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Spirality in Single Jersey fabrics

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Introduction

One of the objectives of the K1/K2 single jersey project is to "…. obtain a clear insight into the problems of spirality of single jersey fabrics …. (so as to) …. allow a rational plan of research to be drawn up for the solution of this problem".

To meet this objective, spirality has been measured on the full range of fabrics made from both singles and two-fold yarns, finished through a wide range of different processing routes. In addition, for three of the yarn counts (20, 28, and 36 Ne) fabrics were knitted from alternate feeders of S and Z twist and, for one of the yarn counts (28 Ne) yarns were knitted with high (twist factor = 4.0) and low (twist factor = 3.0) twist levels.

Twist liveliness was measured on all the yarns in the hope that spirality in the finished fabric might be found to be capable of prediction from measurements made on the raw materials.

Definitions

Twist-liveliness is the number of turns (or turns per unit length) developed in a yarn loop of standard length under a standard loading when both ends are held and slowly brought together so that the loop snarls. The method was described in *Research Record No. 103* which was also *Appendix O* (December 1979).

Spirality is the angle made between the wales and a line drawn perpendicular to the courses. Positive spirality indicates that the wale line is displaced to the right or clockwise. Negative spirality has the wales displaced to the left or anticlockwise.

Materials and Methods

The test methods as well as the production and processing and identification coding of the K1/K2 fabrics have been fully described in previous reports so these will not be repeated here.

The presentation of results in this report will be somewhat superficial with the immediate aim of enabling a decision to be made whether it is worthwhile to proceed to a more detailed mathematical analysis whilst at the same time gaining an insight into the major variables which affect spirality.

These major variables can be supposed to be: yarn twist (twist-liveliness), fabric construction (tightness) and finishing route (reduction of twist liveliness through setting).

In accordance with the aims mentioned above, the present report attempts to answer the following questions.

1. What is the "normal" level of spirality in single jersey fabrics?
2. How is the spirality affected by the initial yarn twist-liveliness and the tightness of fabrics?
3. Is a difference in spirality brought about by the choice of different finishing routes?
4. Is there a good chance that the level of spirality can be accurately predicted from a knowledge of a few key yarn and/or fabric parameters?

The "Normal" Level of Spirality

Assuming that the yarns and fabrics of the K1 controls are "normal" then we can discover the typical spirality behaviour by first examining these fabrics. From previous work we had already formed the impression that spirality is strongly dependent upon the tightness of the fabric and the parameter $\sqrt{Tex}/L$ tends to give reasonably good linear plots. However, other tightness parameters such as Tex/L, $1/L$, and S (stitches/cm^2) were checked to see if better plots were possible. None were found, and the remainder of what follows assumes that $\sqrt{Tex}/L$, the so-called *Tightness Factor*, is the appropriate parameter for fabric tightness.

Figures 1, 2, and 3 show the plot of spirality in the fully-relaxed K1 fabrics as a function of tightness factor for the 18G, 24G and 28G fabrics respectively. Several conclusions can easily be drawn from these graphs.

1. Spirality is strongly dependent upon tightness factor. The tighter the fabric, the less the spirality.
2. In singles-yarn fabrics, spirality in the grey cloth is consistently and probably significantly higher than in the dyed and finished materials.
3. Although (and maybe because) there is a good deal of scatter, it is not possible to separate the two different dyeing and finishing routes, i.e. tubular *vs.* open-width, used for the K1 series.
4. The fabrics made from two-fold yarns have a very low level of spirality which is almost invariably negative.

Point No. 3 can be investigated further by plotting the spirality of the tubular finished goods (R-95) against that of the open-width processed material (RS-OW). However, due to the important influence of the tightness factor, it is first necessary to compare this parameter for the two materials.

Tightness factor is compared in *Figure 4* and spirality in *Figure 5*. The former shows a rather tight 1:1 relationship which suggests that the influence of the two finishing routes upon tightness factor has been the same.

Figure 5 shows a good deal more scatter but, overall, a 1:1 relationship still holds. It is clear that spirality is a much less stable parameter than tightness factor.

Since the two sets of finished fabrics are (in these two respects) indistinguishable it is perhaps permissible to average the results for comparison with grey cloth or other finishing routes.

Figure 6 shows the plot of tightness factor in grey cloth against the average of R-95 and RS-OW and yields the rather surprising conclusion that this parameter shows no change (with an apparently high level of confidence) as a result of finishing. This result does not of course mean that there has been no change in the yarn since tightness factor is a ratio; the numerator and denominator could both have changed in a self-compensating way. This is a possibility which must be checked if and when a more detailed analysis is performed.

Figure 7 shows the comparison of spirality between grey and dyed (average R-95 and RS-OW) fabrics. The generally lower levels of spirality in the dyed and finished fabrics is now very clear but, due to the scatter, it is not certain whether the data should project back through the origin, or to a positive intercept.

Finally, *Figure 8* shows the combined (averaged) data for the R-95 and RS-OW upon which a calculated regression line has been drawn. The curve drawn has the following equation.

$$SprAW = 250.57 \,.\, EXP\,[-0.192 \,.\, \sqrt{Tex}/L] - 0.986$$

This model was chosen because the data does appear to have some curvature in it and one would instinctively expect spirality to level off at some low value as the tightness increased.

However, it is possibly an unrealistic model for very open fabrics since it has a positive intercept at 250° for zero tightness factor. Whether realism is lost before the corresponding fabrics become imaginary (i.e. impossible to produce) is unknown for the time being, but the fit is good over the current range of fabrics so the curve can be used as a basis for comparing the effects of other finishing routes.

Twist and Twist-Liveliness

Figure 9 shows the results of twist-liveliness testing on the yarns used for knitting. Twist liveliness was measured in the dry and also the wet state (with the yarn loop immersed in hot water). The results plotted are the averages of several measurements made on samples taken over a period of about 18 months. The accuracy of individual twist-liveliness readings is about ±5%. The twist of the two-fold yarns is the approximate residual twist, calculated as

$$(Ts - 2Td)$$

where: *Ts* is the twist in the original singles;

Td is the doubling twist.

Most of the two-fold yarns turn out to have a negative residual twist and this explains the negative spirality observed for the corresponding fabrics in *Figures 1, 2, and 3*.

For this series of yarns it is clear from *Figure 9* that the twist liveliness of the yarn is directly proportional to the twist so, in all that follows, yarn twist will be used as the major independent variable. This approach would, of course, not be permissible in a study where mixed yarn types were used, (e.g. dyed yarns, rotor yarns, blended yarns), in which case separate relationships would be expected to exist for the different yarn types.

Figure 10 shows the plot of spirality in the fully-relaxed (*Reference State*) grey fabrics as a function of yarn twist for the singles-yarn fabrics. Clearly the twist (twist-liveliness) has a major effect upon spirality. The vertical spread in the data represents the modifying effect of fabric tightness.

Figure 11 gives the same plot for the dyed and finished fabrics (RS-OW). In this plot, the general level of spirality is lower (*cf Figure 7*), but more interesting is the fact that the general slope is apparently less steep and the vertical spread is greater. This presumably means that, after finishing the effect of twist is somewhat less pronounced compared to that of fabric tightness. One is tempted to speculate that the entire drop in spirality from grey to finished is caused by a reduction in twist-liveliness. This would presumably be due to release of stress (relaxation) in the twisted fibres caused by the wet processing. This hypothesis would lead to the prediction that a further reduction should be seen with mercerising or liquid ammonia treatment, and especially with cross-linking treatments.

Figure 12 shows the same parameters plotted for some of the special yarns, i.e. those with high, low, and reverse twist. On this plot, S-twist is defined as negative twist and the 28S yarns clearly produce negative spirality. Spirality of the fabrics made from alternate feeders of S and Z (not shown in Figure 12) gave virtually zero spirality. *Figure 13* shows that the special Z-twist yarns conform closely to the K1 control series so that twist (twist-liveliness) rather than yarn count is confirmed as the fundamental parameter of interest.

Figures 14 and 15 show, for grey and RS-OW fabrics respectively, the comparison between the control fabrics and the special yarns as a function of fabric tightness factor. The alternate S and Z fabrics are shown on these plots.

In the grey fabrics there is a clear distinction between the 28 Ne high, low, and normal twist levels, but in finished cloth, this distinction is much less clear. In general, the results conform to those of the K1 controls. Use of alternate S and Z yarns has completely eliminated spirality - the small readings that were obtained can be explained by the small differences in absolute twist levels between the S yarns and the Z yarns. Once again the reduction in spirality brought about by wet finishing is clear.

A stepwise multiple linear regression analysis was carried out on the complete data set for the RS-OW fabrics in the order:

1. Z-twist singles (including specials)
2. Add S-twist singles
3. Add alternate S and Z fabrics
4. Add two-fold fabrics

In the case of the alternate S and Z fabrics yarn twist was defined as *(Tz - Ts).*

The dependent variable was spirality and the independent variables were yarn twist and tightness factor. Thus the model is:

$$SprAW = a \, . \, tpi + b \, . \, \sqrt{Tex}/L + c$$

The results of the analysis are shown in *Figure 16* where it can be seen that the inclusion of the S twist data is sufficient to raise the correlation coefficient to over 0.9. That the S and Z and the two-fold yarn fabrics are compatible with the model is shown in steps 3 and 4, where further slight improvements in the correlation coefficients are found.

However, from the shape of the plot in *Figure 8*, one may actually presume that a linear model is inadequate and a future analysis might choose e.g. the natural logarithm of the tightness factor as more appropriate.

Notwithstanding, it seems that for this particular series of fabrics, spirality can be predicted reasonably accurately from a knowledge of the twist in the yarns and the tightness of the fabrics. Since the yarn twist is only a substitute for twist-liveliness, it becomes interesting to see whether some estimate could be made of the liveliness of the yarn in a finished fabric. This is work for a future project.

Effect of Finishing Route

The K2 project examined, for a somewhat limited range of 24G and 28G fabrics, the influence of different dyeing and finishing routes and the effect of mercerising.

Dyeing Method

Figure 17 shows the collected data for both singles and two-fold fabrics, and *Figure 18* shows the comparison with the K1 controls for the singles-yarn fabrics only. It is clear that there are some differences caused (presumably) by the different routes. K2/RS-E is a very similar route to Kl/RS-OW - although carried out in a different mill - and it is interesting to see that this gives the closest agreement to the K1 controls (*Figure 18*). The greatest difference is shown by finish WD, the winch-dyed material, with RS, SS, and Brazzoli lying in between with little to distinguish them from one another.

Some comparisons between the various routes are given in *Figures 19, 20, and 21* for tightness factor and in *Figures 22, 23, and 24* for spirality. No very simple picture emerges since no comparison was found in which both tightness factor and spirality were not systematically different. Thus, the apparent similarity between RS, SS and Brazzoli conceals some self-compensating differences. In order to try to resolve these it will be necessary to develop the test method mentioned in the previous section for measuring twist-liveliness in finished fabrics.

At least what can be said is that, judged by these results, the lowest spirality figures are given by the winch dyed materials although it should be noted that the differences between finishing routes tend to be less in the tighter fabrics than the slacker ones.

Mercerising

Two different mercerising procedures were used: the tubular machine of Omez and the open-width equipment of Kleinewefers.

The results of spirality measurements on these fabrics are shown in *Figures 25 and 26* respectively. These two plots are very interesting because they reveal apparently quite different trends.

- For the tubular mercerised, singles-yarn materials not only is the spirality lowered (as predicted by the relaxation hypothesis) but the tightness factor is increased - thus leading to a further lowering of spirality angles. In the two-fold fabrics, the negative spirality is increased.
- For the open-width mercerised fabrics, those made from two-fold yarns are scarcely changed. In the singles-yarn fabrics spirality angles are lowered in a way consistent with relaxation of internal stress, but there is no systematic change in tightness factor. The net result is that the tubular mercerised singles-yarn fabrics have generally lower spirality than the open-width mercerised materials, although, for an equivalent tightness factor, spirality is about the same.

The combined results are shown in *Figure 27*.

Conclusions

The four questions posed in Section 3 can now be answered.

1. If our results are typical and the K1 series is taken as an acceptable control series, then the normal level of spirality is between 7 and 30 degrees after finishing, depending upon fabric tightness.
2. Twist-liveliness in the yarn and the tightness of the fabric both exert a major influence over spirality in the expected directions. This conclusion can be extended to fabrics made from alternate S and Z yarns as well as those made from two-fold yarns.
3. Different finishing routes affect spirality to different degrees. All the wet processing routes examined resulted in lower spirality than that shown by grey fabrics. The greatest decline was produced by mercerising. An hypothesis to explain these changes would have to take account of changes in fabric tightness but also in the twist liveliness in the yarns brought about by relaxation and setting. The hypothesis naturally leads to the

prediction that spirality might be lowered further by crosslinking - the most efficient setting treatment known for cotton - and also by a treatment in liquid ammonia.

4. There is a strong possibility that spirality can be predicted by a mathematical model whose main parameters would be fabric tightness and yarn twist-liveliness. However, in order to avoid arbitrary calibration constants, it will be necessary to develop a method for measuring twist liveliness in finished fabrics.

Figure 1

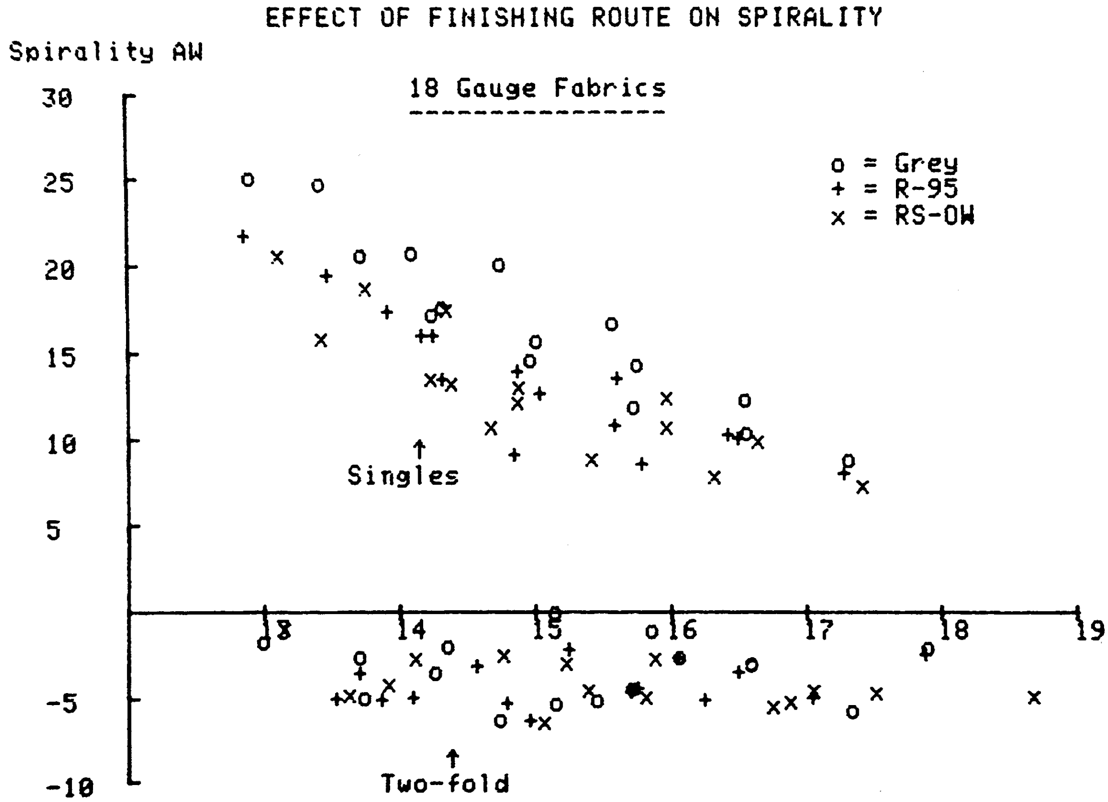


Figure 2

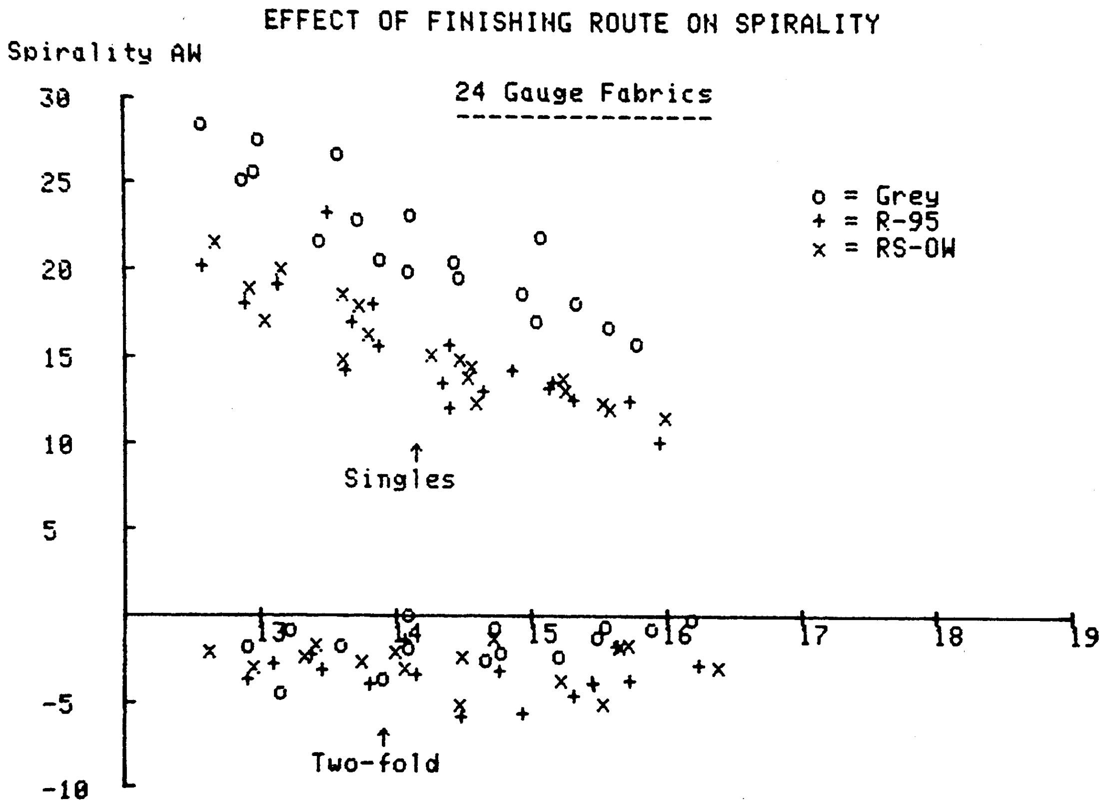


Figure 3

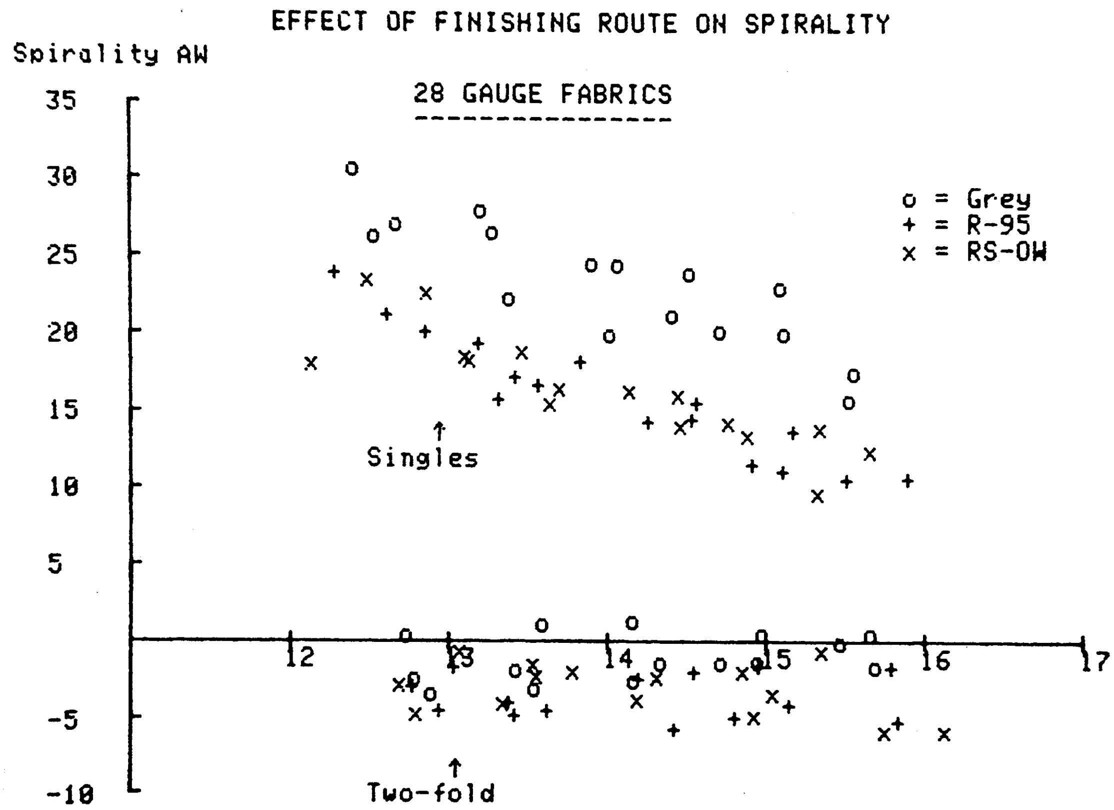


Figure 4

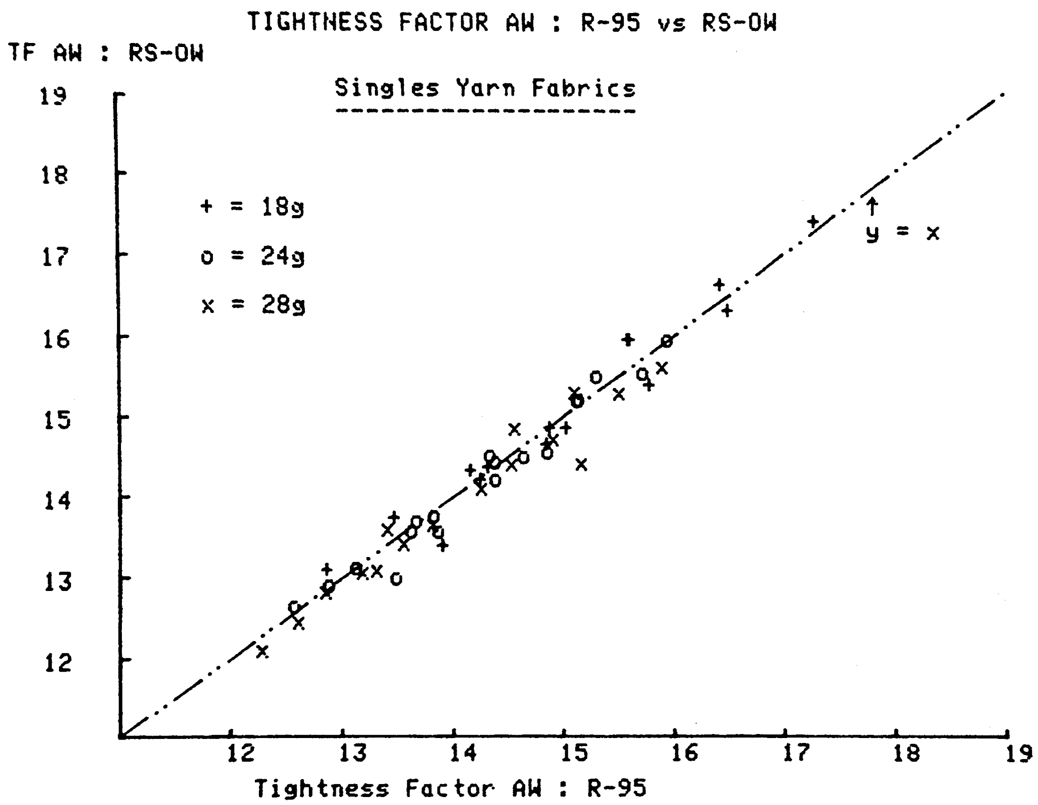
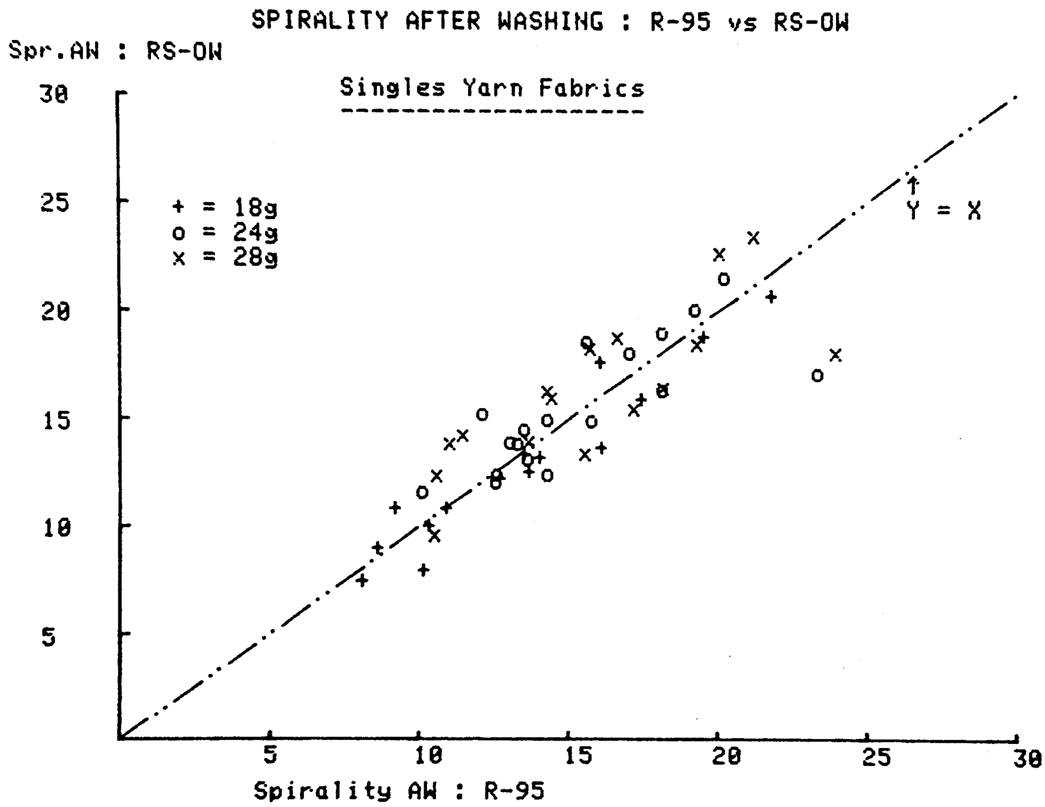


Figure 5



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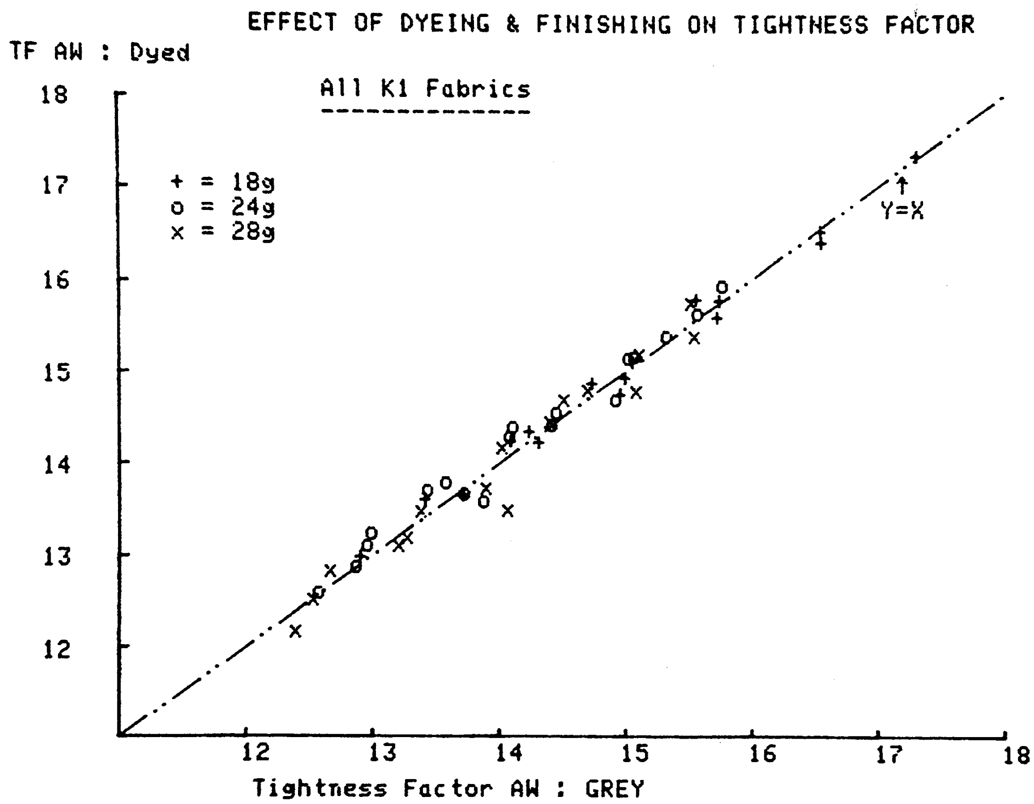


Figure 7

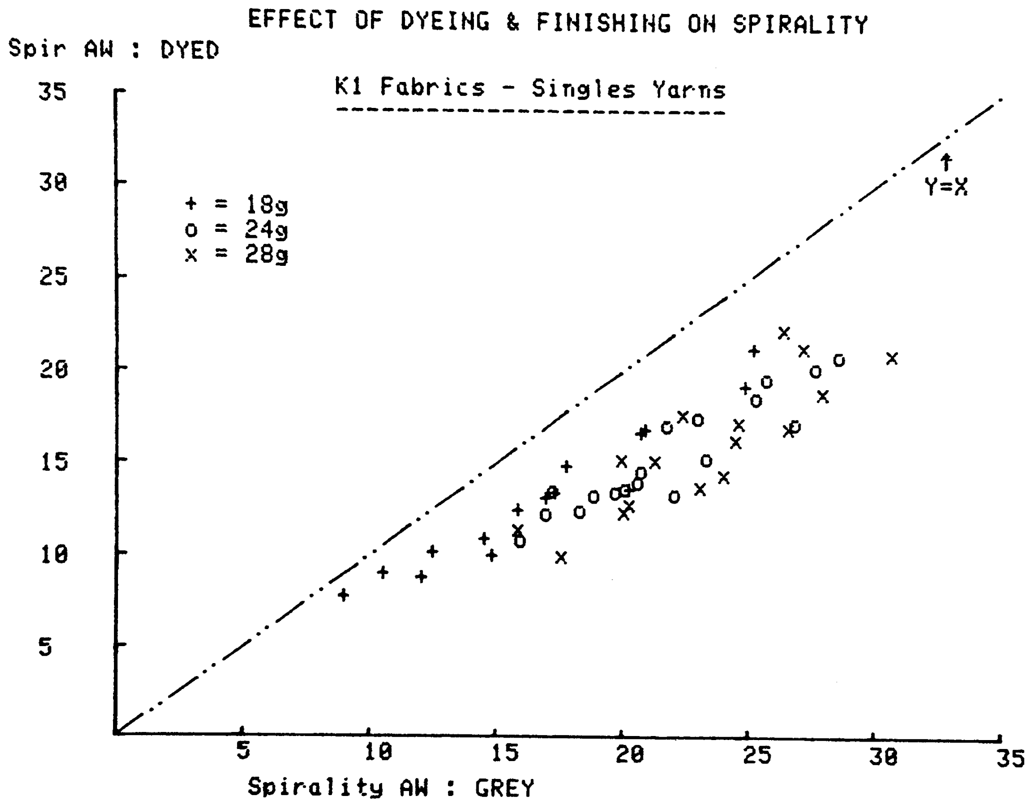


Figure 8

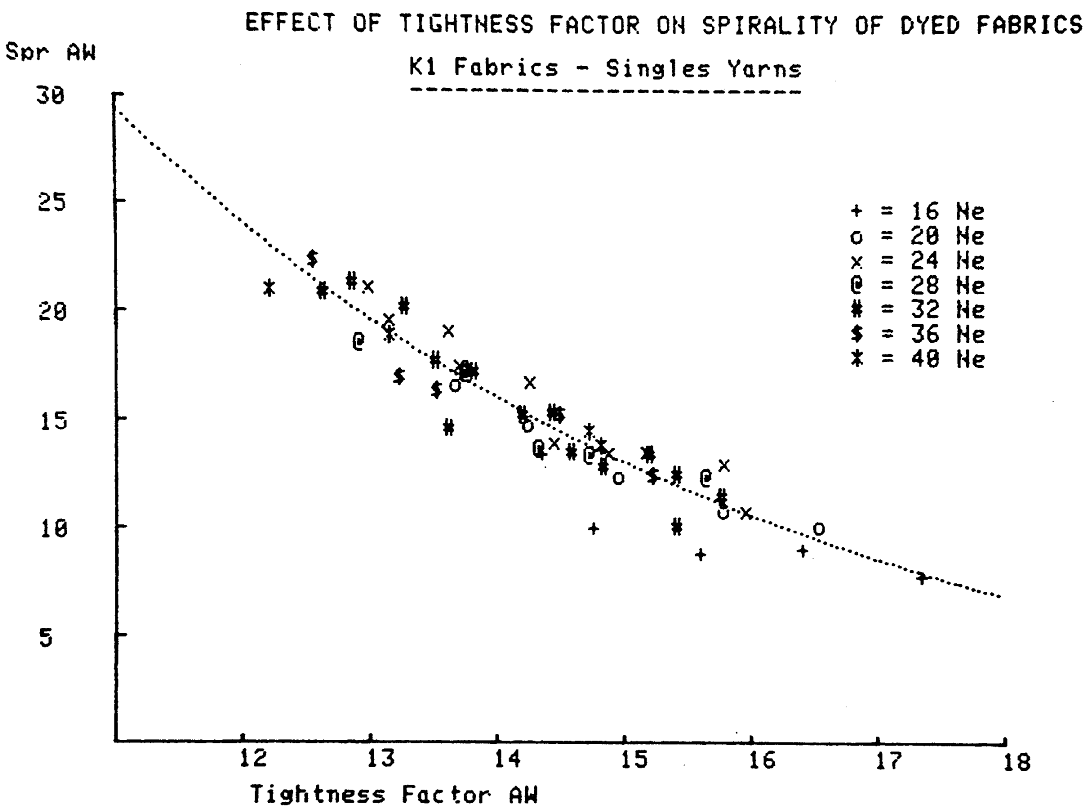


Figure 9

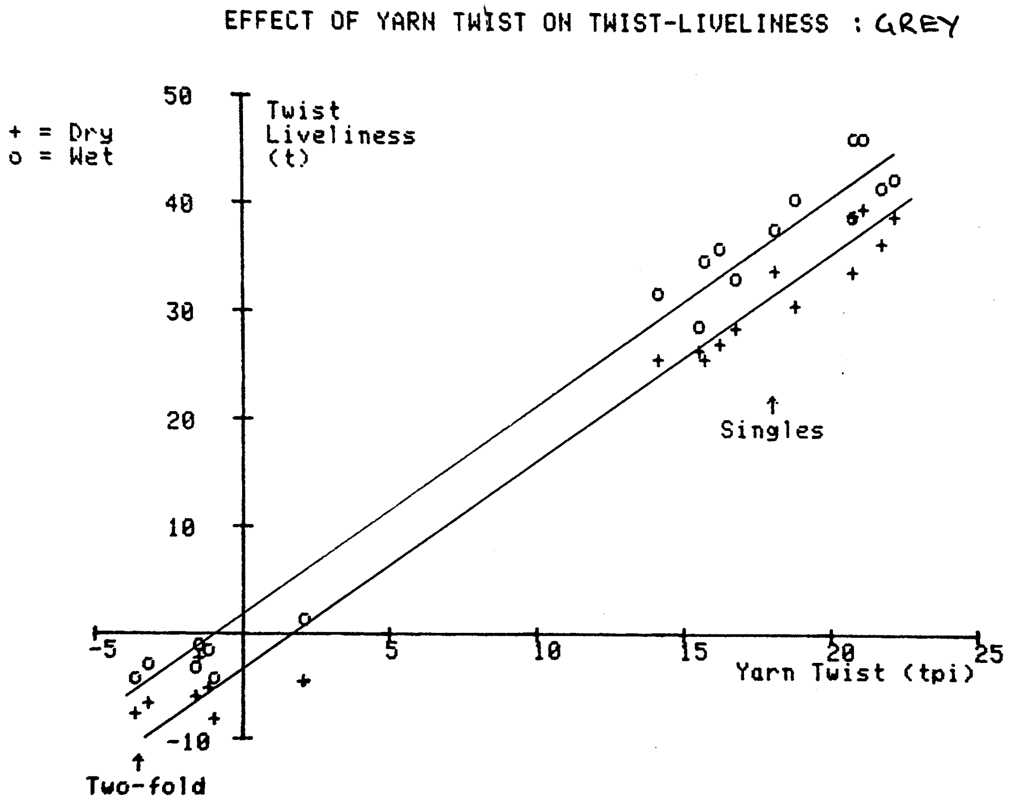


Figure 10

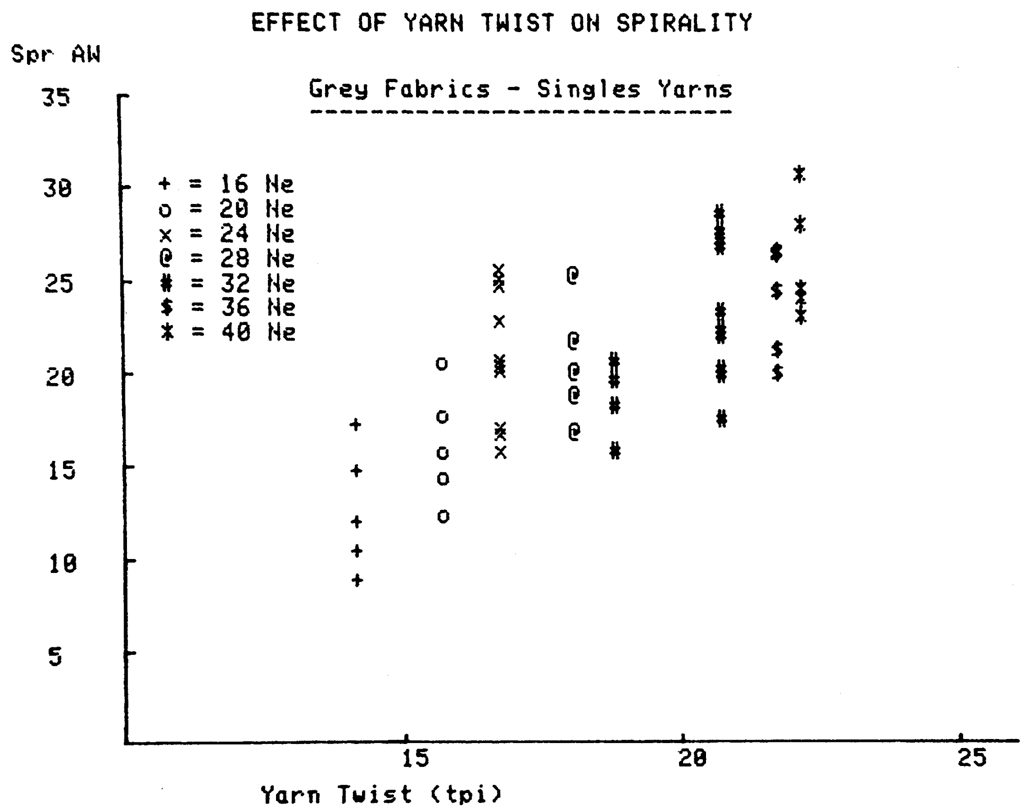


Figure 11

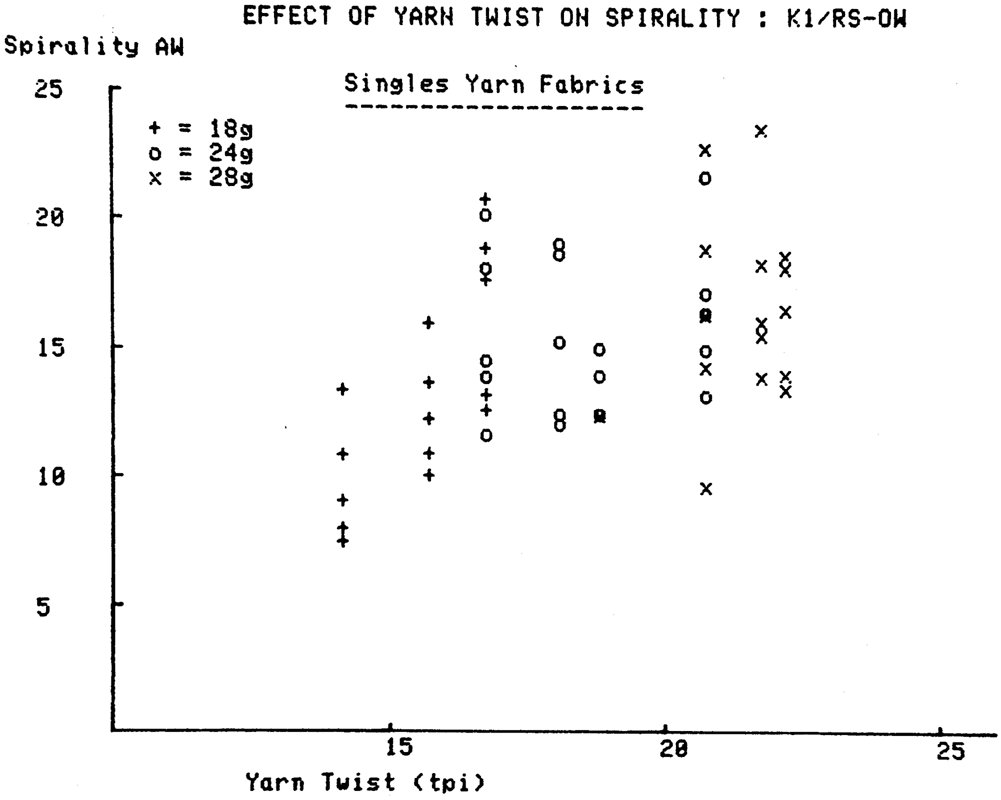


Figure 12

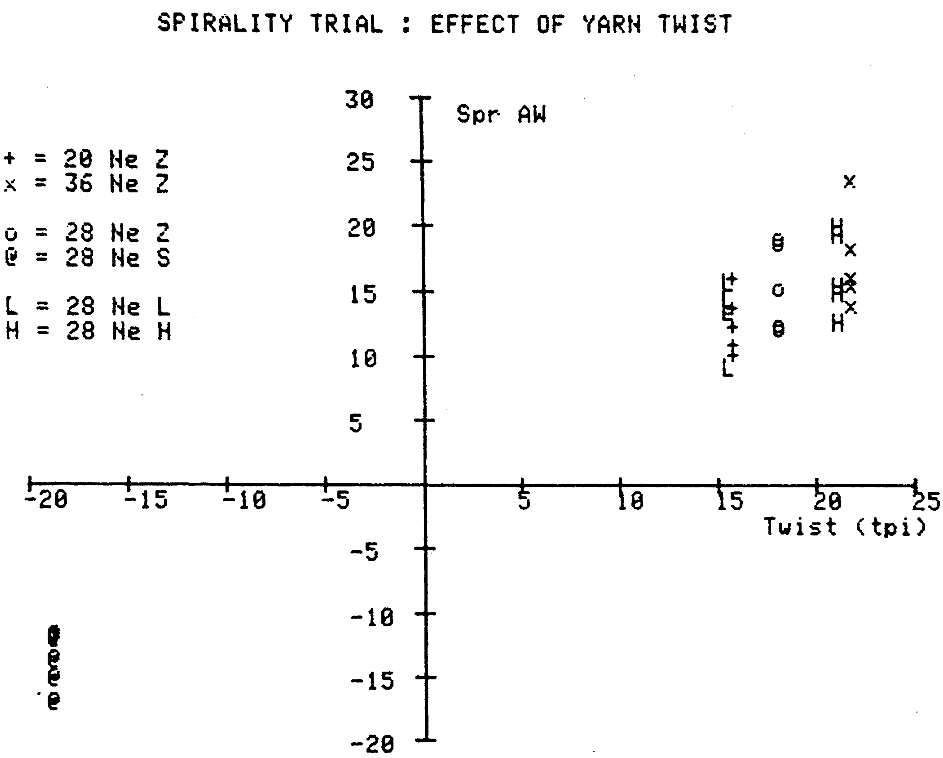


Figure 13

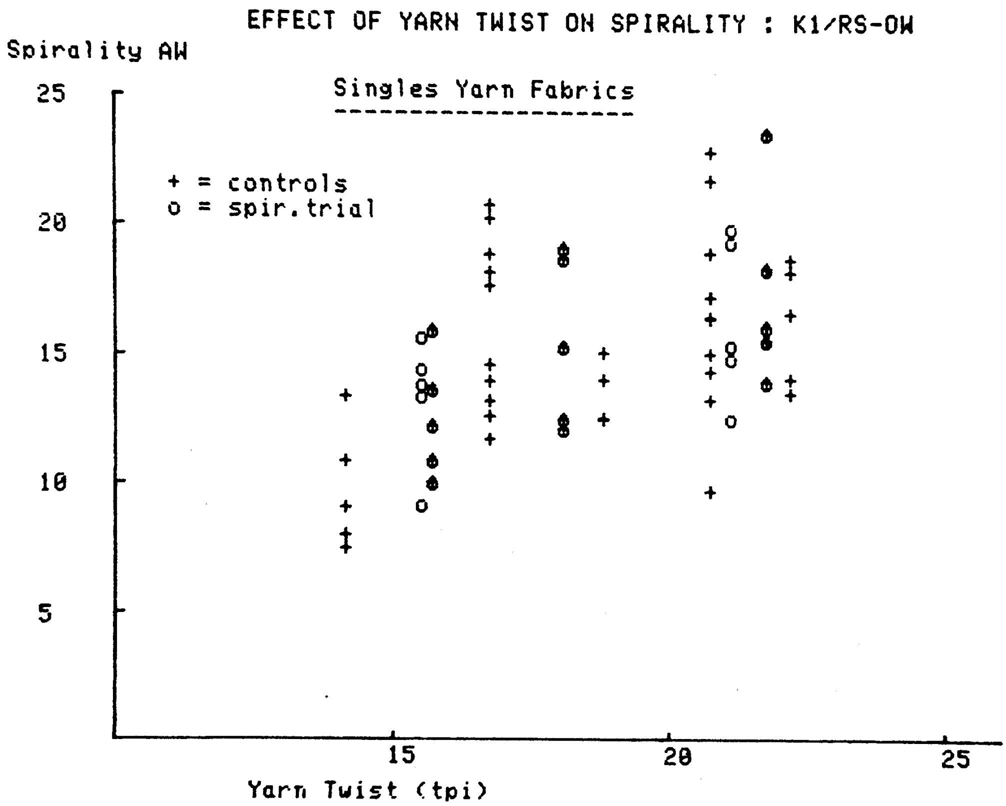


Figure 14

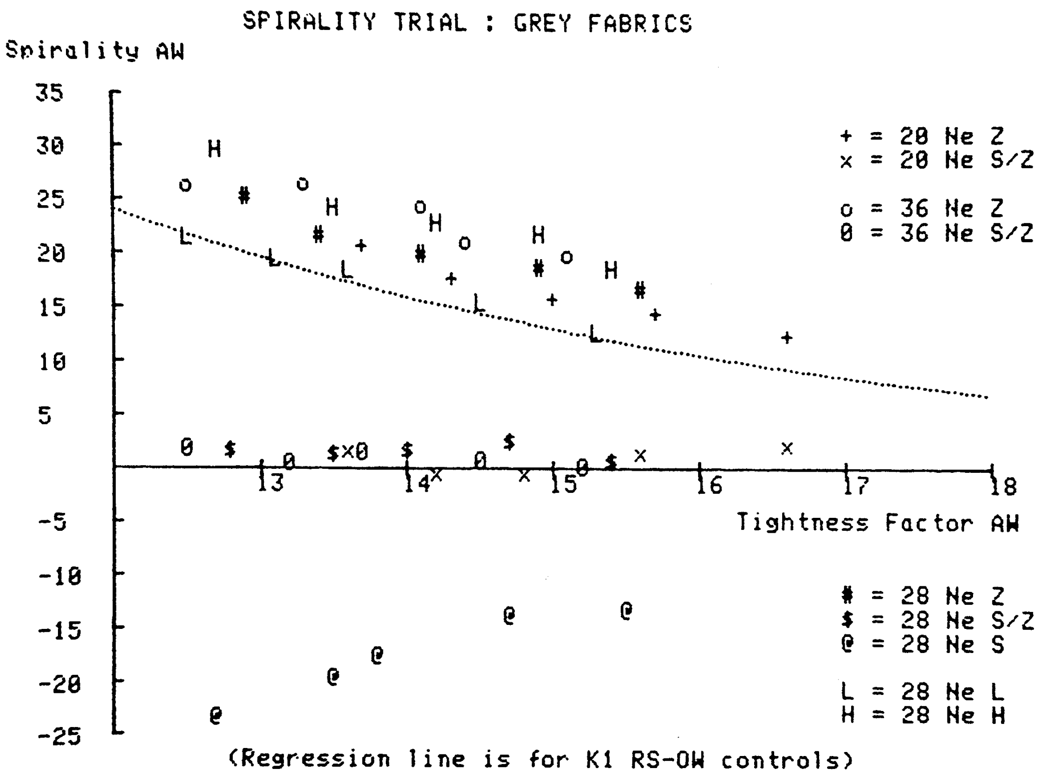


Figure 15

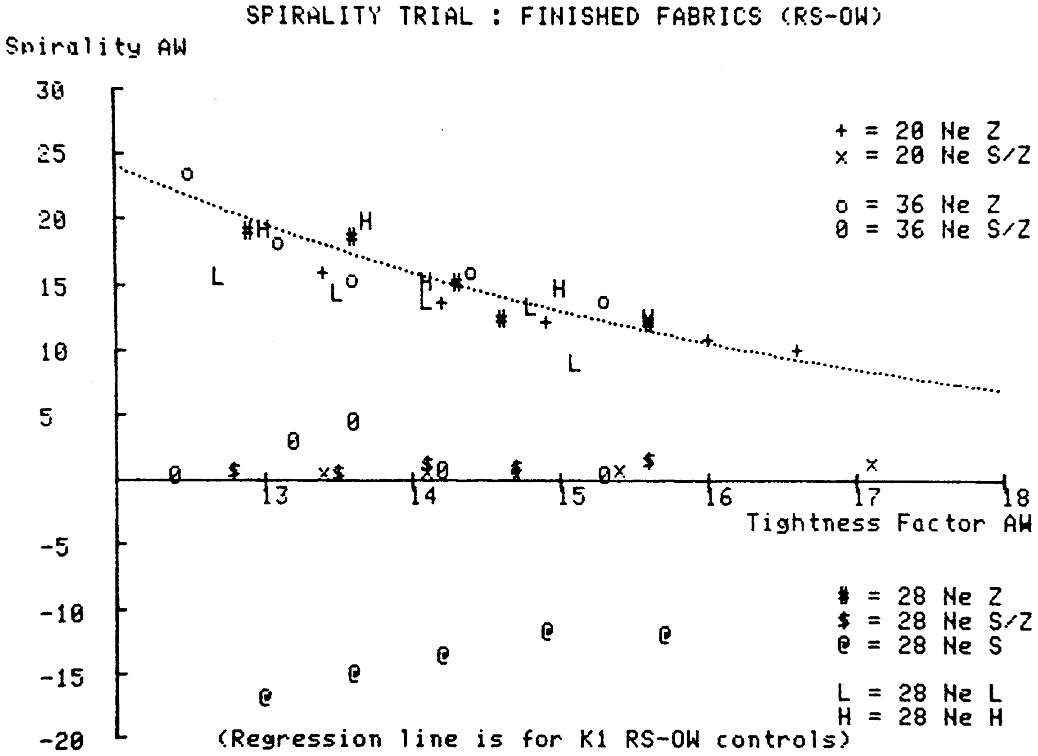


Figure 16

<u>RESULTS OF STEPWISE MULTIPLE LINEAR REGRESSION ANALYSIS OF THE RS-OW FABRICS</u>

STEP	DATA	N	a	b	c	r^2
1	Z	74	0.25	-2,54	46.9	0.79
2	Z & S	79	0.74	-1.91	28.7	0.92
3	Z+S + S/Z	94	0.75	-1.55	23.5	0.93
4	Z+S+S/Z+two-fold	139	0.83	-1.12	15.6	0.94

model: $SprAW = a * tpi + b * \sqrt{Tex}/\ell + c$

Figure 17

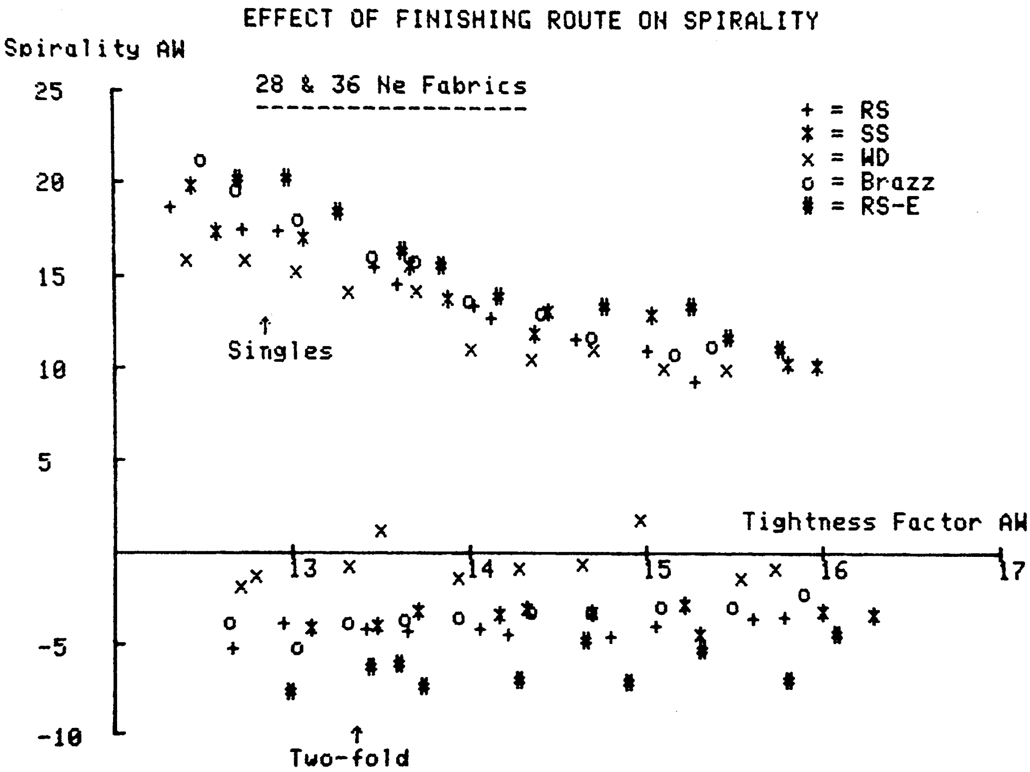


Figure 18

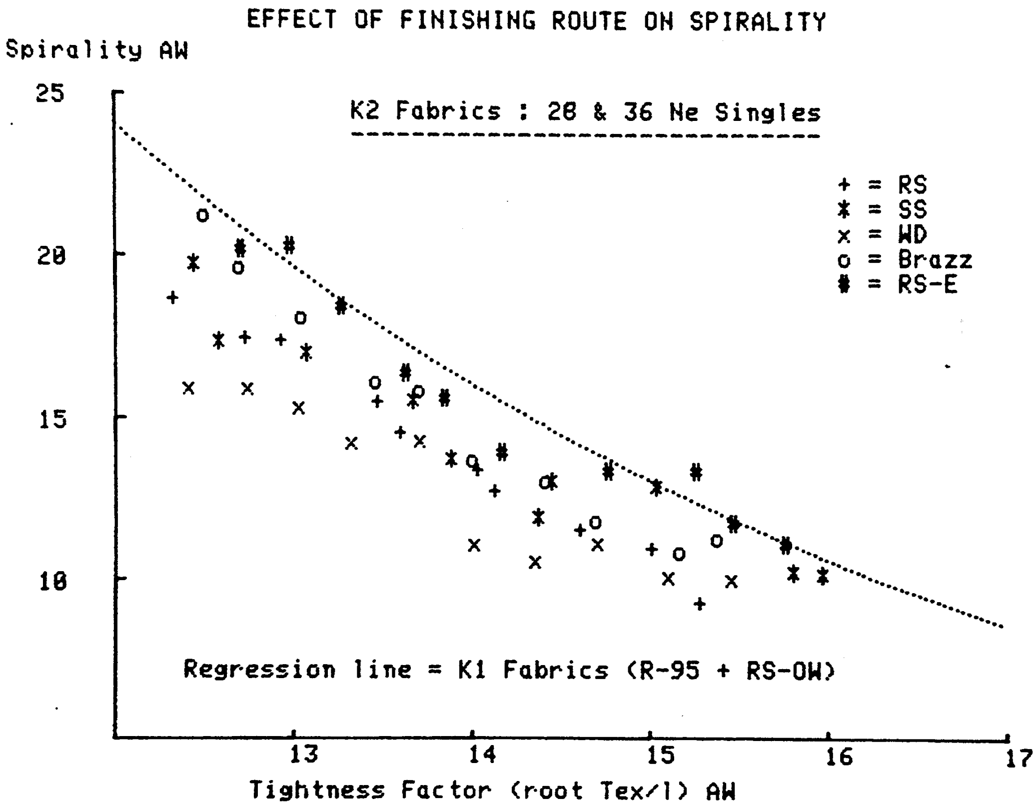


Figure 19

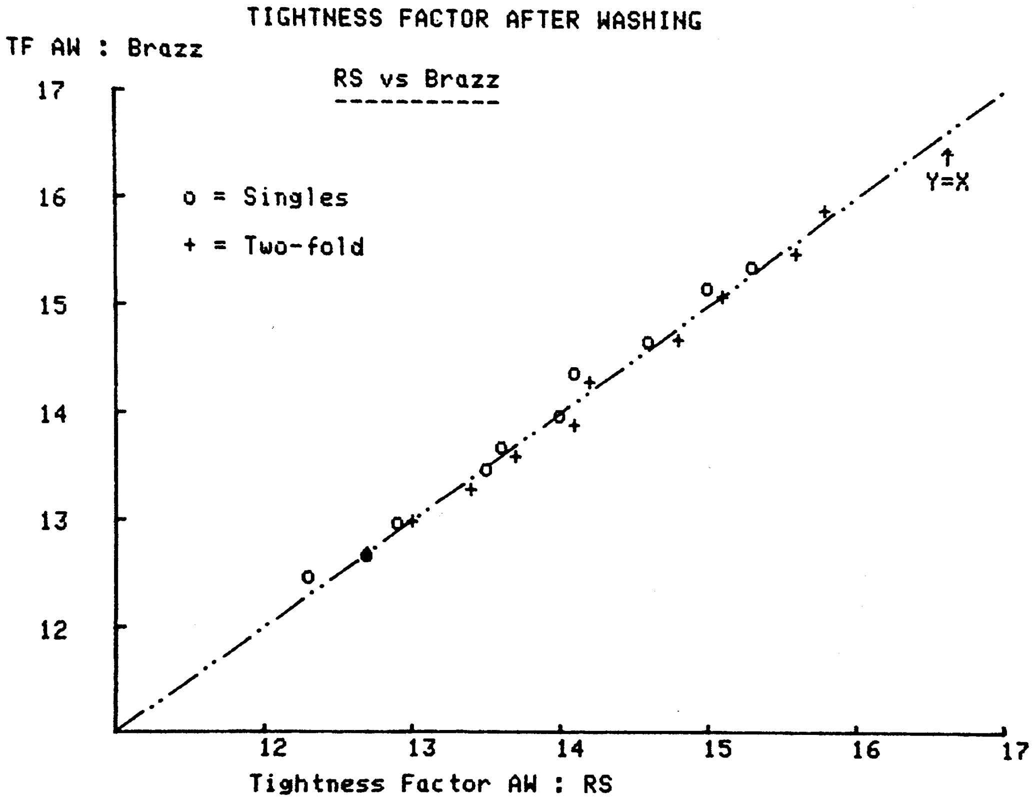


Figure 20

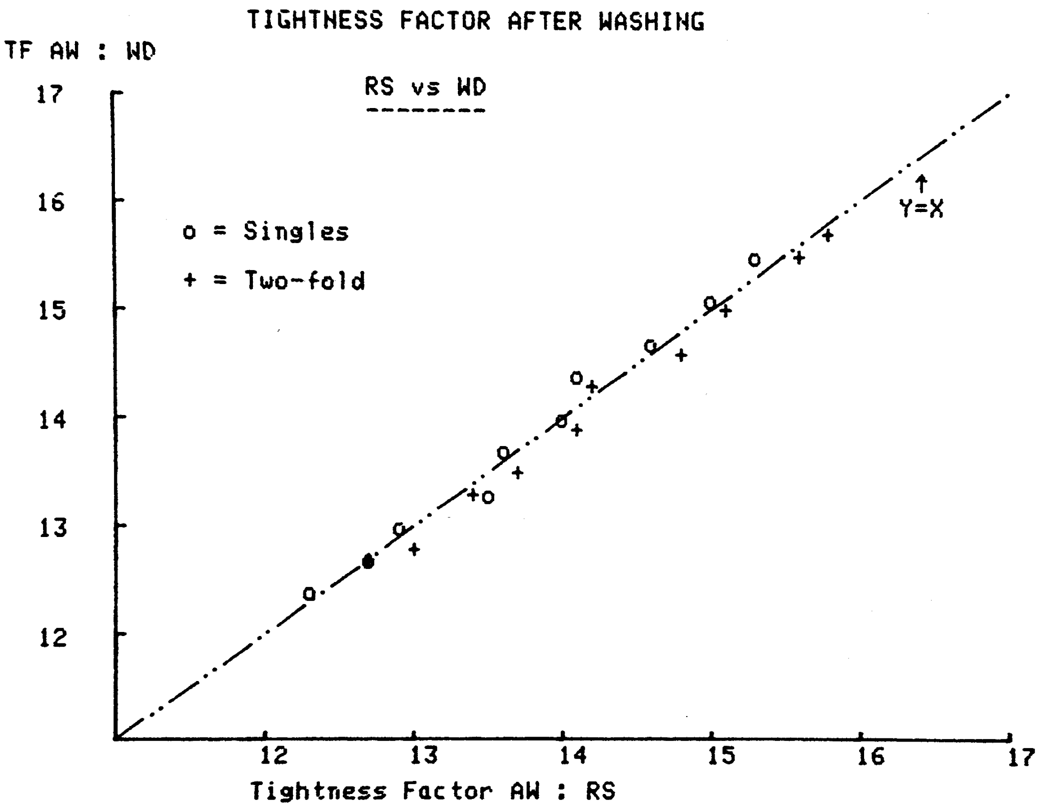


Figure 21

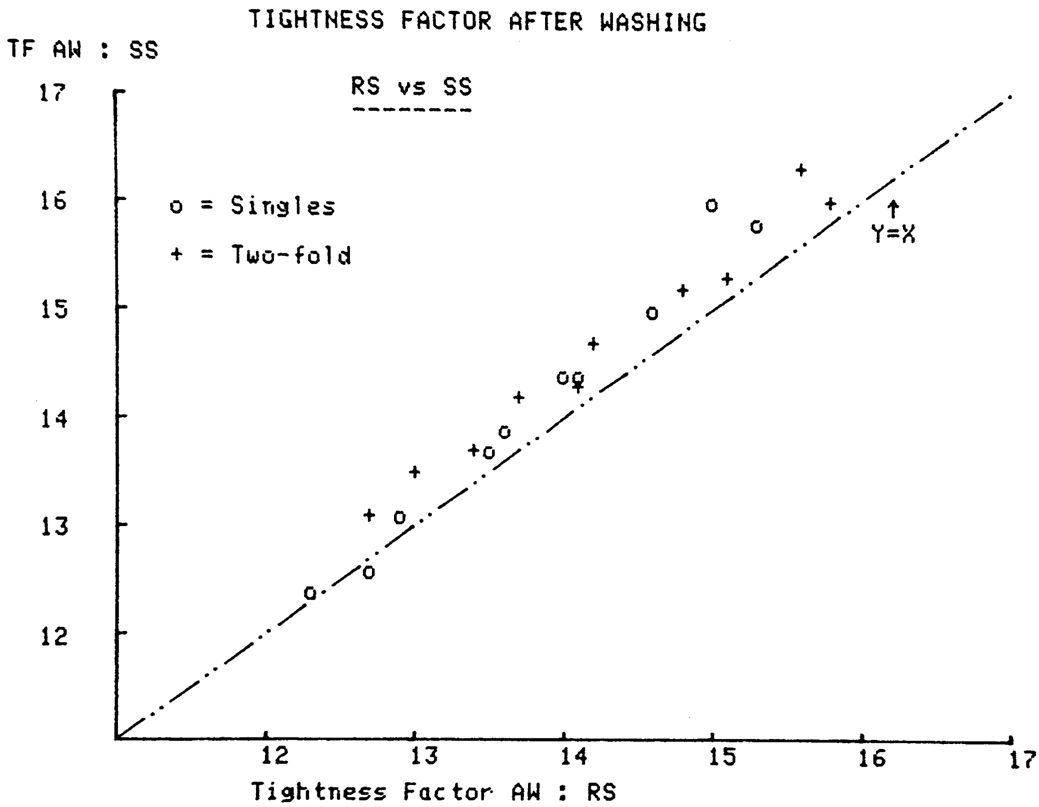
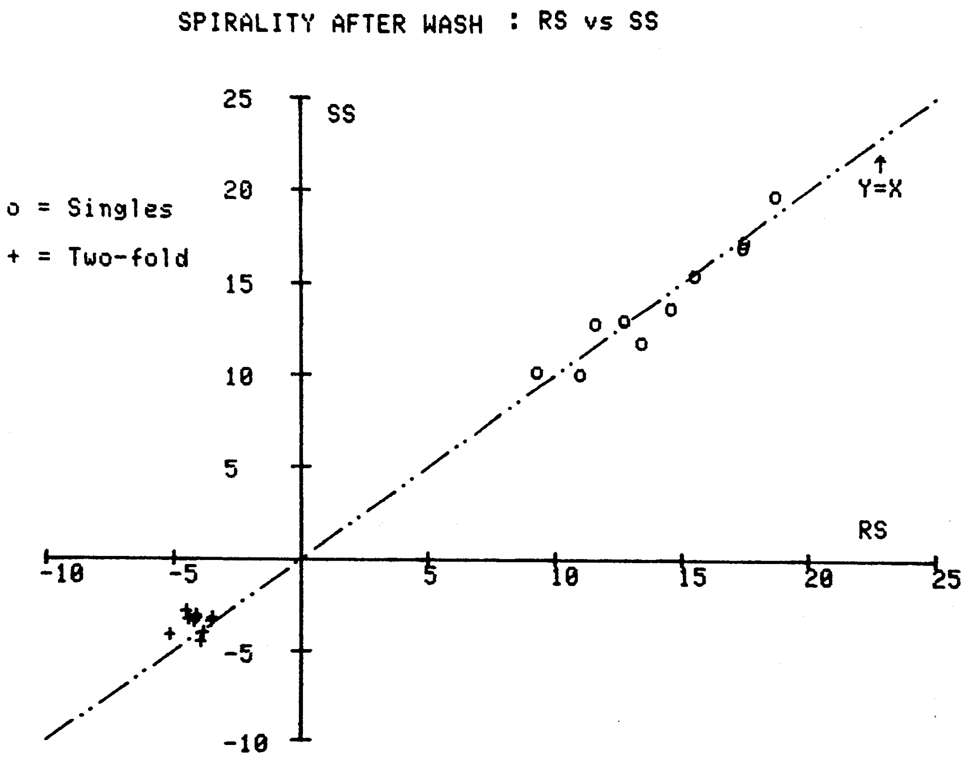


Figure 22



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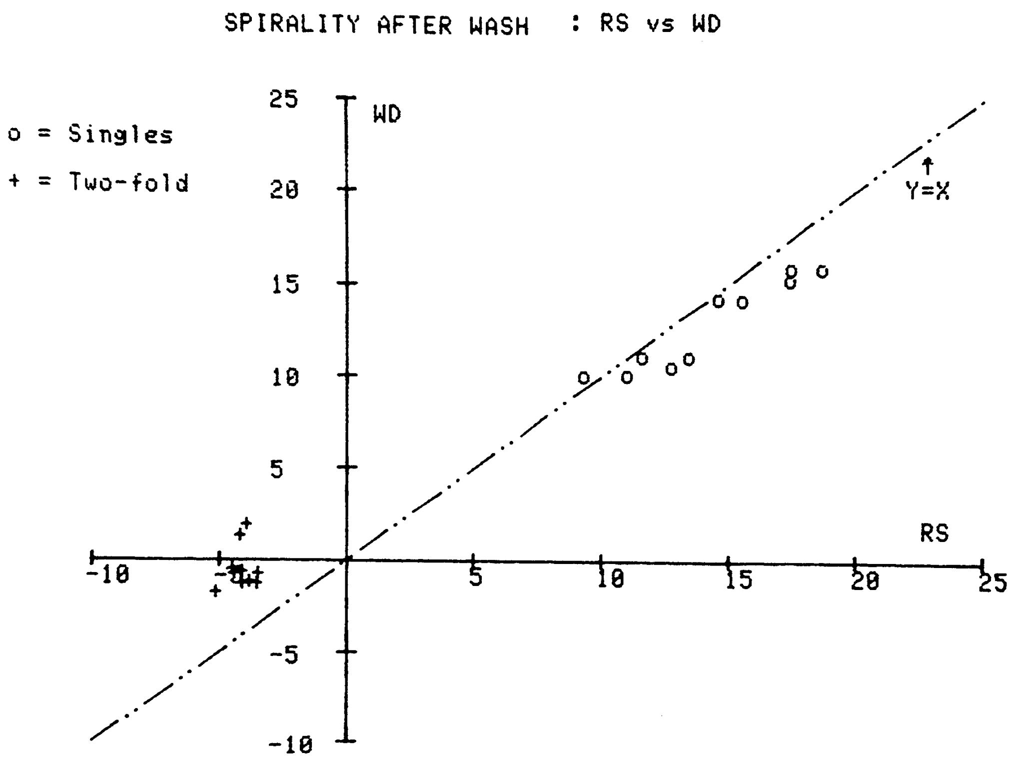


Figure 24

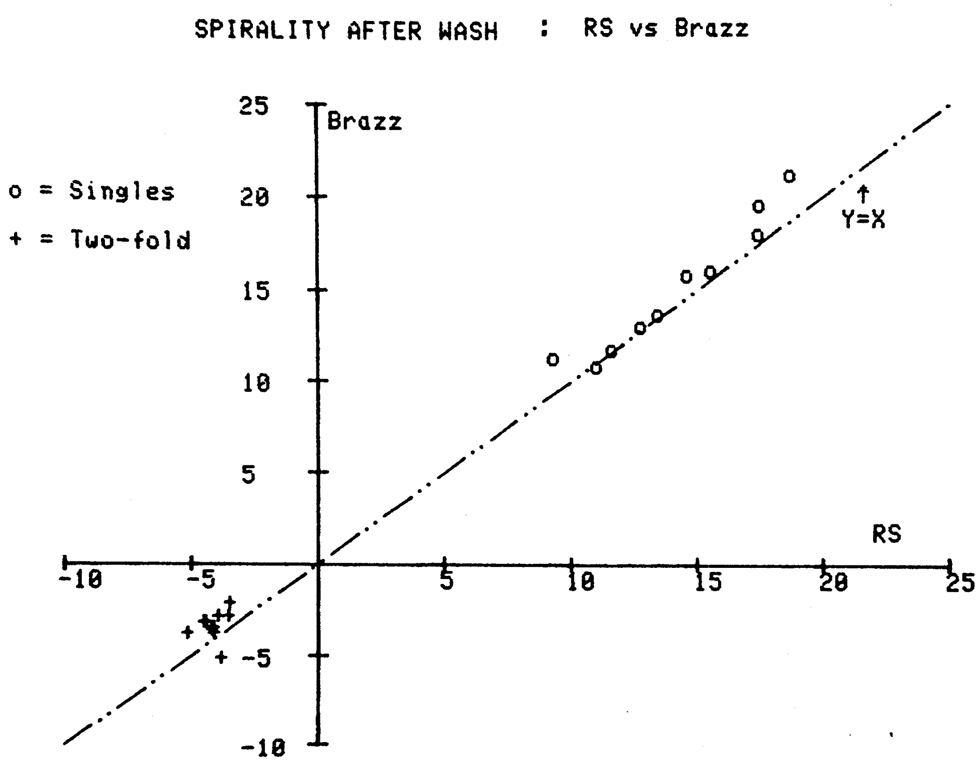


Figure 25

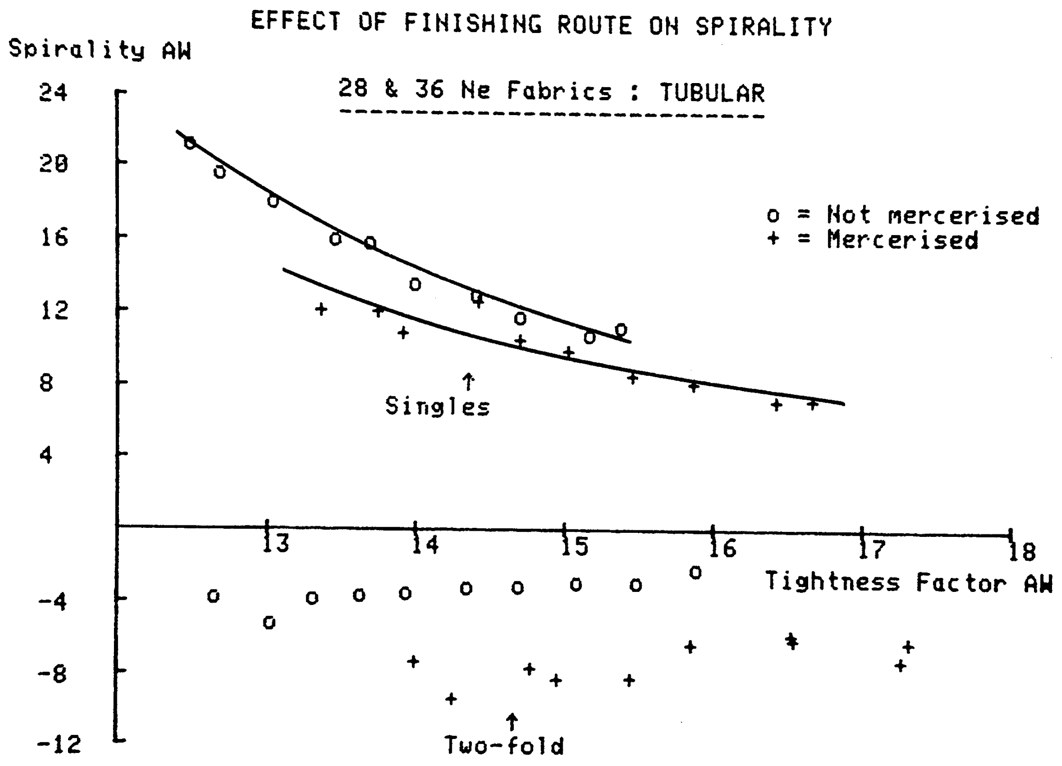


Figure 26

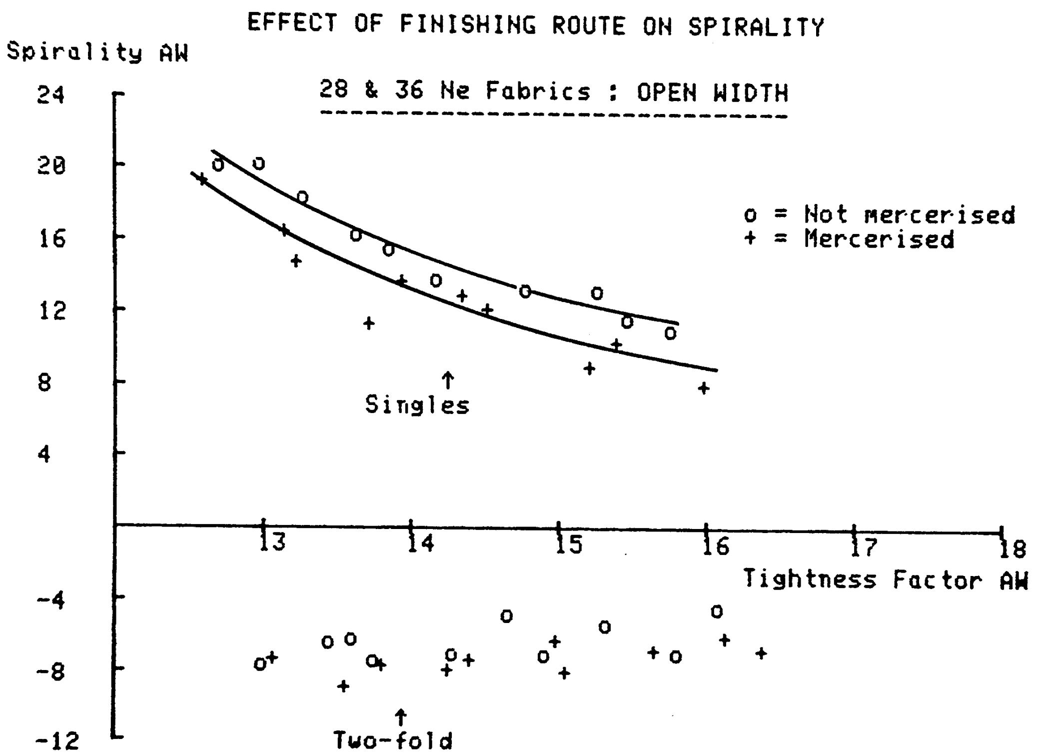
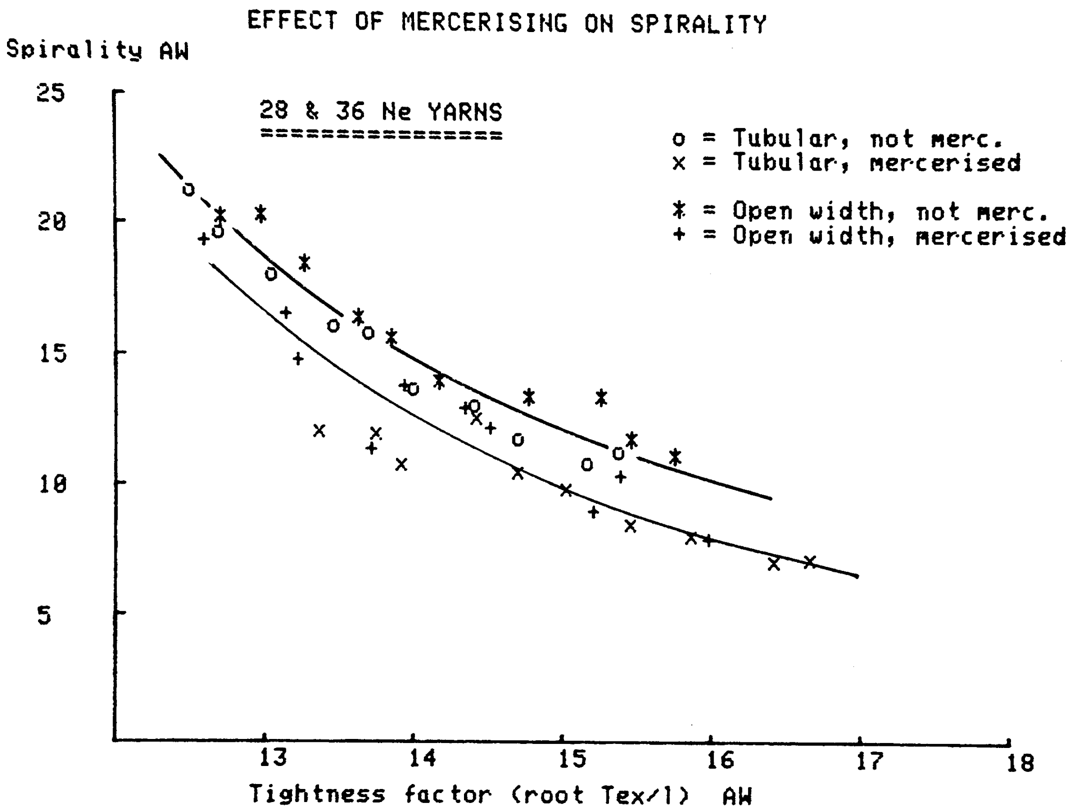


Figure 27


EFFECT OF MERCERISING ON SPIRALITY
Spirality AW
28 & 36 Ne YARNS
o = Tubular, not merc.
x = Tubular, mercerised
* = Open width, not merc.
+ = Open width, mercerised
25
20
15
10
5
13
14
15
16
17
18
Tightness factor (root Tex/l) AW