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A New Generation of Grain Moisture Meters

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One of the technologies currently used in the commercial determination of grain moisture is dielectric technology, a technology that has been in use for over 60 years. Although dielectric technology has some inherent limitations, meter moisture determination has improved over the years with its use. Research in recent years by the Agriculture Research Service (ARS) and the United States Department of Agriculture (USDA) has provided new insight into the way moisture is sensed by dielectric type grain moisture meters. In addition to providing a brief history of dielectric technology, this article describes research that will give rise to a new generation of dielectric moisture meters, the impact of this new technology, and the selection of a new official meter.

Dielectric Moisture Meters – Pre-1998 Meters

Although some meters were automatic and displayed the results digitally without calculations, many of the first commercial dielectric grain moisture meters, including non-National Type Evaluation Program (NTEP) meters supplied measurements for the final moisture result. That is, the operator must make separate measurements of temperature, volume, and/or weight and apply those measurements in making the final moisture determination.

Some of these meters have interchangeable modules that have to be connected to and interchanged for different grain types. Some meters need lookup tables to determine the final moisture content of the grain sample. Along with the many user applied measurements and interactions that must be performed with these moisture meters, the meter calibrations for the various meter types are based on different prediction equations, and grain sample sets. All of these factors can affect uniformity among the various meters and the accuracy of the moisture determination.

A manual temperature correction is used for many of the meters that were placed into service before January 1, 1998. For these meters, the user manually determines the temperature of the grain. The grain moisture reading is obtained, then the temperature of the grain and moisture reading are compared to a look-up table that provides the final moisture results based on the grain temperature and the moisture reading. Some moisture levels exceed the look-up table so the user must calculate the temperature correction and final moisture result. Any user errors due to improper temperature measurements, improper use of the look-up table, incorrect look-up tables, and improper calculation of the temperature correction will contribute to errors in the final grain moisture result.

The weight of the grain is also a factor that will affect the moisture result. For many of the meters that were placed into service prior to January 1, 1998, the user must weigh the sample of grain prior to putting the sample in the grain moisture meter's hopper. Some of these meters have a scale within the hopper and the operator must read graduated lines to ensure that the sample weight is appropriate prior to making the measurement. Errors can occur due to improper weighing of the grain sample or inoperable or malfunctioning built-in scales.

Some of these grain moisture meters use "calibration modules," which are attachments for the meter that contain the calibrations for various grain types. These grain specific modules are connected to the meter and are interchanged by the user based on the various grain types for which the moisture determinations are made. Inappropriate use of the modules may cause errors in the test results.

Some of these meters do not directly indicate percent moisture. For these meters, a number based on the dielectric reading of the grain sample is obtained from the device by user-operated dials on the meter and the number obtained from the meter corresponds to a moisture value on a look-up table. User error due to inappropriate use of the meter and look-up tables could lead to errors in the test results of these meters.

Many of the variations and errors in the results obtained from this earlier generation of moisture meters could be attributed to operator error and calibration sample set variations.

Dielectric Moisture Meters – Post-1998 Meters

In 1991 a National Type Evaluation Technical Committee (NTETC) Grain Sector was established to improve the uniformity and accuracy of commercial grain moisture meters and their associated measurements. As a result of the work of the Grain Sector, a National Type Evaluation Program (NTEP) for grain moisture meters was established; a new Code was developed in National Institute of Standards and Technology (NIST) Handbook (HB) 44, *Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices* for field evaluation; and new criteria were developed in National Conference on Weights and Measures (NCWM), Inc. Publication 14 for NTEP evaluation of grain moisture meters for meters that were manufactured or placed into service after January 1, 1998.

Although there was no change to basic measurement technologies, improvements were made in commercial moisture determinations because meters manufactured or placed into service after January 1, 1998, were designed to meet the new criteria in NIST HB 44 and NCWM Publication 14. Changes to the design criteria for these meters were such that the operator was no longer required to determine grain volume, weight, and/or temperature of the grain sample; these measurements became a function of the meter and eliminated much of the user errors associated with these measurements. Operating range criteria for these meters is an automatic function to ensure that meter moisture determinations are only made within the specified meter and grain temperature and the grain moisture ranges of the meter. In addition, commercial meters under the new criteria are required to directly display and record the moisture content value as percent moisture content to eliminate errors associated with the use of look-up tables.

In addition to new design criteria, the development of the NTEP program for grain analyzers provides some assurance that grain moisture meters are designed in accordance with NIST HB 44 before that same pattern or type of device is used commercially. An added benefit of the NTEP program for grain moisture meters is the addition of a second phase of NTEP evaluation called the "Ongoing Calibration Program." The NTEP program for grain moisture meters is different than other device evaluations because of these two phases of evaluation: the NTEP phase I (device evaluation) and the NTEP Phase II

program (ongoing calibration program). In phase I, the device is evaluated similar to other NTEP device evaluations to ensure that the device meets the criteria of NIST HB 44 and NTEP Criteria. The NTEP phase II program is a program whereby meter calibrations are tested annually. This annual meter calibration addresses the concerns with the calibrations of the older commercial meters, which were based on varying grain sample sets and different air oven reference laboratories. The NTEP calibration data is based on a national sample set which consists of samples of grain from across the United States and calibrations for NTEP meters that are aligned to a single air oven laboratory. This program reduces average differences between different meter models. The program does little to reduce sample-by-sample variability due to inherent design differences between meter models.

A New Generation of Grain Moisture Meters

Although there have been improvements in moisture determination with the implementation of new criteria and ongoing updates to the calibrations of all meters manufactured or placed into service after January 1, 1998, described earlier, there are inherent limitations in dielectric technology. Dielectric moisture meters are influenced by the grain variety, size, weight, growing seasons, etc. and different sensing techniques and algorithms are in use by each meter. As such, separate calibrations for each grain type are needed. Since there are changes in crops from year to year, the relationship between the measured dielectric constant and the moisture are not stable from year to year and calibrations must be tested annually and adjusted appropriately. The cost of annual calibrations is exceeding the cost of the meter. The various sensing technologies have not changed for many years because each meter type has a specific sensing technology that is used in conjunction with a specific algorithm for predicting moisture. To further improve the grain moisture measurement system, research, which began in 1995, was conducted by the Agriculture Research Service (ARS) and the U.S. Department of Agriculture (USDA) in the dielectric response to grain moisture to improve the technology of dielectric grain moisture determination.

The radio frequency (RF) range for most commercial meters is 1 to 20 MHz. The research conducted by ARS and USDA was conducted at a much higher RF of 1 MHz to 501 MHz. The equipment used to conduct the research were a test cell, which was developed for the higher frequency, a funnel apparatus, which was used to adequately repeat fill the test cell, and a HP-4291A RF Impedance Analyzer, which was used to measure and record information at the high frequencies. USDA, Grain Inspection Packers and Stockyards Administration (GIPSA) collected data using this equipment on 3700 samples of grain that was collected from across the United States through the USDA annual moisture program. The goal was to get results that agreed closely with the official air oven moisture analysis.

One of the purposes of this research was to make a more effective grain moisture algorithm that could be used across meter types. This would further improve the uniformity among grain moisture meters. Several tests were conducted to include tests over wide frequency ranges, density tests at varying frequencies and dielectric loss at varying moisture levels. As a result of this research, it was determined that the 100 MHz to 200 MHz range was the optimal range for dielectric constant measurements and a unified moisture algorithm was developed based on a test frequency of 149 MHz.

With the unified moisture algorithm, meter designs operating at 149 MHz can be brought into better alignment with appropriate adjustments for grain density and cell dimensions. What this means for future grain moisture meters is greater uniformity in results on a sample-by-sample basis.

The results of this research and the unified moisture algorithm was provided to U.S. grain analyzer manufacturers and state and federal government representatives on August 22, 2001, in a technical presentation on "Theory and Engineering Aspects of a New Unified Grain Moisture Measurement Algorithm" presented by Dr. David Funk, USDA, GIPSA. At the current time, NTEP moisture certificates have been issued for three high frequency meter models.

This unified algorithm will likely impact the NTEP Phase II program for grain moisture meters, since calibrations for these meters will be unified through the new algorithm. The impact of new meter technology, to the extent that industry migrates to this technology, could mean an end to the need for NTEP Phase II evaluation for grain moisture meters as it currently exists.

This could impact the NTEP program in 5 to 10 years and even to the extent that the current five–year interagency agreement between NIST and GIPSA, which currently extends from 2010 to 2014, to fund the NTEP Phase II program, may no longer be necessary as it currently exists.

Selection of GIPSA's New Official Meter(s)

The Grain Inspection Advisory Committee (GIAC) is an advisory committee of the GIPSA, which is comprised of 15 members representing grain producers, processors, merchandisers, handlers, exporters, consumers, grain inspection agencies, and scientists. At its November 2009 meeting, the GIAC recommended that GIPSA evaluate the current moisture calibration for high moisture rough rice for accuracy when compared to the air oven reference method. After investigating the 2009 crop calibration, GIPSA reported that year to year differences and growing conditions in 2009 contributed to inaccuracies in the rough rice calibration. GIPSA concluded that improvements to the official meter's accuracy for grain samples with inaccuracies, such as the rough rice calibration, would degrade the overall accuracy and suggested that, for better official meter calibrations, a new meter technology is needed. The GIAC recommended that GIPSA move forward with expediency to determine the feasibility and selection of a new official moisture meter with a new measurement technology. GIPSA plans to implement the new technology for initial grains in May 2013 and implement the new technology for other grains in September 2013 and later. But, at its December 2011 meeting, the Grain Inspection Advisory Committee recommended the implementation of the 149 MHz technology for moisture measurements in August 2012 for fall harvest grains.

As the new meter technology is introduced into the market, more uniformity among meters will further improve the system of commercial grain moisture measurements. Impacts of this new technology will be discussed in future *Weights and Measures Connection* newsletter articles.

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