottom to the top on the stitching field. Spring stitches are anchored to the point shown on Figure 4.2.

The third step is to measure all the independent variables in the regression equation, as in Figure 4.2. These are listed below:

	Areas and lengths on the 2X drawing	Actual areas and lengths
Area of the background stitch	10.19/4	2.55 sq. in.
Area of the fill in stitch	7.77/4	1.94 sq. in.
Length of the cover stitch	30.00/2	15.00 in.
Length of the spring stitch	14.50/2	7.25 in.
Length of the linear stitch	61.60/2	30.80 in.

The fourth step is to decide on the number of rows (n) of the emblem required to fill the given order Q = 3000 emblems. Here m_r is 230, the number of emblems per row in the 12/4 repeat.

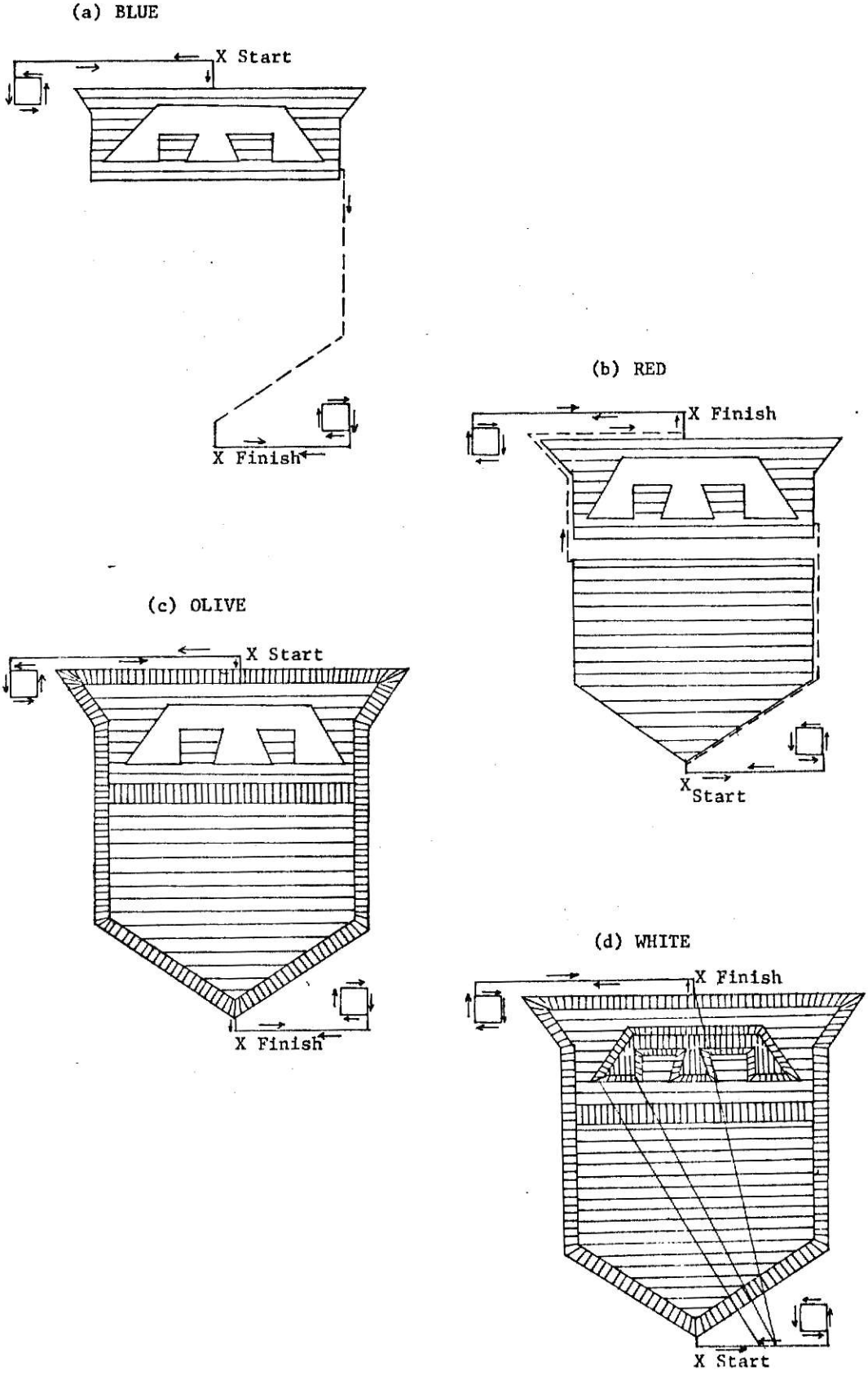
Hence, from Equation 4.3,

n = the smallest integer containing (Q/m_r), that is 3000/230,

= 14,

Hence, 14 rows of emblems or 3220 emblems have to be stitched to complete the order.

Fig. 4.3 How the Emblem is Stitched



Next, the number of stitching fields, f, required to stitch 14 rows of emblems shall be decided. For this emblem h = 2.75,

and n_s = the largest integer contained in 39/h or 39/2.75,

= 14,

indicating that f = 2 and the order can be completed on one span of 42 inch width goods. Next we shall decide on the number of rows of the emblem that shall be stitched on the top half span (n_t) and the number of rows that shall be stitched on the bottom half span (n_b): n_t and n_b shall then correspond to the values of n_1 and n_2 in Equation 4.8. From Equation (4.5),

n_t = largest integer contained in 23/h or 23/2.75

= 8,

and n_b = 14-8

= 6.

Hence the values of n_i for the first and second stitching fields are 8 and 6 respectively. Since all the available height of the span has been stitched in these two fields, x_1 = 1 and x_2 = 1.

From Equation 4.2 the stitch count for the emblem is estimated as:

$$SC = 66.45 + 468.57\ (2.55) + 317.41\ (1.94) + 38.82\ (15.00) + 6.00\ (7.25) + 8.34\ (30.80)$$

$$= 2755.95 = 2756 \text{ stitches.}$$

and the machine running time, R, for one row of emblems from Equation 4.1 is:

$$R = (2756 + 2(7.25))/60$$

$$= 46.2 \text{ minutes.}$$

Also, from Table 4.1, for the 12/4 repeat, and a four color emblem,

$V(c) = cf\ (L + U + P)$

$= 4 \times 2\ (3.61 + 3.65 + 3.37)$

$= 85.04$ minutes.

Substituting in Equation 4.8,

$$T = 1.84 + 85.04 + \{\frac{59.41(1)}{2} + 22.85(4) + 8(46.2) + 4 \times 6\ (2.38)\}$$

$$+ \{\frac{59.41(1)}{2} + 22.85(4) + 6(46.2) + 4 \times 6\ (2.38)\}$$

$= 1088.49$ minutes

$= 18.14$ hours

Hence a normal stitching time of 18.14 hours is required to stitch a batch of 3220 emblems. This formula (Equation 4.8) may be put into the form of readily usable multi-entry tables if so desired. Since the object of this research is to enable the inexperienced estimator to make an estimate of stitching times, the equation developed serves its purpose.

4.6 Use of Normal Time

In the body of this research normal stitching times have been developed which form the input to a standard cost accounting system. The normal times developed may be modified, using rating and allowance factors, to obtain standard times. These factors are subjective in nature and vary among installations. It is left to the individual installation to work these normal times into the framework of their cost accounting system.

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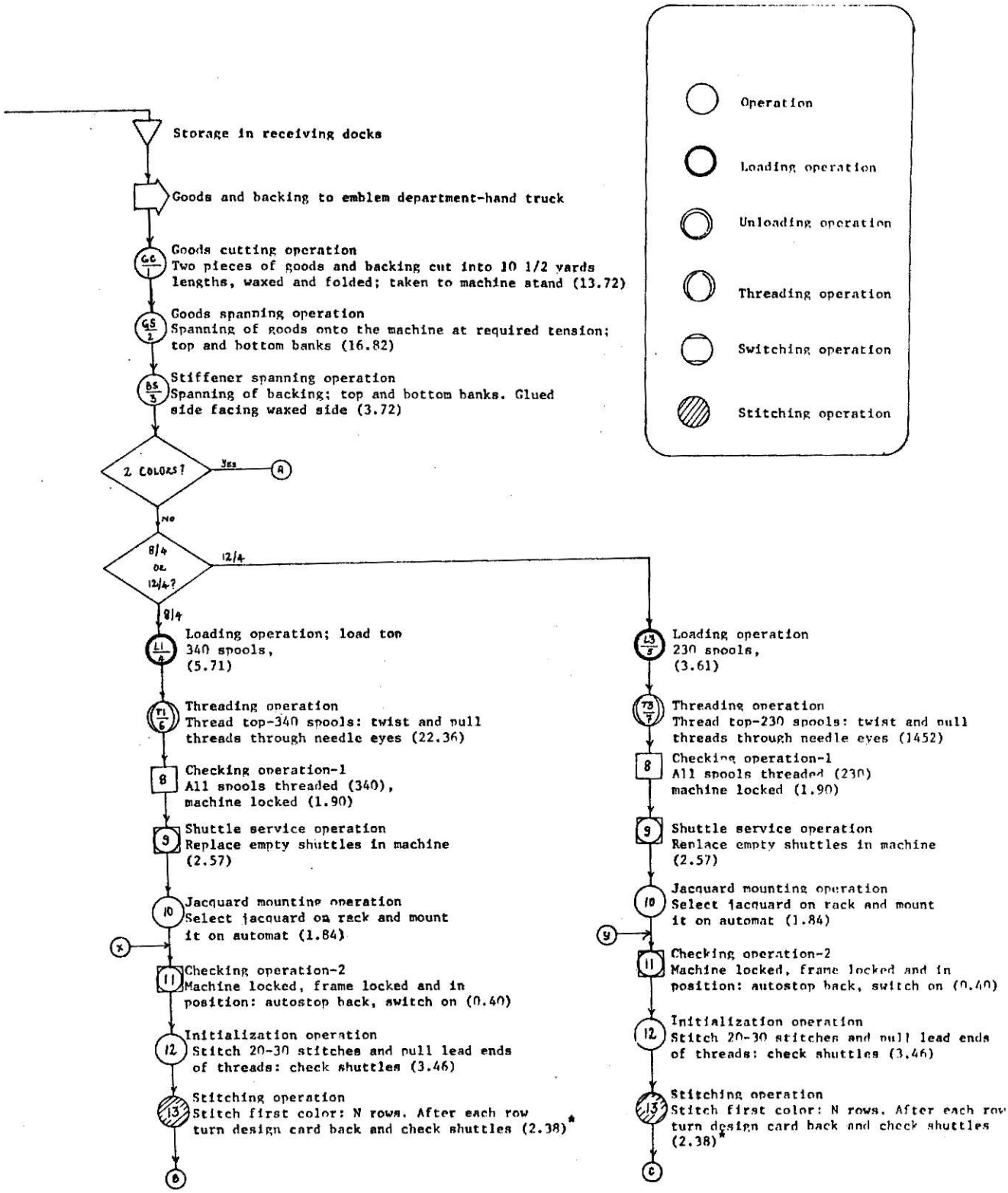
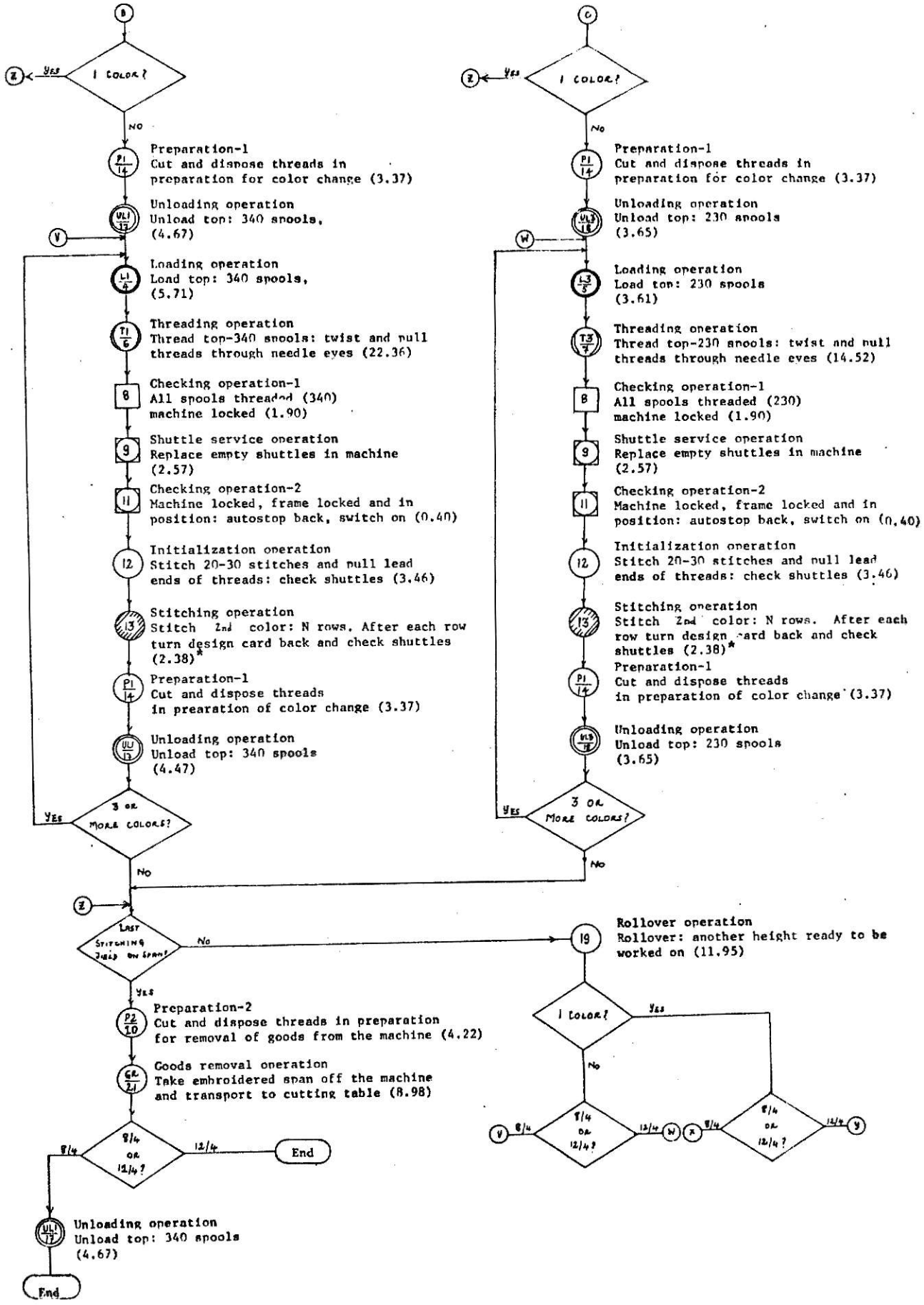
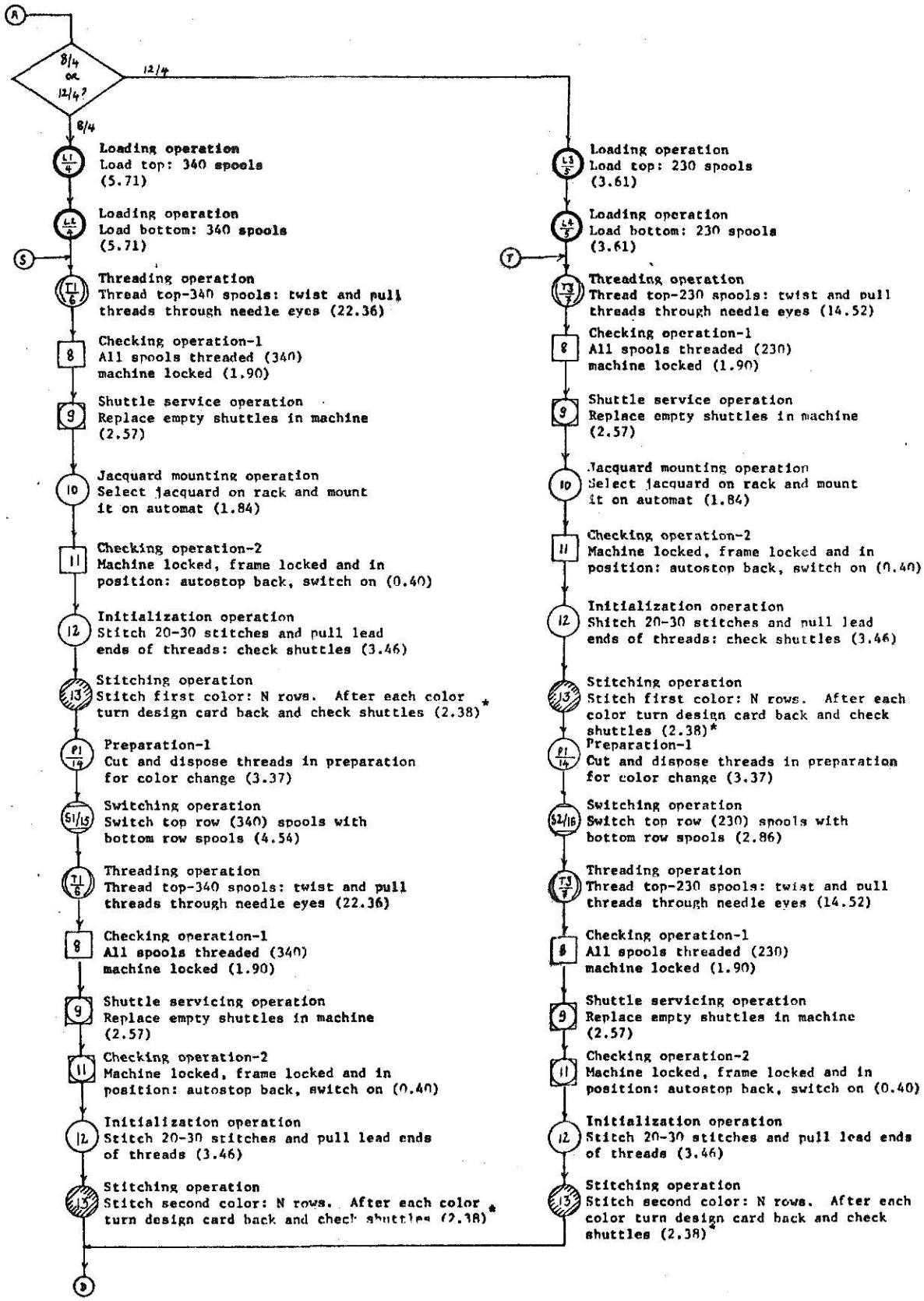
APPENDIX A

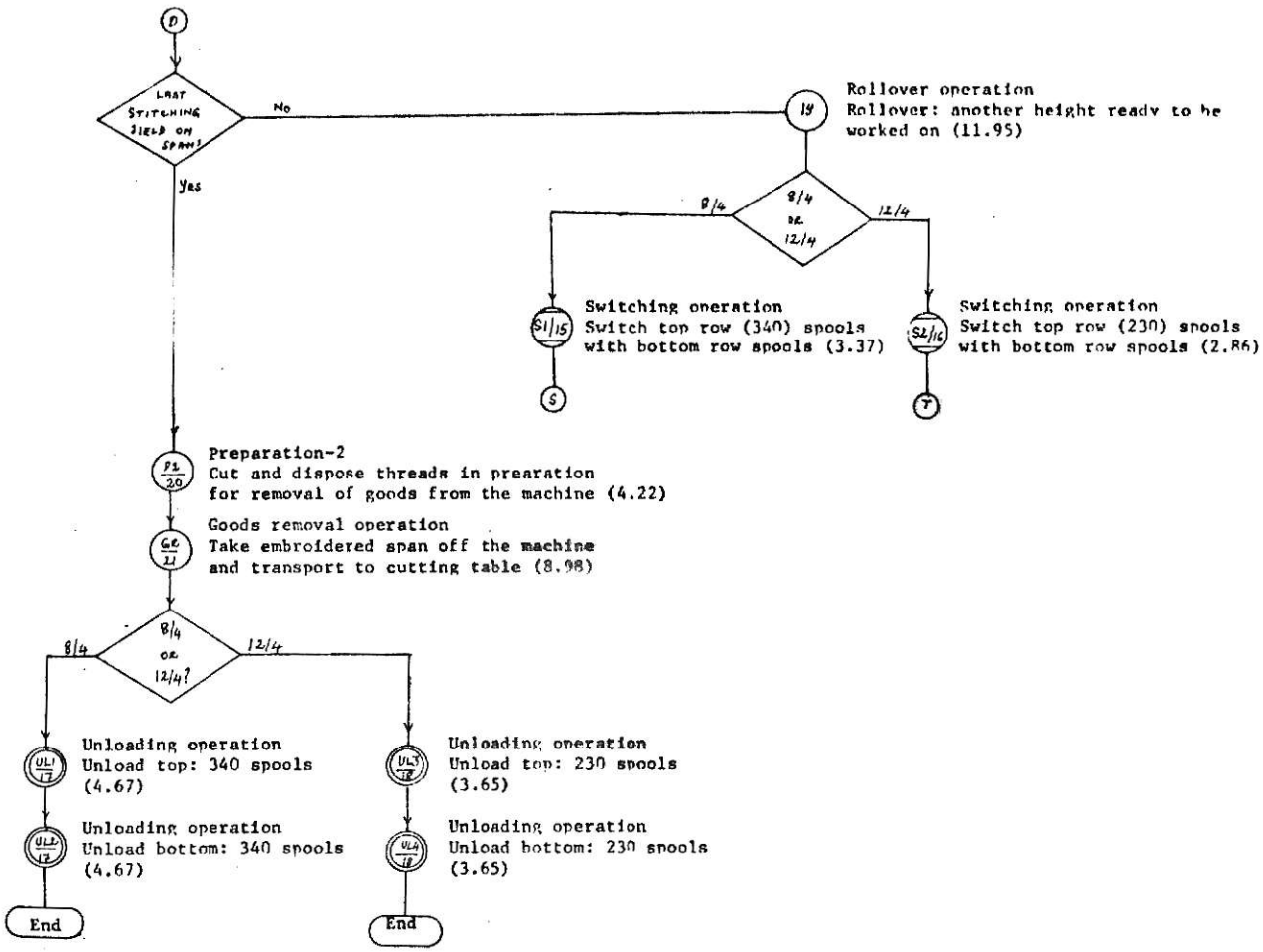
Flowchart for the Emblem Embroidery Process for one Span of Goods

Figure A1. Flowchart for the Emblem Embroidery Process for one Span of Goods




B
1 COLOR?
YES
Z
NO
PI/14
Preparation-1
Cut and dispose threads in preparation for color change (3.37)
UL1/17
Unloading operation
Unload top: 340 spools,
(4.67)
V
L1/4
Loading operation
Load top: 340 spools,
(5.71)
T1/6
Threading operation
Thread top-340 spools: twist and pull threads through needle eyes (22.36)
8
Checking operation-1
All spools threaded (340)
machine locked (1.90)
9
Shuttle service operation
Replace empty shuttles in machine
(2.57)
11
Checking operation-2
Machine locked, frame locked and in position: autostop back, switch on (0.40)
12
Initialization operation
Stitch 20-30 stitches and pull lead ends of threads: check shuttles (3.46)
13
Stitching operation
Stitch 2nd color: N rows. After each row turn design card back and check shuttles (2.38)*
PI/14
Preparation-1
Cut and dispose threads in preparation of color change (3.37)
UU/13
Unloading operation
Unload top: 340 spools
(4.47)
3 OR MORE COLORS?
YES
NO
C
1 COLOR?
YES
Z
NO
PI/14
Preparation-1
Cut and dispose threads in preparation for color change (3.37)
UL3/18
Unloading operation
Unload top: 230 spools
(3.65)
W
L3/5
Loading operation
Load top: 230 spools
(3.61)
T3/7
Threading operation
Thread top-230 spools: twist and pull threads through needle eyes (14.52)
8
Checking operation-1
All spools threaded (230)
machine locked (1.90)
9
Shuttle service operation
Replace empty shuttles in machine
(2.57)
11
Checking operation-2
Machine locked, frame locked and in position: autostop back, switch on (0.40)
12
Initialization operation
Stitch 20-30 stitches and pull lead ends of threads: check shuttles (3.46)
13
Stitching operation
Stitch 2nd color: N rows. After each row turn design card back and check shuttles (2.38)*
PI/14
Preparation-1
Cut and dispose threads in preparation of color change (3.37)
UL3/18
Unloading operation
Unload top: 230 spools
(3.65)
3 OR MORE COLORS?
YES
NO
Z
LAST STITCHING JOB ON SPAN?
NO
YES
19
Rollover operation
Rollover: another height ready to be worked on (11.95)
PZ/10
Preparation-2
Cut and dispose threads in preparation for removal of goods from the machine (4.22)
GR/21
Goods removal operation
Take embroidered span off the machine and transport to cutting table (8.98)
8/4 OR 12/4?
8/4
12/4
End
UL1/17
Unloading operation
Unload top: 340 spools
(4.67)
End
1 COLOR?
YES
NO
8/4 OR 12/4?
V
8/4
12/4
W
X
8/4 OR 12/4?
8/4
12/4
Y


A
8/4 or 12/4?
12/4
8/4
L1/4
Loading operation
Load top: 340 spools
(5.71)
L2/4
Loading operation
Load bottom: 340 spools
(5.71)
S
T1/6
Threading operation
Thread top-340 spools: twist and pull threads through needle eyes (22.36)
8
Checking operation-1
All spools threaded (340)
machine locked (1.90)
9
Shuttle service operation
Replace empty shuttles in machine
(2.57)
10
Jacquard mounting operation
Select jacquard on rack and mount it on automat (1.84)
11
Checking operation-2
Machine locked, frame locked and in position: autostop back, switch on (0.40)
12
Initialization operation
Stitch 20-30 stitches and pull lead ends of threads: check shuttles (3.46)
13
Stitching operation
Stitch first color: N rows. After each color turn design card back and check shuttles (2.38)*
P1/14
Preparation-1
Cut and dispose threads in preparation for color change (3.37)
S1/15
Switching operation
Switch top row (340) spools with bottom row spools (4.54)
T1/6
Threading operation
Thread top-340 spools: twist and pull threads through needle eyes (22.36)
8
Checking operation-1
All spools threaded (340)
machine locked (1.90)
9
Shuttle servicing operation
Replace empty shuttles in machine
(2.57)
11
Checking operation-2
Machine locked, frame locked and in position: autostop back, switch on (0.40)
12
Initialization operation
Stitch 20-30 stitches and pull lead ends of threads (3.46)
13
Stitching operation
Stitch second color: N rows. After each color turn design card back and check shuttles (2.38)*
B
T
L3/5
Loading operation
Load top: 230 spools
(3.61)
L4/5
Loading operation
Load bottom: 230 spools
(3.61)
T3/7
Threading operation
Thread top-230 spools: twist and pull threads through needle eyes (14.52)
8
Checking operation-1
All spools threaded (230)
machine locked (1.90)
9
Shuttle service operation
Replace empty shuttles in machine
(2.57)
10
Jacquard mounting operation
Select jacquard on rack and mount it on automat (1.84)
11
Checking operation-2
Machine locked, frame locked and in position: autostop back, switch on (0.40)
12
Initialization operation
Stitch 20-30 stitches and pull lead ends of threads: check shuttles (3.46)
13
Stitching operation
Stitch first color: N rows. After each color turn design card back and check shuttles (2.38)*
P1/14
Preparation-1
Cut and dispose threads in preparation for color change (3.37)
S2/16
Switching operation
Switch top row (230) spools with bottom row spools (2.86)
T3/7
Threading operation
Thread top-230 spools: twist and pull threads through needle eyes (14.52)
8
Checking operation-1
All spools threaded (230)
machine locked (1.90)
9
Shuttle servicing operation
Replace empty shuttles in machine
(2.57)
11
Checking operation-2
Machine locked, frame locked and in position: autostop back, switch on (0.40)
12
Initialization operation
Stitch 20-30 stitches and pull lead ends of threads (3.46)
13
Stitching operation
Stitch second color: N rows. After each color turn design card back and check shuttles (2.38)*
B


D
LAST STITCHING YIELD ON SPAN?
No
Yes
19
Rollover operation
Rollover: another height ready to be worked on (11.95)
8/4 OR 12/4
8/4
12/4
S1/15
Switching operation
Switch top row (340) spools with bottom row spools (3.37)
S2/16
Switching operation
Switch top row (230) spools with bottom row spools (2.86)
S
T
P2/20
Preparation-2
Cut and dispose threads in prearation for removal of goods from the machine (4.22)
GR/21
Goods removal operation
Take embroidered span off the machine and transport to cutting table (8.98)
8/4 OR 12/4?
8/4
12/4
UL1/17
Unloading operation
Unload top: 340 spools
(4.67)
UL2/17
Unloading operation
Unload bottom: 340 spools
(4.67)
End
UL3/18
Unloading operation
Unload top: 230 spools
(3.65)
UL4/18
Unloading operation
Unload bottom: 230 spools
(3.65)
End

APPENDIX B

Application Data for Methods - Time - Measurement

and

Universal - Standard - Data

compiled from H. B. Maynard,

INDUSTRIAL ENGINEERING Handbook, 2nd edition, 1963

SELECTED FINGER, HAND AND ARM

"METHODS-TIME MEASUREMENT" (MTM)

TABULAR DATA & MOTION DESCRIPTIONS

Notes:

1. Tabular time data are given in TMU (1 TMU = 0.00001 hour). No allowances (PF & D) are included; hence, the data are "select" Times.

2. Conversion Factors:

Multiply	by	to get
TMU	10^{-5}	hours
TMU	6×10^{-4}	minutes
TMU	3.6×10^{-2}	seconds
Hours	10^{5}	TMU
Minutes	1.667×10^{3}	TMU
Seconds	27.77	TMU

3. Combined motions are those which occur when two or more motions are performed by the same body member at the same time.

4. Simultaneous motions are those which are performed by two or more body members at the same time.

5. Principle of Limiting (or Dominant) Motion: When combined or simultaneous motions occur, the motion requiring the longest time is the dominant or limiting motion, and its TMU is the value to be used for the complex motion.

SELECTED MTM BASIC MOTIONS

Basic Motion	Class
1. REACH (R) (Transport hand EMPTY to a destination, x inches distant)	A. Symbol R(x) A = Reach to single object in fixed location; to single object in other hand; or to single object on which other hand rests. B. Symbol R(x) B = Reach to single object whose general location is known; requires eye travel to coordinate moving hand. C. Symbol R(x) C = Reach to an object jumbled with others; involves "select" during hand motion. This is the most difficult Reach to perform. D. Symbol R(x) D = Reach to a single object, to be followed by an accurate grasp of the object. Requires sight and concentration. E. Symbol R(x) E = Reach to an indefinite location to preserve body balance, to get ready for next motion, or to get hand out of the way.

Notes: a. If hand is initially in motion, the symbol is mR(x) A or mR(x) B. Read the appropriate "hand in motion" column in the REACH table.

b. If hand is still in motion at the end of the Reach, the symbol

is R(x) Am, or R(x) Bm. (Class C, D and E Reaches cannot be made with the hand in motion at the end of the reach.) For Am and Bm Reaches, read the appropriate "hand in motion" column.

c. Distance (x) is measured or estimated along the actual motion path.

Table B1 MTM application data-Reach R

(Tables courtesy MTM Association)

Distance Moved Inches	Time TMU				Hand In Motion		CASE AND DESCRIPTION
	A	B	C or D	E	A	B	
Hor less	2.0	2.0	2.0	2.0	1.6	1.6	A Reach to object in fixed location, or to object in other hand or on which other hand rests.
1	2.5	2.5	3.6	2.4	2.3	2.3	
2	4.0	4.0	5.9	3.8	3.5	2.7	
3	5.3	5.3	7.3	5.3	4.5	3.6	B Reach to single object in location which may vary slightly from cycle to cycle.
4	6.1	6.4	8.4	6.8	4.9	4.3	
5	6.5	7.8	9.4	7.4	5.3	5.0	
6	7.0	8.6	10.1	8.0	5.7	5.7	C Reach to object jumbled with other objects in a group so that search and select occur.
7	7.4	9.3	10.8	8.7	6.1	6.5	
8	7.9	10.1	11.5	9.3	6.5	7.2	
9	8.3	10.8	12.2	9.9	6.9	7.9	
10	8.7	11.5	12.9	10.5	7.3	8.6	D Reach to a very small object or where accurate grasp is required.
12	9.6	12.9	14.2	11.8	8.1	10.1	
14	10.5	14.4	15.6	13.0	8.9	11.5	
16	11.4	15.8	17.0	14.2	9.7	12.9	
18	12.3	17.2	18.4	15.5	10.5	14.4	
20	13.1	18.6	19.8	16.7	11.3	15.8	E Reach to indefinite location to get hand in position for body balance or next motion or out of way.
22	14.0	20.1	21.2	18.0	12.1	17.3	
24	14.9	21.5	22.5	19.2	12.9	18.8	
26	15.8	22.9	23.9	20.4	13.7	20.2	
28	16.7	24.4	25.3	21.7	14.5	21.7	
30	17.5	25.8	26.7	22.9	15.3	23.2	

2. GRASP (G)

(Gain control of object(s) by fingers or hand)

1A. Symbol G1A = Simple closing of fingers to gain control of object.

G1A = 2 TMU.

1B. Symbol G1B = Very small or thin object lying close to flat surface:

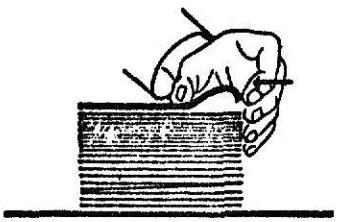


Figure B1 G1B Grasp used when cloth or paper is stacked in layers

Time = 3.5 TMU.

"Pick-up" Grasps

1C. All 1C Grasps are of nearly cylindrical objects that interfere with each other:

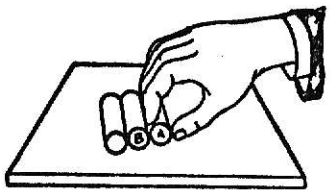


Figure B2 G1C Grasp used when cylindrical objects are in contact with one another

Symbol G1C1 = Interference between objects. Object Diameter > 1/2".

Time = 7.3 TMU

Symbol G1C2 = Interference between objects. 1/4" < Object Dia. < 1/2".

Time = 8.7 TMU

Symbol G1C3 = Interference between objects. Object Dia. < 1/4".

Time = 10.8 TMU

2. Regrasp. Symbol G2 = Regrasp or shifting of an object by the same hand to gain better control.

Time = 5.6 TMU

3. Transfer Grasp. Symbol G3 = Changing control of an object from one hand to the other. Time = 5.6 TMU.

4. Jumbled Object Grasp. All G4 Grasps secure control of an object jumbled with others:

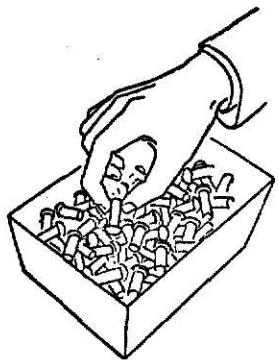


Figure B3 G4 Grasp used when object is jumbled with other objects in a group

G4A = Jumbled object > 1" x 1" x 1". Time = 7.3 TMU.

G4B = Jumbled object > 1/4" x 1/4" x 1/8" and less than G4A. Time = 9.1 TMU.

G4C = Jumbled object smaller than 1/4" x 1/4" x 1/8". Time = 12.9 TMU.

5. Contact, Hook, or Sliding Grasp. Symbol G5 = operator has sufficient control when hand contacts, hooks, or slides on object. Time = 0 TMU.

---

3. MOVE (M)

(Transport an object to a destination)

A. Symbol M(x) A = Move an object to the other hand or up against a stop. Care required to prevent damage to object.

B. Symbol M(x) B = Move an object to a general or indefinite location. Requires reasonable amount of sight and/or concentration.

C. Symbol M(x) C = Move object to an exact location. It is a careful, precise motion requiring sight, concentration and maximum physical control. (If extreme accuracy is required, follow a M(x)C move with a POSITION motion for final adjustment.)

Table B2 MTM application data--Move M

Distance Moved Inches	Time TMU				Wt. Allowance			CASE AND DESCRIPTION
	A	B	C	Hand In Motion B	Wt. (lb.) Up to	Factor	Constant TMU	
Motion	2.0	2.0	2.0	1.7	2.5	0	0	A Move object to otherhand or against stop.
1	2.5	2.9	3.4	2.3				
2	3.6	4.6	5.2	2.9	7.5	1.06	2.2	
3	4.9	5.7	6.7	3.6				
4	6.1	6.9	8.0	4.3	12.5	1.11	3.9	
5	7.3	8.0	9.2	5.0				
6	8.1	8.9	10.3	5.7	17.5	1.17	5.6	
7	8.9	9.7	11.1	6.5				
8	9.7	10.6	11.8	7.2	22.5	1.22	7.4	B Move object to approximate or indefinite location.
9	10.5	11.5	12.7	7.9				
10	11.3	12.2	13.5	8.5	27.5	1.28	9.1	
12	12.9	13.4	15.2	10.0				
14	14.4	14.6	16.9	11.4	32.5	1.33	10.8	
16	16.0	15.8	18.7	12.8				
18	17.6	17.0	20.4	14.2	37.5	1.39	12.5	C Move object to exact location.
20	19.2	18.2	22.1	15.6				
22	20.8	19.4	23.8	17.0	42.5	1.44	14.3	
24	22.4	20.6	25.5	18.4				
26	24.0	21.8	27.3	19.8	47.5	1.50	16.0	
28	25.6	23.1	29.0	21.2				
30	27.1	24.3	30.7	22.7				

Note 1: MOVES in motion initially (mM(x)_), see Table.

Note 2: Effect of Weight on MOVE. For weights up to 2.5 lbs., no correction to tabular MOVE TMU's is needed. For weights greater than 2.5 lbs.:

(1) Opposite the tabulated weight which is next greater than

the known weight moved, read "factor" and "constant".

(2) Now, let the weightless MOVE time (for distance (x)) be V; then

Corrected MOVE TMU = (factor)(V) + (constant)

Example: Move, 12 inches, Case B, object 15 lbs. Symbol notation is M12B15.

From MOVE Table, M12B = 13.4 TMU; factor = 1.17; constant = 5.6. Then:

Corrected TMU = (1.17)(13.4) + 5.6

= 21.5 TMU for M12B15.

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4. TURN (T)

(Turn hand, empty or loaded, by a movement that rotates hand, wrist and forearm about long axis of forearm).

1. Symbol T(Y)S = turn hand Y degrees with S = small load (< 2 lbs.)
2. Symbol T(Y)M = turn hand Y degrees with M = medium load (2.1 < M < 10)
3. Symbol T(Y)L = turn hand Y degrees with L = large load (L > 10.1 lbs.)

Table B3 MTM application data-Turn and Apply pressure- T and AP

Weight	Time TMU for Degrees Turned										
	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
Small— 0 to 2 Pounds	2.8	3.5	4.1	4.8	5.4	6.1	6.8	7.4	8.1	8.7	9.4
Medium—2.1 to 10 Pounds	4.4	5.5	6.5	7.5	8.5	9.6	10.6	11.6	12.7	13.7	14.8
Large— 10.1 to 35 Pounds	8.4	10.5	12.3	14.4	16.2	18.3	20.4	22.2	24.3	26.1	28.2
APPLY PRESSURE CASE 1—16.2 TMU. APPLY PRESSURE CASE 2—10.6 TMU											

---

5. APPLY PRESSURE (AP)

1. Symbol AP1 = Regrasp or squeeze and apply pressure. Time = 16.2 TMU.
2. Symbol AP2 = apply pressure only; no regrasp or squeeze necessary. Time = 10.6 TMU

6. POSITION (P)

(Minor alignment, orientation and engagement of an object with another object)

Three types of fit and three types of symmetry are tabulated, as follows; also degree of difficulty.

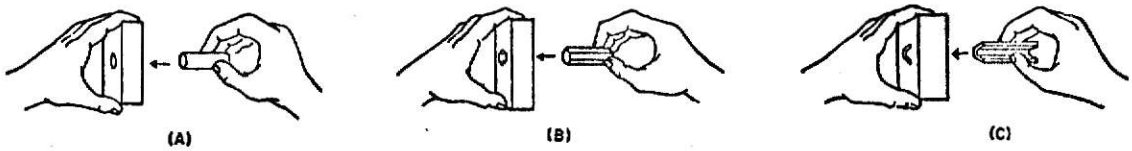
Type of Fit

1 = Loose (P1) = gravity is sufficient to seat the object, or no pressure is required; Alignment is usually to tolerances of 1/32" to 1/2".

2 = Close (P2) = light pressure required; alignment is to a tolerance of < 1/32".

3 = Exact (P3) = heavy pressure required.

Symmetry



(a) Symmetrical (S)

(b) Semisymmetrical (SS)

(c) Nonsymmetrical (NS)

Table B4 MTM application data-Position P

CLASS OF FIT		Symmetry	Easy To Handle	Difficult To Handle
1—Loose	No pressure required	S	5.6	11.2
		SS	9.1	14.7
		NS	10.4	16.0
2—Close	Light pressure required	S	16.2	21.8
		SS	19.7	25.3
		NS	21.0	26.6
3—Exact	Heavy pressure required.	S	43.0	48.6
		SS	46.5	52.1
		NS	47.8	53.4

*Distance moved to engage—1" or less.

7. RELEASE (RL) (Relinquish control of an object)	1. Symbol RL1 = normal release; a simple opening of the fingers. Time = 2 TMU. 2. Symbol RL2 = contact release; begins and ends just as the following Reach occurs. Time = 0.
8. DISENGAGE (D) (break contact of an object with another object)	Required variables are degrees of fit and ease of handling:

Degree of Fit

1. Loose (D1) = Slight effort; blends with subsequent motion; no hand recoil
2. Close (D2) = normal effort; slight hand recoil
3. Tight (D3) = considerable effort; hand recoils markedly

Ease of Handling

1. Easy (E) = object readily grasped & handled
2. Difficult (D) = object cannot be readily grasped; additional grasping motions necessary

Example of DISENGAGE:

DZE = disengage, close fit, object easy to handle.

Table B5 MTM application data-Disengage D

CLASS OF FIT	Easy to Handle	Difficult to Handle
1—Loose—Very slight effort, blends with subsequent move.	4.0	5.7
2—Close — Normal effort, slight recoil.	7.5	11.8
3—Tight — Considerable effort, hand recoils markedly.	22.9	34.7

UNIVERSAL STANDARD DATA

Notes

1. Data are tabulated in Time-Measurement Units (TMU).

2. 1 TMU = 0.00001 hour.

3. Conversion Factors:

Multiply:	by:	To get:
TMU	10^{-5}	hours
TMU	6×10^{-4}	minutes
TMU	3.6×10^{-2}	seconds
Hours	10^{5}	TMU
Minutes	1.667×10^{3}	TMU
Seconds	27.77	TMU

4. Relative error magnitudes:

Job Length	Probable Relative Error
< 0.6 min.	1 to 10% of MTM Synthesis
0.6 - 1.0 min.	1 to 5% " " "
1.0 - 3.0 min.	1 to 3% " " "
>3.0 min.	< 2% " " "

5. If motion(s) cannot be found in USD tables, synthesize the needed motion(s) from MTM tables.

TABLE B6- GET OBJECT

Symbol	Distance reached (inches) f(<1)	1-3	4-6	7-9	10-14	15-21	22-30	Type of Grasp	Description
G_S	4	6	10	12	15	19	25	Simple pickup	Easily grasped object (G1A,G1B,G5)
G_E	10	14	18	20	22	27	32	Jumbled	Easily jumbled or some interference (G4A,G4B,G1C1,G1C2)
G_A	15	19	22	24	27	31	37	or	Average jumbled or medium interference (G4C,G1C3)
G_D	21	24	28	30	33	37	42	Interference	Difficult jumbled; separation problem (G4C + G2; G4A + 2G2)
G_N	6	8	12	14	17	21	27	New hold	Get new grasp (RL1 + R_B + G1A)
G_T	8	9	13	15	19	23	30	Transfer	One hand to other hand (M_A + G3)

TABLE B7 - PLACE OBJECT (Nominal Weight, to 2 1/2 lb.)

Symbol	Distance Moved (inches) f(<1)	1-3	4-6	7-9	10-14	15-21	22-30	Class of Position	Description
P_B	4	7	10	13	15	19	24	None	Against stop; indefinite location. (M_B or M_A + RL1)
P_L	13	16	20	23	26	32	38	P1	Loose fit (M_C + P1 + RL1)
P_C	24	27	31	34	37	42	49	P2	Close fit (M_C + P2 + RL1)
P_E	51	54	58	60	64	49	76	P3	Exact fit (M_C + P3 + RL1)

TABLE B8 - PLACE OBJECT (Significant weight, > 2 1/2 lb.)

Symbol	Wt. (lb) up to	Distance Moved (inches) f(<1)	1-3	4-6	7-9	10-14	15-21	22-30	Class of Position	Description
P_B_	10	6	9	13	15	18	22	27	None	Against stop, or to indefinite location (M_B or M_A + RL1)
	20	10	13	17	20	23	28	33		
	30	14	17	21	25	28	33	39		
P_L_	10	15	19	23	26	29	35	42	P1	Loose fit (M_C + P1 + RL1)
	20	19	23	28	31	35	41	49		
	30	23	27	32	35	40	46	55		
P_C_	10	26	29	34	36	40	46	53	P2	Close fit (M_C + P2 + RL1)
	20	30	33	38	41	45	51	59		
	30	33	38	43	46	50	57	66		
P_E_	10	53	56	61	63	67	72	80	P3	Exact fit (M_C + P3 + RL1)
	20	56	60	65	68	72	78	86		
	30	60	64	69	73	77	84	93		

TABLE B9 - GET/TURN AND PLACE/TURN

Symbol	Weight (lbs.)	Degrees Turned				Description
		45	90	135	180	
GT PT_S	Small (0-2)	6	7	9	11	Get turn or place turn. (T+G1A; T__S + RL1)
PT_M	Medium (2.1-10)	8	11	14	17	Place turn. (T__M + RL1)
PT_L	Large (10.1-35)	13	18	24	30	Place Turn. (T__L + RL1)

TABLE B10 WALK DISPLACEMENT

Symbol	Con-dition	Number of Paces								Description
		1	2	3	5	8	11	14	18	
W__	Unobst.	34	49	64	94	139	184	229	289	TBC1+W__P
WO__	Obstr.	36	53	70	104	155	206	257	325	TBC1+W__PO

TABLE B11 - MISCELLANEOUS BODY MOTIONS

Symbol	TMU	Components	Description
BD1	18	SSC1; TBC1	Turn body, Case 1, to pick up part
BD2	32	SSC2; TBC2; B; S; KOK; A...; W2P	Complete side-step; or turn body w/side-step; or bend; or stoop; or kneel on one knee; or arise from bend, kneel, or stoop
BD3	73	KBK; AKBK	Kneel on 2 knees, or arise from same
FL	13	FM; FMP; LM10	Foot motion (at ankle) with or without pressure; or foreleg motion < 10"
ST	39	SIT; STD	Sit; or stand from a sitting position

TABLE B12 - CRANK

Symbol	Diam.	Force (lbs.) up to:	Number of Revolutions			
			1	2	4	8
__CS	< 6"	10	19	31	56	106
__CSF	same	30	29	43	73	132
__CL	> 6"	10	21	36	66	125
__CLF	same	30	31	49	84	155

BASIC

Body Movements - Part Handling - Tool Handling

BODY MOVEMENTS				CODE BBM-xx-xx		
Operation	Variable or Type	Range		Symbol		.0001 Hours
Use Foot or Leg	Foot or leg motion	–	12" LM	FL	01	1
Horizontal Body Displacement	Small (SSC1 or TBC1)	–	2 ft.	HD	01	2
	Large (SSC2 or TBC2)				02	4
Vertical Body Displacement	Small (B, S, or arise)			VD	01	3
	Large (KBK or arise)				02	7
‡ Turn and Walk	Two paces	2	5 ft.	TW	02	5
	Four paces	5	10 ft.		04	8
	Six paces	10	15 ft.		06	11
	Eight paces	15	20 ft.		08	14
	Ten paces	20	25 ft.		10	17
‡Walk-Distances	Per each 10 feet	over 25 ft.		WD	10	6
Use Stairs	Climb or descend 2 steps	—		ST	02	3
Use Chair or Stool	Act of sitting or standing	—		CH	01	10

All movements are displacements in one direction only.
‡ When load is bulky, or greater than 35#, apply a factor of 1.5

PART HANDLING					CODE BPH-xx-xx		
Operation	Variable or Type		Range		Symbol		.0001 Hours
Get and Place or Get and Dispose,	Easy pickup (G1A)	Variable location	–	8"	EV	06	2
			9	15"		12	3
			16" and over			20	4
		Loose position (P21)	–	8"	EL	06	3
			9	15"		12	4
			16" and over			20	5
		Close position (P22,P23)	–	8"	EC	06	4
			9	15"		12	5
			16" and over			20	6
	Jumbled or complex pickup (G4B)	Variable location	–	8"	JV	06	3
			9	15"		12	4
			16" and over			20	5
		Loose position (P21)	–	8"	JL	06	4
			9	15"		12	5
			16" and over			20	6
		Close position (P22,P23)	–	8"	JC	06	5
			9	15"		12	6
			16" and over			20	7
Miscellaneous Additives	Secondary position	Loose (P21)	—		SP	01	1
		Close (P22,P23)				02	2
	Difficult handling		—		DH	01	1
	Apply pressure		—		AP	01	1
	Disengage - recoil		—		DE	01	1
	New hold		–	8"	NH	01	1
	Weight factor (ENW)		10	25 lb.	WF	01	1
			over 25 lb.			02	2

ACTUATE																			CODE FAC-xx-xx					
Var. / Oper.	Crank Dia.		To 8"						9 to 15"						16" and over									
	No. Rev.	Pounds / Symbol	0	5	10	15	20	25	0	5	10	15	20	25	0	5	10	15	20	25				
			A	B	C	D	E	F	G	H	J	L	M	N	P	Q	R	S	T	U				
Crank	1	CR xA	2	2	2	3	3	3	2	2	3	3	3	4	2	3	3	3	3	4				
	2	xB	3	4	4	4	5	5	4	4	4	5	5	5	4	4	5	5	5	6				
	3	xC	4	5	5	6	6	7	5	6	6	6	7	7	5	6	6	7	7	8				
	4	xD	6	6	7	7	8	8	7	7	8	8	9	9	7	8	8	9	9	10				
	5	xE	7	8	8	9	9	10	8	9	9	10	11	11	9	10	10	11	11	12				
	6	xF	8	9	9	10	11	11	10	10	11	12	12	13	10	11	12	13	13	14				
	7	xG	9	10	11	12	12	13	11	12	13	13	14	15	12	13	14	15	15	16				
	8	xH	11	12	12	13	14	15	13	14	14	15	16	17	14	15	16	17	17	18				
	9	xJ	12	13	14	15	15	16	14	15	16	17	18	19	15	16	17	18	19	21				
	10	xL	13	14	15	16	17	18	16	17	18	19	20	21	17	18	19	20	21	23				
Dial	Set dial or knob		Loose (P21SA)						—						DL	01	1							
			Close (P22, P23)													02	2							
Switch	Push or turn switch								—						SW	01	1							
Lever	Move lever								—			14"			LV	01	1							
									15			26"				02	2							
	Apply force – add per occurrence								—							03	1							
	Latch, unlatch, or mesh gears															04	2							
	Engage splines															05	3							

Data do not include gaining control of actuating device – use BPH-EV-xx

NOTES

APPENDIX C

Basic elemental motions and predetermined time standards for operations in the embroidery process.

Table C1 Synthesis of "Goods cutting operation" by MTM and USD

Operation Name: Goods cutting operation

Symbol used in Flowchart (Figure A1) to represent operation: GC/1

Contents of operation:

Operator:

1) Cut 2 pieces of twill goods 10 1/2 yds long, 42" wide
2) Hand-wax the goods with wax bars on the 'wrong side'
3) Fold the goods in a prespecified manner and carry them to the machine stand at the far end of the machine
4) Cut 2 pieces of backing 10 1/2 yds long, 42" wide
5) Fold the backing and transport to the machine stand at the far end of the machine

Helper:

Assist the operator in performing functions 1 through 5

Purpose of operation:

The goods cutting operation ensures that a fresh span of cloth and backing is ready to be put on the machine

Operation starts:

Both operator and helper at machine center and front

Operation ends:

Both operator and helper at machine stand

Sketch:

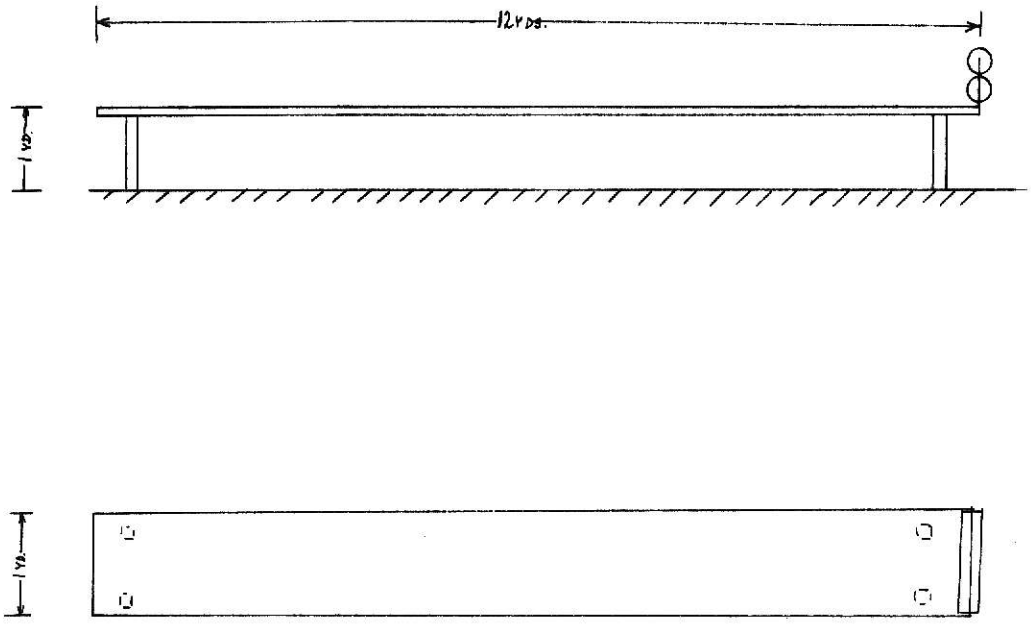


Figure C1. Layout of the Goods Cutting Table.

Synthetic cycle time: 13.72 minutes.

ILLEGIBLE

THE FOLLOWING DOCUMENT (S) IS ILLEGIBLE DUE TO THE PRINTING ON THE ORIGINAL BEING CUT OFF

ILLEGIBLE

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
1) Walk to the head of the cutting table An average distance of 40 feet								1) Walk to the head of the cutting table An average distance of 40 feet								
				*RBM-TW-10 (25 ft.)	170.0							*RBM-TW-10 (25 ft.)	170.0				
				*RBM-TW-10 (15 ft.)	90.0							*RBM-WD-10 (15 ft.)	90.0				
Total					260.0	260.0							260.0	260.0		260.0
2) Grasp goods and walk with them to the far end of the table								2) Grasp goods and walk with them to the far end of the table								
*G21S	19.0					19.0				*G21S	19.0			19.0		19.0
				TBC1	18.6							TBC1	18.6			
				*W18	289.0							*W18	289.0			
Total					307.6	307.6		Total					307.6	307.6		307.6
3) Help operator to flip comb into working posn.								3) Flip comb (mounted at the end of the table) into working position								
		*GT135S	9.0					*GT135S	9.0							
		RL1	2.0					RL1	2.0							
Total			11.0			11.0		Total	11.0					11.0		11.0
4) Walk back to table head. Get scissors, cut goods (42" wide). Replace scissors								4) Tack goods firmly onto comb (approx. 20" long) then walk to table head								
				*W18	289.0	289.0		R20B	18.6	R8B	10.1	*2xBD2	64.0	64.0		
		R10A	8.7					G5	0.0	G5	0.0					
		G1C1	7.3					P1SE	5.6	P1SE	5.3					
		M14B	14.6					R18B	18.6							
R14A	10.5	M30B+mM26B		*BD2	32.0			G5	0.0							
G1B	3.5		37.1					Tacking goods on comb requires 8 strokes								
		AP2	10.6													
		M30B+mM26B		*BD2	32.0			8xR2B	32.0	8xM1/2Bm	13.6					
			44.1							8xAP1	129.6					
		RL1	2.0							8xRL2	0.0	SSC1	17.0			
										8xR3Bm	28.8					
										8xG5	0.0					
Total	14.0		124.4		64.0	124.4		Total	56.2		177.6		17.0	177.6		
Get Wax blocks and hand one to operator																
		*G10S	15.0			15.0		R20E	16.7	R20E	16.7	*W18	289.0	289.0		
						428.4								530.6		530.6
		M30A	27.1							R30A	17.5					
		G3	5.6							G3	5.6					
		M12Bm	10.0							M12Bm	10.0					
Total			42.7			42.7		Total			42.7			42.7		42.7
5) Wax the span with large curved strokes. (8 strokes-approx. 57" should cover 21") then side-step. 10 cycles are required to wax span First cycle								5) Wax the span with large curved strokes. (8 strokes-approx. 57" should cover 21") then side-step. 10 cycles are required to wax span First cycle								
		8(M30B+mM27B)	364.0			364.0				8(M30B+mM27B)	364.0			364.0		
				*2xBD2	64.0	64.0						*2xBD2	64.0	64.0		
9 other cycles								9 other cycles								
		9(364.0+64.0)	3852.0			3852.0				9(364.0+64.0)	3852.0			3852.0		
						4280.0								4280.0		4280.0

HELPER					OPERATOR				TOTAL
LEFT HAND 1	RIGHT HAND 2	BODY 3	TOTAL 4		LEFT HAND 5	RIGHT HAND 6	BODY 7	TOTAL 8	9
SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--		SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 5 8 at --*--*--*--
7) Hand over wax block to operator					6) Collect wax block from helper and walk to the head of the cutting table. Replace blocks				
	M16A 16.0 G3 5.6					R16A 11.4 G3 5.6			
Total	21.6		21.6			17.0		17.0	21.6
8) Get around the table and disengage the goods from the comb. Flip comb back							*W18 289.0	289.0	
R20E 16.7	R20E 16.7	*2XBD2 64.0	64.0			RL1 2.0	TBC2 37.2	37.2	
G1A 2.0 D1E 4.0 R3A 5.3 G5 0.0 T90S 5.4 Total 18.7	G1A 2.0 RL1 2.0 R3A 5.3 G5 0.0 T90S 5.4 18.7		18.7						
		*2xBD2 64.0	64.0						
			146.7					326.2	326.2
9) Help operator to fold span in half, waxed face outside. Place span on table top					7) Grasp goods, fold span in half, waxed face outside. Place span on table top				
R10B 11.5 G1B 3.5 M30Bm7.5 26.3 Total 41.3			41.3			R10B 11.5 G1B 3.5 M30Bm7.5 26.3 Total 41.3		41.3	41.3
	R10B 11.6 G1A 2.0 Total 13.6		13.6		R10B 11.6 G1A 2.0 Total 13.6			13.6	13.6
M20Bm7.5 26.3 G3 5.6 M27Bm7.5 24.5 RL1 2.0 R20E 16.7 Total 75.1	M20Bm7.5 26.3 G3 5.6 R20A 13.1 M27Bm7.5 24.5 RL1 2.0 R20E 16.7 88.2	*BD2 32.0 *BD2 32.0 64.0	88.2		M20Bm7.5 26.3 G3 5.6 R20A 13.1 M27Bm7.5 24.5 RL1 2.0 R20E 16.7 Total 88.2	M20Bm7.5 26.3 G3 5.6 M27Bm7.5 24.5 RL1 2.0 R20E 16.7 75.1	*BD2 32.0 *BD2 32.0 64.0	88.2	88.2
10) Start folding span at far end. Each fold covers 15" approx. 25 cycles reqd. to fold span					8) Walk to the other side of the table head in order to change tasks				
R20E 16.7	R20E 16.7	*2xBD2 64.0	64.0				*W5 94.0		
First cycle									
G1B 3.5 M20Bm 15.6 G2 5.6 M30B+mM18B 28.5 G2 5.6 Total 68.8	G1B 3.5 M20Bm 15.6 G2 5.6 M30B+mM18B 38.5 G2 5.6 68.8		68.8						
The other twenty four cycles									
24xM30B mM6B 720.0 24xG2 134.4 24xM30B mM18B 924.0 24xG2 134.4 Total 1912.8	24xM30B mM6B 720.0 24xG2 134.4 24xM30B mM18B 924.0 24xG2 134.4 1912.8		1912.8						
11) Pick up goods and walk to machine stand									

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 5 at --*--*--*--
R15B	15.8	R15B	15.8	TBC1	18.6									
G1B	3.5	G1B	3.5											
Total	19.3		19.3		18.6	19.3								
				*BBM-TW-10 (25')x1.5 x1.5 bulky load	255.0	255.0								
12) Deposit goods on machine stand and walk to head of cutting table														
M10B	12.2	M10B	12.2	*BD2	32.0									
P1Se	5.6	P1SE	5.6											
RL1	2.0	RL1	2.0	*BD2	32.0									
R20E	16.7	R20E	16.7	*BBM-TW-10 (25')	170.0									
Total	36.5		36.5		234.0	234.0								
						2554.2							94.0	2554.2
														8496.0
Here 1 piece of goods has been cut							Here 1 piece of goods has been cut							
13) Exactly in the same manner proceed to cut the second span of goods, 10 1/2 yds long 42" wide							9) Exactly in the same manner proceed to cut the second span of goods, 10 1/2 yds long 42" wide							8496.0
Exactly in the same manner as the goods, proceed to cut 2 pieces of backing, 10 1/2 yds long, 42" wide (No waxing reqd.)							Exactly in the same manner as the goods, proceed to cut 2 pieces of backing, 10 1/2 yds long, 42" wide (No waxing reqd.)							
14) Grasp backing and walk with it to the far end of the cutting table							10) Grasp backing and walk with it to the far end of the cutting table							
*G21S	19.0						*G21S	19.0					19.0	
				TBC1	18.6						TBC1	18.6		
				*W18	289.0						*W18	289.0		
Total					307.6	307.6	Total					307.6	307.6	307.6
15) Walk back to table head, get scissors, cut backing. Replace scissors. Identical to helper col. no. 4							11) Walk to side of table and hold firm while helper cuts the backing							
					289.0		R20E	16.7	R20E	16.7	*2xBD2	64.0	64.0	
					124.4		12) Fold backing, pick up backing, walk to machine stand, deposit backing and walk to head of cutting table. Identical to helper cols. 10, 11, 12.							
													64.0	
													68.8	
													1912.8	
													19.6	
													255.0	
													234.0	
													2618.2	2618.2
														2944.8
Here 1 piece of backing has been cut							Here 1 piece of backing has been cut							
16) Exactly in the same manner proceed to cut 1 more piece of backing, 10 1/2 yds long 42" wide							13) Exactly in the same manner proceed to cut 1 more piece of backing, 10 1/2 yds long 42" wide							2944.8

G. Total 22881.6

Table C2 Synthesis of "goods spanning operation" by MTM and USD

Operation Name: Goods spanning operation

Symbol used in Flowchart (Figure A1) to represent operation: (GS/2)

Contents of operation:

Operator:

1) Mount a fresh span of goods onto the top bank at the desired tension: cloth tacked satisfactorily onto the top, bottom, and side combs.

2) Mount a fresh span (of cloth) onto the bottom bank at the desired tension: cloth tacked satisfactorily onto the top, bottom, and side combs.

Helper: Assist operator in mounting of fresh spans of cloth onto the machine

Purpose of operation:

To mount fresh spans of goods onto the machine in order to process the next batch of emblems

Operation starts:

Operator and helper at machine stand

Operation ends:

Operator and helper at machine stand

Sketch:

Figure 2.1

Synthetic cycle time: 16.82 minutes.

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
1) Grasp cloth and take it to top bank of machine																
*G18S	19.0	*G12R	22.0	*BD2	32.0	32.0										
RL1	2.0	M20Bm	15.6													
*G8S	12.0															
Total	14.0		15.6			15.6										
				*BB-TW-02x1.5	75.0											
				*BBm-VD-02x1.5	105.0											
				x 1.5 Bulky Load	180.0											
Total						180.0										
2) Lay goods on shield board and flip goods over																
M26A	15.8	M26A	15.8													
RL1	2.0	RL1	2.0													
R12A	9.6	RL2A	9.6													
G1B	3.5	G1B	3.5													
M12B(13.4)		M12B(13.4)														
T180M(14.8)		T180M(14.8)														
	14.8		14.8													
RL1	2.0	RL1	2.0													
		R10B	11.5													
		G1B	3.5													
		M10B	11.3													
		RL1	2.0													
		R15R	14.2													
Total	47.7		90.0			90.0										
						317.6										317.6
								1) Take the end of cloth and move towards the automat end of the machine								
								R20A	13.1							
								G1B	3.5							
								Total	16.6					16.6		
												TBC1	18.6			
												*3xBD2	96.0			
								Total					114.6	114.6		
								Cross left hand side pole								
										M8R	10.6	SSC1(15")	18.6			
										R18A	12.3					
										G1B	3.5					
								Total			26.4		18.6	26.4		
												*2xBD2	64.0	64.0		
								Cross left hand side foundation pillar								
										M10B	12.2	SSC1(15")	18.6			
										R24A	14.0					
										G1B	3.5					
								Total			30.6		18.6	30.6		
												*3xBD2	96.0	96.0		
								Cross centre pole								
										M8R	10.6	SSC1(15")	18.6			
										R18A	12.3					
										G1B	3.5					
								Total			26.4		18.6	26.4		
												*3xBD2	96.0	96.0		
								Cross right hand side foundation pillar								

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
										M10B	12.2					
										R24A	14.9					
										G1B	3.5					
								Total			30.6			30.6		
												*2xBD2	64.0	64.0		
								Cross right hand side pole								
										M8B	10.6	SSC1(15")	18.6			
										R18A	12.3					
										G1B	3.5					
								Total			26.4		18.6	26.4		
												*3xBD2	96.0	96.0		
								2) Secure cloth into comb								
								G2	5.6					5.6		
										R20A	13.1					
										G1A	2.0					
								Total			15.1			15.1		
								M16B	15.8	M16B	15.8			15.8		
								G2	5.6					5.6		
								P3NSD	53.4	P3NSD	53.4			53.4		
										G2	5.6					
										M6Bm	5.7					
										AD1	16.2					
								Total			27.5			27.5		
														810.6		810.6
3) Secure the end of cloth to the comb																
R15A	11.4	R15A	11.4													
G1C	3.5	G1C	3.5													
M16B	15.8	M16B	15.8													
AP1	16.1	AP1	16.1													
Total	46.8		46.8			46.8										
		G2	5.6			5.6										
P3NSD	53.4	P3NSD	53.4			53.4										
G2	5.6															
M6Bm	5.7															
AP1	16.2															
RL1	2.0	RL1	2.0													
Total	29.5		2.0			29.5										
						135.3										135.3
								3) Okay centering of span								
												ET	20.0	20.0		20.0

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
		(60-1)(12.8+18.2+5.6) 2159.4				2159.4			(60-1)(12.8+18.2+5.6) 2159.4				2159.4	
Allowance for crossing left hand side foundation pillar							Allowance for crossing right hand side pole							
RL2	0.0			SSC1(15")	18.6		RL2	0.0			SSC1(15")	18.6		
R28A	16.7						R10A	8.7						
G1B	3.5						G1B	3.5						
Total	20.2				18.6	20.2	Total	12.2				18.6	18.6	
		RL1	2.0						RL1	2.0				
		R28A	16.7	*FL	13.0				R12A	9.6	*FL	13.0		
		G1B	3.5						G1B	3.5				
Total			22.2		13.0	22.2	Total			15.1		13.0	15.1	
RL1	2.0						RL1	2.0						
R10A	8.7						R10A	8.7						
G5	0.0						G5	0.0						
Total	10.7					10.7	Total	10.7					10.7	
Allowance for crossing left hand side pole							Allowance for crossing left hand side foundation pillar							
RL2	0.0						RL2	0.0						
R10A	8.7			SSC1(15")	18.6		R28A	16.7			SSC1(15")	18.6		
G1B	3.5						G1B	3.5						
Total	12.2				18.6		Total	20.2				18.6	20.2	
		RL1	2.0						RL1	2.0				
		R12A	9.6	*FL	13.0				R28A	16.7	*FL	13.0		
		G1B	3.5						G1B	3.5				
Total			15.1		13.0	15.1	Total			22.2		13.0	22.2	
RL1	2.0						RL1	2.0						
R10A	8.7						R10A	8.7						
G5	0.0						G5	0.0						
Total	10.7					10.7	Total	10.7					10.7	
R30F	22.7	R30E	22.7			22.7	R30E	22.7	R30F	22.7	TBC1	18.6	22.7	
							7) Walk to automat end and grasp top roller							
											*RBM-TW-OR	140.0	140.0	
R30A	17.5	R30A+aR6A	23.2				R30A+aR6A	23.2	R30A	17.5				
G1A	2.0	G1A	2.0				G1A	2.0	G1A	2.0				
Total	13.5		25.2			25.2	Total	13.5		25.2			25.2	
						2578.9							2849.1	2849.1
											RT	20.0	20.0	20.0
6) Start rolling the cloth onto the roller till it comes over shuttle rail (8 strokes - 3" per stroke are required)							8) Start rolling the cloth onto the top roller till there is sufficient overhang to reach bottom comb, (8 strokes -3" per stroke are required).							
8xG2	44.8	8xM3R17.5 (98.4) 8xTGOL (98.4)	98.4				8xM3R17.5 (98.4) 8xTGOL (98.4)	98.4	8xG2	44.8				
		8xAP1	120.6				8xAP1	120.6						
		8xR6A	48.8				8xR6A	48.8						
Total	44.8		276.8			276.8	Total	276.8		44.8			276.8	
						276.8							276.8	276.8

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
R30E	22.9	R30E	22.9	TBC1	18.6	22.9	4) Go to centre of comb and tack cloth at midpoint							
				*BBM-TW-04	80.0	80.0	R30E	22.9	R30E	22.9	TBC1	18.6	22.9	
				TBC2	37.2						*BBM-TW-08	140.0		
				*FL	13.0						TBC2	37.2		
Total					50.2	50.2					*FL	13.0		
							Total					190.2	190.2	
							R30B+mR6B	31.5	R30B	24.3				
							G1A	2.0						
							G2	5.6						
							M4A	6.1						
							G3	5.6	G1A	2.0				
							G2	5.6						
							Total	56.4		26.3			56.4	
											FT	20.0	20.0	
							M2C	5.6	M3/4A	2.0				
							G2	5.6	AP1	16.2				
							AP2	10.6	RL1	2.0				
							RL2	0.0						
							R30E	22.9	R30E	22.9	TBC1	18.6		
							Total	44.7		43.1		18.6	44.7	
						173.1							334.0	334.0
4) Secure cloth at 1/4 span point							5) Secure cloth at 1/4 span point							
											*BBM-TW-04	80.0	80.0	
R30B+mR6B	31.5	R30B+mR6B	31.5											
G1A	2.0										TBC2	37.2		
G2	5.6										*FL	13.0		
M4A	6.1						Total					50.2	50.2	
G3	5.6	G1A	2.0											
G2	5.6						Identical to that of helper col no. 4							
Total	56.4		33.5			56.4							56.4	
													44.7	
M2C	5.6	M3/4A	2.0											
G2	5.6	AP1	16.2											
AP2	10.6	RL1	2.0											
RL2	6.0													
R30E	22.9	R30E	22.9	TBC1	18.6									
Total	44.7		43.1		18.6	44.7								
5) Go to mid-length of span and start tacking the cloth onto the comb. Always proceed from left to right							6) Go to automat end and start tacking the cloth onto the comb. Always proceed from left to right							
				*BBM-TW-04	80.0	80.0					*BBM-TW-04	80.0	80.0	
R30B+mR6B	31.5	R30B+mR6B	31.5				R30B+mR6B	31.5	R30B+mR6B	31.5				
G1A	2.0						G1A	2.0						
G2	5.6						G2	5.6						
M4A	6.1						M4A	6.1						
G3	5.6	G1A	2.0				G3	5.6	G1A	2.0				
G2	5.6						G2	5.6						
Total	56.4		33.5			56.4	Total	56.4		33.5			56.4	
For one tack stroke covering 3"							For one tack stroke covering 3"							
P2SD	12.8					12.8	P2SD	12.8					12.8	
		M3/4A	2.0						M3/4A	2.0				
		AP1	16.2						AP1	16.2				
Total			18.2			18.2	Total			18.2			18.2	
M3B	5.3	G2	5.6			5.6	M3B	5.3	G2	5.6			5.6	

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
RL1	2.0	RL1	2.0				9) Climb down and open completely to facilitate entry of cloth into machine							
R20E	16.7	R20E	16.7											
Total	18.7		18.7			18.7	RL1	2.0	RL1	2.0	TBC2	37.2		
							R30E	22.9	R30E	22.9				
							Total	24.9		24.9		37.2	37.2	
											*BBM-VD-02	70.0		
											*BBM-TW-04	80.0		
							Total					150.0	150.0	
							R26A	15.8	R14A	10.5	TBC1	18.6		
							G1A	2.0	G1C1	7.3				
							Total	17.8		17.8		18.6	18.6	
							AP1	16.2	M18A7.5	20.8	*FL	13.0		
									G2	5.6				
									*FAC-LV -20	20.0				
									*FAC-LV -03	10.0				
									M18A7.5	20.8				
							RL1	2.0	RL1	2.0				
							R20E	20.4	R20E	20.4				
							Total	38.6		92.2		13.0	92.2	
											*BBM-TW-04	80.0		
											*BBM-VD-02	70.0		
							Total					150.0	150.0	
R26B	22.5								R26B	22.9				
G4A	7.3								G4A	7.3				
Total	30.2					30.2	Total			30.2			30.2	
						48.9							478.2	478.2
7) Guide cloth between shuttle rails and needle rails into the machine							10) Guide cloth between shuttle rails and needle rails into the machine							
M4A	6.1					6.1			M4A	6.1				
						6.1	Total		AP1	16.2			22.3	22.3
M4A	6.1								M4A	6.1				
AP1	16.2													
Total	22.3												22.3	22.3
M4A	6.1					6.1			M4A	6.1				
									AP1	16.2				
						6.1	Total			22.3			22.3	22.3
M4A	6.1								M4A	6.1			6.1	
AP1	16.2													
Total	22.3					22.3							6.1	22.3
M4A	6.1								M4A	6.1				
									AP1	16.2				
RL1	2.0								RL1	2.0				
Total	8.1					8.1	Total			24.3			24.3	24.3
8) Climb down							11) Climb down; go to automat, open vertical catch and lower the frame to 1/4 height being the vertical hand wheel							
R30E	22.9	R20E	16.7	TBC1	18.6	22.9	R20E	16.7	R30E	22.9	TBC1	18.6	22.9	
				*BBM-VD-02	70.0						*BBM-VD-02	70.0		
				*BBM-TW-02	50.0						*BBM-TW-06	110.0		
Total					120.0	120.0	R14A	10.5	R12A	9.6	*BD2	32.0		

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
R14A	10.5	R14A	10.5	*BD2	32.0	32.0		Total	10.5		9.6		212.0	212.0		
9) Raise left hand side bench								G1A	2.0	G1A	2.0					
										*PAC-LV--04	20.0					
G1A	2.0	G1A	2.0					Total	2.0		22.0			22.0		
M14A40	35.0	M14A40	35.0	*BD2	32.0											
RL1	2.0	RL1	2.0													
R10E	10.5	R1DE	10.5					*4C3(L6"-101bs)	73.0					73.0		
Total	49.5		49.5		32.0	49.5				*PAC-LV-04	20.0					
				*BBM-TW-06	110.0	110.0		RL1	2.0	RL1	2.0					
								Total	2.0		22.0			22.0		
10) Raise centre bench																
R14A	10.5	R14A	10.5	*BD2	32.0	32.0		R14E	13.0	R12E	11.8	*BD2	32.0	32.0		
G1A	2.0	G1A	2.0					12) Walk to the back of the machine and raise the right hand side bench								
M14A40	35.0	M14A40	35.0	*BD2	32.0							*BBM-TW-08	140.0	140.0		
RL1	2.0	RL1	2.0					R14A	10.5	R14A	10.5	*BD2	32.0	32.0		
R10E	10.5	R10E	10.5													
Total	49.5		49.5					G1A	2.0	G1A	2.0					
				*BBM-TW-08	140.0			M14A40	35.0	M14A40	35.0	*BD2	32.0			
				TBC2	37.2			RL1	2.0	RL1	2.0					
Total					177.2	177.2		R10E	10.5	R10E	10.5					
								Total	49.5		49.5		32.0	49.5		
												*2xBD2	64.0	64.0		
						593.1								669.4		669.4
11) Tack the ends of the cloth onto bottom comb								13) Tack the ends of the coth onto the bottom comb								
R28A	15.8	R26A	15.8					R28A	15.8	R28A	15.8					
G1B	3.5	G1B	3.5					G1B	3.5	G1B	3.5					
M4A	6.1									M4A	6.1					
AP1	16.2	G2	5.6					G2	5.6	AP1	16.2					
P2NSD	28.6	P2NSD	26.6					P2NSD	26.6	P2NSD	26.6					
G2(5.6)		M314A	2.0							G2(5.6)						
M68m(5.7)		AP1	16.2							M6Bm(5.7)						
	5.7										5.7					
AP1	16.2							AP2	10.6	RL1	2.0					
Total	90.1		69.7			90.1				M6A	8.1					
										G5	0.0					
										M3/4A	2.0					
										AP1	16.2					
12) Go to mid-length of span and start tacking cloth onto the comb proceed from left to right								Total	62.1		102.2			102.2		
R22	0.0	RL2	0.0					14) Continue to tack cloth onto the comb. Always done from left to right: For 1 cycle covering 3"								
R30E	22.9	R30E	22.9	TBC1	18.6											
Total	22.9		22.9		18.6	22.9		R3B	5.3	R3B	5.3					
								P2SD	21.8	M3/4A	2.0					
				*BBM-TW-08	140.0					AP1	16.2					
				*TBC2	37.2			Total	27.1		23.5					
Total					177.2	177.2										
13) Start tacking -identical as operator col. no. 14								For 15' - 60 identical tacking cycles are required								
										(60-1)27.1		*8xBD2	256.0			
R26A	15.8	R2BA	15.8							1598.9				1598.9		
G1B	3.5	G1B	3.5													
		RL1	2.0					Allowance for crossing right hand side pole								
P2SD	21.8	R3B	5.3													
		M3/4A	1.0					R22	0.0							
		AP1	16.2					R10A	8.7							
Total	41.1		44.8			44.8										

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
For 15'-60 identical tacking cycles are required:																
		(60-1)27.1 1598.9		*8xBD2	256.0	1598.9										
								G5	0.0							
								Total	8.7					8.7		
										RL2	0.0					
										R12A	8.7					
										G5	0.0					
								Total			8.7			8.7		
Allowance for crossing left hand side foundation pillar. Identical as for crossing of right hand side foundation pillar for operator								Allowance for crossing righthand side foundation pillar								
						18.6		RL2	0.0							
						16.7		R28A	16.7			SSC1(15")	18.6			
								G5	0.0							
								Total	16.7				18.6	18.6		
Allowance for crossing left hand side pole. Identical as for crossing of right hand side pole for operator										RL2	0.0					
						8.7				R28A	16.7	*FL	13.0			
						8.7				G2	0.0					
								Total			16.7		13.0	16.7		
						1986.6								1780.9		1986.6
14) Go towards centre and help operator flip comb								15) Wait for helper to come and then flip comb								
RL2	0.0	RL2	0.0	TBC1	18.6											
R30E	22.9	R30F	22.9		18.6											
Total	22.9		22.9			22.9										
				*BBM-TW-06	110.0	110.0										
R30A	17.5	R30A	17.5													
G5	0.0	G5	0.0													
Total	17.5		17.5			17.5										
						150.4										150.4
G2	5.6	G2	5.6					G2	5.6	G2	5.6					
B3/4B7.5	4.3	M3/4B7.5	4.3					M3/4B7.5	4.3	M3/4B7.5	4.3					
AP1	16.2	AP1	16.2					AP1	16.2	AP1	16.2					
Total	26.1		26.1			26.1		Total	26.1		26.1			26.1		26.1
15) Hold comb in flipped position								16) Go to automat end, pull right hand side bend down and climb up								
								RL1	2.0	RL1	2.0					
								R30E	22.7	R30E	22.7					
								Total	24.7		24.7			24.7		
												*BBM-TW-06	110.0	110.0		
								R12A	9.6	R12A	9.6					
								G1A	2.0	G1A	2.0					
								M10A17.5	18.8	M10A17.5	18.8	*BD@	32.0			
								Total	30.4		30.4		32.0	32.0		
								RL1	2.0	RL1	2.0					
								R14E	13.0	R14E	13.0	*BD2	32.0			
								Total	15.0		15.0		32.0	32.0		
												*BBM-TW-02	50.0			
												*BBM-VD-02	70.0			
												*FL	13.0			
								Total					133.0	133.0		
								17) With left hand grasp top roller and with right hand grasp lower roller								

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
							-R30A+mR6A	23.3	R24A	14.9	*BD2	32.0		
							G1A	2.0	G1A	2.0				
							Total	25.3		16.9		32.0	32.0	
													363.7	363.7
16) Let go of comb fast as operator starts to roll the cloth:							18) Roll both top and bottom rollers towards yourself i.e. inwards to take up slack in cloth							
RL2	0.0	RL2	0.0				T60L	12.3	T60L	12.3				
							AP1	16.2	AP1	16.2				
							Total			28.5			28.5	28.5
17) Pull down centre bench and right hand side bench							19) Roll cloth on both rollers in the inward direction till the cloth is hand tight:							
R30E	22.7	R30E	22.7				RL1	2.0	RL1	2.0				
R12A	9.6	R12A	9.6				R6A	7.0	R6A	7.0				
G1A	2.0	G1A	2.0				G1A	2.0	G1A	2.0				
M10A17.5	18.8	M10A17.5	18.8	*BD2	32.0		T60L	12.3	T60L	12.3				
Total	53.1		53.1		32.0	53.1	AP1	16.2	AP1	16.2				
							RL1	2.0	RL1	2.0				
							Total	41.5		41.5			41.5	
RL1	2.0	RL1	2.0											
R14E	13.0	R14E	13.0	*BD2	32.0		R30E+R6E	30.9	R24E	19.2	*BD2	32.0	32.0	
Total	15.0		15.0		32.0	32.0								
				*BBM-TW-06	110.0	110.0	20) The cloth is now hand tight. Now tighten it by tommy bar to see if the cloth is tacked onto all of the bottom comb satisfactorily:							
R12A	9.6	R12A	9.6				R16B	15.8	R20A	13.1				
G1A	2.0	G1A	2.0				G1A	2.0	G1C1	7.8				
M10A17.5	18.8	M10A17.5	18.8						M22B7.5	19.4				
Total	30.4		30.4			30.4	P2SD	21.8	P2SD	21.8				
							M12A27.5	25.6	M12A27.5	25.6				
RL1	2.0	RL1	2.0				D2D	11.8	D2D	11.8				
R14E	13.0	R14E	13.0	*BD2	32.0		Total	151.9		171.3			171.3	
Total	15.0		15.0		32.0	32.0								
				*BBM-TW-02	50.0	50.0	M16Bm7.5	5.8	M16Bm7.5	15.8	TBC2	37.2		
											*BBM-VD-02	70.0		
18) Make sure that cloth is tacked to entire length of comb satisfactorily											*BBM-TW-06	110.0		
				*BBM-TW-06	110.0						*BBM-TW-06	110.0		
				*BBM-TW-06	110.0						*BBM-VD-02	70.0		
Total					220.0	220.0	Total	15.8		15.8		397.2	397.2	
							21) Release top roller:							
							M24B7.5	25.5	M24B7.5	25.5				
							P25D	21.8	P2SD	21.8				
							M3/4B27.5	11.7	M3/4B27.5	11.7				
							RL1	2.0						
							R8A	7.9						
							G1A	2.0						
							M2A	3.6						
							RL1	2.0						
							R6A	7.0						
							G1A	2.0						
							AP1	16.2						
							Total	101.7		59.0			101.7	
									D2D	11.8				
									M16A7.5	19.2				
									RL1	2.0				
							Total			33.0			33.0	
23) Make sure that roller rolls smoothly on the centre spoon on centre pole as operator is rolling cloth onto bottom roller							R22A	14.0	*RL	13.0				
							G1A	2.0	*BD2	32.0				
							Total			16.0		45.0	45.0	

HELPER						OPERATOR						TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3	TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7	TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU Greater times at --*--*--	*USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
				*BBM-TW-06 110.0 *BBM-VD-02 70.0								
Total				180.0	180.0							
*G30S	25.0	*G30S	25.0	*FL 13.0	25.0							
2xM3Bm47.5	42.8	2xMBBm47.5	42.8									
2xAP1	32.4	2xAP1	32.4									
2RL2	0.0	2xRL2	0.0									
Total	75.2		75.2		75.2							
						22) Unroll cloth from the top roller and roll it onto the bottom roller: (Strokes are required to perform this function)						
								6xM4B27.5	108.0			
						6xG2	33.6					
						6xAP2	63.6	6xAP1	97.2			
								6xRL1	12.0			
								5xR4A	30.5			
								5xG1A	10.0			
						Total	97.2		257.7		257.7	
						23) Flip catch onto the rarmet of top roller						
								R20E	16.7	*BD2	32.0	
										*FL	13.0	
						Total			16.7		45.0	45.0
								R30A	17.5			
								G1A	2.0			
								M3/4A	2.0			
								RL2	0.0			
						24) Raise upper comb to marked level and make sure the inside tooth of the catch is engaged:						
						G2	5.6	R6A	7.0			
								G1A	2.0			
						M4C27.5	19.3	M4C27.5	19.3			
						RL1	2.0	RL1	2.0			
						R30E	22.7	R30E	22.7	*FL	13.0	
						Total	49.6		74.5		13.0	74.5
					777.7							1198.9
												977.87
24) Assist operator in tightening of cloth. This figure taken from the M+m analysis film directly[1].						25) Tighten cloth to required tension with the use of pry bar and the extension tube: This figure has been taken from M+m. Analysis film directly[1].						
25) Tack cloth onto side comb						26) Tack cloth onto side comb and test to see if tension of the cloth is satisfactory. This figure is taken directly from the M+m film analysis[1].						42.40 14018.7
26) In exactly the same way as spaning the top cloth, go ahead and span the bottom span to required tension						27) In exactly the same manner as spanning the top span go ahead and span the bottom span to required tension						14018.0
											G Total	28077.4

1. Table. 2.3 Item 14

Table C3 Synthesis of "Stiffener spanning operation" by MTM and USD

Operation Name: Stiffener spanning operation

Symbol used in Flowchart (Figure A1) to represent operation: (BS/3)

Contents of operation:

Operator:

1) Mount a fresh length of backing (stiffener) onto the top bank of the machine, glued side facing waxed side of goods. Backing need only be tacked intermittently on top comb, and on the whole length of the side combs.
2) Mount a fresh length of backing (stiffener) onto the bottom bank of the machine, glued side facing waxed side of goods. Backing need only be tacked intermittently on top comb and on the whole length of the side combs.

Helper:

Assist operator in mounting of fresh spans of backing

Purpose of operation:

To mount fresh span of backing onto the machine in order to process the next batch of emblems. Backing is required to stiffen the emblems stitched on that span of goods.

Operation starts:

Operator and helper at machine stand

Operation ends:

Operator and helper at machine stand

Sketch:

Figure 2.1

Synthetic cycle time: 3.72 minutes.

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
1) Get backing from machine stand:								1) Climb up to receive backing from helper:								
*G25D	42.0	*G25D	42.0	*BD2	32.0	42.0						*BBM-TW-02	50.0			
												*BBM-VD-02	70.0			
M12Bm	10.0	M12Bm	10.0	*BD2	32.0			Total					120.0	120.0		
				TBC2	17.2											
				*BBM-TW-02x1.5	75.0											
				*BBM-VD-02	105.0											
				(1.5 Bulky load)												
Total					249.2	249.2										
2) Flip the backing around to get the glued side to face the waxed side of cloth:																
RL1	2.0	M6B	8.9													
*G8E	20.0	RL1	2.0													
G2	5.6	R6B	8.6													
M12B	13.4	G1C3	7.3													
Total	41.0		26.8			41.0										
						332.2								120.0		332.2
3) Hand end of backing to operator																
		M10A	11.3					R10A	8.7							
		G3	5.6					G3	5.6							
Total			16.9			16.9		Total	16.9					16.9		16.9
								2) Drag the backing along the length of the machine along the top bank; behind the three poles and two foundation pillars:								
								M10A	11.3	R10A	8.7					
								AP1	16.2							
								G3	5.6	G1A	2.0					
								Total	33.1		10.7			33.1		
								20-18" strokes are required to drag backing to the automat end:								
										20xM18B	340.0	*20xBD2	640.0			
										20xAP1	324.0					
								Total			664.0		640.0	664.0		
								Allowance for crossing 3 poles:								
										3xRL1	6.0					
										*3xG8S	36.0					
										3xM6B	26.7					
								Total			68.7			68.7		
								3xRL1	6.0							
								*3xG8S	36.0							
								Total	42.0					42.0		
								Allowance for crossing 2 foundation pillars								
										2xRL1	4.8					
										*2xG20S	38.0					
										2xM6B	17.8					
								Total			59.8			59.8		
								2xRL1	4.0							
								*2xG20S	38.0							
								Total	42.0					42.0		
								3) Position backing on top segment right hand side comb:								

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
8) Raise left hand side bench								8) Raise right hand side bench								
				*BBM-TW-02	50.0	50.0						*BBM-TW-02	50.0	50.0		
R14A	10.5	R14A	10.5	*BD2	32.0	32.0		R14A	10.5	R14A	10.5	*BD2	32.0	32.0		
G1A	2.0	G1A	2.0					G1A	2.0	G1A	2.0					
M14A40	35.0	M14A40	35.0					M14A40	35.0	M14A40	35.0					
RL1	2.0	RL1	2.0	*BD2	32.0			RL1	2.0	RL1	2.0	*BD2	32.0			
R10E	10.5	R10E	10.5					R10E	10.5	R10E	10.5					
Total	49.5		49.5		32.0	49.5		Total	49.5		49.5		32.0	49.5		
9) Walk to machine stand:								9) Raise the centre bench and walk to far end:								
				*BBM-TW-04	80.0	80.0						*BBM-TW-06	110.0	110.0		
10) Get backing from machine stand: Identical to type col. no. 1						42.0		R14A	10.5	R14A	10.5	*BD2	32.0	32.0		
						249.2		G1A	2.0	G1A	2.0					
								M14A40	35.0	M14A40	35.0					
								RL1	2.0	RL1	2.0	*BD2	32.0			
								R10E	10.5	R10E	10.5					
11) Flip the backing around to get the glued side to face the waxed side of the cloth: identical to helper col. no. 2:						41.0		Total	49.5		49.5		32.0	49.5		
						543.7								323.0		543.7
12) Hand end of backing to operator:																
		M10A	11.3					R10A	8.7							
		G3	5.6					G3	5.6							
Total			16.9			16.9			14.3					14.3		16.9
								10) Drag the backing along the length of the machine along the bottom bank: behind the three poles, two foundation pillars and nine shuttle rail driving shafts. Identical to this col. no. 2 except for allowance for nine shuttle driving shafts.								
														33.1		
														664.0		
														68.7		
														42.0		
														59.8		
														42.0		
								Allowance for crossing 9 shuttle drivingshafts:								
										9xRL1	18.0					
										*9xG8S	108.0					
										9xM6B	80.1					
								Total			206.1			206.1		
								9xRL1	18.0							
								*9xG8S	108.0							
								Total	128.0							
								11) Follow through this col. no. 3 thru no. 5								
														39.2		
														27.0		
														206.4		
														320.0		
														18.6		
														140.0		

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
															121.9	
															22.7	
									*		*					
								12) Pull down right hand side bench								
									*		*	*BBM-TW-02	50.0		50.0	
								R12A	9.6	R12A	9.6					
								G1A	2.0	G1A	2.0					
								M10A17.5	18.8	M10A17.5	18.8	*BD2	32.0			
								Total	30.4		30.4		32.0		32.0	
									*		*					
								RL1	2.0	RL1	2.0					
								R14E	13.0	R14E	13.0	*BD2	32.0			
								Total	15.0		15.0		32.0		32.0	
									*		*					
								13) Go to automat and lower the frame to the starting point:								
									*		*	*BBM-TW-08	140.0		140.0	
								R14A	10.5	R12A	9.6	*BD2	32.0		32.0	
									*		*					
								G1A	2.0	G1A	2.0					
										*FAC-LV-04	20.0					
								Total	2.0		22.0				22.0	
									*		*					
								*4CS(L6" -10lbs.)	73.0						73.0	
									*		*					
										*FAC-LV-04	20.0					
								RL1	2.0	RL1	2.0					
								Total	2.0		22.0				22.0	
									*		*					
								R14E	13.0	R18E	11.8	*BD2	32.0		32.0	
									*		*					
												*BBB-TW-04	80.0		80.0	
									*		*					
															2526.5	2526.5
			*				*							*		
															G. Total	6201.1

Table C4 Synthesis of "Loading operation (1) and (2) " by MTM and USD

Operation Name: Loading operation (1) and (2)

Symbols used in Flowchart (Figure A1) to represent operations: (L1/4) (L2/4)

Contents of operation:

Operator:

1) Bring the loaded carton of spools from the storage area
2) Load the spools onto the machine on the 8/4 repeat (340 spools in number-170 spools on the top bank and 170 spools on the bottom bank) making sure that all spools are loaded in the right direction; that is, thread going up from the right hand side.
3) Carry the empty or near empty carton to the racks for storage

Helper:

Assist the operator in loading the spools.

Purpose of operation:

This operation is necessary when a new color has to be stitched on an emblem. The operation takes place entirely on the font of the machine, on the top and bottom banks.

Operation starts:

Operator and helper in rack storage area.

Operation ends:

Operator and helper in rack storage area

Sketch:

Figure 2.3

Loading operation (1) involves loading of the top row of spools

(340 spools) on both banks ((a) and (c) in Figure 2.3)

Loading operation (2) involves loading of the bottom row of spools (340 spools) on both banks ((b) and (d) in Figure 2.3)

Loading operation (1) and Loading operation (2) are exactly the same except for a physical disposition difference. They will be treated as being the same for analysis purposes.

For analysis purposes, it is assumed that there are 18 spools per yard length. Also, it is assumed that the average top bank to center of carton distance is 36", and the average bottom bank to center of carton distance is 30".

The operation proceeds as follows:

The operator works on one side of the carton and the helper on the other side. Each loads 4 spools on the top bank and then 6 spools on the bottom bank and then the carton is dragged by the operator along the bench. No more than 5 loading cycles are required for the top bank per yard length and no more than 3 loading cycles are required for the bottom bank per yard length. Each loading cycle of the bottom bank is followed by the dragging of the carton along the bench. Also, the operator is required to carry the carton 4 times along the bench in the process of loading the 10 yard length of the machine.

Synthetic cycle time: 5.71 minutes

HELPER				OPERATOR				TOTAL
LEFT HAND 1	RIGHT HAND 2	BODY 3	TOTAL 4	LEFT HAND 5	RIGHT HAND 6	BODY 7	TOTAL 8	9
SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
1) Wait at bench:		*BBM-TW-06 110.0	110.0	1) Get carton of the color to be loaded and carry it to the bench		*5xBD2 160.0	160.0	
				R20A 13.1	R20A 13.1	*BD2 32.0	32.0	
				G4A 7.3 M8B32.5 24.8 G2 5.6 M8B32.5 24.8 G2 5.6 Total 66.1	G4A 7.3 M8B32.5 24.5 G2 5.6 M8B32.5 24.5 G2 5.6 66.1	SSC1(15") 18.6	66.1	
				2) Take the loaded carton over to the bench		*BBM-TW-06x15 165.0 (1.5 Bulky load)	165.0	
				3) Place the box on the bench and uncover the flaps:				
				P2SD 21.8 RL2 0.0 R8A 7.9 G5 0.0 M8B32.5 24.8 RL2 0.0 Total 54.5	P2SD 21.8 RL2 0.0 R8A 7.9 G5 0.0 M8B32.5 24.8 RL2 0.0 54.5		54.5	
				*G18S 19.0	*G18S 19.0	TBC1 18.6	19.0	
					M25B 21.8		21.8	
				M25B 21.8			21.8	
				RL1 2.0	RL1 2.0	SSC1(15") 18.6	18.6 558.8	558.8
			110.0					
2) Uncover flaps of carton								
*G18S 19.0	*G18S 19.0	TBC1 18.6	19.0					
	M25B 21.8		21.8					
M25B 21.8			21.8					
RL1 2.0	RL1 2.0	SSC1(15") 18.6	18.6 81.2					81.2
3) Start to load spools systematically as specified, as soon as operator gets started: Work here should be in unison with operator activity. Wait.			57.6	4) Start to load the spools onto the machine systematically as specified: 1 loading cycle:				
				R8C 11.5	R8C 11.5		11.5	
	R8C 11.5	R8C 11.5	11.5	For top bank - 5 loading cycles are required for yd.				
				5xR1C 57.3 5xG1C1 36.5 5(R30B+mR6B) Total 157.5	5xR1C 57.3 5xG1C1 36.5 5(R30B+mR6B) 157.5		251.3	

HELPER				OPERATOR				TOTAL
LEFT HAND 1	RIGHT HAND 2	BODY 3	TOTAL 4	LEFT HAND 5	RIGHT HAND 6	BODY 7	TOTAL 8	9
SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
				5xM5C 46.0 5xP1SD 56.0 5xM3A 24.5 5xRL1 10.0 5xM5C 46.0 5xP1SE 28.0 5xM3A 24.5 Total 235.0 *	*		235.0	
					5xM5C 46.0 5xP1SD 56.0 5xM3A 24.5 5xRL1 46.0 5xP1SE 26.0 5xM3A 24.5 Total 224.0 *		224.0	
				(R30B+mR6B) 31.5 *	(R30B+mR6B) 31.5 *		31.5	
				For the bottom bank. 3 loading cycles are required per yard in each 1, the carton is to be dragged along the bench				
				3xR8C 34.4 3xG3 16.8 Total 51.2 *	3xR8C 34.4 3xG1C1 21.9 3xG3 16.8 73.1 *		73.1	
				3xM3A 14.7 Total 14.7 *	3xR3C 28.2 3xG1C1 21.9 3xM3A 14.7 64.8 *		64.8	
				3xR30B 77.4 *	3xR30B 77.4 *		77.4	
				3xP1SD 33.6 3xM3B 17.1 3xRL1 6.0 3xM4C 24.0 3xP1SD 33.6 3xM3B 17.1 3xRL1 6.0 Total 137.4 *	3xP1SD 33.6 3xM3B 17.1 3xRL1 6.0 3xM4C 24.0 3xP1SD 33.6 3xM3B 17.1 3xRL1 6.0 137.4 *		137.4	
				3xM4B 20.7 3xM4B 20.7 Total 41.4 *	3xM4C 24.0 3xP1SD 33.6 3xM3A 14.7 3xRL1 6.0 3xM4C 24.0 3xP1SE 16.8 3xM3A 14.7 3xRL1 6.0 139.8 *		139.8	
				Transfer both spools to right hand to load:				
				3xM2A 10.8 3xG3 18.6 Total 29.4 *	3xR4A 18.3 3xG3 18.6 3xM5C 27.6 3xP1SE 16.8 3xM3A 14.7 3xRL1 6.0 102.0 *		102.0	
				3xM3A 15.9 3xG3 18.6 Total 34.5 *	3xR4A 18.3 3xG3 18.6 38.9 *		38.9	

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 4 8 at --*--*--*--
								3xR20B	55.8	3xM5C	27.6					
										3xP19E	16.8					
								Total	55.8		44.4				44.4	
								3xG1A	6.0	3xM3A	15.9	*3xBD2	96.0			
								3xM8B12.5	15.6	3xRL1	6.0					
								3xRL1	6.0	3xR16E	42.6					
								Total	77.6		64.5		96.0		96.0	
															1527.1	1527.1
								This covers 2 yds. Five such loading cycles are required to cover the entire 10 yards.								
								(5-1)(11.5+251.3 + 235.0 + 224.0 + 31.5 + 73.1 + 64.8 + 77.4 + 137.4 + 139.8 + 102.0 + + 44.4 + 96.0)			6108.4				38.9	6108.4
								5) Move carton 4 times, a yard at a time:								
								4xR12A	38.4	4xR12A	38.4	*4xBD2	128.0			
								4xG1A	8.0	4xG1A	8.0					
								Total	46.4		46.4		128.0		128.0	
												*4xBBM-TW-02x1.5 (15 Bulky Load)	300.0		300.0	
								4xP1SD	87.2	4xP1SD	87.2					
								4xRL1	8.0	4xRL1	8.0					
								4xR16E	56.8	4xR16E	56.8	4xTBC1	74.4			
								Total	152.0		152.0		74.4		152.0	
															580.0	580.0
								6) Cover flans of the unloaded carton:								
								*G18S	19.0	*G18S	19.0	TBC1	18.6			
										M25B	21.8					
								Total	19.0		40.8		18.6		40.8	
								M25B	21.8							
								RL1	2.0	RL1	2.0					
								Total	23.8		2.0				23.8	
															64.6	64.6
5) Cover flaps																
*G18S	19.0	*G18S	19.0	TBC1	18.6											
		M25B	21.8													
Total	19.0		40.8		18.6	40.8										
M25B	21.8															
RL1	2.0	RL1	2.0													
Total	23.8		2.0			23.8										
						64.6										64.6
								7) Pick unloaded carton and carry it to the rack area:								
								R16A	11.4	R16A	11.4					
								G1A	2.0	G1A	2.0					
								MBB7.5	15.7	MBB7.5	15.7					
								G2	5.6	G2	5.6					
								Total	34.7		34.7				34.7	
												*BBM-TW-10x1.5 (25') *BBM-WD-10x1.5	255.0			

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
								Total				(15')	135.0 390.0	390.0		
												*BD2	32.0	32.0		
								8) Locate carton in rack and leave in storage								
								P2SD	21.8	P2SD RL1 R15E	21.8 2.0 14.2	*BD2	32.0			
								Total	21.8		38.0		32.0	38.0		
								M15A12.5	21.6					21.6		
								RL2 R20E Total	2.0 16.7 16.7	R10E	10.5 10.5			16.7 533.1		533.1
															G. Total	9517.8

Table C5 Synthesis of "Loading operation (3) and (4) " by MTM and USD

Operation Name: Loading operation (3) and (4)

Symbol used in Flowchart (Figure A1) to represent operations: (L3/5) (L4/5)

Contents of operation:

Operator:

1) Bring the loaded carton of spools from the storage area
2) Load the spools onto the machine on the 12/4 repeat (230 spools in number-115 spools on the top bank and 115 spools on the bottom bank) making sure that all spools are loaded in the right direction; that is, thread going up from the right hand side.
3) Carry the empty or near empty carton to the racks for storage.

Helper:

Assist the operator in loading the spools

Purpose of operation:

This operation is necessary when a new color has to be stitched on an emblem. The operation takes place entirely on the front of the machine, on the top and bottom banks.

Operation starts:

Operator and helper have unloaded the last color and are in the rack storage area

Operation ends:

Operator and helper in rack storage area

Sketch:

Figure 2.4

Loading operation (3) involves loading of the top row of spools

(340 spools) on both banks ((a) and (c) in Figure 2.4). Loading operation (4) involves loading of the bottom row of spools (340 spools) on both banks ((b) and (d) in Figure 2.4)

Loading operation (3) and Loading operation (4) are exactly the same except for a physical disposition difference. They will be treated as being the same for analysis purposes. For analysis purposes, it is assumed that there are 12 spools per yard length. Also, it is assumed that the average top bank to center of carton distance is 36", and the average bottom bank to center of carton distance is 30".

The operation proceeds as follows:

The operator works on one side of the carton and the helper on the other side. Each loads 4 spools on the top bank and then 6 spools on the bottom bank and then the carton is dragged by the operator along the bench. No more than 3 loading cycles are required for the top bank per yard length and no more than 2 loading cycles are required for the bottom per yard length. Each cycle of loading the bottom bank is followed by dragging of the carton along the bench. Also the operator is required to carry the carton 4 times along the bench in the process of loading the 10 yard length of the machine.

Synthetic cycle time: 3.61 minutes

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*-
1) Wait at bench								1) Get carton of the color to be loaded and carry it to the bench								
				*BBM-TW-06	110.0	110.0						*5xBD2	160.0	160.0		
								R20A	13.1	R20A	13.1	*BD2	32.0	32.0		
								G4A	7.3	G4A	7.3					
								M8B32.5	24.8	M8B32.5	24.8					
								G2	5.6	G2	5.6					
								M8B32.5	24.8	M8B32.5	24.8					
								G2	5.6	G2	5.6	SSC1(15")	18.6			
								Total	66.1		66.1		18.6	66.1		
								2) Take the loaded cartoon over to the bench								
												*BBM-TW-06x1.5 (x Bulky load)	165.0	165.0		
								3) Place the box on the bench and uncover the flaps.								
								P2SD	21.8	P2SD	21.8					
								RL2	0.0	RL2	0.0					
								R8A	7.9	R8A	7.9					
								G5	0.0	G5	0.0					
								M8B32.5	24.8	M8B32.5	24.8					
								RL2	0.0	RL2	0.0					
								Total	54.5		54.5			54.5		
								*G18S	19.0	*G18S	19.0	TBC1	18.6	19.0		
										M25B	21.8			21.8		
								M25B	21.8					21.8		
								RL1	2.0	RL1	2.0	SSC1(15")	18.6	18.6		
														558.8		558.8
2) Uncover flaps of carton																
*G18S	19.0	*G18S	19.0	TBC1	18.6	19.0										
		M25B	21.8			21.8										
RL1	2.0	RL1	2.0	SSC1(15")	18.6	18.6										
						81.2										81.2
3) Follow operator activity and in unison with operator								4) start to load the spools onto the machine systematically as specified 1 loading cycle								
								R8C	11.5	R8C	11.5			11.5		
								For top bank - 3 loading cycles are required per yd.								
								3xR3C	35.0	3xR3C	35.0					
								3xG1C1	21.9	3xG1C1	21.9					
								3(R30B+nR6R)	94.5		94.5	3(R30B+mR6R)				
								Total	151.4		151.4			151.4		
								3xM5C	27.6							
								3xP1SD	34.6							
								3xM3A	14.7							

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
								3xRL1	6.0							
								3xM5C	27.6							
								3xP1SE	16.8							
								3xM3A	14.7							
								Total	142.0	*		*				142.0
										3xM5C	27.6					
										3xP1SD	34.6					
										3xM3A	14.7					
										3xRL1	6.0					
										3xM5C	27.6					
										3xP1SE	16.8					
										3xM3A	14.7					
								Total			142.0	*		142.0		
								(R30B+mR6B)	31.5	(R30B+mR6B)	31.5	*		31.5		
								For the bottom bank - 2 loading cycles are required per yard in each the carton is to be dragged along the bench:								
								2xR8C	23.0	2xR8C	23.0					
										2xG1C1	14.6					
								2xG3	11.2	2xG3	11.2					
								Total	34.2	*	48.8	*		48.8		
										2xR3C	23.0					
										2xG1C1	14.6					
								3xM3A	9.8	2xM3A	9.8					
								Total	9.8	*	47.4	*		47.4		
								2xR30B	51.6	2xR30B	57.6	*		51.6		
								2xP1SD	22.4	2xP1SD	22.4					
								2xM3B	11.4	2xM3B	11.4					
								2xRL1	4.0	2xRL1	4.0					
								2xM4C	16.0	2xM4C	16.0					
								2xP1SD	22.4	2xP1SD	22.4					
								2xM3B	11.4	2xM3B	11.4					
								2xRL1	4.0	2xRL1	2.0					
								Total	91.6	*	91.6	*		91.6		
								Transfer both spools to right hand to load								
								2xM2A	7.2	2xR4A	12.2					
								2xG3	11.2	2xG3	11.2					
										2xM5C	18.4					
										2xP1SE	11.2					
										2xM3A	9.8					
										2xRL1	4.0					
								Total	18.4	*	66.8	*		66.8		
								2xR20B	36.4	2xM5C	18.4					
										2xP1SE	11.2					
								Total	36.4	*	29.6	*				
								2xG1A	4.0	2xM3A	10.6	*2xBD2	64.0			
								2xM8B12.5	10.4	2xRL1	4.0					
								2xRL1	4.0	2xR16E	28.4					
								Total	18.4	*	43.0	*		43.0		
*		*		*										827.6		827.6
								This covers 2 yards Five such loading cycles are required to cover the entire 10 yards								
								(5-1)(827.6)			3309.6	*		3309.6		

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
							5) Move carton 4 times a yard at a time							
							4xR12A	38.4	4xR12A	38.4	*4xBD2	128.0		
							4xG1A	8.0	4xG1A	8.0				
							Total	46.4		46.4		128.0	128.0	
											*4xBBM-TW-02	300.0	300.0	
											1.5 Bulky load			
							4xP1SD	87.2	4xP1SD	87.2				
							4xRL1	8.0	4xRL1	8.0				
							4xR16E	56.8	4xR16E	56.8	4xTBC1	74.4		
							Total	152.0		152.0		74.4	152.0	
													3889.6	3889.6
							6) Cover flaps of the loader carton							
							*G18S	19.0	*G18S	19.0	TBC1	18.6		
									M25B	21.8				
							Total	19.0		40.8		18.6	40.8	
							M25B	21.8						
							RL1	2.0	RL1	2.0				
							Total	23.8		2.0			23.8	
													64.6	64.6
5) Cover flpas														
*G18S	19.0	*G18S	19.0	TBC1	18.6									
		M25B	21.8											
Total	19.0		40.8		18.6	40.8								
M25B	21.8													
RL1	2.0	RL1	2.0											
Total	23.8		2.0			23.8								
						64.6								64.6
							7) Pick up unloaded carton and carry it ot the rack area:							
							R16A	11.4	R16A	11.4				
							G1A	2.0	G1A	2.0				
							M8B7.5	15.7	M8B7.5	15.7				
							G2	5.6	G2	5.6				
							Total	34.7		34.7			34.7	
											*BBM-TW-10x1.5			
											(25')	255.0		
											*BBM-WD-10x1.5			
											(15')	135.0		
							Total					390.0	390.0	
											*BD2	32.0	32.0	
							8) Locate carton in rack and leave in storage							
							P2SD	21.8	P2SD	21.8	*BD2	32.0		
									RL1	2.0				
									R15E	14.2				
							Total	21.8		38.0		32.0	38.2	
							M15A12.5	21.6					21.0	
							RL2	0.0						
							R20E	16.7	R10E	10.5				
							Total	16.7		10.5			16.7	
													532.4	532.4
													G. Total	6018.8

Table C6 Synthesis of "Threading operation (I) " by MTM and USD

Operation Name: Threading operation (I)

Symbol used in Flowchart (Figure A1) to represent operation: (T I / 6)

Contents of operation:

1) Twist threads on top bank in a prespecified manner (See Figure 2.5) on the 8/4 repeat (170 spools) taking care to pass the threads through guideholes at bearing joints. Then pull these threads through the needle eyes. The twisting operation should proceed from left to right and the threading operation from right to left.

Helper:

1) Twist threads on bottom bank in a prespecified manner (See Figure 2.5) on the 8/4 repeat (170 spools) taking care to pass the threads through the guideholes at the bearing joints and foundation pillars. Then pull these threads through the needle eyes. The twisting operation should proceed from left to right and the threading operation from right to left. This operation is performed entirely on the front side of the machine.

Purpose of operation:

After a color has been stitched and the next color of the yarn loaded onto the machine each thread has to be twisted around the emery roller (to avoid slippage) and under the small brass rod and over the big brass rod (to provide the tension while the stitch is being formed); then the thread is passed through the needle eye, entering from the left hand side. See Figure 2.5.

There are 9 rollers in a 10 yard machine and it is required that the first two threads on either side of the bearing joints be passed through the guidehole, which gives 36 guided threads on the top bank. In addition, on the bottom bank one thread on either side of the foundation pillar is to guided, which gives 40 guided threads on the bottom bank.

Operation starts:

Operator and helper in the rack area after having loaded the machine.

Operation ends:

Operation and helper at automat end and at the front side of the machine

Synthetic cycle time: 22.36 minutes

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
1) Walk to back of the machine, get picker and come to the machine front and middle								1) Walk to automat end and get picker from apron.								
				*BBM-TW-10	170.0	170.0						*BBM-TW-10	170.0			
												*BBM-WD-10 (15')	90.0			
								Total					26.0	260.0		
		*G15D	37.0							*G15D	37.0					
		*P15B	19.0							*P15B	19.0					
Total			56.0			56.0		Total			56.0			56.0		
				*BBM-TW-10	170.0											
				*BBM-VD-10 (15')	90.0			R20E	16.7	R20E	16.7	*BBM-VD-02	70.0	70.0		
Total					260.0	260.0										
2) Produced to twist from the middle gong from left to right, to avoid interference at the end, walk back to automat end and proceed from left to right to twist the threads on the bottom bank. When twisting is done start from far end to thread. Working towards the automat end: Interference correction:								2) Start to twist the threads on the top bank: 1 Unguided twisting cycle: (Starting at the point the thread has been grasped and twisting begins):								
				*BBM-TW-10	170.0					M6B(8.9)						
				*BBM-WD-10 (10')	60.0			M1/2A	2.0	T180S(9.4)						
				*BBM-TW-10	170.0			RL1	2.0		9.4					
Total					400.0	400.0		R12B	12.9							
								Total	16.9		9.4			16.9		
Twisting and threading for the bottom bank proceeds exactly as on the top bank except that there are 40 guided twisting cycles and (170-40)=130 unguided twisting cycles due to the foundation pillars: Identical as in operator col. no. 2: Twisting.								R2A	4.0	P1SE	5.6					
								G3	5.6	RL2	0.0					
								M8B	10.6	R3B	5.3					
								RL1	2.0	G3	5.6					
								Total	22.2		16.5			22.2		
130(16.9+22.2+10.1+20.5+62.6)								R8B	10.1					10.1		
=130x132.3																
	17199.0					17199.0		G3	5.6	G3	5.6					
								M5Bm	5.0	R4Bm	4.3					
								RL1	2.0	G5	0.0					
								R8A	7.9	M7B	9.7					
40(18.6+21.9+26.0+22.2+10.1+20.5+62.6)								Total	20.5		19.6			20.5		
=40x181.9																
	7276.0					7276.0				P1SE	5.6					
								G3	5.6	G3	5.6					
								M2B	4.6	RL1	2.0					
								M1B	2.9	R2B	4.0					
								RL2	0.0	G3	5.6					
								R10A	8.7	M10A	11.3					
								G3	5.6	G3	5.6					
								M8B	10.6	R6Bm	5.7					
								RL1	2.0	G5	0.0					
								R4B	6.4	M/B	2.9					
								T30S(2.8)		G1C3	10.8					
								R2A(4.0)								
								G5(0.0)	4.0							
								G1A	2.0							
								T30S(2.8)								
								M1B(2.9)								
									2.9							
								E7	7.3							
								Total	62.6		58.8			62.6		
Foundation allowance for crossing 2 pillars:								Twist the (170-36) = 134 threads in the same manner:								
				*2xBD2	64.0	64.0		(152-1)(16.9+22.2+10.1+20.5+62.6)								
										=134x132.3						
										17728.2				17728.2		
								I guided cycle is threaded thus: (Starting by the point the thread has been grasped and twisting begins):								

HELPER						OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3	TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
						M4B 6.9 RL2 0.0 R4A 6.1 G3 5.6 Total 18.6 *		R3B 5.3 G1A 2.0 T90S(5.4) M1/2B(2.0) 54 G3 56 18.3 *				18.6	
						M3C 6.7 P15D 11.2 M1/2B 2.0 RL1 2.0 Total 21.9 *		R3B 5.3 G1A 2.0 7.3 *				21.9	
						G3 5.6 M4B 6.9 R8B 10.1 Total 22.6 *		M3B 5.7 G3 5.6 R3A 5.3 M6B(89) T180S(9.4) G5(0.0) 9.4 26.0 *				26.0	
						R2A 4.0 G3 5.6 M8B 10.6 RL1 2.0 Total 22.2 *		P1SE 5.6 RL2 0.0 R3B 5.3 G3 5.6 16.5 *				22.2	
						R8B 10.1 *		*				10.1	
						G3 5.6 M5Bm 5.0 RL1 2.0 R8A 7.9 Total 20.5 *		G3 5.6 R4Bm 4.3 G5 0.0 M7B 9.7 19.6 *				20.5	
						G3 5.6 M2B 4.6 M1B 2.9 RL2 0.0 R10A 8.7 G3 5.6 M8B 10.6 RL1 2.0 R4B 6.4 T30S(2.8) R2A(4.0) G5(0.0) 4.0 G1A 2.0 T30S(2.8) M1B(2.9) 2.9 EF 7.3 Total 62.6 *		P1SE 5.6 G3 5.6 RL1 2.0 R2B 4.0 G3 5.6 M10A 11.3 G3 5.6 R6Bm 5.7 G5 0.0 M1B 2.9 G1C3 10.8 58.8 *				62.6	
						Twist the 36 guided threads in exactly the same manner: (36-1)(18.6+21.9+26.0+22.2+10.1+20.5+62.6) =35x181.9 6366.5 *		*				6366.5	
						3) Get nicker from ear-top and start threading the twisted threads through the needle eyes: Proceed from right to left for threading needles: G3 5.6 M10R(12.2) T90S(5.4) 12.2		G3 5.6 *G18S 19.6					

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
							Total	17.8		24.6			24.6	
							1 threading cycle[2]: starts with both hand come to a stop at the needle eye:							
							P1SSD	14.7	P1SD	11.2				
							E7	7.3						
							RL1	2.0	M7Bm	6.5	*FL	13.0		
							R10E	10.5						
							R3B	5.3						
							ET	15.1						
							G1A	2.0						
							M10B(12.2)		R7B	9.3	*FL	13.0		
							T90S(5.4)	12.2						
							Total	69.1		27.0		28.0	69.1	
Threading of the bottom bank							In the same manner thread the remaining 169 threader:							
		170x69.1	-1174.70						169x69.1	-11677.9			1677.9	
Foundation allowance for creasing two pillars:				*2xBD2	64.0	64.0								
3) Replace picker on ear-top:							4) Replace picker on ear-top and climb down							
		*P18B	19.0						*P18B	19.0			19.0	
R20E	16.7	R20E	16.7											
						37271.5	R20E	16.7	R20E	16.7	*BBM-VD-02	70.0	70.0	
													36655.5	37271.5
													G. Total	37271.5

1. Table 2.3 Item 2,3,11

2. Table 2.3 Item 4

Table C7 Synthesis of "Threading operation (3) " by MTM and USD

Operation Name: Threading operation (3)

Symbol used in Flowchart (Figure A1) to represent operation: (T3/7)

Contents of operation:

Operator:

1) Twist threads on top bank in a prespecified manner (See Figure 2.5) on the 12/4 repeat (115 spools). Then pull these threads through the needle eyes. The twisting operation should proceed from left to right and the threading operation from right to left.

Helper:

1) Twist threads on the bottom bank in a prespecified manner (See Figure 2.5) on the 12/4 repeat (115 spools). Then pull these threads through the corresponding needle eyes. The twisting operation should proceed from left to right and the threading operation from right to left.

   This operation is performed entirely on the front side of the machine.

Purpose of operation:

After a color has been stitched and the next color of the yarn loaded onto the machine, each thread has to be twisted around the emery roller (to avoid slippage) and under the small brass rod and over the big brass rod (to provide the tension while the stitch is being formed); then the thread is passed through the needle eye, entering from the left hand side. See Figure 2.5

There are 9 rollers in a 10 yard machine and since in a 12/4 repeat the needles are spaced approximately 3" apart, no threads are required to be guided through the guideholes. This gives 115 threads on the top bank and 115 threads on the bottom bank.

Operation starts:

Operator and helper are in the rack area after having loaded the machine

Operation ends:

Operator and helper are at the automat end and at the front side of the machine

Synthetic cycle time: 14.52 minutes

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--
1) Walk to back of the machine, get picker and come to machine front and middle:				*BBM-TW=10	170.0	170.0	1) Walk to automat end and get picker from apron:				*BBM-TW-10 *BBM-WD-10 (15')	170.0 90.0		
							Total					260.0	260.0	
		*G15D *P15B	37.0 19.0						*G18D *P15B	37.0 19.0				
Total			56.0			56.0	Total			56.0			56.0	
				*BBM-TW-10 *BBM-WD-10 (15')	170.0 90.0		R20E	16.7	R20E	16.7	*BBM-VD-02	70.0	70.0	
Total					260.0	260.0								
2) Proceed to twist from the middle going from left to right to avoid interference: At the end, walk back to automat end and proceed from left to right to twist the threads on the bottom bank. When twisting is done start from far end to thread working toward the automat end: Interference correction:				*BBM-TW-10 *BBM-WD-10 (10') *BBM-TW-10	170.0 60.0 170.0		2) Start to twist[1] the threads on the top bank: This is done in an identical manner to the twisting on the 8/4 setting. See Table C6 operator col. no. 2 1 Unguided twisting cycle:						16.9 22.2 10.1 20.5 62.6	
Total					400.0	400.0								
Twisting and threading for the bottom band proceeds exactly as on the top bank except that there are foundation pillars to cross. Operator col. no. 2 Twisting:							Twist the top bank 115 threads in the same manner							
115(16.9+22.2+10.1+20.5+62.6							(115-1)(16.9+22.2+10.1+20.5+62.6)							
		115x132.3 15214.5				15214.5			=114x132.3 14968.2				14968.2	
Allowance for crossing 2 foundation pillars				*2xBD2	64.0	64.0	2) Get picker from ear-top and start threading the twisted threads through the needle eyes: Proceed from Right to left for threading needles:							
Threading:							G3 M10B(12.2) TG0S(5.4)	5.6 12.2	G3 *G18S	5.6 19.0				
		115x70.4 8096.0					Total	17.8		24.6			24.6	
Allowance for crossing 2 foundation pillars				*2xBD2	64.0	64.0	1 threading cycle[2]: starts with both hands coming to a stop at the needle eye:							
3) Replace picker on ear top		*P18B	19.0				P1SSD E7 RL1 R12E R3B ET G1A M10B(12.2) T90S(5.4	14.7 7.3 2.0 11.8 5.3 15.1 2.0 12.2	P1SD M7Bm R9B	11.2 6.5 11.5	*FL *PL	13.0 13.0		
R20E	16.7	R20E	16.7				Total	70.4		29.2		26.0	70.4	
							In the same manner thread the remaining 114 spools							
									114x70.5 8025.6				8025.6	
							4) Replace picker on ear-top and climb down:							
									*P18B	19.0			19.0	
							R20E	16.7	R20E	16.7	*BBM-VD-02	70.0	70.0	
													23698.0	24207.2

G. Total 24207.2

1. Table 2.3 Items 2.1, 11.

2. Table 2.3 Item 12

Table C8 Synthesis of "Checking operation-1" by MTM and USD

Operation Name: Checking operation-1 -- Inspection

Symbol used in Flowchart (Figure A1) to represent operation: [8]

Contents of operation:

Operator:

1) Inspect the threaded machine to see that all the threads are alligned correctly and all the lead ends go through the needle eyes; if not, the defective threads must be corrected.

2) Put on apron

Helper:

1) Go to the back of the machine and lock it

2) Put on apron

Purpose of operation:

After the threading operation is over the spools are checked to see if they are correctly threaded. Wrong threading may result in the corresponding emblems being defective. Also, the machine may be damaged if started in the open position.

Operation starts:

Operator and helper at the automat end of the machine on the front side.

Operation ends:

Helper at the center of the machine on the back side. Operator at the automat end of the machine on the front side.

Synthetic cycle time: 1.90 minutes.

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
1) Go to back of the machine.								1) Side-step along the top bank and check threads: 30 side-steps should be required to cover top bank:								
				*BBM-TW-10	170.0											
				*BBM-WD-10	60.0											
Total					230.0	230.0						*30xBD2	360.0	360.0		
2) Close the machine (shuttle rails)								3) Thread the five threads (assumed) that out of the needles: Identical as in Table D6 operator col. no. 3:								
R26A	15.8	R14A	10.5	TBC1	18.6			5xR20B	93.0	5xR20B	93.0			93.0		
G1A	2.0	G1C1	7.3													
Total	17.8		17.8		18.6											
								5x(649.1)			345.5			345.5		
AP1	16.1	M18A7.5	20.8	*FL	13.0											
		G2	5.6					5xR20E	93.5	5xR20E	83.5			83.5		
		*FAC-LV -02	20.0													
		*FAC-LV -03	10.0					3) Climb down and check the bottom bank in an identical manner								
		M18A	20.8													
RL1	2.0	RL1	2.0									*BBM-VD-02	70.0	70.0		
R26E	20.4	R14E	13.0													
Total	38.6		92.2		13.0	92.2								960.0		
3) Go to latches and lock them:														93.0		
				*BBM-TW-04	80.0	80.0								345.5		
														83.5		
R30B	25.8	R30B	25.8					4) Pick up apron and tie it:								
G5	0.0	G5	0.0													
MLA	2.0	M1/2A	2.0					R20B	18.6	R20B	18.6					
AP1	16.2	AP1	16.2					G1C3	10.8	G1C3	10.8					
RL2	0.0	RL2	0.0					M30A	27.1	M30A	27.1					
R30B	25.8	R30B	25.8					G2	5.6	G2	5.6					
G5	0.0	G5	0.0					T30S	2.8	R2A	4.0					
m1/2A	2.0	M1/2A	2.0					M1/2A	2.0	G1C3	10.8					
AP1	16.2	AP1	16.2	*FL	13.0			M4A	6.1	M4A	6.1					
RL2	2.0	RL2	2.0					AP1	16.2	AP1	16.2					
R20E	16.7	R20E	16.7					M4A	6.1	M4A	6.1					
Total	106.7		106.7		13.0	106.7		G2	5.6	G2	5.6					
								T30S	2.8	R2A	4.0					
				*BBM-TW-04	80.0	80.0		M1/2A	2.0	G1C3	10.8					
								M4A	6.1	M4A	6.1					
4) Pick up apron from drawer top and tie it: Identical as operator col. no. 4								AP1	16.1	AP1	16.2					
						148.0		Total	127.9		148.0			148.0		
						755.5								3182.0		3182.0

G. Total 3182.0

Table C9 Synthesis of "Shuttle servicing operation" by MTM and USD

Operation Name: Shuttle servicing operation: Inspection/Operation

Symbol used in Flowchart (Figure A1) to represent operation: 

Contents of operation:

Operator:

Helper:

1) Check all the shuttles and replace empty shuttles with full shuttles

Purpose of operation:

To fill the machine with full shuttles

Operation starts:

Operator at machine center on the front side, helper at machine center on the back side.

Operation ends:

Operator at machine center on the front side, helper at automat end on the back side.

Synthetic cycle time: 2.57 minutes.

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
1) Go to automat end:								-								
				*BBM-TW-08	140.0	140.0										
2) Side-step along the length of the machine checking the bottom bank of shuttles:																
				*30xBD2	960.0	960.0										
3) Replace the six (assumed) shuttles that are empty with full shuttles from approx: To replace 1 shuttle:																
M20A	19.2	R20A	13.1			19.2										
P1SE	5.6	G1A	2.0													
		M3/4A	2.0													
		AP1	16.2													
Total	5.6		20.2			20.2										
M2B	4.6	RL1	2.0													
		R3/4A	2.0													
		G1A	2.0													
		*P26B	24.0													
		*G12S	15.0													
		G4B	5.6													
		G2	5.6													
		*P26C	49.0													
		RL1	2.0													
		R3/4B	2.0													
		G1A	2.0													
		M3/4A	2.0													
		RL1	2.0													
R16E	14.2	R16E	14.2													
Total	18.8		123.2			123.2										
For the other 5 cycles																
5(19.2+20.2+123.2)		=5(162.6)														
		+	813.0			813.0										
4) Climb up																
				*BBM-VD-02	70.0	70.0										
5) Check all the shuttles in the top bank identically as in the bottom bank:																
						960.0										
						19.2										
						20.2										
						123.2										
						813.0										
6) Climb down																
				*BBM-VD-02	70.0	70.0										
7) Walk to machine middle																
				*BBM-TW-08	140.0	140.0										
						4291.2										4291.2
														G Total		4291.2

Table C10 Synthesis of "Jacquard mounting operation" by MTM and USD

Operation Name: Jacquard mounting operation

Symbol used to Flowchart (Figure A1) to represent operation: (10)

Contents of Operation:

Operator:

1) Select correct design tape and bring it to the automat
2) Unload old design tape on the automat and replace it in the rack
3) Load new design tape on automat

Helper:

Purpose of operation:

To get the correct design tape for stitching the current order onto the machine and to remove the preceding design tape and repalce it

It is assumed that the design has 1900 stitches (from the sample of 62 emblems used in the study the average number of stitches in an emblem was found to be 1899.09)

Operation starts:

Operator at automat end on the front side of the machine

Operation ends:

Operator at automat end on the front side of the machine

Synthetic cycle time: 1.84 minutes

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL	TIME *USD TMU	SYMBOL	TIME *USD TMU	SYMBOL	TIME *USD TMU	Greater times at --*--*--		SYMBOL	TIME *USD TMU	SYMBOL	TIME *USD TMU	SYMBOL	TIME *USD TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
								1) Confirm design number and go to racks:								
												*BBM-TW-02	50.0			
												EF	7.3			
												*BBM-TW-10	170.0			
												*BBM-WD-10	60.0			
								Total					287.3		287.3	
								2) Search for correct tape number								
												*BBM-TW-02	50.0		50.0	
								R25A	15.8	R25A	15.8					
								G1C1	7.3	G1C1	7.3					
								Total	23.1		23.1				23.1	
								3) Take tape to automat end and place it on the bench								
												*BBM-TW-10	170.0			
												*BBM-WD-10	60.0			
								Total					230.0		230.0	
										M20B	18.2					
										P1SE	5.6					
										RL1	2.0					
								Total			25.8				25.8	
												*BBM-TW-04	80.0		80.0	
								4) Open catch:								
								R15A	14.2	R15A	14.2	BD2	32.0		32.0	
										G5	0.0					
										M2B	4.6					
								Total			4.6				4.6	
								G1B	3.5							
								M3/4A	2.0							
								Total	5.5						5.5	
										M2A	4.6					
										RL2	2.0					
								Total			6.6				6.6	
								R15E	14.2	R15E	14.2	*BD2	32.0		32.0	
								5) Release tape from indexing wheel								
										R15A	11.4					
										G1C3	10.8					
										M3/4A	2.0					
										AP2	16.2					
										RL2	0.0					
								Total			40.4				40.4	
								6) Grasp end of tape and get it rolling								
												*SSC2	34.1		34.1	
								R15B	15.8	R15B	15.8					
								G2	5.6	G2	5.6					
								G2	5.6	G2	5.6					
								G2	5.6	G2	5.6					

HELPER				OPERATOR				TOTAL
LEFT HAND 1	RIGHT HAND 2	BODY 3	TOTAL 4	LEFT HAND 5	RIGHT HAND 6	BODY 7	TOTAL 8	9
SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
				Total 32.6 *	32.6 *		32.6	
				7) Roll tape. 16-T30S motions are required for each metre (100 stitches) of tape. Assume the design has 1900 stitches.				
				19x16xT30S	=19x16x2.8 = 851.2 *		851.2	
				8) Replace tape in racks				
						*BBM-TW-10 170.0 *BBM-WD-02 68.0		
				Total *	*	230.0	230.0	
				*	*	*BBM-TW-02 50.0	50.0	
				M20A 19.2 P1SE 5.6 RL1 2.0 Total 28.8 *	M20A 19.2 P1SE 5.6 RL1 2.0 26.8 *		26.8	
						*BBM-TW-10 170.0 *BBM-WD-10 60.0 *BBM-TW-04 80.0		
				Total *	*	310.0	310.0	
				9) Pick up new tape and mount it on automat:				
				R15A 11.4 G1A 2.0 Total 13.4 *	R15A 11.4 G1A 2.0 13.4 *		13.4	
				G2 5.6 *	G2 5.6 *	*BBM-TW-04 80.0	80.0	
				P1SE 5.6 Total 5.6 *	G1C1 7.3 P1SE 5.6 12.9 *		12.9	
				*	*	SSC1(15") 18.6	18.6	
				G2 5.6 *	6xM3B 33.6 *		33.6	
				RL1 2.0 *G18S 19.0 P1SD 11.2 Total 32.2 *	P1SD 11.2 11.2 *		32.2	
				*	*	SSC2 34.1	34.1	
				RL1 2.0 *G10S 15.0 Total 17.0 *	*		12.0	
				M20B 18.2 P1SD 11.2 Total 29.4 RL1 2.0 G10S 15.0 Total 17.0 *	R20B 18.6 G1A 2.0 P1SD 11.2 31.8 *	SSC1 34.1 34.1	31.8 34.1	
				1920B 18.2 P2SSD 25.3	R20B 18.6 G1A 2.0 P2SSD 25.3			

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 5 at --*--*--*--
								G2	5.6	RL1	2.0					
								Total	49.5		47.9			49.5		
										RGA	7.0			7.0		
								P2SSD	25.3					25.3		
								M1/2A	2.0	G1B	3.5					
								RL1	2.0	M20B	18.6					
								R20B	18.2							
								G1A	2.0							
								Total	24.2		22.1			24.2		
								P1SD	11.2	P1SD	11.2			11.2		
								RL1	2.0							
								*G10S	15.0							
								Total	17.0					17.0		
								M20B	18.2	R20B	18.6					
										G1A	2.0					
								P1SD	11.6	P1SD	11.6					
								Total	29.8		43.8			43.8		
								RL1	2.0			SSC1	34.1			
								*G10S	15.0							
								Total	17.0				34.1	34.1		
								P1SD	11.2	P1SD	11.2					
										AP2	16.2					
										M3/4A	2.0					
								Total	11.2		29.4		29.4			
								*G12S	15.0					15.0		
												*BD2	32.0	32.0		
								M3/4A	2.5	RL1	2.0					
								RL1	2.0	G12S	15.0					
										M3/4A	2.5					
								Total	4.5		19.5			19.5		
								R20E	22.9	R20E	22.9	*BD2	32.0	32.0		
												*BBM-TW-04	80.0	80.0		
														3079.7		3079.7
														G Total		3079.7

Table C11 Synthesis of "Checking operation-2" by MTM and USD

Operation Name: Checking operation-2

Symbol used in Flowchart (Figure A1) to represent operation: 

Contents of operation:

Operator:

1) Check to see that machine frame is closed
2) Check to see that the design tape is locked on the correct position
3) Check to see that the machine is locked, that is, the shuttle rails are locked.
4) Check to see that the automatic stopping lever is activated.
5) Turn power switch on.

Helper:

Purpose of operation:

This check is preparatory to starting the machine. The automat may be damaged if one of the controls is not activated.

Operation starts:

Operator at automat end on the front side of the machine

Operation ends:

Operator at the automat end on the front side of the machine

Synthetic cycle time: 0.40 minutes

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--
								1) Check to see that the machine frame is locked								
												*2xBD2	64.0			
												DT	20.0			
								Total					84.0		84.0	
								2) Check to see that jacquard is in position and is locked								
												*2xBD2	64.0		64.0	
										R20A	13.1					
										G5	0.0					
										M3/48	2.0					
										RL2	0.0					
								Total			15.1				15.1	
												*BD2	32.0		32.0	
								3) Check to see that machine is locked (shuttle rails are closed)								
												*BBM-TW-04	80.0		80.0	
												ET	20.0		20.0	
								4) Check autostop to see that it is activated								
												*BBM-TW-08	140.0		140.0	
										R20A	13.1					
										G1A	2.0					
										AP1	16.2					
										RL1	2.0					
										R20E	16.7					
								Total			50.0				50.0	
								5) Turn swithc on								
										R30A	17.5					
										G1A	2.0					
										*FAC-SW -10	10.0					
										RL1	2.0					
										R20E	16.7					
								Total			48.2				48.2	
								6) Start the machine								
												*BBM-TW-06	110.0		110.0	
										R30A	17.5					
										G1A	2.0					
										*FAC-TW -01	10.0					
								Total			29.5				29.5	
															672.8	672.8
														G. Total		672.8

Table C12 Synthesis of "Initialization" by MTM and USD

Operation Name: Initialization

Symbol used in Flowchart (Figure A1) to represent operation: (12)

Contents of operation:

Operator:

1) Stitch 20-30 stitches and stop the machine

2) Pull lead ends of threads

Helper:

1) Let machine stitch 20-30 stitches

2) Check shuttles and replace shuttles that are not stitching

3) Help operator pull lead ends

Purpose of operation:

To initialize stitching. This makes sure that all needles are working and stitching correctly

Operation starts:

Operator at automat end on the front side of the machine, helper at center on the back side of the machine

Operation ends:

Operator at automat end on the front side of the machine, helper at center on the back side of the machine

Synthetic cycle time: 3.46 minutes

HELPER				OPERATOR				TOTAL
LEFT HAND 1	RIGHT HAND 2	BODY 3	TOTAL 4	LEFT HAND 5	RIGHT HAND 6	BODY 7	TOTAL 8	9
SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
				1) Start machine and let it stitch 30 stitches				
						*BBM-TW-04 80.0	80.0	
					R30A 17.5 G1A 2.0 *FAC-SW -01 10.0			
				Total	30.5		30.5	
				Time for stiching 30 stitches = 1/2 min.				
							834.0	
				2) Stop machine				
					*FAC-SW -01 10.0 RL1 2.0			
				Total	12.0		12.0	
						*BBM-VD-02 70.0	70.0	
							1026.5	1026.5
1) Check shuttles and replace shuttles not stitching. This is identical to Table D9: Service Shuttles			4291.2	3) Start pulling the threads: top bank One thread pulling cycle: to pull 8 threads in 8/4				
				R26B 22.9 G1A 2.0 Total 24.9	R26B 22.9 G1A 2.0 24.9	*BD2 32.0	32.0	
2) Start clearing the bottom bank starting from the automat end: Identical as operator col. no. 3: 8 cycles are required to reach left hand foundation pillar 8x113.2 905.6			905.6	T30S 5.4 AP1(1.62) M2Bm(2.9) 16.2 P6B(8.6) T90S(5.4 8.6 G1A(2.0) G2(5.6) 5.6 T90S 5.4 AP1(16.2) M2Bm(2.9) 16.2 M2BBm 19.8 RL1 2.0 Total 81.2	T30S 5.4 AP1(16.2) M2Bm(2.9) 16.2 P6B(8.6) T90S(5.4 8.6 G1A(2.0) G2(5.6) 5.6 T90S 5.4 AP1(16.2) M2Bm(2.9) 16.2 M2BBm 19.8 RL1 2.0 81.2	*BD2 32.0 *BD2 32.0 64.0	81.2	
				25 cycles are required to clear the top bank (25-1)(32.0+81.2) 24x113.2 2716.8			2716.8	
				4) climb down		*BBM-VD-02 70.0	70.0	
				5) start clearing threads from the far end on the bottom 16 clearing cycles are required to left hand foundation pillar				
				16x113.2 1811.2			1811.2 4711.2	4711.2
				6) start machine to stitch N rows of the color				
					R30A 17.5 G1A 2.0 *FAC-SW -01 10.0			
				Total	29.5		29.5 29.5	29.5
							G. Total	5767.2

Table C13 Synthesis of "Preparation-1" by MTM and USD

Operation Name: Preparation-1

Symbol used in Flowchart (Figure A1) to represent operation: (P1/13)

Contents of operation:

Operator:

1) Cut off power to the machine
2) Pull the autostop lever back into position
3) Crank the gearwheel into neutral position
4) Cut the front yarn with a knife at the cloth line and with a scissors at the guide-bar
5) Remove the threads from the machine for disposal

Helper:

1) Unlock the machine
2) Open the machine
3) Help the operator with functions 4 and 5

Purpose of operation:

This precedes a color change. The purpose of this preparatory operation is to detatch the span of cloth from the front yarn, in order to able to load the next color of yarn

Operation starts:

The moment the machine stitches its last stitch and snaps the autostop lever. The operator is at the center on the front side of the machine and the helper is at the center on the back side of the machine

Operation ends:

Operator and helper at machine center on the front side of the machine

Synthetic cycle time: 3.37 minutes

HELPER				OPERATOR				TOTAL
LEFT HAND 1	RIGHT HAND 2	BODY 3	TOTAL 4	LEFT HAND 5	RIGHT HAND 6	BODY 7	TOTAL 8	9
SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
This column shall reference helper column in Table C19				This column shall reference operator column in Table C19				
1) Place shuttles in apron:				1) Put picker in apron, as you walk to automat:				
2) Untie apron and place on drawer top:				2) Untie apron and place it on bench as you walk to the automat: Stop in front of power switch:			189.0	
3) Walk to machine locks			80.0	3) Turn off power to machine			46.9	
4) Get prybar and open top catch				4) Go to automat and take up position in front of autostop:			71.2	
5) Open bottm catch				5) Pull autostop and reset catch:			53.6	
6) Replace prybar				5a) Crank gearwheel to neutral position using handwheel:			32.0 52.1 32.0	
7) Go to machine locking lever			80.0 18.6	6) Walk to drawer (beneath bench) and get 2 knives and 2 scissors from drawer. Identical as helper col. no. 11 Table C19		*BBM-TW-04 80.0	80.0	
8) Open machine (shuttle) rail			92.0				21.3 54.2 61.0 32.0	
9) Walk to front side and get one knife from operator			545.0				725.3	725.3
			18.5	7) Hand one knife to operator			19.5	18.5
10) Walk to far end of machine. Wait for operator to start and then proceed: Helper Col. No. 14 Table C19			266.2	8) Walk to far end of the machine and climb to the top bank: Operator col. no. 11 Table C19			299.0	
			266.2	9) Tension front yarn by roller before starting TOWT: Operator col. no. 12 Table C19			27.3 32.0	
11) Tension front yarn by roller before starting to cut			32.0 27.3				358.3	358.3
12) Cut the bottom threads to the cloth line: Identical to helper col no. 16 Table C19				10) Continue cutting[1]:			632.0	
				12) Replace knife in drawer: Identical to operator col. no. 15 Table C19			19.5	

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL	TIME *USD TMU	SYMBOL	TIME *USD TMU	SYMBOL	TIME *USD TMU	Greater times at --*--*--		SYMBOL	TIME *USD TMU	SYMBOL	TIME *USD TMU	SYMBOL	TIME *USD TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
						192.0								10.9		
						66.1								19.7		
						192.0										
						66.1										
						192.0		13) Pick up scissors and walk to far end of machine and climb up: Identical operator Col. No. 16 Table C19								
						224.0								20.0		
13) Replace knife in drawer: Identical to operator col. no. 15 Table C19														327.0		
						19.5								17.1		
						10.9										
						19.7		14) Cut ton front yarn: Identical to operator Col. No. 17 Table C19								
14) Pick up scissors and walk to far end of machine: Identical to helper col. No. 29 Table C19														11.4		
						20.0								79.8		
						294.0								866.4		
15) Cut bottom yarn: Identical to helper Col. No. 30 Table C19								15) Place scissors on bench-top: Identical to operator Col. No. 18 Table D19								
						11.4								11.7		
						79.8								64.0		
						775.2		16) Begin removing threads from top bank: Identical to operator Col. No. 19 Table D19								
						64.0										
						43.0								46.2		
						25.6								138.6		
						19.5								1478.4		
						10.9										
						19.7										
16) Start removing threads from bottom bank Identical as top bank operator col. no. 19 Table C19 Except for pillar correction:								17) Climb down				*BBM-VD_02	70.0	70.0		
						46.2										
						138.6										
						1478.4										
17) Negotiate 2 foundation pillars:				*BD2	32.0											
				*BD2	32.0											
Total					64.0	64.0								3812.7		4141.9
						4141.9										
18) Collect waste yarn from operator for disposal								18) Give waste yarn to helper for disposal								
		R14B	14.4							M14B	14.6					
		G3	5.6							G3	5.6					
Total			20.0			20.0		Total			20.2			20.2		20.2
19) Go to dispose threads and return to machine centre: Identical to helper col. no. 36. Table C19																
						170.0										
						14.2										
						170.0										354.2
						354.2										
														G. Total		5618.4

Table C14 Synthesis of "Switching operation (1) " by MTM and USD

Operation Name: Switching operation (1)

Symbol used in Flowchart (Figure A1) to represent operation: (S1/14)

Contents of operation:

Operator:

1) Starting from the automat end of the top bank switch the bottom row of spools with the top row of spools for the 8/4 repeat, systematically one for one, using both hands

Helper:

1) Starting from the far end of the bottom bank switch the bottom row of spools with the top row of spools, for the 8/4 repeat, systematically one for one, using both hands. This operation is performed entirely on the front side of the machine.

Purpose of operation:

In a two color emblem when both colors have been loaded onto the machine and the first color has been stitched the switching operation is performed to bring the bottom row on top to enable further processing of the span

Operation starts:

Operator and helper at machine front and center

Operation ends:

Operator and helper at machine front and center.

Synthetic cycle time: 4.54 minutes

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
1) Walk to far end of machine							1) Walk to automat end of machine and reach for spools							
				*BBM-TW-10	170.0	170.0					*BBM-TW-10	170.0	170.0	
P16A	16.0	P16A	16.0			16.0	R28A	24.2	R28A	24.2			24.2	
2) Start switching the positions of spools on the top and bottom rows of the bottom bank. (170 spools). Identical to the operation of switching on the top bank. Operator Col. No. 2							2) Start switching the positions of spools on the top and bottom row of the top bank: 1 switch cycle:							
									R2B	4.0				
(170/2)(14.9+31.1+25.7)							R2B	4.0	G1A	2.0				
85x71.7									M6B	8.9				
6094.5						6094.5	Total	4.0		14.9			14.9	
							G1A	2.0	M3B	5.7				
Allowance for crossing 2 foundation pillars:							M4B	6.9	P1SE	5.6				
							M2B	4.6	M2B	4.6				
2xP15E	28.4	2xR15E	28.4	*2xBD@	64.0	64.0	M5E	5.6	RL1	2.0	SSC1	17.0		
							M2B	4.6	R2B	4.0				
2xR16A	32.0	2xR16A	32.0			32.0	RL1	2.0	G1A	2.0				
							R2B	4.0	M4B	6.9				
							Total	29.7		31.1		17.0	31.1	
3) Return to centre														
							G1A	2.0	M3B	5.7				
R15E	14.2	R16E	14.2			14.2	M4B	6.9	P1SE	5.6				
							M2B	4.6	M2B	4.6				
				*BBM-TW-10	170.0	170.0	P1SE	5.6	RL1	2.0	SSC1	17.0		
							M2B	4.5						
							RL1	2.0						
							Total	25.7		17.9		17.0	25.7	
							This completes one switching cycle for two spools in the same fasion go ahead and switch all 170 spools from top to bottom							
							(170/2-1)(14.9+31.1+25.7)							
							84x71.7							
							=6022.8						6022.8	
							3) Return to centre							
							R30E	22.9	R30E	22.9			22.9	
											*BBM-TW-10	170.0	170.0	
						6560.7							6481.8	6560.7
												G. Total		6560.7

Table C15 Synthesis of "Switching operation (2) " by MTM and USD

Operation Name: Switching operation (2)

Symbol used in Flowchart (Figure A1) to represent operation: (S2/15)

Contents of operation:

Operator:

1) Starting from the automat end of the top bank switch the bottom row of spools with the top row of spools for the 12/4 repeat, systematically one for one, using both hands.

Helper:

1) Starting from the far end of the bottom bank switch the bottom row of spools with the top row of spools for the 12/4 repeat, systematically one for one, using both hands. This operation is performed entirely on the front side of the machine

Purpose of operation:

In a two color emblem when both colors have been loaded onto the machine and the first color has been stitched the switching operation is performed to bring the bottom row on top to enable further processing of the span.

Operation starts:

Operator and helper at machine front and center

Operation ends:

Operator and helper at machine front and center

Snythetic cycle time: 2.86 minutes.

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*-
Walk to far end of machine				*BBM-TW-10	170.0	170.0		1) Walk to the automat end of the machine and reach for spools				*BBM-TW-10	170.0	170.0		
2) Start switching the positions of spools on the top and bottom rows of the bottom bank. (115 spools). Identical to the operation of switching on the top bank								R28A	24.2	R28A	24.2			24.2		
(115/2)(10.9 + 31.1 + 32.6) 58 x 74.6 = 4326.8						4326.8		2) Start switching the positions of spools on the top and bottom row of the top bank: 1 switch cycle:								
										G1A	2.0					
										M6B	8.9					
Allowance for crossing 2 foundation pillars								Total			10.9			10.9		
2xR15E	28.4	2xR15G	28.4	*2xBD2	64.0	64.0		G1A	2.0	M3B	5.7					
								M4B	6.9	P1SE	5.6					
								M2B	4.6	M2B	4.6					
2xR16A	32.0	2xR16A	32.0			32.0		M5E	5.6	RL1	2.0	SSC1	17.0			
								M2B	4.6	R2B	4.0					
								RL1	2.0	G1A	2.0					
3) Return to centre								R2B	4.0	M4B	6.9					
								Total	29.7		31.1		17.0	31.1		
R16E	14.2	R16E	14.2			14.2		G1A	2.0	M3B	5.7					
								M4B	6.9	P1SE	5.6					
								M2B	4.6	M2B	4.6					
				*BBM-TW-10	170.0	170.0		P1SE	5.6	RL1	2.0	SSC1	17.0			
								M2B	4.5	M4B	6.9					
								RL1	2.0							
								M4B	6.9							
								Total	32.6		24.8		17.0	32.6		
								This completes one switching cycle for two spools in the same manner go ahead and switch all 115 spools from top to bottom								
								(115/2 - 1)(10.9 + 31.1 + 32.6) 57 x 74.6 = 4252.2						4252.2		
								3) Return to centre								
								R30E	22.9	R30E	22.9			22.9		
												*BBM-TW-10	170.0	170.0		
						4777.0								4713.9		4777.0
														G. Total		4777.0

Table C16 Synthesis of "Unloading operation (1) and (2) " by MTM and USD

Operation Name: Unloading operation (1) and (2)

Symbol used in Flowchart (Figure A1) used to represent operations: (ULI 16) (UL2 16)

Contents of operation:

Operator:

1) Bring the empty or near empty carton of spools from the storage area
2) Unload the spools from the machine on the 8/4 repeat (340 spools in number-170 spools on the top bank and 170 spools on the bottom bank) and place them in an orderly manner in their carton.
3) Carry the full carton to the racks for storage.

Helper:

Assist the operator in unloading the spools.

Purpose of operation:

When one color has been stitched and the next color on the same emblem or another emblem has to be stitched unloading of the spools of yarn is necessary in order to be able to load the next color. This operation takes place entirely on the front of the machine, on the top and bottom banks.

Operation starts:

Operator and helper in center on the front side of the machine

Operation ends:

Operator and helper in rack storage area

Sketch:

Figure 2.3

Unloading operation (1) involves the unloading the top row of spools (340) on both banks ((a) and (c) in Figure 2.3). Unloading operation (2) involves unloading of the bottom row of spools (340) on both banks ((b) and (d) in Figure 2.3). Unloading operation (1) and Unloading operation (2) are exactly the same except for a physical disposition difference. They will be treated as being the same for analysis purposes. For analysis purposes it is assumed that there are 18 spools per yard length. Also, it is assumed that the average top bank to center of carton distance is 36" and the average bottom bank to center of carton distance is 30".

The operation proceeds as follows:

The operator works on one side of the carton and the helper works on the other side. Each unloads 4 spools on the top bank, two in each hand, then unloads 4 spools on the bottom bank. No more than 5 such unloading cycles are required per yard. The operator and helper work on one yard at a time and then the helper moves the carton along the bench. Hence the helper is requred to carry the carton 4 times along the bench (2 yards at a time) in the process of unloading the 10 yard length of the machine

Synthetic cycle time: 4.67 minutes.

HELPER						OPERATOR						TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3	TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7	TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	
					Greater times at --*--*--						Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
1) Go to storage racks area:						1) Go to storage racks and get the carton of the color to be unloaded:						
				*BBM-TW-08	140.0					*BBM-TW-10	170.0	
					140.0						170.0	
						R20A	13.1	R20A	13.1	*BD2	32.0	
											32.0	
						G4A	7.3	G4A	7.3			
						M8B75	13.4	M8B75	13.4			
						G2	5.6	G2	5.6			
						M8B12.5	15.7	M8B12.5	15.7			
						G2	5.6	G2	5.6	SSC1	18.6	
						Total	47.6		47.6		18.6	
											47.6	
						2) Take the carton over to the bench						
										*BBM-TW-06x1.5 (1.5 bulky load)	165.0	
											165.0	
						3) Place the box on the bench and uncover flaps						
						P2SD	21.8	P2SD	21.8			
						RL2	0.0	RL2	0.0			
						R8A	7.9	R8A	7.9			
						G5	0.0	G5	0.0			
						M8B12.5	15.7	M8B12.5	15.7			
						RL2	0.0	RL2	0.0			
						Total	45.4		45.4			
											45.4	
						*G18S	19.0	*G18S	19.0	TBC1	18.6	
											19.0	
								M25B	21.8			
											21.8	
						M25B	21.8					
											21.8	
						RL1	2.0	RL1	2.0	SSC1(15")	18.6	
											18.6	
					140.0						541.2	541.2
2) Uncover flops of cartoon												
*G18S	19.0	*G18S	19.0	TBC1	18.6							
	19.0											
		M25B	21.8									
	21.8											
M25B	21.8											
	21.8											
RL1	2.0	RL1	2.0	SSC1(15")	18.6							
	18.6											
	81.2											81.2
3) Start to unload spools and place them systematically in the carton Unload 4 spools at a time 2 in each hand no more than 5 such cycles are required per yard:						4) Start to unload spools and place them systematically in the carton Fig. (6): Unload 4 spools at a time, 2 in each hand, no more than 5 such cycles are required per yard:						
5(R30A+mR10A)		5(R30A+mR10A)		*5xFL	65.0	5(R30A+mR10A)		5(R30A+mR10A)		*5xFL	65.0	
	124.0		124.0				124.0		124.0			
5xG1C1	36.5	5xG1C1	36.5			5xG1C1	36.5	5xG1C1	36.5			
5xD1D	28.5	5xD1D	28.5			5xD1D	28.5	5xR1D	28.5			
5(M30B+mM10B)		5(M30B+mM10B)				5(M30B+mM10B)		5(M30B+mM10B				
	164.5	164.5					164.5		164.5			
5xP1SSD	73.5	5xP1SSD	73.5			5xP1SSD	73.5	5xP1SSD	73.5			

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
5xRL1	10.0	5xRL1	10.0					5xRL1	10.0	5xRL1	10.0					
Total	437.0		437.0		65.0	437.0		Total	437.0		437.0		65.0	437.0		
Similarly for the bottom bank unload 4 spools at a time, 2 in each hand: no more than 5 such cycles are required per yard:								Similarly for the bottom bank unload 4 spools at a time, 2 in each hand: No more than 5 such cycles are required per yard:								
5(R30A+mR6A)	116.0	5(R30A+mR6A)	116.0	*5xFL	65.0			5(R30A+mR6A)	116.0	5(R30A+mR6A)	116.0	*5xFL	65.0			
5xG1C1	36.5	5xG1C1	36.5					5xG1C1	36.5	5xG1C1	36.5					
5xD1D	28.5	5xD1D	28.5					5xD1D	28.5	5xD1D	28.5					
5(M30B+mM6B)	150.0	5(M30B+mM6B)	150.0					5(M30B+mM6B)	150.0	5(M30B+mM6B)	150.0					
5xP1SSD	73.5	5xP1SSD	73.5					5xP1SSD	73.5	5xP1SSD	73.5					
5xRL1	10.0	5xRL1	10.0					5xPL1	10.0	5xRL1	10.0					
Total	414.5		414.5		65.0	414.5		Total	414.5		414.5		65.0	414.5		
						851.5								851.5		851.5
4) Move carton 2 yds:																
R12A	9.6	R12A	9.6	*BD2	32.0											
G1A	2.0	G1A	2.0													
Total	11.6		11.6		32.0	32.0										
				*BBM-TW-06x1.5 (1.5Bulky load)	165.0	165.0										
P2SD	21.8	P2SD	21.8													
RL1	2.0	RL1	2.0													
R16E	14.2	R16E	14.2	TBC1	18.6											
Total	38.0		38.0		18.6	38.0										
						235.0										235.0
5) Continue unloading along the entire length of machine. For 10 yds. 5 unload cycles are required: Identical to the helper co. no. 3.								5) Continue unloading along the entire length of machine. For 10 yds. 5 unloaded cycles are required: Identical to operator col. no. 4:								
(5.1)(437.0+414.5)		3406.0				3406.0		(5.1)(437.0+414.5)		3406.0				3406.0		
Also move the care on 5 times: Identical to the helper column, no. 4.																
		(5.1)(32.0+165.0 + 38.0)	940.0			940.0										
						5286.0								3406.0		5286.0
								6) Cover flaps of the loaded carton:								
								*G18S	19.0	*618S	19.0	TBC1	18.6			
										M25B	21.8					
								Total	19.0		40.8		18.6	40.8		
								M25B	21.8							
								RL1	2.0	RL1	2.0					
								Total	23.8		2.0			23.8		
														64.6		64.6
6) Cover flaps:																
*G18S	19.0	*G18S	19.0	TBC1	18.6											
		M25B	21.8													
Total	19.0		40.8		18.6	40.8										
M25B	21.8															
RL1	2.0	RL1	2.0													
Total	23.8		2.0			23.8										
						64.6										64.6

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 6 8 at --*--*--*--
7) Pick un loaded carton of spools and carry it to the racks area:								7) Pick up loaded carton of spaces and carry it to the rack area:								
R16A	11.4	R16A	11.4					P16A	11.4	R16A	11.4					
G1A	2.0	G1A	2.0					G1A	2.0	G1A	2.0					
M8B22.5	20.3	M8B22.5	20.3					M8B22.5	20.3	MRB22.5	20.3					
G3	5.6	G2	5.6					G2	5.6	G2	5.6					
Total								Total								
				*BBM-TW-10x1.5 (25')	255.0							*BBM-TW-10x1.5 (25')	255.0				
				*BBM-WD-10x1.5 (1.5 Bulky load)	135.0							*BBM-WD-10x1.5 (15') (1.5 Bulky load)	135.0			
Total					490.0	490.0		Total					490.0	490.0		490.0
				*BD2	32.0	32.0						*BD2	32.0	32.0		
8) Locate in rack and leave in storage:								8) Locate carton in rack and leave in storage:								
P2SD	21.8	P2SD	21.8	*BD2	32.0			P2SD	21.8	P2SD	21.8	*BD2	32.0			
RL1	2.0									RL1	2.0					
R15E	14.2							R15E	14.2							
Total	38.0		21.8		32.0	38.0		Total	21.8		38.0		32.0	38.0		
		M15A47.5	40.0			40.0		M15A47.5	40.0					40.0		
R20E	16.7	R10E	10.5	*BD2	32.0	32.0		RL2	0.0							
								R20E	16.7	R10E	10.5	*BD2	32.0			
								Total	16.7		10.5		32.0	32.0		
						671.3								671.3		671.3
															G. Total	7795.4

Table C17 Synthesis of "Unloading operation (3) and (4) " by MTM and USD

Operation Name: Unloading operation (3) and (4)

Symbols used in Flowchart (Figure A1) to represent operations: (UL3/17) (UL4/17)

Contents of operation:

Operator:

1) Bring the empty or near empty carton of spools from the storage area
2) Unload the spools from the machine on the 12/4 repeat (230 spools in number-115 spools on the top bank and 115 spools on the bottom bank) and place them in an orderly manner in their carton
3) Carry the full carton to the racks for storage

Helper:

Assist the operator in unloading the spools

Purpose of operation:

When one color has been stitched and the next color on the same emblem or another emblem has to be stitched unloading of the spools of yarn is necessary in order to be able to load the next color. This operation takes place entirely on the front of the machine, on the top and bottom banks.

Operation starts:

Operator and helper in center on the front side of the machine

Operation ends:

Operator and helper in rack storage area

Sketch:

Figure 2.4

Unloading operation (3) involves the unloading of the top row of

spools (230) on both banks ((a) and (c) in Figure 2.4). Unloading operation (4) involves the unloading of the bottom row of spools (230) on both banks ((b) and (d) in Figure 2.4). Unloading operation (3) and Unloading operation (4) are exactly the same except for a physical disposition difference. They will be treated as being the same for analysis purposes. For analysis it is assumed that there are 12 spools per yard length. Also, it is assumed that the average top bank to center of carton distance is 36" and the average bottom bank to center of carton distance is 30".

The operation proceeds as follows:

The operator works on one side of the carton and the helper works on the other side. Each unloads 4 spools on the top bank, two in each hand, then unloads 4 spools on the bottom bank. No more than 3 such unloading cycles are required per yard. The operator and helper work on one yard at a time and then helper moves the carton along the bench. Hence the helper is required to carry the carton 4 times along the bench (2 yards at a time) in the process of unloadint the 10 yard length of the machine

Synthetic cycle time: 3.65 minutes

HELPER				OPERATOR				TOTAL
LEFT HAND 1	RIGHT HAND 2	BODY 3	TOTAL 4	LEFT HAND 5	RIGHT HAND 6	BODY 7	TOTAL 8	9
SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
1) Go to storage racks area.				1) Go to storage racks and get the carton of the color to be unloaded:				
		*BBM-TW-08 140.0	140.0			*BBM-TW-10 170.0	170.0	
				R20A 13.1	R20A 13.1	*BD2 32.0	32.0	
				G4A 7.3 MBB12.5 15.7 G2 5.6 MBB12.5 15.7 G2 5.6 Total 49.9	G4A 7.3 MBB12.5 15.7 G2 5.6 MBB12.5 15.7 G2 5.6 49.9	SSC1(15") 18.6 18.6	49.9	
				2) Take the carton over to the bench				
						*BBM-TW-06x1.5 165.0 (1.5 Bulky load)	165.0	
				3) Place the box on the bench & uncover the flaps				
				P2SD 21.8 RL2 0.0 R8A 7.9 G5 0.0 MBB12.5 15.7 RL2 0.0 Total 45.4	P2SD 21.8 RL2 0.0 R8A 7.9 G5 0.0 MBB12.5 15.7 RL2 0.0 45.4		45.4	
				*G18.5 19.0	*G18S 19.0	TBC1 18.6	19.0	
					M25B 21.8		21.8	
				M25B 21.8			21.8	
				RL1 2.0	RL1 2.0	SSC1(15") 18.6	18.6 543.5	543.5
			140.0					
2) Uncover flaps of carton:								
*G18S 19.0	*G18S 19.0	TBC1 18.6	19.0					
	M25B 21.8		21.8					
M25B 21.8			21.8					
RL1 2.0	RL1 2.0	SSC1(15") 18.6	18.6 81.2					81.2
3) Start to unload spools and place them systematically in the carton: Unload 4 spools at a time, 2 in each hand, no more than 3 such cycles are required per yard.				4) Start to unload spools and place them systematically in the cartoon. Unload 4 spools at a time, 2 in each hand. No more than 3 such cycles are required per yard.				
3(R30A+mR10A) 74.3 3xG1C1 21.9 3xD1D 17.1 3(M30B+mM10B) 98.7 3xP1SSD 44.1 3xRL1 6.0 Total 262.1	3(R30A+mR10A) 74.3 3xG1C1 21.9 3xD1D 17.1 3(M30B+mM10B) 98.7 3xP1SSD 44.1 3xRL1 6.0 262.1	*3xFL 39.0 39.0	262.1	3(R30A+mR10A) 74.3 3xG1C1 21.9 3xD1D 17.1 Total 262.1	3(R30A+mR10A) 74.3 3xG1C1 21.9 3xD1D 17.1 262.1	*3xFL 39.0 39.0	262.1	

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
Similarly for the bottom bank unload 4 spools at a time, 2 in each hand. No more than 3 such cycles are required per yard							Similarly for the bottom bank unload 4 spools at a time, 2 in each hand. No more than 3 such cycles are required per yard							
3(R30A+mP6A)	69.6	3(R30A+mP6A)	69.6	*3xFL	39.0		3(R30A+mR64)	69.6	3(R30A+mR6A)	69.6	*3xFL	39.0		
3xG1C1	21.9	3xG1C1	21.9				3xG1C1	21.9	3xG1C1	21.9				
3xD1D	17.1	3xD1D	17.1				3xD1D	17.1	2xD1D	17.1				
3(M30B+mM6B)	90.0	3(M30B+mM6B)	90.0				3(M30B+mM6B)	90.0		90.0				
3xP1SSD	44.1	3xP1SSD	44.1				3xP1SSD	44.1	3xP1SSD	44.1				
3xRL1	6.0	3xRL1	6.0				3xRL1	6.0	3xRL1	6.0				
Total	248.7		248.7		39.0	248.7	Total	248.7		248.7		39.0	248.7	
4) Move carton 2 yds.														
R12A	9.6	R12A	9.6	*BD2	32.0									
G1A	2.0	G1A	2.0											
Total	11.6		11.6		32.0	32.0								
				*BBM-TW-06x1.5	165.0 (1.5 Bulky load)	165.0								
P2SD	21.8	P2SD	21.8											
RL1	2.0	RL1	2.0											
R16E	14.2	R16E	14.2	TBC1	18.6									
Total	38.0		38.0		18.6	38.0								
						745.8								745.8
5) Continue unloading along the entire length of machine for 10 yds. 5 unload cycles are required identical to helper co. no. 3.							5) Continue unloading along the entire length of machine 5 load cycles are required. Identical to operator col. no. 4							
(5-1)(262.1+248.7)		2043.2				2043.2	5(262.1+248.7)		2043.2					2043.2
Also move the carton 5 times: Identical to helper col. no. 4														
		(5-1)(32.0+165.0 +38.0)	940.0			940.0								
						3923.2							2043.2	3923.2
							6) Cover flaps of loaded carton:							
							*G18S	19.0	*G18S	19.0	TBC1	18.6		
									M25B	21.8				
							Total	19.0		40.8		18.6	40.8	
							M25B	21.8						
							RL1	2.0	RL1	2.0				
							Total	23.8		2.0			23.8	
													64.6	64.6
6) Cover flaps														
*G18S	19.0	*G18S	19.0	TBC1	18.6									
		M25B	21.8											
Total	19.0		40.8		18.6	40.8								
M25B	21.8													
RL1	2.0	RL1	2.0											
Total	23.8		2.0			23.8								
						64.6								64.6
7) Pick up loaded carton of spools and carry it to the racks area.							8) Pick up loaded cartoon and carry to the rack area.							

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
	11.4	P16A	11.4					R16A	11.4	R16A	11.4					
G1A	2.0	G1A	2.0					G1A	2.0	G1A	2.0					
M8B22.5	20.3	M8B22.5	20.3					M8B22.5	20.3	M8B22.5	20.3					
G2	5.6	G2	5.6					G2	5.6	G2	5.6					
Total	39.3		39.3			39.3		Total	39.3		39.3			39.3		
	*		*						*		*					
				*BBM-TW-10x1.5 (25')	255.0							*BBM-TW-10x1.5 (25')	255.0				
				*BBM-WD-10x1.5	135.0							*BBM-WD-10x1.5	135.0				
				1.5 Bulky load								1.5 Bulky load					
Total					490.0	490.0		Total					490.0	490.0		
	*		*						*		*					
				*BD2	32.0	32.0						*BD2	32.0	32.0		
	*		*						*		*					
8) Locate carton in rack and leave in storage								8) Locate carton in rack and leave in storage								
P2SP	21.8	P2SD	21.8	*BD2	32.0			P2SD	21.8	P2SD	21.8	*BD2	32.0			
RL1	2.0							RL1	2.0							
R15E	14.2							R15E	14.2							
Total	38.0		21.8		32.0	38.0		Total	38.0		21.8		32.0	38.0		
	*		*						*		*					
		M15A47.5	40.0			40.0		M15A47.5	40.0					40.0		
	*		*						*		*					
R2nE	16.7	R10E	10.5	*BD2	32.0	32.0		RL2	0.0							
	*		*					R20E	16.7	R10E	10.5	*BD2	32.0			
								Total	16.7		10.5		32.0	32.0		
	*					671.3	*		*				*	671.3		671.3
															G. Total	6094.2

Table C18 Synthesis of "Rollover operation" by MTM and USD

Operation Name: Rollover operation

Symbol used in Flowchart (Figure A1) to represent operation: (RO/18)

Contents of operation:

Operator:

1) Perform Preparation-2
2) Loosen cloth on the top and bottom banks and rollover fresh stitching field
3) Tighten span and tack ends of goods onto side combs

Helper:

1) Perform Preparation-2
2) Assist operator with rollover
3) Help operator tighten span and tack ends of goods onto side combs

Purpose of operation:

When one stitching field has been processed the finished goods are rolled onto the top roller and the unworked goods simultaneously unroll from the bottom roller. A fresh stitching field is thus set for processing.

Operation starts:

Operator and helper at machine center on the front side of the machine

Operation ends:

Operator at automat end on the front side of the machine, helper at the machine center on the back side of the machine

Synthetic cycle time: 11.95 minutes

HELPER				OPERATOR				TOTAL
LEFT HAND 1	RIGHT HAND 2	BODY 3	TOTAL 4	LEFT HAND 5	RIGHT HAND 6	BODY 7	TOTAL 8	9
SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
1) Perform preparation - 2 Table C19			7044.7	1) Perform preparation - 2 completely This shall not be repeated here: Table C19			7044.7	
Here we shall reference - Table - C20 Removal of finished goods from machine				Here we shall reference Table - D20 - Removal of finished goods from machine,				
2) Go to the automat and center frame vertically: Identical to helper col. no. 1, Table D20			352.0 22.0 43.0 22.0 142.0	2) Go to automat end, identical to operator col. no. 5 Table C20			260.0	
			7625.7	3) Get prybar and extension tube and position it on gearwheel: Identical to operator col. no. 6 Table C20			25.0 64.0 25.3 7419.4	7625.7
3) Loosen top span: Identical to helper col. no. 5, Table C 20				4) Loosen: Top span: Identical to operator col. no. 7, Table C20			708.4	708.4
5) Help loosen bottom span				5) Loosen the bottom span:				
				D2D 11.8 M30C 30.7 P2SSD 25.3 Total 67.8	D2D 11.8 M30C 30.7 25.3 67.8	*BD2 32.0 32.0	67.8	67.8
			708.4				708.4	708.4
6) Go to far end of the machine: Identical to operator col. no. 6, Table C20			260.0	6) Replace prybar and extention tube				
				*P3ALP1 42.0 R30E 22.9 Total 64.9	*P30LP1 42.0 R30E 22.9 64.9	*BD2 32.0 *BD2 32.0 64.0	64.9	
7) Climb up and take the cloth off the comb: Identical to operator col. no., Table C20			102.0 224.1 586.1	7) Climb up and take the cloth off the comb: Identical to operator col. no. 9, Table C20			102.0 224.1 391.0	586.1
8) Climb down and take the cloth off the comb: Same as above			102.0 224.1 326.1	8) Climb down and take the cloth off the comb: same as above			102.0 224.1 326.1	326.1
				9) Go to automat, open vertical catch and lower frame to initial setting using vertical handwheel				
				R14A 10.5 Total 10.5	R12A 9.6 9.6	*BRM-TW-06 110.0 *BD2 32.0 142.0	212.0	
				G1A 2.0 Total 2.0	G1A 2.0 *FAC-LV -04 20.0 22.0		22.0	

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater o 4 & 8 at --*--*--*-
								*4GS(16" -10 lbs)	73.0					73.0		
								RL1	2.0	*FAC-LV -04	20.0					
								Total	2.0	RL1	2.0			22.0		
										22.0							
								R14E	13.0	R12E	11.8	*BD2	32.0	32.0		
								10) Go to the back of the machine and climb up:								
												*BBM-TW-06	110.0			
												*BBM-VD-02	70.0	180.0		
								R30A	23.2	R30A	23.2					
								G1A	2.0	G1A	2.0					
								Total	25.2		25.2			25.2		
												ET	20.0	20.0		
								11) Start rolling the finished goods on the top roller: Identical to operator col. no. 8 Table C2								
														276.8		
														863.0		863.0
								12) Roll finished goods to desired level and make sure that the inside tooth of the catch is engaged identical to operator no. 24 Table C2						74.5		
13) Climb down, raise bench and start rolling the finished goods on the top roller				*BBM-VD-02	70.0			13) Climb down raise bench and start rolling the finished goods on the top roller in the same manner as above				*BBM-VD-02	70.0	70.0		
								R14A	10.5	R14A	10.5	*BD2	30.0	32.0		
								G1A	2.0	G1A	2.0					
								M14A40	35.0	M14A40	35.0	*BD2	32.0			
								RL1	2.0	RL1	2.0					
								R10E	10.5	R10E	10.5					
								Total	49.5		49.5		32.0	49.5		
R30A	23.2	R30A	23.2					R30A	23.2	R30A	23.2					
G1A	2.0	G1A	2.0					G1A	2.0	G1A	2.0					
Total	25.2		25.2			25.2		Total	25.2		25.2			25.2		
						74.5								74.5		
								14) Get prybar and extension tube and tighten both top and bottom rollers and tack cloth onto the comb[1]:								
								*2xG30S	50.0	*2xG30S	50.0			50.0		

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*
										*2XG30S	50.0	*2xBD2 *2xBD2	64.0 64.0			
								Total			50.0		128.0	128.0		
								2xP2SSD	50.6	2xP2SSD	50.6			50.6		
														554.3		554.
14) Help operator tighten spans						8480.0				2x4240.0 = 8480.0				8480.0		8480.(
															G. Total	19919.(

1. Table 2.3 Item 4

Table C19 Synthesis of "Preparation-2" by MTM and USD

Operation Name: Preparation-2

Symbol used in Flowchart (Figure A1) to represent operation: (P2/19)

Contents of operation:

Operator:

1) Cut off power to the machine
2) Pull the autostop lever back into position
3) Crank the gearwheel into neutral position
4) Raise the frame
5) Cut the front yarn with a knife at the cloth line and with a scissors at the guide-bar
6) Remove the threads from the machine for disposal

Helper:

1) Unlock the machine
2) Open the machine
3) Cut the shuttle threads
4) Help operator with functions 5 and 6

Purpose of operation:

This precedes mounting a fresh span of cloth onto the machine. The purpose of this preparatory operation is to detatch the finished span of cloth from the front yarn and bobbin yarn, in order to set the cloth free for removal.

Operation starts:

The moment the machine stitches its last stitch and snaps the auto-stop lever. The operator is at the center on the front side of the machine

and the helper is at the center on the back side of the machine

Operation ends:

Operator and helper at machine center on the front side of the machine

Synthetic cycle time: 4.22 minutes

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
1) Place shuttles in apron:								**1) Put picker in apron, as you walk to automat**								
P10B	19.8	*P10B	19.8							*G30S	25.0	*RBM-TW-08	140.0			
										*P24B	24.0					
2) Untie apron and place on drawer top:								**2) Untie apron and place it on the bench as you walk to the automat: Stop in front of the power switch**								
R20D	19.8	R20D	19.8					R20D	19.8	R20D	19.8					
G1C3	10.8	G1C3	10.8					G1C3	10.8	M6Bm	5.7					
M6Bm	5.7	M6Bm	5.7					M6Bm	5.7	T30S	2.8					
T30S	2.8	T30S	2.8					T30S	2.8	G2	5.6					
G2	5.6	G2	5.6					G2	5.6	M30A	27.1					
M15Bm	12.8	M15Bm	12.8					M30A	27.1	G3	5.6					
P1SSE	9.1	P1SSE	9.1					G3	5.6	R10E	10.5					
RL1	2.0	RL1	2.0					R10E	10.5	M10Bm	8.9					
Total	88.4		88.4				88.4			P1SE	4.0					
										RL1	2.0					
3) Walk to machine locks:										R10E	10.5	*W2	49.0			
				*BBM-TW-04	80.0		80.0	Total	87.9		102.8		189.0		189.0	
4) Get prybar and open top latch								**3) Turn off power to machine**								
*G30S	25.0	*G30S	25.0							R30A	17.5					
T45M	5.5	T45M	5.5							G5	0.0					
P1SD	11.2	P1SD	11.2							M4Bm	4.3					
M8C	11.8	M8C	11.8							AP1	16.2					
AP1	16.2	AP1	16.2							RL2	0.0					
										R3BE	28.9					
5) Open bottom latch:								Total			46.9				46.9	
M30B	26.2	M30B	26.2					**4) Go to automat and take up position in front of autostop%**								
G2	5.6	G2	5.6									*W1	34.0			
P1SD	11.2	P1SD	11.2									TBC2	37.2			
M8C	11.8	M8C	11.8					Total					71.2		71.2	
AP1	16.2	AP1	16.2													
6) Replace prybar:								**5) Pull autostop back and reset catch:**								
*P30LP1	42.0	*P30LP1	42.0							*G16S	19.2					
R30E	22.9	R30E	22.9							M5A7.5	7.9					
Total	205.6		205.6				205.6			R14Bm	11.5					
										G5	0.0					
7) Go to machine locking lever:										M3/4A	2.0					
				*BBM-TW-04	80.0		80.0			RL2	0.0					
										R14E	13.0					
R26A	15.8	R14A	10.5	TBC1		18.6		Total			53.6				53.6	
G1A	2.0	G1C1	7.3													
Total	17.8		17.8			18.6	18.6	**5a) Crank gearwheel to neutral position using the handlever:**								
8) Open machine (shuttle rail):								R15A	11.4	R15A	11.4	*BD2	32.0			
								G1A	2.0	G1A	2.0					
AP1	16.2	M18A7.5	20.8	*FL	13.0			Total	13.4		13.4		32.0		32.0	
		G2	5.6													
		*FAC-LV 02	20.0							M3/4A	2.0					
		*FAC-LV -03	10.0							AP1	16.2					
		M18A7.5	20.8					M8B12.5	15.7	M8R12.5	15.7					
RL1	2.0	RL1	2.0					AP1	16.2	AP1	16.2					
R20E	20.4	R14E	13.0					RL1	2.0	RL1	2.0					
Total	22.6		92.2		13.0		92.2	Total	33.9		52.1				52.1	
9) Walk to machine front and grasp top and bottom rollers								R20E	22.9	R20E	22.9	*BD2	32.0		32.0	
				*W011	208.0		206.0	**6) Open horizontal lock on automat and use hand wheel to centre machine horizontally:**								
R30A	17.6	R12A	9.6	*BD2	32.0			*G30S	25.0	*G12S	15.0	*BD2	32.0		32.0	
G1A	2.0	G1A	2.0													
Total	19.6		11.6		32.0		32.0			*FAC-LV -04	20.0					

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater times at --*--*--
										M3/4A	2.0					
								Total			22.0				22.0	
								M3B7.5	8.2							
								AP1	16.2							
								Total	24.4						24.4	
										M3/4A	2.0	E2	7.3			
										*FAC-LV -04	20.0					
								Total			22.0		7.3		22.0	
								R30E	22.9	R12E	11.8	*BD2	32.0		32.0	
								7) Go to side of automat and grasp vertical handwheel and vertical lock.								
												SSC2	34.1			
												*BD2	32.0			
								Total					66.1		66.1	
								R14A	10.5	R12A	9.6	*BD2	32.0			
								G1A	2.0	G1A	2.0					
								Total	12.5		11.6		32.0		32.0	
							802.2								616.8	802.
10) Loosen rollers (3x45°) to enable frame to rise easily:								8) Open vertical lock and turn (2x60°) vertical handwheel to raise frame:								
										*FAC-LV -04	20.0				20.0	
M3B7.5	8.2	M3B7.5	8.2					T18DL	28.2							
AP1	16.2	AP1	16.2					AP1	16.2							
RL1	2.0	RL1	2.0					RL1	2.0							
R2A	4.0	R2A	4.0					R6A	7.0							
G1A	2.0	G1A	2.0					G1A	2.0							
M3B7.5	8.2	M3B7.5	8.2					T18OL	28.2							
AP1	16.2	AP1	16.2					AP1	16.2							
RL1	2.0	RL1	2.0					RL1	2.0							
R2A	4.0	R2A	4.0					R6A	7.0							
G1A	2.0	G1A	2.0					G1A	2.0							
M3B7.5	8.2	M3B7.5	8.2					Total	110.8						110.8	
AP1	16.2	AP1	16.2													
RL1	2.0	RL1	2.0													
Total	91.2		91.2				91.2									
R30E	22.9	R12E	11.8	*BD2	32.0		32.0	9) Close horizontal lock								
										*FAC-LV -04	20.0					
								RL1	2.0	RL1	2.0					
								Total	2.0		22.0				22.0	
								R12E	11.8	R10E	10.5	*BD2	32.0		32.0	
							123.2								183.8	183.
				*SSC2	34.1		34.1	10) Walk to helper and take one knife from her:								
												*W5	94.0		94.0	
11) Open drawer (mounted beneath bench): Get knives (2) from drawer:																
R12A	9.6															
G1A	2.0															
M8A	9.7															
Total	21.3						21.3									
RL1	2.0	R12C	14.2													
		*BPR-JV -06	30.0													

HELPER					OPERATOR				TOTAL
LEFT HAND 1	RIGHT HAND 2	BODY 3	TOTAL 4		LEFT HAND 5	RIGHT HAND 6	BODY 7	TOTAL 8	9
SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--		SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
	*BPH-NV -01 10.0								
Total 2.0	54.2		54.2						
12) Get scissors (2 nos) from drawer and place them on the bench. Close drawer:									
*B04-JV -06 20.0									
*BPH-NV -01 10.0									
*P10B 13.0									
R12Bm 10.1									
G5 0.0									
M8A 7.9									
RL2 0.0									
Total 61.0			61.0						
13) Hand one knife to operator									
R12A 9.6	M12A 12.9	*BD2 32.0							
G3 5.6	G3 5.6								
Total 15.2	18.5	32.0	32.0						
			202.6					94.0	202.6
	M12A 12.9					R12A 9.6			
	G3 5.6					G3 5.6			
Total	18.5		18.5		Total	18.5		18.5	18.5
14) Walk to far end of machine. Wait for operator to start and then proceed:					11) Walk to far end of machine and climb to the top bank				
		TBC2 37.2					*W14 229.0		
		*W14 229.0					*BBM-VD-02 70.0		
Total		266.2	266.2		Total		299.0	299.0	
					12) Tension front yarn by roller before starting to cut.				
					R10A 8.7	M12B 10.0			
					G1A 2.0				
					M2B 4.6	P1NSE 10.4			
					AP2 10.6				
					RL1 2.0				
					Total 27.3	20.4		27.3	
					13) Start cutting (top front yarn):				
							*BD2 32.0	32.0	
			266.2					358.3	358.3
15) Tension front yarn by roller before starting to cut					14) Continue cutting[1]: Six side steps per section of 3.33 yds. At end climb down. Total of 18 side steps for a 10 yd. Machine:				
		*BD2 32.0	32.0				*(18-1)BD2 544.0		
							TBC1 18.0		
							*BBM-VD-02 70.0		
					Total		632.0	632.0	
R10A 8.7	M12B 10.0				15) Replace knife in drawer:				
G1A 2.0					R12A 0.6	M14A 15.8			
M2B 4.6	P1NSE 10.4				G1A 2.0				
AP2 10.6					M8A 7.9				
RL1 2.0					Total 19.5	15.8		19.5	
Total 27.3	20.4		27.3						
16) Start cutting[1] (bottom front yarn). 6 side steps for each section of 3.33 yds. 3 sections in a 10 yd machine: Negotiate foundation pillar between sections:						M6B 8.9			
		*6xBD2 192.0	192.0			RL1 2.0			

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
		M30B	22.4	SSC2	34.1		Total			10.9			10.9	
		P1NSE	10.4	*BD2	32.0									
Total			32.8		66.1	66.1								
				*6xBD2	192.0	192.0	M8A	7.9						
							RL2	0.0						
							R12E	11.8	R12E	11.8				
							Total	19.7		11.8			19.7	
		M30B	22.4	SSC2	34.1		16) Pick up scissors. Walk to far end of machine and climb up							
		P1NSE	10.4	*BD2	32.0									
Total			32.8		66.1	66.1			*BPH-EV -06	20.0			20.0	
				*6xBD2	192.0	192.0								
				*BD2	32.0						*W014	257.0		
Total					224.0	224.0					*BRM-VD-02	70.0		
							Total					327.0	327.0	
17) Walk to back of machine for cutting top shuttle threads. Climb to top:														
				*BBM-TW-10	170.0				R10B	11.5				
				*BBM-VD-02	70.0				P1SE	5.6				
Total					240.0	240.0	Total			17.1			17.1	
		M12B	13.4				17) Cut ton front yarn. 8 scissor cutting stroker per roller (= 40" on the average). 9 roller, (one stroke of the scissor)							
		P1NSE	10.4											
Total			23.8			23.8			M2A	3.6				
									M2B(4.6)					
18) Proceed cutting:									R5B(7.8)	7.8				
							Total			11.4			11.4	
		3xM15B	47.4	*3xBD2	96.0	96.0	(The next seven strokes)							
19) Cross right hand side pole. Continue cutting:									*7x11.4	79.8			79.8	
		R14B	14.4				(For the remaining 8 rollers)							
		P1NSE	10.4											
Total			24.8			24.8			*8(17.1+79.8)+11.4) = 8(108.3)					
		2xM15B	31.6	*2xBD2	64.0	64.0				= 866.4			866.4	
20) Cross right hand side foundation pillar and continue cutting:							18) Transfer scissors to left hand and bend down to place scissors on bench-top.							
		R30B	25.8				R4A	6.1	M4A	6.1				
		P1NSE	10.4				G3	5.6	G3	5.6				
Total			36.2			36.2	Total	11.7		11.7			11.7	
		3xM15B	47.4	*3xBD2	96.0	96.0	M14Bm	11.4			*BD2	32.0		
							RL1	2.0			*BD2	32.0		
21) Cross centre pole and continue cutting:							Total	13.4				64.0	64.0	
		R14B	14.4				19) Begin removing yarn from top bank for disposal clean-up. 4 cycles per roller (= 40" on the average) (one cycle)							
		P1NSE	10.4											
Total			24.8			24.8			R18Bm	14.4				
		3xM15B	47.4	*3xBD2	96.0	96.0			G5	0.0				
									M8Bm(7.2)	7.2	SSC1	17.1		
22) Cross left hand side foundation pillar and continue cutting:									T30S(2.8)					
							R6A	7.0	G2(5.6)					
		R30B	25.8						M20A(19.2)					
		P1NSE	10.4							19.2				
Total			36.2			36.2			AP2(10.6)					
							G3	5.6	G3	5.6				
		2xM15B	31.6	*2xBD2	64.0		Total	12.6		46.2		17.1	46.2	
							(For other 3 cycles)							
									3x46.2	138.6			138.6	
							(Similarly, clean-up the other 8 rollers)							

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
23) Cross left hand side pole and continue cutting														
		R14B	14.4											
		P1NSE	10.4											
Total			24.8			24.8				1478.4			1478.4	
		3xM15B		*3xBD2	96.0									
				*BD2	32.0									
Total					128.0	128.0								
24) Climb down to start cutting bottom shuttle threads with left hand														
				*BBM-VD-02	70.0	70.0								
R12A	9.6	M12A	12.9											
G3	5.6	G3	5.6											
Total	15.2		18.5			18.5								
25) Take two side-steps for cutting between shuttle-rail driver shafts (9) cross two foundation pillars. (Between two driver-shafts)														
		M12A	12.9											
		P1NSE	10.4											
Total			23.3			23.3								
				*2xBD2	64.0	64.0								
(For the other 8 segments:														
		8(64.0+23.3)												
			698.4			698.4								
26) Negotiate two foundation pillars														
		2M30B	46.4											
		2P1NSD	20.8											
Total			67.2			67.2								
27) Cut last segment and go to machine front:														
				*2xBD2	64.0									
		R14E		*BD2	32.0									
				*BBM-TW-08	140.0									
Total					236.0	236.0								
28) Replace knife in drawer. Identical as operator col. no. 15														
						19.5								
						10.9								
						19.7								
29) Pick up scissors and walk to far end of machine														
		*BPH-EV-06	20.0			20.0								
				*W014	257.0									
				TRC2	37.2									
Total					294.2	294.2								

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater o 4 & 3 at --*--*--*
30) Cut bottom front yarn. 8 scissor cutting, strokes per roller. Identical as operator col. 17, except for foundation pillar correction.						11.4 79.8 775.2								
31) Negotiate two foundations pillars:		2xM26B	22.9	*2xBD2	64.0	64.0								
32) Pick up the other pair of scissors and replace both in drawer:		R14E	14.2	*W02	53.0	53.0								
		*BPH-EV-06	20.0											
		G2	5.6											
Total			25.6			25.6								
R12A	9.6	M14A	15.8											
G1A	2.0													
M8A	7.9													
Total	19.5		15.8			19.5								
		M6B	8.9											
		RL1	2.0											
Total			10.9			10.9								
M8A	7.9													
RL2	0.0													
R12E	11.8	R12E	11.8											
Total	19.7		11.8			19.7								
33) Walk to bottom first roller and start clearing front yarn till you meet the operator				*W3	64.0	64.0	29) Climb down							
							R20E	16.7	R20E	16.7	*BRM-VD-02	70.0	70.0	
34) Clear first section (2 3/4 roller lengths approx): Identical as operator col. no. 19							21) Start clearing front yarn till you meet helper. Clear first section (2 3/4 roller lengths approx): Identical as operator col. no. 19.							
		(2 3/4x4x46.2	508.2			508.2			(2 3/4x4x46.2	508.2			508.2	
							22) Negotiate right hand side foundation pillar							
											*RD2	32.0	32.0	
							23) Clear mid-section front yarn (3 1/2 roller lengths approx: Identical as operator col. no. 19.							
									(3 1/2x4x46.2)	646.8			646.8	
						5119.1							4008.5	5119.1
35) Helper takes waste yarn from operator for disposal:														
		R14B	14.4						M14B	14.6				
		G3	5.6						G3	5.6				
Total			20.0			20.0				20.2			20.2	20.2

HELPER						OPERATOR					TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3	TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7	TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
36) Go to dispose off threads and return to machine centre														
				*BBM-TW-10	170.0	170.0								
Total		M10B RL1	12.2 2.0 14.2			14.2								
				*BBM-TW-10	170.0	170.0								
						340.0								340.0
													G. Total	7044.7

1. Table 2.3 Item 6
2. Table 2.3 Item 7
8. Table 2.3 Item 8

Table C20 Synthesis of "Goods removal operation" by MTM and USD

Operation Name: Goods removal operation

Symbol used in Flowchart (Figure A1) to represent operation: (GR/20)

Contents of operation:

Operator:

1) Mount shield boards on the machine
2) Take the top and bottom spans of finished goods off the machine and lay them on the cutting table

Helper:

Assist the operator in performing 1 and 2

Purpose of operation:

Remove finished goods from the machine to be able to load a fresh span. All activities are carried on at the back of the machine.

Operation starts:

Both operator and helper are at the machine stand

Operation ends:

Both operator and helper are at the machine stand

Synthetic cycle time: 8.98 minutes

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--
								1) Go to rack area, pick up shield boards (6 nos) and carry them to machine front center								
												*BBM-TW-10	170.0			
												*BD2	32.0			
								Total					202.0	202.0		
										R12A	9.6					
										G1B	3.5					
								R20A	13.1	M20B12.5						
								G1B	3.5		24.1	TBC1	18.6			
										AP1	16.2					
								M20Bm27.5		M20Bm27.5						
									29.1		29.1	*BD2	32.0			
								Total	45.7		82.5		50.6	82.5		
												*BBM-TW-10x1.5	225.0			
												*BD2	32.0			
												*BD2	32.0			
								Total					289.0	289.0		
														573.5		573.5
1) Pick up board no. 5 and mount on top bank: Wait for operator to clear out								2) Boards are sequentially numbered 1 thru 6 1 goes on the automat end 6 on the far end. Pickup board no. 6 and mount on the bank:								
				*W2	49.0	49.0										
								G2	5.6	G2	5.6					
								M10Bm	8.6	M10Bm	8.6					
								Total	14.2		14.2			14.2		
R10B	11.5	R10B	11.5													
G1B	3.5	G1A	3.5													
M10Bm	8.6	M10Bm	8.6													
Total	23.6		23.6			23.6		RL1	2.0	T60L	12.3	*BBM-TW-06x1.5				
								R15Am	9.7				165.0			
								G1A	2.0							
								Total	13.7		12.3		165.0	165.0		
RL1	2.0	T60L	12.3	*BBM-TW-04x1.5												
R15Am	9.7				120.0											
G1A	2.0															
Total	13.7		12.3		120.0	120.0		M30Bm7.5	26.2	M30Bm7.5	26.2	TBC2	37.1			
								P2NSD	26.6	P2NSD	26.6					
								RL1	2.0	RL1	2.0					
								R30E	22.9	R30E	22.9					
								Total	77.7		77.7		37.1	77.7		
M30Bm7.5	26.2	M30Bm7.5	26.2	TBC2	37.1							BBM-TW-08	110.0	110.0		
P2NSD	26.6	P2NSD	26.6													
RL1	2.0	RL1	2.0													
R30E	22.9	R30E	22.9													
Total	77.7		77.7		37.1	77.7										
				*BBM-TW-04	80.0	80.0		3) Pick up board no. 3 and mount it on top bank. Do exactly as for board no. 4 in helper col. no. 2								
													23.6	23.6		
													75.0	75.0		
													77.7	77.0		
2) Pick up board no. 4 and mount it on top bank.																
R10B	11.5	R10B	11.5													
G1B	3.5	G1B	3.5													
M10Bm	8.6	M10Bm	8.6													
Total	23.6		23.6			23.6										
RL1	2.0	T60L	12.3	*BBM-TW-02x1.5				4) Pick up board no. 1 and mount it on top bank. Do exactly as for board no. 6 in operator co. no. 2								
R15Am	9.7				75.0											
G1A	2.0															
Total	13.7		12.3		75.0	75.0		R10B	11.5	R10B	11.5					
								G1B	3.5	G1B	3.5					
								M10Bm	8.6	M10Bm	8.6					
								Total	23.6		23.6			23.6		
M30Bm7.5	26.2	M30Bm7.5	26.2	TBC2	37.1											
P2NSD	26.6	P2NSD	26.6													
RL1	2.0	RL1	2.0											165.0		
R30E	22.9	R30E	22.9											77.7		
Total	77.7		77.7		37.1	77.7								110.0		
3) Pick up board no. 2 and mount it on top bank. Do exactly as for board no. 5 in helper co. no. 1																

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
						77.7 80.0 827.9								919.5		919.5
4) Start removing the finished goods from the m/c. Go to the automat and center fram vertically								5) Start removing the finished goods from the m/c. Go to the automat end and get prybar								
				*BBM-TW-10 (25')	170.0							*BBM-TW-10 (25')	170.0			
				*BBM-WD-10 (20')	120.0							*BBM-WD-10 (15')	90.0			
R14A	10.5	R12A	9.6	*BD2	32.0								260.0			
Total	10.5		9.6		352.0	352.0		Total						260.0		
G1A	2.0	G1A	2.0					6) Get prybar and extension tube and position it on gearwheel:								
		*FAC-LV-04	20.0					*G30S	25.0	*G30S	25.0			25.0		
Total	2.0		22.0							*G30S	25.0	*BD2	32.0			
*2CSF(26" - 30lbs.)	43.0					43.0		Total			25.0	*BD2	32.0 64.0	64.0		
		*FAC-LV-04	20.0					P255D	25.3	P2SSD	25.3			25.3		
RL1	2.0	RL1	2.0													
Total	2.0		22.0			22.0										
R12E	11.8	R10E	10.5	*BD2	32.0											
				*BBM-TW-06	110.0											
Total					142.0	142.0								374.3		581.0
						581.0										
5) Loosen top span using prybar tube. Here the time required for loosening the cloth has been taken from the actual observation and inserted, because it was felt that MTM-USD were inadequate for the purpose.								7) Loosen top span using prybar and extension								
						708.4								708.4		708.4
6) Walk to far end of the machine								8) Replace prybar								
				*BBM-TW-10 (25')	170.0			*P30LP1	42.0	*P30LP1	42.0	*BD2	32.0			
				*BBM-WD-10 (15')	90.0			R30E	22.9	R30E	22.9	*BD2	32.0			
Total					260.0	260.0		Total	64.9		64.9		64.0	64.9		
7) Climb up and take the cloth off the comb								9) Climb of and take the cloth off the comb								
				*BBM-VD-02	70.0							*BBM-VD-02	70.0			
R20D	19.8	R20D	19.8	*BD2	32.0			R20D	19.8	R20D	19.8	*BD2	32.0			
Total	19.8		19.8		102.0	102.0		Total	19.8		19.8		102.0	102.0		
Four strokes required to disengage the cloth								Four strkes are required to disengage the cloth								
4G1B	14.0	4xG1A	8.0	*FL	13.0			4xG1A	8.0	4G1B	14.0	*FL	13.0			
4xD3D	138.8	4xD3D	138.8					4xD3D	138.8	4xD3D	138.8					
4xR4	8.0	4G2	22.4					4xG2	22.4	4xRL1	8.0					
4xR6D	40.4									4xR6D	40.4					
R30E	22.9	R30D	22.9	*BD2	32.0			R30E	22.9	R30E	22.9	*BD2	32.0			
Total	224.1		192.1		45.0	224.1		Total	192.1	Total	224.1		45.0	224.1		
						586.1								391.0		586.1
								10) Slacken span (by manipulating top roller) to facilitate disengagement off the lower comb								

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
							R30A	17.5	R30A	17.5	*FL	13.0		
							G1A	2.0	G1A	2.0				
							T30L	8.4						
							AP1	16.2						
							Total	44.1		19.5		13.0	44.1	
									M3B	2.0			2.0	
							T16SL	26.1	RL1	2.1			26.1	
											ET 15.2x3/1720.0	20.0	20.0	
							RL1	2.0	RL1	2.0	*BD2	32.0		
							R30E	22.9	R30E	22.9				
							Total	24.9		24.9		32.0	32.0	
8) Proceed to disengage span from lower comb.							11) Proceed to disengage span from lower comb.							
*G30D	42.0	R15B	15.8	*BD2	32.0		R15B	15.8	*G30D	42.0	*BD2	32.0		
		G1A	2.0				G1A	2.0						
Total	42.0		17.8		32.0	42.0	Total	17.8		42.0		32.0	42.0	
						42.0							166.2	166.2
9) Disengage cloth from lower comb							12) Disengage cloth from lower comb							
T18OL	28.2								T18OL	28.2				
AP1	16.2								AP1	16.2				
D3D	34.7								D3B	34.7				
M8Bm	7.2								M8Bm	7.2				
AP2	10.6								AP2	10.6				
D3D	34.7								D3D	34.7				
*P8B									*P8B					
(22 1/2 lbs)									(2 1/2 lbs.)					
	15.0									15.0				
R30E	22.9	R30E	22.9	*BD2	32.0		R30E	22.9	R30E	22.9				
	169.5		22.9		32.0	169.5	Total	22.9		169.5		32.0	169.5	169.5
10) Straighten out comb and lay it straight on roller							13) Straighten out comb and lay it straight on roller							
				*BBM-VD-02	70.0	70.0					*BBM-VD-02	70.0	70.0	
R2BD	23.9	R30D	26.7				R2BD	23.9	R30D	26.7				
G5	0.0	G5	0.0				G5	0.0	G5	0.0				
Total	23.9		26.7			26.7	Total	23.9		28.7			26.7	26.7
6M15B	94.8	6M15B	94.8	*6xBD2	192.0	192.0	6xM15B	94.8	6xM15B	94.8	*6XBD2	192.0	192.0	
Negotiate left hand side foundation pillar							Negotiate right hand side foundation pillar							
		RL2	0.0	SSC1(15")	18.6		RL2	0.0			SSC1(15")	18.6		
		R30D	26.7				R30D	26.7						
		G5	0.0				G5	0.0						
Total			28.7		18.6	26.7	Total	26.7					26.7	
RL2	0.0			SSC1(15")	18.6				RL2	0.0	SSC1(15")	18.6		
R30D	26.7								R30D	26.7				
G5	0.0								G5	0.0				
Total	26.7				18.6	26.7	Total			26.7		18.6	26.7	
3xM15B	47.4	3xM15B	47.4	*3xBD2	96.0		3xM15B	47.4	3xM15B	47.4	*3xBD2	96.0		
R30E	22.9	R30E	22.9	*BBM-TW-08	140.0		R30E	22.9	R30E	22.9	*BBM-TW-08	140.0		
				*BBM-VD-02	70.0						*BBM-VD-02	70.0		
R30A	17.5	R24B	21.5	*BD2	32.0		R30A	17.5	R24B	21.5	*BD2	32.0		
G1A	2.0	G1A	2.0				G1A	2.0	G1A	2.0				
Total	89.8		89.8		338.0	338.0	Total	89.8		89.8		338.0	338.0	

HELPER							OPERATOR							TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--
						680.0							680.1	680.1
11) Roll over span on top roller (3"ϕ) so that bottom edge clears shuttle rail completely: Six strokes are required to perform this function:							14) Roll over span on top roller (3"ϕ) so that bottom edge clears shuttle rail completely: 6 strokes are required to perform this function:							
6x6.2	33.6	6xM4B(27.5)	108.0				6xM4B(27.5)	108.0	6x6.2	33.6				
		6xAP1	97.2				6xAP1	97.2						
		6xRL1	12.0				6xRL1	12.0						
		5xR4A	30.5				5xR4A	30.5						
		5xG1A	10.0				5xG1A	10.0						
R20E	16.7	R30E	22.9				R30E	22.9	R20E	16.7				
Total	50.3		280.6			280.6	Total	280.6		50.3			280.6	280.6
				TBC2	37.2	37.2	15) Climb down, half-close the machine using the machine locking oever, and return:							
											*BBM-VD-02	70.0		
											*BBM-TW-04	80.0		
							Total					150.0	150.0	
							R26A	15.8	R14A	10.5	TBC1	18.6		
							G1A	2.0	G1C1	7.3				
							Total	17.8		17.8		18.6	18.6	
							AP1	16.2	M18A7.5	20.8	*FL	13.0		
									G2	5.6				
									*FAC-LV-02	20.0				
									*FAC-LV-03	10.0				
									M18A	20.8				
							RL1	2.0	RL1	2.0				
							R26E	20.4	R14E	13.0				
							Total	38.6		92.2		13.0	92.2	
											*BBM-TW-04	80.0		
											*BBM-VD-02	70.0		
							Total					150.0	150.0	
							16) Release catch on top roller ratchet:							
							R30A	17.5	R30A	17.5	FL	13.0		
							G1A	2.0	G1A	2.0				
							T30L	8.4						
							AP1	16.2						
							Total	44.1		19.5		13.0	44.1	
									M2B	4.6				
									RL1	2.0				
							Total			6.6			6.6	
*G12S	15.0			*FL	13.0	15.0			*G12S	15.0	*FL	13.0	15.0	
						52.2							476.1	476.1
12) Start unrolling span from top roller							17) Start unrolling span from top roller							
M6B27.5	19.4	RL1	2.0				RL1	2.0	M6B27.5	19.4				
		*G10S	15.0				*G10S	15.0						
RL1	2.0	M6B27.5	19.4				M6B27.5	19.4	RL1	2.0				
Total	21.4		36.4			36.4	Total	36.4		21.4			36.4	36.4
13) Walk to center pole and raise roller over spoon to facilitate removal of span									*G10S	15.0			15.0	
R20E	16.7	R20E	16.7	TBC1	18.6									
				*BBM-TW-10	170.0									

HELPER								OPERATOR								TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3		TOTAL 4		LEFT HAND 5		RIGHT HAND 6		BODY 7		TOTAL 8		9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	Greater times at --*--*--		Greater of 4 & 8 at --*--*--*--
Total	16.7		16.7		188.6	188.6										
*G30S	25.0	*G30S	25.0	*FL	13.0											
M3Bm47.5	21.4	M3Bm47.5	21.4													
AP1	16.2	AP1	16.2													
Total	62.6		62.6		13.0	62.6										
						251.2								15.0		251.2
14) Help operator by continually raising roller off the centre role spoon.								18) Continue to unroll span completely								
M3Bm47.5	21.4	M3Bm47.5	21.4					RL1	2.0	M6B27.5	19.4					
AP1	16.2	AP1	1 .2					*G6S	10.0	RL1	2.0					
M3Bm47.5	21.4	M3Bm47.5	21.4					M6B27.5	19.4	*G6S	10.0					
AP1	16.2	AP1	16.2					RL1	2.0	M6B27.5	19.4					
RL2	0.0	RL2	0.0					*G6S	10.0							
*G65(10.0)		G6S(10.0						M6B27.5	19.4							
T180S(9.4)		T180S(9.4)						RL1	2.0							
	10.0		10.0					*G10S	15.0							
T60M	6.5	T60M	6.5					Total	79.8		50.8			79.8		
AP2	10.6	AP2	10.6													
RL1	2.0	RL1	2.0							RL1	2.0					
Total	104.3		104.3			104.3				*G14S	15.0					
										M1A	2.5					
										RLI	2.0					
15) Walk back to far end of machine:								G2	5.6	*G8S	12.0					
								M3B12.5	10.2	M3B12.5	10.2					
R30E	22.9	R30E	22.9	*FL	13.0	22.9		AP1	16.2	AP1	16.2					
								RL1	2.0	RL1	2.0					
				*BBM-TW-10	170.0	170.0		Total	34.0		61.9			61.9		
						297.2								141.7		297.2
13) Proceed to disengage span from top comb								19) Proceed to disengage span from top comb								
*G10E	22.0	*G10A	15.0					*G10A	15.0	*G10E	22.0					
T180L	28.2	D2D	11.8					D2D	11.8	T180L	28.2					
AP1	16.2									AP1	16.2					
D3D	34.7									D3D	34.7					
M12Bm12.5										M12Bm12.5						
	15.0										15.0					
D3D	34.7									D3D	34.7					
RL1	2.0	RL1	2.0					RL1	2.0	RL1	2.0					
R20E	16.7	R20E	16.7	TBC1	18.6			R20E	16.7	R20E	16.7	TBC1	18.6			
Total	169.5		45.5		18.6	169.5		Total	45.5		169.5		18.6	169.5		
				*BBM-TW-04	80.0	80.0						*BBM-TW-04	80.0	80.0		
*G18E	27.0	*G18E	27.0					*G18E	27.0	*G18E	27.0					
T180L	28.2	T180L	28.2					T180L	28.2	T180L	28.2					
AP1	16.2	AP1	16.2					AP1	16.2	AP1	16.2					
D3D	34.7	D3D	34.7					D3D	34.7	D3D	34.7					
M12Bm12.5		M12Bm12.5						M12Bm12.5		M12Bm12.5						
	15.0		1.50						15.0		15.0					
D3D	34.7	D3D	34.7					D3D	34.7	D3D	34.7					
RL1	2.0	RL1	2.0					RL1	2.0	RL1	2.0					
R18E	16.5	R18E	15.5	TBC1	18.6			R18E	15.5	R18E	15.5	TBC1	18.6			
Total	173.3		173.3		18.6	173.3		Total	173.3		173.3		18.6	173.3		
						422.8								422.8		422.8
14) Return to far end:																
				*BBM-TW-04	80.0	80.0										
15) Start folding the span each fold covers approx 18" running or 21 folds for 10 1/2 yd.								20) If the span is obstructed while being folded from the same follow along till far end of m/c.								
R30E	22.9	R30A	17.5	TBC1	18.6	22.9		2xG1A	4.0	2xG1A	4.0	*15xBD2	480.0			

HELPER					OPERATOR				TOTAL
LEFT HAND 1		RIGHT HAND 2		BODY 3	TOTAL 4	LEFT HAND 5		RIGHT HAND 6		BODY 7	TOTAL 8	9
SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	SYMBOL *USD	TIME TMU	SYMBOL *USD	TIME TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
First Fold:						2xM8B	21.2	2xM8B	21.2			
						Total	25.2		25.2	480.0	480.0	
G5	0.0	G5	0.0									
M30B+mM5B	29.3	M20Bm	15.6			21) Climb down walk to side of cutting table and wait.						
		RL2	0.0									
		R20E	18.6							*BBM-VD-02	70.0	
		G5								*BBM-TW-06	110.0	
AP1	16.2	AP1	16.2			Total				180.0	180.0	
R30E	22.9											
M18B17.5	25.5	M18B17.5	25.5									
Total	93.9		75.9		93.9							
The other 20 fords are made identically												
		20(93.9) =1878.0			1878.0							
17) Get the bundled span and take it to the cutting table:												
RL2	0.0	RL2	0.0									
*G10S	15.0	*610S	15.0									
				*BD2	32.0							
				*BBM-VD-02x1.5	105.0							
				*BBM-TW-06x1.5 (1.5Bulky Load)	165.0							
M20B	18.2	M20B	18.2	*BD2	32.0							
RL1	2.0	RL1	2.0	*BD2	32.0							
Total	20.2		20.2		366.0	366.0						
18) Start unfolding span on cutting table												
		20xM16Bm	256.0	20xSSC1(15")	372.0							
		20xA12	212.0									
Total			468.0		372.0	468.0						
				*2xBD2	64.0	64.0	22) Straighten out span on cutting table:					
						R12A	9.6	R20A	13.1	*BD2	32.0	32.0
19) Straight out span on cutting table												
R12A	9.6	R12A	9.6		9.6							
					3170.2					692.0	3170.2	3170.2
G1A	2.0	G1A	2.0			G1A	2.0	G1A	2.0			
M10A	11.0	M10A	11.3			M10A	11.3	M10A	11.3			
AP1	16.2	AP1	16.2			AP1	16.2	AP1	16.2			
M10A12.5	16.4	M10A12.5	16.4			M10A12.5	16.4	M10A12.5	16.4			
AP1	16.2	AP1	16.2			AP1	16.2	AP1	16.2			
M20A12.5	25.2	M20A12.5	25.2			M20A12.5	25.2	M20A12.5	25.2			
AP1	16.2	AP1	16.2			AP1	16.2	AP1	16.2			
RL1	2.0	RL1	2.0			RL	2.0	RL1	2.0			
R20E	16.7	R20E	16.7			R12E	11.8	R20E	16.7	*BD2	32.0	
Total	122.2		122.2		122.2	Total	117.3		122.2	32.0	122.2	
20) Walk to machine stand:						23) Walk to machine stand						
				*BBM-TW-10 (25')	170.0					*BBM-TW-06	110.0	110.0
				*BBM-WD-10 (15')	90.0							
Total					260.0							
					382.2					232.2		382.2
												8234.7

HELPER				OPERATOR				TOTAL
LEFT HAND 1	RIGHT HAND 2	BODY 3	TOTAL 4	LEFT HAND 5	RIGHT HAND 6	BODY 7	TOTAL 8	9
SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	SYMBOL TIME *USD TMU	Greater times at --*--*--	Greater of 4 & 8 at --*--*--*--
20) Exactly in the same manner remove the finished goods from the bottom bank				24) Exactly in the same manner remove the finished goods from the bottom bank				
*			*		8234.7-1493.0		*	6741.7

G. Total 14976.4

THE DEVELOPMENT OF NORMAL STITCHING TIMES FOR THE MANUFACTURE OF EMBROIDERED EMBLEMS

by

RAJU JAIKRISHINDAS MUKHI

B. E. (Mech.), University of Poona, India, 1969.

AN ABSTRACT OF A MASTER'S THESIS

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Manhattan, Kansas

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ABSTRACT

This research is concerned with the development of normal times, using Methods-Time-Measurement and Universal Standard Data, for the operations in the embroidery manufacturing process as applied to emblem manufacture. These times may be used as a basis for bidding on prospective jobs.

Machine running time in embroidery manufacture depends on the number of stitches in a design. An estimating equation for the stitch count using an artist's sketch was developed to estimate the machine running time.

A micro-motion film, taken during an in-plant study covers cycles from 80% of the operations in the embroidery process. This film forms the raw data for the analysis.

The procedure developed estimates the normal time for the stitching of emblems in a consistent and methodical manner, based on certain physical characteristics of the emblem.