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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15886-3 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/third/... edition cancels and replaces the first/second/... edition (), [clause(s) / subclause(s) / table(s) / figure(s) / annex(es)] of which [has / have] been technically revised.

ISO 15886 consists of the following parts, under the general title *Irrigation equipment — Irrigation sprinklers*:

— *Part 1: Classification*

— *Part 2: Design and operational requirements*

— *Part 3: Characterizing of distribution and test methods*

— *Part 4: Test methods for durability (Pending)*

Irrigation equipment — Irrigation sprinklers — Part 3: Characterizing of distribution and test methods

1 Scope

Part 3 of ISO 15886 deals both with indoor and outdoor tests and radial and full grid tests. It is organized so as to deal with conditions common to all tests first and then to the conditions unique to indoor testing only and then outdoor testing only.

Part 3 of ISO 15886 specifies the conditions and methods used for testing and characterizing the water distribution patterns from irrigation sprinklers. The term sprinkler is used in a broad generic sense and is meant to cover a wide variety of products as classified by ISO 15886-1. The specific performance measurements addressed include distribution uniformity, wetted radius, and water jet trajectory height. This standard applies to all irrigation sprinkler classifications for which uniformity of application, wetted radius, and water jet trajectory height evaluation are required for the design objectives as defined by the manufacturer.

For any given sprinkler, a wide range of nozzle configurations, operating conditions, and adjustments generates at least a theoretical need for a correspondingly large number of tests. Testing agencies and manufacturers may use interpolation techniques to reduce the number of actual test runs provided accuracy standards are still being met.

The standard does not address the specific performance testing required for sprinklers intended for frost protection use under freezing conditions.

The standard also does not address the topic of drop spectrum measurement and characterization and the related questions of soil compaction, spray drift, evaporative losses, etc.

To apply the standard to evaluate irrigation coverage, all sprinklers shall be identical and arranged in a fixed repeating geometric pattern. The standard does not apply to moving systems or sprinklers with a radius of throw of less than 1,0 meters.

2 Terms and Definitions

For the purpose of this part ISO 15886 the following definition applies:

2.1
ambient temperature
temperature of the air surrounding a sprinkler test site

2.2
area of coverage
wetted area from a sprinkler operated as specified in the manufacturers literature where water is deposited at rates equal to or greater than the "Effective Application Rates"

2.3
Christiansen's Uniformity Coefficient
UCC (see also Annex A.2.1): A method of characterizing the uniformity of water application of sprinklers from full grid data that utilizes arithmetic deviations.

NOTE The concept was introduced in 1942 and has been widely accepted as a measure of how well designs relate with 80 percent considered as the minimum acceptable Uniformity Coefficient. The coefficient lacks physical significance, however. Full grid data may be developed by actual field test or computer simulated from distribution curves

2.4
clean water
water processed so as to contain suspended particles no larger than 200 mesh equivalent (74 microns) and to contain no dissolved chemicals known to have short-term effects on the sprinklers materials

2.5
collector
receptacle used for collecting irrigation water discharged by a sprinkler during a water distribution test

2.6
contour graphs
method of representing the area of coverage that shows a set of contour curves each connecting locations in a horizontal plane receiving water at the same application rate.

NOTE The number of contour lines plotted should be large enough to convey a visual impression of the physical significance of the data. The concept is useful in constructing area of coverage diagrams

2.7
densogram
method of representing the area of coverage that utilizes the density of dots shading as directly proportional to the relative application rates in the area of coverage

2.8
distribution curve
graph of application rate (ordinate) versus distance (abscissa) measured along a particular section (leg) or line of the area of coverage

2.9
distribution uniformity (DU)
(see also Annex A.2.3): method of characterizing the uniformity of water application of sprinklers from full grid data by a coefficient that utilizes an arbitrary definition of the lower 25% as the critical area.

NOTE The concept has had some acceptance in agricultural crops, but continues to suffer from the arbitrary nature of the definition

2.10
effective application rate
application rate equal to or exceeding 0,26 mm/h for sprinklers with flow rates exceeding 75 L/h and 0.13 mm/h for sprinklers with flow rates equal to or less than 75 L/h

2.11
Effective radius of throw
The interpolated radius at which 98% of the reconstituted volume is applied (See section 10.3)

2.1
flow rate
volume of water flowing through an irrigation component per unit of time

2.13
full grid collector arrays
a number of collectors located at the intersection of a 2-axis geometric grid pattern determined to give a desired statistical result and represent the area of coverage

2.**14**
inlet connection
nominal pipe size designation for commercial purposes with no specific relationship to actual dimensions except as may be defined by reference to a recognized standard

2.15
irrigation lateral
branch supply line in an irrigation system on which water distribution devices such as sprayers, sprinklers and emitters are mounted directly or by means of fittings, risers, or tubes

2.16
maximum working pressure, Pmax
maximum pressure at which a device will properly function hydraulically and operate mechanically

2.17
minimum working pressure, Pmin
minimum pressure at which a device will properly function hydraulically and operate mechanically

2.18
nozzle
aperture or adjutage of the sprinkler through which the water is discharged.

NOTE : A sprinkler may contain one or several cylindrical nozzles, or nozzles of other shapes. It may refer to either a single nozzle, or to a combination of nozzles in a multi-nozzled sprinkler

2.19
nozzle pressure
pressure as measured immediately upstream of the nozzle or as inferred by a pitot tube measurement at the nozzle orifice vena contracta.

2.20
nozzle size
nominal size designation for commercial purposes with no specific relationship to hydraulic properties. Nozzles are more accurately defined by their hydraulic properties

2.21
part-circle sprinkler
sprinkler with an adjustable feature that enables it to irrigate any sector of a circular area or the entire circular area.

2.22
pop-up sprinkler
irrigation sprinkler designed for installation so that the sprinkler nozzle is below ground level when it is not pressurized and above ground level when it is pressurized.

2.23
pressure tap
precisely fabricated connection for communicating internal conduit pressures to an external pressure-measuring device.

NOTE Tap construction is shown for example in ISO 9644 “Pressure Losses In Irrigation Valves-Test Methods”

2.24
radial collector arrays method
a number of collectors located only on the radial axis projected from the sprinkler centerline used to characterize the distribution curves

2.25
radius of throw
distance measured from a continuously operating sprinkler or sprayer centerline to the most remote point at which the sprinkler or sprayer deposits water at a minimum rate of 0,26 mm/h for a sprinkler or sprayer with a discharge exceeding 75 L/h or at a minimum rate of 0,13 mm/h for a sprinkler or sprayer with a discharge equal to or less than 75 L/h measured at any arc of coverage except near the arc extremes for part-circle sprinklers or sprayers (also called wetted radius)

2.26
range of working pressure
all of the pressures between the minimum working pressure, Pmin, and the maximum working pressure

2.27
rotating sprinkler
device, which by its rotating motion around its vertical axis distributes water over a circular area or part of a circular area

2.28
scheduling coefficient (see also Annex A.2.4)
method of characterizing the uniformity of water application of sprinklers from full grid data by a single coefficient that utilizes a definition of critical dry area.

NOTE The concept is especially well suited to lawn and turf management. The concept gives a run time multiplier based on critical dry area turf quality management

2.29
sprinkler spacings
distance between the sprinklers along an irrigation lateral and the distance between consecutive irrigation laterals

2.30
statistical uniformity coefficient
(see also Annex A.2.2) method of characterizing the uniformity of water application of sprinklers from full grid data by one coefficient that utilizes standard deviation as a measure of dispersion in statistical theory. Although introduced in 1947, the coefficient fails to enjoy any wide base of acceptance. The method presupposes that the distribution data is normally (Gaussian) distributed

2.31
test pressure
pressure at the inlet of a sprinkler declared by the manufacturer as the pressure to be used for test purposes

2.32
trajectory angle
angle, above a horizontal plane, of the water stream or spray discharged from a sprinkler or a sprayer operated at test pressure

2.33
trajectory height
maximum height above a sprinkler or sprayer, of the trajectory of the water stream discharged from the sprinkler nozzle or sprayer operating at test pressure

2.34
water application rate
mean depth of water applied per unit time

2.35
wetted diameter
sum of the radii of throw on the same diameter

2.36
wind speed
speed of the wind at a test site averaged over the time required for a test of the distribution uniformity of a sprinkler or a sprayer

2.37
working pressure
pressure shown in the manufacturers catalog literature at which the sprinkler is known to function mechanically as designed.

NOTE Working pressure bears no relationship to hydraulic properties except as may be defined by the manufacturer

3 Collectors

All collectors used for any one test shall be identical. They shall be designed to minimize water splashes in or out.

The height of the collector shall be at least twice the maximum depth of the water collected during the test, but not less than 150 mm.

They shall have a circular opening with sharp edges free from deformities. The diameter shall be ½ to 1 times the height, but not less than 85 mm.

Alternative collector designs may be used, provided that their measuring accuracy is not less than for those described above.

The catchment from a collector shall be quantified from a direct reading of mass, depth or a volumetric determination provided that the required accuracy standard is met.

3.1 Collector Orientation

The openings of all collectors shall be in a common horizontal plane with a slope not exceeding 2 percent in any direction. The difference in height between any two adjacent collector rings shall not exceed 20 mm.

For indoor testing, collector height is not critical. For outdoor testing, the collector height shall be sufficient to insure that vegetation does not interfere with jet access to the collectors.

4 Installation of Sprinklers Under Test

The sprinkler selected for testing shall be representative of general production capabilities particularly as relates to speed of rotation. New sprinklers shall be operated before the test for a period sufficient to demonstrate that the time per revolution has stabilized to ± 5 percent.

Mount the sprinkler on a riser with nominal size designation the same as the sprinkler inlet connection. Ensure that the riser is fixed rigidly vertically, and that it does not vibrate sufficiently to cause a visual effect on the sprinkler operation, bend or deviate from the vertical during the test. The maximum allowable deviation from the vertical during the test shall not exceed 2 degrees.

A steel pipe riser is recommended to provide the required mechanical strength and facilitate the installation of a standard pressure tap.

Sprinkler nozzle height above the collectors should simulate the conditions under which the sprinkler is normally used. For example, with the turf sprinklers the top of the sprinkler body should coincide with the top of the collectors.

For agricultural sprinklers used under a variety of field conditions the following height requirement applies: The height of the principal sprinkler nozzle above the openings of the collectors shall be selected among the following (0, 0.3m, 0.5m, 0.6m, 1.0m, or 1.5m) Except as otherwise specified by the manufacturer.

If the manufacturer specifies any special test related conditions, for example, testing at a minimum riser height or with straightening vanes, they shall be used if such items are provided as standard equipment with the sprinkler.

For a sprinkler not riser mounted as described above, the test mounting shall be as specified by the manufacturer.

For single leg distribution patterns a shelter may be used around the sprinkler to baffle jet action provided the following conditions are met:

-The shelter is large enough and so constructed as to trap the jet and not let it interfere with the sprinkler's operation.

-The shelter shall be designed to allow air circulation to develop around the jets.

-The shelter provides a minimum sector for unrestricted jet operation of 45 degrees centered on the collector radius. If the testing agency uses an angle less than 45º, it must demonstrate that the integrity of the results are not compromised. Special attention shall be put to sector size, to avoid interception of projections (spoon spit) generated by the impact arm.

-No jet deflection or splash is directed into the collectors.

5 Accuracy of Measurements

The accuracy required for all measurements not specifically addressed in this standard is ±3,0 percent.

Application depths within collectors shall be measured with an accuracy of ± 3,0 percent.

The pressure shall be measured with an accuracy of ± 1,0 percent.

The flow rate through the sprinkler shall be measured with an accuracy of ± 2,0 percent.

The temperature shall be measured with an accuracy of ± 0,5 °C.

Time shall be measured with stop watches accurate to ± 0,1 seconds.

5.1 Pressure measurement

The test pressure shall be measured at the height of the main nozzle. The location of the pressure tap shall be at least 200 mm upstream of the sprinkler base. Refer to ISO 9644 for pressure tap construction. There shall be no flow obstructions between the pressure tap and the sprinkler base.

5.2 Atmospheric measurements

Relative humidity and ambient temperature shall be measured at the start, midpoint, and end of the test. For indoor testing, changes in temperature and humidity during the test shall not exceed ±5,0 percent of the pretest ambient.

5.3 Measure Evaporative losses within collectors

Place a volume of water approximately equal to the volume to be collected during the test. Measure the volume of water after the test and apply the difference to the volume of water in each collector.

6 Collector arrangement, spacing and number

6.1 Full grid collector arrays

This method refers to the use of a square grid of collectors with a sprinkler located inside the grid. It is especially useful in characterizing the impact of wind on sprinkler performance and characterizing sprinklers that do not produce symmetrical areas of coverage.

The same collector spacing shall be used for both axes of the grid. Additional collectors can be located on the down wind edge of the collector array if required to cover the anticipated wetted area. A minimum of 80 collectors shall be located within the area of coverage.

6.1.1 Sprinkler location relative to grid

The sprinkler shall be located midway between four adjacent collectors.

Alternatively, the sprinkler can be located at the intersection of the grid axis.

6.2 Radial collector arrays method

This method refers to the use of collectors located along a radius or several radii (usually 4, spaced 90°) for purposes of characterizing the sprinklers water application rate as a function of radial distance from the sprinkler. It is especially useful for sprinklers with a symmetrical pattern and under no wind conditions.

The objective of the test is to develop an accurate relationship between water application rate and radius. If the sprinkler is known to have discontinuities between combinations of nozzles for example, sufficient collectors shall be used to adequately characterize these features. In all cases a minimum of 10 collectors shall be used on each radius.

6.2.1 Collector Spacing and Number

Maximum spacing of collectors along the radius is shown in the following table:

Table 1

Dimensions in meters

Sprinkler radius of throw	**Maximum collector spacing (center to center) (1)**
1,0-3,0	0,30
3,0-6,0	0,60
6,0-12,0	0,75
Over 12,0	1,00

(1) Minimum number of collectors required is 7 for a radius less than 4m and 10 for a radius larger than 4 m

6.2.2 Location of sprinkler

The sprinkler shall be located one collector spacing from the first collector and on the same radius.

6.2.3 Wetted Radius (Diameter)

For multiple array tests the radius shall be the average of all of the arrays used.

7 Additional Tests

7.1 Time of rotation

The sprinkler time of rotation shall be measured only while the sprinkler is rotating from its own drive mechanism. It shall be measured at the beginning, the midpoint, and the end of the test. In addition, at the midpoint in the test, the time shall be measured through each quadrant. The quadrant locations shall be indexed to the collector grid. The time shall be measured by an instrument capable of giving the required accuracy (±0,1 second).

7.2 Trajectory Height

The measurement is taken from a horizontal plane through the main nozzle. As with the radius of throw definition, occasional drops that achieve a higher height shall be ignored in favor of some general representation of the top surface of the main jet. Care shall be taken to insure that the sprinkler riser meets the 2 degree tolerance on verticality. The radial distance to the location of maximum trajectory height shall be noted. Both height and radius measurements require an accuracy of ±5 percent.

8 Test Operation

8.1 Rotation of sprinkler riser

During the radial collector array test, (paragraph 8.2) the riser supporting the sprinkler shall be manually rotated a quarter of a revolution (90°) about the axis three times at equal intervals of time. This rotation to be performed during the periods when the jet of the sprinklers is not passing over the collectors.

For sprinklers with special operating modes, riser rotation shall be accomplished so as not to bias the test.

The test period shall begin after the sprinkler has run for a time period long enough to establish stable conditions (for example: All air is evacuated). This can be accomplished by shrouding the sprinkler during unstable start-up periods and removing the shroud to start the test.

The test pressure shall not vary by more than ±4 percent during the test period and the water temperature shall not vary by more than ±5,0 °C during the test.

Care shall be taken in starting and stopping tests to avoid direct deposition in collectors by under pressure jets or unstable rotational movement.

Care shall be taken also to avoid subjecting collector legs or portions of the grid to an unequal number of sprinkler rotations or cycles.

For sprinklers with programmed variations in operating characteristics, the duration of the test shall be long enough to subject all collectors to the same identical operational sequences.

8.2 Test duration

A minimum number of 30 passes shall be made over all collectors. In general, test conditions not specifically covered by the standard shall reflect first, the reality of how and where the product is to be used and secondarily, how the manufacturer defines the product performance testing. Considerations that fall in this category include, for example, 1) sprinkler height in relation to crop canopy, 2) riser or drop tube length, configuration or construction, 3) sprinkler orientation (supply flow up or down).

The test duration shall be long enough to generally allow the standard for reading accuracy of the collectors to be met (±3 percent) for a minimum of 80% of the collectors. The water applications accounted for in the collectors shall be a minimum of 90% of the theoretically calculated amount based on the sprinkler flow calibration.

9 Test location specifications

9.1 Indoor testing building specifications

To meet the assumption that test buildings conditions represent no-wind conditions, there shall be no ventilating structures (doors, windows, etc.) that permit bulk air movement at velocities exceeding 0,10 m/s. In general, the building shall be sized to permit unconfined jet development of the largest jet for which it is designed to test.

The test building design shall meet the following criteria:

- Floor slope as required to provide surface drainage not to exceed 1.0 percent. (Reminder: collector ring inlet surfaces must be in a common horizontal plane.)

- Minimum length equal to 125 percent of the maximum sprinkler wetted radius of throw.

- Minimum width equal to 60 percent of the sprinkler radius of throw measured at the actual radius of throw.

- Minimum clear ceiling height equal to 125 percent of the maximum trajectory height anticipated.

- The building shall have no structural column or truss members that mechanically interfere with the jet when it is passing over the collector radial array.

9.2 Outdoor Site Specification

The test area where collectors are positioned shall be graded evenly in a horizontal plane with a maximum slope of 2,0 percent in any direction. The surface shall be free of obstacles that could block the movement of airborne spray. Surface roughness, including vegetative cover, shall not exceed 150 mm in height so as to not interfere with spray droplet access to collectors.

There shall be no trees, buildings, or other obstruction in the vicinity of the test site that could alter the normal wind patterns. A minimum clear area upwind of the test site of 6 heights of any wind break for each 0,45 m/s of wind speed up to a maximum of 30 heights for winds of 2,24 m/s or greater is required. A minimum clear area downwind of the test site equal to 5 heights of any downwind windbreak is required.

9.2.1 Measurement of atmospheric conditions

Relative humidity and ambient temperature measurements shall be taken during the test at equal time intervals that give a minimum of 10 readings during the duration of the test.

Wind speed and direction measuring instruments shall be set at a height corresponding to the maximum sprinkler trajectory height ± 10 percent. The actual height used shall be measured and recorded on the data sheets.

The sensing equipment shall be located a maximum distance of 45 m from the edge of the wetted area. The location shall be selected as most representative of the test site exposure.

Wind speed and direction shall be continuously recorded or measurements shall be taken at the beginning and end of the test and at regular time intervals not to exceed 10 percent of the test period. Wind speed shall be recorded to the nearest 0,2 m/s and directions to the nearest 10 degrees. Direction shall be referenced to one of the principal axes of the collector array layout. For single leg tests, the maximum allowable wind speed is 0,4 m/s. For four leg tests, the average allowable wind speed shall not exceed 1,3 m/s and in no case shall the maximum allowable wind speed exceed 2,2 m/s.

10 Characterizing distribution

This section of the standard refers to developing the results from the full grid test procedure so as to effectively characterize the sprinkler performance. The objective for specific characterizations is driven by the sprinkler design objectives as defined by the manufacturer.

10.1 Application pattern coverage and uniformity

Four methods of calculating pattern uniformity are as follows (ref. Annex "A").

Table 2

Name	Scientific notation	Ref. Annex "A" Section
1. Christiansen uniformity coefficient	UCC	A.2.1
2. Statistical coefficient of uniformity	UCS	A.2.2
3. Distribution uniformity	DU	A.2.3
4. Scheduling coefficient	SC	A.2.4

The method best suited to the design objectives of the sprinkler or its intended use shall be selected.

Patterns of coverage can be shown giving geometrically accurate representations augmented by densograms or contour graphs if required to compare the actual performance to the design objectives.

10.2 Generating performance measurements from radial arrays

The standard recognizes that the full grid method of characterizing sprinkler performance is preferred over the radial arrays method. If the testing agency decides to use the radial arrays method it shall satisfy questions of accuracy when compared to the full grid method. If wind is a factor in design, only the full grid method can be used. Wind is a factor by definition when the manufacturer warrants the sprinkler for general field use.

Computer generated full grid patterns may be developed from radial array data provided that the results are identified as based on simulated data and the sprinkler can be demonstrated to have a generally symmetrical pattern. The radial array data is analyzed using a curve fit routine. The curve fit routine identifies a mathematical equation that gives water deposition as a function of radius from the sprinkler axis of rotation. This equation is used to calculate the deposition at the grid line intersections thereby simulating a full grid pattern.

10.3 Validation of test results

To be validated, a reconstituted flow rate (Q rel) shall not deviate by more 5% from the flow rate measured by the water meter for sprinkler discharging 0.141 L/S or higher and 7% for flow rates less than 0.141 L/S. The reconstituted flow rate is calculated from the following formulas:

1) $Vrel = \sum 2 X \prod r_1 \, drx_1$

   Where: r_1 is the radius at which x_1 is measured and dr is the measurement spacing

2) $Qrel = \frac{Vrel}{t}$

   Where: t is the sprinkler run time

Annex A

(informative)

Procedures for sprinkler pattern uniformity

A.1 The purpose of testing for sprinkler performance is usually carried on to meet at least one the following objectives:

1. To provide a characterization of current levels of performance from which to judge the efficacy of changes in design or operating conditions. This is useful primarily to product engineers. Sprinkler mechanical and hydraulic changes can be valued for their potential contribution to product improvement.

2. To provide data useful to manufacturers in the development of product specifications and performance literature. This data is used by system designers in designing system components, forecasting irrigation schedules, economic comparisons and product comparisons.

3. To provide certified standards of performance that characterize specific products. This data is useful in the development of specifications in contract documents. This insures that products will perform at required design levels.

4. To provide a standard for evaluating system field performance. This allows designers, engineers, and growers to evaluate existing installations in an "as-built" context. This is useful in determining if construction meets contract requirements and acceptance test conditions. It is also useful in auditing system performance. Auditing studies are commonly used as a basis for improving application uniformity and efficiency.

A.2 Procedures[1] for characterizing the uniformity of distribution.

The standard recognizes that there is no one best method of characterizing the "Uniformity of Distribution". The diversity of intended uses, and the associated requirements for each use, preclude setting a single standard for characterizing uniformity of distribution. The testing agency, manufacturers, and users are free to use the procedure most appropriate for the intended use. Four procedures are given. At lease one procedure shall be used.

Other methods and calculating procedures may also be used as long as their logic is defensible in the context of the intended sprinkler use. This latitude in procedures presupposes that all sprinklers suited for a specific use will be evaluated by the same procedure as described in the standard.

A.2.1 Christiansen[2] developed his uniformity coefficient (UCC) in 1942 to study sprinkler irrigation. UCC is one of the most common indicators of sprinkler uniformity, predominantly for historical reasons.

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1) In some situations, the geometry of the test pattern grid does not correspond directly to the pattern grid being characterized. In this case interpolation of catchment values shall be made. Interpolation procedures shall be used that do not unreasonably bias the results.

2) Christiansen, JE. 1942. Irrigation by Sprinkling. California Agricultural Experiment Station Bulletin 670, University of California, Berkeley, California, 1942.

$$UCC = 100 \times \left[1 - \frac{d}{m}\right]$$

where:

UCC = Christiansen's Uniformity Coefficient

m = Average Value = $\frac{1}{n}\sum_{i=1}^{n} \chi_i$

D = Average absolute deviation = Average of individual absolute deviations = $\frac{1}{n}\left[\sum_{i=1}^{n} D_i\right]$

D_i = Individual absolute deviation = Absolute difference of individual values from m = $\left|[x_1 - m]\right|$

x_i = Individual values in the array of values being analyzed for uniformity

n = The number of values in the array being analyzed for uniformity

A.2.2 The statistical coefficient of uniformity (ucs) was first proposed by Wilcox and Swailes in 1947[3] . They preferred it to UCC because of the utility of the standard deviation as a measure of dispersion in statistical theory. It has also been called the Wilcox-Swailes coefficient, after its proposers.

$$UCS = 100 \text{ x } \left[1 - \frac{s}{m}\right]$$

where:

UCS = Statistical Uniformity Coefficient

m = Average value = $\frac{1}{n}\left[\sum_{i=1}^{n} x_i\right]$

s = Standard deviation = $\sqrt{\frac{1}{n}\left[\sum_{i=1}^{n} (x_1 - m)^2\right]}$

x_i = Individual values in the array of values being analyzed for uniformity

n = the number of values in the array being analyzed for uniformity

A.2.3 Distribution Uniformity (DU) is a uniformity concept that was originally proposed by the Soil Conservation Service of the U.S. Department of Agriculture. At that time, it was called Pattern Efficiency (PE), Lower 25% (the modifier referring to the Low Quarter - another version of PE was defined based on the Upper Quarter. Even though the word "efficiency" appeared in its name, PE is actually a uniformity coefficient, and not an efficiency measure. PE depends only on the uniformity of the irrigation application, and not on any assumed or actual irrigation management scheme (which would make it an efficiency measure).

Numerous other workers have used the PE concept, calling it by names such as Distribution Uniformity (DU) or (drip irrigation) Emission Uniformity (EU). The On-Farm Irrigation Committee of the Irrigation and Drainage

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3) Wilcox JC and Swailes GE. 1947. Uniformity of Water Distribution by Some Under-Tree Orchard Sprinklers. Scientific Agriculture 27(11):565-583.

Division, American Society of Civil Engineers recognizes DU and UCC as two recommended uniformity measures[4] .

DU = 100 x $\left[\frac{1q}{m}\right]$

where:

DU = Distribution uniformity

m = Average value = $\frac{1}{n}\left[\sum_{i=1}^{n} x_i\right]$

1q - Average low quarter value = $\frac{1}{n_{1q}}\left[\sum_{i=1}^{n} x_i : \chi_i \in LQ\right]$

x_i = Individual values in the array of values being analyzed for uniformity

LQ = The set containing the 25% of the xi values that are the smallest

LQ = $\{x_1, x_2, x_3, \ldots x_j, \ldots x_q\}$

where: x_i is the smallest value of the x_i

x_2 is the second smallest value of the x_i

x_3 is the third smallest value of the x_i etc.

q is the integer closest to 25% of n

n = The number of values in the array being analyzed for uniformity

Several empirical studies of sprinkler irrigation uniformity have found essentially linear relationships between UCC, UCS and DU. Numerous studies have concluded that distributions of sprinkler application depths are often adequately described by a normal (Gaussian) distribution function. When application values are normally distributed, the following theoretical relationships between the coefficients are true (exactly).

The relationships are approximately true for many actual distributions of sprinkler application depths or microirrigation emission rates that do not deviate too much from the normal distribution.

UCC = 0,798 UCS + 20,2

UCC = 0.63 DU + 37.0

UCS = 1,253 UCC – 25,3

UCS = 0,79 DU + 21,0

4) C1978. Describing Irrigation Efficiency and Uniformity. On-Farm Irrigation Committee, Irrigation and Drainage Division, ASCE. J. Irrig. & Drain. Div. ASCE 104(IR1):35-41.

DU = 1,59 UCC – 59,0

DU = 1,27 UCS – 27,0

A.2.4 The Scheduling Coefficient (SC) is a measure of uniformity specially designed for physical significance in the circumstance of turf or lawn irrigation. In these instances, even relatively small areas of inadequately watered turf show up with high visual impact. Turf managers often "water to the dry spot," that is, increase watering times until the unsightly critical area receives enough water to be visually satisfactory. By forming the ratio of field average to average in critical area, SC tells in relative terms how much the irrigation time shall be increased in order to overcome dry spot nonuniformity.

The Scheduling Coefficient is dependent on the relative size of the critical dry area and should be computed for different-sized critical areas. In the U.S., commonly used critical dry area sizes are 1%, 2%, 5% and 10% of the irrigated area. Even the largest of these is considerably smaller than the low quarter (25%) used in the DU computation. Experience has shown that SC calculated on a 5% window gives appropriate results in many practical situations. Experience has also shown that the contiguous dry area shape varies from rectangular to square. "Line" shaped dry areas are not usual. This is probably due to the generally smooth shape of the sprinkler distribution pattern where discontinuities are rare.

$$SC = \left[\frac{m}{m_{crit}} \right]$$

where:

SC = Scheduling coefficient

m = Average value = $\frac{1}{n}\left[\sum_{i=1}^{n} \chi_i \right]$

x_i = Individual values in the array of values being analyzed for uniformity

n = The number of values in the array

Critical dry area = The contiguous area "dry spot" within the array being analyzed for uniformity that has the lowest average application rate or amount. Note that because of pattern symmetry there may be other areas of equal dryness, but nothing dryer.

m_{crit} = The average of the values within the critical dry area

Bibliography

[1] ISO 9644:1993, *Pressure losses in irrigation valves – Test methods*