MOISTURE CORRECTION OF HVI DATA

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Abstract

Sample moisture and its variance is discussed and related to the conditioning equipment in the laboratory. Tests were conducted on a wide range of samples from a variety of international growth areas conditioned at different sample moistures. Both the strength and length measurements increase with sample moisture. Neither micronaire nor uniformity were affected. An algorithm was developed to correct the length and strength measurements to 7.5% sample moisture. Guidelines of when to apply the moisture correction algorithm are given. An argument that correction of length and strength values for the sample moisture is the next big step in reducing variance in these measurements is made.

Introduction

Cotton is a hygroscopic material. Moisture is either absorbed from the air or released to the air to maintain equilibrium with the moisture in the surrounding atmosphere. It is well known that the moisture in the cotton sample affects strength results. The most common explanation for this phenomena is the increased hydrogen bonding between adjacent sheaths of cellulose. Because of the hygroscopic nature of cotton, ASTM standards specify standard conditions for testing of cotton samples. These are a temperature of 21°C +/- 0.6°C and a relative humidity of 65% +/- 2%. Note that both must be specified since the moisture in the cotton sample is in equilibrium with the absolute concentration of water in the atmosphere, which is a function of both the temperature and relative humidity. In general, for a laboratory to have the samples properly conditioned as per ASTM standards and produce reliable results, the following considerations must be met:

- The conditioning equipment must function properly.

- Vents should be adjusted to provide as uniform distribution as possible. Large rooms may show variations in relative humidity of greater than 5% throughout the room. As portable relative humidity measurement instrument is required to adjust the angles and openings of a properly designed venting system.

- Double air locks or some such mechanism should be used to avoid transients. Excessive traffic will cause large localized swings in moisture in the air.

- Samples should always be conditioned for 24 hours either from the dry side or from the wet side.

- Calibration cottons should be stored in the same area as the test samples to allow comparable conditioning in appropriate containers.

Experimental Procedures

A unique set of cotton samples was collected including cottons from many different international growth areas. The values, types and origins are very broad covering the entire range of fiber properties. The samples were originally measured on an AFIS for maturity ratio and short fiber and on an HVI for micronaire, length, uniformity, strength and elongation values. These range from:

Micronaire	2.72 to 8.47
Length	0.688 in. to 1.502 in.
Uniformity	73.5% to 88.4%
Short Fiber	2.7% to 39.3%
Strength	20.3 g/tex to 43.7 g/tex
Maturity Ratio	0.69 to 1.05

These samples were placed in a controlled room with the HVI. The control unit for the room was adjusted to a temperature of 21°C and 65% relative humidity. The samples were allowed to equilibrate for 24 hours. All samples were then tested on the HVI ten times. Moisture content of each cotton sample was measured using both the Uster moisture probe and a standard hand-held moisture unit. The relative humidity of the control unit for the room was adjusted down to 50% relative humidity in several steps. After each adjustment, the samples were allowed to equilibrate for 24 hours and retested on the HVI. The relative humidity of the control unit for the room was adjusted up to 75% relative humidity (the maximum range of the control unit) in several steps. After each adjustment, the samples were allowed to equilibrate for 24 hours and retested on the HVI.

Experimental Results

Figure 1 shows the Uster moisture readings on the samples conditioned at different relative humidities as compared to a traditional hand-held moisture probe. Experience has shown that the Uster moisture probe is not operator dependent. There is no user calibration of the moisture probe. The unit is checked at Uster using a series of test blocks, adjusted and then sealed. The only requirement is placing an adequate amount of cotton under the pressure hand.

Micronaire does not show any measurable effect due to the moisture in the sample. A decrease of 1% moisture would represent an additional 0.100 grams of fiber for a 10-gram sample. Theoretically, for a 4.0 micronaire cotton, this should mean a decrease of approximately 0.5 for the micronaire value. To evaluate this theory and study the influence of moisture on cotton's micronaire, an experiment was designed. A cotton sample was measured after conditioning at standard conditions. The sample was then dried to different two moisture contents and measured. The results are shown in Table I. A linear extrapolation would indicate that theoretically we should see a decrease of 1.38 mic units for the sample dried for 30 min. (a decrease of 2.6% moisture). However, the results of the experiment show only a decrease of 0.08 mic units for the above experiment. Even this small decrease is within experimental error when the standard deviations of the measurements are considered. This agrees with the experiments on complete sample set shown in figure 2. The correlation with sample moisture is very low, as is the slope. This suggests the effect of sample moisture on the micronaire measurement is much more than simply the effect on the mass of the sample and may be related to shape changes as moisture of the cotton fiber changes.

Strength and length both show a significant variation due to moisture. The variation of length and strength with sample moisture for several samples is shown in Figure 3 and Figure 4. Although different varieties show slightly different responses, it is possible to model an average behavior. The average strength measurement shows a dependency on the sample moisture of approximately 5.9% per percent change in moisture. Although typically ignored, length also is dependent on the sample moisture and shows a dependency on the sample moisture of approximately 1.2% per percent change in moisture. Uniformity does not show any measurable effect due to the moisture in the sample. This is because uniformity is a ratio of two lengths and the numerator and denominator are affected in the same ratio. Typical variations for length and strength at different moistures for several upland cottons are shown in Table II.

It is tempting to simply conform to the ASTM standards and ignore the fact that moisture affects both strength and length. However, these effects will appear even in a well-conditioned laboratory. Table III gives the moisture in the air at different temperatures and relative humidifies as a percentage of the moisture at standard conditions. The moisture in the sample at equilibrium is proportional to the moisture in the air. When we consider the limits in the control box (entries indicated by **bold** type), we see that the allowed limits correspond to a change of +/- 10% in the sample moisture. Thus a sample whose moisture is 8.0% at equilibrium with the laboratory at standard conditions could have its moisture change from 7.2% to 8.8% depending on the controls. Thus long calibration cotton may swing in strength from 32.2 g/tex to 34.3 g/tex when the laboratory is within tolerance. This implies that even a well-controlled laboratory may see an advantage in moisture correction of length and strength data.

One important fact is that different cotton samples will equilibrate at different moistures when exposed to the same conditions. This is shown for 55% relative humidity in Figure 5 and for 75% relative humidity in Figure 6. Using individual regressions between sample moisture and relative humidity for each sample, the sample moisture at standard conditions was calculated for each cotton. Attempts were made to estimate this equilibrium moisture at standard conditions using multiple regression (both linear and non-linear) with all known properties of the samples were not successful. Ideally, we would measure the sample moisture and correct fiber length and strength to the moisture that the cotton would equilibrate to, at standard conditions. However, since we have found no method of estimating this moisture level from fiber properties, we have taken the approach of correcting the values to 7.5 % moisture. This seems to be an appropriate mean moisture value at standard conditions as the average equilibrium moisture at 65% relative humidity using the Uster moisture probe was 7.58%. The correction to a standard moisture level results in making some cottons appear stronger or weaker than they measure under current practices. Since the standard deviation of the moisture distributions seems to be about 0.4 % moisture, this seems to be an acceptable error, particularly since the sample moisture may swing +/- 0.8% and still be within ASTM standards.

In Figure 7 we show a normalized strength error calculated by subtracting the ratio of the raw strength at a given moisture to the raw strength value at 7.5 % moisture from one. Thus an error of -0.10 represents a multiplier of 0.90 for a 10 % error in the raw strength result. The data in this graph represents the sample set conditioned and tested at 55 % relative humidity (data to the left side) and at 75 % relative humidity (data to the right side). The result of applying the moisture correction is shown in Figure 8. The standard deviation means that when tested at extreme conditioning levels, 67 % of the samples have less than +/- 4% error when compared to results obtained when testing at 7.5 % moisture levels. This is approximately the same as that obtained by a laboratory whose conditioning met the above standards.

Application Notes

The purpose of the moisture correction is to provide long-term corrections due to significant changes in the sample moisture. Conditions that would suggest that the moisture correction algorithm should be used are:

1. The laboratory conditions are poorly maintained. If excursions for either the temperature or relative humidity are common, the sample moisture will follow the moisture in the laboratory. The rate that the sample approaches the laboratory conditions depends on the openness of the sample. We have detected significant changes in the strength of a cotton sample (2-3 g/tex) within 60 seconds for fibers on a fiber comb.

2. The laboratory conditions are well maintained but samples are not allowed to come to equilibrium. Often, samples are stored in another area before testing due to a shortage of space in the conditioned laboratory. If these samples are tested soon after being brought into the laboratory, they will not be in equilibrium with the laboratory atmosphere. ASTM standards suggest that samples be conditioned to the laboratory atmosphere for 24 hours. Samples that are bagged but open only on one side will require longer. Open weave plastic containers are suggested.

The implementation of the moisture correction algorithm corrects the raw test values to 7.5% moisture. This means that the calibration constants with moisture correction enabled are slightly different than those with moisture correction disabled. This requires that the HVI Spectrum be calibrated whenever the moisture correction status is changed. A very important point is that the HVI Spectrum MUST measure the correct moisture of the calibration cotton during calibration in order to properly correct the values to 7.5% moisture. The moisture sensor is located in the Spectrum color/trash sample hand. Thus cotton samples MUST be placed under both the length/strength sample hand and the color/trash hand.

It is also important to insure that the moisture of the cotton samples is in an appropriate range. The initial accepted range was 6.5% to 9%. However, subsequent experiments showed that the algorithm worked well in the 5.5% to 10.5% range.

We have also seen that relative humidities below approximately 40-45% have a detrimental effect on the sample preparation of an HVI. A low relative humidity may result in a large buildup of static electricity in the sample that leads to repulsion between individual fibers. This may prevent the fibers from entering the optical system properly and results in higher test standard deviations.

The impact of the moisture correction algorithm is shown in Figure 9 and Figure 10. Calibration check samples were tested on a daily basis at a customer site. Both the uncorrected and moisture corrected data is shown. The variation in both length and strength is considerably reduced by use of the moisture correction algorithm.

Conclusions

Several conclusions may be drawn from this paper:

- The strength measurements increase with sample moisture at a rate of approximately 5.9% per percent change in moisture.

- The length measurements increase with sample moisture at a rate of approximately 1.2% per percent change in moisture.

- Neither the micronaire or uniformity measurements are affected.

- Different cotton samples will equilibrate at different moistures when exposed to the same conditions. This equilibrium moisture does not seem to be related to any of the commonly measured cotton properties.

- An algorithm was developed to correct the length and strength measurements to 8% sample moisture. The correction to a standard moisture level results in making some cotton appear stronger or weaker than they measure under current practices. Since the standard deviation of the moisture distributions seems to be about 0.4% moisture, this seems to be an acceptable error, particularly since the sample moisture may swing +/- 0.8% and still be within ASTM standards.

- The moisture correction algorithm should be used when either the laboratory conditions are poorly maintained or the laboratory conditions are well maintained but samples are not allowed to come to equilibrium.

- The accepted range of sample moisture is 6.5% to 9% but has worked well in the 5.5% to 10.5% range for some applications.

Table I: Micronaire Measurements for Dried Cotton Sample

Rep	Conditioned			120ºF for 15 min			120ºF for 30 min		
	Mois.	**Mic**	**Mass**	**Mois.**	**Mic**	**Mass**	**Moist.**	**Mic**	**Mass**
1	7.6%	4.09	10.05	6.1%	4.04	9.99	4.6%	4.04	9.94
2	7.4%	4.08	10.03	6.0%	4.00	9.94	4.5%	4.00	9.93
3	7.4%	4.12	10.00	5.7%	4.01	9.94	5.2%	4.04	10.00
4	7.2%	4.07	10.05	5.9%	4.06	9.98	4.9%	4.01	10.03
5		4.07	10.05		4.04	10.12	4.7%	3.96	10.04
Avg	7.4%	4.09	10.04	5.9%	4.03	9.99	4.8%	4.01	9.99
Sdev		0.02	0.02		0.02	0.07		0.03	0.05

Table II: Typical Variations for Several Upland Cottons

Cotton	Length (inch)				Strength (g/tex)			
	6%	**7%**	**8%**	**9%**	**6%**	**7%**	**8%**	**9%**
31	0.940	0.952	0.964	0.976	21.6	23.1	24.5	26.0
35	1.053	1.067	1.080	1.093	24.0	25.6	27.2	28.8
37	1.137	1.151	1.166	1.180	29.6	31.6	33.5	35.5
Pima	1.269	1.285	1.301	1.317	33.4	35.6	37.8	40.1

Table III: Moisture in Air at Different Temperatures and Relative Humidifies as Percentage of Moisture at 20 °C. and 65 % R.H.

	17 °C	18 °C	19 °C	20 °C	21 °C	22 °C	23 °C
60% RH	75.1	80.3	86.0	92.3	99.2	106.6	114.7
61% RH	76.3	81.6	87.5	93.9	100.8	108.4	116.6
62% RH	77.6	83.0	88.9	95.4	102.5	110.1	118.5
63% RH	89.8	84.3	**90.3**	**96.9**	**104.1**	111.9	120.4
64% RH	80.1	85.7	**91.8**	**98.5**	**105.8**	113.7	122.3
65% RH	81.3	87.0	**93.2**	**100.0**	**107.4**	115.5	125.2
66% RH	82.6	88.3	**94.6**	**101.5**	**109.1**	117.3	126.1
67% RH	83.8	89.7	**96.1**	**103.1**	**110.7**	119.0	128.0
68% RH	85.1	91.0	97.5	104.6	112.4	120.8	129.9
69% RH	86.3	92.3	98.9	106.2	114.0	122.6	131.9
70% RH	78.6	93.7	100.4	107.7	115.7	124.4	133.8

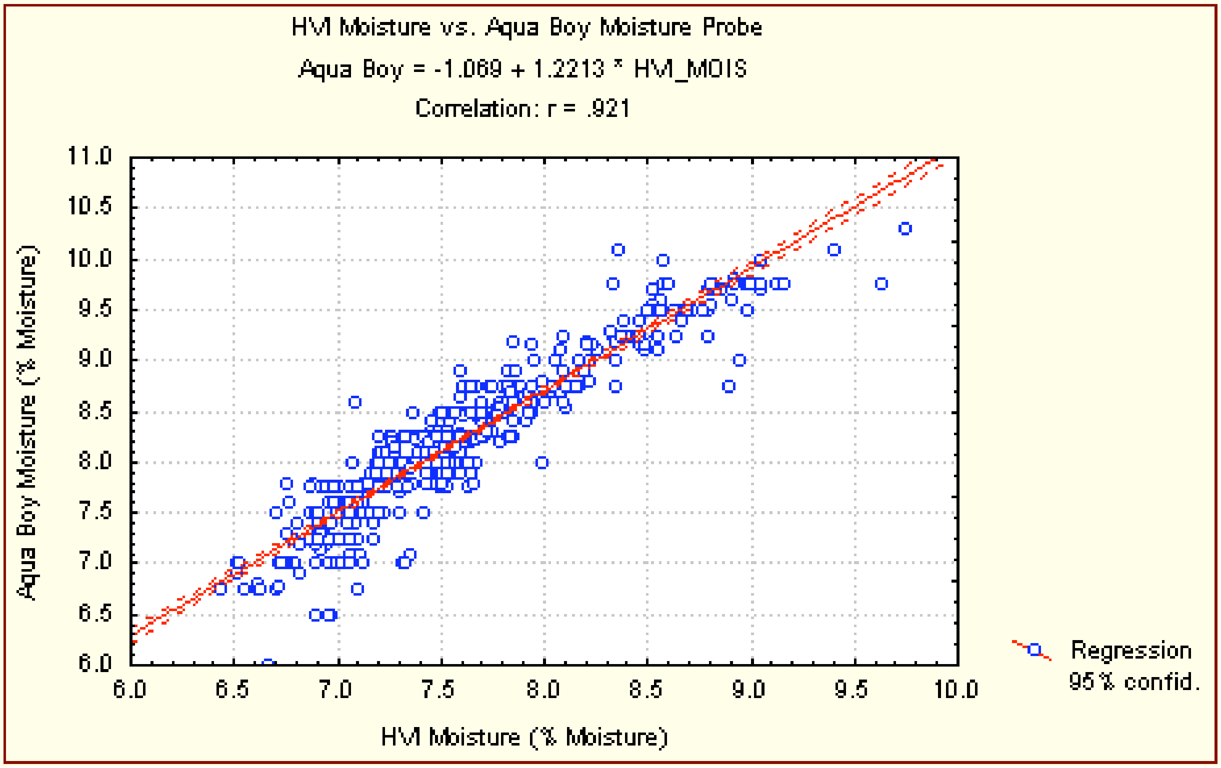

Figure 1: Uster Moisture Reading vs. Aqua Boy Moisture Probe

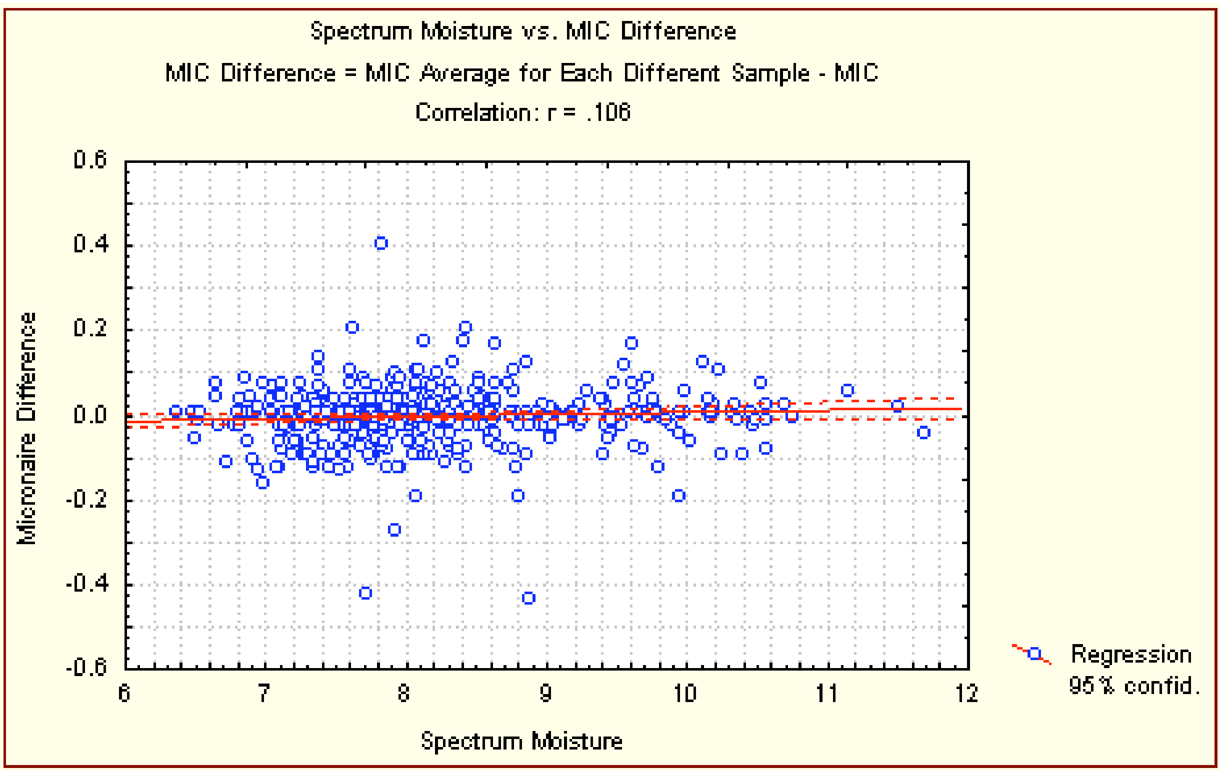

Figure 2: Sample Moisture vs. Micronaire Difference

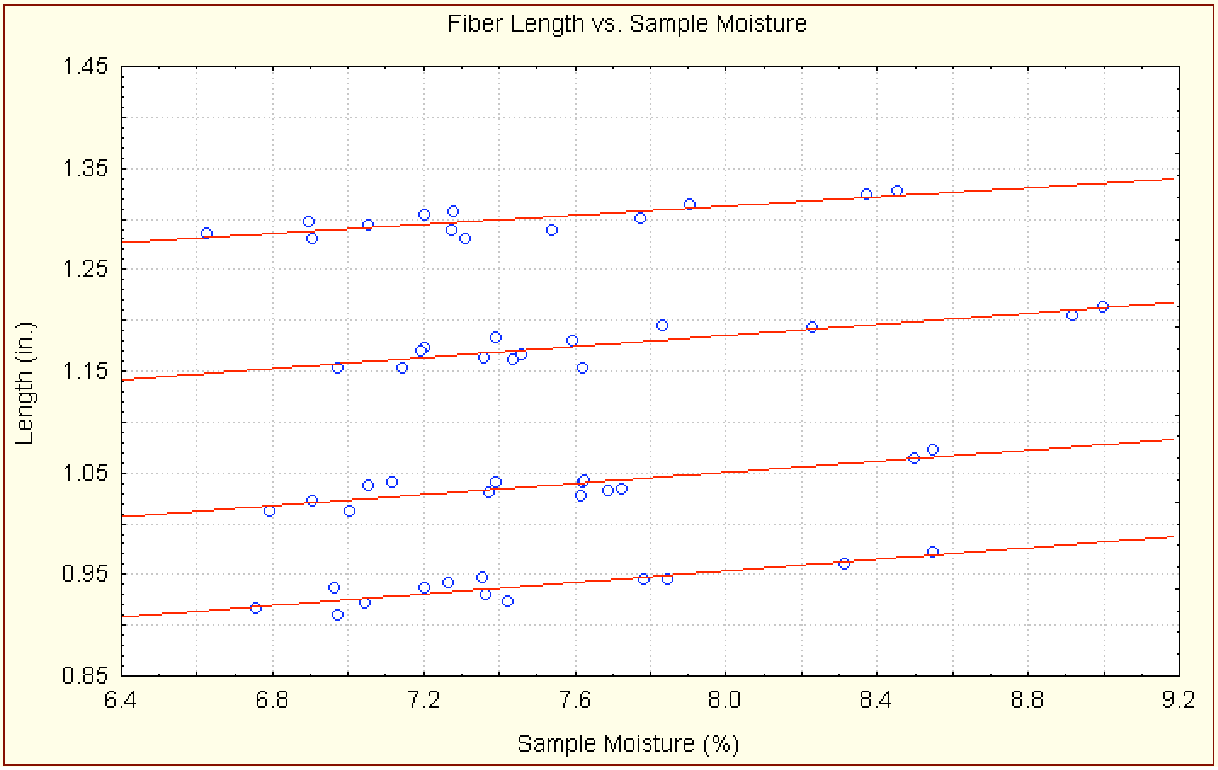

Figure 3: Fiber Length vs. Moisture

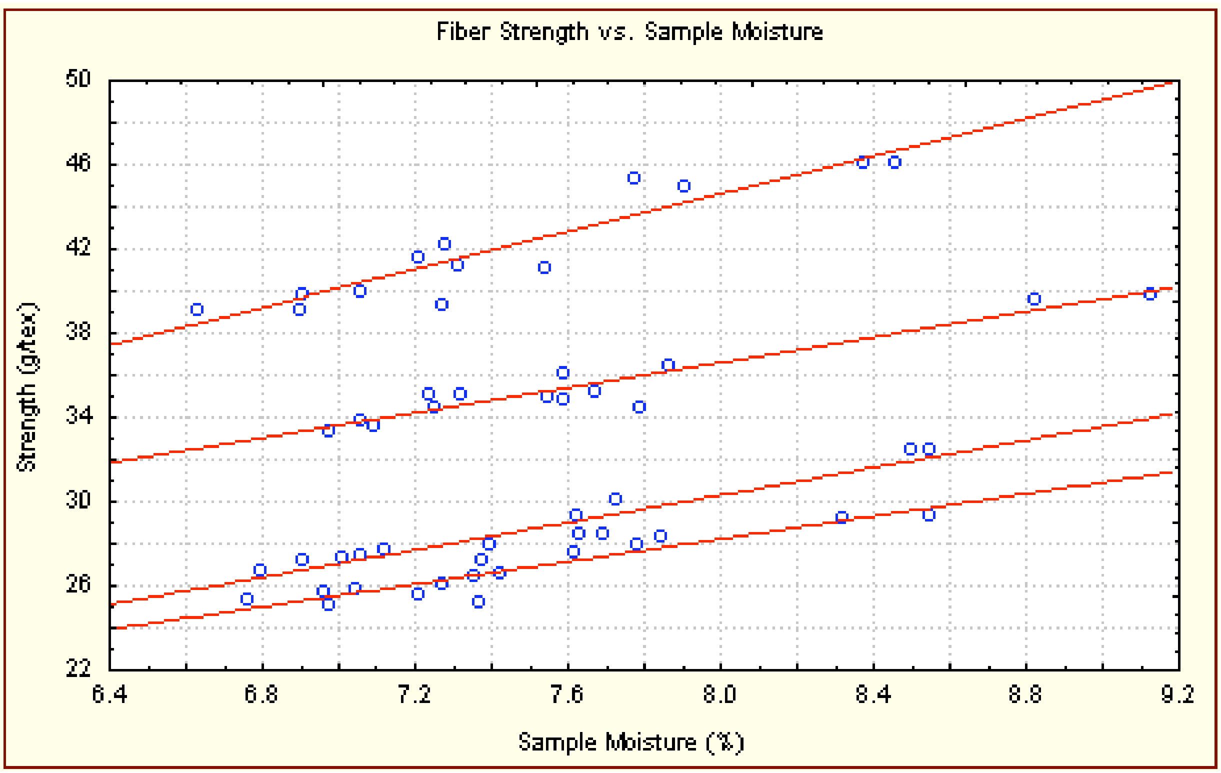

Figure 4: Fiber Strength vs. Moisture

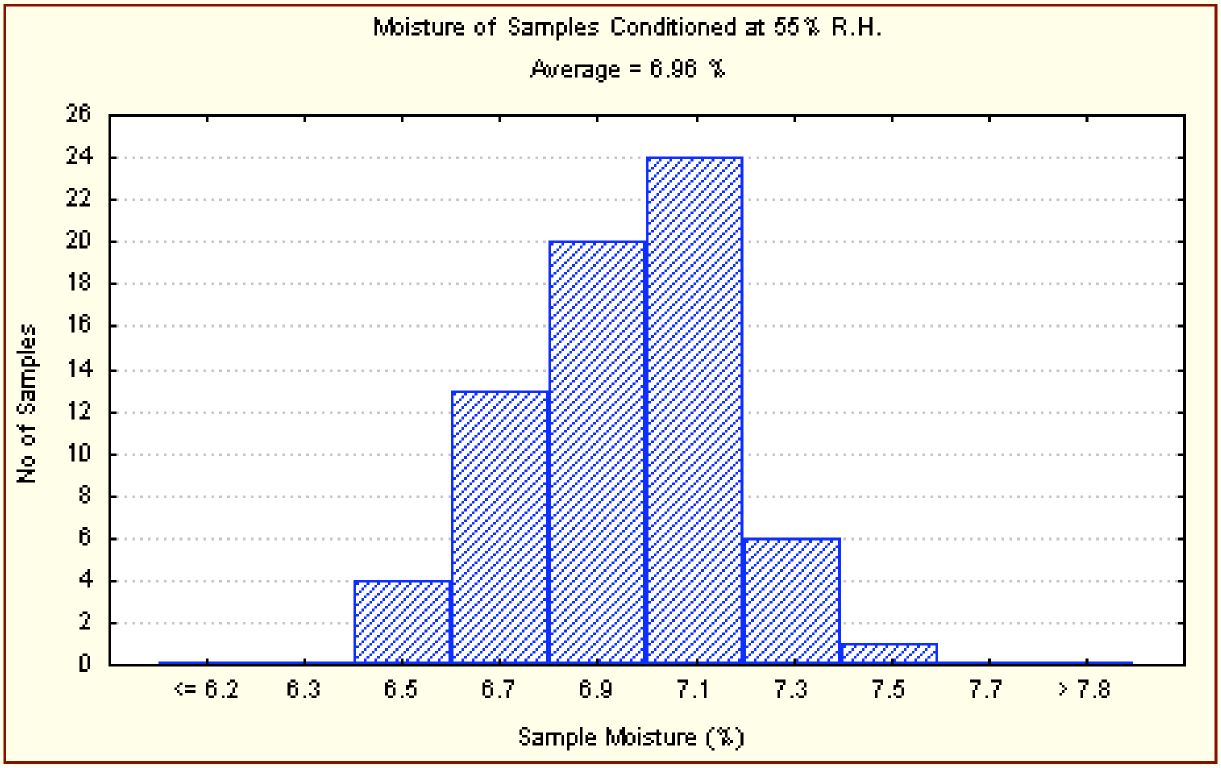

Figure 5: Distribution of Moisture for Samples Conditioned at 55 % R.H.

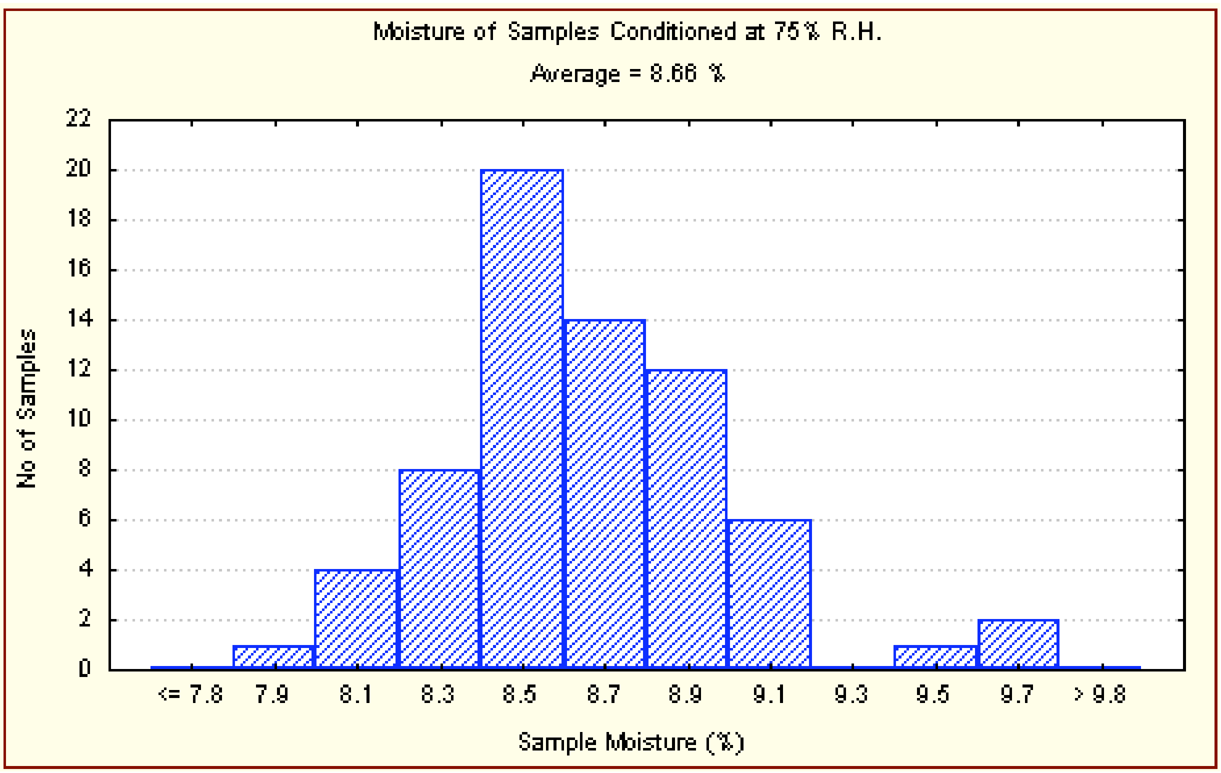

Figure 6: Distribution of Moisture for Samples Conditioned at 75 % R.H.

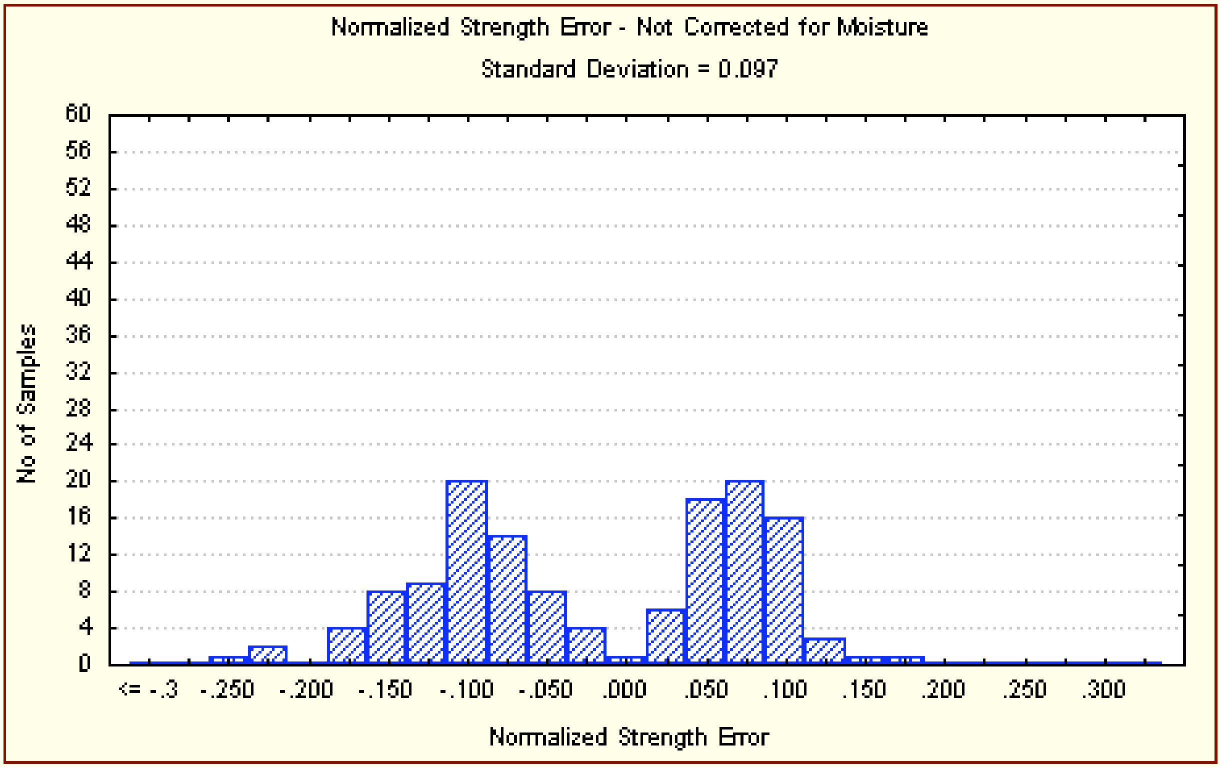

Figure 7: Distribution of Strength Error for Samples Conditioned at 55% and 75% R.H.

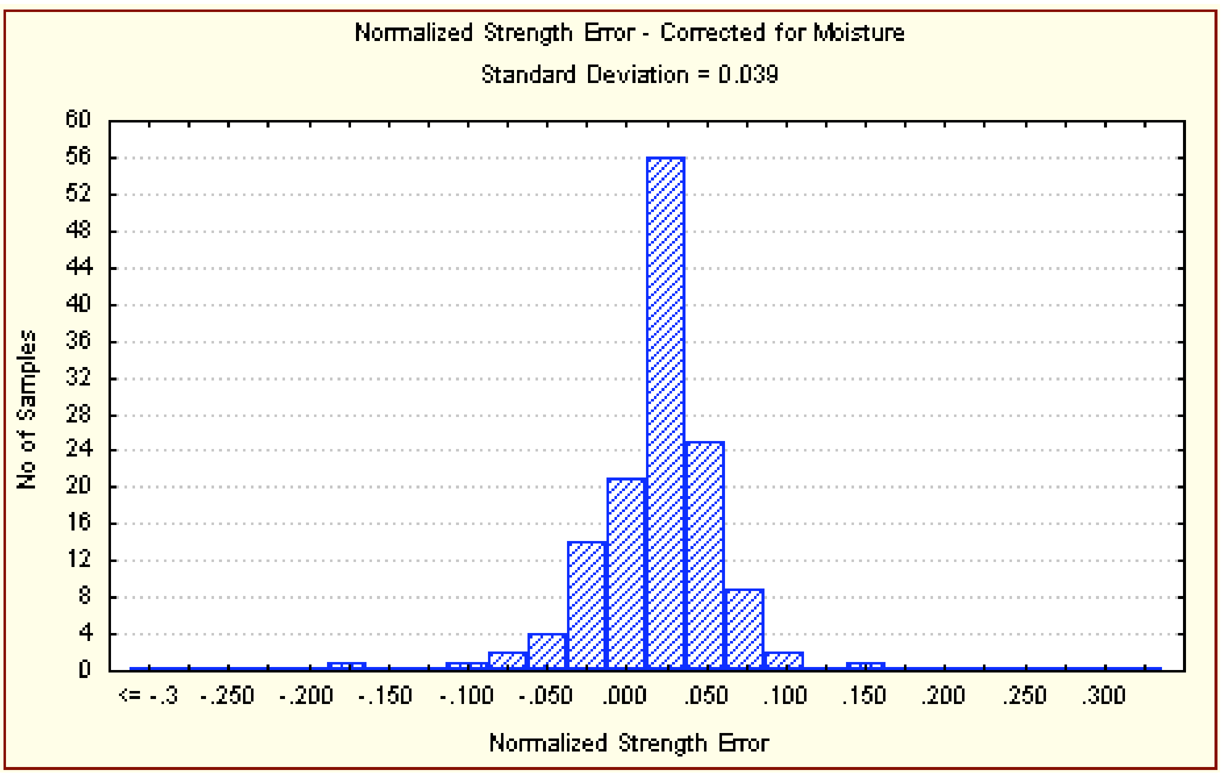

Figure 8: Distribution of Strength Error for Samples Conditioned at 55% and 75% R.H. after Correction for Moisture

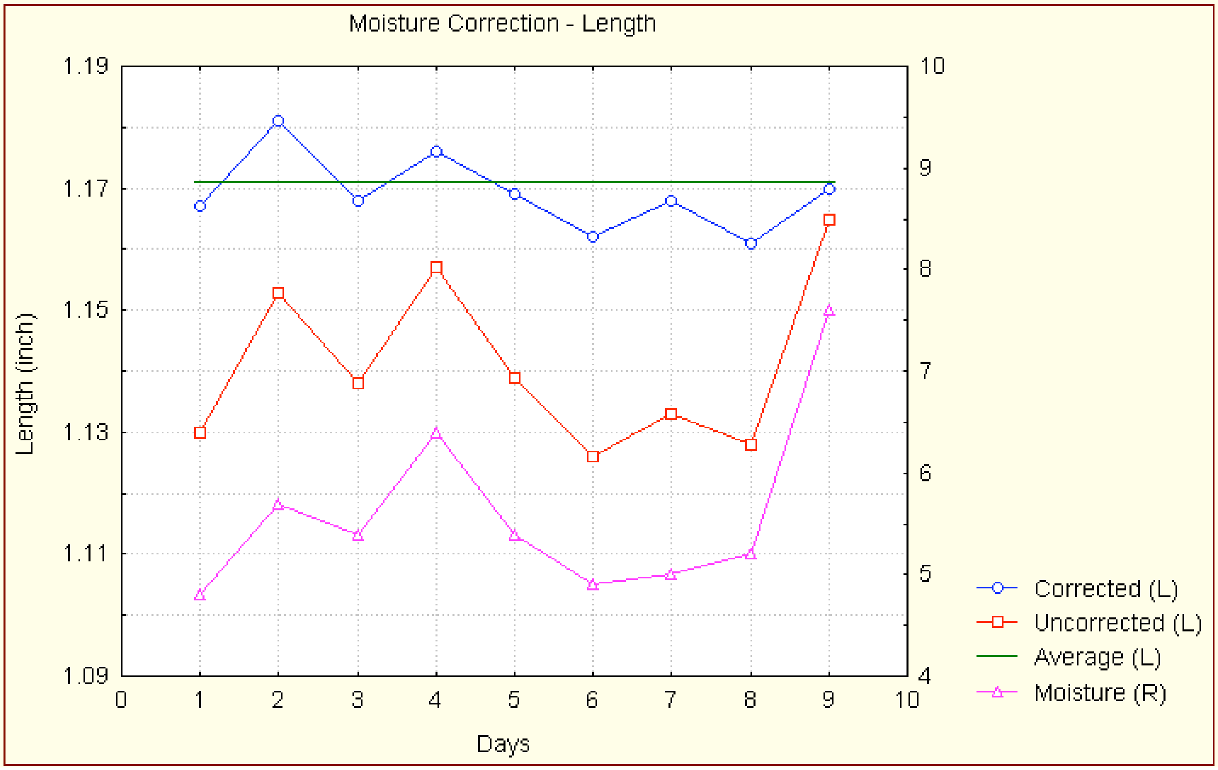

Figure 9: Length Calibration Checks

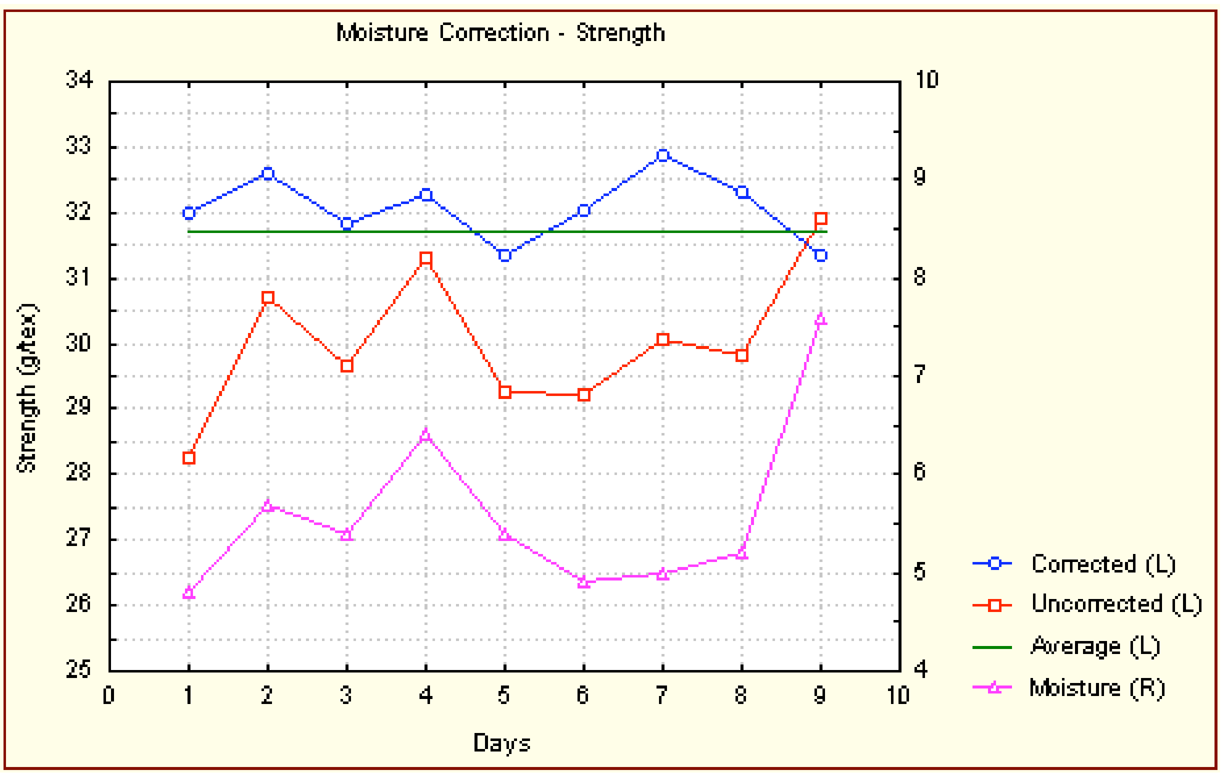

Figure 10: Strength Calibration Checks