# ANSI/ASAE S436.1 DEC01
# Test Procedure for Determining the Uniformity of Water Distribution of Center Pivot and Lateral Move Irrigation Machines Equipped with Spray or Sprinkler Nozzles

®

**American Society of Agricultural Engineers**

STANDARD



**ASAE-The Society for engineering in agricultural, food, and biological systems**
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ANSI/ASAE S436.1 DEC01
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# Test Procedure for Determining the Uniformity of Water Distribution of Center Pivot and Lateral Move Irrigation Machines Equipped with Spray or Sprinkler Nozzles

*Developed jointly by The Irrigation Association and the ASAE Sprinkler Irrigation Committee; approved by the ASAE Soil and Water Division Standards Committee; adopted by ASAE June 1983; reconfirmed December 1988; approved as an American National Standard May 1989; revised editorially June 1989; reconfirmed December 1989, December 1990, December 1991; reaffirmed by ANSI September 1992; reaffirmed by ASAE December 1992, December 1993, December 1994, December 1995; revised June 1996; revision approved by ANSI October 1997; revised editorially September 1998; reaffirmed by ASAE for one year January 2001; reaffirmed by ANSI March 2001; reaffirmed for five years December 2001.*

## 1 Purpose and scope

**1.1** The purpose of this Standard is to define a method for characterizing the uniformity of water distribution of sprinkler packages installed on center pivots and lateral move irrigation machines. This test produces data to be used in computing the coefficient of uniformity, which can assist in system design and/or selection, and can be used to quantify certain aspects of system performance in the field. The coefficient of uniformity is only one factor in evaluating total system performance. Application rates, runoff, wind, amount of water applied, pump performance, and overall system management can greatly affect the total performance of irrigation systems.

**1.2** This Standard specifies a method for measuring water application depths in the field and calculating a coefficient of uniformity from the data. The Standard covers evaluation of water distribution from center pivots and lateral move irrigation machines equipped with sprinklers or spray devices. The Standard does not apply to systems in which the water application device is less than 1.5 m above the soil surface, or in which the water distribution from adjacent devices does not overlap.

## 2 Normative references

The following standard contains provisions which, through reference in this text, constitute provisions of this Standard. At the time of publication, the edition indicated was valid. All Standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent edition of the Standard indicated below. Standards organizations maintain registers of currently valid Standards.

ASAE S526.1 DEC96, *Soil and Water Engineering Terminology*

## 3 Definitions

**3.1 effective length of the lateral move system:** The nominal distance parallel to the pipeline that is to be irrigated. Calculated as the distance between the *terminal* devices (see clause 3.5) on *ends* of the pipeline, plus 75% of the wetted radius of each *terminal* device.

If a portion of the area under the pipeline is used for the water supply system and not for crop production, that distance should not be included in the definition of the effective length. For this case, the effective length is the distance between the *terminal sprinkler* or spray devices *on each end of the lateral*, plus 75% of the wetted radius of each terminal water applications device, minus the distance used for the water supply system.

An alternative definition for effective length may be used, and shall be clearly stated in the test results.

**3.2 effective radius of the center pivot:** The nominal radius of the circular field area that is to be irrigated. Calculated as the distance from the pivot point to the terminal sprinkler or spray device on the pipeline, plus 75% of the wetted radius of the terminal water application device. If an alternative definition for effective radius is used, it shall be clearly stated in the test results.

**3.3 endgun:** A set of one or more sprinklers installed on the distal end of a center pivot or lateral move machine to increase the irrigated area. The endgun operates a fraction of the time required to irrigate the entire field. *Sprinklers* at the distal end of the machine that operate continuously while the field is being irrigated are not considered endguns.

**3.4 sprinkler package:** A collection of water distribution devices fitted to the outlets of either a center pivot or a lateral move system. The devices may consist of sprinklers, spray devices, piping, pressure or flow control devices, and supporting plumbing designed for a specific machine and set of operating parameters.

**3.5 terminal device:** The sprinkler or spray device at the moving end of a center pivot system or at one or both ends of a lateral move system. The terminal device operates continuously and is not an endgun.

**3.6 test pressure:** The pressure at the inlet *where water enters the lateral pipeline.* The test pressure shall be measured at the first available outlet downstream of the inlet to the pipeline.

**3.7 wetted radius:** Distance measured from the sprinkler or spray device centerline to the farthest point at which deposition of water declines to approximately 1 mm/h. The wetted radius is based on tests conducted when there was no wind. For the purposes of this test, the wetted radius can be estimated from manufacturer's catalog data as half of the diameter of coverage, or by observation of the machine operating in the field.

## 4 Test conditions and equipment

### 4.1 Collectors

**4.1.1** All collectors used in the test to measure the depth of water applied shall be identical and shaped such that water does not splash in or out. The lip of the collector shall be symmetrical and without depressions. The height of the collectors shall be at least 120 mm. The entrance diameter of the collector shall be one-half to one times its height, but not less than 60 mm. The collector should be of a *light color to reflect solar radiation and minimize evaporation*.

**4.1.2** The collectors shall be spaced uniformly along two or more straight lines perpendicular to the direction of travel of the machine (see figures 1 and 2). The collector spacing along each line shall not be more than 3 m for spray devices and 5 m for impact sprinklers. Collectors can be moved to avoid wheel tracks. If possible, the collector spacing should not be an even multiple or fraction of the sprinkler or spray device spacing. The location of the collectors shall be recorded.

**4.1.3** The collectors shall be located so that obstructions, such as the crop canopy, do not interfere with the measurement of water application. When the obstruction is higher than the elevation of the collector, but

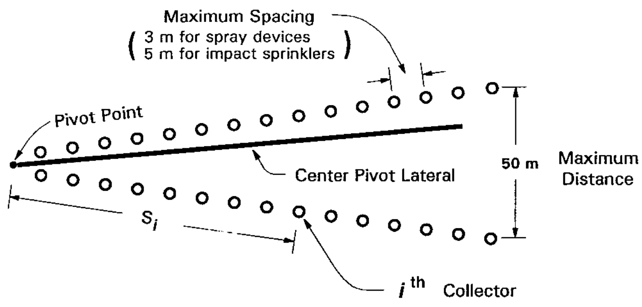



**Figure 1 – Collector layout for determining the water distribution of center pivot irrigation machines**

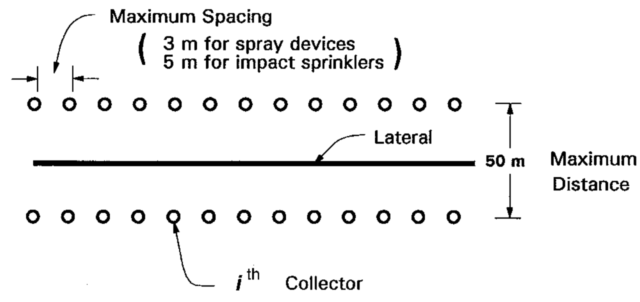



**Figure 2 – Collector layout for determining the water distribution of lateral move irrigation machines**

below the nozzle height, an unobstructed *space of at least twice the distance between the height of the obstruction and the top of the collector* shall be maintained on both sides of the collector rows as shown in figure 3. For systems with nozzles that operate below the crop canopy height, an unobstructed distance of at least 1.25 times the wetted radius of the sprinkler shall be maintained on each side of the collector rows as shown in figure 3.

**4.1.4** The entrance portion of the collectors shall be level. When wind speeds during the test are expected to exceed 2 m/s, the collectors should be no more than 0.3 m above the ground or crop canopy. Nozzle and collector heights shall be recorded. The discharge elevation of the nozzle shall be at least 1 m above the elevation of the collector.

**4.2** Wind velocity during the test period shall be measured with a rotating anemometer or equivalent device.

**4.2.1** The wind direction, relative to the line of collectors, shall be determined with a vane indicating at least eight points of the compass.

**4.2.2** The wind velocity–measuring equipment shall be located at a minimum height of 2 m above the ground surface and within 200 m of the test site, in a location that is representative of the wind conditions at the test site.

**4.2.3** The anemometer shall have a threshold velocity of 0.3 m/s or less and be capable of measuring the actual velocity to within $\pm$ 10%.

**4.2.4** The wind velocity and prevailing direction at the time of the test shall be measured and recorded at intervals of not longer than 15 minutes.

**4.2.5** Accuracy of this test procedure decreases when wind speeds exceed 1 m/s. If wind speed exceeds 5 m/s, this test may not be a valid measure of uniformity or the performance of the sprinkler package. Any results obtained when wind speeds exceed 5 m/s shall be prominently labeled with "wind speeds during this test exceeded the criteria of ASAE S436."

**4.3** It is recommended that the test be conducted during periods that minimize the effect of evaporation such as at night or during early daylight hours. Dry bulb temperature and a humidity parameter (wet bulb temperature, relative humidity, or dew point temperature) shall be measured upwind of the machine and recorded near the beginning and at the end of the test. The time of measurement shall be recorded.

**4.3.1** To minimize the effect of evaporation from collectors during the test, the volume of water in each collector shall be measured and recorded as soon as water application at the specific collector is complete. If the volume caught in each collector will be adjusted for evaporation loss, the time that each collector contains water, i.e. from the time water reaches the collector until the collector volume is measured, shall be estimated.

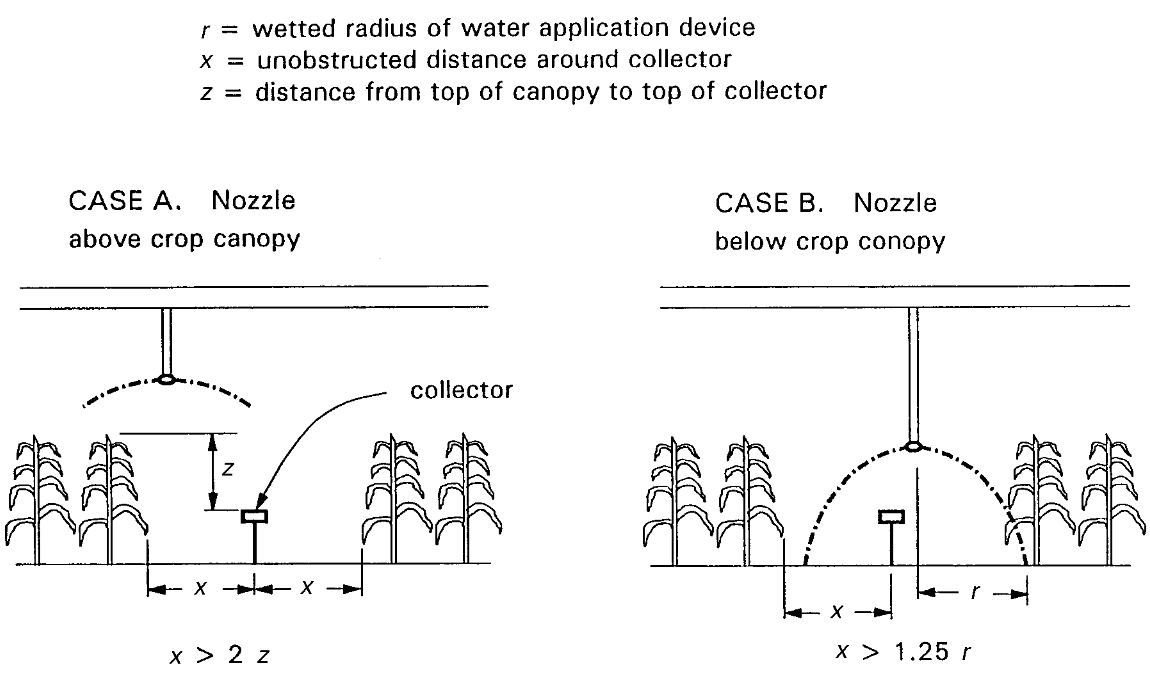



**Figure 3 – Diagram of the required unobstructed area around the collectors**

**4.3.2** If an adjustment is made on the collected data to account for evaporation from the collectors, a minimum of three control collectors containing the anticipated catch shall be placed at the test site and monitored to determine the rate of evaporation. Control collectors shall be located where the microclimate is essentially unaffected by the operation of the machine. The time that control collectors are measured shall be recorded.

**4.3.3** Alternate procedures for minimizing evaporation are to use an evaporation suppressant or a specially designed collector. The methods used to suppress evaporation shall be recorded.

**4.4** The test shall be conducted in an area that has elevation differences that are within the design specifications of the sprinkler package. Elevation differentials should be measured with an instrument capable of measuring an elevation change of $\pm$ 0.2 m in a 50-m length. A sketch of the ground surface profile along each line of collectors should be included with the test results.

## 5 Test procedures

**5.1** General

**5.1.1** Before a machine is tested, it shall be verified that the sprinkler package has been installed and adjusted according to the design specifications. If not installed or adjusted properly, the package shall be corrected before testing.

**5.1.2** The desired test pressure shall be specified prior to the test. For many applications the specified test pressure should match the pressure used to design the sprinkler package on the machine. The test pressure shall be recorded and shall be maintained during the test to within $\pm$ 5% of the specified test pressure. The pressure-measuring device shall be capable of accurately measuring to within $\pm$ 2% of the specified test pressure.

**5.1.3** The machine shall be operated at a speed that will deliver an average depth of application of not less than 15 mm. The irrigation system shall be operated long enough for the water application pattern to completely pass over all collectors.

**5.1.4** The application depth data shall be recorded by measuring the volume or mass of water caught in the collectors. The measuring device shall be accurate to $\pm$ 3% of the average amount of water collected.

**5.1.5** Obviously erroneous observations caused by leaking or tipped containers, or other explainable variances, may be eliminated from the water distribution analysis. The number of deleted observations shall not exceed 3% of the total number of depth measurements. All observations shall be reported. The number of obviously wrong observations and reasons for the deletion shall be recorded.

**5.1.6** Observations beyond the effective radius or length of the machine shall be eliminated from the analysis.

**5.1.7** The sprinkler package can be designed with the endgun operating *or with the endgun not operating*. The test shall be performed with the *endgun in the same operational mode as used for designing the sprinkler package*. The number of water application devices that apply water should remain constant during the test. If desired, the test can also be performed with the endgun *in the alternative operational mode* to evaluate the water distribution for those conditions.

**5.1.8** This standard is not adequate to test the uniformity of corner pivots during the time that only part of the corner watering system of the pivot is in operation. The test can be performed when the corner pivot is fully extended and all sprinkler or spray devices are operating. However, the uniformity determined from testing the fully extended corner pivot will not represent the uniformity for the entire field. If the uniformity of application across the entire field is required, additional data shall be collected or additional weighting factors applied, or simulation modeling may be used.

**5.2 Center pivot**

**5.2.1** The collectors shall be located along lines extending radially from the pivot point. If lines of collectors are too far apart, the duration of the test becomes excessive and environmental conditions or topographic features may change during the test. Therefore, distal ends of the radial lines shall be no more than 50 m apart (see figure 1).

**5.2.2** Collectors are not required for the inner 20% of the effective radius of the pivot if mutually agreed upon by the testor and the client.

**5.2.3** All other conditions as outlined in clauses 4 and 5.1 shall be followed.

**5.3 Lateral move**

**5.3.1** The collectors shall be located along lines parallel to the pipeline. The lines of collectors shall extend across the effective length of the machine and shall not be more than 50 m apart (see figure 2). The maximum spacing of 50 m prevents unduly long tests and minimizes environmental or topographic changes during the test.

**5.3.2** All other conditions as outlined in clauses 4 and 5.1 shall be followed.

## 6 Data analysis

**6.1** The center pivot coefficient of uniformity will be calculated using the modified formula of Heermann and Hein:

$$CU_H = CU_H = 100\left[1 - \frac{\sum_{i=1}^{n} S_i|V_i - \overline{V}_p|}{\sum_{i=1}^{n} V_i S_i}\right] \tag{1}$$

where:

- $CU_H$ is the Heermann and Hein uniformity coefficient;
- $n$ is the number of collectors used in the data analysis;
- $i$ is a number assigned to identify a particular collector beginning with $i = 1$ for the collector located nearest the pivot point and ending with $i = n$ for the most remote collector from the pivot point.
- $V_i$ is the volume (or alternately the mass or depth) of water collected in the $i$th collector;
- $S_j$ is the distance of the $i$th collector from the pivot point;
- $\overline{V}_p$ is the weighted average of the volume of water caught.

It is computed as:

$$\overline{V}_p = \frac{\sum_{i=1}^{n} V_i S_i}{\sum_{i=1}^{n} S_i} \tag{2}$$

**6.2** The coefficient of uniformity for a lateral move is calculated using the Christiansen formula:

$$CU_C = 100\left[1 - \frac{\sum_{i=1} |V_i - \overline{V}|}{\sum_{i=1}^{n} V_i}\right] \tag{3}$$

where:

- $CU_C$ is the Christiansen uniformity coefficient;
- $n$ is the number of collectors used in data analysis;
- $V_i$ is the volume (or alternatively the mass or depth) of water collected in the $i$th collector;
- $\overline{V}$ is the arithmetic average volume caught by all collectors.

Location of Test ______________________ Date ______________

## Machine Description:

Make ______________________

Lateral Length, m ______________________

Diameter of Lateral, mm ______________________

Type of Sprinkler Package ______________________

Endgun Description:

Area Irrigated (ha) with:

Endgun Off __________

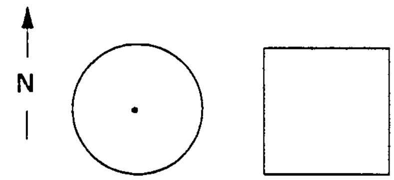
Endgun On __________

Nominal Height of Nozzle Above Ground, m __________

Height of Collector Above Ground, m __________

Pressure at Lateral Inlet: Desired __________ kPa Actual __________ kPa

Show lateral location during test.




Center Pivot Lateral Move

## Climatic Conditions:

Maximum Wind Speed Meets S436 Criteria (<5 m/s) ________(Y/N)

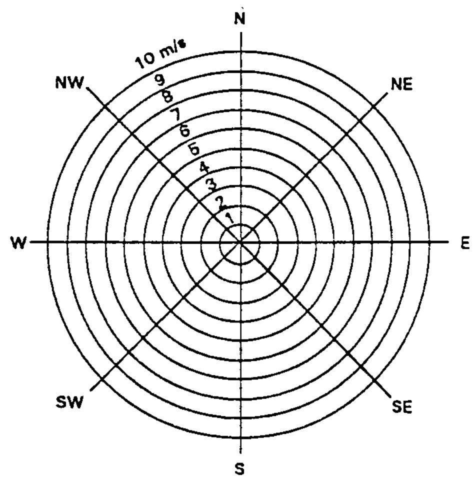
Type of Humidity Measurement __________

| Time During Test | Dry Bulb Temp., Deg C | Humidity Parameter | Units for Humidity |
|---|---|---|---|
| Beginning | ______ | ______ | |
| Ending | ______ | ______ | |
| Average | ______ | ______ | |

Mean Wind Speed, m/s __________

Maximum Wind Speed, m/s __________

Plot vector for each wind measurement.

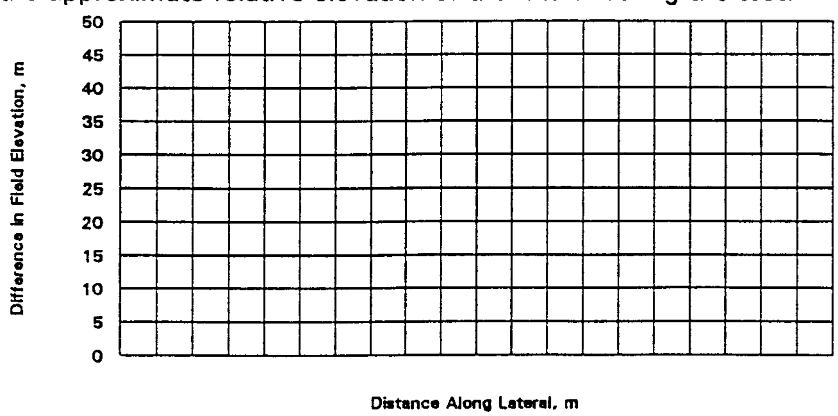



Evaporation from control collectors

| Collector No. | 1 | 2 | 3 |
|---|---|---|---|
| Initial volume, ml | ____ | ____ | ____ |
| Time, hr | ____ | ____ | ____ |
| Final volume, ml | ____ | ____ | ____ |
| Time, hr | ____ | ____ | ____ |
| Loss (El), ml | ____ | ____ | ____ |
| Elapsed time, hr | ____ | ____ | ____ |
| Loss rate, ml/hr | ____ | ____ | ____ |

## Elevation:

Plot the approximate relative elevation of the lateral during the test.




Show the location of the inlet to the lateral on the diagram.

Figure 4 – Field and machine data sheet

Collector Line Number ____________ Page _______ of ________

Diameter of Collectors ($D_c$) ____________ mm
Area of Collector Opening ($A_c = 0.785 * D_c^2$) ____________ $mm^2$
Nominal Spacing of Collectors ____________ m

| Collector [1] or Tower Number | Location of [2] Collector or Tower m | Time Water was in Collector h | Catch Volume mL | Adjusted Catch Volume [3] mL | Depth [4] Applied mm | Product [5] of Depth and Distance | Comments |
|---|---|---|---|---|---|---|---|
| $i$ | $S_i$ | $T_i$ | $V_i$ | $Va_i$ | $D_i$ | $S_i * D_i$ | |
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1. Record the collector and tower number. Use a code such as C # for collectors and T # for towers.
2. For center pivots record the distance from the pivot point to each collector or Tower. For lateral move systems record the distances from a designated end.
3. The adjusted volume equals the volume caught in each collector plus the amount of water that evaporated from the control collectors while water was in the specific collector:
   i.e. $Va_i = V_i + EI * T_i$
4. The depth applied is the adjusted volume divided by the area of the collector opening.
   i.e. $D_i = 1000 * Va_i / A_c$
5. The product of depth and distance is only used for calculating the coefficient of uniformity for center pivots.

**Figure 5 – Sample data sheet to record test results**

It is computed as:

$$\bar{V} = \frac{\sum_{i=1}^{n} V_i}{n} \qquad (4)$$

**6.3** $CU_H$ or $CU_C$, whichever is appropriate, shall be calculated for each line of collectors. A composite uniformity coefficient shall be computed using the volumes caught from both lines of collectors.

**6.4** Other measures of uniformity, such as distribution uniformity, may be reported along with $CU_H$ or $CU_C$ as long as the equations used to compute the measure are also provided.

EFFECTIVE LENGTH OF MACHINE, m ________

NUMBER OF COLLECTORS INSTALLED ________

NUMBER OF COLLECTORS USED IN ANALYSIS (n) ________

PERCENT OF COLLECTORS OMITTED FROM ANALYSIS ________

WEIGHTED MEAN DEPTH ($\overline{D}$) FOR:

| CENTER PIVOTS: | | COLLECTOR LINE 1 | 2 | TOTAL |
|---|---|---|---|---|
| SUM OF DEPTH AND DISTANCE PRODUCT | $\sum_{i=1}^{n} S_i D_i =$ | ____ | ____ | ____ |
| SUM OF DISTANCES | $\sum_{i=1}^{n} S_i =$ | ____ | ____ | ____ |
| WEIGHTED MEAN DEPTH | $\overline{D} = \dfrac{\sum_{i=1}^{n} S_i D_i}{\sum_{i=1}^{n} S_i} =$ | ____ | ____ | ____ |
| **LATERAL MOVES:** | | | | |
| MEAN DEPTH | $\overline{D} = \dfrac{\sum_{i=1}^{n} D_i}{n} =$ | ____ | ____ | ____ |

COEFFICIENTS OF UNIFORMITY FOR:

CENTER PIVOTS:

$$CU_H = 100\left[1 - \frac{\sum_{i=1}^{n}\{S_i \,|D_i - \overline{D}\,|\}}{\sum_{i=1}^{n} S_i D_i}\right] = \_\_\_\_ \quad \_\_\_\_ \quad \_\_\_\_$$

LATERAL MOVES:

$$CU_C = 100\left[1 - \frac{\sum_{i=1}^{n} |D_i - \overline{D}\,|}{n\overline{D}}\right] = \_\_\_\_ \quad \_\_\_\_ \quad \_\_\_\_$$

**Figure 6 – Test summary sheet**

**6.5** If a machine with an endgun is tested, use the procedure in clause 5.1 to measure the coefficient of uniformity when the endgun is on, and optionally when it is off. Characterize the operation of the endgun by recording (see figure 4) the approximate area of the field that is irrigated while the endgun operates and the area irrigated while the endgun is turned off.

**6.6** A graph should be prepared showing the depth of water caught in each collector versus the distance from the pivot point or along the lateral. Data from each line of collectors should be plotted separately.

## 7 Evaluation

**7.1** The coefficient of uniformity computed from test results shall be used as an indication of sprinkler or sprayer package performance. The coefficient of uniformity of a new sprinkler package can be used for comparison of different types of sprinkler or sprayer packages and as a reference for similar machines that have been used for a period.

**7.2** If the coefficient of uniformity for an installed machine deviates from the value specified in the initial design, other investigations should be conducted to determine the cause. A coefficient of uniformity smaller than the design value may indicate worn, broken, or malfunctioning water application devices.

**7.3** The graph of the depth applied along the lateral can help identify problems in the operation of the machine. Locations along the lateral where the depth applied is 10% higher or lower than the arithmetic average depth should be investigated to determine the cause of variation.

## 8 Reporting

**8.1** The data measured according to this standard shall be recorded on forms similar to the Standard Data Presentation Forms shown in figures 4 and 5 and the Test Summary Form shown in figure 6. Special arrangements between the testor and the client shall be explained. Justification of data deleted from analysis shall be indicated on the data forms. Additional data not required by this Standard should be included with the test results if the data will help characterize uniformity.