United States Department of Agriculture
Agricultural Marketing Service
Federal Grain Inspection Service

Criteria & Specifications

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Design Criteria for Unified Grain Moisture Algorithim (UGMA)
and Official System Compatibility

Contents

0. BASIC CRITERIA

0.1 As a prerequisite for consideration, the instrument must be National Type Evaluation Program (NTEP)-certified as complying with all design criteria and performance requirements of the National Conference on Weights and Measures' (NCWM) current Moisture Meter Code 5.56 (a) using the evaluation processes for moisture meters specified in NCWM Publication 14.

0.2 The model number must clearly identify a UGMA-Compatible version of an NTEP-certified moisture meter if the original NTEP-certified version was not subject to all standardization processes or hardware or software modifications needed to achieve UGMA-Compatibility. The manufacturer must ensure that the UGMA-certified version is also certified under NTEP prior to Official use.

0.3 The temperature ranges for which the instrument may be used for official inspection will be no wider than those for which it is currently NTEP-certified.

0.4 If other conditions (such as, but not limited to, leveling) that were passed under NTEP testing must be maintained more stringently to achieve the tolerances in this document, then the manufacturer is responsible to provide suitable means* to ensure proper operating conditions (such as a bubble level with appropriate sensitivity, for instance).

0.5 The proposed model must have been included in the NTEP Phase II Calibration Accuracy Study for at least one harvest season to allow FGIS to assess conformance to some of the criteria listed below.

0.6 The manufacturer is responsible to ensure that the instruments submitted for the Phase II Calibration Accuracy Study (or those purchased by FGIS to serve as "standard" units for the model) are aligned and maintained to represent the model as "standard" units as defined within the criteria below.

0.7 Any operational deficiencies* or recurrent failure modes* identified by FGIS in the course of its testing of the model (but not otherwise specifically covered by the following list of Criteria) must also be resolved to FGIS' satisfaction prior to the delivery of UGMA-Compatible instruments and to maintain FGIS approval for Official use.

0.8 For any hardware, software, or manufacturing process whose description is required to be submitted to demonstrate UGMA-Compatibility, the manufacturer shall not change such hardware, software, or manufacturing process without disclosing* such changes and detailed description thereof to FGIS for full review. Failure to do so may result in revocation of UGMACompatible status for the model.

0.9 These criteria may be modified at the discretion of FGIS to reflect the current status of an Official moisture system based on the UGMA. This could include additional requirements that were not previously envisioned but that are met by those instruments that have been previously certified as UGMA-Compatible.

1. UGMA COMPATIBILITY CRITERIA

1.1. The moisture meter design must be based on measurements of complex reflection coefficient or complex impedance of a parallel-plate transmission line type test cell at a precisely known and controlled frequency (+/- 0.05 MHz) within the range of 148.5 to 150.5 MHz. The manufacturer must provide a block diagram* of the measurement circuitry to illustrate what is actually being measured. The error analyses required (for Criteria 2.2, 2.5, etc.) that are affected by the measurement frequency shall include assessment of the effects of measurement frequency error.

1.2. The parallel-plate transmission line test cell must have (metrologically significant) dimensions* that are based on the “master” test cell design that FGIS uses for calibration development. (Detailed drawings of the master test cell are available from FGIS upon request, PDF_dwgs_14May08.zip.) The manufacturer must provide documentation* to demonstrate that variations in test cell dimensions are controlled sufficiently to have negligible effects (see Sensitivity Analyses section of UGMA Recipe Book) on dielectric constant measurements OR that the test cell model for each individual instrument is sufficiently corrected to cancel the effects of dimensional variations.

1.3. A detailed microwave-type test cell model* (based on ABCD matrices, signal flow graphs, or equivalent) must be used to compute dielectric constant from complex reflection coefficient or complex impedance measured at the manufacturer-defined frequency. (This does not preclude the instrument actually using a lookup table to implement the routine conversion to dielectric constant.) The manufacturer must provide the test cell model*, including a description of the mathematics used, and test data* as needed to permit FGIS to verify its sufficiency. The expected level of detail is similar to that provided by FGIS in the following publication: DIELECTRIC REFERENCE MATERIALS FOR MATHEMATICALLY MODELING AND STANDARDIZING GRAIN MOISTURE METERS, D.B. Funk and Z. Gillay, Trans. ASABE, Vol. 53(1), 2010. (Reprint available upon request.) The dimensions* and other parameters* used in the test cell model must be specified and the means* of arriving at those values must be described in sufficient detail for FGIS staff to assess their adequacy.

1.4. The test cell must be loaded through a circular funnel opening that is designed to minimize the operator dependency on the orientation of kernels in the test cell. Grain types with elongated kernels are most sensitive to this problem and will be used by FGIS to assess the suitability of the sample loading design. Minimizing the funnel opening diameter (while avoiding bridging with moist coarse grains) tends to result in the least operator-dependence. The manufacturer must supply a description* of experiments and results* performed to verify the operatorindependence of the loading method.

1.5. The design* must ensure that sufficient grain is placed in the loading hopper to ensure overfilling of the test cell so that a constant struck-off volume is achieved. The manufacturer must provide documentation* to show how this is accomplished.

1.6. The moisture meter must automatically strike off the filled test cell to provide a constant measured volume of grain. The manufacturer must provide the value of the nominal volume* of the test cell and process* used in production to ensure that the volume is controlled (or measured and corrected) on production units.

1.7. The moisture meter must determine the mass of the grain in the struck-off test cell to a resolution of 0.1 g or better.

1.8. The instrument must determine and display sample temperature with a resolution of 0.1 °C or better (or 0.1 °F or better if Fahrenheit display is provided).

1.9. The instrument must use the steps and mathematics shown in UGMA Steps 1-8 (UGMA Recipe Book pgs. 3-6) and the coefficients (which will be updated periodically by FGIS) listed in the tables in the UGMA Recipe Book—except as allowed by Paragraph 1.10, below. The data produced at each intermediate step must be accessible in a recorded data stream (at least in a special test mode or with special calibration coefficients) with sufficient digital precision to allow FGIS headquarters staff to confirm that the instrument is correctly applying the specified equations and coefficients and to troubleshoot instrument problems.

1.10. Any grain-group-specific correction factors required to account for minor differences in loading methods must be applied prior to producing density-corrected dielectric constants. The use of any such corrections* must be completely documented* and technically justified to demonstrate to FGIS that the correction is not inappropriately compensating for errors within the dielectric constant measurement system. The stability of any such corrections across similar grains must be documented*. The appropriateness of the loading corrections must be established based upon: 1) confirmation of the fitness of the test cell model*, 2) re-prediction of NTEP Phase-II data (and/or other data)* with the manufacturer's final test cell parameters*, and 3) final calibration review* (jointly with manufacturer and FGIS) of NTEP Phase-II calibration data (and/or other data) including volume ratio or other justified loading corrections.

1.11. The sample-by-sample agreement expressed as Standard Deviation of Differences (SDD) of the instrument (single tests) with the FGIS "master" UGMA system must be no worse than the SDD for the agreement of the FGIS "master" with the FGIS Air Oven method (single tests on UGMA) and no greater than 2 times the SDD of differences between two instruments of the model (single tests), (but the tolerance shall be no less than 0.15%) for each of the "major" grain types listed in Table 1 for grain less than or equal to 20.0% moisture. This assessment will be based on data from the FGIS Annual Calibration Study, which is conducted at 22 +/- 2°C. FGIS will evaluate conformance to this requirement based on FGIS' re-prediction of data* using final manufacturer-supplied test cell model parameters* and loading corrections*. Outliers shall be removed before computing the SDD values. The method for arbitrating decisions for identifying outliers will be the Grubb's Test (approximately 3 standard deviations).

1.12. The magnitude of the average bias (below 20% moisture) between the instrument model (average of two tests on each of two standard instruments) and the FGIS "master" UGMA system shall not exceed 0.10% moisture (+ 90% CI) for any "major" grain group (Table 1). This assessment* will be based on data from the FGIS Annual Calibration Study, which is conducted at 22 +/-2°C. FGIS will evaluate conformance to this requirement based on FGIS' re-prediction of data using final manufacturer-supplied test cell model parameters* and loading corrections*. Outliers will be removed as described in 1.11.

2. OFFICIAL SYSTEM COMPATIBILITY CRITERIA FOR UGMA MOISTURE METERS

2.1. The FGIS Regulations (§ 801.6 Tolerances for moisture meters) state the basic operational tolerances for "headquarters standard meters" and "other meters" as follows: (1) Headquarters standard meters. By direct comparison using mid-range Hard Red Winter wheat, ±0.05% mean deviation from the average of the Headquarters standard moisture meters. (2) All other than Headquarters standard meters. By sample exchange using mid-range Hard Red Winter wheat, ±0.15% mean deviation from the mean value obtained by standard meters. Therefore, the subsystems comprising standard instruments maintained at FGIS Headquarters must be capable of being "fine tuned" (but not metrologically different in any way from production instruments) to meet considerably tighter tolerances than normal production instruments. Production instruments must be standardized at the factory (or repair center) to provide at least 90% confidence in meeting the sample exchange tolerances with Hard Red Winter wheat. Instruments failing the tolerance must be repaired at no charge (if under warranty) and demonstrate compliance with the tolerance prior to use in Official service (or being returned to Official service). The manufacturer shall submit documentation* to demonstrate the capability to achieve the 90% confidence in meeting the tolerance for individual instruments when tested with independent samples that were not used in the standardization/normalization production process.

2.2. The manufacturer must demonstrate and document* that the accuracy (0.67 times NCWM field verification meter-to-meter tolerances (+/-0.5% M x 0.67 = +/-0.335% M) or better with respect to the FGIS "master" UGMA system (average of three tests)) for all grain types and moisture levels up to 22% moisture can be adequately assured by routine field testing of Official meters with medium moisture Hard Red Winter wheat (HRWW) (plus additional field-applicable tests that the manufacturer and FGIS may prescribe). Such additional tests may include a scale accuracy test (see (2.3)) and/or a temperature accuracy test (see (2.4)). The goal of this Criterion is to confirm that a check test performed with HRWW is a viable way of verifying the instrument's performance (or conformance to the model pattern) on every grain that might be tested. The manufacturer must document* how the instrument's design and standardization processes* achieve this—assuming that the "standard" instruments for the model are closely aligned with the FGIS "master" UGMA system. Again, this is not about absolute accuracy but rather about agreement among all of a manufacturer's production units—and how a practical set of in-field performance tests by Official inspectors can verify that agreement.

2.3. It must be possible for the operator to capture the grain contained in the struck-off test cell for subsequent external mass determination (with a precision grain scale)—for purposes of periodic performance testing of official moisture meters. The value of the measured mass of the grain in the test cell (resolution of 0.1 g or better) must be readily accessible to the operator without using auxiliary equipment. The tolerance for mass accuracy for new or newly repaired instruments (in comparison with precision grain scales) shall be +/- 0.3 grams, average difference for five tests. For routine field verification tests the tolerance shall be +/- 0.5 grams, average difference for five tests. The accuracy tolerances apply over the range of cell weights corresponding to grain with test weights of 25 to 70 lb/bu.

2.4. The instrument must provide a suitable test mode and display of temperature to permit operator assessment of temperature measurement accuracy by comparison to a precision reference thermometer. The accuracy tolerance (average of three tests) for Headquarters Standard Meters is +/- (0.2 °C + (0.05 x |T – 22 °C|)). For other Official instruments, the tolerance (average of three tests) is +/- (0.5 °C + (0.05 x |T – 22 °C|)). If the temperature readout is in Fahrenheit, the tolerances will be scaled accordingly. The manufacturer must provide documentation* to show how Headquarters Standard Meters will be adjusted to meet the tighter tolerances.

2.5. The manufacturer must describe in detail the processes* used to ensure that production instruments (and repaired instruments) are standardized (with respect to manufacturer's production standard instruments) to provide agreement in density-corrected dielectric constant within +/-1% of reading (but not less than +/-0.027) (average of less than or equal to 5 repeat tests) for grain or artificial sample materials over the range of density-corrected dielectric constants from 2.2 to 8.0 with loss tangents of 0.03 to 0.2. (The ranges of dielectric constant and loss tangent for grains are shown in Figures 8-10 of the UGMA Recipe Book, and the moisture prediction errors associated with this 1% of reading tolerance are shown in Figure 12 of the UGMA Recipe Book.) Note that the tolerances for dielectric constant measurements will need to be considerably tighter for Headquarters Standard Meters to meet the 0.05% matching on HRWW, and that the 1% tolerance is insufficient to ensure passing the field verification test (+/- 0.15% moisture for mid-moisture Hard Red Winter wheat, for which density-corrected dielectric constant is approximately 3.0), since it would exceed the moisture tolerance. (0.01 x 3 = 0.03; 0.03 x 6 = 0.18% M). Therefore, the density-corrected dielectric constant measurement accuracy will need to be controlled more carefully in the critical range around 3.0.

2.6. The manufacturer shall provide means* for FGIS to create calibration transfer files that permit updating calibrations electronically in all Official moisture meters. Such transfer files must allow for coexistence of calibration files from other UGMA instrument manufacturers on the same physical device (such as a USB drive) so that the same physical device can be used for updating any official UGMA-compatible meter model. The means* (programs, etc.) to create and alter calibration files must be protected by strong passwords or other security to prevent unauthorized persons from altering Official or NTEP moisture calibration files.

2.7. The instrument shall provide means* for measurement results to be output in real time via a RS232 serial interface (or through USB to serial adaptor) in a prescribed tab-delimited format (UGMA Criteria—Attachment A). It must also be possible for the measurement results to be stored internally in the instrument and subsequently downloaded through a USB port or other similar means. Such downloadable file shall conform to a defined format (Attachment A) for compatibility in calibration data processing. The manufacturer may provide a user-selectable option for outputting data in the FGIS-specified format rather than making that the only available format.

*** The indicated information shall be considered company-proprietary and not subject to release under Freedom of Information Act (FOIA) requests. The lack of specific designation (*) as company-proprietary in this document shall not affect the proprietary status of relevant company-proprietary information.**