BIOLOGICAL SYSTEMS ENGINEERING
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June 2004

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Uniformity of water distribution test procedure
for center pivot and lateral move irrigation systems

Purpose: This is test procedure is based on the ASAE standard S436.1 but simplified and updated to make it more practical and accurate to use. Uniformity testing is a troubleshooting procedure to check that the water distributed by the irrigation system is being applied uniformly to the field within practical limitations. The test procedure only measures the amount of water applied to the soil surface and is not intended to indicate the amount of water that infiltrated the soil into the root zone. Evaporation, runoff and leaching could all affect the amount of water available to plants in the root zone. A low coefficient of uniformity could lead to plant stress and disease issues because of a water deficit or too much water in different sections of the field despite the average application rate being acceptable.

Recommended equipment:
- Catch Containers and stakes
- 500 ml plastic graduated cylinder
- 25 foot tape ruler
- 100’ to 300’ foot measuring tape and/or measuring wheel
- Wind meter (anemometer)
- Compass
- Thermometer
- Measurement device for wet bulb temperature, relative humidity or dew point temperature
- Wheel barrow, wagon, dolly (aid for moving equipment to and from field)
- Large Hammer
- Clip Board
- Worksheets
- 0-160 psi Pressure Gauge
- Ladder (may be needed to inspect sprinkler nozzles)
- Rubber boots
- Rain suit

Observation:
1) Before beginning this test, observe the irrigation system in operation and note obvious operating and equipment problems such as leaky boots between laterals, plugged nozzles and under inflated tires. Problems should be fixed before uniformity testing begins unless wanting to document the affect of the deficiency.
2) Electrical Safety – Check the system for short circuits before touching or climbing on the irrigation system. Using an Ohmmeter, check for voltage between the irrigation metal structure and a ground while the system is running dry. Monitor the system long enough until all towers have run.
3) Look for signs of non-uniform crop growth and run-off or erosion.

Test Equipment and Conditions:

1) Water collection container (Gauge):
A container is needed to collect the water applied by the irrigation system. The container must have a minimum opening diameter of 3-3/4" and a minimum height of 8". The height of the collection container must be 1 to 1.5 times the diameter of the opening. A 6" or larger opening collection container is recommended for systems outfitted with fixed plate spray nozzles that have distinct streams of water to get accurate results. The container shall have a sharp edge.

2) Gauge Location:
A single row of uniformly placed gauges are placed perpendicular to the direction of travel of the irrigations system to collect a sample. For a center pivot, the gauges are placed radially from the center pivot and parallel to the lateral pipe for a lateral move system. Gauges shall be placed at a spacing of 80% of the sprinkler spacing at a maximum with the following conditions:
No more than 10 feet apart for spray type sprinklers and 16 feet for impact sprinklers.

Do not use a gauge spacing that is an even increment of the sprinkler spacing. (Example: Impact sprinklers are at 32 foot spacings; 80% of 32 is 26 ft which is wider than the maximum spacing of 16 ft. However, 16 feet is an even multiple of 32 feet so a spacing less than 16 feet needs to be used. The recommendation would be to use a spacing of 12 feet (80% of 16 feet). Closer spacing will result in more reliability and accuracy of data and doesn't add a significant amount of setup time.

Gauges should be located above crop canopy or when not possible, maintain an unobstructed horizontal distance of twice the obstruction height for above canopy sprinklers and an unobstructed horizontal distance of 1.25 the obstruction height for in-canopy sprinklers.

3) Gauge Entrance Height - The opening of the gauge shall be level and a minimum of 3.25 feet below the discharge level of the sprinkler.

4) Wind Velocity – Wind velocities shall be recorded with a rotating anemometer with a threshold velocity of 0.7 mph or less and accuracy of +/- 10%. Wind velocity readings shall be taken at a minimum height of 6 feet above the ground and within 600 feet of the test site. (NOTE: Accuracy of the uniformity test may be decrease as wind speed increases. Wind speeds above 10 mph may invalid uniformity test depending on wind direction compared to lateral position.)

5) Wind Direction – Use a compass with at least 8 points and an anemometer to determine the wind direction. Wind direction in relation to the irrigation lateral during testing should be recorded.

6) Wind velocity and direction should be taken at the test site at the beginning and end of the test. Record the average and maximum wind velocity and the direction.

7) Temperatures – Dry bulb temperature and wet bulb temperature or relative humidity shall be taken upwind of the irrigation machine at the beginning and end of the test. Record the temperature on the data sheet.

8) Evaporation adjustment - If not using low evaporation collection gauges and the catch cans or gauges are left in the field for several hours after the irrigation lateral passes or overnight before recording catch amounts, the evaporation from the cans should be estimated. Set out a minimum of three cans (same as used for catching irrigation water) up wind of the lateral filled with the anticipated amount of water (measure and record) that will be applied by the irrigation system at the beginning of the test. When collecting catch can samples, measure the water left in the evaporation cans. Average the readings and subtract from the initial value to determine the evaporation loss. Adjust all measurements by the evaporation loss.

Test Procedure:

1) Determine system operating pressure at center pivot during the test. The preference is to use a calibrated pressure gauge. If not possible, note that existing gauge was used on data sheet.

2) Operate the system at a speed that will apply and average depth of 0.6 inches (15mm) of water or more.

3) Measure the water collected in the gauges by volume or mass within 3% accuracy of average amount collected. Using a graduated cylinder or reading the amount directly from the graduations on the collection container is probably the easiest.

4) Omit obviously erroneous data from leaking or tipped containers. Omitted samples can not exceed 3% of total measurements taken (3 per 100 catch cans).

5) Observations beyond 75% of the wetted radius of end sprinklers or end gun(s) at the terminal end(s) shall be omitted from uniformity calculations. If an end gun has a wetted radius of 80 feet then any catch cans beyond 60 feet (80 feet x 0.75) will not be used for calculation.

6) Testing shall be done with end guns in the same operational mode throughout the test: either operating or not operating. It is recommended that systems using end guns that are operated intermittently be tested in both operational modes. This would provide data about changes in application depth with the end gun on and off. If the difference is extreme, some adjustments to the systems might be warranted.

7) Uniform spacing of gauges should be used except when gauge locations fall in the path of an obstacle such as tire paths or locations that would come in contact with the tower structure. In these cases, relocate the gauge that will cause interference.

<u>Center Pivot Testing:</u>

8) Gauges should be located in one line extending radially from the pivot point at a great enough distance from the pipeline that water will not initially fall into the gauges until the system starts moving.

9) Gauges are not required on the inner 20% of the effective radius of the pivot if agreed on by the grower.

<u>Lateral Move Testing:</u>

10) Gauges shall be placed in one line parallel to the lateral pipeline at a great enough distance from the pipeline that water will not initially fall into the gauges until the system starts moving.

11) Allow lateral to completely pass over containers before recording results of gauges.

**Data Analysis**

Record Keeping:

1) Record the location of the irrigation system, Well number (if available), make of the system, pipe diameter of the main lateral, length of spans, number of spans, total system length, type of sprinkler package, sprinkler spacing, nozzle height, use of an end gun, end gun wetted radius, percent of time end gun is "on" and number of irrigated acres.

2) Record the amount of water (volume or weight) collected from each gauge and the distance the gauge is from the center pivot or end of a lateral move system. Record the height the gauges are located above the ground. All gauges should be the same height.

3) Record the wind speed (average and maximum) and direction at the beginning and end of the test period.

4) Sketch a map of the position of the collection gauges in relation to the wind direction.

5) Record the dry bulb temperature and humidity at the beginning and end of the test period.

Calculations: *(An Excel spreadsheet application is available to do these calculations)*

1) Calculate conversion factor for collection can sized used.
   d = diameter of collection can / gauge in inches
   $A_c$ = Area of collector = 5.067 x $d^2$ ($cm^2$)
   CF = Conversion Factor (ml per inch) = 2.54 x $A_c$

2) Convert volume of water in ml (milliliters) collected ($V_i$) into depth of water in inches applied ($D_i$).

$$D_i = V_i / CF$$

$V_i$ = Volume of water measured in gauge "i".
$D_i$ = Calculated depth of water applied as measured in gauge "i".

***Center Pivot***

3) Weighted Average Depth ($D_w$) of water samples collected:

$$D_w = \frac{D_1S_1 + D_2S_2 + D_3S_3 + D_4S_4 + D_5S_5 + \ldots\ldots}{S_1 + S_2 + S_3 + S_4 + S_5 + \ldots..}$$

$S_i$ = Distance from pivot for gauge "i".

4) Calculation of the "Coefficient of Uniformity" using the Heermann and Hein modified formula:

$$CU_H = 100 \left[ 1 - \frac{\sum S_i \, | D_i - D_w |}{\sum D_i S_i} \right]$$

OR

$$= 100 \left[ 1 - \frac{(S_1 |D_1 - D_w| + S_2 |D_2 - D_w| + S_3 |D_3 - D_w| + S_4 |D_4 - D_w| + \ldots)}{(D_1S_1 + D_2S_2 + D_3S_3 + D_4S_4 + \ldots\ldots)} \right]$$

$|V_1 - D_w|$ is define as the absolute value of the difference between $D_1$ and $D_w$. If the difference is negative, the negative sign is ignored and is treated as a positive.

***Lateral Move***

5) Arithmetic Average ($\bar{A}$) of water samples collected:

$$\bar{A} = \frac{D_1 + D_2 + D_3 + D_4 + D_5 + \ldots\ldots D_i}{n}$$

$D_i$ = Calculated depth of water applied as measured in gauge "i".
n = total number of water measurements

6) Calculation of the "Coefficient of Uniformity" for a lateral move system using the Christiansen formula:

$$CU_c = 100 \left[ 1 - \frac{\sum | D_i - \bar{A} |}{\sum D_i} \right]$$

OR

$$= 100 \left[ 1 - \frac{(|D_1 - \bar{A}| + |D_2 - \bar{A}| + |D_3 - \bar{A}| + |D_4 - \bar{A}| + |D_5 - \bar{A}| + \ldots)}{(D_1 + D_2 + D_3 + D_4 + D_5 + \ldots\ldots)} \right]$$

$|D_1 - \bar{A}|$ is define as the absolute value of the difference between $D_1$ and $\bar{A}$. If the difference is negative, the negative sign is ignored and is treated as a positive.

7) Calculation of the percentage of deviation each sample varies from average.

$DV\%_i = 100 \times (D_i - D_w) / D_w$ Center pivot systems
$DV\%_i = 100 \times (D_i - \bar{A}) / \bar{A}$ Lateral systems

A Microsoft Excel spreadsheet program is available to calculate all of the above formulas. Contact Scott Sanford at 608-262-5062 or e-mail at sasanford@wisc.edu.

Analysis of Results

In an ideal world one would strive for a Coefficient of Uniformity of 100% but in practice this is not possible. For center pivot and lateral move systems a CU of 90 to 95% is very good to excellent.

| | |
|---|---|
| Excellent | 95% |
| Very Good | 90% |
| Good | 85% |
| Fair | 80% |
| Poor | 75% |

If your system is less than 85% you should be able to easily improve by checking sprinklers for plugged or enlarged nozzles or the wrong nozzle size for the location on the irrigation system. An 85% CU indicates that some areas of the field are receiving 15% less water and some areas are receiving 15% more than the average applied.

The percentage deviation from the average of any sample greater than 10% would indicate a problem area. The sprinklers on either side of high or low sample readings should be checked for proper operation.

After corrections have been made, the system should be re-checked.

This project was funded in part by Wisconsin Focus on Energy

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Uniformity Testing Data Collection Form Date:_____

Grower Name: _____ Phone #:_____
Contact Information:_____
_____
Tested By:_____

Location of Irrigation System:_____
Well Number:_____ Rated Pump Capacity: _____gpm @ _____ psi

**Irrigation System Description:**
Center Pivot - Degrees of rotation:_____ Lateral Move - Length of run(ft): _____
Lateral Length, ft: _____ Diameter of lateral, inch: _____
No. of spans:_____ Length of span (Ft):_____ Overhang length (Ft):_____
Type of sprinklers: Fixed plate spray
Spinner Height of nozzle above ground, ft: _____
Wobbler Sprinkler spacing, ft: _____
Rotator
Impacts
Are Pressure regulators being used at each sprinkler? Yes No Don't Know
Pressure rating:_____
End gun: Yes No End gun operational mode during testing: On Off
Wetted radius of end gun, feet: _____
System Pressure at pivot or first sprinkler, psi: _____

Tower Speed control Setting: _____ Proportional timer interval (sec):_____

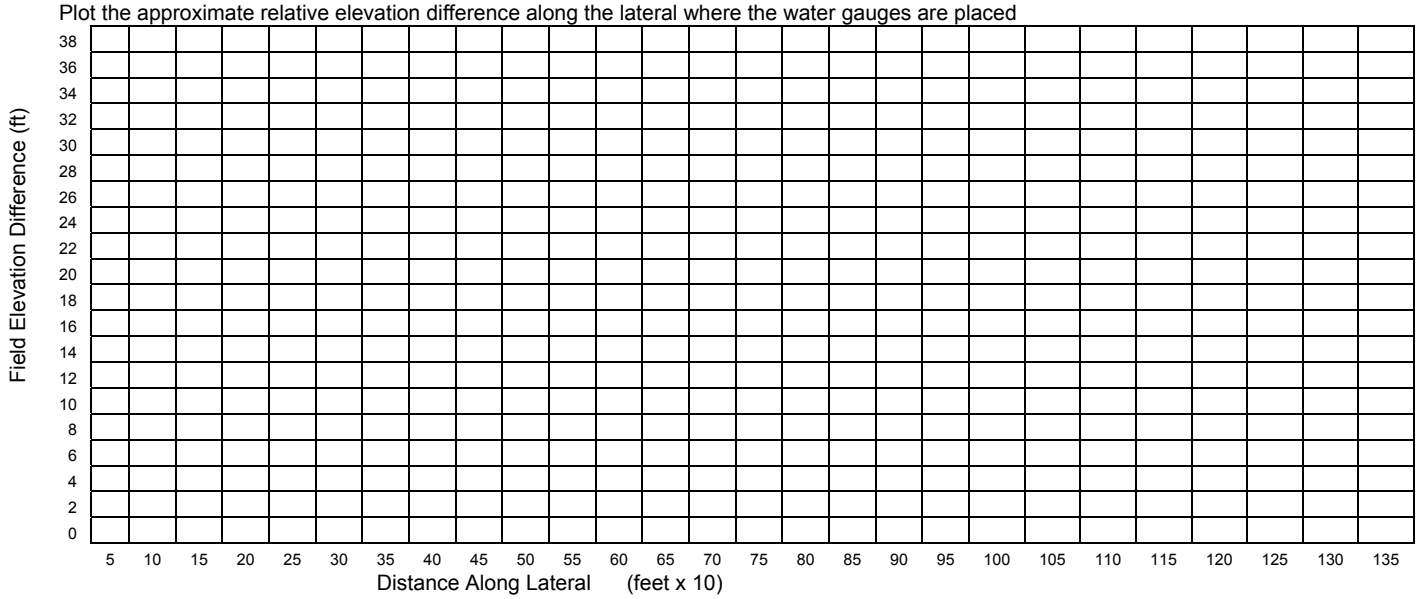
Length from CP to end tower: _____ ft x 6.28 x degrees of rotation _____/360
= _____ ft of travel

Time for end tower to travel _____ feet. Start time:_____ End Time:_____
Total Travel time: _____Min.

**Collection container:**
___ Irrigauge (UW Kit)
___ Grower supplied container
Diameter of opening, inch: _____
Height of container, inch: _____
Height of collector above ground: _____inches
Collector spacing, ft:_____ (80% of sprinkler spacing or 10 ft for spray nozzles and 16 ft for impact sprinklers - Maximum)
Number of collectors used:_____

## Elevation:

Plot the approximate relative elevation difference along the lateral where the water gauges are placed

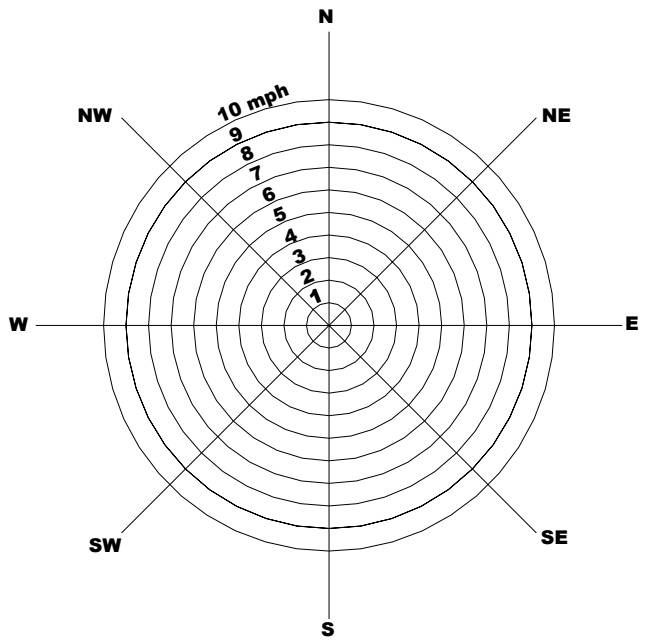



## Climatic Conditions:

| | Ave Wind speed | Max Wind Speed | Wind Direction: |
|---|---|---|---|
| Start: | _____ | _____ | _____ |
| End: | _____ | _____ | _____ |
| Average: | _____ | _____ | |

| Temperatures: | Dry Bulb,°F | % Relative Humidity |
|---|---|---|
| Beginning: | _____ | _____ |
| Ending: | _____ | _____ |
| Average: | _____ | _____ |

Plot Vector for each wind measurement.




Indicate the relative position of collection containers for the test.

Direction of rotation:
___ Clockwise
___ Counter Clockwise