1907-2007

American Society of
Agricultural and Biological Engineers

CONTACT
Dolores Landeck
269-428-6339
*landeck@asabe.org*

# *News Release*

**FOR IMMEDIATE RELEASE**
October 11, 2007

## REVISED ASABE STANDARD AVAILABLE ON TESTING OF ANIMAL-FEED MIXING EQUIPMENT

ST JOSEPH, MICHIGAN—The American Society of Agricultural and Biological Engineers (ASABE) has completed a revision to the standard for testing solids-mixing equipment for animal feeds. This animal-feed mixer test standard provides a means to ultimately ensure the quality of animal feed mixtures.

The use of salt (sodium chloride), the tracer primarily referenced in the previous standard, had limitations in validating mixer performance, particularly the mixing of micro-ingredient (drug) feed additions and in validating "augmentation" or cross-contamination control procedures. The revised standard, ASAE S303.4 SEP2007, Test Procedure for Solids-Mixing Equipment for Animal Feeds, specifically references the use of colored iron particles or colored iron powder to use as tracers in these situations. The revision allows US and Canadian feed manufacturers to satisfy both domestic regulatory and non-regulatory testing requirements while also satisfying requirements of trading partners in Europe.

A copy of the document can be ordered by contacting ASABE headquarters directly at: martin@asabe.org. ASABE members and those with site-license privileges to the ASABE online Technical Library, at www.asabe.org, can obtain an electronic copy of the standard in about 6 weeks.

ASABE is recognized worldwide as a standards developing organization for food, agricultural, and biological systems, with more than 225 standards currently in publication. Conformance to ASABE standards is voluntary, except where required by state, provincial, or other governmental requirements, and the documents are developed by consensus in accordance with procedures approved by the American National Standards Institute. For information on this or any other ASABE standard, contact Scott Cedarquist at ASABE, 269-429-0300, cedarq@asabe.org.

The American Society of Agricultural and Biological Engineers is an educational and scientific organization dedicated to the advancement of engineering applicable to agricultural, food, and biological systems. Founded in 1907 and headquartered in St Joseph, Michigan, ASABE comprises 9,000 members representing more than 100 countries. For further information about the Society, or for an electronic copy of this news release, contact Dolores Landeck at ASABE, 269-428-6339, landeck@asabe.org.

*– 30 –*

# ANSI/ASAE S303.4 SEP2007
# Test Procedure for Solids-Mixing Equipment for Animal Feeds


American Society of
Agricultural and Biological Engineers

STANDARD

ASABE is a professional and technical organization, of members worldwide, who are dedicated to advancement of engineering applicable to agricultural, food, and biological systems. ASABE Standards are consensus documents developed and adopted by the American Society of Agricultural and Biological Engineers to meet standardization needs within the scope of the Society; principally agricultural field equipment, farmstead equipment, structures, soil and water resource management, turf and landscape equipment, forest engineering, food and process engineering, electric power applications, plant and animal environment, and waste management.

**NOTE:** ASABE Standards, Engineering Practices, and Data are informational and advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. The ASABE assumes no responsibility for results attributable to the application of ASABE Standards, Engineering Practices, and Data. Conformity does not ensure compliance with applicable ordinances, laws and regulations. Prospective users are responsible for protecting themselves against liability for infringement of patents.

ASABE Standards, Engineering Practices, and Data initially approved prior to the society name change in July of 2005 are designated as 'ASAE', regardless of the revision approval date. Newly developed Standards, Engineering Practices and Data approved after July of 2005 are designated as 'ASABE'.

Standards designated as 'ANSI' are American National Standards as are all ISO adoptions published by ASABE. Adoption as an American National Standard requires verification by ANSI that the requirements for due process, consensus, and other criteria for approval have been met by ASABE.

Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

**CAUTION NOTICE:** ASABE and ANSI standards may be revised or withdrawn at any time. Additionally, procedures of ASABE require that action be taken periodically to reaffirm, revise, or withdraw each standard.



ASABE, 2950 Niles Road, St. Joseph, MI 49085-9659, USA ph. 269-429-0300, fax 269-429-3852, hq@asabe.org

ANSI/ASAE S303.4 SEP2007
Approved September 2007 as an American National Standard

# Test Procedure for Solids-Mixing Equipment for Animal Feeds

*Proposed by the American Feed Association; approved by the ASAE Grain and Feed Processing and Storage Committee; approved by the Electric Power and Processing Division Technical Committee and the Power and Machinery Division Technical Committee; adopted by ASAE as a Tentative Standard December 1966; revised by the Animal Feed Processing Implements Subcommittee of the Power and Machinery Division December 1969; approved by the Electric Power and Processing Division as a full Standard December 1969; reconfirmed December 1973, December 1978, December 1983; revised December 1984; reconfirmed by the Food and Processing Institute Standards Committee December 1989; revised March 1991; reaffirmed December 1995, January 2001, December 2001, February 2003. Revised editorially March 2003; revised September 2007; approved as an American National Standard September 2007.*

**Keywords:** Feeds, Mixing, Solids-mixing, Test, Tracer

## 1 Purpose

1.1 This Standard is intended to:

1.1.1 Promote uniformity and consistency in the terms used to describe and evaluate animal feed mixers.

1.1.2 Provide a procedure for testing mixers which ultimately improves the quality of animal feed mixtures.

## 2 Scope

2.1 This Standard is applicable to equipment used to prepare animal feed mixtures and includes both batch type and continuous type. It covers mixers intended for the addition of liquid ingredients as well as dry ingredients.

2.2 Within the scope of this Standard, a mixer may include required auxiliary equipment which would normally be required to operate the mixer. Auxiliary equipment for dry and liquid ingredients may include feeders, surge bins, integral discharge augers, etc., but would not include normal conveying equipment used to convey material beyond the surge bins under quick discharge mixers.

## 3 Standard performance criteria

3.1 The following criteria are used to judge the performance of mixing equipment:

3.1.1 Uniformity of dispersion of the ingredients throughout the entire batch or run.

3.1.2 Time required for batch mixing.

3.1.3 Throughput (feed rate or discharge rate) of continuous mixers and residence time in mixer.

3.1.4 Operating power or torque requirements for electric motors are applicable.

## 4 Standard test conditions

### 4.1 Standard feed product formulas

**4.1.1 Batch mixers.** The standard formula for testing the performance of a batch mixer shall consist of a mixture of 98% ground shelled corn, U.S. Grade No. 2 of less than 14% moisture, (wet basis) and 2% sodium chloride salt (see paragraph 13.1.1). The corn shall be ground to a fineness defined by geometric mean diameter of 0.85 ± 0.15 mm and a geometric standard deviation of 2.0 ± 0.50 (see ASAE Standard S319.1, Method of Determining and Expressing Fineness of Feed Materials by Sieving). The salt shall have a geometric mean diameter of 0.45 ± 0.10 mm and a standard deviation of 1.5 ± 0.25. Formulations in addition to the standard formula may be tested. The particle size distribution and density of all ingredients comprising more than one percent of the formula, excluding any tracers, such as salt, shall be reported. The particle size distribution and density of each tracer material shall be reported.
Alternately, colored iron particles or colored iron powder may be used as tracer compounds instead of salt. In this case, the standard formula will consist of ground shelled corn as in the paragraph above or a corn/soybean base mash formula feed with the colored iron particles or the colored iron powder formulated as an ingredient to yield 50 grams per 2,000-lbs of feed.

**4.1.2 Continuous mixers.** Continuous mixers shall be tested using the standard formula listed under paragraph 4.1.1. In addition, mixers designed for the application of molasses shall be tested using a mixture of 80% wheat bran and 20% molasses mixture. The molasses mixture shall consist of 95% cane blackstrap molasses having a Brix of 78 and viscosity of 300 to 1000 mPa·s (300 to 1000 centipoises) at 43 °C (110 °F) (method of measurement to be specified), 2.5% potassium chloride and 2.5% ammonium chloride. Mixers designed for mixing heated molasses shall be tested with the molasses heated to 43 °C (110 °F) while those mixers designed for mixing unheated molasses shall be tested with molasses at 20 ± 5 °C (70 ± 10 °F). The dry feed ingredients shall enter the mixer at 20 ± 5 °C (70 ± 10 °F). Other formulations may be tested and the test report shall describe the materials used, particle size and density of dry ingredients, and the density and viscosity of the liquid at the temperature of addition.

**4.2 Mixer characteristics.** A description of the equipment used should include the make, model, and serial numbers. The following specifications shall be measured and reported:

**4.2.1 Major vessel dimensions and total calculated volume.** The maximum and minimum working volume of the mixer, as stated by the manufacturer, shall be reported.

4.2.2 Any special modifications to mixer made for testing.

4.3 Mass of each ingredient added shall be reported.

**4.4 Mixing conditions.** The following information shall be reported:

**4.4.1 Method, sequence, place and rate of adding each ingredient.** Note at what point during the charging cycle the mixer is started. For continuous mixing, check feed rates prior to and following the test. Note conveyors between feeders and mixer which may contribute to mixing.

4.4.2 Mixing time in batch mixers or throughput and residence time of continuous mixers.

## 5 Standard procedures

### 5.1 Mixer operations

**5.1.1 Batch mixing.** The mixer shall be started and then filled with all ingredients, other than the tracer material. The tracer is the last ingredient added to the mixer. In horizontal mixers, the tracer shall be added to one end. In vertical mixers it shall be placed on the top of the charge or at the point of normal charging. For a mixer that utilizes a charging screw or chute for filling, the mixer shall be filled with 95% of the ground shelled corn, the tracer shall be added, and then the remainder of the corn shall be added. Mixing time shall start once the tracer has been added, and end when discharge begins. Final results shall be reported on the basis of at least 10 samples drawn at approximately uniform time intervals during the mixer discharge. Samples shall be drawn from the discharge stream, or the discharge from surge bins if such equipment is included as a part of the mixer. These samples shall be taken at the end of an uninterrupted mixing cycle. At least three trials should be made and results reported separately.

**5.1.2 Continuous mixing.** A minimum of 10 samples shall be taken from the discharge of the mixer during each of three test periods. A minimum test period should be at least three times and preferably more than 10 times the average residence time of solids in the mixing equipment. Continuous mixers are highly dependent upon the accuracy of associated feeders. If such feeders are an integral part of the mixing device and if the mixer is intended for continuous, automatic operation without the presence of an operator, it should be equipped with devices to stop the equipment when material flow from supply bins is interrupted or reduced. The operation of such systems devices should be checked separately over an extended period of time, and the sensitivity in terms of ability to respond to a reduced feed rate should be reported.

### 5.2 Sampling

**5.2.1 Sampling batch mixers.** If possible, samples should be taken from the discharge of the mixer by cutting through the discharge stream of the mixer. If this is not possible, as in a drop bottom mixer, then samples should be taken when discharged at the end of the recommended operating time of the mixer. If internal sampling is to be done, samples should be taken which will represent a wide cross section of the mixer (e.g., three samples from various depths in each quarter of the length of a horizontal mixer).

**5.2.2 Sampling continuous mixers.** Samples should be taken at equal time intervals during the mixer discharge. No samples should be taken until the mixer has been running for a period of at least twice the residence time plus time required to fill the mixer or has stabilized operating conditions.

**5.2.3 Sample size.** At least 10 samples of about 0.5 kg (1 lb) should be taken and assayed separately. In general, the size of samples should be large enough to contain a minimum of 1000 tracer particles (the active ingredient which will be assayed). If this size of sample must be reduced for assay purposes, it should be ground before dividing to a fineness which gives at least 1000 tracer particles in the assay sample.

#### 5.2.4 Sampling methods

5.2.4.1 Samples from the flowing discharge should remove a cross section of the entire stream. Sampling the discharge will aid in locating segregation effects caused by emptying.

5.2.4.2 Internal probe sampling of batch mixers can be used to obtain data to plot a curve for mixing time or to locate points of nonuniformity. Sampling should disturb the mixture as little as possible.

5.2.4.3 A sampling thief, of 25 mm (1 in.) or larger diameter adapted to withdraw about the sample size desired, should be inserted into the batch with a minimum of disturbance, with the sample holes covered. The holes should be covered after the sample is taken and before the probe is withdrawn. Sample thieves may cause segregation and are not well adapted to the sampling of mixtures containing large particles or large amounts of liquids, such as molasses.

## 6 Methods of measurement

### 6.1 Analysis of samples

6.1.1 The samples shall be analyzed for level of salt, using a chemical procedure. The value of the analytical error of the assay should be determined and included in the test report. Other tracers may be used, but the chemical component of the tracer material should not be found in large amounts in other ingredients. An assay value showing the background level of the active component of the tracer in the other ingredient should be included for comparison. The mixing quality of a molasses feed shall be assayed by assaying for chloride ion concentration.

If colored iron particles are used as the tracer for the test, they will be determined by magnetically retrieving the particles from feed samples, sprinkling them onto a filter paper wetted with the appropriate solvent (50% ethanol when working with water soluable colors) and drying the paper to "fix" the colored spots once they stain the test paper.

If colored iron particles are used, the variability inherent to Poisson particle statistics must be accepted with an additional variability due to analytical error added. A minimum of 100 tracer particles should be counted per sample analysis to yield a Poisson standard deviation of 10 and an inherent statistical coefficient of variation of 10%.

If colored iron powder is used as the tracer for the test, it will be determined by magnetically retrieving the iron powder from the feed samples, dissolving the dye from the powder and reading the color of the resulting solution on a spectrophotometer.

### 6.2 Power measurements

6.2.1 Input power (watts) to the motor should be obtained with a wattmeter or power meters having an accuracy of at least ± 5%. The meters should have a response time of 1.5 s or less. Input power can also be obtained by measuring energy for a 10 to 15 min time period and then dividing the energy measurement by the time period. Output power can be calculated by multiplying the input power by the motor efficiency as taken from the motor manufacturer's efficiency curve. The nominal efficiency designation of the motor (National Electrical Manufacturers Association Standard), average running power requirements, and method of measuring power should be reported.

6.2.2 Suitable torque meters may be used to measure the torque input to the mixer when starting and under normal load. Torque and speed data may be reported in lieu of electrical power measurements after converting to power requirements. The accuracy of the torque and speed measurements should be reported.

## 7 Test report for feed mixer using standard formula

**Feed Characteristics, Solids**

| Material | Particle size | | Moisture %, w.b. |
|---|---|---|---|
| | Geometric mean dia, mm | Geometric std. dev. | |
| | | | |

**Feed Characteristics, Liquids**

| Material | Temp. °C(°F) | Density kg/L (g/cc) | Viscosity mPa·s (cps) | pH | Other |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |

**Mixer characteristics**

Make _____; Model_____; Serial no. _____

Volume: Total_____ $m^3$ ($ft^3$)

Max recommended _____ $m^3$ ($ft^3$)

Min recommended _____ $m^3$ ($ft^3$)

Solids feed rate (continuous)

Max recommended _____ $m^3$/min ($ft^3$/min)

Min recommended _____ $m^3$/min ($ft^3$/min)

Motor: Make_____; kW (hp)_____; Volts _____;

Type_____; Phase_____

Drive _____

Special starter (if applicable): _____

Vessel or agitator speed during operation, r/min: _____

Diameter of vertical screw or agitator, cm: _____

Type of timing or safety devices to insure proper feeding: _____

_____

Special modifications made for testing:_____

**Charging Schedule for Full Batch**
(Listed in order of addition to mixers)

| Ingredient | Batch mass, kg (lb) | Feed rate (continuous mixing) kg/min (lb/min) | Vol $m^3$ ($ft^3$) | Method of addition | Point of addition | Time* min |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| Total | | | | | | |

* Time required to add ingredients to the mixer

**Quality of Mixing**

| Characteristic assayed | Accuracy of assay | Background ingredients other than tracer | Sample size assayed, g | Method of assay* |
|---|---|---|---|---|
| | | | | |

* Reference for the assay method

Coefficient of variation, CV, of level of tracer found in ten (if more, specify _____) discharge samples. Tracer assayed _____

| Feeder no. | Material | Percent of normal |
|---|---|---|
| | | |

Mixing time in batch mixer _____ min

Average power _____ kW; or torque _____ N·m (lbf·ft)

## 8 Augmented performance criteria

8.1 In many cases, when a mixer or mixing system is to be used to mix materials whose physical characteristics are not similar enough to the standard product formula, more extensive testing may be required. Additional criteria which should be considered in evaluating the total performance of a mixer or system include:

8.1.1 Particle size reduction of friable ingredients during mixing.

8.1.2 Time required for filling and emptying the mixer.

8.1.3 Possibility of contamination of the product by lubricants, metals, or other materials.

8.1.4 Other equipment required such as ventilation.

8.1.5 Time required for cleanout.

8.1.6 Product loss during operation.

8.1.7 Effect of partial filling and overfilling on mixer performance.

8.1.8 Weight of residue left in the mixer after discharging.

## 9 Augmented test conditions

9.1 **Feed characteristics.** In addition to recording a complete identification of each feed component, such as source, grade, composition, and previous processing history, the following physical properties shall be reported:

9.1.1 Particle size distribution.

9.1.2 Bulk density and specific density.

9.1.3 Moisture content and temperature of solid materials.

9.1.4 Density, viscosity, *p*H, and temperature of any liquids added.

9.1.5 Observations of any unusual particle shape, surface characteristics, or electrostatic properties.

9.2 **Mixer characteristics.** A description of the equipment used should include the make, model, and serial numbers. The following specifications shall be measured and reported:

9.2.1 **Major vessel dimensions and total calculated volume.** The maximum and minimum working volume of the mixer, as stated by the manufacturer, shall be reported.

9.2.2 Dimensions, number and type of agitator and/or baffle components, including end and side clearances between agitator, or other moving parts, and body of mixer. Adjustments available.

9.2.3 Size, location and type of access and discharge openings.

9.2.4 Motor power and type of drive.

9.2.5 Vessel or agitator speeds in revolutions per minute and range of speeds, if any. Direction of rotation of moving elements.

9.2.6 Means provided for assuring completeness of discharge.

9.2.7 Type, location and number of ingredient feeders (including liquids). This does not include feeders to scale bins of batch mixers.

9.2.8 Details of equipment supports and vibration damping devices.

9.2.9 Specifications of any timing or other safety devices provided to insure the uniformity of the finished product.

9.2.10 Schematic diagram of mixer.

9.2.11 Any special modifications made to mixer for testing.

9.2.12 Grounding devices supplied to discharge static electricity.

9.3 **Charge mass and ingredient proportions**

9.3.1 Mass and calculated bulk volume of each ingredient added.

9.4 **Mixing conditions**

9.4.1 **Method, sequence, place and rate of adding each ingredient.** Note at what point during the charging cycle the mixer is started. For continuous mixing, check feed rates prior to and following the test. Note conveyors between feeders and mixer which may contribute to mixing.

9.4.2 Measured operating speed, r/min or m/s (ft/s).

9.4.3 Mixing time in batch mixers of throughput and residence time of continuous mixers.

9.4.4 Visually note, if possible, any apparent changes in volume, points of accumulation or uneven motion of the mass.

9.4.5 Average operating power required or if torque measurements are made, the average operating torque may be reported.

9.4.6 Record ambient air temperature and relative humidity.

9.4.7 Mixing time before addition of liquids.

## 10 Augmented procedures

10.1 In addition to the procedures described in paragraphs 5.1.1 and 5.1.2, the following tests may be made and reported:

10.1.1 Trials should be repeated with the batch (including drum-type) mixer loaded to 25, 75, and 110% of rated volumetric capacity and each loading condition repeated during three trials. Note, in certain types of mixers, it may not be possible to fill beyond 100% rated volumetric capacity. In this case, mixers should be tested at maximum volumetric capacity and this should be stated in the report. For part-load trials, only assay results need be reported. A batch mixer may be sampled internally by stopping it at intervals and removing probe samples. A plotted curve of the results obtained may be used to select the optimum, or an adequate mixing time. If such results are to be reported, three trials of at least 10 samples per trial should be made.

## 11 Augmented residue data

11.1 After a test is complete, the equipment should be inspected and thoroughly cleaned. The weight of material removed by brushing and the amount of material removed by scraping should be recorded separately. The location and weight of all major accumulations should be recorded and appropriate tests made to identify the composition of the residue. Consistent patterns of residual accumulation of one or more ingredients should be reported.

If colored iron particles or colored iron powder has been used as the tracer for the test, these can be magnetically retrieved from samples of the following batch of feed. In this case, the sample weight taken and analyzed should be increased by a factor of 10. For the colored iron particles, instead of counting 100 particles per sample analysis, one would then expect 1,000 particles if the sample was taken from the initial batch. If 1% cross-contamination has occured, one would then expect to find 10 tracer particles from the feed sample analyzed.

## 12 Augmented test report form for feed mixer using standard feed product formula

**Feed Characteristics, Solids**

| Material | Particle size | | Density | | Moisture %, w. b. | Temp. °C (°F) |
|---|---|---|---|---|---|---|
| | Geometric mean dia., mm | Geometric std. dev. | Bulk kg/m (g/cc) | True kg/m (g/cc) | | |
| | | | | | | |

Remarks: (Unusual particle shape, surface characteristics or electrostatic properties)

**Feed Characteristics, Liquids**

| Material | Temp. °C (°F) | Density kg/L (g/cc) | Viscosity mPa·s (cps) | pH | Other |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |

**Mixer characteristics**

Make _____; Model _____; Serial no. _____

Volume: Total _____ $m^3$ ($ft^3$)

Max recommended _____ $m^3$ ($ft^3$)

Min recommended _____ $m^3$ ($ft^3$)

Solids feed rate (continuous)

Max recommended _____ $m^3$/min ($ft^3$/min)

Min recommended _____ $m^3$/min ($ft^3$/min)

Motor: Make _____; kW (hp) _____; Volts _____;

Type _____; Phase _____

Drive _____

Special starter (if applicable): _____

Vessel or agitator speed during operation, r/min: _____

Diameter of agitator or vertical screw, cm: _____

Type of timing or safety devices to insure proper feeding: _____

_____

Special modifications made for testing: _____

**Charging Schedule for Full Batch**
(Listed in order of addition to mixers)

| Ingredient | Batch mass, kg (lb) | Feed rate (continuous mixing) kg/min (lb/min) | Vol $m^3$ ($ft^3$) | Method of addition | Point of addition | Time min |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| Total | | | | | | |

Ambient conditions: _____ °C (°F) _____ %RH

Mixing time in batch mixer _____ min

Average power _____ kW (hp); or torque _____ N·m (lbf·ft)

Observation regarding volume increase during mixing: _____

_____

Observation regarding residue left in mixer after discharging: _____

_____

Observations regarding material lost from system when mixing full batch or feed rate:

| Point of loss | Amount kg (lb) | Composition and how determined |
|---|---|---|
| | | |

**Quality of Mixing**

| Characteristic assayed | Accuracy of assay | Background ingredients other than tracer | Sample size assayed, g | Method of assay* |
|---|---|---|---|---|
| | | | | |

* Reference for the assay method

Coefficient of variation, CV, of level of tracer found in ten (if more, specify _____) discharge samples. Tracer assayed _____

| Test no. | 25% Fill or rate, CV, % | 75% Fill or rate, CV, % | 110% Fill or rate, CV, % | Rated capacity or rate |
|---|---|---|---|---|
| | | | | |

Response of feeders to poor flow from bin.
(For each feeder measure rate of flow as a percent of normal rated setting at which safety device will stop operation or sound alarm.)

| Feeder no. | Material | Percent of normal |
|---|---|---|
| | | |

Schematic of mixer; show key dimensions, number of agitators (see paragraphs 4.2.1 to 4.2.9).

Note: the results reported here are for typical feed materials and may not necessarily apply to materials having unusual mixing properties.

## 13 Statistical concepts and tests

13.1 When dealing with a procedure where count is used for measuring uniformity, the Poisson distribution is applicable. In procedures where chemical analysis are used, then a normal distribution is applicable. With a Poisson distribution, the standard deviation due to a small number of tracer particles in a sample is given by:

$$S = \sqrt{N}$$

where

$S$ = standard deviation

$N$ = number of tracer particles in sample

Variation due to this distribution is minimized by using samples containing more tracer particles.

13.1.1 For design and development testing, it may be desirable to use lower levels of salt which will meet the normal animal feed requirements. The decreased levels of salt particles may be compensated for by using a larger assay sample which will supply the same number of tracer particles.

13.2 **Additive property of variances.** Variances are additive and include mixing, sampling and assay variations. If the variance of each of a number of variables is known, then

$$S^2 \text{ total} = S_1^2 + S_2^2 \ldots S_n^2$$

13.3 **Coefficient of variation.** The coefficient of variation given by:

$$CV = \frac{S}{m} \times 100$$

where

CV = coefficient of variation

$m$ = mean value of all samples

$S$ = standard deviation

The coefficient of variation can be used to calculate the probability of a given percentage of samples falling within specified tolerance limits, if it is assumed that the distribution of assay values is normally distributed. Assume that the distribution of assay values is given by $f(y)$ with given $m$ and $S$. It is desired to ascertain the probability that a given sample will fall within the range of $(1 - B)m$ to $(1 + B)m$. A transformation can be made to the standard normal distribution by:

$$Z = \frac{y - m}{S} \text{ with corresponding tolerance limits} = \frac{(-)B}{CV} < Z < \frac{B}{CV}$$

$$\text{or } = \frac{(-)Bm}{S} < Z < \frac{Bm}{S}$$

where

$B$ = tolerance

The areas under the distribution curve, $F(Z)$ for the indicated limits can be taken from any standard table, and this area represents the probability that any given sample will fall within the given tolerance.

13.4 **F test for variances.** It is frequently desirable to determine if there is a statistically significant difference between the results obtained under different operating conditions, e.g., mixing times. If the means of the two sets of data are the same, then the $F$ test may be applied to the variances to determine if the degree of mixing is the same in both cases.

13.5 **Sample calculations**

13.5.1 **Sample A**

Number of Tracer Particles

| Sample no. | Value of sample $X$ | Value of $(X-m)^2$ |
|---|---|---|
| 1 | 1.985 | 0.0204 |
| 2 | 1.625 | 0.0471 |
| 3 | 1.715 | 0.0161 |
| 4 | 1.625 | 0.0471 |
| 5 | 1.950 | 0.0012 |
| 6 | 1.800 | 0.0018 |
| 7 | 2.025 | 0.0337 |
| 8 | 1.950 | 0.0012 |
| 9 | 1.800 | 0.0018 |
| 10 | 1.800 | 0.0018 |
| 11 | 2.025 | 0.0337 |
| 12 | 1.625 | 0.0471 |
| 13 | 1.915 | 0.0053 |
| | $23.840 = \Sigma X$ | $0.2583 = \Sigma(X-m)^2$ |

$n$ = number of samples taken in one test

$X$ = measured value of each sample

$m$ = mean value of all the samples taken

$S$ = standard deviation of the samples, based on the normal curve. 68% of all samples should fall within this range.

CV = coefficient of variation

$N$ = number of tracer particles in one sample

$$m = \frac{\Sigma X}{n} = \frac{23.840}{13} = 1.842$$

$$S^2 = \frac{\Sigma(X-m)^2}{n-1} = \frac{0.2583}{12} = 0.0214$$

$$S = 0.1464$$

CV based on one standard deviation due to test sample measurement:

$$CV = \frac{S}{m} \times 100 = \frac{0.1464}{1.8420} \times 100 = 7.95\%$$

13.5.2 **Sample B**

CV based on one standard deviation due to the number of tracer particles in test sample:

$$N = 1350$$

$$CV = \frac{1}{\sqrt{N}} \times 100 = \frac{1}{\sqrt{1350}} \times 100$$

$$= \frac{1}{36.74} \times 100 = 2.72$$

### 13.6 Target coefficient of variation

The target coefficient of variation of the finished mixed product should be less than 1.5 times the coefficient of variation of the assay or analytical procedures used.

## References


1. Luhman, C. A. A. Aug. 15, 1955. Rapid potentiometric method for the determination of soluble chlorine in feeds. Association of Agricultural Chemists Journal 38:76.
2. Lindstrom, H. R., *et al.* 1968. Farm feed mixer evaluation. TRANSACTIONS of the ASAE 11:771–775.
3. Solids mixing equipment. Standard Testing Procedure. American Institute of Chemical Engineers, New York, NY.
4. Herdan, G. 1960. Small particle statistics. Butterworths, London.
5. Freund, J. 1962. Mathematical statistics. Prentice Hall.
6. Pfost, H. B., *et al.* 1967. Factors affecting performance of feed mixers. TRANSACTIONS of the ASAE 10:526-533.
7. Pfost, H. B. 1966. Statistical concepts for evaluating feed mixers. TRANSACTIONS of the ASAE 9:335–337.


### Cited Standard

ASAE S319, Method of Determining and Expressing Fineness of Feed Materials by Sieving