# International Institute For Cotton

## Technical Research Division

## Manchester

### Research Record No. 103

# Testing For Twist Liveliness In Cotton Yarns

**S. Allan Heap & Pauline Keher**

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## Introduction

In connection with the investigation of the spirality in single jersey fabrics which forms part of projects K1 and K2, it would be desirable to obtain an estimate of the amount of residual torque in the yarns at the time they are knitted, since this is bound to be the main factor causing spirality.

One clear and reproducible manifestation of yarn torque is snarling, and a British Standard test method exists for measuring snarling twist. However, the method seems to be a rather antiquated one - probably based upon work done in the 1930s (1, 2, 3) - and it deserves to be modernised.

Three good papers have been found in the literature which deal with the subject of spirality in knits. *Davis, Edwards and Stanbury* (4) carried out an extensive investigation using wool yarns with a wide range of twist in both normal and reverse direction, knitted on a $3^3/_4$ inch diameter circular hose machine with 18.7 needles per inch. Three different fabric "textures" were obtained by changing the stitch length to give 27, 30, and 36 courses per inch respectively in the dry-relaxed fabric.

Twist in the yarns was estimated from the spinning machine parameters with corrections applied for twist changes anticipated during knitting.

Spirality was measured on dry-relaxed fabric. Experiments were done in combining various pairs of yarns and with pre-setting yarns in steam or boiling water. Two-fold yarns with balanced or unbalanced twist were used. Both botany and crossbred wools were investigated. The conclusions were as follows.

1. Spirality is caused mainly by twist in the yarn. It increases uniformly with this twist and takes the same direction.
2. The effect is generally higher for crossbred (coarse fibre) yarns than for botany (fine fibre) yarns of the same characteristics.
3. The effect can be corrected only temporarily by treatment of the fabric in the steam press.
4. The effect can be almost completely prevented by previous setting of the yarn. Water setting is rather more effective than steam setting.
5. Where two ends of yarn are used, spirality will not be evident if they have equal and opposite twists.
6. Suitably balanced two-fold yarns can be constructed to give a fabric free from spirality.
7. Slack fabrics exhibit greater spirality than tight ones, for a given yarn.

As was usual in that decade, the work was a thorough and useful piece of research. Unfortunately, it had some major limitations so far as we are concerned.

- All the yarns were of wool.
- The fully-relaxed structure was not used.
- The actual stitch lengths were not measured.

Nevertheless, some guiding principles emerged and the first major limitation was removed by a follow-up paper by the same authors (5).

For this work, a range of cotton yarns was spun from Tanguis fibre in 8 Ne, 16 Ne, and 32 Ne and a wide range of twists. The yarns were knitted on three different types of machine as follows.

1. 3 inch diameter circular half-hose; 12.3 n.p.i.
2. 20 gauge Terrot machine (using one feeder); 13 n.p.i.
3. 21 gauge Cotton's patent flat frame; 14 n.p.i.

For the first machine, three tightnesses ware made, i.e. 15, 19 and 27 courses/inch. For the other two, only one fabric was made on each viz 19 c.p.i. and 25 c.p.i. respectively.

Again, a wide range of combinations of yarns was knitted and the conclusions were as follows.

1. Cotton yarns behave similarly to wool in causing spirality.
2. Over the ranges of twist which can possibly be knitted, cotton yarns produce almost the same degree of spirality as wool yarns of corresponding count and twist.

3. The action of heat and moisture on cotton yarns, in setting the twist, is not nearly so effective as on wool yarns. The (yarn) mercerising process is more efficient but is not a complete preventative.
4. The alteration of spirality for equal changes of stitch length varies from one machine to another.
5. For a constant *angle* of yarn twist, the spirality of a fabric increases with the fineness of the machine gauge, and the rate of increase appears to depend on the type of machine used.

Again, a very nice piece of work, but incomplete for our purposes because of the lack of stitch length and fully-relaxed structure measurements. Furthermore, the effect of fabric finishing procedures was not evaluated and neither were the fine yarns and fine gauges which are currently of interest. In addition, the concentration upon yarn twist rather than torque is a severe limitation.

A further document exists in our files (6) which seems to be a HATRA research report (published perhaps in the late 1950s ?) by *T.S. Nutting*, and which takes the subject a little further for wool yarns. After a general discussion of the problem, in which a mechanism is proposed for the observed distortion, an account is given of some experimental work in which a range of fabrics was knitted from 88.5, 55, and 37 Tex, 64s quality wool yarns, each with a range of worsted twist factors, namely 1.8, 2.0, and 2.2, and knitting to "cover factors" ( = *l/d*) of 14.8, 16.9, and 18.

Properties measured were:-

- stitch length
- yarn twist liveliness in air
- yarn twist liveliness in water
- spirality in dry-relaxed fabric
- spirality in wet-relaxed fabric (centrifuge, flat dry)

The twist liveliness test was of the same type as the BS snarling test (but somewhat improved), i.e. the number of turns in a loop of standard length was counted.

Some of the conclusions were, of course, similar to those of *Davis et al* but in addition it was found that:-

1. the twist liveliness measured under water is much greater than when measured in air;
2. spirality is increased by wet relaxation and measurements on the wet-relaxed fabrics are much more reliable than those on dry-relaxed;
3. for a given twist factor and *l/d* the spirality of wet-relaxed fabrics is greatest for the finer counts.

The concept of testing yarn for snarling twist under water seems to be a useful one and the measurement of wet-relaxed fabrics was a step in the right direction, but we are still left without quantitative information on fine gauge cotton fabrics, especially after finishing and on the fully-relaxed structure. Furthermore, the HATRA report made no mention of why the particular conditions of their snarling twist test method were chosen as such. Telephone enquiries have left one with the impression that this is old work, long forgotten by the present HATRA staff.

A modern paper by *Postle* (7) suggests that the conditions of the test will be very important. In particular, *Postle* considers that the torque in a yarn will be affected by the tension placed upon it so that in a snarling-test situation, the torque due to unrelaxed strains (which we wish to estimate) will be augmented as follows.

$T = T_s + T_t$ where $T$ = total torque

$T_t$ = torque due to tension

$T_s$ = torque due to unrelaxed strain

and

$T_t = \pi r^2 . n . t$ $r$ = yarn radius

$n$ = turns per unit length

$t$ = tension

therefore

$$T = T_s + [\pi r^2 . n] . t$$

This suggests that the torque due to unrelaxed strains can be estimated by measuring the snarling twist at a range of tensions and extrapolating the results back to zero load. Notice also that the effective diameter of the yarn can be estimated from the slope of such a curve, if the number of turns, *n*, is known.

Finally, it should be observed that two of the early papers (2, 3) proposed an alternative method of estimating yarn torque which was based upon the principle of forming a loop in a length of yarn and not allowing it to snarl but constraining it by means of a spacer bar at the bottom of the loop so that the torque causes only a fraction of one revolution to occur, this fraction being measured.

A routine for correcting for the effect of tension is included in the method, but neither the method of calibrating the instrument nor the method of calculating the results are well described and the whole system seems rather delicate and time-consuming.

Furthermore, when a series of tests was run comparing the results from it with those of the simple loop snarling system, it seemed that for single and two-fold yarns the results were essentially equivalent. For manifold yarns - where the diameter was important - the more complicated method was said to be more useful, but we are not concerned with such situations.

Therefore, the next section describes a series of preliminary experiments designed to consider the primary characteristics of a snarling twist test in the dry state. The wet state will be considered in a later phase.

## Experimental

### Apparatus

A length of plastic curtain rail with a pair of sliders and draw-string type fittings was screwed to a horizontal wooden beam. Two small pulleys were mounted at either side of the centre line with their inner edges about 1 cm apart. The moving sliders were fitted with close-coiled springs to serve as yarn clamps. Stops were provided to fix the maximum distance between the sliders.

### Procedure

1. With the sliders drawn back to the stops, a length of yarn is withdrawn from the package over-end (as would happen in the creel of the knitting machine), care being taken not to loose any twist.
2. The yarn is clamped into one of the springs and a small weight (Tex/2 g) is attached to the other end so that the yarn may be properly pre-tensioned before clamping it.
3. The required-loop loading weight is hung over the centre of the clamped section, between the two guide pulleys.
4. The sliders are then drawn to the centre, causing a loop of yarn to fall down between the pulleys. The loop quickly begins to snarl.
5. Five minutes are allowed to elapse before the number of turns in the loop are counted by carefully untwisting it by hand.
6. Ten replications are made with several metres of yarn being run to waste between each test.

### Calculation of Results

A small part of the yarn does not become included in the twisted loop and should therefore presumably be eliminated from the expression of results.

If this length be $l$ ($^1/_2\ l$ on each side) and the total length of yarn between the clamps at the start be $L$ and the number of turns in the final loop is $N$ then the snarling twist $T$ has been defined as

$$T = N / (L - l) \text{ turns per metre}$$

### Effect of Yarn Length

Three yarns were chosen from knitting department stock.

Rotor spun yarn: 24 Ne, twist factor 4.7

Ring yarn: 24 Ne, twist factor 3.5

Dyed ring yarn: 24 Ne, twist factor 3.2

All these yarns had been in stock for at least one year.

Extra stops were made in the apparatus so that the initial test length, $L$, could be 71 cm, 60 cm, 40 cm, or 20 cm.

In a preliminary check on loop-loading weights, it was found that a 5 g weight resulted in much lower percent CV than 2 g so the 5 g weight was used throughout this series.

$l$ was measured for each of 80 tests and was established as 7.2 cm. Results are shown in *Table 1* and *Figure 1*.

It is clear from these results that short test lengths are to be avoided, but there is apparently no great sensitivity over about 40 cm. Due to the small inaccuracies inevitably introduced by the slightly arbitrary correction factor, $l$, it was decided to use the longest convenient test length viz 71 cm, to minimise any such problems. Note that some of the HATRA measurements in ref. (6) were made using a relatively short test length.

### Effect of Loop-Loading Weight

With $L$ held at 71 cm, the same three yarns were remeasured with a range of loading weights up to 25 g. Results are in *Table 2* and *Figure 2*.

The progressive increase in snarling twist as predicted by *Postle* is indeed found and the least squares best fit linear regressions for the three sets of data were found to be as follows, where $W$ is the load in g.

| | | |
|---|---|---|
| Ring yarn | $T = 1.55W + 16.65$ | with $r^2 = 0.986$ |
| Dyed yarn | $T = 1.31W + 6.69$ | with $r^2 = 0.990$ |
| Rotor yarn | $T = 2.26W + 3.16$ | with $r^2 = 0.998$ |

The graphs for these regressions are given in *Figures 3, 4 and 5*.

### Effect of Separation of the Guide Pulleys

The distance apart of the guide pulleys must affect the result, especially when $L$ is small, since it controls the angle between the upper legs of the loop. For the experiments described above, distance between the outer rims at their closest approach had been about 1 cm, but now they were set as close as conveniently possible - about 0.5 mm - and a series of measurements was made at relatively high loop loadings. The correction $l$ had to be remeasured and was found to be 6.6 cm. Results are in *Table 3*. Viewed alone, these four data pairs seem significantly different from the earlier set and, when the best fit straight line is extrapolated (a long way!) back to zero load, the intercept is 28.1 turns/metre instead of 16.7. However, this result depends mainly on one data pair (that at $W = 10$g). When the two sets of data are combined, we find

$$T = 1.55W + 17.83 \qquad \text{with } r^2 = 0.946$$

From a commonsense point of view, it seems reasonable to keep to the minimum separation for the guide pulleys, so it was decided not to devote further effort to this aspect, particularly since the yarn for knitting the K1 and K2 fabrics was just being delivered at that time and it would be imperative to carry out some form of twist liveliness testing on the yarn “as delivered”.

## Choice of Test Conditions

As a provisional test method,

$L$ was set at 71 cm;

$l$ is 6.6 cm (closest guide wheel setting);

*W* was set at 10g; this is approximately the load at which $T_t$ and $T_s$ are equal.

## Results on Project K1 / K2 Yarns

Using the chosen conditions, measurements were made, with at least 10 replications, on several packages of all the single and two-fold yarns which had been purchased for the single jersey project. All yarns were tested within a couple of weeks of delivery and had been preconditioned in the standard atmosphere for several days. During the same period, the count and twist were measured on the same samples. Results are in *Table 4*. The 95% confidence limits were generally within:-

| | | |
|---|---|---|
| ± 4% | of the mean | for Tex |
| ± $7^{1}/_{2}$% | | for Turns/m |
| ± 6% | | for (singles) snarling |
| ± 9% | | for (two-fold) snarling |

*Figure 6a* shows a plot of snarling twist as a function of yarn twist for the singles yarns. The best fit straight line has been drawn in and is a reasonable approximation but there is a suggestion of curvature to the data and, indeed, the power law fit shown in *Figure 6b* is rather better, and also has the advantage that it passes through the origin.

Presumably, however, the yarn twist is not the only factor involved, since by using the standard load of 10g for the snarling twist test, we are introducing a partial dependency upon yarn diameter. Therefore, a multiple linear regression analysis was carried out using *Yarn Twist* and *Tex* as the major independent variables but also including $\sqrt{Tex}$ and $\sqrt{Tex}.T/m$, and $Twist^{1.5}$ as transforms.

*Table 5* shows the correlation matrix for this analysis which confirms the dominant effect of yarn twist and suggests that the square root of Tex (diameter) is a better parameter than Tex. Of course, twist and root Tex are highly correlated in this data set because most of the yarns have been ordered with the same twist factor. *Figure 7* shows the relationship. There is a suggestion that a couple of the yarns are out of line - whether this is a sampling or a spinning problem remains to be seen as the project proceeds.

Even allowing for the narrow range represented here, *Twist Factor* itself seems to be a rather poor predictor of snarling twist (*Figure 8*).

*Table 6* shows the coefficients for the regression as well as the analysis of variance when only *Twist* and $\sqrt{Tex}$ are included. The square of the correlation coefficient has been raised from 0.919 to 0.924 by including $\sqrt{Tex}$ - probably a non-significant contribution.

The two-fold yarns could not really be made to fit into this picture by simple means. For example, *Figure 9* shows the data of *Figure 6* re-plotted to include the two-fold yarns, where yarn twist has been defined as the difference between the singles and the folding twist (see refs 4 and 5 for justification of this). Quite possibly, the measured snarling twist on these two-fold yarns is due purely that caused by the 10 g load and the yarns are essentially “dead”.

This last point, as well as the question of testing in the wet state can hopefully be taken up in the next phase of the work.

## Conclusions

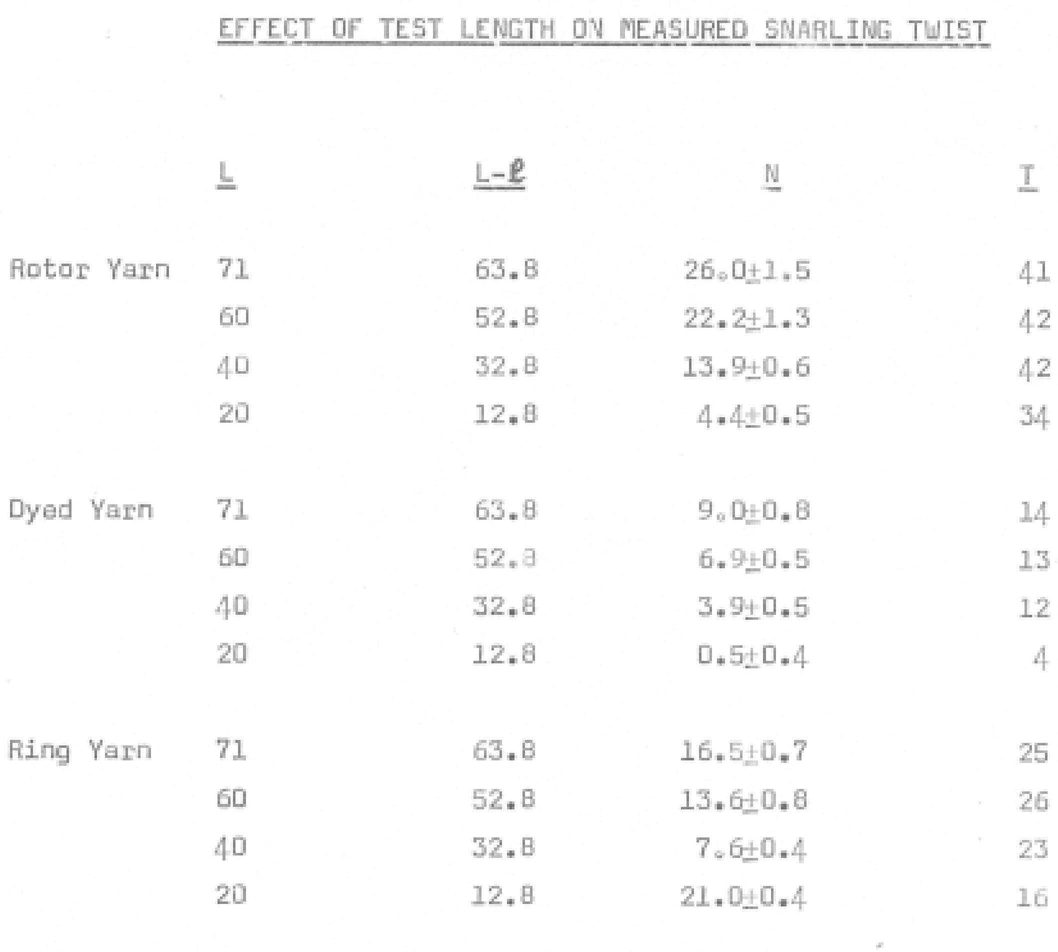
1. A reasonably workable test method has been devised and evaluated for measuring snarling twist, based on the self-twisting loop principle.
2. Ideally, for a given sample, a range of snarling measurements at different loop-loading tensions should be made, in order to correct for snarling due purely to the tension. However, the arbitrary choice of a 10 g load gave reasonably consistent results which correlate well with the yarn twist.

# References

1. *Determination of Snarling Twist*; BS Handbook No.11, 1974, p.3
2. *The Snarling Tendency of Single and Doubled Yarns*; Shirley Institute Bulletin, 1930, p.50
3. *The Snarling of Doubled Yarns*; Shirley Inst. Bull., 1937, p.101
4. *The Snarling of Manifold Threads*; Shirley Inst. Bull., 1938, p.179
5. *Spirality in Knitted Fabrics*; W. Davis, G.H. Edwards, and G.R. Stanbury, Journ. Text. Inst., 1931, T122
6. *Spirality in Knitted Fabrics: II Cotton*; W. Davis & G.H. Edwards, Journ. Text. Inst., 1935, T103
7. *Spirality in Weft Knitted Fabrics*; T.S.N., HATRA, Research Note?, date unknown
8. *A Study of Torsional Stability in Plied Yarns*; J.M. Bennett and R. Postle, Journ. Text. Inst., 1979, p.142.

Note: A paper from the Centre de Recherches de la Bonneterie which appeared in L'Industrie Textile, 1974, p.184, deals with the affect of various knitting machine parameters upon spirality - in particular the direction of rotation of the machine. Effects were shown to be small.

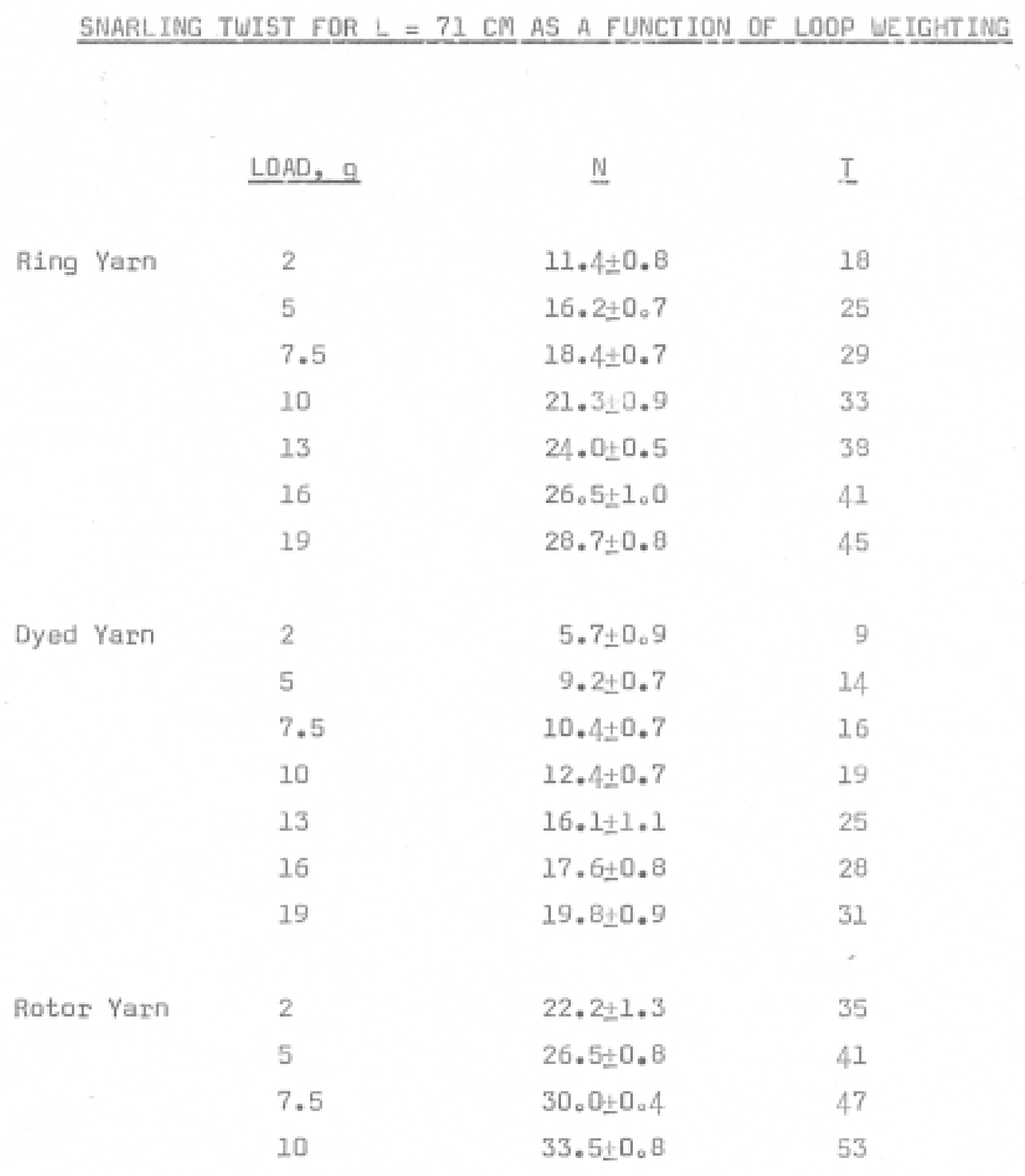
## Table 1



EFFECT OF TEST LENGTH ON MEASURED SNARLING TWIST

| | $L$ | $L-\ell$ | $N$ | $T$ |
|---|---|---|---|---|
| Rotor Yarn | 71 | 63.8 | 26.0±1.5 | 41 |
| | 60 | 52.8 | 22.2±1.3 | 42 |
| | 40 | 32.8 | 13.9±0.6 | 42 |
| | 20 | 12.8 | 4.4±0.5 | 34 |
| Dyed Yarn | 71 | 63.8 | 9.0±0.8 | 14 |
| | 60 | 52.8 | 6.9±0.5 | 13 |
| | 40 | 32.8 | 3.9±0.5 | 12 |
| | 20 | 12.8 | 0.5±0.4 | 4 |
| Ring Yarn | 71 | 63.8 | 16.5±0.7 | 25 |
| | 60 | 52.8 | 13.6±0.8 | 26 |
| | 40 | 32.8 | 7.6±0.4 | 23 |
| | 20 | 12.8 | 21.0±0.4 | 16 |

**Table 2**

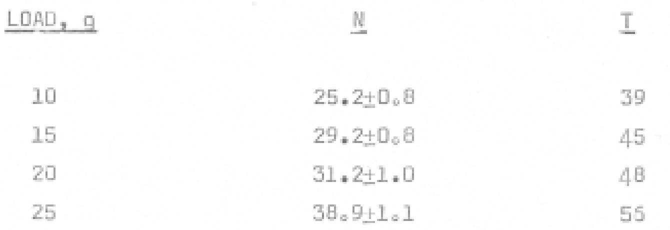


SNARLING TWIST FOR L = 71 CM AS A FUNCTION OF LOOP WEIGHTING

| | LOAD, g | N | I |
|---|---|---|---|
| Ring Yarn | 2 | 11.4±0.8 | 18 |
| | 5 | 16.2±0.7 | 25 |
| | 7.5 | 18.4±0.7 | 29 |
| | 10 | 21.3±0.9 | 33 |
| | 13 | 24.0±0.5 | 38 |
| | 16 | 26.5±1.0 | 41 |
| | 19 | 28.7±0.8 | 45 |
| Dyed Yarn | 2 | 5.7±0.9 | 9 |
| | 5 | 9.2±0.7 | 14 |
| | 7.5 | 10.4±0.7 | 16 |
| | 10 | 12.4±0.7 | 19 |
| | 13 | 16.1±1.1 | 25 |
| | 16 | 17.6±0.8 | 28 |
| | 19 | 19.8±0.9 | 31 |
| Rotor Yarn | 2 | 22.2±1.3 | 35 |
| | 5 | 26.5±0.8 | 41 |
| | 7.5 | 30.0±0.4 | 47 |
| | 10 | 33.5±0.8 | 53 |

**Table 3**

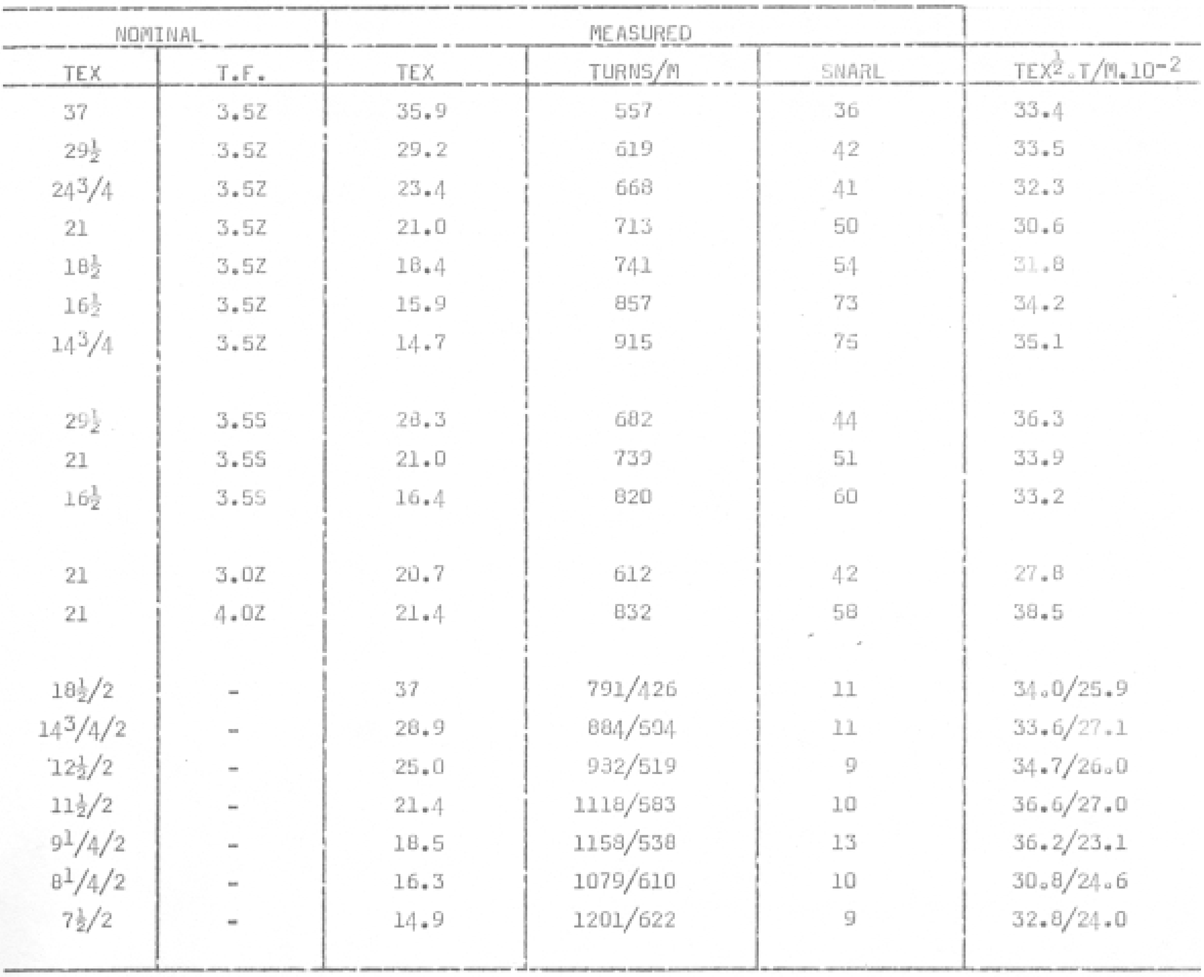
SNARLING TWIST OF THE RING YARN WITH MINIMUM GUIDE PULLEY SEPARATION



| LOAD, g | N | T |
|---|---|---|
| 10 | 25.2±0.8 | 39 |
| 15 | 29.2±0.8 | 45 |
| 20 | 31.2±1.0 | 48 |
| 25 | 38.9±1.1 | 55 |

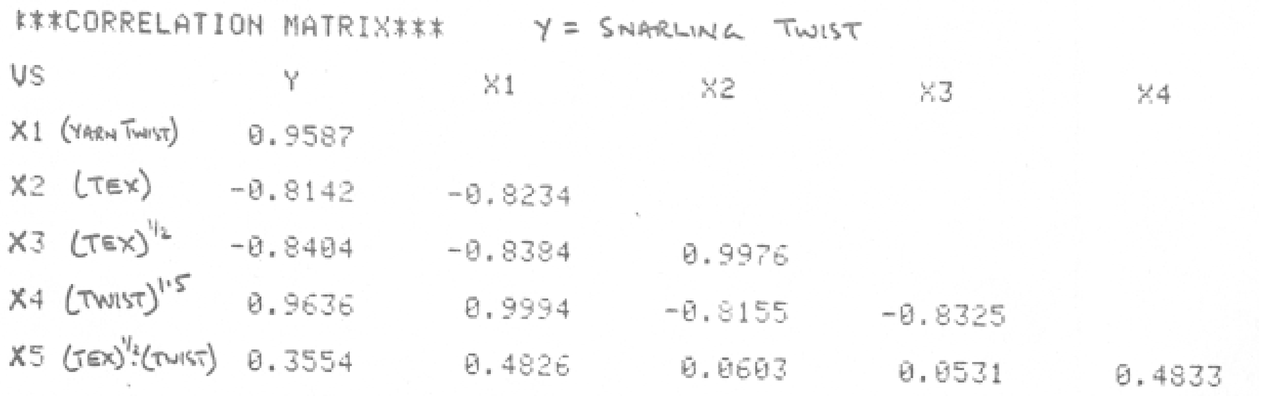
**Table 4**

CHARACTERISTICS OF K1 AND K2 PROJECT YARNS



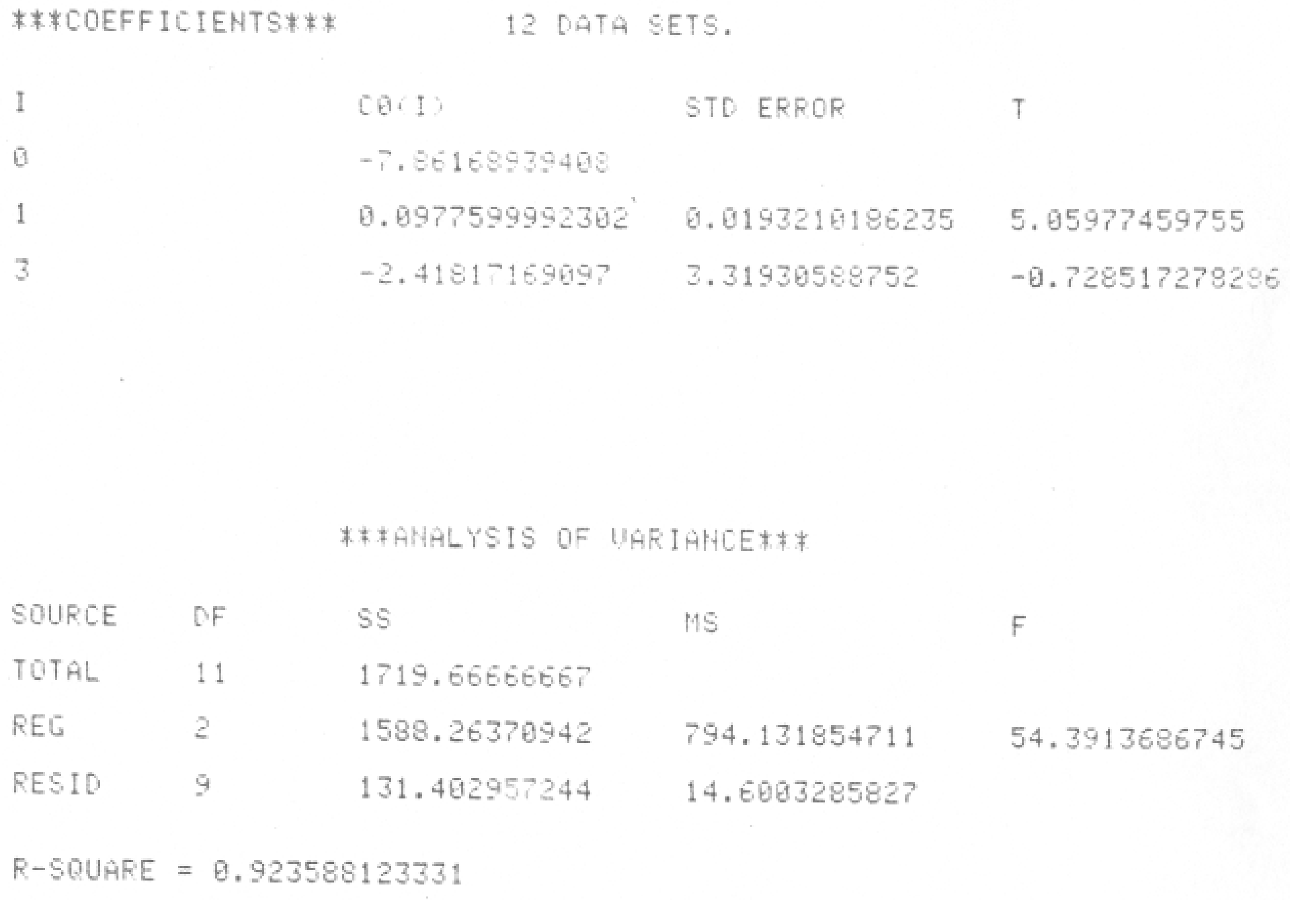
| NOMINAL | | MEASURED | | | |
|---|---|---|---|---|---|
| TEX | T.F. | TEX | TURNS/M | SNARL | $TEX^{\frac{1}{2}}.T/M.10^{-2}$ |
| 37 | 3.5Z | 35.9 | 557 | 36 | 33.4 |
| 29½ | 3.5Z | 29.2 | 619 | 42 | 33.5 |
| 24¾ | 3.5Z | 23.4 | 668 | 41 | 32.3 |
| 21 | 3.5Z | 21.0 | 713 | 50 | 30.6 |
| 18½ | 3.5Z | 18.4 | 741 | 54 | 31.8 |
| 16½ | 3.5Z | 15.9 | 857 | 73 | 34.2 |
| 14¾ | 3.5Z | 14.7 | 915 | 75 | 35.1 |
| | | | | | |
| 29½ | 3.5S | 28.3 | 682 | 44 | 36.3 |
| 21 | 3.5S | 21.0 | 739 | 51 | 33.9 |
| 16½ | 3.5S | 16.4 | 820 | 60 | 33.2 |
| | | | | | |
| 21 | 3.0Z | 20.7 | 612 | 42 | 27.8 |
| 21 | 4.0Z | 21.4 | 832 | 58 | 38.5 |
| | | | | | |
| 18½/2 | - | 37 | 791/426 | 11 | 34.0/25.9 |
| 14¾/2 | - | 28.9 | 884/594 | 11 | 33.6/27.1 |
| 12½/2 | - | 25.0 | 932/519 | 9 | 34.7/26.0 |
| 11½/2 | - | 21.4 | 1118/583 | 10 | 36.6/27.0 |
| 9¼/2 | - | 18.5 | 1158/538 | 13 | 36.2/23.1 |
| 8¼/2 | - | 16.3 | 1079/610 | 10 | 30.8/24.6 |
| 7½/2 | - | 14.9 | 1201/622 | 9 | 32.8/24.0 |

**Table 5**



```
***CORRELATION MATRIX***     Y = SNARLING TWIST
VS                      Y          X1          X2          X3          X4
X1 (YARN TWIST)      0.9587
X2  (TEX)           -0.8142    -0.8234
X3  (TEX)^1/2       -0.8404    -0.8384      0.9976
X4  (TWIST)^1.5      0.9636     0.9994     -0.8155     -0.8325
X5 (TEX)^1/2·(TWIST) 0.3554     0.4826      0.0603      0.0531      0.4833
```

**Table 6**



```
***COEFFICIENTS***          12 DATA SETS.

I                     C0(I)               STD ERROR           T
0                     -7.86168939408
1                     0.0977599992302     0.0193210186235     5.05977459755
3                     -2.41817169097      3.31930588752       -0.728517278296



                  ***ANALYSIS OF VARIANCE***

SOURCE    DF      SS                  MS                  F
TOTAL     11      1719.66666667
REG       2       1588.26370942       794.131854711       54.3913686745
RESID     9       131.402957244       14.6003285827

R-SQUARE = 0.923588123331
```

**Figure 1**

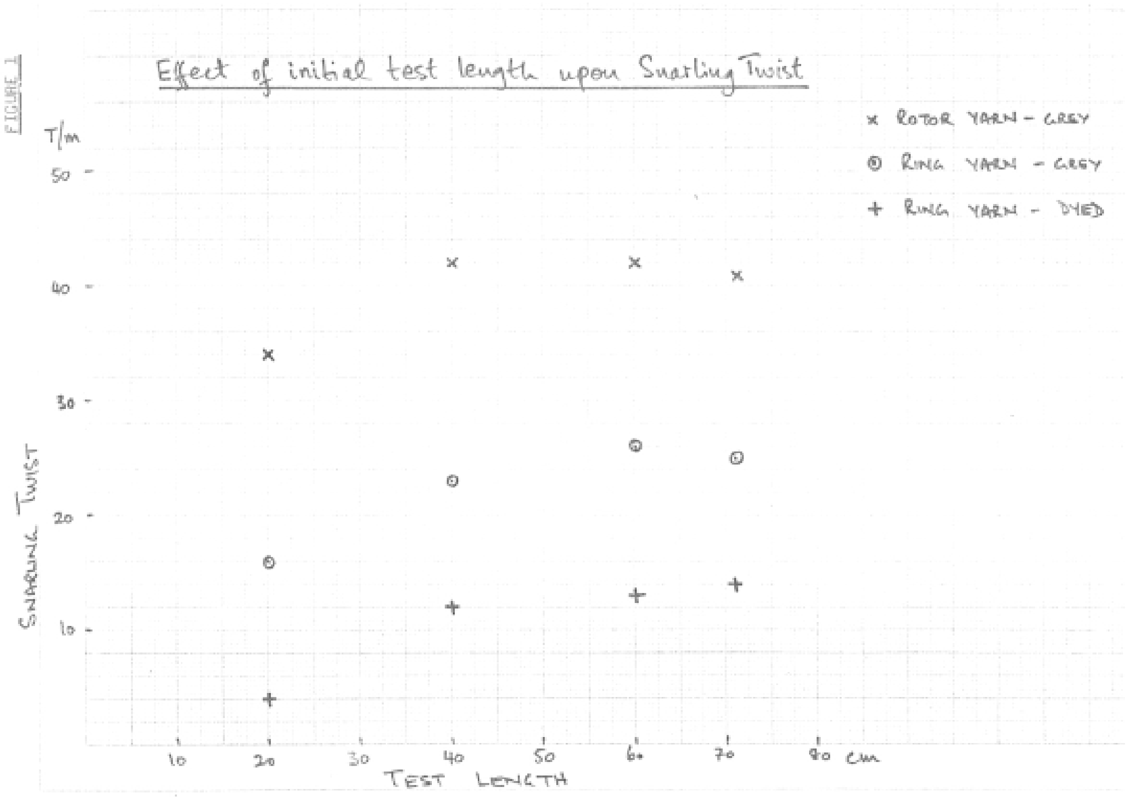


FIGURE 1
Effect of initial test length upon Snarling Twist
× ROTOR YARN – GREY
⊙ RING YARN – GREY
+ RING YARN – DYED
T/m
50
40
30
20
10
SNARLING TWIST
10
20
30
40
50
60
70
80 cm
TEST LENGTH

**Figure 2**

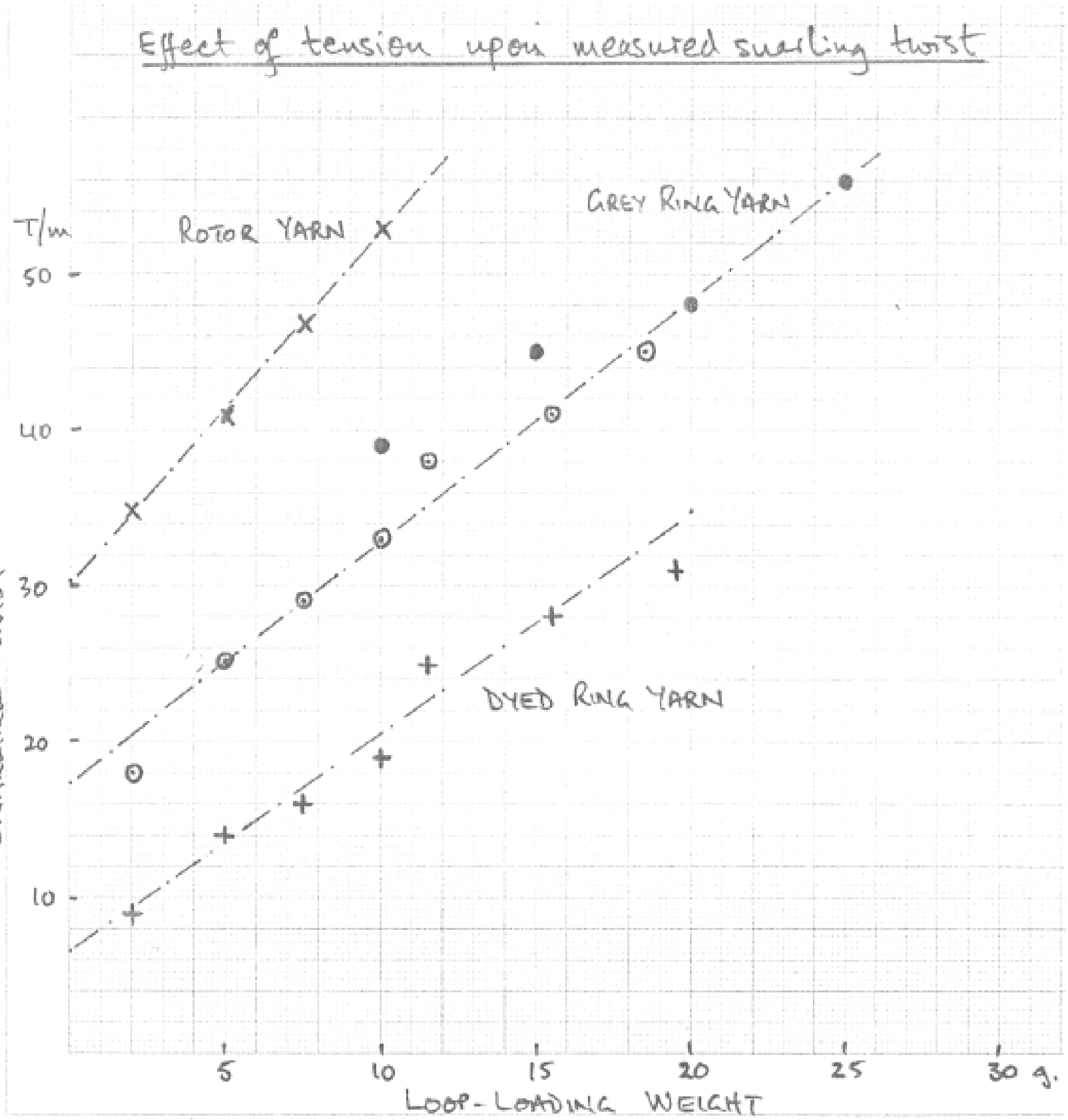
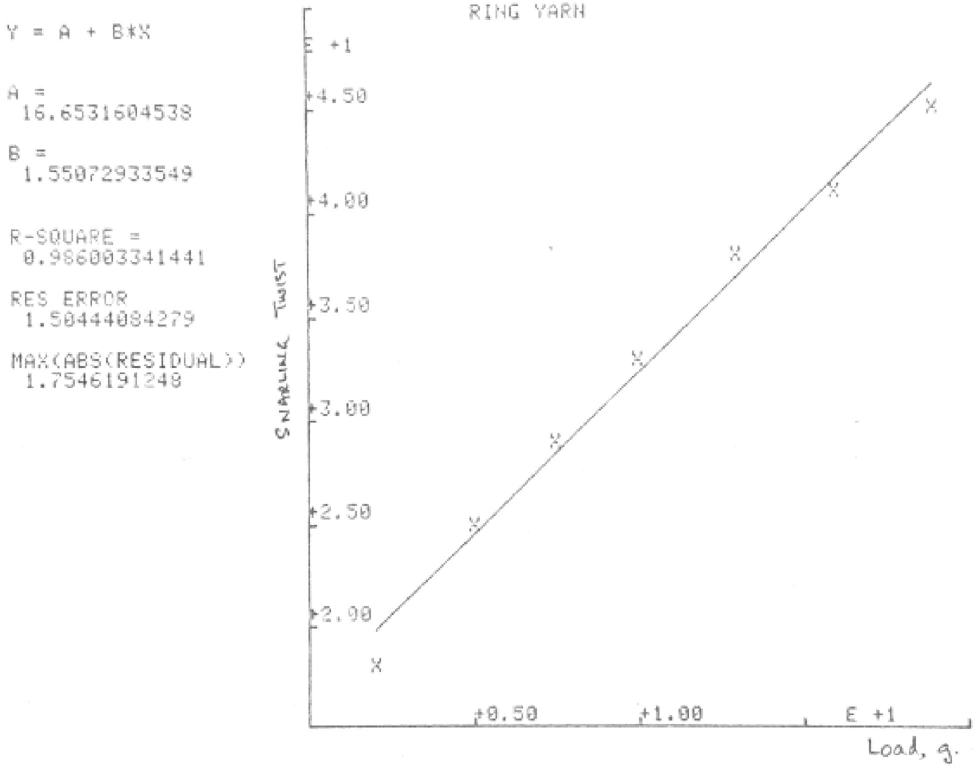
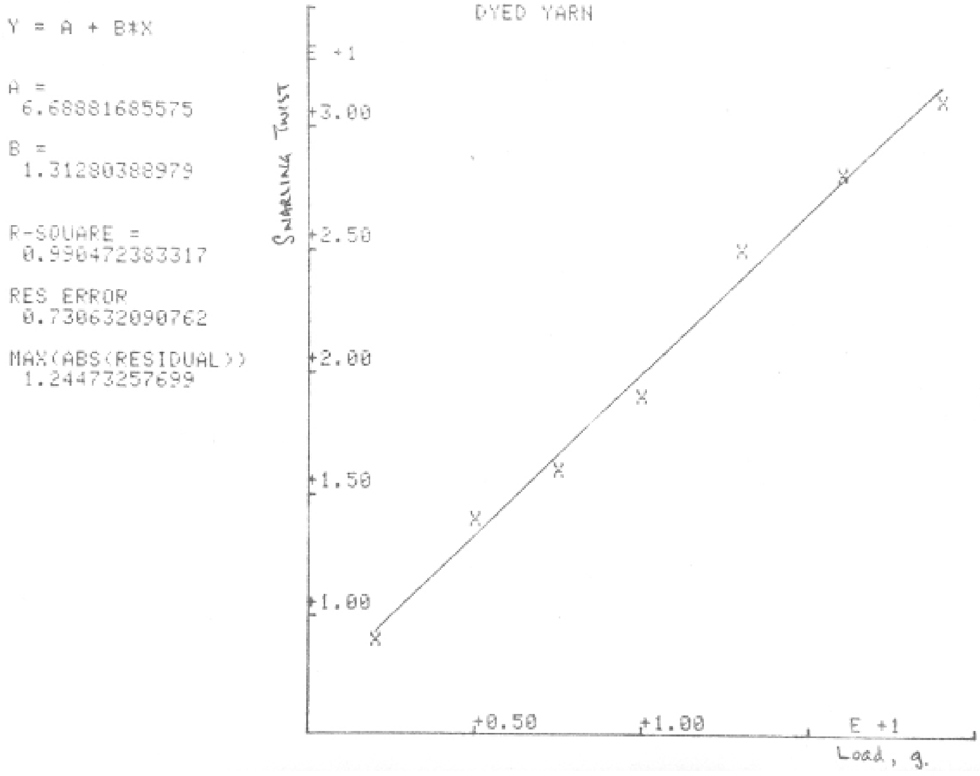

Effect of tension upon measured snarling twist
FIGURE 2
T/m
50
40
30
20
10
ROTOR YARN
GREY RING YARN
DYED RING YARN
SNARLING TWIST
5
10
15
20
25
30 g.
LOOP-LOADING WEIGHT

**Figure 3**



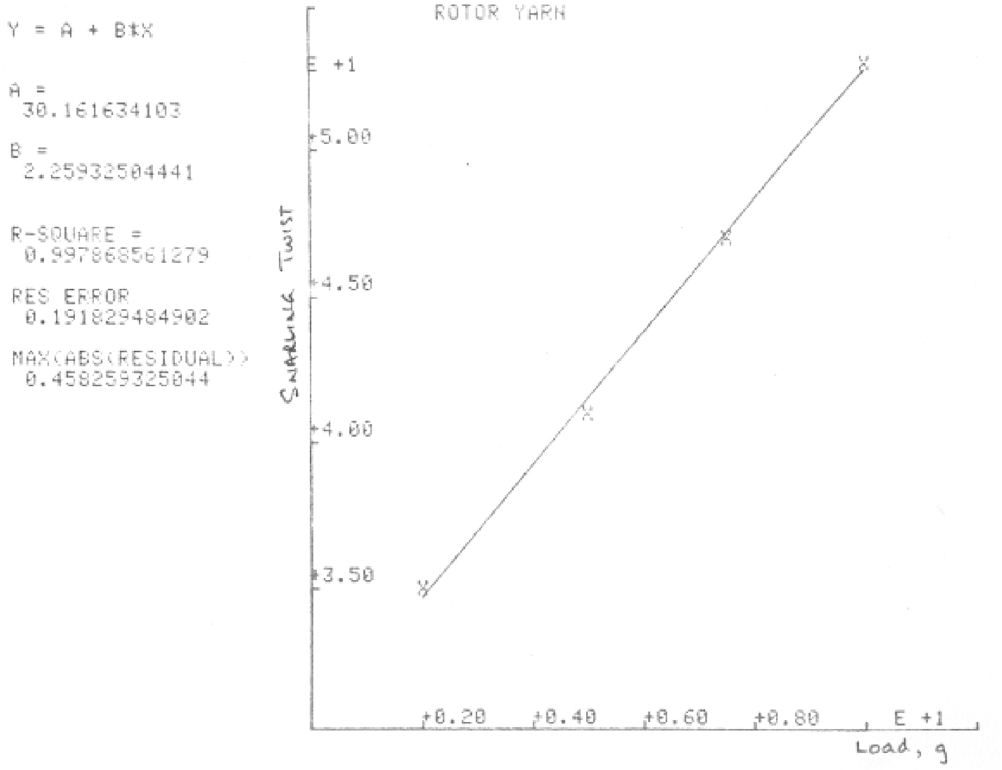
```
Y = A + B*X

A =
 16.6531604538

B =
 1.55072933549

R-SQUARE =
 0.986003341441

RES ERROR
 1.50444084279

MAX(ABS(RESIDUAL))
 1.7546191248
```

**Figure 4**



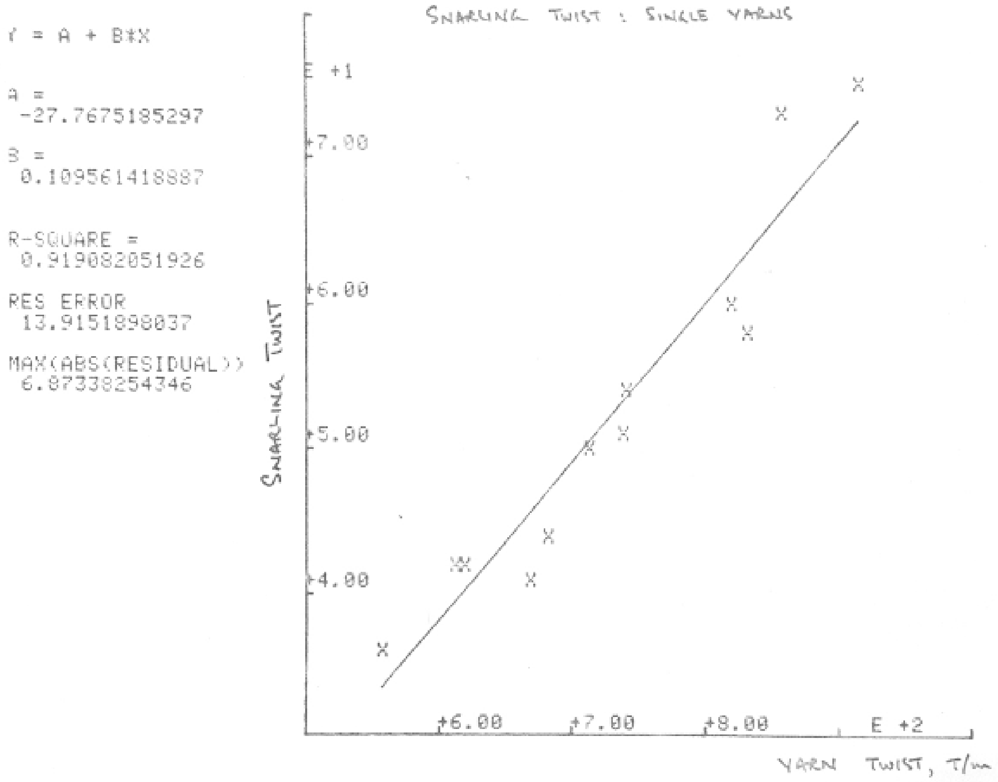
```
Y = A + B*X

A =
 6.68881685575

B =
 1.31280388979

R-SQUARE =
 0.990472383317

RES ERROR
 0.730632090762

MAX(ABS(RESIDUAL))
 1.24473257699
```

**Figure 5**



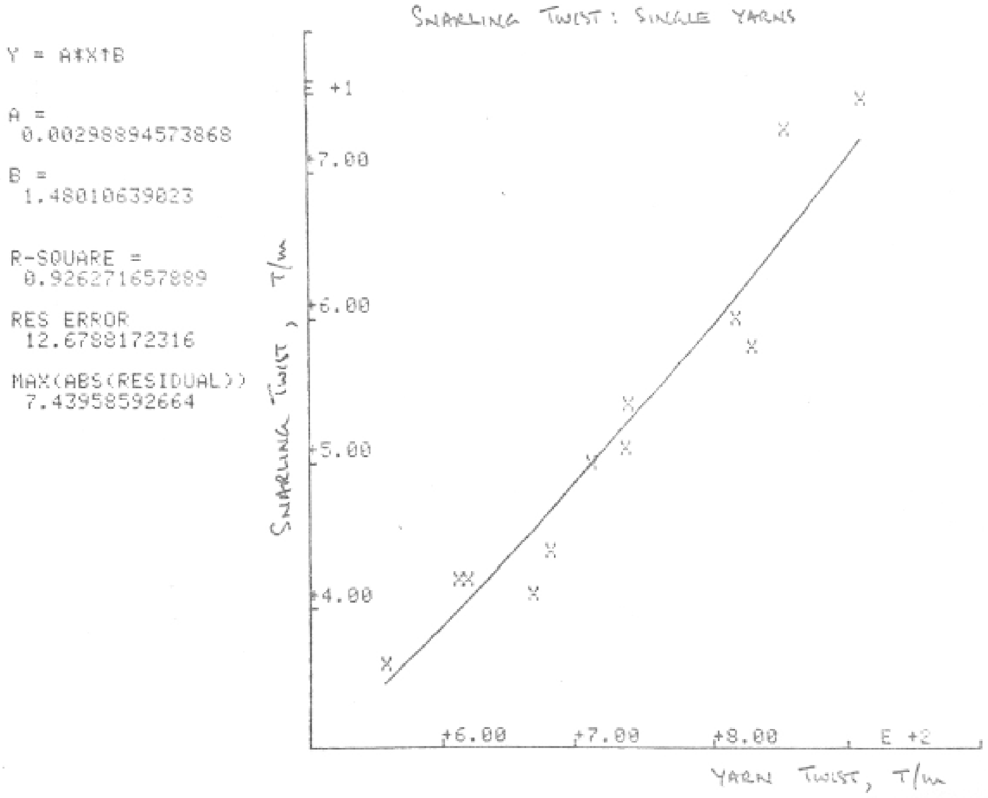
```
Y = A + B*X

A =
 30.161634103

B =
 2.25932504441

R-SQUARE =
 0.997868561279

RES ERROR
 0.191829484902

MAX(ABS(RESIDUAL))
 0.458259325044
```

**Figure 6a**



```
Y = A + B*X

A =
 -27.7675185297

B =
 0.109561418887

R-SQUARE =
 0.919082051926

RES ERROR
 13.9151898037

MAX(ABS(RESIDUAL))
 6.87338254346
```

**Figure 6b**



```
Y = A*X↑B

A =
 0.00298894573868

B =
 1.48010639023

R-SQUARE =
 0.926271657889

RES ERROR
 12.6788172316

MAX(ABS(RESIDUAL))
 7.43958592664
```

**Figure 7**

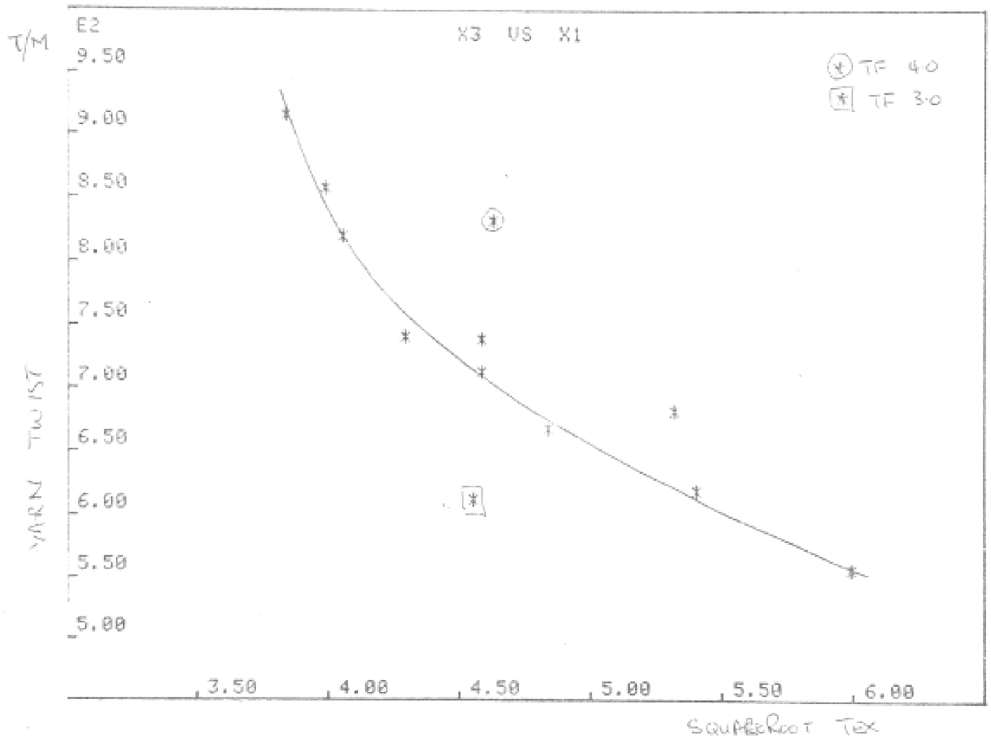


**Figure 8**

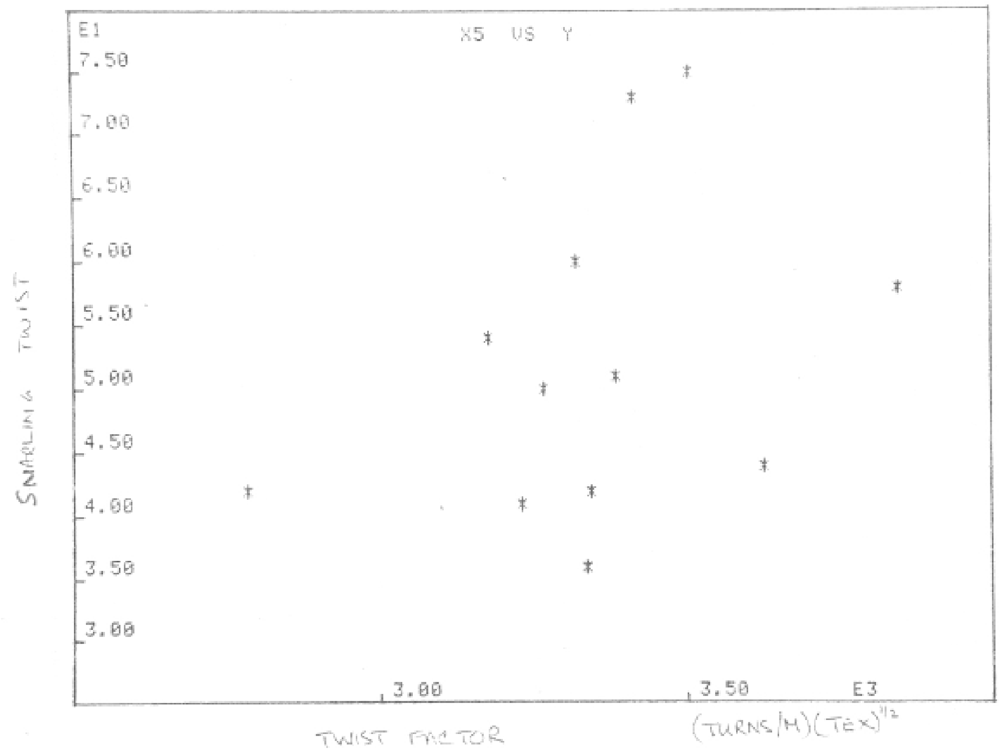
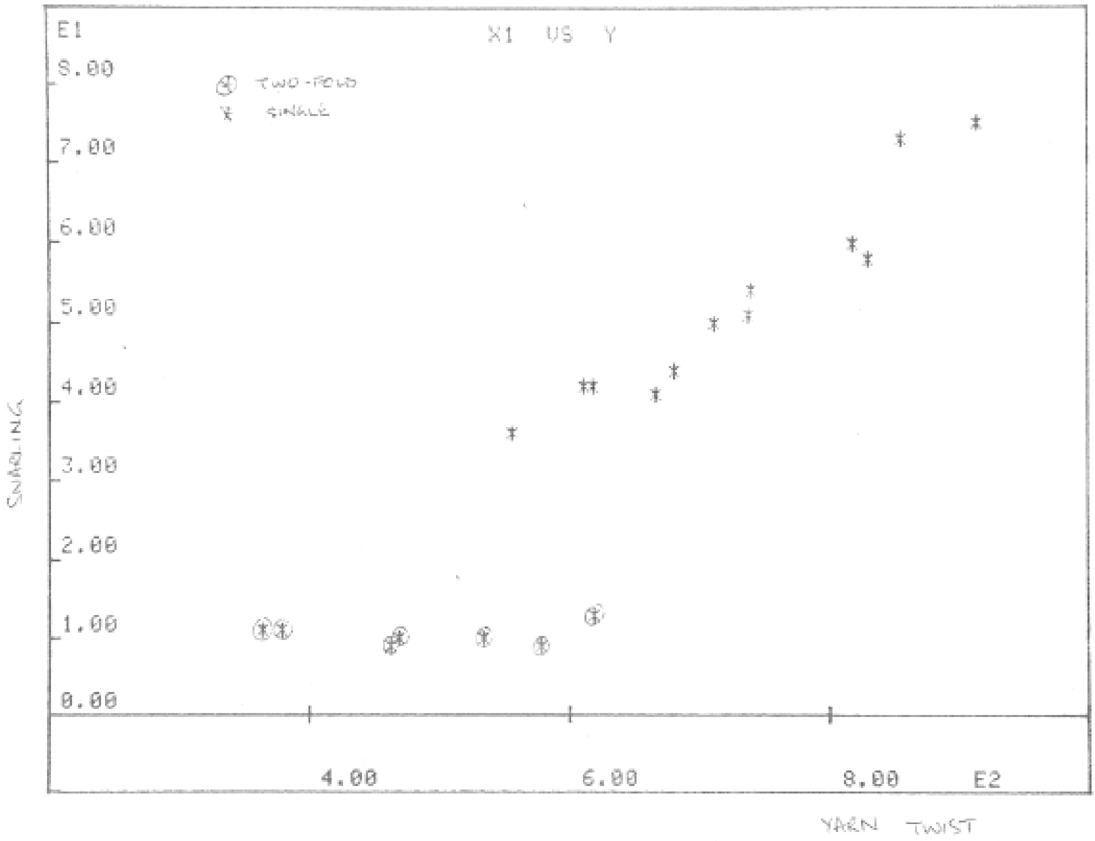


**Figure 9**


E1
X1 VS Y
TWO-FOLD
SINGLE
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
SNARLING
4.00
6.00
8.00
E2
YARN TWIST