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**The N.T.I. Project - Fabric Production**

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## Contents

1. Introduction
2. Machinery & Instrumentation
3. Knitting Plan
4. Yarn
5. Fabric Production
6. Comparison Of Stitch Lengths Measured On The Machine And In The Laboratory.
7. Grey Fabric Test Results

Tables 1 - 8

Figures 1 - 3

Appendix 1 Yarn Fault Rate Analysis

Appendix 2 Production Data Charts

Appendix 3 Yarn Utilisation

## **1. Introduction**

Early in 1982 TRD was asked by the Norwegian Textile Institute (NTI) for advice in planning a project to investigate the potential of liquid ammonia as a finishing treatment for cotton knitgoods.

The main objectives of the project were as follows.

1. To evaluate the effect of a liquid ammonia treatment on fabric appearance and performance in comparison to piece mercerisation.
2. To assess whether liquid ammonia can be used to upgrade the appearance or performance of fabric made from carded as compared to combed yarn.

From previous experience we have established that, ideally, a minimum of 15 qualities (3 yarn counts x 5 stitch lengths) is needed to enable a reasonably accurate determination of the effect of a particular finishing route on any given fabric structure.

Consequently, a proposal was put forward, with consideration to the cost of producing and processing large quantities of fabric, which was considered to be the minimum requirement necessary to enable objective (1) to be satisfied while in addition going some way towards providing an answer to objective (2).

The proposed plan, in summary, suggested that 15 qualities (3 yarn counts x 5 stitch lengths) of 24 gauge single jersey fabric should be produced from combed cotton yarn in sufficient quantities to allow processing through three finishing routes.

- e.g.
1. dyed only control
  2. dyed and liquid ammonia
  3. dyed and piece mercerisation

In addition 5 qualities (1 yarn count x 5 stitch lengths) of carded cotton should be produced and processed through the same three routes. By choosing 24 gauge single jersey for the evaluation, the KI/K2 data base and fabric samples immediately provide a wide ranging basis for additional comparisons.

The proposal was accepted by NTI and it was agreed that, as the first stage in implementing the project, TRD would carry out the production of the grey fabric. This commenced towards the end of 1982 and all the knitting and grey fabric testing was completed by the end of January 1983.

The information recorded in this report covers the details of the fabric production and includes the raw test data for the yarns and grey fabric. No attempt has been made, at this stage, to analyse the results of the grey fabric testing with the exception of stitch length in the as-knitted grey fabric. These figures have been analysed in comparison with the measurements of course length made during the fabric production and serve as an additional check on fabric quality.

## **2. Machinery And Instrumentation**

The single jersey knitting machine used in these trials is located at TRD's premises in Manchester and has the following characteristics.

Monarch XL-JS, 24 gauge, 26" diameter, 60 feeders, 1920 needles equipped with triptape positive feed and side creels.

Course length (run-in) was measured using a Welmstar Type RS100 electronic course length/yarn speed meter. Yarn input tension was measured using a Schmidt Type 2 yarn tension meter.

### **3. Knitting Plan**

The knitting plan, as summarised in the introduction is shown in detail in *Table 1*. The combed yarn counts and stitch lengths are replications of those included in Project KI. Tightness factors are calculated from nominal tex.

In the original plan it was proposed that the carded yarn would be knitted to the same five qualities as the equivalent combed yarn. During production of the fabric, however, it was not possible to produce the tightest stitch length 0.291 cm from the carded yarn we had available, without an unacceptably high fault rate. Consequently the plan for the carded yarn was amended and an additional, slacker quality, with a stitch length 0.372 cm, was included as replacement. In every other respect the knitting plan proposed to NTI was adhered to.

### **4. Yarn**

The yarn was ordered from Courtaulds Northern Spinning Division.

Combed quality KCW hosiery yarn, waxed on cone.

Ne 1-24      340 kilos

Ne 1-28      316 kilos

Ne 1-32      283 kilos

All with a twist factor of 3.5, Z twist.

Carded quality hosiery yarn.

Tandem carded, waxed on cone.

Ne 1-28      316 kilos

Twist factor 3.5, Z twist.

After the yarn had been delivered, samples were submitted to the IIC laboratory for testing, before knitting commenced.

The yarns were tested for count, twist, friction against steel, single end strength and extension, according to IIC standard testing procedures.

#### **4.1. Yarn Testing**

The results of the preliminary yarn testing carried out by the laboratory are reported in *Table 2*. The results for count, friction, single end strength and extension were well within commercial tolerances. Although the twist factors were slightly on the high side, this was not by a significant amount.

#### **4.2. Yarn Faults**

After producing three pieces of quality 291 (stitch length = 2.91mm) from the 1/28's cc

combed yarn, the carded yarn was put up on the machine. After approximately half a piece had been produced it was clear that there was a high incidence of thick places in the yarn which were causing an excessively high fault rate in the fabric. Courtaulds were contacted, and on examination, agreed to take back the carded yarn and re-clear it to closer tolerances. Knitting proceeded with the combed yarn until the carded yarn was returned. By this stage quality 321 was in production and it was decided to continue with our normal production flow, returning to the two tightest qualities for the carded yarn at the end of the trials. The fault rate produced in the carded yarn was still high but was not considered to be unrealistic and therefore no further action was taken.

After completion of the production of the combed yarns, quality 306 was produced from the carded yarn. On attempting to produce quality 291, however, the fault rate again became uncommercial and, consequently, the decision was taken to substitute this quality for the slacker quality 372 which was then produced satisfactorily.

### **4.3. Fault Rate**

To obtain a general idea of the performance of each yarn count during knitting and also to test for an effect of stitch length/tightness factor on the performance of the yarn, a fault rate analysis was carried out. Every time a fault appeared in the fabric that could be specifically related to the yarn, as opposed to the machine or operative, a record was kept and the totals for each piece recorded on the production data charts.

The detailed analysis of fault rate, averaged to faults per 100,000 metres of yarn, for each count and stitch length is recorded in *Appendix 1*. The nominal length of yarn knitted per piece is calculated from target course length readings, as follows.

$$\text{yarn length in m} = \text{course length in cm} \times \text{feeders} \times \text{revs} / 100$$

The performance of the combed yarn in terms of average faults was perfectly acceptable. The much higher fault rates for the carded yarn reflect the inferior quality of this yarn as compared to the combed product.

On average, there is no conclusive evidence to suggest that, for the yarn used in this project at the stitch lengths knitted, there is a systematic effect of stitch length/tightness factor on the incidence of yarn related fabric faults, with the exception of this quality of carded yarn which was found to be un-knitable at a stitch length of 0.291 cm.

However, it would be dangerous to deduce too much from the figures presented here because, although a substantial amount of yarn has been knitted, significantly larger quantities of yarn for each variable would need to have been tested to arrive at reliable or meaningful conclusions.

### **4.4. General Yarn Performance and Quality**

The combed yarn performed adequately during knitting, causing no special production problems. By contrast the carded yarn created production problems due to its unevenness and irregularity which resulted in quite high fabric fault rates. In addition the amount of fly generated by the carded yarn during knitting was excessive which also contributed to production problems, e.g. frequent stops to enable the machine to be cleared of the fly build-up, loose fly blocking feeder holes and yarn guides resulting in additional fabric faults.

## 5. Fabric Production

The pieces were produced according to the revised production plan - *Table 3*.

### 5.1. Production Data/Quality. Control

All quality control and production measurements recorded during the course of knitting are listed on the production charts - *Appendix 2* - arranged in yarn count order.

#### *Course length*

The course length target figure for each piece was calculated from the nominal stitch length in cm multiplied by the number of needles in the machine. The course length figures quoted for the start and end of each piece are mean results from several readings taken over at least five feeders, selected at random around the machine.

The accuracy of the Welmstar course length meter is quoted by the manufacturers as being  $\pm 1\%$  and, therefore, the production tolerance on course length measurements was also set at  $\pm 1\%$  i.e. adjustments to the run-in would only be made, after a quality was initially set up, if the mean course length measurement deviated from the target figure by  $>1\%$ . In fact, it was not found necessary to make any such adjustments, and an inspection of the figures will confirm that in all cases the measurements were very much better than  $\pm 1\%$ . *Figure 1* shows the linear regression analysis, as additional confirmation.

#### *Courses/3cm Off Machine*

This measurement was intended only as a quick ready reckoner to enable the number of machine revolutions required to produce a length of 100 metres to be calculated. After each quality/yarn change a piece of the fabric was taken from the machine and allowed to relax free of tension for several minutes. Courses/3cm were then measured, converted to C/cm and this figure used to calculate machine revolutions.

$$\text{required machine revs} = \text{courses/cm} \times 100 \times 100 / \text{No. of feeders}$$

#### *Courses/3cm*

As an additional production/quality control measurement the courses/3cm were measured at the beginning and the end of each piece, centrally above the take-down rollers.

#### *Yarn Tension*

At the beginning and end of each piece, yarn input tension was checked, adjusted where necessary and maintained throughout the production at between 3-5 g.

#### *Additional Information*

Each piece includes a cutting line.

At the end of each piece of combed yarn the machine was thoroughly blown down to clear fly and contamination from the guides and the feeder holes. For carded yarns the machine was

cleaned at least twice per piece.

Samples for fabric testing were removed from Piece 1: 5 metres for IIC and 5 metres for NTI. Each piece was weighed and the piece weights noted on the production charts and piece tickets.

## 5.2. Piece Identification

Each piece was marked at the beginning and end with a piece identification number.

e.g. Code: N24/1-24/321/1

Decode: NTI 24g / Ne 1-24 / 3.21mm stitch length / Piece No. 1

The fabrics produced from carded yarn are identified by the letters CD following the yarn count.

e.g. N24/1-28CD/354/1

In addition to the code which is written on each piece, each piece also has a piece ticket attached to it. On these are written the project code - NTI - the piece identification code, the weight of the piece and any knitting comments. For example, any faults in the fabric which need to be noted by the finishers. The piece tickets are also colour-coded according to yarn count.

Ne 1-24	Pink + red stripe
Ne 1-28	Green + red stripe
Ne 1-32	Blue + red stripe
Ne 1-28 Carded	Green + green X

## 5.3. Fabric Faults

Any holes created in the fabric during knitting were mended to avoid processing problems during finishing. The faults are recorded on the piece tickets.

## 5.4. General Comments

Apart from routine maintenance and general wear and tear repairs, the machine, in general, performed well throughout the knitting. There was, however, one problem which developed concerning the rev. counter. On one or two occasions it apparently jumped during the production of a piece. Consequently, although the revs shown indicated that the correct length of fabric had been knitted, on weighing the piece the roll was found to be light. Where the discrepancy was found to be excessive an additional part-piece was produced and sewn to the main piece. The total weight for both pieces was then recorded. In the main, however, on the few occasions when this occurred the shortfall was not considered to be serious as the method of calculating length from dry relaxed courses practically ensures a minimum running length of 100 metres per piece for processing.

In the original estimates for yarn requirements, an allowance was made to cover wastage during production which naturally occurs, for example when changing a quality. *Appendix 3* contains a breakdown by yarn count of yarn utilisation in the project.

Estimates for weight of yarn knitted plus the weight of yarn remaining are deducted from the



actual net weight of yarn delivered as invoiced by Courtaulds. This figure is expressed as a percentage of the weight delivered.

The average overall loss in production across all yarns was 4.8%. The particularly high percentage loss figure for the carded yarn can be accounted for because of the additional knitting problems experienced with this yarn; high fault rate, cast-offs etc.

## **6. Comparison Of Stitch Lengths Measured On The Machine With Those Measured In The Fabric In The Laboratory**

As one of the main objectives of this project is to evaluate the effect of certain finishing procedures on the dimensional properties of the fabric, it is essential that stitch length can be accurately determined. It is also important that the method of measuring gives a consistent and reliable estimate of the stitch length from which the fabric is known to have been knitted.

*Figure 1* confirmed that the stitch length, recorded by the Welmstar run-in meter, going in to the fabric was the same as the target figure. Therefore, to confirm that the stitch length in the fabric as measured in the laboratory was also essentially the same, these figures have also been compared.

*Table 4* records the mean % differences between the target and on-machine measurements and target and laboratory measurements. The average values are 0.01% and 0.43% respectively. *Figure 2* illustrates the results for laboratory stitch length graphically. *Figure 3* illustrates the linear regression analysis for the target vs. laboratory results.

There does not appear to be a significant difference between the laboratory estimates of stitch length and target/on machine values. The  $r^2$  figure of 0.997 indicates a high degree of correlation between the two sets of figures. Consequently stitch length measurements as recorded by the laboratory can be accepted as giving a reliable estimate of actual fabric stitch length within practical discernible limits.

## **7. Grey Fabric Test Results**

The grey fabric test data as recorded in the laboratory in the “as-received” and the “fully-relaxed” state, as defined by IIC, are included in *Tables 5 & 6*. As previously stated, no attempt has been made to analyse these data at this stage, they are recorded here for information only.

The carded yarns are identified in the tables printed by the computer by the letter C immediately following the yarn count.

e.g. 24/1-28C321/

**Table 1**

KNITTING PLAN  
24 GAUGE SINGLE JERSEY

FABRIC CONSTRUCTION AND TIGHTNESS FACTORS

24 GAUGE MONARCH XL-JS 26" DIAMETER, 60 FEEDERS, 1920 NEEDLES

COMBED YARN

YARN COUNT		STITCH LENGTH CM (TIGHTNESS FACTORS)						
Ne 1-24	l			.306	.321	.337	.354	.372
	k			(16.21)	(15.45)	(14.72)	(14.01)	(13.33)
Ne 1-28	l		.291	.306	.321	.337	.354	
	k		(15.78)	(15.01)	(14.31)	(13.63)	(12.97)	
Ne 1-32	l	.276	.291	.306	.321	.337		
	k	(15.56)	(14.76)	(14.04)	(13.38)	(12.76)		

CARDED YARN

Ne 1-28	l			.306	.321	.337	.354	.372
	k			(15.01)	(14.31)	(13.63)	(12.97)	(12.34)

l = stitch length

k = tightness factor =  $\sqrt{\frac{\text{tex}}{l}}$  from nominal tex

**Table 2**

PRELIMINARY YARN TESTING

NOMINAL COUNT NE	YARN COUNT		FRICTION U	TURNS		TWIST FACTOR		SES G	EXT %
	NE	TEX		INCH	METRE	ENG	METRIC		
COMBED									
1-24	23.7	24.8	0.12	17.8	701.0	3.7	34.9	340.1	6.1
1-28	27.2	21.8	0.12	19.2	753.8	3.7	35.2	302.3	5.7
1-32	32.2	18.4	0.11	20.5	807.5	3.6	34.6	240.0	5.4
CARDED									
1-28	27.9	21.2	0.11	18.8	739.2	3.6	34.0	240.2	5.2

**Table 3**

24 GAUGE SINGLE JERSEY  
ORDER OF KNITTING

NE	STITCH LENGTH CM	COURSE LENGTH	PIECE NUMBERS		
1/32 COMBED	.276	530	1	2	3
1/32 COMBED	.291	559	1	2	3
1/28 COMBED	.291	559	1	2	3
1/28 COMBED	.306	588	1	2	3
1/24 COMBED	.306	588	1	2	3
1/32 COMBED	.306	588	1	2	3
1/32 COMBED	.321	616	1	2	3
1/28 COMBED	.321	616	1	2	3
1/28 CARDED	.321	616	1	2	3
1/24 COMBED	.321	616	1	2	3
1/24 COMBED	.337	647	1	2	3
1/32 COMBED	.337	647	1	2	3
1/28 CARDED	.337	647	1	2	3
1/28 COMBED	.337	647	1	2	3
1/28 COMBED	.354	680	1	2	3
1/28 CARDED	.354	680	1	2	3
1/24 COMBED	.354	680	1	2	3
1/24 COMBED	.372	714	1	2	3
1/28 CARDED	.306	588	1	2	3
1/28 CARDED	.372	714	1	2	3

Total number of pieces = 60

Piece No. 1 knitted approximately 110 metres in length; 10 metres removed for grey fabric testing; 5 metres IIC, 5 metres NTI.

Piece Nos. 2 and 3 knitted approximately 100 metres in length

Table 4

COMPARISON OF STITCH LENGTH  
TARGET/ON M/C    TARGET/LAB BW

TARGET No	SL mm	SL. ON M/C $\bar{x}$ mm	% DIFFERENCE Target/on m/c	SL. LAB BW $\bar{x}$ mm	% DIFFERENCE Target/Lab BW
1-24/	3.06	3.065	+ 0.16	3.079	+ 0.62
	3.21	3.211	+ 0.03	3.229	+ 0.59
	3.37	3.372	+ 0.06	3.390	+ 0.59
	3.54	3.54	0	3.567	+ 0.76
	3.72	3.712	- 0.22	3.735	+ 0.40
1-28/	2.91	2.91	0	2.929	+ 0.65
	3.06	3.058	- 0.07	3.068	+ 0.26
	3.21	3.213	+ 0.09	3.218	+ 0.25
	3.37	3.371	+ 0.03	3.382	+ 0.36
	3.54	3.541	+ 0.03	3.547	+ 0.2
1-32/	2.76	2.761	+ 0.04	2.796	+ 1.3
	2.91	2.911	+ 0.03	2.956	+ 1.6
	3.06	3.063	+ 0.1	3.052	- 0.26
	3.21	3.203	- 0.22	3.213	+ 0.09
	3.37	3.375	+ 0.15	3.387	+ 0.5
1-28CD/	3.06	3.059	- 0.03	3.072	+ 0.39
	3.21	3.214	+ 0.12	3.202	- 0.26
	3.37	3.368	- 0.06	3.382	+ 0.36
	3.54	3.541	+ 0.03	3.546	+ 0.17
	3.72	3.718	- 0.05	3.722	+ 0.05
			$\bar{x}$ + 0.01		$\bar{x}$ + 0.43

Table 5

IIC/NTI KNITTING PROJECT 1983  
24 GAUGE SINGLE JERSEY : GREY FABRIC AS RECEIVED

SAMPLE	TexBW G	StLBW G	C3cmB G	W3cmB G	WtCWB G	SprBW G
24/1-24/306/	25.1	3.079	50.4	32.1	137.8	6.4
24/1-24/321/	25.0	3.229	48.3	32.7	138.4	12.1
24/1-24/337/	25.0	3.390	43.0	33.2	130.7	14.6
24/1-24/354/	24.7	3.567	39.7	32.8	127.0	14.9
24/1-24/372/	25.2	3.735	37.3	32.7	125.5	17.6
24/1-28/291/	22.1	2.929	53.4	32.7	128.7	8.5
24/1-28/306/	21.9	3.068	51.0	33.3	125.4	14.0
24/1-28/321/	22.0	3.218	43.9	33.3	116.3	13.4
24/1-28/337/	22.1	3.382	42.7	33.7	117.0	18.3
24/1-28/354/	22.2	3.547	38.6	33.2	107.2	16.0
24/1-32/276/	18.3	2.796	57.0	33.4	105.8	10.0
24/1-32/291/	18.0	2.956	52.0	35.2	108.0	10.5
24/1-32/306/	18.3	3.052	47.3	34.3	100.6	14.3
24/1-32/321/	18.4	3.213	43.8	33.6	96.5	14.3
24/1-32/337/	18.2	3.387	41.3	33.3	96.0	17.9
24/1-28C306/	21.2	3.072	48.7	33.5	120.0	14.5
24/1-28C321/	21.1	3.202	44.4	33.0	108.7	10.4
24/1-28C337/	21.0	3.382	41.9	33.3	105.8	13.3
24/1-28C354/	20.8	3.546	38.4	32.3	103.9	15.2
24/1-28C372/	21.3	3.722	35.5	32.1	101.3	16.4

SAMPLE	WidBW G	BstBW G	DistBW G	ThknsB G	YStrB G	extBW G
24/1-24/306/	89.1	652.2	14.3	633	333.4	6.7
24/1-24/321/	89.3	688.6	14.6	653	322.2	6.8
24/1-24/337/	88.3	650.8	14.8	641	337.1	6.5
24/1-24/354/	89.0	592.1	14.9	643	309.2	5.8
24/1-24/372/	87.7	564.7	14.0	652	327.0	6.7
24/1-28/291/	86.6	674.8	13.9	593	310.0	7.5
24/1-28/306/	85.5	582.5	14.6	618	301.1	7.0
24/1-28/321/	86.9	588.4	14.6	598	285.9	7.0
24/1-28/337/	87.9	576.8	14.8	651	283.1	6.3
24/1-28/354/	89.2	544.8	14.9	623	307.5	6.9
24/1-32/276/	85.7	529.6	14.3	552	218.9	6.3
24/1-32/291/	80.8	516.4	15.5	560	225.6	6.9
24/1-32/306/	84.3	496.5	15.2	571	231.9	7.4
24/1-32/321/	86.7	462.8	15.3	570	224.4	6.3
24/1-32/337/	89.9	448.2	15.1	570	218.2	5.7
24/1-28C306/	86.4	513.3	15.5	657	219.1	5.3
24/1-28C321/	87.8	453.5	14.8	619	226.1	6.0
24/1-28C337/	91.9	459.4	15.7	615	224.4	5.6
24/1-28C354/	89.3	437.3	14.7	635	225.6	5.9
24/1-28C372/	91.2	446.1	15.5	625	230.4	5.3

Table 6

IIC/NTI KNITTING PROJECT 1983  
24 GAUGE SINGLE JERSEY : GREY FABRIC RELAXED

SAMPLE	ShrL G	ShrW G	BstAW G	DistAW G	ThknsA G	YStrA G	extAW G
24/1-24/306/	12.3	20.5	661.3	16.1	868	314.4	8.4
24/1-24/321/	10.8	18.8	665.4	15.7	882	306.4	9.0
24/1-24/337/	18.0	13.9	620.8	15.6	869	297.4	8.4
24/1-24/354/	17.4	13.7	566.9	16.3	903	287.8	8.4
24/1-24/372/	22.4	7.1	577.8	16.4	886	303.8	8.6
24/1-28/291/	11.2	24.0	658.0	16.4	832	265.6	8.0
24/1-28/306/	12.1	21.8	603.5	16.5	842	273.1	8.7
24/1-28/321/	19.6	17.6	579.2	15.9	841	286.4	8.7
24/1-28/337/	18.0	14.1	559.8	16.3	880	292.5	8.8
24/1-28/354/	21.9	9.8	525.2	15.9	902	278.6	8.5
24/1-32/276/	11.0	26.5	530.7	16.7	780	207.9	7.2
24/1-32/291/	14.3	19.9	501.7	16.2	802	207.5	7.7
24/1-32/306/	14.5	19.8	492.5	16.4	812	223.7	8.2
24/1-32/321/	17.9	18.3	472.8	16.1	831	216.6	8.5
24/1-32/337/	20.4	13.8	459.2	16.4	828	213.2	7.8
24/1-28C306/	15.6	18.7	512.5	16.5	860	194.4	7.0
24/1-28C321/	18.2	17.7	447.4	15.9	877	218.8	7.6
24/1-28C337/	21.2	14.2	437.6	16.6	879	235.9	7.6
24/1-28C354/	22.7	10.0	439.4	16.5	892	220.8	7.7
24/1-28C372/	23.6	8.6	419.8	15.8	885	233.8	8.0

SAMPLE	TexAW G	StLAW G	C3cmA G	W3cmA G	WtCWA G	SprAW G
24/1-24/306/	24.5	3.044	57.5	40.9	191.4	13.4
24/1-24/321/	24.8	3.180	54.0	40.0	185.8	15.6
24/1-24/337/	24.4	3.360	51.4	39.0	178.8	17.1
24/1-24/354/	23.8	3.545	48.1	37.6	169.5	20.4
24/1-24/372/	24.0	3.749	46.1	36.0	164.1	21.9
24/1-28/291/	21.7	2.891	60.4	43.5	181.6	16.6
24/1-28/306/	21.8	3.040	57.3	42.4	174.2	18.8
24/1-28/321/	21.8	3.181	52.4	41.2	167.9	21.5
24/1-28/337/	21.2	3.369	51.3	40.2	164.6	22.3
24/1-28/354/	21.0	3.520	48.0	38.9	157.6	25.1
24/1-32/276/	17.7	2.763	63.1	46.5	158.3	19.9
24/1-32/291/	17.8	2.901	57.2	45.6	151.0	21.7
24/1-32/306/	18.0	3.039	55.1	44.3	147.3	24.0
24/1-32/321/	17.9	3.171	52.0	43.2	142.2	25.9
24/1-32/337/	17.5	3.023	49.3	41.9	139.6	28.7
24/1-28C306/	21.5	3.019	57.6	41.7	162.5	16.7
24/1-28C321/	20.9	3.195	51.8	40.3	153.9	19.1
24/1-28C337/	20.6	3.351	50.6	39.3	149.3	20.6
24/1-28C354/	20.4	3.634	48.0	37.5	144.6	23.1
24/1-28C372/	20.4	3.678	46.2	36.8	139.9	25.9

Figure 1

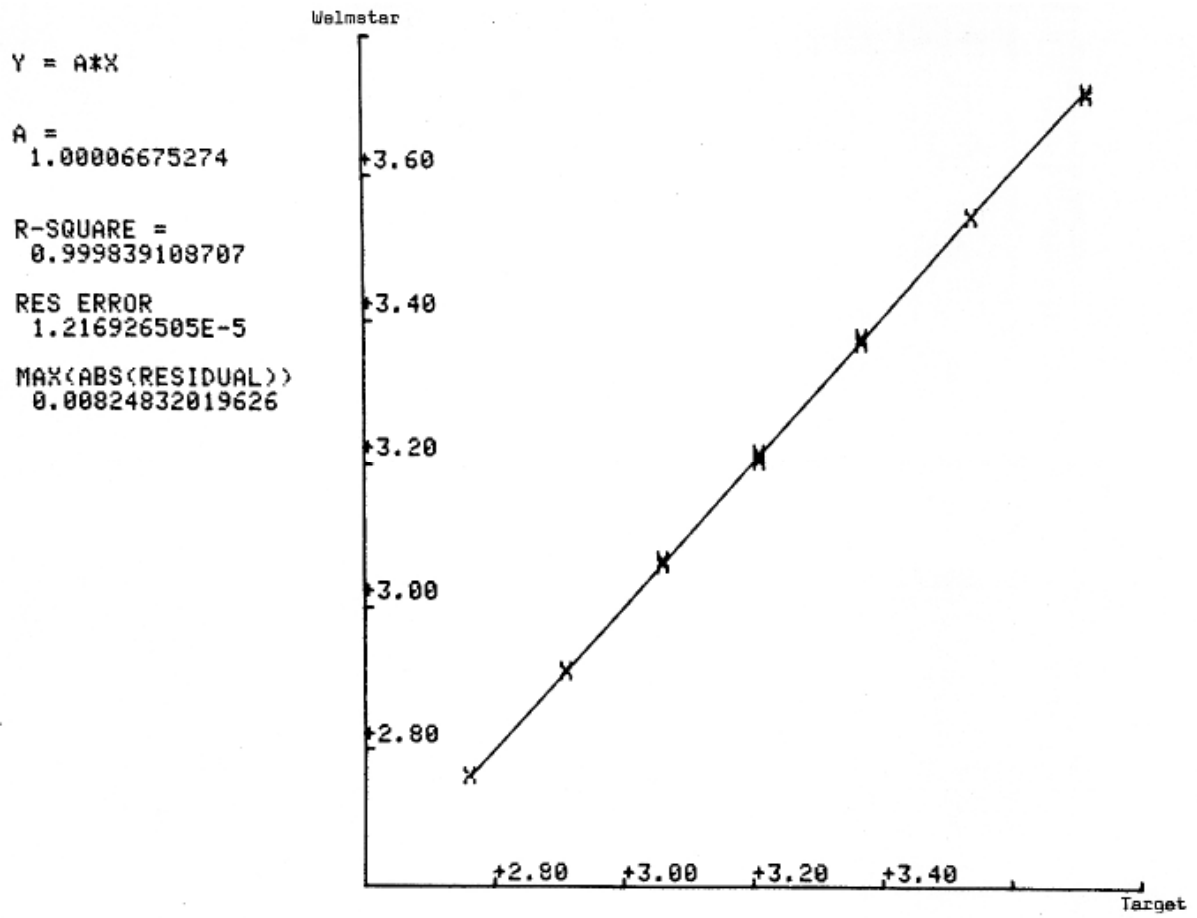




Figure 2

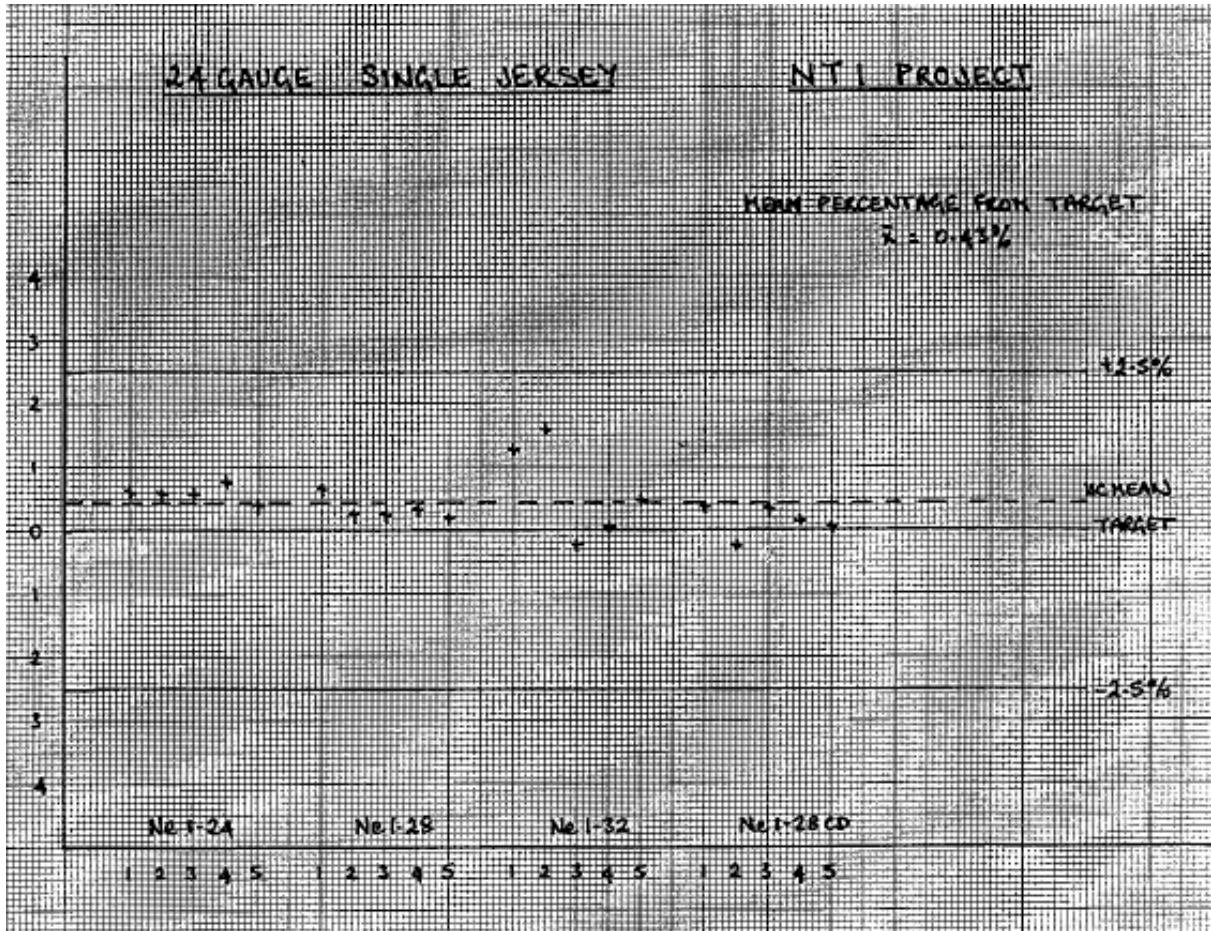


Figure 3

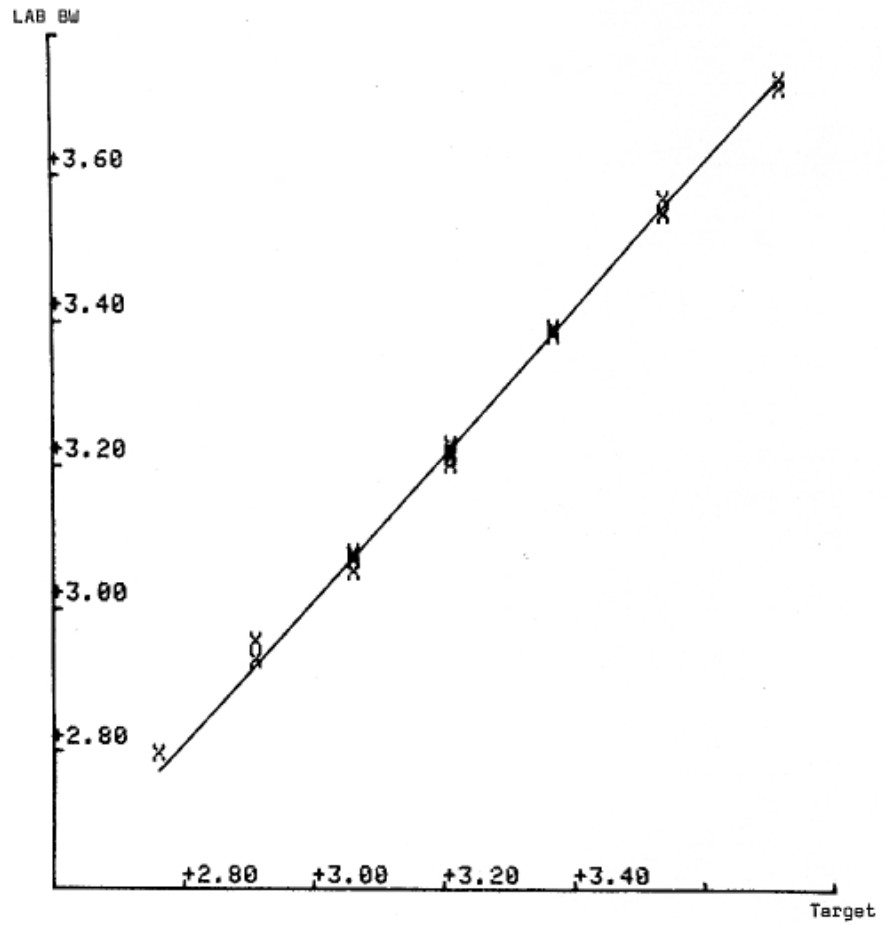
$$Y = A * X$$

$$A = 1.00404069112$$

$$R\text{-SQUARE} = 0.997420876583$$

$$\text{RES ERROR} = 1.906236995E-4$$

$$\text{MAX}(\text{ABS}(\text{RESIDUAL})) = 0.0342415888274$$



## Appendix 1: Fault Rate Analysis

YARN COUNT № 1/24 COMBED

MACHINE GAUGE 24

PIECE NO.		FAULTS	LENGTH OF YARN KNITTED PER PIECE METRES	LENGTH OF YARN KNITTED PER SL METRES	CALC. FAULTS PER 100,000M OF YARN
24/1-24/306/	1	5	1,034,762.4	2,915,892.0	0.89
	2	9	940,564.8		
	3	12	940,564.8		
24/1-24/321/	1	9	1,016,400.0	2,864,400.0	0.87
	2	10	924,000.0		
	3	6	924,000.0		
24/1-24/337/	1	8	972,441.0	2,740,303.8	0.77
	2	7	883,931.4		
	3	6	883,931.4		
24/1-24/354/	1	8	947,376.0	2,669,952.0	0.67
	2	5	861,288.0		
	3	5	861,880.0		
24/1-24/372/	1	8	915,919.2	2,581,538.4	0.74
	2	3	832,809.6		
	3	8	832,809.6		

TOTAL LENGTH OF YARN KNITTED = 13,772,086.2 M  
 TOTAL FAULTS = 109  
 AVERAGE FAULTS PER 100,000m  
 OF YARN = 0.79

PIECE NO.		FAULTS	LENGTH OF YARN KNITTED PER PIECE METRES	LENGTH OF YARN KNITTED PER SL METRES	CALC. FAULTS PER 100,000M OF YARN
24/1-28/291/	1	8	1,209,117.0	3,407,328.6	0.68
	2	6	1,099,105.8		
	3	9	1,099,105.8		
24/1-28/306/	1	3	991,720.8	2,795,234.4	0.32
	2	3	901,756.8		
	3	3	901,756.8		
24/1-28/321/	1	7	971,308.8	2,743,540.8	0.47
	2	4	889,257.6		
	3	2	882,974.4		
24/1-28/337/	1	1	972,441.0	2,740,203.8	0.29
	2	1	883,931.4		
	3	6	883,931.4		
24/1-28/354/	1	4	947,376.0	2,669,952.0	0.3
	2	1	861,288.0		
	3	3	861,288.0		

TOTAL LENGTH OF YARN KNITTED = 14,356,259.6 M  
 TOTAL FAULTS = 61  
 AVERAGE FAULTS PER 100,000m  
 OF YARN = 0.43

PIECE NO.	FAULTS	LENGTH OF YARN KNITTED PER PIECE METRES	LENGTH OF YARN KNITTED PER SL METRES	CALC. FAULTS PER 100,000M OF YARN
24/1-32/276/	1 5 2 5 3 0	1,126,992.0 1,024,596.0 1,024,596.0	3,176,184.0	0.32
24/1-32/291/	1 1 2 7 3 6	1,045,106.4 950,188.2 950,188.2	2,945,482.8	0.48
24/1-32/306/	1 7 2 1 3 3	1,034,762.4 940,564.8 940,564.8	2,915,892.0	0.38
24/1-32/321/	1 3 2 1 3 5	971,308.8 882,974.4 882,974.4	2,737,257.6	0.33
24/1-32/337/	1 1 2 2 3 4	940,608.6 883,931.4 883,931.4	2,708,471.4	0.26

TOTAL LENGTH OF YARN KNITTED = 14,483,287.8  
TOTAL FAULTS = 51  
AVERAGE FAULTS PER 100,000m  
OF YARN = 0.35

E

YARN COUNT No 1/28 CARDEDMACHINE GAUGE 24

PIECE NO.	FAULTS	LENGTH OF YARN KNITTED PER PIECE METRES	LENGTH OF YARN KNITTED PER SL METRES	CALC. FAULTS PER 100,000M OF YARN
24/1-28CD/306/1	17	991,720.8		
2	10	901,756.8	2,795,234.4	1.72
3	21	901,756.8		
24/1-28CD/321/1	20	971,308.8		
2	6	882,974.4	2,737,257.6	1.21
3	7	882,974.4		
24/1-28CD/337/1	15	972,441.0		
2	13	883,931.4	2,740,303.8	1.31
3	8	883,931.4		
24/1-28CD/354/1	10	947,376.0		
2	15	861,288.0	2,669,952.0	1.39
3	12	861,288.0		
24/1-28CD/372/1	3	915,919.2		
2	4	832,809.6	2,581,538.4	0.7
3	11	832,809.6		

TOTAL LENGTH OF YARN KNITTED = 13,524,286.2

TOTAL FAULTS = 172

AVERAGE FAULTS PER 100,000m  
OF YARN = 1.27

## Appendix 2: Production Data

Machine: MONARCH XL-JS

Gauge: 24

No. of Needles: 1920

No. of Feeders: 60

Machine Diameter: 26 INCH

PIECE NO.	COURSE LENGTH TARGET	MEAN CL AT START OF PIECE	MEAN CL AT END OF PIECE	C/3CM ON MACHINE		C/3CM OFF MACHINE	WIDTH AT ROLLER(CM)	WIDTH ON ROLL (CM)	REVS PRODUCED	PIECE WEIGHT KG	FAUL
				Start	End						
N24 1-24 306 1	588	588	588	42	43	48	83	83	2433	22.7	5
N24 1-24 306 2	588	588	588	42	43		83	83	2666	23.5	9
N24 1-24 306 3	588	589	591	43	43		83.5	82.5	2666	23.6	12
N24 1-24 321 1	616	616	617	39	39	45	83.5	82.5	2750	22.3	9
N24 1-24 321 2	616	616	617	39	40		83	82	2500	22.9	10
N24 1-24 321 3	616	617	617	39	39		83	82	2500	21.8	6
N24 1-24 337 1	647	647	648	36	35	41	83	83	2505	21.7	8
N24 1-24 337 2	647	647	648	36	35		83	83	2277	21.7	7
N24 1-24 337 3	647	648	647	36	36		83	83	2277	20.2	6
N24 1-24 354 1	680	679	680	33	32	38	83	83	2322	19.75	8
N24 1-24 354 2	680	680	681	32	32		83	83	2111	20.75	5
N24 1-24 354 3	680	679	680	32	32		83	82	2111	20.6	5
N24 1-24 372 1	714	714	713	30	29	35	83	83.5	2138	19.5	8
N24 1-24 372 2	714	713	712	29	29		83	83.5	1944	19.8	3
N24 1-24 372 3	714	712	713	29	29		83	83.5	1944	18	8

Machine: MONARCH XL-JS

Gauge: 24

No. of Needles: 1920

No. of Feeders: 60

Machine Diameter: 26 INCH

PIECE NO.	COURSE LENGTH TARGET	MEAN CL AT START OF PIECE	MEAN CL AT END OF PIECE	C/3CM ON MACHINE		C/3CM OFF MACHINE	WIDTH AT ROLLER(CM)	WIDTH ON ROLL (CM)	REVS PRODUCED	PIECE WEIGHT KG	FAUL
				Start	End						
N24 1-28 291 1	559	558	559	47	47	59	82.5	83	3605	25	8
N24 1-28 291 2	559	559	559	47	47		83	82.5	3277	23.4	6
N24 1-28 291 3	559	558	560	46	47		83	83	3277	24.5	9
N24 1-28 306 1	588	587	588	43	42	46	82	82.5	2811	19	3
N24 1-28 306 2	588	587	587	42	42		82	82	2556	19.5	3
N24 1-28 306 3	588	587	587	42	42		82	82	2556	19.3	3
N24 1-28 321 1	616	615	617	38	37	43	82.5	82	2628	19.3	7
N24 1-28 321 2	616	618	618	39	38		83	82	2406	19.3	4
N24 1-28 321 3	616	617	617	39	38		82.5	82	2389	18.6	2
N24 1-28 337 1	647	647	648	35	34	41	82.5	81.5	2505	14.7	1
N24 1-28 337 2	647	647	647	34	34		83	81.5	2277	18.2	1
N24 1-28 337 3	647	647	648	35	34		83	81.5	2277	19	6
N24 1-28 354 1	680	680	679	31	31	38	82	81	2322	20	4
N24 1-28 354 2	680	680	680	31	31		82	81	2111	18.8	1
N24 1-28 354 3	680	680	681	31	31		82	81	2111	17.3	3

Machine: MONARCH XL-JS  
 No. of Feeders: 60

Gauge: 24

No. of Needles: 1920  
 Machine Diameter: 26 INCH

PIECE NO.	COURSE LENGTH TARGET	MEAN CL AT START OF PIECE	MEAN CL AT END OF PIECE	C/3CM ON MACHINE		C/3CM OFF MACHINE	WIDTH AT ROLLER(CM)	WIDTH ON ROLL (CM)	REVS PRODUCED	PIECE WEIGHT KG	FAUL
				Start	End						
N24 1-32 276 1	530	530	530	48	47	58	82	81	3544	20	5
N24 1-32 276 2	530	530	531	47	47		82	81	3222	19	5
N24 1-32 276 3	530	530	530	47	48		82	82	3222	19	0
N24 1-32 291 1	559	559	558	44	44	51	81	81	3116	17	1
N24 1-32 291 2	559	560	559	44	43		81	81	2833	17	7
N24 1-32 291 3	559	559	559	44	44		81	81	2833	17.5	6
N24 1-32 306 1	588	588	588	38	39	48	82	80.5	2933	17.2	7
N24 1-32 306 2	588	588	588	41	40		82	80.5	2666	17	1
N24 1-32 306 3	588	589	588	41	40		82	80.5	2666	17	3
N24 1-32 321 1	616	615	615	36	36	43	82	80.5	2628	16.3	3
N24 1-32 321 2	616	615	615	36	36		81	80.5	2389	15.6	1
N24 1-32 321 3	616	615	615	36	36		81	80.5	2389	15.9	5
N24 1-32 337 1	647	648	648	34	34		81.5	80.5	2423	16.3	1
N24 1-32 337 2	647	648	648	34	34		81	80.5	2277	15.4	2
N24 1-32 337 3	647	648	648	34	34		81	80.5	2277	15	4

Machine: MONARCH XL-JS  
 No. of Feeders: 60

Gauge: 24

No. of Needles: 1920  
 Machine Diameter: 26 INCH

PIECE NO.	COURSE LENGTH TARGET	MEAN CL AT START OF PIECE	MEAN CL AT END OF PIECE	C/3CM ON MACHINE		C/3CM OFF MACHINE	WIDTH AT ROLLER(CM)	WIDTH ON ROLL (CM)	REVS PRODUCED	PIECE WEIGHT KG	FAUL
				Start	End						
N24 1-28CD 306 1	588	587	587	42	42	46	82.5	82.5	2811	15.9	17
N24 1-28CD 306 2	588	588	588	42	42		83	82.5	2556	18.25	10
N24 1-28CD 306 3	588	587	588	41.5	42		83	82.5	2556	15.5	21
N24 1-28CD 321 1	616	617	618	38	38	43	82.5	81	2628	18.6	20
N24 1-28CD 321 2	616	617	617	37	37		82.5	81.5	2389	18.4	6
N24 1-28CD 321 3	616	617	617	37	37		82	82	2389	18.6	7
N24 1-28CD 337 1	647	647	647	34	34	41	83	82	2505	18.1	15
N24 1-28CD 337 2	647	646	645	34	33		83	82	2277	17.2	13
N24 1-28CD 337 3	647	647	648	34	34		83	82	2277	17.5	8
N24 1-28CD 354 1	680	679	680	31	31	38	83	82	2322	18	10
N24 1-28CD 354 2	680	680	681	31	31		83	82	2111	15.5	15
N24 1-28CD 354 3	680	680	680	31	31		82.5	82	2111	16.5	12
N24 1-28CD 372 1	714	713	715	29	29	35	83	83	2138	14.5	3
N24 1-28CD 372 2	714	714	714	29	29		83	83	1944	18.5	4
N24 1-28CD 372 3	714	714	714	29	28.5		83	83	1944	18.2	11



### Appendix 3: Yarn Utilisation

#### NTI 24G SINGLE JERSEY

##### SUMMARY

TOTAL WEIGHT OF FABRIC FOR PROCESSING	Ne 1/32	255.2 kg
	Ne 1/28	295.9 kg
	Ne 1/24	318.8 kg
	Ne 1/28CD	<u>259.3 kg</u>
		<u>1129.2 kg</u>

60 pieces at approximately 100 metres length = 6,000 metres  
Total weight of grey fabric = 1129.2 kg

Total Yarn delivered	1318.5 kg
Yarn remaining	<u>88.3</u> kg
	1230.2
Weight of grey fabric	<u>1129.2</u>
	101.0 kg
Weight yarn/fabric for testing	<u>37.6</u>
Loss in manufacture	63.4 kg
Overall % loss	4.8 %

NTI 24G SINGLE JERSEY

QUALITY	PIECE WEIGHT Kg	WEIGHT/QUALITY
1-24/306/1	22.7	
2	23.5	
3	23.6	69.8
1-24/321/1	22.3	
2	22.9	
3	21.8	67.0
1-24/337/1	21.7	
2	21.7	
3	20.2	63.6
1-24/354/1	19.75	
2	20.75	
3	20.6	61.1
1-24/372/1	19.5	
2	19.8	
3	18	57.3
		= 318.8kg

COMBED YARN  
KENT MILL

Total Length of fabric produced approx. 1500 mts at 100m/piece

Total weight of fabric for processing = 318.8kg

Weight of yarn/fabric removed for testing = 10.6kg

Total weight of yarn knitted = 329.0kg

Nett weight of yarn delivered = 348 kg

Weight of yarn knitted = 329 kg

19 kg

Nett weight of yarn remaining = 12.8 kg

Loss in manufacture = 6.2 kg

% Loss = 1.8%

NTI 24G SINGLE JERSEY

QUALITY	PIECE WEIGHT Kg	WEIGHT/QUALITY
1-28/291/1	25	
2	23.4	
3	24.5	72.9
1-28/306/1	19	
2	19.5	
3	19.3	57.8
1-28/321/1	19.3	
2	19.3	
3	18.6	57.2
1-28/337/1	14.7	
2	18.2	
3	19	51.9
1-28/354/1	20	
2	18.8	
3	17.3	56.1
		= 295.9 kg

COMBED YARN  
KENT MILL

Total Length of fabric produced approx. 1500 mts at 100m/piece

Total weight of fabric for processing = 295.9kg  
 Weight of yarn/fabric removed for testing = 9.86kg  
 Total weight of yarn knitted = 305.76 kg

Nett weight of yarn delivered = 322 kg  
 Weight of yarn knitted = 305.8  
 16.2

Nett weight of yarn remaining = 12.0  
 Loss in manufacture = 4.2 kg  
 % Loss = 1.3%

NTI 24G SINGLE JERSEY

QUALITY	PIECE WEIGHT Kg	WEIGHT/QUALITY
1-32/276/1	20	
2	19	
3	19	58
1-32/291/1	17	
2	17	
3	17.5	51.5
1-32/306/1	17.2	
2	17.0	
3	17.0	51.2
1-32/321/1	16.3	
2	15.6	
3	15.9	47.8
1-32/337/1	16.3	
2	16.4	
3	15.0	46.7
		= 255.2 kg

COMBED YARN  
KENT MILL

Total Length of fabric produced approx. 1500 mts at 100m/piece

Total weight of fabric for processing = 255.2 kg

Weight of yarn/fabric removed for testing = 8.5 kg

Total weight of yarn knitted = 263.7 kg

Nett weight of yarn delivered = 305 kg

Weight of yarn knitted = 263.7  
41.3

Nett weight of yarn remaining = 24.3

Loss in manufacture = 17.0 kg

% Loss = 5.6%

NTI 24G SINGLE JERSEY

QUALITY	PIECE WEIGHT Kg	WEIGHT/QUALITY
1-28CD/306/1	15.9	
2	18.25	
3	15.5	49.65
1-28CD/321/1	18.6	
2	18.4	
3	18.6	55.6
1-28CD/337/1	18.1	
2	17.2	
3	17.5	52.8
1-28CD/354/1	18.0	
2	15.5	
3	16.5	50.0
1-28CD/372/1	14.5	
2	18.5	
3	18.2	51.2
		= 259.25 kg

CARDED YARN  
MAPLE MILL

Total Length of fabric produced approx. 1500 mts at 100m/piece  
 Total weight of fabric for processing = 259.25 kg  
 Weight of yarn/fabric removed for testing = 8.64 kg  
 Total weight of yarn knitted = 267.89 kg

Nett weight of yarn delivered = 343.5 kg  
 Weight of yarn knitted = 267.89  
 75.61 kg

Nett weight of yarn remaining = 39.2  
 Loss in manufacture = 36.41 kg  
 % Loss = 10.6%