INSTRUMENT APPROVAL PROCESS:
INSTRUMENT GRADING SYSTEMS FOR BEEF CARCASSES

1. Purpose

The U.S. Department of Agriculture (USDA), Agricultural Marketing Service (AMS), Livestock and Poultry (L&P) Program, has implemented a program to predict beef carcass quality and yield factors made by approved instrument systems. The purpose of this document is to provide the performance standard by which the instruments will be evaluated for the ability to accurately and precisely measure USDA grade factors used to predict final yield and quality grades. For a technology provider that wants their instrument approved, two like instruments must be tested, and each instrument must meet the following requirements to gain approval from the L&P Program.

The approval process consists of three phases:

Phase I   Submission of approval request and determination of designation as either a "New" instrument, which includes both previously unapproved instruments or currently approved instruments that have undergone significant upgrades. A currently approved instrument that has undergone non-significant upgrades will be considered an "Upgrade", see Section 10.

Phase II   Demonstration of the accuracy and repeatability of marbling score, ribeye area, fat thickness and final yield grade predictions on stationary beef carcasses.

Phase III   Demonstration of the accuracy and precision of marbling score, ribeye area, fat thickness and final yield grade predictions at line speeds consistent with intended use.

Note: The intent of this document is for an instrument to pass both quality grade and yield grade requirements before being officially utilized by the industry. L&P reserves the right to approve an instrument for either quality grade or yield grade only, if a manufacturer can show that meeting the requirements for both grade measures either:

1. Creates a hardship that would significantly limit an applicant's ability to reach the marketplace.

2. The manufacturer can show that the technology can provide output that can accurately and consistently predict grade factors for quality grade or yield grade, but not both.

2. Scope

The intent of utilizing beef carcass instrument grading augmentation is to improve the accuracy and uniformity of grade application nationwide.

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3.   References

QAD 500 Procedure: *Beef, Bullock, and Bull Grading Methods and Procedures*

QAD 512 Procedure: *Instrument Installation Process, Instrument Grading Systems for Beef Carcasses*

QAD 513 Procedure: *Data Requirements, Instrument Grading Systems for Beef Carcasses*

QAD 515 Procedure: *Beef Carcass Instrument Grading Procedures United States Standards for Grades of Carcass Beef*

Standard Practice for User Requirements for Livestock, Meat, and Poultry Evaluation Devices or Systems. American Society of Testing Materials (ASTM) International Standard F 2341-05.

Standard Specification for Developing and Validating Prediction Equation(s) or Model(s) Used in Connection with Livestock, Meat, and Poultry Evaluation Device(s) or System(s) to Determine Value. ASTM International Standard F 2340-05

4.   Definitions

A "New" instrument is described as either a new instrument or a currently approved instrument that has undergone significant upgrades.

- Significant upgrades can be described to include, but are not limited to:

    - Any change that can affect at least one of the predicted independent variables, to include both hardware and/or software changes.

5.   Approval Process

5.1   Phase I

Submission of approval request and determination of designation as either a "New" instrument or an "Upgrade" to an already approved instrument.

5.1.1   The applying technology provider will send a request for approval to the Standards and Specifications Division (SSD). Details in this request should include:

i.   Both a basic and an in-depth summary of how their instrument works.

ii. Whether this is a:

- "New" instrument

    - An instrument not previously approved for use.

    - A significant "Upgrade" to a currently approved instrument.

> ➢ List all upgrades to the instrument if utilizing a previously approved device as the base for the upgrade.

- A Non-significant "Upgrade" to a currently approved instrument.

iii. A signed affidavit acknowledging that L&P requires that no additional changes to an instrument will be made without prior knowledge of L&P after the initial sample collection has begun.

5.1.2   L&P will make the final determination if the instrument is a new instrument or a non-significant upgrade not needing approval or a significant upgrade needing approval. The instrument manufacturer may provide data and any other relevant information needed for L&P to make the decision to identify the instrument as a new instrument, a significant upgrade to an instrument, or a non-significant upgrade.

5.2   Phase II

Demonstration of the repeatability of marbling score, ribeye area, fat thickness and final yield grade predictions on stationary beef carcasses.

5.2.1   Marbling - A minimum of 200 stationary carcass sides will be measured three times[1] to provide a minimum of 600 observations for the evaluation of repeatability. Instruments can be evaluated for repeatability at any of the two approval trials or prior to the approval trials (see 5.3 Phase III). Repeatability will be estimated from carcasses that represent the U.S. fed beef population[2] and are distributed over the full range of degrees of marbling, see Table 1.

Table 1

Marbling Scores	Minimum required for Phase II	Minimum required for Phase III
Traces or less	5	50
Slight 0-49	20	200
Slight 50-99	30	200
Small	60	600
Modest	40	400
Moderate	25	300
Slightly Abundant	15	200
Moderately Abundant or higher	5	50
Totals per location	200	2000

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[1] The Triple Placement method will be used for collecting images (data) from stationary carcasses for marbling, REA, and fat thickness. L&P may determine, for certain conditions, that a Triple Trigger method may be used as an alternative.
[2] Estimates of the distribution of the U.S. fed beef population was provided by the AMSA Beef Grading Committee.

5.3   Phase III

Demonstration of the accuracy and precision of marbling score, ribeye area, fat thickness and final yield grade predictions at typical line speeds.

5.3.1   Marbling - A "New" instrument must be tested in at least two separate trial locations to ensure that any carcass variation due to environmental conditions (e.g., bloom time/chain speed, carcass temperature, sawing, and ribbing) is considered. The locations will be regionally diverse and approved by L&P. The technology provider will be responsible for contacting the location and obtaining approval to collect samples.

> At each trial location, a minimum of 1,000 carcasses will be collected for testing purposes and 1,000 carcasses for algorithm development purposes. These carcasses will adequately represent the U.S. fed beef population and the full range of marbling scores. Of the 2,000 carcasses coming from each of the trial locations, no more than two-thirds (2/3) of the samples in any one of the marbling categories can come from a single location. The official marbling calls for the carcasses used in algorithm development will be provided to the applicant.

Sample collection will occur in each of the two locations for a minimum of 1 full production shift per location. If the total number of carcasses per marbling category cannot be collected during these two shifts, collection over a third shift may be necessary. At least 90% of samples within each marbling score must be fulfilled before the sample collection for an approval trial may be completed. It will be at the discretion of L&P as to whether additional production shifts and/or additional plant/facility will be utilized.

> Carcasses must be presented for image capture and analysis at a continuous normal operating chain speed. The degree of marbling matrix shown in Table 1 will serve as the template in guiding carcass selection. L&P personnel will select the side of the carcass to be evaluated by the instrument and the Gold Standard Committee as outlined in 5.3.1.1. No more than 65 percent of the images will derive from one side (left or right).

5.3.1.1   The Gold Standard Committee (Committee) is responsible for establishing the Official Marbling Score. The Official Marbling Score will be determined by a panel of three L&P experts. The Committee will include three L&P experts from the following: National Meat Supervisor, Assistant National Meat Supervisor, and Meat Supervisors from the Gold Standard Team. Once the instrument trial has started, the Committee will remain unchanged until the completion of the instrument trial.

5.3.1.2   Procedure for Determining the Official Marbling Score

Prior to or immediately following the on-line evaluation by the instrument, carcasses will be evaluated by the Committee in an adequately illuminated (a minimum of 100-foot candle power) area. The Committee will independently evaluate the marbling score in accordance with the *United States Standards for Grades of Carcass Beef* and will be recorded to the nearest 10 degrees of marbling. The marbling score will be numerically coded as follows:

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Table 2

Degree of Marbling	Marbling Score
Practically Devoid	100
Traces	200
Slight	300
Small	400
Modest	500
Moderate	600
Slightly Abundant	700
Moderately Abundant	800
Abundant	900

A final Official Marbling Score will be computed from the independent observations for each carcass. Carcass data will be excluded from the test if the standard deviation of the samples for that carcass is greater than 50 marbling units and/or if the absolute difference between any one expert's independent observation is greater than or equal to 50 marbling units from the average of the independent observations for that carcass.

Standard deviation of the carcass is calculated by finding the mean of the observations of the team members for that carcass. Once that is calculated, find the deviation from the mean of each score. Square each of these deviations from the mean. Add up all these squared deviations to get a sum of squares. Divide the sum of squares by (n-1). Take the square root of the resulting variance to get the resulting standard deviation.

The Committee will compute the final Official Marbling Score and the standard deviation (SD) for each carcass. Carcasses will be ranked by the final Official Marbling Score in ascending order by trial location and then every other carcass will be assigned to a calibration data set. The other half of the data will become the test data set. Data entry, data checking, and assignment to calibration and test data sets will be conducted in duplicate by the Committee and the results reconciled before release of information to the technology provider. The Committee will provide all data parameters to the technology provider for the carcasses assigned to the calibration data set. The technology provider may use the calibration data to develop or refine their marbling score prediction equation.

5.3.1.3   Submission of Predicted Marbling Score and Prediction Equation

At the completion of the two trials, the technology provider will submit the instrument predicted marbling scores to L&P for comparison with the Official Marbling Scores of the test data set. L&P

experts will then compute the necessary statistics to determine if the instrument system meets the requirements outline in Section 5. The technology provider will provide L&P with a copy of the prediction equation used as well as the values for each variable in the prediction equation for each of the predicted marbling scores, which L&P will use to validate the information collected and outputs computed.

5.3.1.4   Quality Control of Images and Data Collected

For the test to provide the best results possible, L&P will review all data and images to determine if the data and images from the selected carcasses were accurately obtained. Technology providers must submit to L&P the original image and the processed display screen image or thumbnail for each carcass in the test so that images can be reviewed to determine if proper image capture occurred.

6.   Performance Requirements for Marbling

Approval will be granted in accordance with the following performance requirements. Approval of the instrument will be determined by L&P and will be based on the intended use of the instrument system. The scope will be set forth in the final approval.

6.1   Phase II: Stationary Measurement of Repeatability

- 95% of the carcasses will have all three of the predicted marbling score observations within 20 marbling score units of the mean predicted marbling score for that carcass.

6.2   Phase III: On-line Measurement of Accuracy and Precision

- Average residual $= 0 \pm 10$ marbling score units where the residual is the difference between the predicted instrument marbling score and mean expert panel marbling score.

- The standard deviation of the residuals (rSD) from the mean expert panel marbling score ≤ 35 marbling score units; and,

- Slope of 0 ± 0.075, using the residual from the MEPMS as the dependent variable (y-axis) and the average of the instrument marbling score and mean expert panel marbling score as the independent variable (x-axis).

7.   Performance Requirements for Ribeye Area

Approval will be granted in accordance with the requirements listed below. Accuracy of ribeye measurement will be evaluated by comparing (correlation and regression) the ribeye area observation to the actual ribeye area.

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To validate the accuracy of an instrument, a mean expert ribeye area measurement must be established for each carcass that is measured. Three experts experienced in measuring ribeye will individually grid the ribeye of each carcass with the official USDA ribeye grid. The three individual measurements will be averaged to establish the mean expert ribeye area measurement.

7.1   Phase II: Stationary Measurement of Repeatability

- Stationary Repeatability

    - 95% of predicted ribeye area measurements within 1.5 square inches of the mean expert ribeye area measurement.

- Stationary Repeatability

    - 95% of predicted ribeye area observations within 0.5 square inches of the mean of the three ribeye area observations for that carcass.

7.2   Phase III: On-line Measurement of Accuracy and Precision

A minimum of 200 carcasses (representing a range of at least 3.0 square inches from the smallest ribeye area to the largest ribeye area sampled) must be presented for image analysis under normal beef carcass grading conditions. Freshly ribbed carcasses must be presented to the instrument on a line where chain speeds are more than 300 head per hour. Following collection of images, carcasses should be placed on a stationary rail for determination of mean expert ribeye area as described in the Phase II.

- R^2 = 0.85 or greater.

- 95% of ribeye area observations within 2.0 square inches of the mean expert ribeye area.

- Residual standard deviation (RSD) will not exceed 1.0 square inches.

8.   Performance Requirements for Fat Thickness

Approval will be granted in accordance with the requirements listed below. Accuracy of fat measurement will be evaluated by comparing (correlation and regression) the fat thickness observation to the mean expert fat thickness of that carcass side. The mean expert fat thickness will be established by calculating the mean of the values derived from three experts, independently, measuring the fat thickness of the 12th – 13th rib interface of the carcass. The fat thickness is a single measurement of fat over the ribeye three-fourths of the length of a ribeye from the chine bone end.

A minimum of 200 carcasses must be presented for image capture and analysis under normal beef carcass grading conditions. Freshly ribbed carcasses must be moving at a minimum chain speed of

300 head per hour. Following collection of images, carcasses should be placed on a stationary rail for determination of actual fat thickness as described above (Phase II).

8.1   Phase II: Stationary Measurement of Repeatability

- Stationary Repeatability

  - 95% of the predicted fat thickness observations within 0.1 inches of the mean expert fat thickness.

8.2   Phase III: On-line Measurement of Accuracy and Precision

- 95% of predicted fat thickness observations within 0.1 inches of the mean expert fat thickness.

- The average of the residuals (between instrument fat thickness and mean expert fat thickness) will equal 0 ± 0.05 inches.

9.   Performance Requirements for Yield Grade

To validate the accuracy of an instrument, an actual expert calculated yield grade must be established for each carcass that is measured. The yield grade factors will be evaluated by three experts from the Gold Standard Team. The panel of three officials will evaluate:

- Adjusted Preliminary Yield Grade based on fat cover over the entire carcass.

- Percent Kidney, Pelvic, and Heart Fat estimated as a percent of the hot carcass weight (pounds) or, if removed, the actual percent.

- Ribeye Area, (square inches), determined by grid measurement. The panel will evaluate the same side evaluated by the instrument being tested.

- The actual expert calculated yield grade will be a consensus yield grade calculated to the nearest 0.1 yield grade unit using the USDA "short-cut method" or the official Yield Grade equation:

    Yield Grade = 2.50 + (2.0 x adjusted fat thickness, inches)

    + (0.20 x percent kidney, pelvic, and heart fat)

    + (0.0038 x hot carcass weight, pounds)

    - (0.32 x area of ribeye, square inches)

Approval will be granted in accordance with the requirements listed below. Accuracy of yield grade will be evaluated by comparing (correlation and regression) the yield grade observation to the

mean expert calculated yield grade. A mean expert calculated yield grade is determined by calculating the mean of the three independent actual calculated yield grades.

9.1   Phase II: Stationary Measurement of Repeatability

- 95% of predicted yield grade observations within 0.5 yield grade units of the mean expert calculated yield grade.

9.2   Phase III: On-line Measurement of Accuracy and Precision

- 95% of predicted yield grade observations within 0.5 yield grade units of the mean expert calculated yield grade.

- The residual standard deviation (RSD) will not exceed 0.25 yield grade units.

Note: Preliminary yield grade observations and adjusted fat thickness predictions will not be evaluated separately from the final yield grade.

10.   Performance Requirements for a Non-Significant Upgrade of an already approved instrument.

Approval will be granted in accordance with the requirements listed below. A non-significant upgrade is an upgrade that does not potentially influence or practically affect at least one independent variable being measured.

10.1   The manufacturer will have the option to choose between expert panel to prototype testing or approved device to prototype testing. The manufacturer will notify L&P of its choice before initiation of testing.

10.2   The prototype instruments will be required to fulfill all requirements listed for Phase III measurements. If the manufacturer choses the approved device to prototype testing method, the measurement values given for the duplicate assessment will be used in place of the mean expert scores.

11.   Supersedes

This document supersedes:

- USDA AMS Prime I: *Instrument Grading Systems for Beef Carcasses*, June 2006

- USDA AMS Addendum A: *Instrument Grading Systems for Beef Carcasses*, December 2012

- USDA AMS: *Procedures for Approval and Use of Instrument Systems for Beef Carcass Ribeye Measurement*, February 2003

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- USDA AMS: *Procedures for Approval and Use of Vision-Based Instrument Systems for Beef Carcass Yield Grade Measurement*, March 2005

- USDA AMS Addendum A: *Procedures for Use of Approved Vision-Based Beef Carcass Yield Grade Instrument Systems for Fat Thickness Measurements*, March 2007

12.   Additional Requirements

12.1   Verification of Approved Equations

The instrument manufacturer will request prior approval from L&P to make any modifications to a device, system, software or process that could affect the original software prediction coding and/or its predictive outcome (see Section 5.2 ASTM International Standard F 2340-05; and Section 5.3.3. ASTM International Standard F 2341-05).

Upon request from L&P, the instrument manufacturer must immediately provide a copy of current and historical unencrypted software coding that could affect predicted grade factors.

The manufacturer will maintain - historic and current software coding, including iterative changes along with descriptions of such changes that have occurred and reasons behind such changes. This information will be provided to L&P personnel immediately upon request.

L&P reserves the right to confirm if changes have been made to the software by utilizing existing monitoring and quality control tools.

12.2   Conditional Approval

Approval of an instrument will be granted on a conditional basis of performance in the field setting for a minimum of one year from date of approval. During this conditional period, L&P may require additional testing of the instruments if field data suggests that the instruments are not performing to the levels achieved in the approval process.

12.3   Use of a Reference Device

The device manufacturer will provide L&P with an instrument to be used as a reference device that represents the approved device and all its software. L&P will possess this device and will utilize it as a reference device when testing instruments in the production setting.

13.   Subject to Change

The provisions of this procedure are subject to revision by the L&P Program at any time.

14. Approval Request

Requests for approval will be submitted to:

Chad Nelson
chad.nelson2@usda.gov
(402) 281-8704

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Mark Perigen, Director
Quality Assessment Division
Livestock and Poultry Program

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Chad Nelson, National Meat Supervisor
Standards and Specifications Division
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