COMPARISON OF SELECTED BALE MOISTURE MEASUREMENTS IN A COMMERCIAL GIN

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Abstract

Proper measurement of bale moisture content (mc) is crucial to proper management of a cotton gin. One issue would be to avoid producing wet cotton, unacceptable for Commodity Credit Corporation Marketing Assistance Loan Program, which is defined to be a bale of cotton which is at or above 7.5% wet basis (8.1% dry basis) anywhere in the bale. Several meters are available from different manufacturers for the measurement of cotton mc. Data were collected with four of these meters at a commercial gin which had limited moisture restoration capability and samples of lint taken from the same bales which were tested by the only standard cotton mc measurement, the oven method. The data included measurements by each meter plus the reference mc for 469 bales. For uncorrected meter readings the Uster Intelligin was the most accurate. After meter calibration the Samuel Jackson Tex-Max was the most accurate with a single factor correction but the Delmhorst manual probe meter was as accurate after correction for the bale temperature and additional slope and offset correction. The best meters after calibration would be expected to be within ±0.9 percent mc most of the time.

Introduction

In US commerce cotton bales weighing approximately 226 kg (500 lb) are formed at the gin and covered with bagging to protect them during transportation and storage. This cotton is transported, stored, and sold based on the bale weight without regard to the lint mc but changing mc directly affects the bale weight and thus the value. Gin managers have always been concerned about the lint mc, ginning at lower mc results in more efficient cleaning while ginning at higher mc results in better fiber length quality (Hughs et al., 1994). Moisture restoration of lint in gins has been practiced for many years (Griffin and Harrell, 1957). In a few cases it became apparent that too much moisture was added and lint quality degradation occurred during bale storage. In response to this problem the industry recommended that the lint leave the gin with mc below 7.5% wet basis (8.1% dry basis). Wet cotton has always been unacceptable for the Commodity Credit Corporation Marketing Assistance Loan Program (CCC Loan) but was not clearly defined. In 2006, the Farm Service Agency (FSA) of the USDA issued a definition of wet cotton, which is unacceptable for the CCC Loan, as that with mc greater than 7.5% wb at any point in the bale (Federal Register, 2006).

There are several different commercially available meters for bale mc determination on the market today. Several companies offer portable hand-held meters for measuring the mc of fiber in a cotton bale. However, they have been regarded as having limited accuracy, are labor intensive in use, and no independent data was available indicating the accuracy of the meters in this application except for one review by Byler et al. (2009). That review found that the model C-2000 meter offered by Delmhorst (Delmhorst Instrument Co., Towaco, NJ), based on sample resistance, was low in cost compared to the competitors and was as accurate or more accurate than the others, although not very accurate with a root mean square residual (rmsr) of 0.8 percent mc, wet basis. The Delmhorst meter readings also need to be corrected for bale temperature.

A meter based on microwave transmission has been available from Vomax®, model 851-B, and is currently offered as the Tex-Max® (Samiel Jackson, Inc, Lubbock, TX). In a limited review of one of these meters by Delhom and Byler (2011) the Vomax meter tracked the reference oven based mc measurements well but consistently read approximately one percentage point too high.

Anthony and McCaskill (1973) and Anthony (1998) documented the increase in bale press pressure at lower mc required to form a bale in a Universal Density press and presented a mathematical model. Byler (2003) developed a microprocessor based system with appropriate electronics to use this model to measure bale mc with a root mean square residual of 0.40 when operated in a commercial gin. Lummus now offers a device using this method as the Bale Moisture Monitor (Lummus, Inc., Savannah, GA).

In addition to these meters, which are designed to measure the lint mc while it is in a bale, several instruments are available which measure lint mc before bale formation which may be useful in controlling bale mc. These include a near infrared based meter (Byler and Anthony, 1992; Anthony and Byler, 1998) and Intelligin (Uster Technologies, Inc., Knoxville, TN). The Intelligin moisture meter takes samples from the lint flue, typically before moisture restoration, measures the mc and then releases them back into the lint flow. If the gin is using moisture restoration the location of the lint meter relative to the moisture addition would affect the accuracy of bale mc reading. Also, past studies (Byler et al., 2002) have shown that moisture addition causes certain meters to read high, presumably because the adsorbed moisture on the lint affects the sensor more than if the same moisture had been absorbed into the fibers.

The only standard method for cotton moisture measurement is to weigh the lint, dry it in an oven, and then reweigh it (Shepherd, 1972; ASTM 2006). The loss in weight is used to calculate the moisture content, defined as the weight lost divided by the original weight. This mc is also called mc wet basis and is different from the percentage of weight lost divided by the dry weight in the sample called moisture regain or mc dry basis. Some published literature on the effects of bale mc use the wet basis moisture and some use the dry basis moisture. The 7.5% limit in the FSA rule is explicitly stated to be wet basis but the corresponding dry basis mc would be 8.1%.

The National Cotton Ginners Association requested that a study be made of commercially available bale mc meters in a commercial gin. The purpose of this study was to examine the results of measuring cotton bale mc using several commercially available moisture meters operating in a commercial gin but did not include the study of the effects of moisture restoration on the meter accuracy.

Materials and Methods

The first step was to identify a cooperating gin which had the appropriate meters available for study. Several gin managers were contacted and Southeastern Gin and Peanut in Surrency GA, was chosen to be the best location for the study. This gin consistently ginned at over 30 bales per hour, had a moisture restoration system capable of only low levels of moisture addition and used the Tex-Max in moisture control but also had Intelligin and the Lummus Bale Moisture Monitor installed. The USDA, ARS Cotton Ginning Research Unit, Stoneville, MS, had available a Delmhorst bale probe meter. The Tex-Max was serviced by a company representative before the data collection began and the gin manager performed the calibration available to him during the testing. A representative from Uster checked the performance of the Intelligin system before the data collection began. The Bale Moisture Monitor had not been calibrated in several years and no calibration was performed on the Delmhorst meter.

Four visits were made to the gin, on Oct. 18, Oct. 25, Nov. 8, and Nov. 15, 2011, to collect data and obtain lint samples for mc determination by the oven method. On the first visit it was determined that there was no appropriate location for the installation of the infrared meter, but Intelligin, Lummus Bale Moisture Monitor, Samuel Jackson Tex-Max, and Delmhorst meters were usable at the gin. Data from Intelligin and the TexMax were logged by bale number on the gin's computer system. Those data were obtained by gin personnel and sent electronically to be included in the study. Bale mc data were calculated by the Bale Moisture Monitor based on bale weights and bale numbers sent by the gin's computer system and the results displayed on the bale press control panel. Those data were manually recorded and the data entered into files for analysis. The indicated bale mc and bale temperature for the Delmhorst meter were recorded manually with the bale number and entered into files for later analysis.

Lint samples from the bale were subsamples of the lint sent to the classing office. On each visit 180 lint samples were obtained, placed in metal cans, sealed, and returned to Stoneville for moisture determination, wet basis, by the oven method (Shepherd, 1972) with a few samples taken at the lint flue. Data from as many of the additional meters as possible were collected for the same bales. All data were compiled by bale number. The data were combined into one data set and read into SAS, (SAS Institute, 2003) and analyzed by procedures MEANS and GLM.

The data were examined and bales for which data were not available for the oven and all four meters were discarded, so that all meters would be compared using data from the same bales. Next the uncorrected residuals were calculated (meter reading – oven reading) and totaled for each bale for all meters. This total was used to detect suspect data and three observations were rejected. This final data set was then used for further analysis. The average oven and meter readings were calculated for each meter and the difference was used as the offset correction. GLM was used to calculate the best fit straight line correction for each meter with and without intercept. Each of these corrections was compared to the oven mc for each bale resulting in four sets of residuals. The root mean square of each of these residual sets (rmsr) was calculated using the appropriate degrees of freedom to calculate a rmsr for each meter with each correction: none, offset, slope, offset and slope. The best meter reading was selected based on the lowest rmsr.

Results and Discussion

There were 626 bales with bale mc data and data for 77 samples taken from the lint flue obtained by the oven method. The data from the flue mc compared with the bale mc data showed that some of the time the bales did not have a higher mc than the lint in the flue, and indeed part of the time the ginner was asked to eliminate moisture restoration. When the mc was greater in the bale than in the flue the average gain was 0.5 percentage points, with data for 48 bales.

Because it was relatively labor intensive to insert the Delmhorst probe into bales a hammer-drill was employed. This approach proved to be quite successful because the insertion force was reduced to a trivial amount and the time required to insert the probe was likewise significantly reduced. A small thermocouple mounted in a needle (Model N, Electronic Development Labs, Danville, VA) was inserted into the hole created with the Delmhorst probe for measurement of the bale temperature.

After the data set was reduced for data missing from any of the four meters being tested there was complete data for 469 bales. The bale probe data was corrected for the bale temperature, the average bale temperature was 116°F, the uncorrected probe mc was 6.7% and the average corrected probe mc was 4.4%.

All oven mc were calculated wet basis. The average oven mc was 4.7% and 90% of the oven mc values were between 3.6% and 6.7%. This cotton was relatively dry, but was not beyond the range often observed in commercial gins. Any meter calibration, such as was conducted as part of this study, is only valid for the range of reference measurements. So this study applies to cotton bales in the range 3.6% to 6.7%. Meters often operate satisfactorily beyond the range for which they are calibrated, but there is no evidence in this study regarding the important question of how these meters operate around the crucial 7.5% mc because no cotton was encountered during the study in that range.

Each set of meter readings was compared to the oven mc for the same bales and rmsr values were calculated for uncorrected readings, readings corrected with an offset only, slope only, and with an offset and slope, Table 1. Based on these data the most accurate prediction of the bale mc without any correction was the data from Uster Intelligin, measured before moisture restoration. During the study some of the bales had not had moisture restoration and the average amount of moisture added was only 0.5 percentage points so logically if the testing had been done with more moisture restoration measurements made before moisture restoration would not have agreed as well. The Delmhorst probe, corrected for temperature, was clearly the second most accurate meter, with no reading correction.

Table 1. Root means square residuals of uncorrected and readings with simple corrections.

	Lummus Bale Moisture Monitor	Sam Jackson Tex-Max	Delmhorst probe	Uster Intelligin (lint in the flue)
Uncorrected	1.26	1.94	0.66	0.57
Offset only	0.56	**0.43**	0.58	0.55
Slope only	0.59	0.46	0.62	0.56
Offset and slope	**0.52**	0.43	**0.43**	**0.49**

With one correction term added the meters were all better with an offset than a slope correction. After the single offset correction for each meter the Tex-Max proved to be the most accurate meter. The simple offset was the best correction for the Tex-Max meter while the other meters required an offset and slope correction for their best accuracies. After correction for offset and slope the Delmhorst probe was as accurate as the Tex-Max after offset correction.

Figure 1 is a plot of the uncorrected Uster Intelligin measurements made in the lint flue, before moisture restoration, compared to the oven mc measurement of lint taken from the same bales. It is observed that Intelligin indicates 4.0%, or slightly above, for all mc measured at that level or below. The uncorrected data appears to fit well in the range above 4.0% for which there was data. The corrected data did not appear to fit much better and obscured the uncorrected data when plotted together and is not shown. This meter probably would not have been the most accurate if more moisture was added, as is done in some gins.

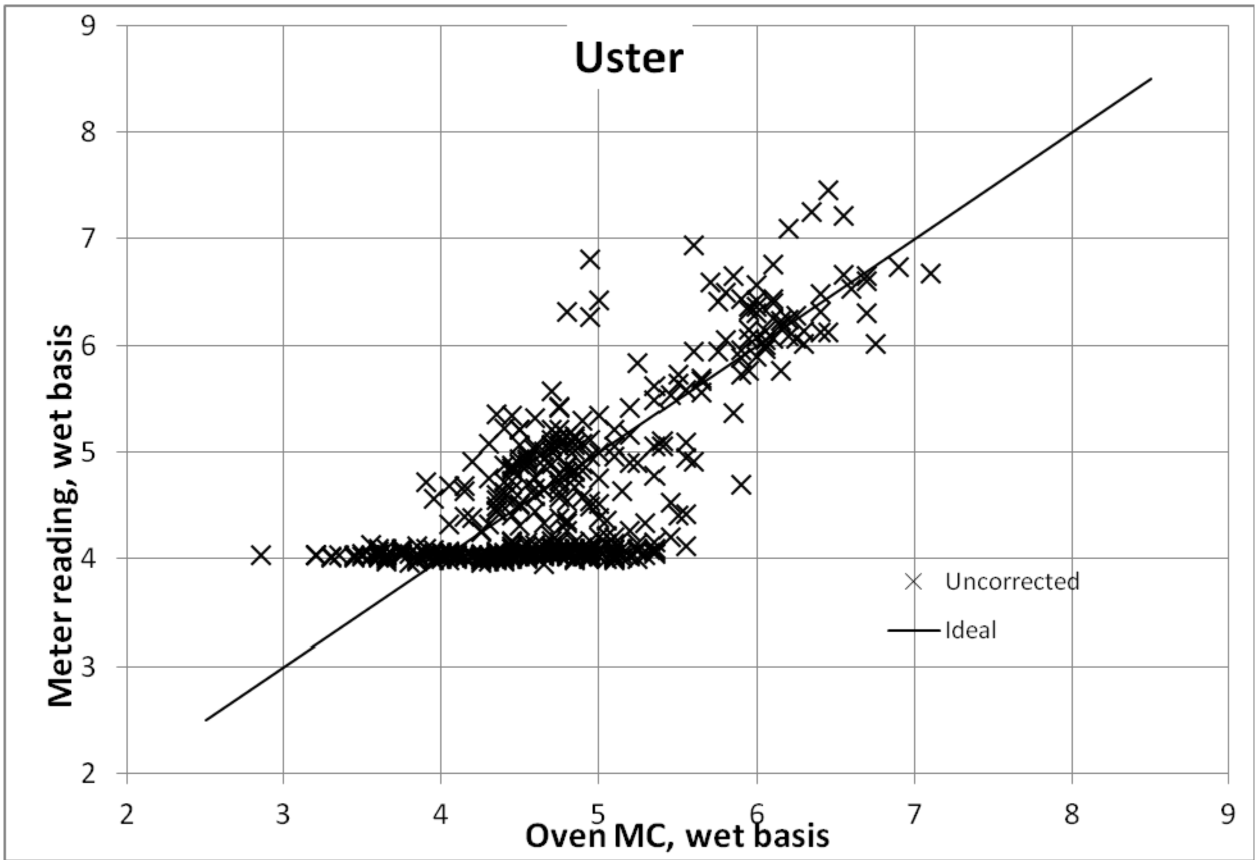

Figure 1. Uster Intelligin moisture measurements, uncorrected, compared to oven mc with line showing perfect fit.

Figure 2 is a plot of the Lummus Bale Moisture Monitor data. In this case the corrected and uncorrected data was different enough to place both on the same plot. Because the line fitting program GLM gave equal emphasis to each data point and the preponderance of data in the 4.2% to 5.2% range it appears that a better fit could be made for the relatively few end points, below 3.5% and above 6.0%, and that fit would be more appropriate for estimating mc levels above 7.0%. Ideally more data should be collected at mc levels above 7.0%, but wetter cotton was not available.

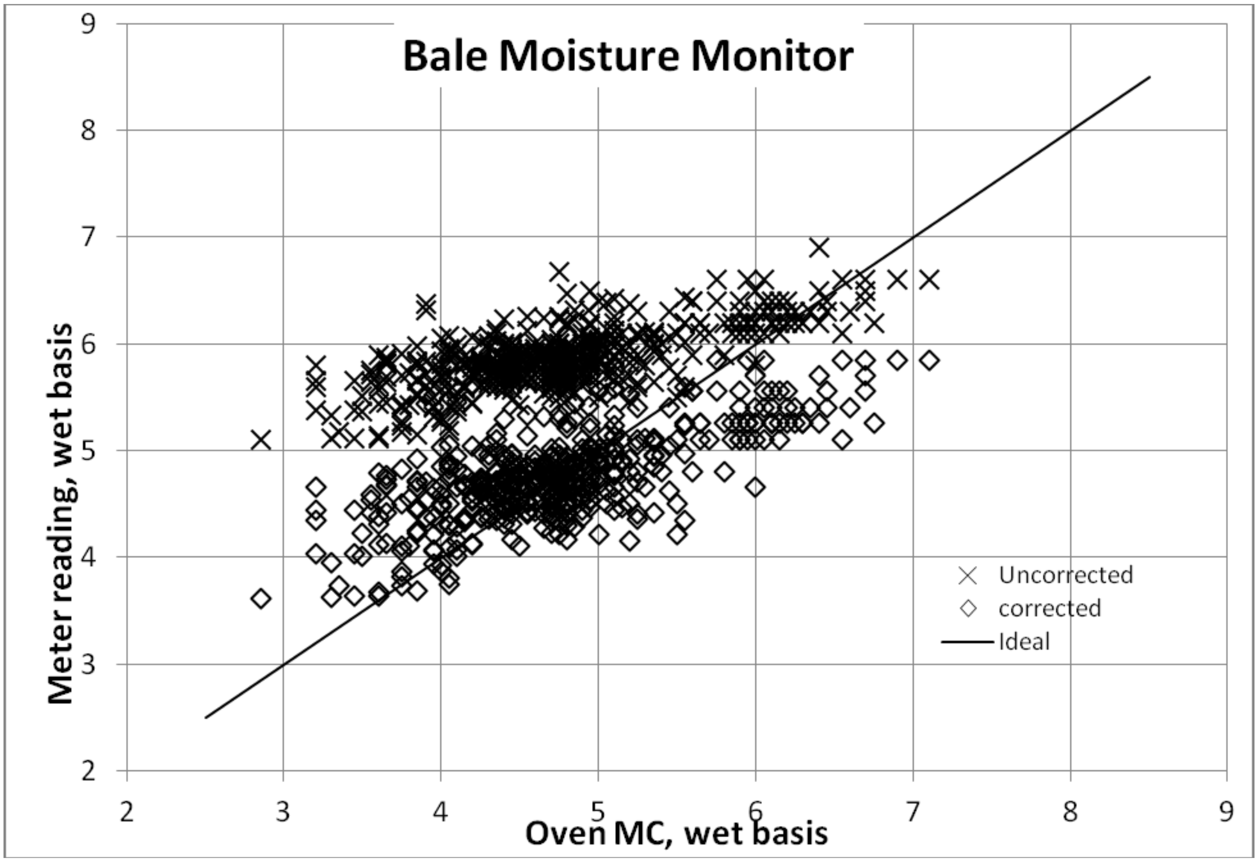

Figure 2. Lummus Bale Moisture Monitor readings, corrected and uncorrected with line showing perfect fit.

Figure 3 is a plot of the Delmhorst hand held probe meter data compared to the oven mc data for the same bales. The corrected and uncorrected data were so close that the uncorrected data obscured the corrected data. With this data it again appears that the large amount of data in the 4.2% to 5.2% range adversely affects the fit to the relatively few measurements below 3.5% and above 6.0%. A correction based on a fit to the data emphasizing the data outside the central range would probably be more appropriate for estimating mc levels above 7.0% for this meter also.

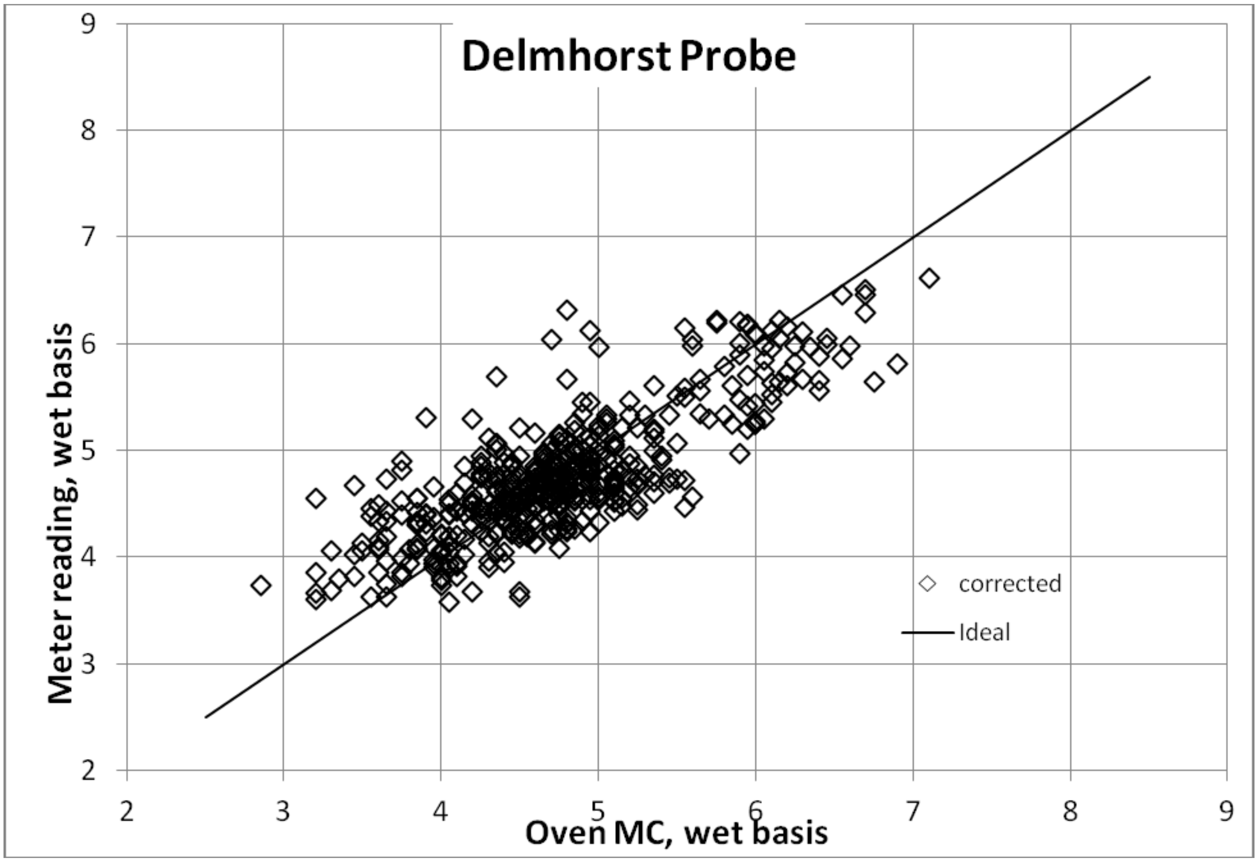

Figure 3. Delmhorst probe measurements, corrected for bale temperature, before offset and slope correction.

Figure 4 is a plot of the Samuel Jackson, Inc Tex-Max readings uncorrected and corrected with an offset compared to the oven mc data for the same bales. The uncorrected data was 1.9% higher than the corrected data. This was the best fit of the four meters after correction.

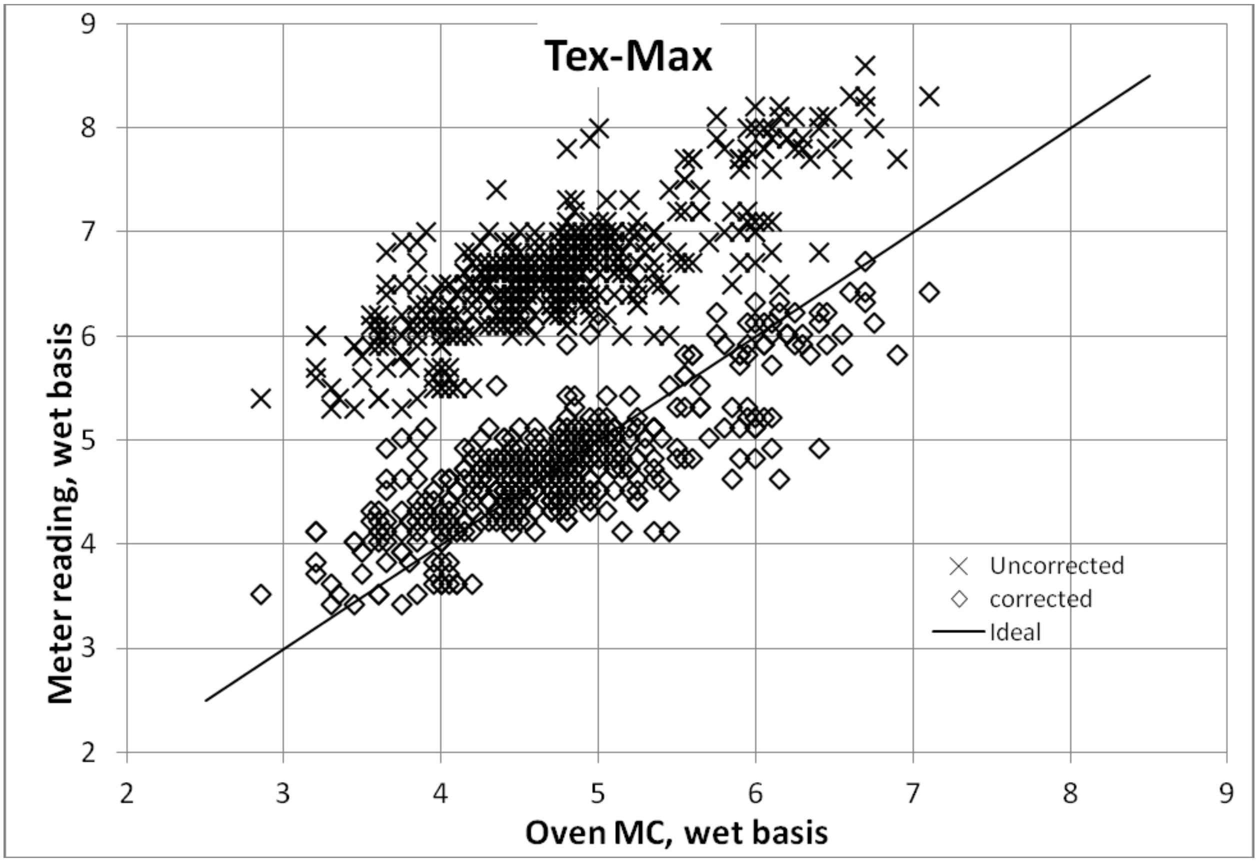

Figure 4. Samuel Jackson, Inc. Tex-Max readings, uncorrected and corrected for offset and line showing perfect fit.

The set point in control of bale mc should be chosen to assure that a maximum level not be attained. Some assurance that the maximum would rarely, but occasionally, be observed would be to use a set point at least two times the rmsr observed during calibration below the desired maximum. In this control situation 7.5% (wet basis) is the maximum and twice the best rmsr would be 0.86% so the maximum reasonable set point would be 6.6%. The readings in this study were for bales, the small samples of lint within the bale would vary from the overall bale mc reading. Therefore the maximum set point should be somewhat lower than this. Also, the only installation which knows that the rmsr is as low as 0.43 is Southeastern Gin and Peanut. Because meters can drift with time and little is known about the drift of these meters the rmsr of 0.43 would only be applicable during the 2011 ginning season. A prudent gin manager should choose a set point lower than 6.6% to allow for these additional issues. If the Delmhorst probe were used without correction a maximum set point might be 6.0%. More accurate meters and meters with a proven stability over time could be developed. With the increasing emphasis on properly measuring cotton bale mc perhaps progress will be made in improving this situation in the cotton ginning industry.

Conclusion

The goal of this project was to collect data with several commercially available cotton bale moisture measurement meters along with oven mc data and then compare the meters with the oven mc data. Several visits were made to a commercial gin which had four commercial meters which were studied resulting in complete data for 469 bales. The gin had limited capacity for moisture restoration and for some of the data the moisture restoration was turned off. The reference mc range was limited with 90% of the oven mc data in the range 3.6% to 6.7% wet basis. With the uncorrected meters the Uster Intelligin was the most accurate. After appropriate linear corrections the Samuel Jackson Tex-Max meter was the most accurate with a one term correction. The Delmhorst probe data corrected for the temperature of the cotton and an additional offset and slope correction was equally as accurate as the Tex-Max.

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Disclaimer

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References

Anthony, W.S. 1998. Development of a method to estimate the moisture content of cotton bales. Proc. Beltwide Cotton Conf. National Cotton Council. Memphis TN. Pp. 1641-1643.

Anthony, W.S. and R.K. Byler. Gin process control: importance to the cotton industry. Proc. Beltwide Cotton Conf. National Cotton Council. Memphis TN. Pp. 703-708

Anthony, W.S. and O.L. McCaskill. 1973. Forces involved in packaging lint cotton. The Cotton Gin and Oil Mill Press. 74(15):7-11.

ASTM. 2006. D 2495-01. Standard test method for moisture in cotton by oven-drying. In *Annual Book of ASTM Standards, Textiles*, 078-01. West Conshohoken, PA.: ASTM Intl.

Byler, R.K. and W.S. Anthony. 1992. Initial experiences in computer control of cotton gin drying. *Applied Eng. In Agric*. 8(5) 703-709.

Byler, R.K. and W.S. Anthony. 2003. Measurement of bale moisture content based on bale compression pressure. Proc. Beltwide Cotton Conf. National Cotton Council. Memphis TN. Pp. 763-766

Byler, R.K., W.S. Anthony, and M.E. Galyon. 2002. Method of estimating bale moisture content after moisture restoration. Proc. Beltwide Cotton Conf. National Cotton Council. Memphis TN. 8 pp.

Byler, R.K., M.G. Pelletier, K.D. Baker, S.E. Hughs, M.D. Buser, G.A. Holt, and J.A. Carroll. 2009. Cotton bale moisture meter comparison at different locations. *Applied Eng. In Agric*. 25(3) 315-320.

Delhom, C.D. and R.K. Byler. 2011. Performance of a microwave cotton bale moisture content meter. *Journal of Agricultural Science and Technology* 5(2) 181-187.

Federal Register. 2006. Storage, handling, and ginning requirements for cotton marketing assistance loan collateral, final rule. *Federal Register* 168:51422-51426.

Hughs, S.E., G.J. Mangialarid, Jr., and S.G. Jackson. Moisture control. In Cotton Ginners Handbook, pp 58-68. US Department of Agriculture, Agricultural Handbook 503, revision.

Griffin, A.C. and E.A. Harrell. 1957. Effects of moisture added at lint slide on lint quality and bale weight in humid cotton-growing areas. USDA Production Research Report No. 14.

SAS Institute. 2003. *SAS System for Windows*, Release 9.1. SAS Institute Inc., Cary, N.C.

Shepherd, J.V. 1972. Standard procedures for foreign matter and moisture analytical tests used in cotton ginning research. USDA Agricultural Handbook No. 422.