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Agricultural irrigation equipment — Centre-pivot and moving lateral irrigation machines with sprayer or sprinkler nozzles — Determination of uniformity of water distribution

Matériel agricole d'irrigation — Pivots et rampes frontales équipés de buses d'arrosage ou d'asperseurs — Méthode de détermination de l'uniformité de la distribution d'eau

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 11545 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 18, *Irrigation and drainage equipment and systems*.

This second edition cancels and replaces the first edition (ISO 11545:1995), which has been technically revised.

Annex A forms a normative part of this International Standard.

Agricultural irrigation equipment — Centre-pivot and moving lateral irrigation machines with sprayer or sprinkler nozzles — Determination of uniformity of water distribution

1 Scope

This International Standard specifies a method for determining the uniformity of water distribution in the field from centre-pivot and moving lateral irrigation machines equipped with sprayer and sprinkler nozzles. The calculation of the coefficient of uniformity is also specified.

This International Standard is applicable to irrigation machines for which the water application device is more than 1,5 m above the soil surface and for which the water distribution from successive devices overlaps.

This International Standard is not applicable to the evaluation of centre-pivot irrigation machines equipped with various corner arm application devices.

2 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

2.1
centre-pivot irrigation machine
automated irrigation machine consisting of a number of self-propelled towers supporting a pipeline rotating around a pivot point and through which water supplied at the pivot point flows radially outward for distribution by sprayer or sprinkler nozzles located along the pipeline

2.2
moving lateral irrigation machine
automated irrigation machine consisting of a number of self-propelled towers supporting a pipeline moving in such a way that the pipeline remains generally in a straight line, traversing the field in a straight path, and through which water supplied to the irrigation machine at any point along the pipeline flows for distribution over a basically rectangular area by sprayer or sprinkler nozzles located along the pipeline

2.3
sprinkler package
collection of devices fitted to the outlets of either centre-pivot or moving lateral irrigation machines, potentially consisting of sprayers or sprinklers and potentially including piping, pressure or flow-control devices and supporting plumbing designed for a specific irrigation machine and set of operating parameters

2.4
endgun
set of one or more sprayer or sprinkler nozzles installed on the distal end(s) of a centre-pivot or moving lateral irrigation machine to increase the irrigated area, and usually operating for only a portion of the time to conform to system boundaries

2.5
test pressure
pressure of a centre-pivot or moving lateral irrigation machine measured at the first available outlet downstream from the elbow or the tee at the top of the inlet structure

2.6
effective radius
radius of the circular-field area to be irrigated by a centre-pivot irrigation machine, conventionally calculated as the distance from the pivot point to the terminal sprayer or sprinkler on the pipeline plus 75 % of the wetted radius of the terminal sprayer or sprinkler

2.7
effective length
dimension parallel to the pipeline of the area to be irrigated by a moving lateral irrigation machine, conventionally calculated as the distance between the two most distant end sprayers or sprinklers on the pipeline plus 75 % of the wetted radius of each end sprayer or sprinkler, except where a portion of the area under the pipeline is used for the water supply system and not crop production, in which case that distance is excluded from the effective length

2.8
wetted radius
distance measured from the centreline of a sprayer or sprinkler to the most remote point at which the application rate of the individual nozzle declines to approximately 1 mm/h, based on tests conducted when there is no wind

2.9
applied depth
d_i
adjusted volume of water caught in each collector in an array of collectors plus the average amount of water that evaporates while the water is in the collector, divided by the area of the collector opening

2.10
collector

receptacle into which the water discharged by a water distribution device is deposited during a test for radius of throw or by several water distribution devices during a test for distribution uniformity

2.11

client
person(s) or organization for whom a test is performed

2.12
tester
person(s) or organization who conduct(s) a test

3 Test conditions and equipment

3.1 Collectors

3.1.1 Ensure that all collectors used for a test are identical and shaped such that water does not splash in or out. Ensure that the lip of the collector is symmetric and without depressions. Ensure that the height of the collectors is at least 120 mm. Ensure that the entrance diameter of each collector is within the range of from half to full height of the collector, but not less than 60 mm. To minimize measurement error, testers are encouraged to use collectors that are as large as practicable.

3.1.2 Place the collectors uniformly along two or more straight lines perpendicular to the direction of travel of the machine. Ensure that the collector spacing within each line is not more than 3 m for sprayers and 5 m for sprinklers. To minimize systematic errors, adjacent lines of collectors should be offset. The offset should be 1/nth the collector spacing, where n is the number of collector lines (see Figure 1 and Figure 2 for collector layout detail). Ensure that the distance between the collectors is not a multiple of the distance between the sprayers or sprinklers. Collectors should be moved to avoid wheel tracks. Record the location of the collectors.

3.1.3 Place the lines of collectors so that the distance between lines is as follows.

For centre-pivot irrigation machines, locate the collectors along two or more lines extending radially from the pivot point. Ensure that the distance between distal ends of the radial lines is no more than 50 m. Record the spacing pattern (Figure 1).

For moving lateral irrigation machines, locate the collectors along two or more lines parallel to the pipeline. Ensure that the lines of the collectors extend across the effective length of the machine and are not more than 50 m apart. Record the spacing pattern (Figure 2).

3.1.4 Locate the collectors so that obstructions, such as the crop canopy, do not interfere with the measurement of water application. When an obstruction is higher than the elevation of the collector, but below the nozzle height, maintain a horizontal unobstructed distance of at least twice the height of the obstruction on both sides of the collector rows (Figure 3, case A). For systems with nozzles that operate below the crop canopy height, maintain a horizontal unobstructed distance of at least 1,25 times the wetted radius of the nozzle on each side of the collector rows (Figure 3, case B).

3.1.5 Ensure that the entrance portion of the collectors is level. When wind velocities during the test are expected to exceed 2 m/s, the entrance of the collectors should be no more than 0,3 m above ground or crop canopy. Ensure that the discharge height of the sprayer or sprinkler is at least 1 m above the elevation of the collector. Record the height of the sprayer or sprinkler nozzles and the entrance to the collectors.

3.2 Wind

3.2.1 Measure wind velocity during the test period with a rotating anemometer or equivalent device.

3.2.2 Determine the wind direction, relative to the line of collectors, with a vane indicating at least eight points of the compass.

3.2.3 Locate the equipment for measuring wind velocity at a height of 2 m and within 200 m of the test site, in a location representative of the wind conditions at the test site.

3.2.4 Ensure that the anemometer has a threshold velocity not exceeding 0,3 m/s and is capable of measuring the actual velocity to within ± 10 %.

3.2.5 The accuracy of the test procedure begins to decrease when the wind velocity exceeds 1 m/s. The test should not be used as a valid measure of the uniformity or performance of a sprinkler package if the wind velocity exceeds 3 m/s. To test at wind velocities greater than 3 m/s, the client and tester must understand the limitations of the test results. Measure and record the wind velocity and the direction prevailing at the time of the test at intervals not longer than 15 min.

3.3 Evaporation

3.3.1 The test should be conducted during periods that minimize the effect of evaporation, such as at night or during early daylight hours. Measure and record dry bulb temperature, as well as either wet bulb temperature, relative humidity or dew point temperature, upwind from the machine and near the beginning and end of the test. Record the time of day for the measurement.

3.3.2 To minimize the effect of evaporation from collectors during the test, measure and record the volume of water in each collector as soon as possible after the collector is no longer within the range of the water pattern. If the volume caught in each collector is to be adjusted for evaporation loss, estimate the time that each collector contains water, i.e. from the time the collector is first within the range of the water pattern until the collector volume is measured.

3.3.3 If an adjustment is made on the collected data to account for evaporation from the collectors, place a minimum of three control collectors containing the anticipated catch at the test site and monitor them to determine the rate of evaporation. Locate the control collectors where the microclimate is essentially unaffected by the operation of the machine. This is normally upwind from the test area. Record the time of day when control collectors are measured.

3.3.4 Employ appropriate procedures for minimizing evaporation. These include the use of evaporation suppressants or specially designed collectors. Record the methods used to suppress evaporation, including, if applicable, the type of suppressant.

3.4 Elevation

Conduct the test in an area having elevation differences that are within the design specifications of the sprinkler package. Measure elevation differences with an instrument capable of measuring an elevation change of ± 0,2 m over a distance of 50 m. Include a sketch of the ground surface profile along each line of collectors with the test results, unless the ground surface is level.

4 Test procedures

4.1 Before testing an irrigation machine, verify that the sprinkler package has been installed according to the design specifications, unless specified otherwise by the client.

4.2 Adjust and maintain the pressure of the water supplied to the irrigation machine during the test to within ± 5 % of a test pressure mutually agreed upon by client and tester. Ensure that the pressure measurement device is capable of accurate measurement to within ± 2 % of the test pressure. Record the test pressure.

4.3 Operate the irrigation machine at a speed that will deliver an average depth of application of not less than 15 mm, unless specified otherwise by the client.

4.4 Record the application depth data by measuring the volume or, alternatively, the mass or depth of water collected in the collectors. Ensure that the measurement device is accurate to within ± 3 % of the average amount of water collected.

4.5 Eliminate any obviously incorrect data points caused by occurrences such as leakage, tipped collectors or other explainable variances from the water distribution analysis. Ensure that the number of eliminated observations does not exceed 3 % of the total number of depth measurements. Report all observations. Record the number of estimate observations, together with the reasons for their elimination.

4.6 Eliminate from the analysis those observations beyond the effective radius or effective length of the irrigation machine.

4.7 If the sprinkler package is designed with an endgun, perform the test with the endgun operating. The number of sprayers or sprinklers should remain constant during the test. If desired, the test may also be performed with the endgun not in operation in order to evaluate the water distribution for those conditions.

4.8 The data from up to 20 % of the collectors on the inner portion of the total length of a centre-pivot irrigation machine can be eliminated from the water distribution analysis if mutually agreed upon by the tester and the client. Collectors need not be placed in the inner portion of the centre-pivot irrigation machine if the intent of the test is to determine the water distribution with the inner portion of the centre-pivot irrigation machine excluded from the analysis.

5 Calculations

5.1 Calculate the coefficient of uniformity for a centre-pivot irrigation machine using the modified formula of Heermann and Hein [1]. Additional performance parameters may be used to characterize the water distribution uniformity. Ensure that the tester clearly identifies any such additional parameters, including the calculation formula.

The modified formula of Heermann and Hein is:

$$C_{\mathrm{uH}} = 100\left[1 - \frac{\sum_{i=1}^{n} \left|V_i - \overline{V_w}\right| S_i}{\sum_{i=1}^{n} \left|V_i S_i\right|}\right]$$

where

C_{uH} is the Heermann and Hein coefficient of uniformity;

n is the number of collectors used in the data analysis;

i is a number assigned to identify a particular collector, normally beginning with the collector located nearest the pivot point (i = 1) and ending with $i = n$ for the collector furthest from the pivot point;

V_i is the volume (or, alternatively, the mass or depth) of water collected in the ith collector;

S_i is the distance of the ith collector from the pivot point;

$\overline{V_{\mathrm{w}}}$ is the weighted average volume (or, alternatively, the mass or depth) of water collected, calculated as:

$$\overline{V_{\mathrm{w}}} = \frac{\sum_{i=1}^{n} V_i S_i}{\sum_{i=1}^{n} S_i}$$

5.2 Calculate the coefficient of uniformity for a moving lateral irrigation machine using the Christiansen [2] formula. Additional performance parameters may be used to characterize the water distribution uniformity. Ensure that the tester clearly identifies any such additional parameters, including the calculation formula.

The Christiansen formula is:

$$C_{\mathrm{uC}} = 100\left[1 - \frac{\sum_{i=1}^{n} \left|V_i - \overline{V}\right|}{\sum_{i=1}^{n} V_i}\right]$$

where

C_{uC} is the Christiansen coefficient of uniformity;

n is the number of collectors used in the data analysis;

i is a number assigned to identify a particular collector;

V_i is the volume (or, alternatively, the mass or depth) of water collected in the ith collector;

$\overline{V}$ is the arithmetic average of the volume (or, alternatively, the mass or depth) of water collected by all collectors used in the data analysis, calculated as:

$$\overline{V} = \frac{\sum_{i=1}^{n} V_i}{n}$$

5.3 Calculate C_{uH} or C_{uC}, whichever is appropriate, for each line of collectors. Calculate a combined coefficient of uniformity, C_{uH} or C_{uC}, using the data from all lines of collectors.

5.4 If an irrigation machine with an endgun is tested, use the procedure given in 4.7 to measure the coefficient of uniformity when the endgun is on, and, optionally, when it is off. To characterize the operation of the endgun, record (see A.1), the approximate area of the field irrigated while the endgun is operating and the approximate area irrigated while the endgun is turned off.

5.5 Prepare a graph showing the volume (or, alternatively, the mass or depth) of water collected in each collector, plotted against the distance from the pivot point or along the lateral, together with the positions of the towers and sprayers or sprinklers. Plot the data from each line of collectors separately.

6 Evaluation

6.1 The calculated coefficient of uniformity shall be used as an indicator of sprinkler package performance with respect to the field, environment, pressure conditions and pressure variations prevailing during the test. The coefficient of uniformity of a new sprinkler package can be used for the comparison of different types of sprinkler packages and as a reference for similar irrigation machines that have been used for a period of time.

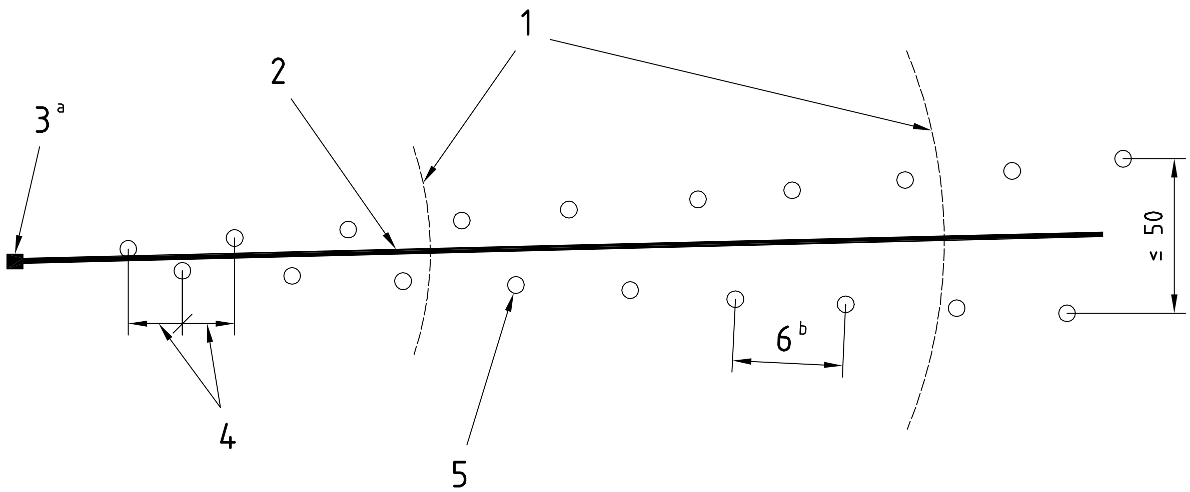
6.2 If the coefficient of uniformity for an installed irrigation machine deviates substantially from the value specified in the initial design, conduct other investigations to determine the cause. A coefficient of uniformity smaller than the design value may indicate worn, broken or malfunctioning water-application devices.

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

7 Reporting of test results

Record the data measured for this test on forms similar to the standard data-presentation forms given in A.1 and A.2, and the test summary form shown in A.3. Document and explain special arrangements between the client and the tester. Justify data inconsistencies on the data forms. Include with the test results additional data not required by this International Standard if that data will help characterize uniformity of water distribution.

Dimensions in metres



Key

1 Wheel tracks
2 Centre-pivot lateral
3 Pivot point
4 Offset
5 ith collector of jth line (staggered from other line)
6 Collector spacing

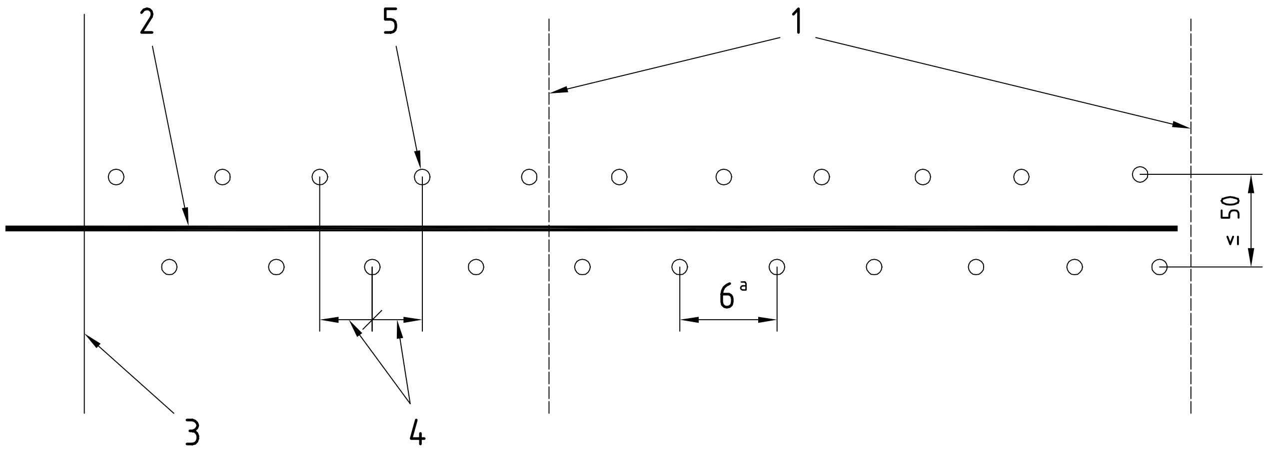
NOTE The catchment offset is approximately equal to 1/nth the collector spacing, where n is the number of collector lines.

a Reference point for S_i.

b Max. spacing for sprayers: 3 m; max. spacing for sprinklers: 5 m.

Figure 1 — Collector layout for determining water distribution of centre-pivot irrigation machines

Dimensions in metres



Key

1 Wheel tracks
2 Moving lateral
3 Arbitrary reference position for distance
4 Offset
5 ith collector of jth line
6 Collector spacing

NOTE The catchment offset is approximately equal to 1/nth the collector spacing, where n is the number of collector lines.

a Max. spacing for sprayers: 3 m; max. spacing for sprinklers: 5 m.

Figure 2 — Collector layout for determining water distribution of moving lateral irrigation machines