EVALUATION OF IMPROVEMENTS IN YARN QUALITY WITH NEW RING SPINNING FRAME

Eric Hequet, Assistant Director
M. Dean Ethridge, Ph.D., Director
William D. Cole, Spinning Manager

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Introduction

Since 1996, the ITC has had a Zinser 330 HS ring-spinning frame. This new-generation of ring spinning technology runs at about twice the speed of the remaining, old Saco Lowell SF-3H frames in the ring-spinning laboratory. Furthermore, the improved geometry and other features of the Zinser 330 HS make possible a higher quality of yarn than is possible with the old technology. This report was prepared to reveal:

- the extent of yarn quality improvements with this new technology;
- the extent of interactions among key variables of interest to fiber and textile producers; and
- the nature of relationships between fiber property variables and yarn quality variables on the two ring spinning frames being compared.

Procedures

Eighteen samples of Upland cottons were selected, consisting of six varieties grown in three different locations.

The following instruments and procedures were used to get data on the raw cotton fibers:

- **Zellweger Uster HVI 900B** – 4 replications for micronaire, color and trash measurements; 10 replications for length and strength measurements.
- **Zellweger Uster AFIS multidata** – 5 replications of 3,000 fibers,
- **Stelometer 654** – 6 replications (2 technicians),
- **Shirley Analyser** – 2 replications.

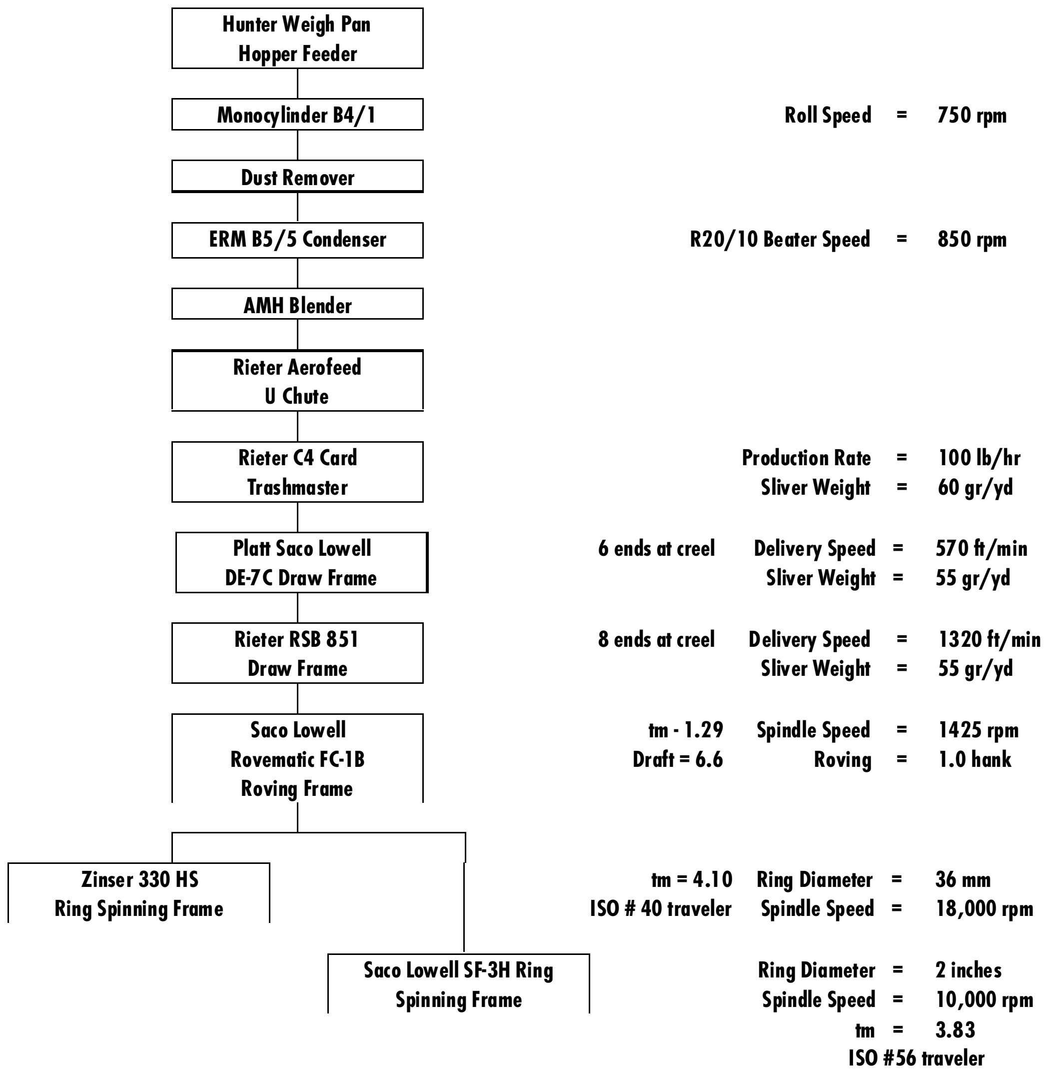
Exhibit 1 contains summary statistics for fiber data from the 18 bales of cotton sampled.

All fiber samples were spun into 30/1 Ne yarns on each of the ring spinning frames. The mechanical spinning process used is

Exhibit 1. Raw Fiber Data

Instrument & Measurement	Units	Mean	Minimum	Maximum
Zellweger Uster HVI 900B				
Micronaire		4.32	3.48	4.83
Leaf Grade		4.7	2.5	6.0
Reflectance	%	72.8	68.2	76.1
Yellowness		8.2	7.0	9.0
Upper Half Mean Length	in	1.11	1.06	1.19
Uniformity	%	82.0	80.0	84.0
Strength	g/tex	29.8	27.0	33.0
Elongation	%	5.8	5.1	6.2
AFIS Multidata				
Mean length (w)	in	0.97	0.90	1.10
Short Fiber Content (w)	%	9.1	6.7	12.3
Upper Quartile Length (w)	in	1.17	1.10	1.27
Maturity Ratio		0.88	0.82	0.97
Immature Fiber Content	%	8.6	5.5	11.4
Fineness	mtex	166	153	176
Nep	cnt/g	189	112	273
Seed Coat Nep	cnt/g	17	13	21
Dust	cnt/g	525	358	735
Trash	cnt/g	123	74	168
Shirley Analyser				
Trash content	%	3.32	2.69	7.38
Stelometer				
Strength	g/tex	22.3	20.6	23.8
Elongation	%	6.5	6.3	6.8

Exhibit 2: Outline of mechanical process



shown in the Exhibit 2. Before spinning the cotton samples, a check test was done on the roving frame and the two ring spinning frames, in order to control the spindle-to-spindle variations during the experiment. Since this test consisted of short spinning runs, reliable data on the number of ends down are not available. It was noted, however, that none occurred on either spinning frame during the test.

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The following instruments and procedures were used to get data on the cotton yarns produced:

- **Skein tester** – 10 replications,
- **Zellweger Uster Tensorapid** – 10 replications of 20 breaks,
- **Zellweger Uster UT3** – 10 replications of 400 yards.

For both the fiber and yarn testing instruments, the long-term and short-term stability of the instruments was verified before, during and after the experiment.

Results

Yarn Quality Improvements

A summary of the yarn property values is given in Exhibit 3 for the Zinser and in Exhibit 4 for the Saco Lowell. Exhibit 5 provides a summary of the percentage differences between the Zinser and the Saco Lowell; i.e., Zinser data is divided by Saco Lowell data. Since the cotton was the same in both cases—and all other processing factors affecting the yarn properties were held virtually constant—these quality differences should be due only to the spinning machines.

Exhibit 3. Yarn Properties from Zinser 330-HS

Instrument & Measurement	Units	Mean	Minimum	Maximum
Scott Tester				
Count-strength Product (CSP)	Ne x lb	2599.1	2338.0	2908.6
Uster Tensorapid				
Tenacity	cN/tex	15.7	14.0	17.5
Elongation	%	5.2	4.8	5.5
Uster UT3				
Non-uniformity	CV%	17.5	16.8	18.2
Thin Places	cnt/1000yd	86	49	138
Thick Places	cnt/1000yd	351	266	416
Neps	cnt/1000yd	195	149	240
Hairiness		4.35	4.00	4.87

Exhibit 4. Yarn Properties from Saco Lowell SF-3H

Instrument & Measurement	Units	Mean	Minimum	Maximum
Scott Tester				
Count-strength Product (CSP)	Ne x lb	2401.6	2108.8	2709.5
Uster Tensorapid				
Tenacity	cN/tex	14.9	12.8	16.9
Elongation	%	6.1	5.7	6.6
Uster UT3				
Non-uniformity	CV%	19.9	18.9	20.8
Thin Places	cnt/1000yd	248	133	382
Thick Places	cnt/1000yd	847	614	1053
Neps	cnt/1000yd	305	233	376
Hairiness		4.57	4.28	4.97

Exhibit 5. Differences in Yarn Properties: Zinser 330-HS vs. Saco Lowell SF-3H

Instrument & Measurement	Units	Mean	Minimum	Maximum
Scott Tester				
Count-strength Product (CSP)	%	+ 8.3	+ 1.4	+ 14.6
Uster Tensorapid				
Tenacity	%	+ 5.7	+ 1.7	+ 11.7
Elongation	%	- 15.9	- 19.4	- 9.1
Uster UT3				
Non-uniformity	%	- 11.9	- 14.7	- 8.3
Thin Places	%	- 64.6	- 72.9	- 47.4
Thick Places	%	- 57.9	- 66.1	- 39.4
Neps	%	- 35.5	- 43.6	- 14.9
Hairiness	%	- 5.0	-7.6	+ 0.2

All of the average percentage differences in Exhibit 5 represent improvements in yarn quality, except that yarn elongation is about 16% less on the Zinser. One reason is the somewhat higher twist multiplier used on the Zinser.

- The larger increase in count-strength product (8.3%) relative to tenacity (5.7%) is probably due to the fact that a generally improved yarn structure will be reflected more accurately in the count-strength product measurement than in the tenacity measurement. The simultaneous breaking of many segments of a wrapped yarn with the count-strength product test better reveals random structural weaknesses.
- The average results from the Uster UT3 measurements are remarkable; especially the large percentage reductions in thin places, thick places, and neps.

Cotton x Machinery Interactions

The minimum and maximum differences in Exhibit 5 serve notice that there were substantial variations in results for different cotton samples. This leads to the important question of interactions between fibers and machines. Such interactions are critical for making decisions about which cottons a textile mill should select for the existing spinning machinery contained in its plants. They are also critical for making decisions about which cotton varieties should be selected for commercialization by cotton breeders.

A basic question: Is the spinning performance and yarn quality of the alternative cottons ranked the same regardless of the machinery used? To answer this question, Exhibit 6 summarizes results of a variance component analysis of the fiber quality data versus the cotton varieties (V), the spinning frames (S), and the production location (L)—as well as versus the pairwise interactions V x S, V x L, and S x L. Clearly most of the yarn properties are significantly related to both V and S. While most of the yarn properties are not related to L, they are often related to the interaction term S x L. These results serve notice that the technically optimum combination of fiber parameters is not always the same for different machinery used to transform the raw material into yarn.

Exhibit 6. Variance Component Analysis Results

	Variety (V)	Spinning Frame (S)	Location (L)	V×S	V×L	S×L
CSP	***	*	NS	NS	NS	**
Tenacity	***	*	NS	NS	NS	NS
Elongation	***	**	NS	NS	NS	NS
CV%	*	**	NS	NS	*	**
Thin Places	*	*	NS	*	NS	***
Thick Places	*	*	NS	*	NS	**
Neps	NS	*	NS	NS	***	**
Hairiness	NS	**	**	NS	NS	NS

NS Non Significant with α = 5% ** Significant with α = 1%
* Significant with α = 5% *** Significant with α = 0.1%

Yarn Quality Results on the Two Spinning Machines

The differing relationships between fiber and yarn properties on the two spinning machines may be clearly illustrated with simple regression analysis. Results for five of these fiber-yarn relationships are shown in Exhibits 7 – 11. In each exhibit, scatterplots and best-fitting regression lines are shown for the two spinning machines. The different levels of the regression lines reveal the average differences of yarn properties between the machines. The different slopes of the regression lines reveal differences in the changes in yarn properties as fiber properties change. Implications of these results include the following:

- The count-strength product (CSP) of yarns produced by both spinning machines is strongly and positively related to the strength of fibers measured by the HVI (Exhibit 7). The Zinser frame produces stronger yarn—approximately 200 units higher than the old Saco Lowell frame. The best-fitting regression lines are approximately parallel; therefore, increases in fiber strength cause approximately the same increases in CSP on both frames. (An increase of one g/tex in fiber strength results in an increase in CSP of approximately 93.) These results are consistent with those seen between CSP and Stelometer, between tenacity and HVI, and between tenacity and Stelometer.
- The count-strength product (CSP) of yarns produced by both spinning machines is strongly and negatively related to the standard fineness of fibers measured by the AFIS (Exhibit 8). The Zinser frame produces stronger yarn—approximately 200 units higher than the old Saco Lowell frame. The best-fitting regression lines are approximately parallel; therefore, increases in fiber standard fineness cause approximately the same decreases in CSP on both frames. (An increase of one mtex in fiber fineness results in an decrease in CSP of approximately 27.) These results are

consistent with those seen between tenacity and standard fineness.

- The non-uniformity (CV%) of yarns produced by the Saco Lowell spinning machine is strongly and positively related to the short fiber content measured by the AFIS; however, the CV% of yarns produced by the Zinser machine is not significantly related to the short fiber content (Exhibit 9). Furthermore, the Zinser produces yarns with a CV% well below that of the Saco Lowell throughout the observed range of short fiber content values. (These results are consistent with those seen between thin places and short fiber content and between thick places and short fiber content.)
- The number of yarn neps produced by the Saco Lowell spinning machine is strongly and positively related to the short fiber content measured by the AFIS; however, the number of yarn neps produced by the Zinser machine is not significantly related to the short fiber content (Exhibit 10). Furthermore, the Zinser produces yarns with nep counts well below those of the Saco Lowell throughout the observed range of short fiber content values.
- The number of yarn neps produced by the Saco Lowell spinning machine is strongly and positively related to the fiber nep count measured by the AFIS; however, the number of yarn neps produced by the Zinser machine is not significantly related to the fiber nep count (Exhibit 11). Furthermore, the Zinser produces yarns with nep counts well below those of the Saco Lowell throughout the observed range of fiber nep values.

The results on yarn neps versus raw fiber neps on the Zinser are really remarkable; not because the Zinser produces less yarn neps throughout the range of the data, but because there is no significant slope to the yarn neps throughout this range. The cause-and-effect realtionships involved need to be examined in depth; with the behavior of nep counts being monitored at every stage of the yarn formation process.

Conclusions

This evaluation of a state-of-the-art ring spinning machine versus a ring spinning machine with 40-year-old technology reveals highly significant and beneficial effects of the new technology on yarn quality. Furthermore, there are notable cotton x machinery interactions, meaning that different cottons may perform differently as the new spinning technology is adopted.

Simple regression analyses clearly show that the impacts of the fiber quality parameters are different on the two machines. The new spinning technology produces consistently superior yarns from the same fiber properties. Furthermore, the new technology is much less sensitive to some fiber quality problems, such as short fiber content and neps. Over the range of values examined here for short fiber content and neps, there were no significant changes in yarn quality values with the new technology.

These results serve to remind us that it is not always true that the faster speeds of textile machinery require higher quality in textile fibers. This report illustrates a case where the newer, faster technology actually compensates for some of the quality problems in the raw material.

Exhibit 7. CSP vs. HVI Strength
(Scatter Plots & Best-Fitting Lines)

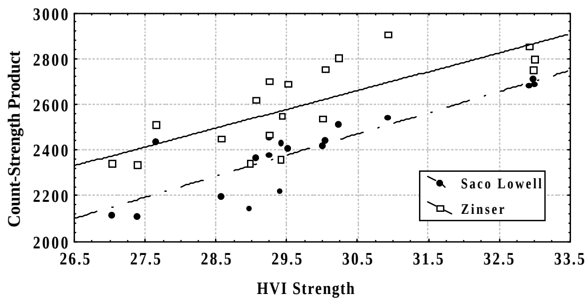

Exhibit 8. CSP vs. AFIS Standard Fineness
(Scatter Plots & Best-Fitting Lines)

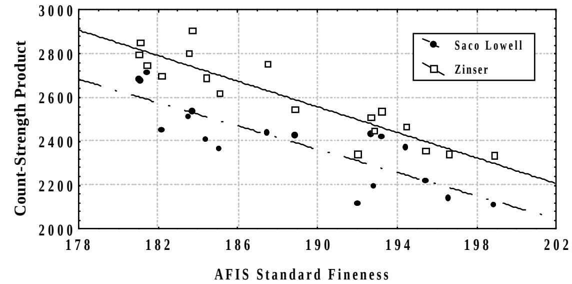

Exhibit 9. Yarn Non-Uniformity vs. AFIS Short Fiber Content
(Scatter Plot & Best-Fitting Lines)

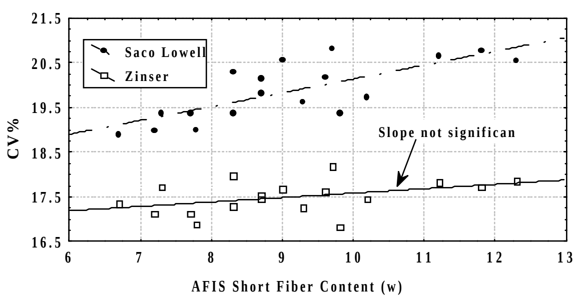

Exhibit 10. Yarn Neps vs. AFIS Short Fiber Content
(Scatter Plot & Best-Fitting Line)

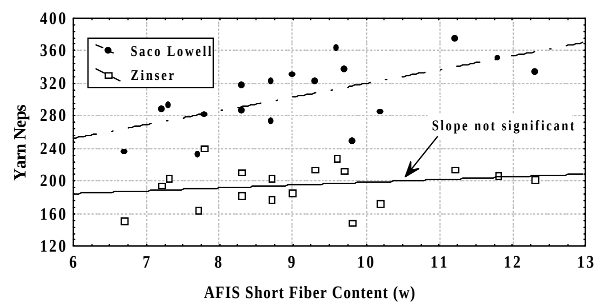

Exhibit 11. Yarn Nep Count vs. AFIS Nep Count
(Scatter Plots & Best-Fitting Lines)