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Piece Mercerising Of Single Jersey

A Comparison Between Tubular And Open-Width Processed Fabrics

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1. Introduction

The majority of cotton single jersey is circular knitted, and there are strong arguments in favour of retaining the tubular state for as long as possible during the finishing process even if the customer, to suit his making up technique, requires the finished fabric to be delivered in the open-width form. Batch dyeing, in winch or jet, is much more suited to tubular fabric, as air trapped within the tube helps to prevent the formation of permanent creases and unlevel dyeing.

As piece mercerisation is usually carried out prior to dyeing to take full advantage of the improvement in colour yield conferred by this process, several machines have been developed in recent years for mercerisation of knitgoods in tubular form. One such machine, the Omez "*Mercelux*", has been examined in IIC trials on no less than three occasions (*Research Records 86, 128, and 139*).

However, some processes, such as printing and resin-finishing, are usually carried out on fabric in the open-width state, and it is conceivable that pad-dyeing, still in the early stages of development, might also be more successfully carried out on a single fabric layer.

In some instances, therefore, if the fabric is to be mercerised, it may be more convenient, or more economical to slit the fabric before processing and mercerise at open-width. Consequently, machinery has also been developed for the open-width mercerising of knitted fabrics. These machines are also usually suitable for the mercerisation of woven goods, and in most cases are developments from the standard woven-fabric mercerising ranges. In fact, before machinery manufacturers had realised the potential market for this type of equipment, several finishers were sufficiently enterprising to carry out the modifications to their mercerising machines necessary for the successful processing of knitted fabrics.

IIC carried out trials on one such machine in a French finishing works (Gillet-Thaon, Roanne) in 1973, in which fabric was processed in both the tubular and open-width state. The main disadvantage of tubular processing on such a machine was reported as being the formation of permanent creases in the fabric, which had to be cut away during making-up, resulting in an increase of about 20% in making-up costs.

More recent trials, on machines developed for open-width mercerising, have been carried out by IIC on Benninger (*Research Record No. 53*) and Kleinewefers (*Research Record No. 133*) equipment.

A major disadvantage was also noted in earlier open-width mercerising trials. This took the form of variability in wale spacing across the fabric width, with the fabric structure becoming more closely packed at the edges than at the centre. The effect was present in the finished goods and was not corrected by wet relaxation. It has been suggested [1] that the development of open-width mercerising of knitgoods must be severely limited if this problem cannot be overcome.

The Kleinewefers trial and the most recent Omez trial were carried out on an identical range of single jersey fabrics under closely parallel conditions; this report consists of a comparison between the two studies.

2. Fabrics

The fabrics were 24 gauge single jersey from Ne 28/1 and Ne 56/2 yarns, and 28 gauge single jersey from Ne 36/1 and Ne 72/2 yarns. Each yarn was knitted at five stitch lengths to give a total of twenty fabric constructions.

The production of these fabrics has been described in *Research Record No. 114*.

3. Processing

One complete set of fabrics was processed through each of the two mercerising ranges, followed by normal commercial dyeing and finishing.

A complete set of control fabrics was processed in the same way in each case, without mercerising; the only difference being that, to compensate for the increased colour yield arising from mercerising, the unmercerised fabrics were dyed with 2% and the mercerised with 1.5% Procion Blue H-EG (ICI).

A comparison of some of the major variables noted during the processing is given in the table below.

	Tubular	**Open-Width**
Mercerising		
Caustic concentration, °Bé	28	28-30
Caustic temperature, °C	16	14-18
Wetting agent	Mercerol PL (Sandoz)	Mercerol SA (Sandoz)
Swelling time, sec	57	37
Fabric speed, m/min	40	16
Dyeing		
Machine	Brazzoli MBC/RL	Thies Roto-Stream
Liquor ratio	10:1	8.9:1
Dyeing temperature, °C	80	80
Dyeing time, hr:min	1:40	4:00
Softener	3% Mykon 449 (ROL) 0.4% Avolan IW (Bayer)	2% Adulcinol AL (Zschimmer & Schwartz)

The main differences here appear to be the processing times, with the open-width route including a shorter period for mercerisation, and a much longer dyeing time (the dyeing times given are the times at dyeing temperature, and do not include pre-wetting or washing off.

Fuller descriptions of the processing are given in *Research Records 133 and 139*.

4. Analysis Of The Test Data

A full analysis of the test results obtained on these fabrics has not been attempted here. Instead some of the more important properties have been surveyed in order to establish the presence or absence of major differences between the products of the two processing routes. Consideration has been given to the possibility that different effects may be found between the machine gauges or between the yarns (e.g. singles *vs*. two-fold).

The conclusions of this survey have been set down under the following headings.

- Relaxed yarn structure
- Relaxed fabric structure
- Strength
- Colour
- Other properties

4.1. Yarn Structure

From changes observed in the average stitch length of the relaxed fabrics (*Table 1*), the yarn processing shrinkages found for each trial can be deduced as

tubular:	control 0.1%	mercerised 5.2%
open-width:	control 1.4%	mercerised 1.8%

Shrinkages due to the mercerising treatment alone are, therefore

tubular	5.1%
open-width	0.4%

The changes noted in average yarn tex (*Table 2*) give a somewhat different picture.

tubular:	control -2.3%	mercerised 4.5%
open-width:	control -1.0%	mercerised 0.1%

so that changes due to mercerising are

tubular:	6.8%
open-width:	1.1%

These figures are, of course, affected by any losses of fibre and non-cellulosic material during processing, and by the added weights of dyes and chemicals. Both sets of figures, however, agree on one conclusion: that the tubular route has resulted in greater yarn shrinkage - of the order of 5%.

4.2. Fabric Structure

Changes in fabric structure are considered under five sub-headings.

- Course and wale spacing
- Variability of wale spacing
- Weight
- Thickness
- Spirality

4.2.1. Course and wale spacing

Course spacing measurements on the relaxed fabrics are given in *Table 3*. The open-width mercerisation has given results which are virtually unchanged from the dyed, unmercerised controls. Tubular mercerisation, however, has resulted in considerable lengthwise extension, of about 10% compared with the unmercerised controls.

Wale spacing measurements on the relaxed fabrics are given in *Table 4*. Again, the open-width mercerising treatment has resulted in wale spacings not very different from the unmercerised controls. The difference is larger than in the case of course spacing, and indicates that this treatment would give a product about 3-4% narrower than the corresponding unmercerised fabric. This conclusion, however, is subject to the caveat described in the next section.

On the other hand, the tubular-mercerised samples produced results indicating that fabric processed by this route should have been finished 20% narrower than the corresponding unmercerised products.

In fact, both sets of mercerised fabrics were finished at about 12% narrower than the corresponding control fabrics, this figure having been decided on after studying the results of earlier trials. For instance, a previous run on the Omez machine (*Research Record No. 86*) indicated a reduction in width, due to mercerising, of 11.1%. The tubular fabrics therefore were not allowed to shrink sufficiently in finishing, and exhibited high residual shrinkage (around 20%, instead of the target of 10-12%).

The reason for this difference in behaviour noted between two trials with similar fabric constructions on the same machine is not clear, although some modifications had been made to the equipment in the interim. The discrepancy confirms the suspicion that operation of equipment for piece mercerisation of knitgoods is not always carried out at a high level of control, and research work is needed to form a more exact understanding of the mechanisms involved.

The effects on fabric structure can be seen even more clearly by studying the changes in the ratio between courses and wales in the relaxed fabrics (*Table 5*). The open-width mercerised series is similar to the dyed only fabric series; the tubular mercerised fabrics, however are markedly different with much lower course to wale ratios.

4.2.2. Variability of Wale Spacing

The wale spacing measurements given in *Table 4* are average values, calculated from measurements carried out at random across the full width of the fabric.

However, it has been found in several earlier studies that considerable variability in wale spacing can occur across the width of open-width, piece-mercerised knitted fabrics, with the structure being significantly more closely packed at the edges. Measurements of wale spacing were therefore carried out on these fabrics at regularly spaced intervals across the fabric width. Initially, the fabrics were studied in the unwashed (BW, as received) state. Wale spacing measurements were made on both sets of mercerised fabrics at intervals of 3 inches (7.6 cm) across the entire fabric width, and the results are shown graphically in *Figure 1*. It can be seen that all the open-width mercerised fabrics exhibit this type of variability, and also that while variations exist in the tubular mercerised fabric, these appear to be solely of a random nature.

Similar measurements were made on the control fabrics which were tubular finished, and on the open-width dyed and open-width mercerised and dyed fabrics after five wash/tumble cycles (AW, relaxed). The dyed only fabrics showed only random variations, while the mercerised fabrics still exhibited the packed-edge structure, even after relaxation.

To try to obtain an insight into this behaviour, the standard deviations of the wale spacing measurements were calculated for each fabric sample, and the results are given in *Table 6*. It can be seen that the average degrees of scatter for both sets of dyed-only fabrics, and for the tubular mercerised fabrics, are about the same; while that for the open-width mercerised fabric is considerably higher, due to the edge-packing effect.

There seems to have been some improvement following the relaxation treatment, which leads to the speculation that further washing and tumbling cycles might produce further improvements.

Diagrams showing the variabilities for each fabric structure after relaxation are given in *Figure 2*.

4.2.3. Stitch Density and Weight

Figures for stitch density (courses/cm *x* wales/cm) and weight for the relaxed fabrics are given in *Tables 7I and 8I*. In summary:

- both stitch density and weight have been reduced by 7-9% by the dyeing processes, compared to the relaxed grey fabrics;
- the open-width mercerised and dyed structures are about 2% heavier and denser than the corresponding dyed only fabrics;
- the tubular-mercerised and dyed fabrics are 10-15% heavier and denser than the corresponding dyed-only fabrics, and 8-10% heavier and denser than the corresponding open-width mercerised fabrics.

4.2.4. Thickness and Specific Volume

Measurements of fabric thickness on the relaxed fabrics are tabulated in *Table 9*, and specific volumes were calculated by dividing thickness by fabric weights. These are recorded in *Table 10*.

Specific volume gives a measure of the fibre-to-air ratio of the fabric, and therefore might be expected to provide an indication of handle, insulation and other “comfort” properties. Compared with the dyed-only controls, tubular mercerising has markedly reduced the specific volume, whereas open-width mercerising has had no significant effect.

Mercerisation by either method, on the other hand, has had little effect on fabric thickness alone, and therefore, the changes in specific volume reflect the changes in fabric weight brought about by the treatment.

4.2.5. Spirality

Spirality measurements on the relaxed fabrics are given in *Table 11*.

So far in this discussion on the changes in relaxed fabric properties brought about by mercerising, there have been no obvious differences in behaviour between the fabrics constructed from two-fold yarns and those made from singles yarn. Spirality presents a very different picture.

With fabrics made from singles yarns, the effect of dyeing is to reduce the angle of spirality by several degrees compared with the results found in the grey, relaxed fabrics. Open-width mercerising appears to make a further, slight, reduction; tubular mercerising, however, produces a significant reduction in spirality compared with the dyed-only controls.

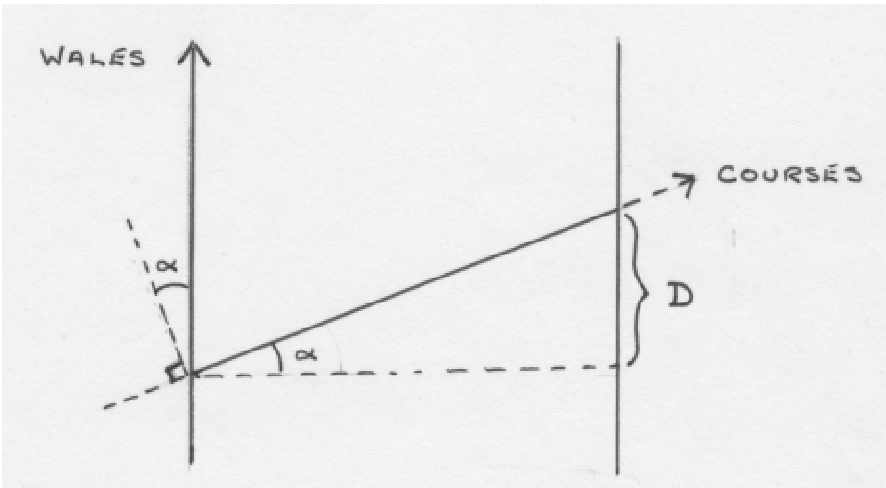
The two-fold yarn constructions, on the other hand, behave completely differently. The angle of spirality is virtually unchanged as a result of the dyeing processes, but mercerisation produces a sharp increase, with both tubular and open-width processing giving similar results.

Although mercerisation has produced an apparent reduction in spirality angle with the singles yarn structures, and an increase with the two-fold constructions, the direction of the change is the same in both cases, that is anti-clockwise.

However, it has already been observed that each finishing treatment can have a different effect on the relaxed fabric linear dimensions, and by geometric considerations alone, these changes will alter the angle of spirality. It would be interesting to discover whether any additional changes, other, that is, than the purely geometric, are being induced in the spirality as a result of the processing method.

One possible technique for achieving this is now described.

Suppose a tube of finished fabric is cut along a wale line and opened into a flat sheet. The courses will lie at an angle to the perpendicular to the wale line, this angle being, by definition, the angle of spirality. Reference to the diagram below will make this clear.



If w = number of wales per cm, and N = number of needles,

then the width of the opened fabric is (N/w) cm.

In order to remove the spirality from the fabric, one edge of the flat sheet must be moved through a distance, D, relative to the other.

This distance is given by $D = (N/w \cdot \tan \alpha)$ cm

and,

if c = number of courses per cm.,

then the number of courses in distance D is equal to $c/w \cdot N \tan \alpha$

If this figure remains unchanged by a processing treatment, it can then be seen that any change in the spirality angle is a purely geometric one. If the figure is reduced, the process can be said to have reduced the spirality in the fabric.

The parameter *c/w* **.** *tan α* can, in fact, be regarded as an *Index Of Spirality*.

Values of the spirality index for the mercerised fabrics, and controls, are tabulated in *Table 12*. It should be noted that the sign indicates only the direction of the effect, not its magnitude; high negative values are as undesirable as high positive values.

The values for singles and two-fold yarn fabrics are shown separately in *Figures 4 (a) and 4 (b)*, plotted against fabric weight. It can be seen that, when the weight increase due to mercerising is taken into account, we obtain a very different picture. With the singles yarns fabrics, there is now little difference between dyed only and mercerised structures; the main variation which shows up now is between the 24 gauge and 28 gauge constructions.

It is interesting to note here that this index of spirality is made up of two components, a yarn component and a machine component. The machine component can be calculated assuming that the yarn plays no dynamic part in the formation of spirality. The number of courses in distance *D* would then be equal to *F*, the number of feeders on the knitting machine, and the index of spirality would be equal to *F/N*.

This "*Machine Index Of Spirality*" is equal to

60 / 1920 = 0.03125 for the 24 gauge fabrics, and

68 / 2112 = 0.0322 for the 28 gauge fabrics.

These values are positive in sign. The convention used in defining the sign of spirality angle (clockwise is positive) will give positive figures for all machines which rotate in a clockwise direction.

By subtracting this machine index from the spirality index, it is suggested that we should obtain a figure which would be related to the residual yarn liveliness, or torque.

4.3. Strength

Yarn strength and tenacity figures are tabulated in *Table 2*. It can be seen that mercerisation produces increases in tenacity averaging about 6%.

Bursting strength figures are given in *Table 13*. Clearly mercerisation has resulted in strength increases, but it must always be remembered that structural changes also take place, and these may themselves be sufficient to account for the improvements. To examine this aspect, the strength data have been plotted against weight for the relaxed fabrics, and the result is shown in *Figure 3*.

This shows very little real strength improvement for the singles yarn constructions, but the two-fold yarn fabrics exhibit clear differences, in the order

open-width dyed < tubular dyed < open-width mercerised < tubular mercerised.

4.4. Colour

In *Research Record No. 141*, a method is described whereby the colour yield for cotton exhaust-dyed in the laboratory with Procion Blue H-EG can be related mathematically to the strength of the dyebath, for unmercerised and mercerised fabric.

In the present trials, the unmercerised fabrics were dyed with 2% Procion Blue H-EG, the mercerised fabrics with 1.5%. Using the equations derived in the laboratory study, the expected values for the CIELAB lightness co-ordinate (L) would be

unmercerised:	38.71
mercerised:	36.45

Actual values are given in *Table 14*. As no consistent difference was found between fabrics differing only in stitch length, the results obtained on the individual fabrics have been averaged.

Three points emerge:

- the observed values are very close to the predicted figures;
- two-fold yarns gave slightly higher figures (perhaps because of lustre);
- there is little difference between tubular and open-width processing.

4.5. Other Properties

There are several other fabric properties that might have been studied in this project, but for one reason or another, were not. These included:

- edge curling;
- hairiness;
- lustre;
- elasticity;
- extensibility under a given load.

From a subjective examination, it appears that edge-curling might have been improved as a result of mercerising; hairiness and lustre are better after tubular processing (perhaps reflecting differences in the mechanical action of the dyeing equipment); elasticity and extensibility seem to be fairly good all round. Some thought should be given in the near future to devising reliable test methods for some or all of these important properties.

5. Conclusions

With the exception of colour yield, for the augmentation of which both processes appear to have been equally effective, the open-width and tubular routes have resulted in mercerised fabrics with markedly differing properties. In every structural property which has been examined (stitch spacings, weight, spirality, thickness) the tubular process has resulted in significant changes in the relaxed structure. Open-width mercerising has produced much smaller structural modifications; in some cases it is impossible to be sure that any change at all has taken place; this was not due to any difference in mercerising strength of the caustic used, although a shorter swelling time may have been a contributing cause.

There were no signs of permanent creasing in the tubular mercerised fabrics. As crease marks still appear on commercially mercerised tubular fabrics available on the market, this gives an indication of the superior quality of the Omez equipment; nevertheless, it has been noted that trials carried out with similar fabrics on virtually the same machine at different times gave very different results in terms of structural changes and there is a clear need for a fundamental study to improve the process control.

The well-documented problem of wale spacing variation in open-width mercerised fabrics was observed, but this may not be an insurmountable problem. Both Artos and Sandoz, with their *Mercevic* and *SM* processes respectively, claim to be able to produce open-width mercerised products without wale spacing variations; Goller are developing a new merceriser which, they think, should solve the problem, and at least one user of a Benninger knitgoods merceriser claims to have succeeded in operating his equipment under conditions which do not result in the production of this fault.

It cannot really be said at this stage that tubular mercerising is better than open-width, or vice versa. They are different, giving products which are different. Indeed, different machines even within one group or the other may give different results, so that we cannot say that knitgoods mercerising is a single process, or even two; and a better insight into the mechanisms governing the technique is urgently required.

REFERENCES

Tuncer, M., "*Wie geeignet sind kettenlose Mercerisiermaschinen für Maschenwaren?*". Wirkerei- und Strickerei Technik; 30 (1980), 6, 400.

Table 1

Stitch length, (mm.), after relaxation.

SAMPLE	G	Tubular Brazz	Tubular Omez	Open-Width RS-E	Open-Width Kwfrs
24/1-28/291/	2.890	2.903	2.769	2.863	2.837
24/1-28/306/	3.015	3.038	2.907	2.957	2.981
24/1-28/321/	3.196	3.189	3.071	3.184	3.161
24/1-28/337/	3.350	3.317	3.199	3.311	3.305
24/1-28/354/	3.496	3.517	3.357	3.477	3.449
24/2-56/291/	2.906	2.857	2.712	2.820	2.809
24/2-56/306/	3.038	3.009	2.839	2.960	2.940
24/2-56/321/	3.150	3.164	2.962	3.094	3.071
24/2-56/337/	3.322	3.330	3.141	3.299	3.228
24/2-56/354/	3.512	3.484	3.296	3.373	3.394
28/1-36/259/	2.614	2.584	2.449	2.542	2.560
28/1-36/273/	2.742	2.720	2.602	2.662	2.715
28/1-36/287/	2.809	2.860	2.736	2.839	2.827
28/1-36/301/	2.976	3.004	2.890	2.963	2.980
28/1-36/316/	3.153	3.135	3.009	3.094	3.129
28/2-72/259/	2.563	2.555	2.388	2.538	2.486
28/2-72/273/	2.727	2.694	2.495	2.692	2.665
28/2-72/287/	2.833	2.839	2.670	2.809	2.786
28/2-72/301/	2.964	2.972	2.792	2.950	2.905
28/2-72/316/	3.114	3.127	2.947	3.088	3.068

Table 2

Average Values for All Stitch Lengths

		Yarn Count (Tex)	Yarn Strength (g)	Tenacity g/tex	% Increase D→M & D
Grey	1-28	20.3	254.1	12.52	
	2-56	21.3	456.1	21.41	
	1-36	15.6	188.5	12.08	
	2-72	16.1	340.7	21.16	
Tub. d	1-28	19.9	279.2	14.03	
	2-56	20.6	473.4	22.98	
	1-36	15.4	213.8	13.88	
	2-72	15.7	354.9	22.61	
Tub.m&d	1-28	21.3	323.9	15.21	8.4
	2-56	22.1	556.5	25.18	9.6
	1-36	16.2	233.5	14.41	3.8
	2-72	17.0	408.9	24.05	6.4
OW d	1-28	20.4	279.8	13.72	
	2-56	20.6	477.9	23.20	
	1-36	15.5	206.8	13.34	
	2-72	16.1	354.1	21.99	
OW m&d	1-28	20.6	298.9	14.51	5.8
	2-56	21.2	521.7	24.61	6.1
	1-36	15.5	213.6	13.78	3.3
	2-72	16.1	375.5	23.32	6.0

Table 3

Courses per 3cm., after relaxation.

SAMPLE	G	Tubular Brazz	Tubular Omez	Open-Width RS-E	Open-Width Kwfrs
24/1-28/291/	61.4	57.4	51.1	58.2	57.2
24/1-28/306/	56.9	54.0	49.6	53.7	54.0
24/1-28/321/	54.1	51.6	48.6	50.3	50.1
24/1-28/337/	50.8	48.6	46.9	48.9	48.4
24/1-28/354/	48.6	45.5	42.6	45.0	46.2
24/2-56/291/	58.9	56.8	50.0	57.3	55.3
24/2-56/306/	56.3	53.3	46.6	51.8	52.5
24/2-56/321/	53.0	50.1	44.8	49.0	50.0
24/2-56/337/	49.3	47.2	41.4	47.6	46.7
24/2-56/354/	46.9	44.0	38.5	45.3	43.9
28/1-36/259/	66.2	63.1	56.8	64.2	62.7
28/1-36/273/	63.6	58.6	54.4	60.3	58.4
28/1-36/287/	59.1	56.4	51.0	56.1	55.7
28/1-36/301/	56.6	53.4	48.3	51.6	52.3
28/1-36/316/	53.8	49.9	44.6	49.0	49.5
28/2-72/259/	64.4	62.3	56.4	62.4	61.3
28/2-72/273/	61.8	58.5	54.4	59.7	57.4
28/2-72/287/	58.1	54.9	48.8	53.9	53.6
28/2-72/301/	55.5	51.9	45.0	51.1	51.8
28/2-72/316/	51.3	48.4	42.2	47.6	47.3

Table 4

Wales per 3cm., after relaxation.

SAMPLE	G	Tubular Brazz	Tubular Omez	Open-Width RS-E	Open-Width Kwfrs
24/1-28/291/	43.8	43.4	53.1	42.8	43.8
24/1-28/306/	42.1	41.7	49.1	42.1	41.5
24/1-28/321/	40.7	40.2	46.8	40.0	41.7
24/1-28/337/	39.9	39.7	44.9	38.8	39.9
24/1-28/354/	39.0	38.1	44.9	37.7	39.1
24/2-56/291/	42.8	42.3	52.3	42.6	43.8
24/2-56/306/	41.3	40.9	50.6	42.0	41.7
24/2-56/321/	40.4	39.5	50.3	40.3	41.0
24/2-56/337/	38.6	37.4	47.8	37.8	39.8
24/2-56/354/	36.3	35.7	47.3	35.7	38.7
28/1-36/259/	50.2	48.8	59.1	48.6	50.1
28/1-36/273/	48.4	47.8	57.0	46.6	49.0
28/1-36/287/	46.9	46.4	55.0	45.9	48.0
28/1-36/301/	46.0	44.6	52.8	44.8	46.0
28/1-36/316/	44.4	43.4	52.9	43.5	45.9
28/2-72/259/	49.0	49.0	58.1	48.9	49.5
28/2-72/273/	47.3	46.8	59.3	46.4	49.0
28/2-72/287/	45.2	44.1	55.2	45.7	46.8
28/2-72/301/	42.4	42.9	56.6	42.9	44.8
28/2-72/316/	41.4	41.3	54.5	42.7	43.4

Table 5

Ratio of courses to wales, after relaxation.

SAMPLE	G	Tubular Brazz	Tubular Omez	Open-Width RS-E	Open-Width Kwfrs
24/1-28/291/	1.40	1.32	0.96	1.36	1.31
24/1-28/306/	1.35	1.29	1.01	1.28	1.30
24/1-28/321/	1.33	1.28	1.04	1.26	1.20
24/1-28/337/	1.27	1.22	1.04	1.26	1.21
24/1-28/354/	1.25	1.19	0.95	1.19	1.18
24/2-56/291/	1.38	1.34	0.96	1.35	1.26
24/2-56/306/	1.36	1.30	0.92	1.23	1.26
24/2-56/321/	1.31	1.27	0.89	1.22	1.22
24/2-56/337/	1.28	1.26	0.87	1.26	1.17
24/2-56/354/	1.29	1.23	0.81	1.27	1.13
28/1-36/259/	1.32	1.29	0.96	1.32	1.25
28/1-36/273/	1.31	1.23	0.95	1.29	1.19
28/1-36/287/	1.26	1.22	0.93	1.22	1.16
28/1-36/301/	1.23	1.20	0.91	1.15	1.14
28/1-36/316/	1.21	1.15	0.84	1.13	1.08
28/2-72/259/	1.31	1.27	0.97	1.28	1.24
28/2-72/273/	1.31	1.25	0.92	1.29	1.17
28/2-72/287/	1.29	1.24	0.88	1.18	1.15
28/2-72/301/	1.31	1.21	0.80	1.19	1.16
28/2-72/316/	1.24	1.17	0.77	1.11	1.09

Table 6

Standard Deviations of Wale Spacing Measurements

	TUBULAR UNRELAXED		OPEN-WIDTH UNRELAXED		OPEN-WIDTH RELAXED
	DYED	MERC.	MERC.	DYED	MERC.
24/1-28/291	0.34	0.49	1.12	0.53	0.84
/306	0.53	0.52	1.04	0.32	0.92
/321	0.32	0.64	1.37	0.53	0.52
/337	0.44	0.68	1.15	0.61	0.86
/354	0.94	0.51	1.31	0.45	0.84
24/2-56/291	0.38	0.76	1.71	0.50	1.13
/306	0.59	0.51	1.46	0.22	0.68
/321	0.34	0.44	1.31	0.47	0.94
/337	0.30	0.66	1.52	0.51	1.35
/354	0.26	0.18	1.88	0.67	1.32
28/1-36/259	0.71	0.48	1.47	0.70	1.27
/273	0.75	0.46	1.17	0.90	0.82
/287	0.72	0.59	1.22	0.38	1.02
/301	0.78	0.47	1.56	0.89	1.22
/316	0.36	0.47	1.12	0.74	0.77
28/2-72/259	0.80	0.60	1.67	0.70	1.25
/273	0.70	0.49	1.71	0.53	1.21
/287	0.53	0.48	1.77	0.44	1.52
/301	0.53	0.57	1.73	0.57	1.86
/316	0.74	0.67	1.78	0.56	1.99
Mean S.D.	0.55	0.53	1.45	0.56	1.12

Table 7

Stitch Density, stitches per square cm., after relaxation.

SAMPLE	G	Tubular		Open-Width	
		Brazz	Omez	RS-E	Kwfrs
24/1-28/291/	298.8	276.8	301.5	276.8	278.4
24/1-28/306/	266.2	250.2	270.6	251.2	249.0
24/1-28/321/	244.7	230.5	252.7	223.6	232.1
24/1-28/337/	225.2	214.4	234.0	210.8	214.6
24/1-28/354/	210.6	192.6	212.5	188.5	200.7
24/2-56/291/	280.1	267.0	290.6	271.2	269.1
24/2-56/306/	258.4	242.2	262.0	241.7	243.2
24/2-56/321/	237.9	219.9	250.4	219.4	227.8
24/2-56/337/	211.4	196.1	219.9	199.9	206.5
24/2-56/354/	189.2	174.5	202.3	179.7	188.8
28/1-36/259/	369.2	342.1	373.0	346.7	349.0
28/1-36/273/	342.0	311.2	344.5	312.2	318.0
28/1-36/287/	308.0	290.8	311.7	286.1	297.1
28/1-36/301/	289.3	264.6	283.4	256.9	267.3
28/1-36/316/	265.4	240.6	262.1	236.8	252.4
28/2-72/259/	350.6	339.2	364.1	339.0	337.1
28/2-72/273/	324.8	304.2	350.4	307.8	312.5
28/2-72/287/	291.8	269.0	299.3	273.7	278.7
28/2-72/301/	261.5	247.4	283.0	243.6	257.8
28/2-72/316/	236.0	222.1	255.5	225.8	228.1

Table 8

Weight, (g/sq.m.), after relaxation.

SAMPLE	G	Tubular		Open-Width	
		Brazz	Omez	RS-E	Kwfrs
24/1-28/291/	168.7	156.4	177.0	157.8	164.0
24/1-28/306/	160.9	149.4	172.4	152.9	152.1
24/1-28/321/	157.8	141.7	168.1	145.8	147.2
24/1-28/337/	152.8	136.1	160.1	139.5	144.9
24/1-28/354/	147.7	130.2	154.7	135.5	145.4
24/2-56/291/	170.5	151.1	177.5	154.2	159.0
24/2-56/306/	163.0	145.4	165.9	147.0	150.9
24/2-56/321/	151.3	137.6	163.1	140.5	148.8
24/2-56/337/	140.0	126.6	151.2	136.3	140.1
24/2-56/354/	137.7	119.8	145.8	123.8	135.3
28/1-36/259/	145.5	133.3	149.2	137.5	136.2
28/1-36/273/	139.4	129.0	145.8	131.0	133.3
28/1-36/287/	128.4	120.8	138.4	124.7	132.3
28/1-36/301/	126.6	117.7	131.4	118.7	122.3
28/1-36/316/	124.3	113.0	130.1	111.7	120.1
28/2-72/259/	142.2	133.4	150.7	135.2	136.7
28/2-72/273/	133.8	123.1	150.5	128.8	136.0
28/2-72/287/	126.4	115.9	138.2	123.1	124.4
28/2-72/301/	119.7	108.3	134.5	116.4	119.7
28/2-72/316/	113.0	104.7	128.7	111.8	110.3

Table 9

Thickness, microns, after relaxation.

SAMPLE	G	Tubular Brazz	Omez	Open-Width RS-E	Kwfrs
24/1-28/291/	867	715	715	695	732
24/1-28/306/	952	732	714	705	728
24/1-28/321/	965	751	740	697	741
24/1-28/337/	957	740	758	724	758
24/1-28/354/	849	740	737	733	789
24/2-56/291/	789	658	621	651	707
24/2-56/306/	774	664	632	645	678
24/2-56/321/	882	674	644	653	679
24/2-56/337/	888	662	667	681	702
24/2-56/354/	836	666	690	668	706
28/1-36/259/	787	652	649	613	689
28/1-36/273/	796	664	679	628	701
28/1-36/287/	876	666	661	642	718
28/1-36/301/	869	677	675	656	717
28/1-36/316/	860	703	708	668	747
28/2-72/259/	719	605	585	572	618
28/2-72/273/	682	593	606	600	620
28/2-72/287/	812	608	608	592	649
28/2-72/301/	809	656	610	585	663
28/2-72/316/	757	615	614	598	610

Table 10

Specific Volume, (cc./g), after relaxation.

SAMPLE	G	Tubular Brazz	Omez	Open-Width RS-E	Kwfrs
24/1-28/291/	5.139	4.572	4.040	4.404	4.463
24/1-28/306/	5.917	4.900	4.142	4.611	4.786
24/1-28/321/	6.115	5.300	4.402	4.781	5.034
24/1-28/337/	6.263	5.437	4.735	5.190	5.231
24/1-28/354/	5.748	5.684	4.764	5.410	5.426
24/2-56/291/	4.628	4.355	3.499	4.222	4.447
24/2-56/306/	4.748	4.567	3.810	4.388	4.493
24/2-56/321/	5.829	4.898	3.948	4.648	4.563
24/2-56/337/	6.343	5.229	4.411	4.996	5.011
24/2-56/354/	6.071	5.559	4.733	5.396	5.218
28/1-36/259/	5.409	4.891	4.350	4.458	5.059
28/1-36/273/	5.710	5.147	4.657	4.794	5.259
28/1-36/287/	6.822	5.513	4.776	5.148	5.427
28/1-36/301/	6.864	5.752	5.137	5.527	5.863
28/1-36/316/	6.919	6.221	5.442	5.980	6.220
28/2-72/259/	5.056	4.535	3.882	4.231	4.521
28/2-72/273/	5.097	4.817	4.027	4.658	4.559
28/2-72/287/	6.424	5.246	4.399	4.809	5.217
28/2-72/301/	6.759	6.057	4.535	5.026	5.539
28/2-72/316/	6.699	5.874	4.771	5.349	5.530

Table 11

Angle of spirality, after relaxation.

SAMPLE	G	Tubular Brazz	Tubular Omez	Open-Width RS-E	Open-Width Kwfrs
24/1-28/291/	17.0	11.4	7.3	11.2	8.0
24/1-28/306/	18.9	11.9	8.2	13.4	9.0
24/1-28/321/	20.1	13.8	10.0	14.0	13.0
24/1-28/337/	21.8	16.2	12.7	16.4	11.4
24/1-28/354/	25.3	19.7	12.1	20.3	16.5
24/2-56/291/	-0.6	-2.1	-6.1	-4.3	-6.8
24/2-56/306/	-2.1	-2.8	-6.0	-5.2	-6.8
24/2-56/321/	-2.3	-3.1	-6.3	-4.7	-6.2
24/2-56/337/	-3.5	-3.5	-8.2	-7.3	-7.9
24/2-56/354/	-4.2	-5.0	-9.4	-6.2	-8.9
28/1-36/259/	20.1	11.0	7.2	11.8	10.4
28/1-36/273/	21.3	13.1	8.6	13.4	12.2
28/1-36/287/	24.5	15.9	10.6	15.7	13.8
28/1-36/301/	26.6	18.2	10.9	18.5	14.8
28/1-36/316/	26.5	21.3	12.2	20.2	19.3
28/2-72/259/	0.6	-2.8	-7.2	-6.9	-6.0
28/2-72/273/	-1.3	-3.0	-5.8	-7.0	-8.0
28/2-72/287/	-2.4	-3.4	-8.2	-6.9	-7.4
28/2-72/301/	-2.9	-3.7	-7.6	-6.0	-7.6
28/2-72/316/	-3.2	-3.7	-7.3	-7.5	-7.3

Table 12

Spirality Index, (courses/wales)x tan alpha, after relaxation

SAMPLE	G	Tubular Brazz	Tubular Omez	Open-Width RS-E	Open-Width Kwfrs
24/1-28/291/	0.427	0.266	0.123	0.268	0.183
24/1-28/306/	0.462	0.272	0.145	0.304	0.206
24/1-28/321/	0.487	0.315	0.182	0.313	0.277
24/1-28/337/	0.509	0.355	0.235	0.372	0.245
24/1-28/354/	0.590	0.420	0.203	0.442	0.351
24/2-56/291/	-0.014	-0.048	-0.103	-0.102	-0.150
24/2-56/306/	-0.050	-0.063	-0.097	-0.113	-0.149
24/2-56/321/	-0.053	-0.068	-0.098	-0.099	-0.133
24/2-56/337/	-0.077	-0.077	-0.125	-0.160	-0.162
24/2-56/354/	-0.095	-0.108	-0.134	-0.138	-0.177
28/1-36/259/	0.482	0.250	0.121	0.276	0.229
28/1-36/273/	0.513	0.286	0.144	0.309	0.250
28/1-36/287/	0.575	0.347	0.173	0.343	0.285
28/1-36/301/	0.616	0.393	0.176	0.385	0.301
28/1-36/316/	0.603	0.448	0.182	0.415	0.378
28/2-72/259/	0.013	-0.061	-0.122	-0.154	-0.130
28/2-72/273/	-0.029	-0.066	-0.093	-0.157	-0.164
28/2-72/287/	-0.054	-0.074	-0.127	-0.142	-0.148
28/2-72/301/	-0.067	-0.070	-0.106	-0.125	-0.154
28/2-72/316/	-0.070	-0.075	-0.099	-0.147	-0.139

Table 13

Burst strength, (kN/sq.m.), after relaxation.

SAMPLE	G	Tubular Brazz	Tubular Omez	Open-Width RS-E	Open-Width Kwfrs
24/1-28/291/	607.6	535.8	672.6	506.0	585.9
24/1-28/306/	575.8	519.8	632.5	493.5	567.3
24/1-28/321/	534.8	511.1	577.8	454.2	542.3
24/1-28/337/	494.0	462.8	542.5	427.5	496.2
24/1-28/354/	471.1	443.4	534.9	410.3	489.0
24/2-56/291/	761.7	718.9	899.0	671.9	795.0
24/2-56/306/	712.2	703.2	908.1	631.4	776.8
24/2-56/321/	702.9	650.4	882.1	588.0	728.0
24/2-56/337/	685.1	620.8	819.7	604.2	715.0
24/2-56/354/	653.4	606.4	831.9	578.8	681.7
28/1-36/259/	483.8	471.0	543.7	438.5	470.5
28/1-36/273/	483.5	429.8	501.0	414.8	456.9
28/1-36/287/	456.1	420.2	505.3	372.0	426.0
28/1-36/301/	412.0	384.0	458.9	369.3	409.5
28/1-36/316/	390.6	374.2	433.6	379.0	408.9
28/2-72/259/	641.6	631.9	808.8	580.3	664.3
28/2-72/273/	624.6	611.2	803.2	557.4	667.7
28/2-72/287/	620.5	572.1	762.0	547.3	605.2
28/2-72/301/	560.1	546.8	746.7	515.2	612.9
28/2-72/316/	544.0	513.8	700.3	493.0	584.3

Table 14

Colour Measurement "L" Values

	Average Values: Controls	Average Values: Mercerised
Singles Yarn fabrics, tubular	39.82	38.54
Singles Yarn fabrics, open-width	37.74	38.31
Two-fold Yarn fabrics, tubular	40.91	39.55
Two-fold Yarn fabrics, open-width	39.18	39.71
Predicted Values (Singles Yarn Fabric)	38.71	36.45

Figure 1 (a)

Variation in Wale Spacing Across Fabric Width - 24 gauge Fabrics, Unrelaxed

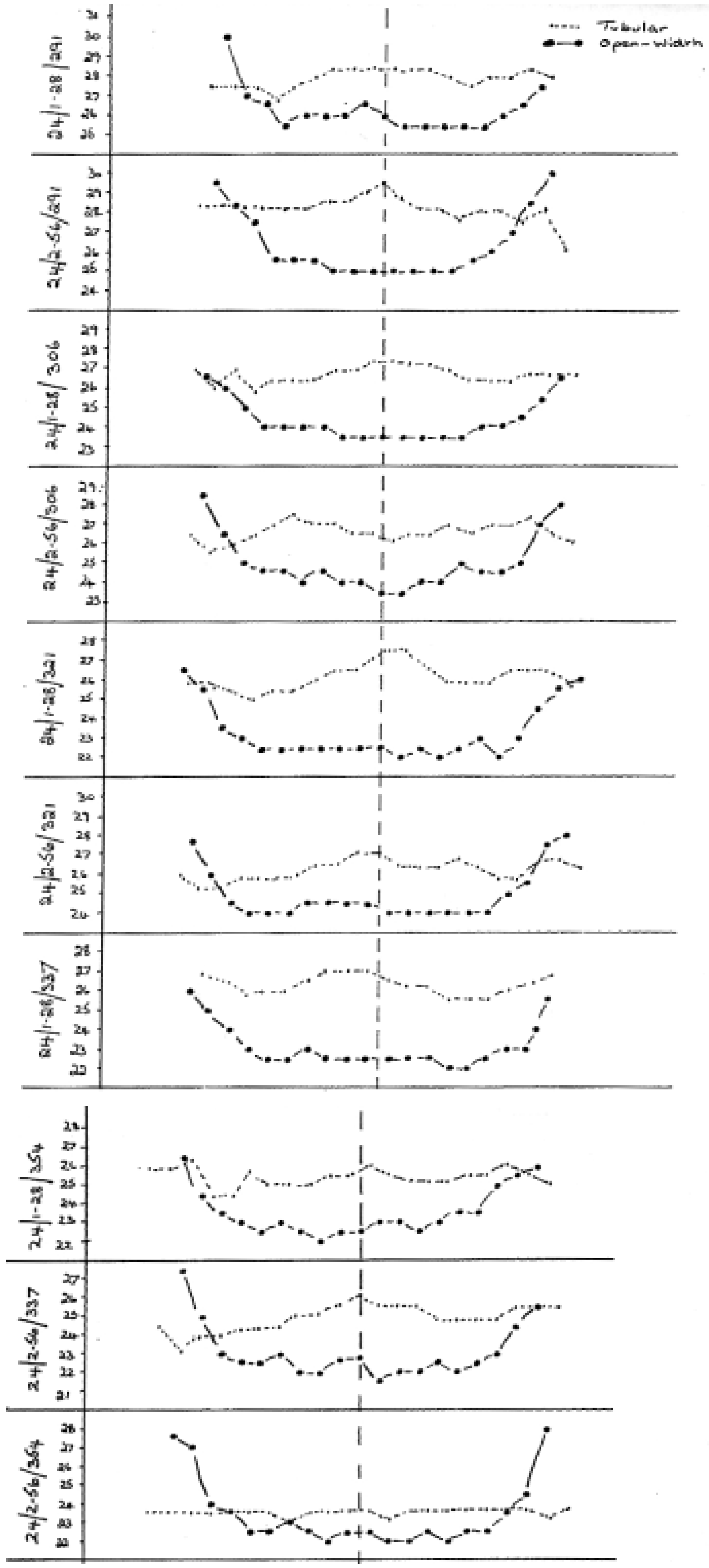


Figure 1 (b)

Variation in Wale Spacing Across Fabric Width - 28 gauge Fabrics, Unrelaxed

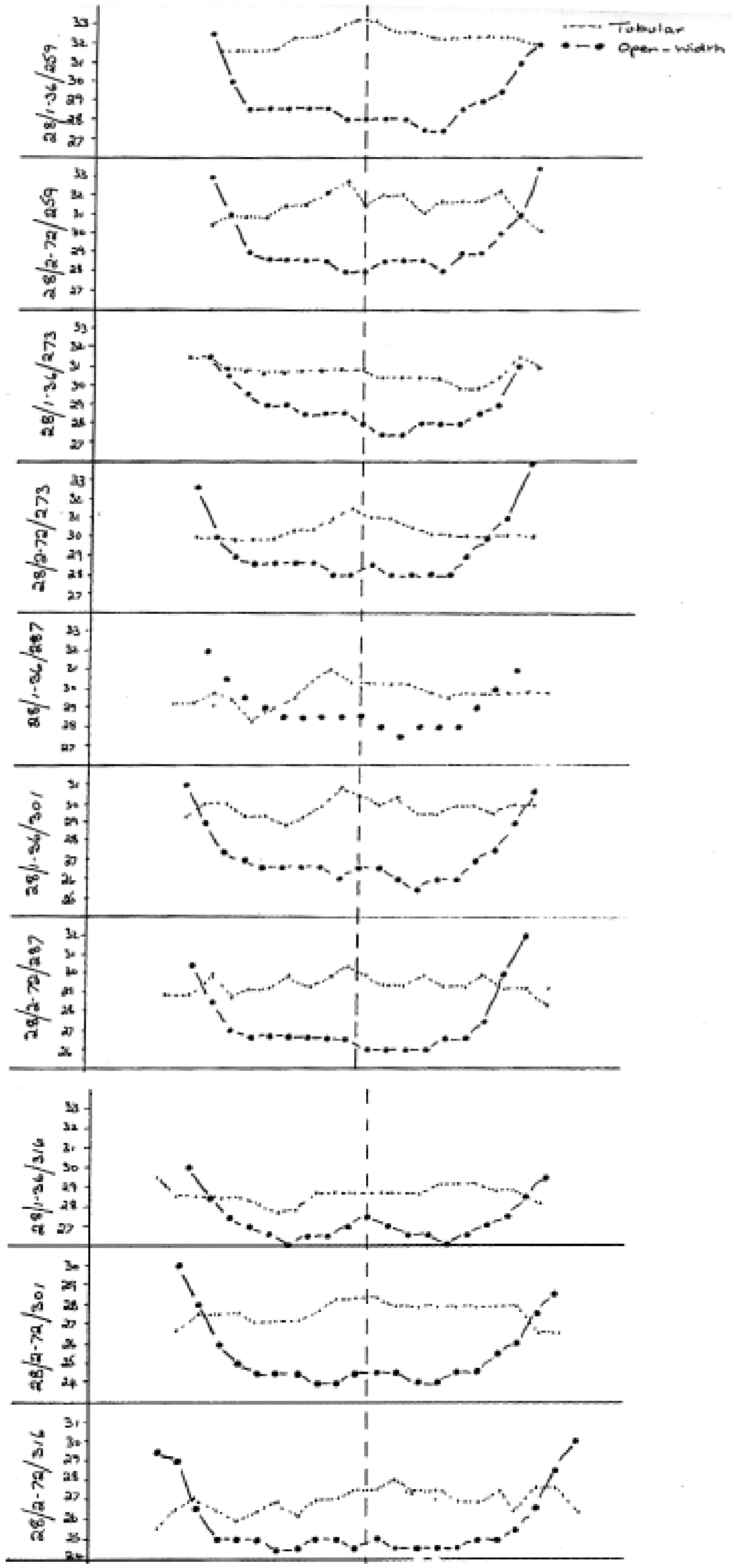


Figure 2 (a)

Variation in Wale Spacing Across Fabric Width - 24 gauge Fabrics, Relaxed

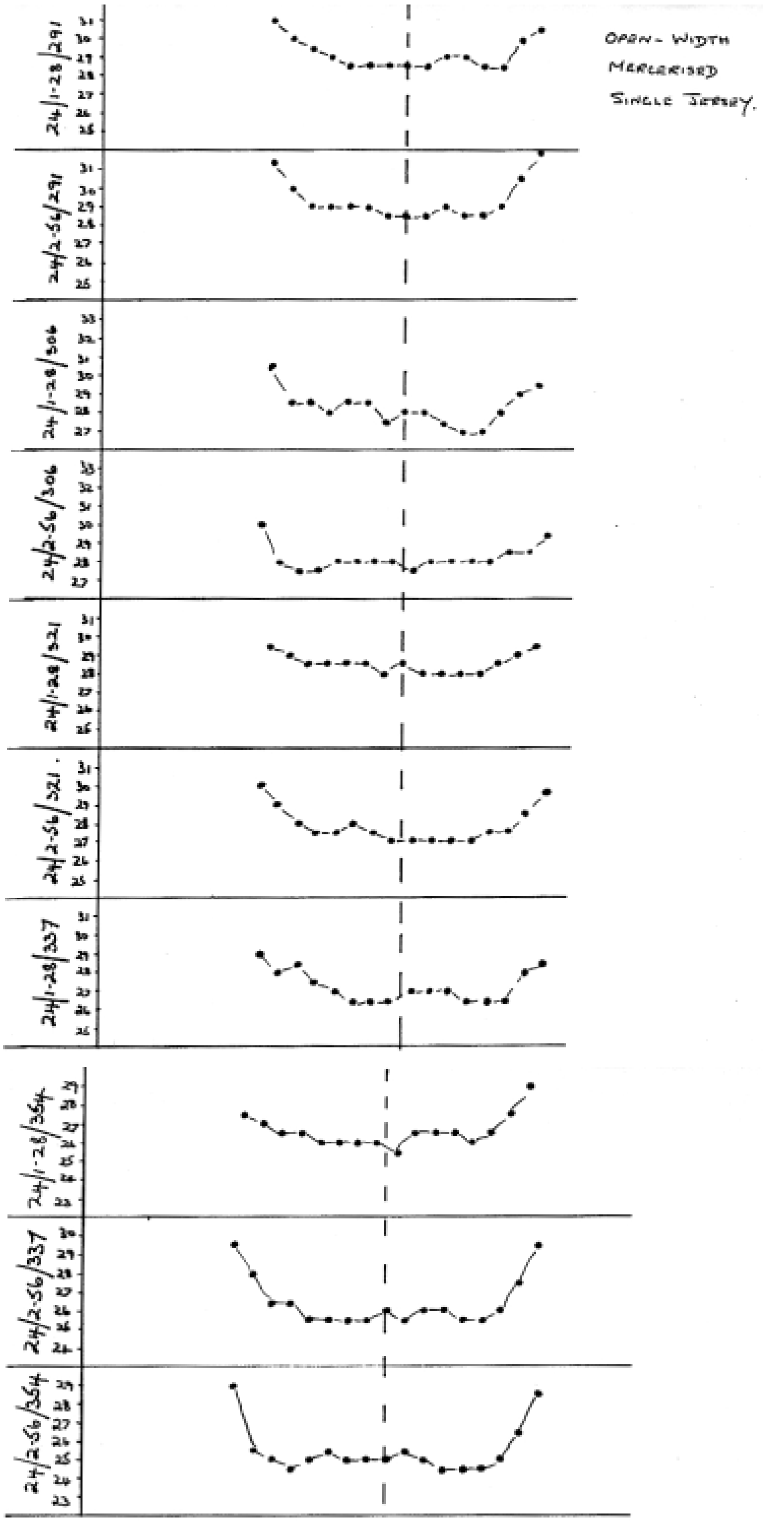


Figure 2 (b)

Variation in Wale Spacing Across Fabric Width - 28 gauge Fabrics, Relaxed

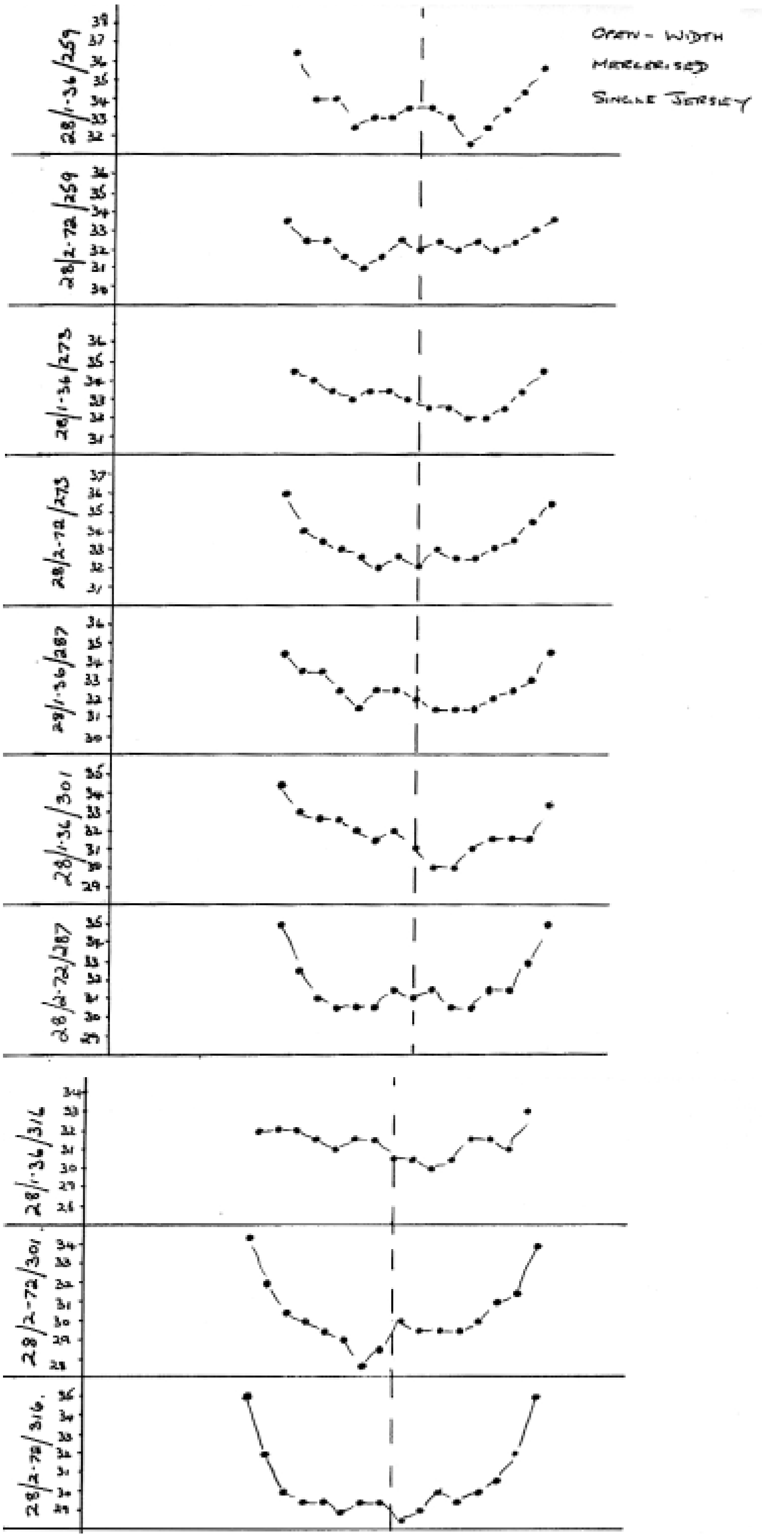


Figure 3 (a)

Strength *vs*. Weight of Singles-Yarn Fabrics

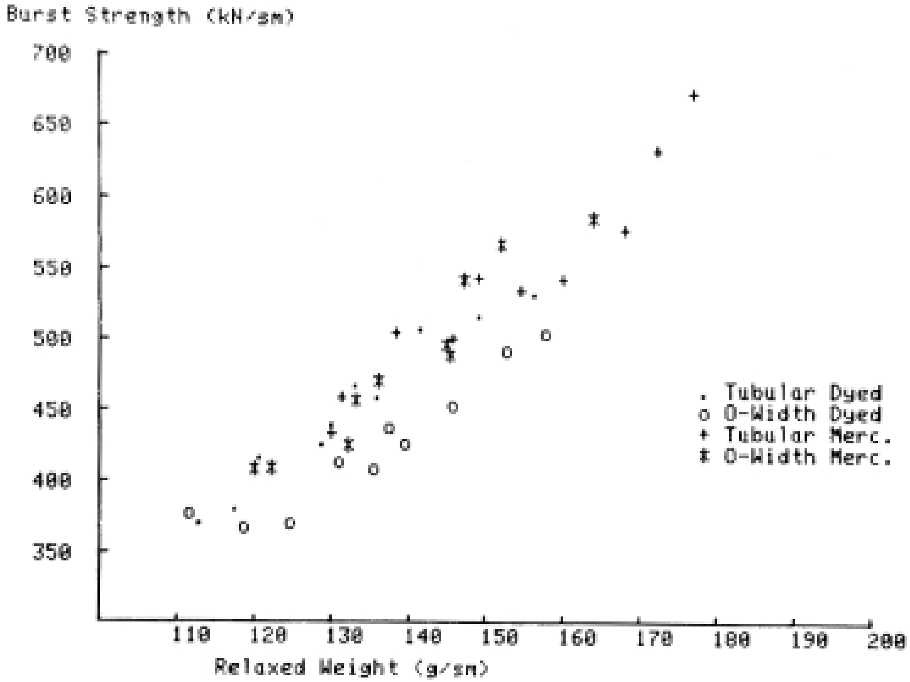


Figure 3 (b)

Strength *vs*. Weight of Twofold-Yarn Fabrics

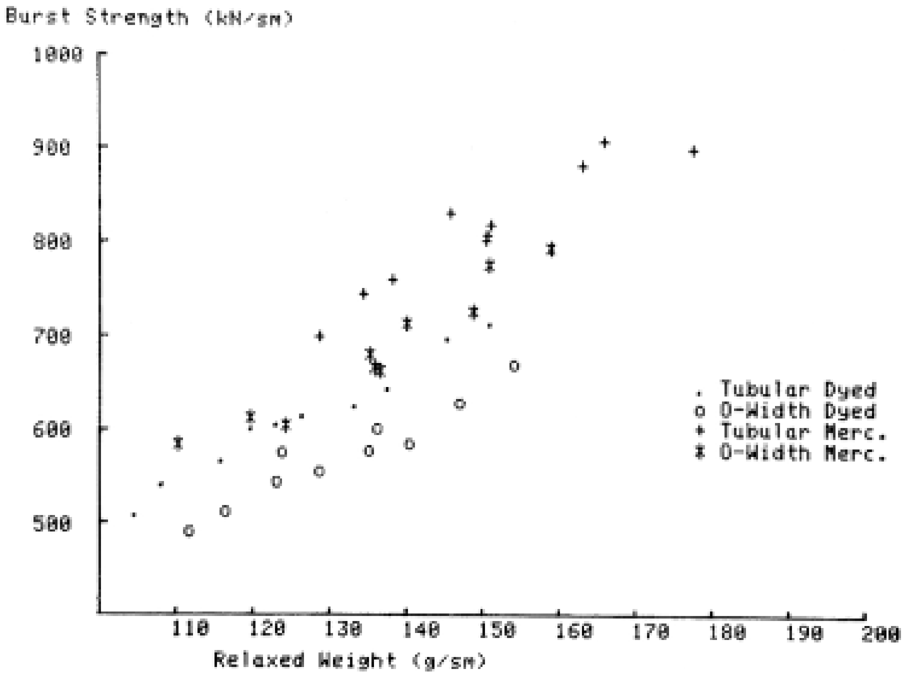


Figure 4 (a)

Spirality *vs*. Weight of Singles-Yarn Fabrics

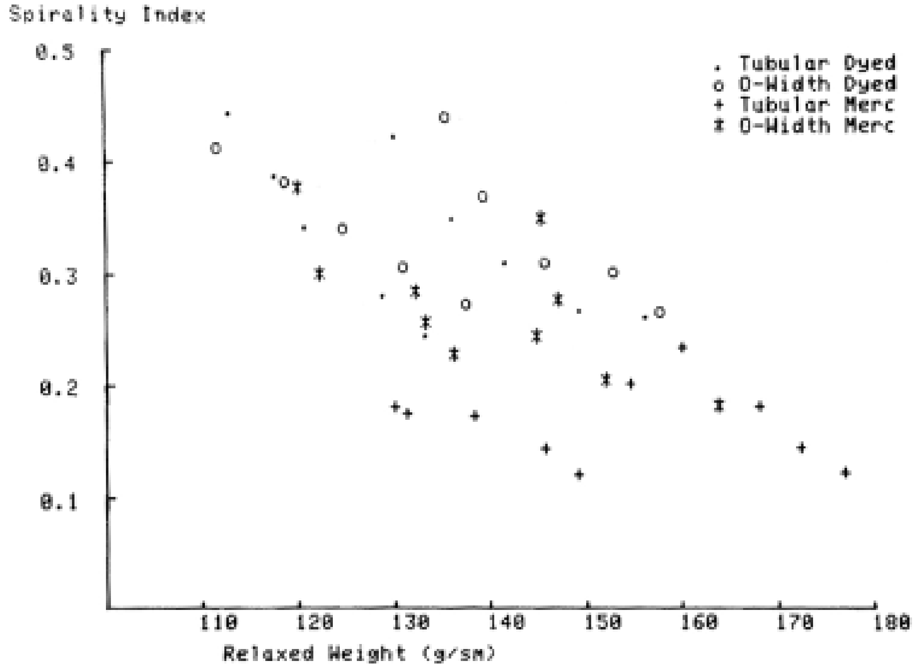


Figure 4 (b)

Spirality *vs*. Weight of Twofold-Yarn Fabrics