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APPLICATION OF QUALITY CONTROL METHODS IN WORSTED SPINNING 1/

by

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APPLICATION OF QUALITY CONTROL METHODS IN WORSTED SPINNING

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A. INTRODUCTION

In the last twenty years there have been certain developments concerning the technology of worsted spinning. These developments shortened to a certain extent the drawing process. At the same time they called for more highly trained technicians able to exercise control and to evaluate objectively the raw material and the final product.

Some of the modern trends introduced into the worsted trade are based on new ideas and I have in mind especially autolevelling, higher drafts, cone winding combined with yarn clearing and a different approach to twisting folded yarns.

This new trend lead to a situation whereby the spinner is confronted by a bewildering range of systems, machines and instruments. Everyone in the wool textile industry is well aware of those changes and tries to cope with the new situation in the best possible way.

It is evident that because of the changes in the construction of machines and modification of processes we have advanced in the rate of production per operative, and often we use less operations between the raw material and the product. This prominent advance in the rate of productivity, amongst other things, was achieved by the considerable increase in machine speed. At this moment, I would like to mention a very important fact, namely that the wool fibres which were before processed under the older slower techniques, are adaptable to the extent that they can be processed under modern conditions without any difficulties. Higher speeds of processing and fewer operations mean increased risks of making a faulty product and we have to adopt more vigilant control of the raw material, the intermediate products and the final product.

For the complete characterisation of a worsted yarn several variable parameters are necessary. Even when using the same wool and the same machinery, the spun yarns vary in quality.

Systematic testing permits the determination of this variability and consequently the establishment of the standards and limits of tolerance towards which the production should be aimed. For this regular and frequent testing, atmospheric room conditions as uniform as possible are necessary. At the same time, when fixing the standard values, it should be kept in mind that only a limited regularity of the product can be achieved. Demands on quality must not be too rigid, but must always be related to the capabilities of the machinery, the process itself and the nature of the raw material.

The information on which the control is based can be obtained only in any particular set of circumstances by various types of tests. The analysis of the data thus obtained should give a clear picture of the variability and, accordingly, permit the establishment of standard values. Since, however, tolerances must be acceptable, the interpretation of the results and their comparison with the standard values should be done with the aid of statistical methods. For control testing in worsted spinning it is necessary to make checks of the most important points in processing. These are at the stage of tops, rovings and yarns. Yarns must be assessed for irregularity, tensile strength, twist and variations in these parameters, and, finally, cleanliness.

Until quite recent times the assessment of wool fibres in any form (tops, slivers, rovings, yarns or fabrics) depended entirely upon the judgement of a skilled classer. After years of experience, the woolman tells by sight and feel of the fibre how a particular lot will process in the mill. This visual sense enables him to allocate different lots for different purposes.

I would like to stress that the skilled personal assessment of wool remains a vital function of the trade and probably will remain so, but much more information is now needed than subjective judgement can supply.

As the textile industry has grown, and ways of working and commercial transactions have changed, controls have increased, so an accurate assessment of tops, yarn and fabric has become more and more essential. To illustrate this point I should like to quote the following examples.

1. There is a tendency for spinners to buy the top being based on fibre diameter in microns (μ) length of fibres in mm, plus the coefficient of variation of fibre length.

2. Specifications are often established concerning the short term and long term variation of the yarn, the strength of the yarn and its variation.

3. Worsted machinery makers, in many cases, clearly specify what length wool fibres should possess and the maximum percentage of the short fibres allowed to obtain good results on the particular set of spinning equipment. These are only a few examples from a list which is becoming longer every day.

In this new situation we must familiarize ourselves with certain new terms and theories. For example, if we have the following specifications for grades of wool

Quality	Mean Fibre Diameter μ (microns)	Standard Deviation (σ)
80^s	18-19	4μ (microns)
60^s	23-24	6 " "
36^s	38-40	11 " "

we must understand the meaning of every detail and how to take advantage of knowing these details quoted in the table. We see that the coefficient of variation (CV) of the fibre diameter can be calculated and that its value depends on the fineness of the fibre.

$$CV = \frac{\text{Standard deviation}}{\text{Mean fibre diameter}} \times 100\%$$

Quality 80^s $\quad CV = \frac{4\mu \times 100\%}{18} = 22.2\%$

Quality 60^s $\quad CV = \frac{6\mu \times 100\%}{23} = 26.1\%$

Quality 36^s $\quad CV = \frac{11\mu \times 100\%}{38} = 29\%$

The importance of the coefficient of variation of the fibre diameter will be seen later in connection with the evaluation of short term variation of rovings and yarns, and for this purpose an average value of CV = 25% is adopted.

The quality of tops depends chiefly on the determination of the fineness of wool fibres, the length, the nep and vegetable matter and the regularity of weight of the unit of length. Visual assessment of colour and crimp is important as well. However, the dominant characteristic of the wool fibre is the average fineness which is a deciding factor as far as the manufacturing possibilities and the value of the finished product is concerned. Up to [illegible] wool fineness was evaluated in the trade chiefly by visual inspection [illegible]. Such an estimate has possibilities of certain errors due to the mental or physical conditions of the person performing the evaluation. The surrounding conditions such as weak light might change the accuracy of the evaluation. Differences in crimp and grease content can influence the valuer's judge-ment.

The introduction of certain instruments changed considerably the whole situation.

b. MEASUREMENT OF FIBRE FINENESS

To determine the fineness of wool fibres a projection miscroscope can be used. The other method, namely the air-flow method, for the determination of the average value of the wool fibre diameter gives results more readily and perhaps more precisely (see Fig. 1). The air-flow method does not give the dispersion of the fibre diameter. It has been shown that in general the air-flow method has proved to be successful in obtaining quick and reliable results.

Any new instrument must be calibrated. This is done with the help of four samples of wool of known fineness, previously measured with a projection microscope. This measurement must be very precise and about 1000 readings are necessary to establish a correct value. The calibration of every air-flow instrument is based on a simple formula which is

$$\text{Constant} = h \times d^2$$

A calibration procedure may produce the following results

Lot	Diameter (μ micron)	h (given by manometer)	Constant = $h \times d^2$
1	18.1μ	422.5	13.900
2	23.0μ	267.0	14.000
3	25.0μ	222.0	13.900
4	28.6μ	173.0	14.100

55.900 | 4 = 14.000

Constant for this particular apparatus = 14.000

AIR-FLOW APPARATUS

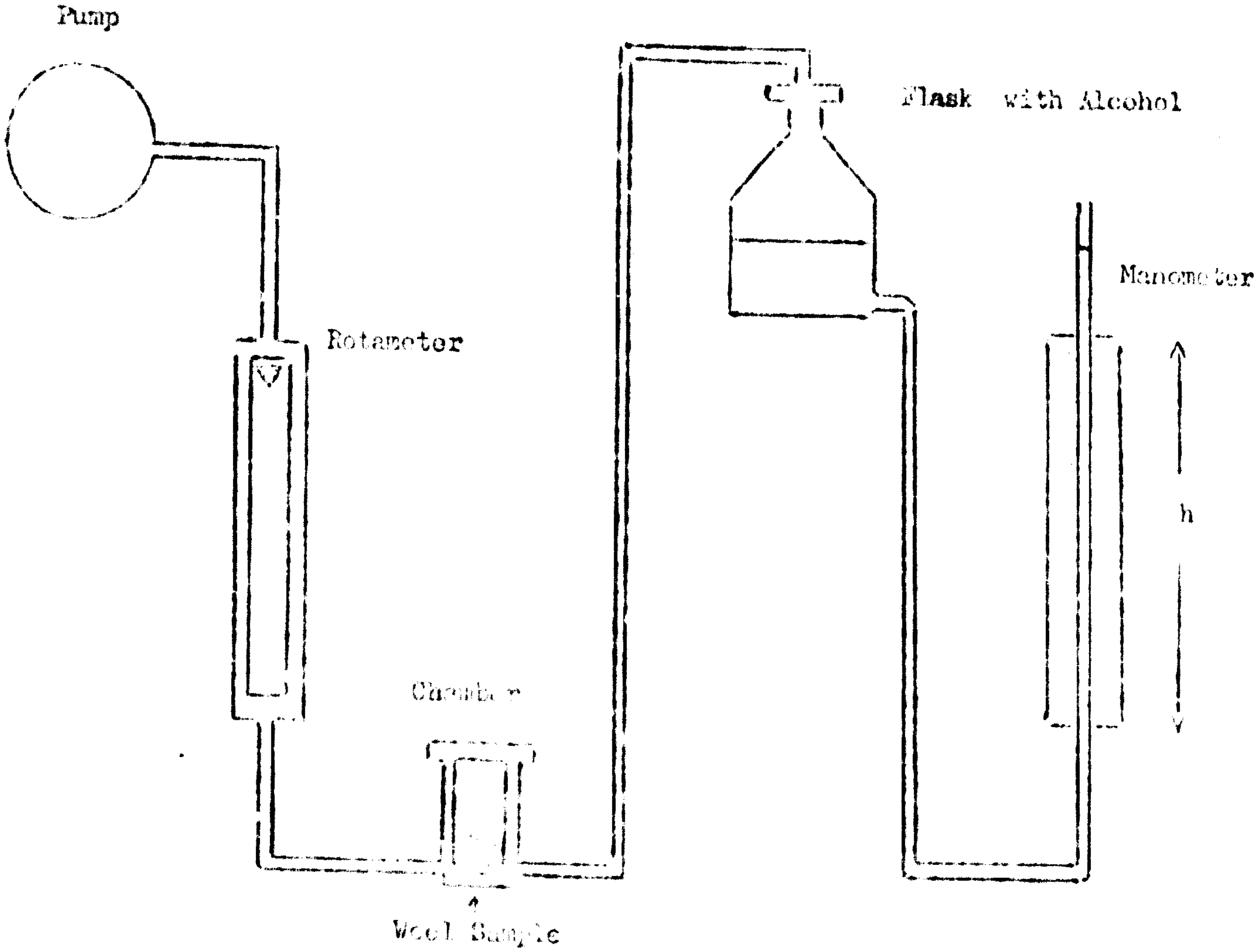


FIGURE 1

C. MEASUREMENT OF FIBRE LENGTH

The average fibre length is recognised as the second most important parameter in the assessment of the value of top. The importance of this parameter cannot be over-emphasised because of its value to the manufacturer in determining the end-use of the material, its conversion cost and the type and character of the yarn and fabric produced.

An early instrument for determining the mean fibre length of twistless slivers was the comb sorter. The device consists of a series of combs separated at intervals of 10 mm. The sample of fibres is held in the combs and separated by hand and forceps into order of length corresponding to a particular comb. The weight of each length group is determined on an accurate balance. The comb sorter method embraces the determination of "barbe" and "hauteur". The "barbe" is the mean length of the fibres in the sliver calculated by using the weight of fibres of every section.

1	2	3	4	5
L (cm) (length)	P mg (weight)	P%	P% x L	Pmg x L
2	40	1.3	2.6	80
3	150	4.3	12.9	450
4	250	6.4	25.4	1000
5	800	21.7	108.5	4000
6	1000	26.7	160.2	6000
7	1500	40.6	284.2	10500
	Σ3740	Σ100.0	Σ594.2	Σ22030

$$\text{Barbe} = \frac{\Sigma P x L}{\Sigma P} = \frac{22.030}{3740} = 5.9\text{cm}$$

OR

$$\frac{\Sigma P\%xL}{\Sigma P\%} = \frac{594}{100} = 5.9\text{cm}$$

The "hauteur" is the mean length of the fibres in the sliver derived from frequences obtained by dividing the weights of the fibres by the group lengths.

The same example as before gives the following results:

1	2	3	4
L (cm) (length)	P mg (weight)	$\frac{P}{L}$	$\frac{P}{L}$ x L
2	40	20	40
3	150	50	150
4	250	62.5	250
5	800	160	800
6	1000	167	1000
7	1500	215	1500
	Σ 3740	Σ674.5	Σ 3740

$$\text{Hauteur} = \frac{\Sigma\left(\frac{P}{L} \times L\right)}{\Sigma\left(\frac{P}{L}\right)} \text{ or } \frac{\Sigma P}{\Sigma\left(\frac{P}{L}\right)}$$

$$\frac{3740}{674.5} = 5.55 \text{ cm}$$

Generally speaking the "barbe" is 15% longer than the "hauteur" (10% in example). The "hauteur" and its distribution is nearly identical with the fibre diagram or staple diagram traditionally obtained by taking a draw of fibres from a squared end of top and arranging them in decreasing order of length on a velvet board.

However, nowadays it is not necessary to perform the above mentioned calculations. More rapid methods of determining the "barbe" and "hauteur" of tops have been developed in the last ten years or so.

Two electronic machines, the Almeter and W.I.R.A. Fibre Diagram Machine became very popular in recent years. In both machines a specially prepared draw of fibres is obtained and fed through an electrical condenser to measure the mass of fibres along the tuft. The Almeter is the more advanced apparatus and being automatic, gives complete results in 4-5 minutes.

D. NEPS AND VEGETABLE CONTENT

As a standard procedure the number of neps and pieces of vegetable matter per constant weight of wool in a lot of top are determined. From a lot of wool top samples are taken, e.g. 20g. every time, and an average of two or upto six are examined.

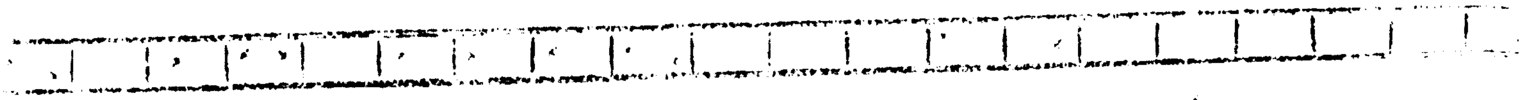
The method used could be as follows: In every case a sample of 20g. should be cut into 20 one g. pieces, and every piece examined separately. Thus attention is given fully to each piece and detection of eventual nep is easier (see Fig. 2). The figure of 1 nep/g is often used in industry as a normal standard value. It would be better if different standards were applied to the following five groups.

(1) 18 - 20μ
(2) 20 - 22
(3) 22 - 25
(4) 25 - 28
(5) 28 - 32

E. THE VARIATION IN WEIGHT PER UNIT LENGTH OF TOP SLIVER

One can detect the differences in the weight per unit length of slivers when the inside of the ball is compared with their outside. This effect is common to the balls made on gill boxes at different stages of processing such as, gilling after carding and combing.

This fault is most apparent in large balls, for example those which reach 10-12kg in weight (see Fig. 3). The variation in weight can be reduced by reducing the weight of the balls to about 6 kg.



No. of piece	Number of neps in this piece
1	2
2	0
3	1
4	2
5	0
6	1
7	1
8	1
9	2
10	0
11	0
12	0
13	1
14	1
15	0
16	0
17	0
18	0
19	1
20	1
	14

Number of neps per piece (1gr) (K)	Number of pieces (1g) with [illegible] neps (N)	K × N
0	9	0
1	8	8
2	3	6
3		
4		
5		
6		
		14 neps/ 20 g.

(0.7 nep/g.)

Vegetable matter should be arranged into:-

1	2	3	4
Straw	Seed	Burr	Bast fibre
1	5	1	3

Total = 10

10 veg. matter/20 g.

(0.5 veg./g.)

FIGURE 2

x	24.0			0.00	x	24.0			0.00
	25.0	+1.00		1.00		24.1	+0.1		0.01
x	24.0			0.00	x	24.0			0.00
	24.0			0.00		23.8		-0.2	0.04
x	24.5	+0.5		0.25	x	23.0		-1.0	1.00
	25.5	+1.5		2.25		24.2	+0.2		0.04
x	22.5		-1.5	2.25	x	24.5	+0.5		0.25
	23.5		-0.5	0.25		25.0	+1.0		1.00
x	24.0			0.00	x	24.0			0.00
	24.0			0.00		24.3	+0.3		0.09
x	23.5		-0.5	0.25	x	24.5	+0.5		0.25
	24.0			0.00		25.0	+1.0		1.00
x	24.00			0.00	x	24.0			0.00
	25.5	+1.5		2.25		25.0	+1.0		1.00
x	24.0			0.00	x	24.1	+0.1		0.01
	24.1	+0.1		0.01		24.5	+0.5		0.25
x	23.0		-1.0	1.00	x	24.0			0.00
	22.5		-1.5	2.25		25.5	+1.5		2.25
x	22.7		-1.3	1.69	x	23.5		-0.5	0.25
	25.0	+1.0		1.00		24.5	+0.5		0.25
							+12.8	-8.0	22.14
							-8.0		-0.56
							+4.8		21.58

x = outside New origin = 24

$\frac{4.8 \times 4.8}{40} = 0.56$

Calculation

$+ 4.8/40 = 0.12$

Average = 24 + 0.12 = 24.12

$\text{Variance} = \frac{21.58}{40 - 1} = 0.55$

$\text{St. Dev} = \sqrt{0.55} = 0.743$

$CV = \frac{0.743 \times 100}{24.12} = 3.08\%$

FIGURE 3

F. THE IRREGULARITY OF SLIVERS AND YARNS

Much attention is now given to the influence of the irregularity of yarn on the fabrics woven or knitted from it. At the present time the most popular instrument for measuring continuously the irregularity of mass per unit of length is the Zellweger. However, the question is, to what degree the results of tests of the irregularity of mass represent the true quality of the yarn, and can be accepted by weavers and knitters as the basic features of the yarn, which will determine the appearance of the fabric. This is because there are other parameters which must be taken into consideration when the quality of yarn is evaluated more completely.

By measuring the irregularity of slivers and rovings on Zellweger apparatus, each operation in worsted drawing may be checked as this gives the control of the drawing set. This becomes more necessary when the number of drawing operations are reduced. No scientific theory of drafting has yet been clearly established in detail, but experience has contradicted the earlier view of the necessity of a high total doubling. The total doubling has been lowered from 25,000 to 500, if not lower. Nevertheless, the reduction of the number of operations magnifies the effect of any accident. In former processes with 10-12 drawing operations an accidental piecing or thinning could be offset by the numerous doublings. This cannot be counted on with the shortened processes which, therefore, need more and closer control by daily inspection <u>of the finished roving or of the yarn.</u>

The ratio of the observed coefficient of variation to a limiting value of the coefficient of variation can be established by using the Martindale formula. This formula of limit CV may have two forms giving, however, the same results.

(a) limit CV = $0.1014 \times R \times d \times \sqrt{Nm}$ where R = 1.11

d = diameter of fibre in microns

Nm = metric count

(b) limit CV = $\dfrac{100\sqrt{1 + 0.0004 \times CVd^2}}{\sqrt{n}}$

where CVd = coefficient of variation of fibre diameter (accepted as 25%)

n = number of fibres per cross section of yarn.

Verification of these two formulae

Ex. Yarn 1/36 Nm fineness = 20μ

(a) limit CV = $0.1014 \times 1.11 \times 20 \times 6$

[illegible]

(b) $\text{limit CV} = \frac{100\sqrt{1 + 0.0004 \times CVd^2}}{\sqrt{n}}$ CVd = 25%

$= \frac{100\sqrt{1 + 0.0004 \times 625}}{\sqrt{n}}$ $\frac{625 \times 0.0004}{0.25}$

$= \frac{100\sqrt{1.25}}{\sqrt{n}} = \frac{100 \times 1.12}{\sqrt{n}} = \frac{112}{\sqrt{n}}$

$n = \frac{971000}{20^2 \times 36} = \frac{971000}{14400} = 68$ fibres (known formula)

$\text{limit CV} = \frac{112}{\sqrt{68}} = \frac{112}{8.3} = 13.5\%$

limit CV = 13.5%

If Zellweger gave us CV = 18%, our irregularity index is $I = \frac{18\%}{13.5\%}$

$= 1.33$

As a spinning mill manager wants things to run normally, consequently he does not want too many end breakages. At any rate, to have them within an acceptable limit which he knows from experience (for example, 20 breakages/100 spin/h). For this reason, the spinner checks the suitability of finished slivers for spinning by inspecting their cross-sectional regularity. If the roving is regular it is not very likely that the yarn will have an excessive number of weak places, and so the rate of breakages will be reasonable.

Experience shows that the irregularity index for rovings should be always below 2, and the count does not enter into consideration. If the value is 1.6 we say that the finished sliver is "overprepared", by this we mean that the improved regularity of the sliver might be meaningless, and that this seemingly beneficial aspect will most probably not be found in the yarn.

<u>Calculation of Degree of Perfection</u> for roving from the last finisher

The count of roving Nm = 4 (weight 0.25 g/m)

Fineness of wool = 20μ

$\text{limit CV} = 0.1014 \times R \times d \times \sqrt{N}$

$\text{limit CV} = 0.1014 \times 1.11 \times 20 \times 2$

limit CV = 4.5% Zellweger gave us CV = 7.5%

$\text{Index} = \frac{7.5}{4.5} = 1.7$ <u>which is normal</u>

It can be seen that to make this calculation we must know the <u>fineness of wool in microns</u>.

We might want to know which yarn is the more regular.

Yarn A 1/36 d = 20μ CV% (8mm) = 18.5% Index = 1.35

or

Yarn B 1/36 d = 21.7μ CV% (8mm) = 20.5% Index =

To do so we do not compare CV = 18.5% with CV = 20.5%

We, as it was said before, compare <u>Indices</u>. So we have to calculate the Index of the first yarn and second yarn.

Yarn A

$$n = \frac{971000}{20^2 \times 36} = \frac{971000}{14400} = 68 \text{ fibres}$$

$$\text{limit CV} = \frac{112}{\sqrt{68}} = 13.5\% \quad \text{Index } \frac{18.5\%}{13.5\%} = 1.35$$

Yarn B

$$n = \frac{971000}{21.7^2 \times 36} = \frac{97100}{17000} = 57 \text{ fibres}$$

$$\text{limit CV} = \frac{112}{\sqrt{57}} = \frac{112}{7.55} = 14.9\% \quad \text{Index} = \frac{20.5\%}{14.9\%} = 1.36$$

The conclusion, as far as a short-term variation (lengths very short, 8 mm) is concerned, would be that although the CV's are different (A = 18.5% and B = 20.5%), this can be explained by the differences in the fineness, but Indices are the same, so there is no difference between the perfection of spinning of these two yarns.

Long Term Variation CV(100 m)

In addition to the above mentioned tests and calculations, it is necessary to determine the coefficient of variation of the count (long-term variation). This is done on lengths of 100 m of yarn. 100 measurements being taken from 100 bobbins. The results are arranged into 20 groups, each of 5 readings.

Ex. Lot 157840 1/45 Nm fineness 21.5

44.11 x
46.23
48.26 x
44.70
46.68

229.98 | 5 = 45.99

Mean (of 20 groups) = 46.03

Mean Range = 3.116

St. Deviation = $\frac{3.116}{2.3259}$ = 1.339

CV(100 m) = $\frac{1.339 \times 100}{46.03}$ = 2.9%

44.94
45.57
44.52
46.44 x
44.11 x

225.58 | 5 = 45.12

Mean Range = dn x 6

n = number in a group

dn = factor depending on n

if n = 5 dn = 2,3259 (obtained from tables)

The coefficient of variation (CV100 m) should be always in the region of 2-3%, the count does not influence the result. If it is higher, let us say 4-5%, this would represent a danger of having visible bars in the woven or knitted fabrics.

Presentation of the results

Ex. Lot 157840 21.5 μ roving 3.175 Nm Yarn 1/45 Nm

No.	Drawing Operations	Doubling	Draft	Weight g/m	Count (Nm)	Speed m/min	Zellweger U%	Index of Irregularities
1		10	8.5	19.3		68	1.67	
2		4	8.5	8.6		68	1.48	
3		2	8	2.2		64	2.71	
4		2	13.7	0.317	3.175	50	5.77	1.76**
Yarn			14.2		1/45		17.2	1.32*

CV(100 m) = 2.9%

$$= \frac{97\,000}{21.5^2 \times 45} = \frac{97\,000}{20.700} = 4[illegible] \text{ fibres}$$

$$\text{Limit CV} = \frac{112}{\sqrt{47}} = \frac{112}{6.85} = 16.3\% \qquad \text{CV Zellweger} = 17.21 \times 1.25 = 21.5\%$$

$$\text{Index} = \frac{21.5\%}{16.3\%} = 1.32$$

CV [illegible] x 1.25

* As was stated previously, a daily inspection of the finished roving [illegible]ary, and always the ratio of the observed coefficient of variation [illegible] limiting value of the coefficient of variation calculated from the [illegible] formula should be considered.

$$n = \frac{971000}{21.5^2 \times 3.175} = \frac{971000}{1460} = 670$$

$$\text{Limit CV} = \frac{112}{\sqrt{670}} = \frac{112}{25.9} = 4.33\%, \quad \text{Index} = \frac{5.77\% \times 1.25}{4.33\%} = 1.76$$

this is normal

The other fact which was very interesting was that after many tests, it was noted that the index of the irregularity was higher for heavier counts and smaller for higher counts, when all the yarns were spun from wool of the same quality. The table (see Fig. 4) illustrates this point.

Two parameters, CV (8 mm) obtained from Zellweger and CV(100 m) obtained by calculation, together describe well the irregularity of any tested yarn. They form, as it is known, the total coefficient of variation, but we quote them separately.

To summarise we can say that the Evenness Tester, based on capacitance measurement, detects the short term variation. This variation is generally attributed to the imperfection of the drafting system and to the random distribution of the number of fibres in the yarn section. Because of this random distribution of the fibres, a certain minimum irregularity is always present and this is expressed as a limited coefficient of variation of short term variation. This type of variation gives the appearance as dark and light places, very noticeable in knitted goods. Up to now, it has not been possible to improve the manufacturing process to such an extent that not more than the minimum irregularity (limit CV) is obtained. Each machine causes additional irregularities, and these additional irregularities themselves give additional periodical cross section variations. The irregularity of any yarn should be always described by at least two parameters (1) short term variation and CV (8 mm) (2) long term variation CV (100 m). This was explained and illustrated

Count	18µ	19µ	20µ	22µ	24µ	27µ (microns
1/32	1.45	1.42	1.37	1.35	1.33	1.3
1/36	1.42	1.37	1.35	1.33	1.3	
1/40	1.4	1.35	1.33	1.3		
1/45	1.37	1.35	1.3			
1/48	1.37	1.25				
1/52	1.3	1.32				
1/56	1.3	1.32				
1/60	1.29	1.3				

FIGURE 4

with examples.

C. THE COUNT CONTROL

To the control of the count the control chart may be used (see Fig. 5). This has advantage of being an objective way to control the count and [illegible] the [illegible]. On the control chart the inner limits equal to the count to be spun ± 2(6) standard deviations, and outer limits equal to the count to be spun ± 3(6) standard deviations. The values for the control limits are based on the CV (100 m) we obtained previously from our tests. Let us take the value of CV (100 m) = 2.63% we obtained from our tests. This in practice should be established after many tests, and the average value should be taken.

Metric Count (Nm)	Fineness of Wool (μ)	Coefficient of Variation CV (100m)	Average Value of CV (100m)	Total Average Value of CV (100m)
1/32	26 - 27	2.57; 2.48; 2.76; 2.84; 2.85	2.7	
1/32	25	2.29; 2.57; 2.75	2.54	
1/32	23 - 24	2.74; 2.83; 2.6; 2.46	2.66	2.63
1/32	20	2.27; 2.45; 2.37	2.36	
1/40	[illegible]	3.22	3.22	

Having established our CV (100m) we proceed as follows. Firstly, we calculate 6.

$$CV = \frac{6 \times 100\%}{Nm} \quad ; \qquad 6 = \frac{CV \times Nm}{100}$$

$$6 = \frac{2.63 \times Nm}{100} = 0.0263 \times Nm$$

In case we control the count on 5 x 100 m (5 bobbins) = 500 m, the inner limits would be for 1/48 Nm.

Inner limits $= Nm \pm 2 \times 0.0263 \times Nm/\sqrt{5}$

$48 \pm 2 \times 0.0263 \times 48/\sqrt{5}$

$48 \pm 1.15 = 46.85 - 49.15$

Outer limits $= Nm \pm 3 \times 0.0263 \times Nm/\sqrt{5}$

But as I mentioned before, first of all the coefficient of variation of the length of 100 m must be established.

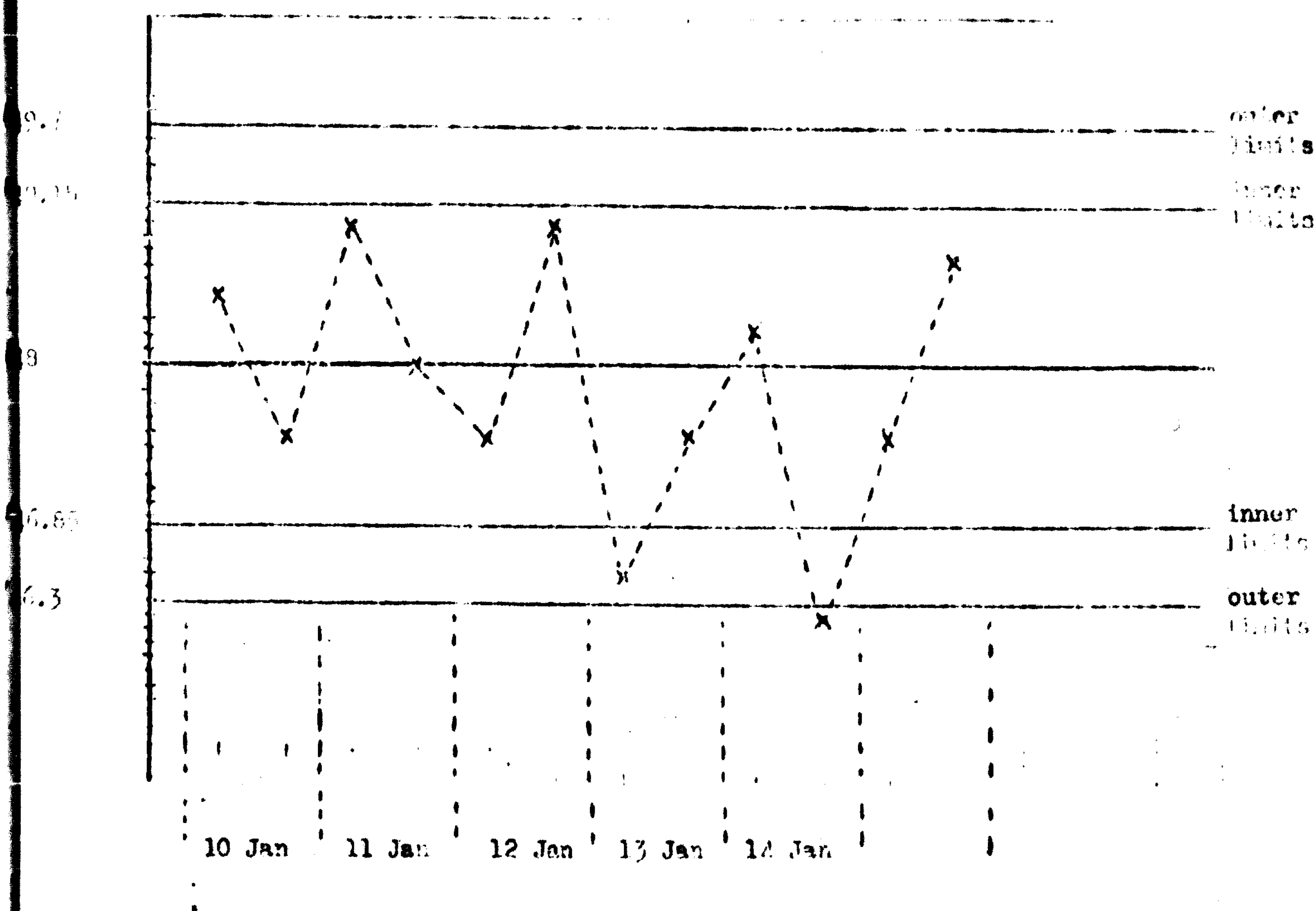

9.7
9.15
8
6.85
6.3
outer
limits
inner
limits
inner
limits
outer
limits
10 Jan
11 Jan
12 Jan
13 Jan
14 Jan

FIGURE 5

To simplify the task of the overlooker, a table with limit values may be calculated

Outer Limits	Inner Limits	Counts to be Spun	Inner Limits	Outer Limits
29	29.[illegible]	1/40	[illegible].7	[illegible]1
34.7[illegible]	35.15	1/4[illegible]	[illegible]	[illegible]
38.6	[illegible].05	1/4[illegible]	4[illegible].95	41.4
43.4	44.0	1/45	46.0	46.6
46.3	46.85	1/50	49.15	49.7

Comparison of the count observed with the values calculated gives an immediate indication of what kind of action is necessary. If a value of observed count is between inner limits, no action is taken, if it is between inner and outer limits another sample is necessary, and only if this too is outside the inner limits should correction be made. When the value of the observed count is outside the limits, alteration of the change wheel is recommended.

H. TENSILE STRENGTH OF YARNS

The dynamometric tests to which the yarn is subjected when tensile strength and elasticity are assessed are of fundamental importance. To get a reasonably accurate average value and coefficient of variation of strength at least 50 tests should be taken. An automatic dynamometer deals with this type of test very efficiently. This test, however, takes much time when the ordinary pendulum type of tester is used. As the time in making strength tests cannot be reduced, the calculation must be shortened if possible. For calculating the coefficient of variation one can use (a) the full method of calculation, (b) the mean range of a certain number of groups, into which the results are divided, (c) a practical method where the Moscrop chart is drawn and where an average strength and the standard deviation are calculated (see Fig. 6). Over the last years, not only the method of testing of yarn has been improved, but also the method of analysis of the results obtained.

In the normal distribution, 68.27% of the observation fall within the range of plus and minus the standard deviation from the mean. The remaining 31.73% fall outside this range, one half below and one half above average. In our test 50 readings have been taken, it is assumed that 68.27% of them or 34 readings fall within plus and minus the standard deviation from the mean, and 8 fall below and 8 above this range.

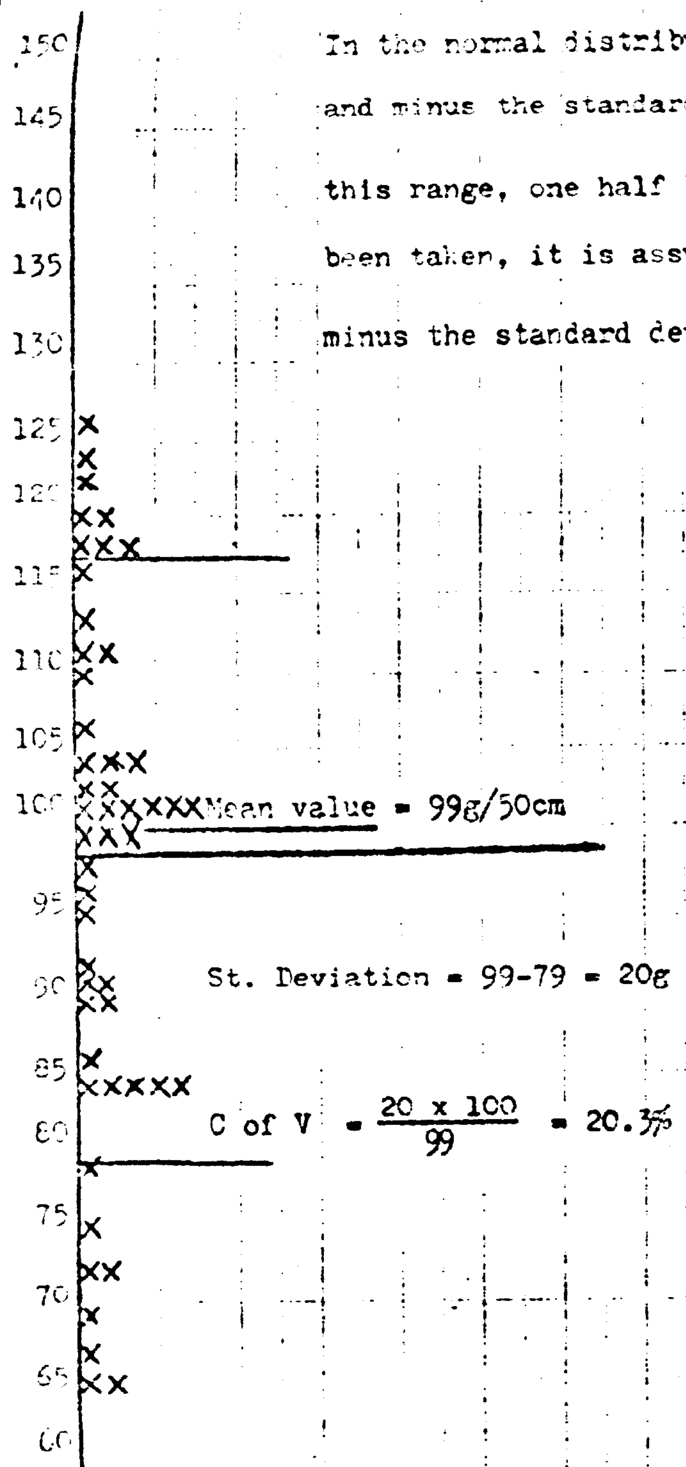


FIGURE 6

It is often possible that the yarn with a lower mean value of strength where the variation in strength is smaller, is better than the yarn with high mean value but higher variation. If the mean value for a particular yarn, let us say, 1/[illegible] Nm in [illegible] is P = 150 g and CV = 10%, then

$$\sigma = \frac{10\% \times 150\ g}{100} = 15\ g$$

Therefore, $P - 3\sigma = 150 - 45 = 105\ g$ (this would be the lowest value in the set of all results)

Another yarn is $P_2 = 180\ g$ and CV = 18%, then

$$\sigma = \frac{18\% \times 180}{100} = 32.5\ g$$

Therefore, $P_2 - 3\sigma = 180 - 97.5 = 82.5\ g$

In other words, in the second case the mean value of breaking load is much higher, but due to the higher variation in breaking strength, the minimum breaking strength value is lower.

Besides the mean value of breaking load and the minimum breaking strength we should calculate the confidence interval of mean value.

confidence interval of mean = mean value $\pm$ 3 x standard error

$$\text{St. error} = \frac{\sigma}{\sqrt{\text{number of tests}}} \qquad n = 100 \text{ (number of tests)}$$

(a) $\text{St. error} = \frac{15}{\sqrt{100}} = 1.5$

confidence interval = $150\ g \pm 1.5 \times 3 = 150\ g \pm 4.5$

$145.5\ g - 154.5\ g$

(b) $\text{St. error} = \frac{32.2}{\sqrt{100}} = 3.25$

confidence interval = $180\ g \pm 3.25 \times 3 = 180\ g \pm 9.75$

$170.25\ g - 189.75\ g$

The interpretation of these results should be as follows:
If we repeat the same test again, let us say 20 times, the chances are that 19 times out of 20 the mean value would be for (a) between 145.5 g - 154.5 g, and for (b) between 170.25 g - 189.7 g. At the same time we should establish a reasonably correct CV of strength, which would eventually be a very valuable indication of the quality of the yarn. At the same time the average results can be presented in a form of tables (see Figs. 7, 8, 9).

Count	Fineness of Wool (approx. in microns)	Coefficient of Variation of Strength (%)					Average CV (%)	Total Average CV (%)
1/28	22-23	19.4	15.6	17.7			17.56	
1/32	26-27	18.2	19.6	19.4	19.5		19.22	
1/36	24-25	17	20.1	18.3	19.6		18.75	18.72
1/36	26-27	18.7	19.9	19			19.20	
1/40	22-23	18.5	20.7	20.2	17.4	17.7	18.90	
1/52	20-21	18.5	18.1				18.30	

The strength of single yarns for weaving (merino qualities). The results obtained will depend on the dynamometer used.

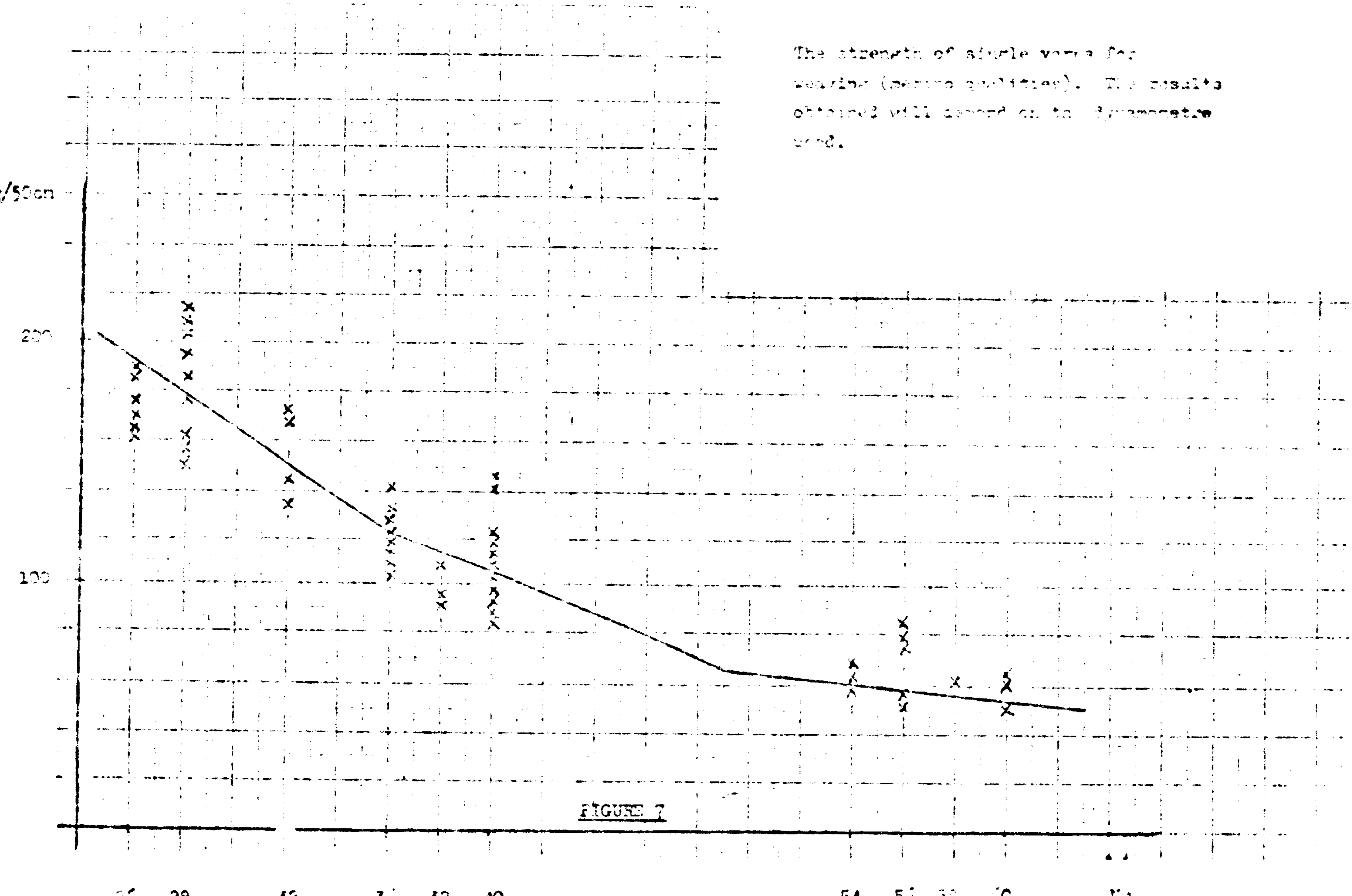


FIGURE 7

The strength of two-folded yarns for weaving (Merino qualities) The results obtained will depend on the Dynamometre used.

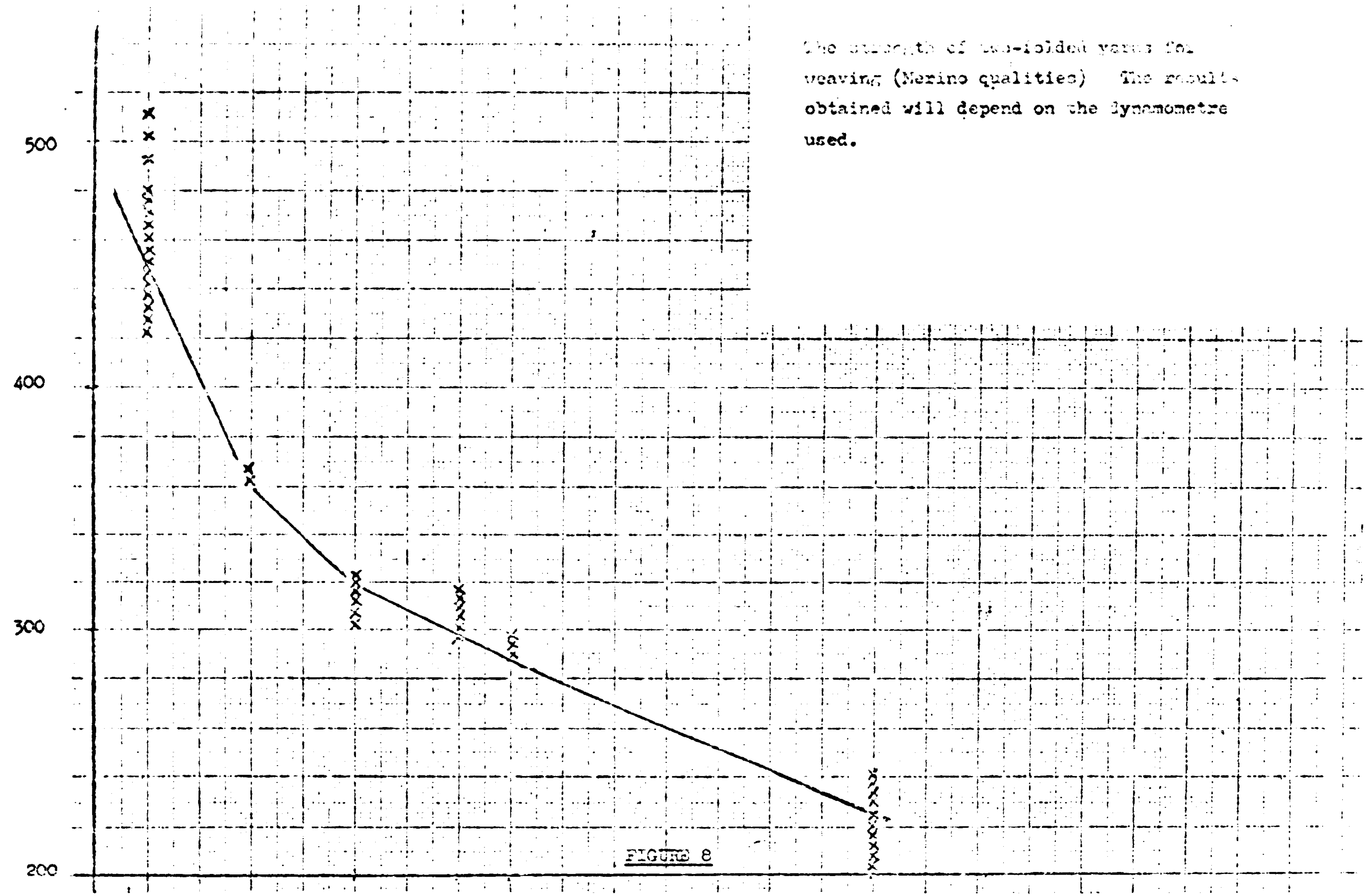
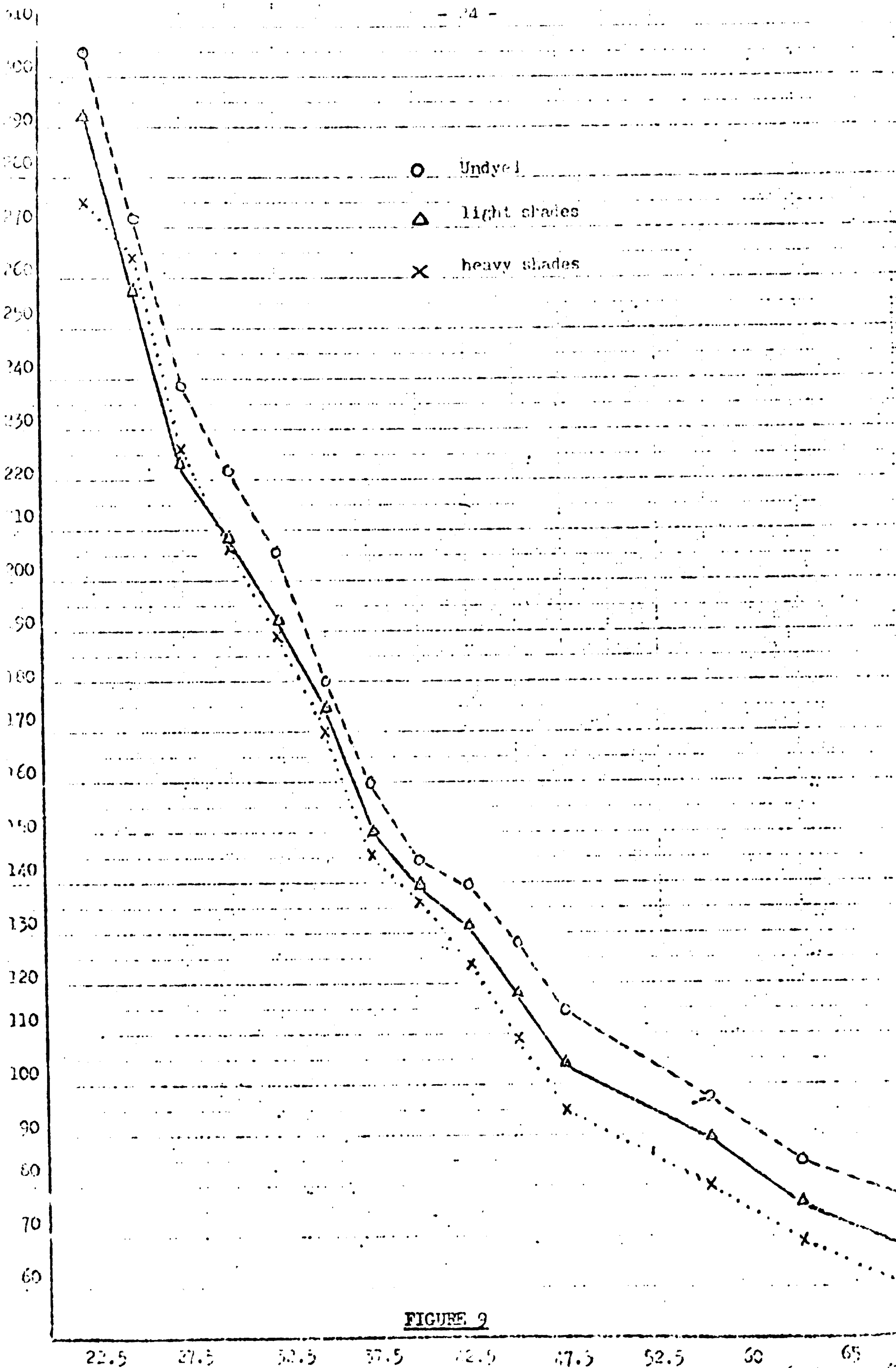


FIGURE 8



Undyed
light shades
heavy shades
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
22.5
27.5
32.5
37.5
42.5
47.5
52.5
60
65

FIGURE 9

I. TWIST AND ITS DISTRIBUTION

This [illegible] variation should be calculated. The coefficient of variation on at least three lengths should be established. When this is done all obtained results should be compared with the established curve.

This is again a very useful indication of the twist distribution, which should be as uniform as possible, but as we already know this factor depends to a very marked degree on the short term variation of the yarn.

The illustration of twist variability (CV%) versus length is given by the following curve (see Fig. 10).

5 cm	12.5cm	25 cm	27.5cm	50cm
19.7%	15.5%	8.7%	7.7%	5.[illegible]
18.5%	16.2%	9.4%	8.3%	5.7%
18.8%	14.2%	8.0%	7.5%	4.6%
19.2%	14.9%	9.6%	7.2%	5.4%
19.5%	15.3%	7.2%	6.9%	4.9%
19.15	15.2	8.6	7.5	5.2

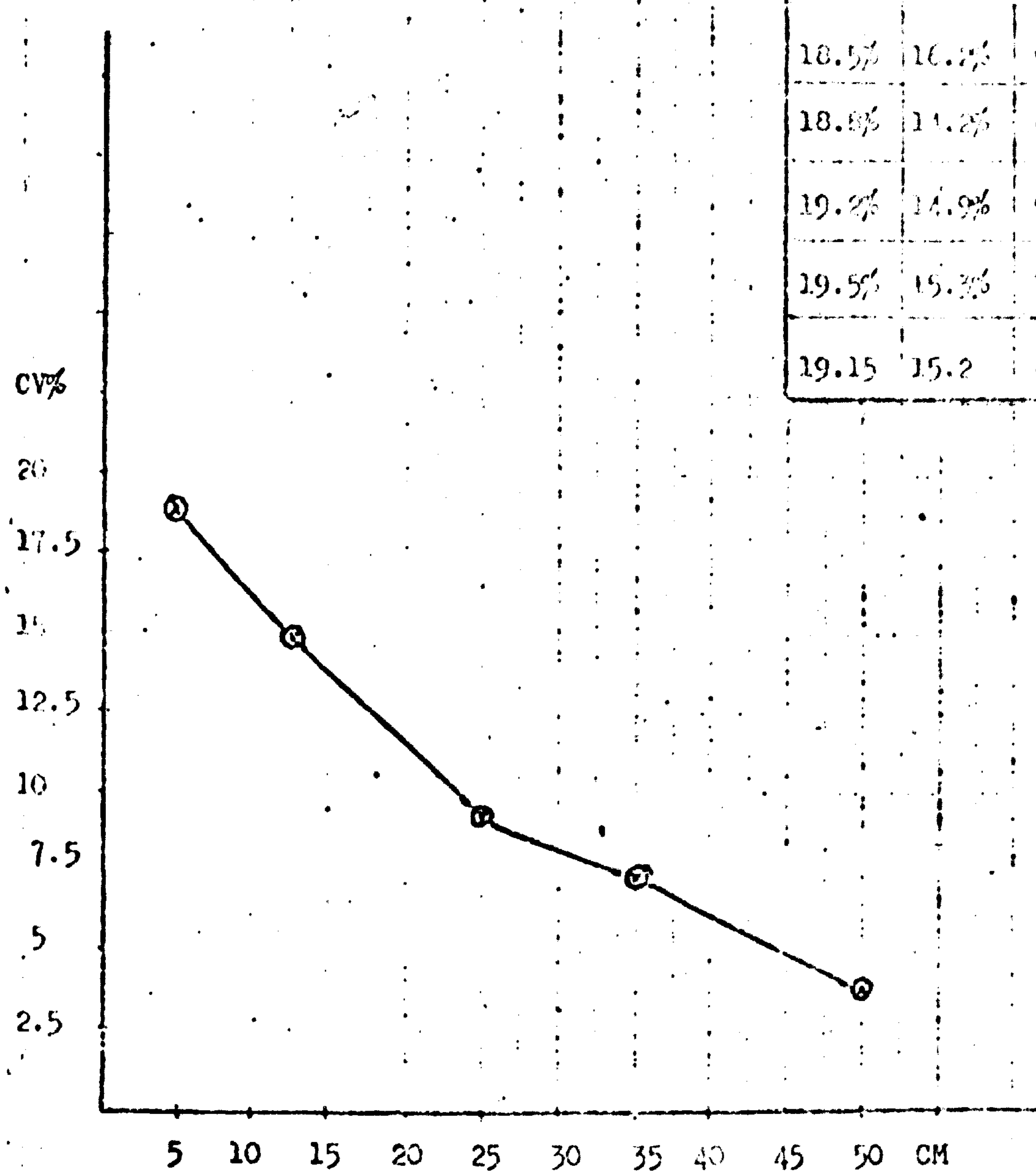


FIGURE 10

If we make this type of test we are in a position to evaluate more rapidly and objectively the performance of one twisting frame against the other, and, of course, the yarn itself (see Fig. 11).

J. SLUB AND IMPURITIES CONTROL

Objectionable faults should be eliminated by the clearing of the yarn during winding. Some impurities may be avoided by some preventative control method, like checking and counting the number of neps and vegetable matter and dark hair in tops before even starting the processing of the yarn. Standard values should be established and constantly compared with new lots. The tests can be carried out on the ordinary winding machine. The evaluation is done by arranging the impurities on paper and calculating the number of impurities per unit of weight (see Fig. 12).

Coefficients of variation obtained on four different twisting frames

Yarn Counts	Twist	Length	Coefficient of Variation %			
			A	B	C	D
2/28 (Nm)	270 t.p.m.	25 cm	5.6	7.2	7.5	5.6
		5 cm	13.1	16.0	13.5	13.0
2/28 (Nm)	400 t.p.m.	25 cm	6.5	7.7	7.9	6.3
		5 cm	16.1	17.0	17.1	16.9
2/36 (Nm)	700 t.p.m.	25 cm	8.6	9.7	9.5	7.7
		5 cm	18.1	18.5	18.3	17.9

FIGURE 11

Lot 20645 1/32 Nm Black 21.5 Cleaner No. = 3 Speed 400 m/min

1	11	111111
2	111	1111
3	1111	11
4	11	11
5	1	1111
6	11	11
7	1111	1
8	11	1
9	111	111
10	11	1
11	11	111
12	111	
13	1	1111
14	1	11111
15	1	11
16	1111	111111
17	111	
18	11111	1
	45	47

92 breaks/36 = 2.56 breaks/bob

1 bob = 130 g.

36 bob = 4.7 kg

4.7 kg = 92 breaks

(1 kg = 19.2 breaks)

+ eventual breaks due to week places in the yarn, and knots necessary to join the bobbins.

FIGURE 12

K. KNOTS

Modern high production methods demand a continuous inspection of yarn to make sure that the eventual spinning faults are selectively removed. This can be done during winding by the cleaners. Of course, it is up to every mill to make their choice and how to operate their cleaners. Although yarn cleaners are primarily a production device, they are also capable of providing valuable information which may be used for quality control (see Fig. 15). At its simplest this could be by keeping a watch on the type of faults being removed and whether the number of faults shows a tendency to increase or decrease for the same kind if yarn. The knots are a replacement of the faults and impurities of any kind. We have to eliminate the faults but we must not be too drastic, otherwise production will suffer and we might replace a minor fault by a more objectionable knot.

Evenuation of knots/unit of weight on [illegible]

Section & Time	Lot	Count	Weight of Bobbin	Number of Bobbins	Number of Knots	Production (Kg)	Knots/Bobbin
(1)							
8.30 - 9.30	(30 min	break)		[illegible]	(4534) (4711) 173	58 kg/7 hr.	173/48 = 3.[illegible]
9.30 - 10.30				(2139) (2272) 133	(4711) ([illegible]102) 391		391/133 = 2.9
10.30 - 12.45	Wool	1/50	76 gr	(2272) (2521) 27[illegible]	([illegible]102) ([illegible]704) 602	66.4 kg/8 hr	602/249 = 2.4
12.45 - 16.00				([illegible]) ([illegible]57) 336	([illegible]) ([illegible]745) 1041		1041/336 = 3.
				766	2207	3[illegible]knots/1 kg	
([illegible])							
8.30 - 9.30	(30 min	break)		(3148) ([illegible]203) 57	(7373) (7578) 205	68 kg/7 hr.	205/57 = 3.6
9.30 - 10.30	Wool	1/45	76 gr	([illegible]) (3368) 163	(7578) ([illegible]026) 448		448/163 = 2.7
10.30 - 12.45				(3368) (3628) 260	([illegible]026) ([illegible]910) 884	77 Kg/8 hr.	884/260 = 3.4
12.45 - 16.00				(3628) (4041) 413	(89[illegible]) (10225) 1314		1315/413 = 3.1
				603	285[illegible]	42 knots/1 kg	
(5)							
8.30 - 9.30	(30 min	break)		([illegible]) ([illegible]) 39	(3680) ([illegible]810) 130	60 Kg/7 hr	130/39 = 3.35
9.30 - 10.30				([illegible]) ([illegible]) 134	([illegible]810) ([illegible]242) 432		432/134 = 3.22
	80% Acrylic 20% Wool		75 gr			69 kg/8 hr.	
10.30 - 12.45		1/45		([illegible]733) (10027) 241	([illegible]242) ([illegible]963) 721		721/241 = 3.0
12.45 - 16.00				(10027) (10[illegible]) 377	([illegible]963) (11169) 1186		1186/377 = 3.1[illegible]
				791	2469	41knots/1kg	

FIGURE 13

References:

1. An Outline of Statistical Methods for Use in the Textile Industry.
   by A. Brearley and D. R. Cox.
   Published by Wool Industrial Research Association, Leeds.

2. Industrial Experimentation
   by K. A. Brownlee
   Published by Her Majesty's Stationery Office, London.

3. Aspects Scientifiques de L'Industrie Lainiere
   by F. Monfort
   Published by Dunod, Paris.

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