Standardizing Grain Moisture Meter Performance: Overview of an On-going Calibration Program

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Abstract. The Grain Quality Incentives Act of 1990, passed as part of the 1990 Farm Bill, outlined a broad-based approach for addressing grain quality concerns and enhancing the competitiveness of U.S. grain exports. One issue addressed by the Act was the need to standardize commercial grain inspection equipment. As a result of this legislation, the Federal Grain Inspection Service was authorized to work with the National Institute of Standards and Technology and the National Conference on Weights and Measures to develop testing and standardization procedures for grain moisture meters used in commercial transactions. This overview summarizes activities and accomplishments for a national grain moisture meter program that was implemented in 1993. Results and discussion focus on efforts to improve uniformity of moisture content measurements for fifteen major grains included in an on-going moisture meter calibration program. Summary results are presented for multiple years of data for a variety of moisture meter technologies.

Keywords. moisture meters, moisture content, grain, calibration, standardization
Introduction

Grain moisture content is an essential measurement for determining grain storability and adjusting grain weight to reflect actual market value. Moisture content is measured virtually every time grain is bought and sold; the measurements are made using rapid instrument technology including dielectric moisture meters and near-infrared instruments. Accurate results are required for fairness to producers and end-users, but uniformity of moisture measurements is also extremely important in facilitating grain marketing. Thus, there has been continued interest in standardizing moisture measurement—not only among meters of the same model type but also between different instrument models. Inherent differences between measurement technologies limit the extent to which results can be standardized. However, calibrations developed and verified using common grain sample sets and common reference analyses allow the greatest possible degree of standardization.

The 1990 Farm Bill authorized the Federal Grain Inspection Service (FGIS) to work with the National Institute of Standards and Technology (NIST) and the National Conference on Weights and Measures (NCWM) to standardize grain inspection equipment used in commercial sales transactions. Early in the process, it was agreed that initial standardization efforts should be for moisture meters, and that the program needed to be developed within the NCWM structure to take advantage of a proven process for establishing technical specifications and performance standards. FGIS was recognized as the appropriate standards-setting agency to provide reference moisture analyses. The NCWM formed a National Type Evaluation Technical Committee (NTETC) Moisture Meter Sector with membership representing State Weights and Measures departments, FGIS, NIST, moisture meter manufacturers, the Grain Elevators and Processors Society (GEAPS), the National Grain and Feed Association (NGFA), and university experts to develop design and evaluation criteria.

The Sector modified existing specifications in NIST Handbook 44 (2009), developed National Type Evaluation Program (NTEP) test procedures for NCWM Publication 14 (2009a), defined an on-going calibration program, and had procedures in place for type evaluation testing to begin in 1993. The evaluation process was defined to include an evaluation of basic instrument performance (Phase I) followed by a mandatory annual review of calibration performance (Phase II). The FGIS Technical Services Division in Kansas City was authorized as the sole NTEP testing laboratory for grain moisture meters. The purpose of this paper is to summarize activities and accomplishments of the NTEP grain moisture meter program.

NTEP Basic Model Performance – Phase I

Type evaluation testing in Phase I is described only briefly in this document with the primary intent of providing a better understanding of how it relates to the Phase II on-going calibration program. The existing NIST Handbook 44 design specifications were updated to require that instruments provided a greater level of automatic operation, sensed when moisture and temperature operating ranges were exceeded and provided appropriate warning messages, and provided security against unauthorized adjustment of metrological parameters that could affect moisture results. Test procedures were developed assuming instruments would be treated as “black boxes” that accept grain samples and provide moisture results. There was to be no evaluation of intermediate measurements such as sample weight, bulk density, or temperature. However, the type evaluation process was structured to test the performance of the “black boxes” under operating conditions that might stress those intermediate measurements. Type evaluation tests were also designed to test calibration performance, either directly or indirectly, in addition to the basic instrument design.
In a full type evaluation, instrument and calibration accuracy, repeatability, and reproducibility are tested for corn, soybeans, and Hard Red Winter (HRW) wheat over a six percent moisture range. A total of thirty samples per grain type, ten samples within each two percent moisture interval, are used for the accuracy test. Phase I testing is limited to a six percent moisture range primarily because of logistical problems with maintaining high moisture samples throughout the year. Meters meeting accuracy tolerances for corn, soybeans, and HRW wheat are not required to undergo Phase I calibration accuracy testing for additional grains before an NTEP Certificate of Conformance can be issued. A calibration for an additional grain type can be listed on the initial Certificate of Conformance after being tested with a set of 10-12 samples to verify the calibration is adjusted to agree, on average, with the FGIS air oven reference laboratory (FGIS air oven procedures are based on AACC (2000), AOAC (2007), and AOCS (2006)). Along with the calibration accuracy tests, testing performance at extreme sample temperatures for corn, soybeans, and HRW wheat represents the bulk of the Phase I testing.

An NTEP Certificate of Conformance is issued at the completion of Phase I testing. The certificate includes a description of instrument model: standard features and options, temperature ranges for which the instrument was tested and is allowed to operate, and calibrations that were tested and verified during evaluation testing. To date, NTEP certificates have been issued for ten instrument types, where each type may represent a model series as noted in table 1. To maintain an "active" certificate and be able to market instruments in NTEP states, manufacturers are required to participate in the Phase II on-going calibration program and make annual calibration updates as needed to keep instrument performance within NTEP tolerances. Over the past 14 years, the number of participants in the on-going calibration program has held fairly steady at between 5 and 7 instruments. NCWM (2009b) maintains a listing of active and inactive grain moisture meter certificates of conformance.

Table 1. The following grain moisture meter models\(^1\) met Phase I NTEP requirements and were issued a Certificate of Conformance.

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>Manufacturer</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAC 2000 NTEP Version, GAC 2100, GAC 2100a and GAC 2100b</td>
<td>RF Dielectric</td>
<td>DICKEY-john Corp.</td>
<td>Active</td>
</tr>
<tr>
<td>Sinar GrainPro Model 6310</td>
<td>RF Dielectric</td>
<td>CSC Scientific Co., Inc</td>
<td>Inactive</td>
</tr>
<tr>
<td>GMA-128</td>
<td>RF Dielectric</td>
<td>Seedburo Equipment Company</td>
<td>Inactive</td>
</tr>
<tr>
<td>Infratec 1227 and Infratec 1229</td>
<td>Near Infrared Transmission</td>
<td>Foss North America, Inc</td>
<td>Active</td>
</tr>
<tr>
<td>Grainspec-A</td>
<td>Near Infrared Transmission</td>
<td>Foss North America, Inc</td>
<td>Inactive</td>
</tr>
<tr>
<td>Motomco 919E and Motomco 919ES</td>
<td>RF Dielectric</td>
<td>Motomco Inc</td>
<td>Inactive</td>
</tr>
<tr>
<td>SL95</td>
<td>RF Dielectric</td>
<td>Steinlite Corp.</td>
<td>Active</td>
</tr>
<tr>
<td>Infratec 1241</td>
<td>Near Infrared Transmission</td>
<td>Foss North America, Inc</td>
<td>Active</td>
</tr>
<tr>
<td>Seedburo 1200A(^{[a]})</td>
<td>RF Dielectric</td>
<td>Seedburo Equipment Company</td>
<td>Inactive</td>
</tr>
<tr>
<td>OmegAnalyzerG</td>
<td>Near Infrared Transmission</td>
<td>Dickey-john Corp.</td>
<td>Inactive</td>
</tr>
<tr>
<td>AM5100</td>
<td>RF Dielectric</td>
<td>Perten Instruments</td>
<td>Active</td>
</tr>
</tbody>
</table>

\(^{[a]}\)In 2003 the rights to the Motomco 919ES were acquired by Seedburo, the instrument was renamed to the Seedburo 1200A, and the Certificate of Conformance was transferred.

\(^1\) The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.
Figure 1. Average difference between moisture predictions and air oven reference values for nine meter models\(^2\) on (a) corn, (b) soybeans, and (c) HRW wheat when using manufacturers' calibration coefficients and standardization settings provided with the instruments for Phase I testing.

\(^2\) Results are shown for comparison purposes. Identities of individual moisture meters are hidden throughout this paper due to restrictions on release of proprietary information.
Phase I accuracy test results are an indicator of instrument and calibration performance prior to participation in the NTEP program and provide a baseline for assessing subsequent improvements due to participation in the on-going calibration program. Accuracy bias (meter – air oven) results for nine NTEP meters are plotted in figure 1 for corn, soybeans, and HRW wheat. A comparison of instrument biases shown in figure 1 indicates average moisture content prediction differences between NTEP models ranged from 0.7 percentage points for corn to approximately 1.0 percentage points for HRW wheat prior to Phase I testing. In many instances, these results do not reflect final performance of the calibrations listed on the initial certificate of conformance because calibrations were typically adjusted to agree more closely with FGIS air oven reference values before proceeding to the Phase II calibration program and being implemented on field instruments prior to harvest. Thus, the basic model evaluation process contributes to an immediate improvement in agreement between different NTEP moisture meter models. Optional testing and bias adjustments for an additional twelve grains included in the NTEP program provides additional opportunity for calibration standardization. Table 2 lists the fifteen grains included in the NTEP moisture meter program.

Table 2. Major grains included in the NTEP annual calibration review.

<table>
<thead>
<tr>
<th>Grain Type</th>
<th>Grain Type</th>
<th>Grain Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>Hard Red Winter Wheat</td>
<td>Long Grain Rough Rice</td>
</tr>
<tr>
<td>Soybeans</td>
<td>Hard Red Spring Wheat</td>
<td>Medium Grain Rough Rice</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Soft Red Winter Wheat</td>
<td>Six-Rowed Barley</td>
</tr>
<tr>
<td>Oats</td>
<td>Durum Wheat</td>
<td>Two-Rowed Barley</td>
</tr>
<tr>
<td>Sunflower Seed</td>
<td>Soft White Wheat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hard White Wheat</td>
<td></td>
</tr>
</tbody>
</table>

NTEP On-going Moisture Calibration Program – Phase II

Program Goals and Scope

Initial goals for the NTEP Phase II on-going calibration program included: (1) verifying calibration performance over a wider moisture range than was realistic in Phase I testing, (2) extending NTEP certification to include additional grain types, (3) providing instrument and reference laboratory data that can be used by manufacturers to update calibrations, and (4) improving agreement among NTEP meter models by providing calibration performance information on a common set of grain samples using common air oven reference values. The relative importance of these program goals for a given model change over time as instruments progress from new designs with limited calibration data available to well established instruments with multiple years of calibration data available.

The NTEP on-going calibration program was designed to provide calibration data for the same samples (and with the same processes) that are collected by FGIS to review and develop calibrations for the moisture meter used in the official inspection system (USDA 1999). One difference, however, is that the scope of the NTEP program is limited to the 15 major grains (table 2) for which FGIS conducts annual calibration reviews; it does not include all 62 calibrations supported for the FGIS’ official meter (USDA 2008). Calibration data are collected on two instruments for each meter model and provided to the manufacturer along with air oven moisture and test weight reference values. Calibration reports are generated for each meter model and grain type and provided to the manufacturer. Calibrations not meeting NTEP performance tolerances are identified in the reports. The manufacturers are responsible for developing and implementing calibration updates that conform to NTEP performance tolerances. NCWM certificates of Conformance are re-issued on July 1; they list the latest calibration coefficients or calibration version identifications.
Calibration Reports and Review

The NTETC Moisture Sector adopted a calibration review process very similar to that used by FGIS for its official meter. Reports are generated using data collected over the most recent three years. Calibration performance results are compared against tolerances for both individual two percent moisture intervals and for overall calibration bias. Primary components of the calibration reports are moisture residual (meter – air oven) versus air oven plots, tables indicating 3-year average bias to air oven information, and similar tables showing individual year results for each of the most recent three years. The 3-year average table also indicates applicable calibration tolerances. When manufacturers update calibrations, they provide the NTEP laboratory with re-predicted moisture results, and a revised calibration report is prepared.

For illustration purposes, a typical calibration report was generated using averaged soybean data for three different NTEP meter models (so as not to disclose proprietary individual meter information) collected on 2006-2008 crop year samples and the results are presented in figure 2 and in tables 3 and 4. The moisture residual information in figure 2 is primarily useful in allowing a quick qualitative assessment of sample distribution and calibration performance across the range of soybean moisture content. The plotted information is also useful in spotting atypical samples.

Table 3 contains most of the information used to verify conformance with NTEP Phase II calibration requirements. The table presents calibration performance data and NTEP tolerances for two percent moisture intervals. Columns 2 through 4 show the number of samples analyzed over the most recent three years, the average bias to air oven (meter results – air oven), and the standard deviation of differences between meter and air oven results for the samples in the moisture intervals, respectively. In the 10-12 percent moisture content interval, for example, the NTEP laboratory analyzed 232 samples, the overall bias to air oven was 0.07 percentage points and the standard deviation of differences was 0.16. Table 4 presents these data for each individual year included in the report.

![Plot of Meter Accuracy vs USDA Air Oven Moisture](image)

Figure 2. Typical soybean moisture residual plot (meter prediction – air oven reference moisture) illustrating calibration performance across the moisture range. Data from three NTEP meter models were averaged to generate this plot.
Table 3. Typical 3-year calibration performance summary for soybeans. Data from three NTEP meter models were averaged to generate this table.

<table>
<thead>
<tr>
<th>Moisture Level</th>
<th>No. of Samples</th>
<th>Avg. Bias</th>
<th>STD.</th>
<th>Approval Tolerance</th>
<th>Adjustment For 95% Confidence Interval</th>
<th>NTEP Phase II Tolerance</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-8</td>
<td>8</td>
<td>0.14</td>
<td>0.11</td>
<td>0.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-10</td>
<td>87</td>
<td>0.10</td>
<td>0.11</td>
<td>0.35</td>
<td>0.02</td>
<td>0.37</td>
<td>*</td>
</tr>
<tr>
<td>10-12</td>
<td>232</td>
<td>0.07</td>
<td>0.16</td>
<td>0.35</td>
<td>0.00</td>
<td>0.35</td>
<td>*</td>
</tr>
<tr>
<td>12-14</td>
<td>166</td>
<td>0.09</td>
<td>0.17</td>
<td>0.35</td>
<td>0.00</td>
<td>0.35</td>
<td>*</td>
</tr>
<tr>
<td>14-16</td>
<td>110</td>
<td>0.03</td>
<td>0.25</td>
<td>0.35</td>
<td>0.00</td>
<td>0.35</td>
<td>*</td>
</tr>
<tr>
<td>16-18</td>
<td>57</td>
<td>0.12</td>
<td>0.29</td>
<td>0.36</td>
<td>0.06</td>
<td>0.42</td>
<td>*</td>
</tr>
<tr>
<td>18-20</td>
<td>6</td>
<td>-0.08</td>
<td>0.31</td>
<td>0.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-22</td>
<td>7</td>
<td>0.05</td>
<td>0.57</td>
<td>0.44</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To Max Limit</td>
<td>673</td>
<td>0.07</td>
<td>0.20</td>
<td>0.20</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>22-24</td>
<td></td>
<td></td>
<td></td>
<td>0.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-26</td>
<td>1</td>
<td>0.05</td>
<td>0.52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

STATUS column: * - meets the NTEP tolerance
** - does not meet NTEP tolerance

Table 4. Typical individual year calibration performance summaries for soybeans. Data from three NTEP meter models were averaged to generate this table.

<table>
<thead>
<tr>
<th>Moisture Level</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Samples</td>
<td>Avg. Bias</td>
<td>STD.</td>
<td>Avg. Bias</td>
</tr>
<tr>
<td>6-8</td>
<td>1</td>
<td>0.23</td>
<td>6</td>
</tr>
<tr>
<td>8-10</td>
<td>25</td>
<td>0.04</td>
<td>41</td>
</tr>
<tr>
<td>10-12</td>
<td>95</td>
<td>0.09</td>
<td>80</td>
</tr>
<tr>
<td>12-14</td>
<td>47</td>
<td>0.14</td>
<td>56</td>
</tr>
<tr>
<td>14-16</td>
<td>20</td>
<td>0.12</td>
<td>45</td>
</tr>
<tr>
<td>16-18</td>
<td>27</td>
<td>0.21</td>
<td>12</td>
</tr>
<tr>
<td>18-20</td>
<td>2</td>
<td>0.20</td>
<td>4</td>
</tr>
<tr>
<td>20-22</td>
<td>3</td>
<td>0.07</td>
<td>2</td>
</tr>
<tr>
<td>To Max Limit</td>
<td>220</td>
<td>0.11</td>
<td>246</td>
</tr>
<tr>
<td>24-26</td>
<td>1</td>
<td>0.05</td>
<td></td>
</tr>
</tbody>
</table>

STATUS column:
a - violates condition a
b - violates condition b
The last four columns in Table 3 show tolerances for the average bias values and indicate approval status for each two percent moisture content interval. Values in the Approval Tolerance column represent one-half of the tolerance specified in NIST Handbook 44 for use in field testing individual instruments. For soybeans (and most small grains), the approval tolerance starts at 0.35 and increases to a value of 0.02 times the upper moisture limit for the two percent interval at moisture contents of 18 percent and above. A similar approach is used for the coarse grains (corn, oats, rice, sorghum, and sunflower seed) where the approval tolerance starts at 0.40 and increases to 0.025 times the upper moisture interval limit at moisture contents above 16 percent. Approval tolerances are applied directly for a six percent moisture range representing the primary market moisture range. For moisture content intervals outside the primary market range, a 95 percent confidence interval is applied to avoid forcing calibration changes based on a relatively small number of samples. For soybeans (Table 3), calibration performance is evaluated in two percent intervals for the 8-18 percent moisture range. The overall calibration bias is evaluated over a moisture range of 6-22 percent against a tolerance of 0.20 percentage points of moisture content. A similar approach is used for all NTEP grains, but different moisture ranges are used as appropriate for the grain being evaluated (NCWM 2009a).

Assessing Impact of NTEP Moisture Meter Standardization

Funk (1998) presented a comprehensive overview of grain moisture measurement in the United States and discussed the role of NTEP moisture meter standardization in that context. At that time, seven meter models were listed as NTEP certified and FGIS had just selected one of those models (Dickey-john GAC 2100) as its new official moisture meter. NTEP certification was one of the qualifying criteria used by FGIS in the selection process. The Phase II on-going calibration was well established by then and was described as a success, but no performance data were presented. The following sections reflect on recent program progress and present calibration performance data.

Introduction of New Instrument Models

It can be argued that the establishment of clearly defined design specifications and performance tolerances has resulted in the development and marketing of more new moisture meter designs than would have occurred in an environment of greater uncertainty as to state certification requirements. Certainly there is a more clearly defined process for moving new instrumentation into the marketplace and developing calibrations for the major grain types. Movement of instruments into and out of the NTEP program has been fairly dynamic. Four of the seven NTEP-certified meter models listed by Funk (1998) no longer have active certificates. Only one of the models listed has not been modified. The initial round of Phase I testing largely represented existing meter models with the minimum amount of modification needed to meet NTEP requirements. The program then went through a period where a few new meter models were submitted for testing, but much of the NTEP test activity involved evaluation of more extensive modifications to previously certified models. New instrument designs, developed to comply with NTEP requirements, are now moving into the program.

Calibration Performance

Considerable effort goes into collection of the calibration sample set used to review calibration performance, and make calibration updates, for the FGIS official meter and NTEP-certified meters. Approximately 1100 samples are collected each year for the 15 major grain types. Within each grain type, samples are obtained from diverse growing areas in the United States in
proportion to the amount of production attributable to each area. The sample set is in itself relatively unique and difficult to assemble on an annual basis. The real value in the sample set, however, is when it is used in the collection of calibration data on each of the NTEP instruments and air oven reference values are available from a common laboratory. Use of a common sample set and air oven reference values provides the information needed to best align results for the different meter models.

Funk (1990 and 1998) discussed technology differences among dielectric moisture meters and observed that model-to-model moisture result comparisons yield differences that are far larger than the unit-to-unit differences within an instrument model. This is true even though different meter models might be equally accurate when compared to air oven reference values. Rather than attempting to reduce inherent, sample dependent differences between meters representing different technologies, the focus of the NTEP Phase II calibration program has been on improving overall agreement with the reference method. NTEP calibration moisture bias results, where meter model are not disclosed, are now reported annually in the minutes of the NTETC sector meeting (NCWM 2008). Results from the 2005-2007 crop year reports for fourteen NTEP grains are shown in Appendix A. There are only four meter models currently in the calibration program for which all three years of data are available. Since data are available for only two instrument models for sunflower seed, bias information for sunflowers is not included in Appendix A.

The charts provide current information on average moisture differences between NTEP meter models across a representative moisture range for each grain type. Similar to the information presented in table 3, the charts also show the number of samples analyzed in each two percent moisture interval. The reported average bias differences are generally smaller in the intervals with the largest number of samples. Comparing the information in figure 1 (based on Phase I testing) with the results in Appendix A for corn, soybeans, and HRW wheat indicates initial average moisture differences between meter models were two to three times larger than the differences now seen between meter models.

While the Phase II calibration review and update process has remained relatively unchanged, the regulatory aspects of the program have been refined over the years. There is now less emphasis placed on calibration performance at moisture extremes, largely because samples are not reliably available at very high (or low) moisture contents for every crop year. The review process now emphasizes performance in the most typical market moisture ranges for each grain type. This shift in emphasis is expected to reduce the frequency of calibration updates without compromising performance in primary market moisture ranges.

**Potential for Program Improvement**

**Calibration Sample Set.** Differences in year-to-year calibration performance may be related as much or more to the randomness of sample availability and selection than they are to long term changes in grain varieties and associated properties. A calibration review process limited to the most recent three years of data can result in situations where calibrations are shifted up one year and back down the next year, or vice versa. A better understanding of the underlying causes for year-to-year variability could facilitate a more optimal standardization process.

**Verifying performance of field instruments.** Most states still verify the performance of individual instruments using samples referenced to their air oven. Field test tolerances are tight enough that samples must be carefully screened and selected to minimize chances of inappropriately failing instruments that might be closely aligned with master units in the Phase II program. Field testing like-meter to like-meter comparisons offers the potential for tightening performance for a network of instruments. This is a viable approach when supported by the Phase II program.
Conclusion

National Type Evaluation Program moisture meter testing (Phase I) and on-going calibration performance review (Phase II) provides needed structure and support for standardization of moisture measurements used in commercial transactions. Clearly defined design specifications and performance expectations take some of the uncertainties out of developing new moisture meter models and have helped promote development of new instruments and measurement technologies. Data collected in the on-going calibration program provides baseline information needed to more closely align moisture results among different meter models. The Phase II calibration program also provides an opportunity to calibrate and standardize meters to the same national sample set and air oven results used by FGIS to support the official inspection system.

References


Appendix A – Calibration Performance for NTEP Moisture Meters

**Moisture Meter Comparison - Corn**
2005 - 2007 Crop Years

- Bias with respect to oven
- Moisture Interval/Number of Samples

**Moisture Meter Comparison - Soybeans**
2005 - 2007 Crop Years

- Bias with respect to oven
- Moisture Interval/Number of Samples
Appendix A (cont). Calibration Performance for NTEP Moisture Meters

Moisture Meter Comparison - Hard Red Winter Wheat
2005 - 2007 Crop Years

Moisture Meter Comparison - Durum Wheat
2005 - 2007 Crop Years
Appendix A (cont). Calibration Performance for NTEP Moisture Meters

Moisture Meter Comparison - Hard Red Spring Wheat
2005 - 2007 Crop Years

Moisture Interval/Number Samples

-0.5 -0.4 -0.3 -0.2 -0.1 0.0 0.1 0.2 0.3 0.4 0.5
8-10% 10-12% 12-14% 14-16% 16-18%
20 51 45 25 13

Bias with respect to oven
Official Meter (+0.10) Meter 1 (+0.17) Meter 2 (+0.11) Meter 3 (+0.17)

Moisture Meter Comparison - Hard White Wheat
2005 - 2007 Crop Years

Moisture Interval/Number of Samples

-0.5 -0.4 -0.3 -0.2 -0.1 0.0 0.1 0.2 0.3 0.4 0.5
8-10% 10-12% 12-14%
47 28 12

Bias with respect to oven
Official Meter (+0.07) Meter 1 (+0.05) Meter 2 (+0.06) Meter 3 (+0.07)
Appendix A (cont). Calibration Performance for NTEP Moisture Meters

Moisture Meter Comparison - Soft Red Winter Wheat
2005 - 2007 Crop Years

Moisture Interval/Number of Samples

Bias with respect to oven

-0.5
-0.4
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5

10-12% 12-14% 14-16% 16-18%
31 73 32 24

Bias with respect to oven

Official Meter (+0.15)
Meter 1 (+0.07)
Meter 2 (+0.03)
Meter 3 (+0.13)

Moisture Meter Comparison - Soft White Wheat
2005 - 2007 Crop Years

Moisture Interval/Number of Samples

Bias with respect to oven

-0.5
-0.4
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5

8-10% 10-12% 12-14% 14-16%
37 29 26 12

Bias with respect to oven

Official Meter (+0.16)
Meter 1 (+0.07)
Meter 2 (-0.02)
Meter 3 (-0.02)
Appendix A (cont). Calibration Performance for NTEP Moisture Meters

Moisture Meter Comparison - Long Grain Rough Rice
2005 - 2007 Crop Years

Moisture Interval/ Number of Samples

- Bias with respect to oven

- Official Meter (+0.16)
- Meter 1 (+0.11)
- Meter 2 (+0.07)
- Meter 3 (+0.05)

Moisture Meter Comparison - Medium Grain Rough Rice
2005 - 2007 Crop Years

Moisture Meter Interval/ Number of Samples

- Bias with respect to oven

- Official Meter (-0.06)
- Meter 1 (-0.15)
- Meter 2 (+0.11)
- Meter 3 (+0.09)
Appendix A (cont). Calibration Performance for NTEP Moisture Meters

Moisture Meter Comparison - Oats
2005 - 2007 Crop Years

Moisture Interval/Number of Samples

Bias with respect to oven

Official Meter (+0.05)  Meter 1 (0.00)  Meter 2 (-0.04)  Meter 3 (-0.08)

Moisture Meter Comparison - Grain Sorghum
2005 - 2007 Crop Years

Moisture Interval/Number of Samples

Bias with respect to oven

Official Meter (-0.06)  Meter 1 (-0.01)  Meter 2 (-0.03)  Meter 3 (-0.02)
Appendix A (cont). Calibration Performance for NTEP Moisture Meters

Moisture Meter Comparison - Six Row Barley

2005 - 2007 Crop Years

<table>
<thead>
<tr>
<th>Moisture Interval/Number of Samples</th>
<th>Bias with respect to oven</th>
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</thead>
<tbody>
<tr>
<td>8-10%</td>
<td>-0.3</td>
</tr>
<tr>
<td>10-12%</td>
<td>-0.4</td>
</tr>
<tr>
<td>12-14%</td>
<td>-0.5</td>
</tr>
<tr>
<td>14-16%</td>
<td>-0.6</td>
</tr>
</tbody>
</table>

Moisture Interval/Number of Samples

- Official Meter (+0.15)
- Meter 1 (+0.07)
- Meter 2 (+0.03)
- Meter 3 (+0.08)

Moisture Meter Comparison - Two Row Barley

2005 - 2007 Crop Years

<table>
<thead>
<tr>
<th>Moisture Interval/Number of Samples</th>
<th>Bias with respect to oven</th>
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</thead>
<tbody>
<tr>
<td>8-10%</td>
<td>-0.1</td>
</tr>
<tr>
<td>10-12%</td>
<td>-0.2</td>
</tr>
<tr>
<td>12-14%</td>
<td>-0.3</td>
</tr>
<tr>
<td>14-16%</td>
<td>-0.4</td>
</tr>
</tbody>
</table>

Moisture Interval/Number of Samples

- Official Meter (+0.13)
- Meter 1 (+0.09)
- Meter 2 (+0.01)
- Meter 3 (+0.02)