BS ISO 15886-3:2012

BSI Standards Publication

Agricultural irrigation equipment — Sprinklers

Part 3: Characterization of distribution and test methods

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National foreword

This British Standard is the UK implementation of ISO 15886-3:2012. It supersedes BS ISO 15886-3:2004 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AGE/30, Irrigation and drainage equipment.

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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 edition cancels and replaces the first edition (ISO 15886-3:2004), which has been technically revised.

ISO 15886 consists of the following parts, under the general title *Agricultural irrigation equipment — Sprinklers*:

— *Part 1: Definition of terms and classification*

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

Agricultural irrigation equipment — Sprinklers —

Part 3: Characterization of distribution and test methods

1 Scope

This part of ISO 15886 specifies the conditions and methods used for testing and characterizing the water distribution patterns of irrigation sprinklers. The term sprinkler is used in this standard 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 these three performance measurements are required to verify the design objectives as defined by the manufacturer.

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

For any given sprinkler, a wide range of nozzle configurations, operating conditions, and adjustments generate 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.

This part of ISO 15886 does not address the specific performance testing required for sprinklers intended for use in frost protection.

This part of ISO 15886 does not address the topic of drop spectrum measurement and characterization and the related questions of soil compaction, spray drift, evaporative losses, etc., all of which can be considerations in the design of sprinkler irrigation systems.

To apply this part of ISO 15886 for evaluating irrigation coverage, all sprinklers must be identical and arranged in a fixed repeating geometric pattern. This part of the standard does not apply to moving systems.

This part of ISO 15886 applies to part-circle sprinklers provided that the testing agency can satisfy questions of potential anomalies in performance parameters.

Annex A addresses the procedures for the characterization of sprinkler pattern uniformity. Annex B addresses testing part-circle sprinklers.

2 Terms and definitions

For the purpose of this part of ISO 15886, the following terms and definitions apply.

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 manufacturer’s literature where water is deposited at rates equal to or greater than the effective application rate

2.3
Christiansen's uniformity coefficient
UCC
coefficient using deviations from the mean to characterize the uniformity of field-measured or simulated water application from a grid of sprinklers

2.4
clean water
water processed, if necessary, so as to contain suspended particles no larger than 200-mesh equivalent (74 µm) and to contain no dissolved chemicals known to have short-term effects on sprinkler materials

2.5
collector
receptacle into which water is deposited during a water distribution test

2.6
critical dry area
experienced-based definition of the dry area size that defines uniformity of coverage objectives

2.7
densogram
areal map utilizing the density of dots representing the water application depth at locations in the areas of coverage of a sprinkler or a grid of sprinklers

2.8
distribution uniformity
DU
coefficient using the lowest 25 % of water application depths to characterize the uniformity of field-measured or simulated water application from a grid of sprinklers

2.9
minimum effective water 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

2.10
effective radius of throw
radius at which 95 % of the reconstituted volume of water discharged by a sprinkler, interpolated between points of measurement, is applied

2.11
flow rate
volume of water flowing through an irrigation component per unit of time

2.12
full grid collector array
collectors located at the intersections of a two-dimensional geometric grid pattern sufficient in number to give a desired statistical basis for determining water distribution uniformity

2.13
inlet connection size
nominal pipe size designation for commercial purposes or to manufacturer's declaration defined by reference to a recognized standard

2.14
irrigation lateral
branch supply line in an irrigation system on which sprinklers are mounted directly or by means of fittings, risers, or tubes

2.15
maximum working pressure
Pmax
highest pressure at the inlet to a sprinkler recommended by the manufacturer to ensure proper operation

2.16
minimum working pressure
Pmin
lowest pressure at the inlet to a sprinkler recommended by the manufacturer to ensure proper operation

2.17
nozzle
aperture of a sprinkler through which the water is discharged

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

2.18
part-circle sprinkler
sprinkler with an adjustable feature that enables it to irrigate a sector of a circular area either with or without an attachment which enables it to be adjusted to irrigate another sector or the entire circular area

2.19
pop-up sprinkler
sprinkler designed for installation so that the sprinkler nozzle automatically rises from below ground when the system is pressurized and automatically lowers to its original position when the system is depressurized

2.20
pressure tap
precisely fabricated connection for accurately communicating internal conduit pressure to an external pressure-measuring device

2.21
radial collector array
collectors located only on the radial axis projected from the centerline of a sprinkler sufficient in number to characterize the water distribution curve

2.22
radius of throw
wetted radius
distance measured from the centerline of a continuously-operating sprinkler to the most remote point at which the sprinkler deposits water at the minimum effective water application rate measured at any arc of coverage except near the arc extremes for part-circle sprinklers

2.23
rotating sprinkler
water distribution device which, as a result of rotating motion around its vertical axis, distributes water over a circular area, part of a circular area, or a non-circular area

2.24
scheduling coefficient
SC
coefficient used to characterize the water uniformity of water application of sprinklers employing an analysis of full-grid data based on a definition of critical dry area

2.25
sprinkler spacings
conventional designation including the distance between the sprinklers along an irrigation lateral and the distance between consecutive irrigation laterals

2.26
statistical uniformity coefficient
UCS
coefficient using standard deviation as a measure of dispersion in statistical theory to characterize the uniformity of field-measured water application from a full grid of sprinklers

2.27
test pressure
pressure at the inlet of a sprinkler declared by the manufacturer as the pressure to be used for test purposes

2.28
maximum trajectory height
maximum height above a sprinkler of the water stream discharged from the sprinkler nozzle operating at test pressure

2.29
water application rate
mean depth of water applied per unit time

2.30
water distribution curve
graphical plot of water application depth as a function of distance from a sprinkler along a specified radius

2.31
wind speed
speed of the wind at a test site averaged over the time required for a sprinkler distribution uniformity test

2.32
working pressure
water pressure range recommended by the manufacturer to ensure proper operation of a sprinkler

3 Collectors

3.1 Collector design

All collectors used for any one test shall be identical. They shall be designed to minimize water splashes in or out and distortions of the catchment volume as may be caused by wind currents.

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

The collectors shall have a circular opening with sharp edges free from deformities. The diameter shall be between 1/2 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 of 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.

3.2 Collector orientation

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

For indoor testing, collector height is not critical. For outdoor testing, the collector height shall be sufficient to ensure 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 the 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 %.

Mount the sprinkler on a riser with the same nominal size designation 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°.

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

The 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 from Table 1. Manufacturers can request additional heights but those in Table 1 must be included.

Table 1 — Sprinkler height

Sprinkler flow rate l/h	**Sprinkler nozzle height above the collector** m
Pop-up	0 (in a non-pressurized state)
0 to 300	0,3
301 to 1 500	0,5
1 501 to 2 500	1,0
> 2 500	1,5

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 that is not riser-mounted as described in above, the mounting shall be as specified by the manufacturer.

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

— The shelter is large enough and so constructed as to trap the water jets and not let them interfere with the sprinkler's operation or contribute to the collector catchment.

— The shelter is designed to allow air circulation to develop around the jets.

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

— The shelter is designed so that no jet deflection or splash is directed into the collectors.

5 Measurements

5.1 Accuracy of measurements

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

Pressure shall be measured with an accuracy of ± 1,0 %.

Flow rate through the sprinkler shall be measured with an accuracy of ± 2,0 %.

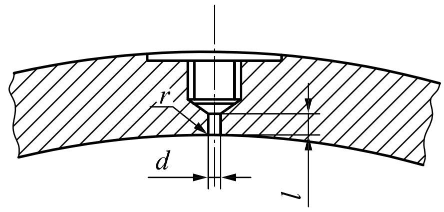
Temperature shall be measured with an accuracy of ± 0,5 °C.

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

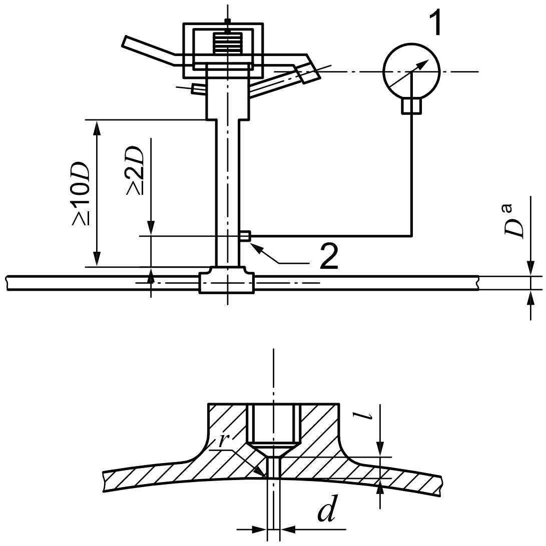
The accuracy required for all measurements not specifically addressed in this part of ISO 15886 is ± 3,0 %.

5.2 Pressure measurement

The test pressure shall be measured at the height of the main nozzle. The pressure tap construction details are shown in Figure 1. There shall be no flow obstructions between the pressure tap and the sprinkler base. The bore of the pipe containing the pressure tap shall be clean and smooth.



a) Thick wall



b) Thin wall

Key

1 pressure gauge

2 pressure tap

a Internal diameter of the pipe.

Figure 1 — Pressure tap location and construction details

Figure 1 a), $l \geq 2{,}5d$ where d = 3 to 6 mm or 1/10 pipe diameter, whichever is smaller

Figure 1 b), $l \geq 2d$; $r \leq d/10$

5.3 Atmospheric conditions 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 % of the pre-test ambient conditions.

Air conditioning systems may be required to ensure that the testing facilities meet this requirement.

5.4 Corrections for evaporative losses within collectors

Under some conditions, evaporative losses within collectors are known to result in measurement errors that exceed the required accuracy of ± 3,0 %. Under these conditions, a correction to the collector readings must be made using the following procedure:

Place a volume of water approximately equal to the average volume to be collected during the test in each of three collectors. Locate the collectors near the test area but outside the area of water application. Measure the volume of water before and 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 array method

6.1.1 Method

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.

6.1.2 Collector spacing

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. Collector spacing as related to sprinkler radius of throw is specified in Table 2.

Table 2 — Collector spacing

Sprinkler effective radius of throw m	**Maximum collector spacing** (centre to centre) m
1,0 to 3,0	0,25
3,0 to 6,0	0,50
6,0 to 12,0	1,00
12,0 to 17,0	2,00
over 17,0	3,00

A minimum of 80 collectors located within the area of coverage is recommended. If fewer than 80 collectors are located within the area of coverage, the testing agency must attest to the statistical quality of results.

6.1.3 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 axes.

6.2 Radial collector array method

6.2.1 Method

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

The objective of the test is to develop an accurate functional relationship between the water application rate and radius. If the sprinkler is known to have hydraulic discontinuities, sufficient collectors shall be used to adequately characterize these features and allow for a continuous functional characterization.

6.2.2 Collector spacing

A guide to collector spacing as related to sprinkler radius of throw is given in Table 2.

6.2.3 Location of sprinkler

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

6.2.4 Wetted radius

For a multiple array test, the wetted radius shall be the average of the results from all of the arrays used. See 2.22 for a definition of wetted radius.

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. A minimum of three measurements shall be recorded for each position. In addition, at the midpoint of the test, the time shall be measured through each quadrant. A minimum of three measurements shall be recorded for each quadrant. The quadrant locations shall be indexed to the collector grid. Calculate the time of rotation required through each quadrant and the maximum deviation (percent, %) in relation to the time of rotation measured. Maximum deviation shall not exceed the time of rotation by more than ± 12 %. This test is not applicable to a sprinkler with a time of rotation of less than 10 s.

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 favour of some general representation of the top surface of the main jet. Care shall be taken to ensure that the sprinkler riser meets the 2° 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 %.

8 Test operation

8.1 Rotation of sprinkler riser

During the radial collector array test (6.2), 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 is 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 requirements shall not bias the outcome of the test.

8.2 Test duration

Test duration shall be long enough to generally allow the standard for reading accuracy of the collectors to be met (± 3 %) 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.

A minimum number of 30 passes shall be made over all collectors.

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 operation sequences.

8.3 Other test details

The test period shall begin after the sprinkler has run for a time period long enough to establish stable hydraulic 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 be within the working pressure range and shall not vary by more than ± 4 % during the test period; 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. This can be accomplished by using a manual lever action valve located at the base of the riser.

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

In general, test conditions not specifically covered by this part of the standard shall reflect, first, the reality of how and when the product is to be used and second, how the manufacturer defines the product performance testing. Considerations that fall in this category include, for example:

— the sprinkler height in relation to the crop canopy;

— the riser or drop tube length, configuration or construction;

— the sprinkler orientation (supply flow up or down).

All tests shall be performed using clean water as defined in 2.4, unless a higher cleanliness of water is specified by the sprinkler manufacturer.

9 Test location specifications

9.1 Indoor testing building specifications

Indoor sprinkler testing is assumed to provide pattern results unaffected by wind. For test building conditions to 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. 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.

— A floor slope not exceeding 1,0 % is recommended to provide surface drainage. (Reminder: collector ring inlet surfaces must be in a common horizontal plane.)

— Minimum length equal to 125 % of the maximum sprinkler wetted radius of throw.

— Minimum width equal to 25 % of the maximum sprinkler wetted radius of throw on each side of the radial collector array.

— Minimum clear ceiling height equal to 125 % 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

9.2.1 General

The test area where collectors are positioned shall be graded evenly in a horizontal plane with a maximum slope of 2,0 % 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 obstructions in the vicinity of the test site that could alter the normal wind patterns. A minimum clear area upwind of the test site of six times the height of any wind break for each 0,45 m/s of wind speed up to a maximum of 30 times the height for winds of 2,24 m/s or greater is required. A minimum clear area downwind of the test site equal to five heights of any downwind windbreak is required.

9.2.2 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 test.

Wind speed and direction measuring instruments shall be set at a height corresponding to the maximum sprinkler trajectory height ± 10 %. 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 % of the test period. Wind speed shall be recorded to the nearest 0,2 m/s and directions to the nearest 10°. 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 wind speed exceed 2,2 m/s.

10 Characterization of distribution

10.1 Introduction

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

10.2 Application pattern coverage and uniformity

Four methods of characterizing pattern uniformity are shown in Table 3.

Table 3 — Pattern uniformity calculation methods

Name	Scientific notation	Reference in Annex A
1. Christiansen uniformity coefficient	UCC	A.2.2
2. Statistical coefficient of uniformity	UCS	A.2.3
3. Distribution uniformity	DU	A.2.4
4. Scheduling coefficient	SC	A.2.5

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.

10.3 Generating performance measurements from radial arrays

If the testing agency decides to use the radial arrays method, it shall have to 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 are analysed 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.

10.4 Validation of test results

To be validated, a reconstituted flow rate (Q_{rel}) shall not deviate by more than 5 % from the flow rate measured by the water meter for sprinkler discharging 0,14 l/s or higher and 7 % for flow rates less than 0,14 l/s. The reconstituted flow rate is calculated from the following formulae.

$$V_{rel} = \sum 2\pi \, r_i d_r x_i \qquad (1)$$

where

r_i is the radius at which x_1 is measured;

d_r is the measurement spacing;

x_i is the depth of water within the collector.

$$Q_{rel} = \frac{V_{rel}}{t} \qquad (2)$$

where

t is the sprinkler run time.

Annex A
(informative)

Procedures for the characterization of sprinkler pattern uniformity

A.1 Introduction

Testing for sprinkler performance is usually carried out to meet at least one of the following objectives:

— 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 evaluated for their potential contribution to product improvement.

— To provide data useful to manufacturers in the development of product specifications and performance literature. The data are used by system designers in designing system components, forecasting irrigation schedules, economic comparisons, product comparisons, and the characterization of system performance for a range of sprinkler spacing.

— To provide certified standards of performance that characterizes specific products. The data are useful in the development of specifications in contract documents. It ensures that products will perform at required design levels.

— 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 Methods for the characterization of the uniformity of sprinkler patterns

A.2.1 Introduction

This part of ISO 15886 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 sprinkler use. Four procedures are given in this Annex. Of these, at least 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 this part of ISO 15886.

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.

A.2.2 Christiansen uniformity coefficient (UCC)

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.

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

where

UCC is Christiansen's uniformity coefficient;

m is the average value $= \frac{1}{n}\sum_{i=1}^{n} \chi_i$;

d is average absolute deviation = average of individual absolute deviations = $\frac{1}{n}\left[\sum_{i=1}^{n} D_i\right]$;

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

x_i is the individual value of depth of water within each collector in the array of values being analysed for uniformity;

n is the number of values in the array being analysed for uniformity.

A.2.3 Statistical coefficient of uniformity (UCS)

This coefficient 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.

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

where

UCS is the statistical uniformity coefficient;

m is the average value $= \frac{1}{n}\left[\sum_{i=1}^{n} x_i\right]$;

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

x_i is the individual value of the depth of water within each collector in the array of values being analysed for uniformity;

n is the number of values in the array being analysed for uniformity.

A.2.4 Distribution uniformity (DU)

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

$$DU = 100 \times \left[\frac{l_q}{m} \right]$$

where

DU is the distribution uniformity;

m is the average value = $\frac{1}{n}\left[\sum_{i=1}^{n} x_i \right]$;

n is the number of values in the array being analysed for uniformity.

l_q is the average low quarter value = $\frac{1}{n_{1q}}\left[\sum_{i=1}^{n} x_i : x_i \in \mathrm{LQ} \right]$;

x_i is the individual value of the depth of water within the collectors in the array of values being analysed for uniformity;

LQ is the set containing the 25 % of the x_i values that are the smallest;

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

x_1 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.

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.

i) UCC = 0,798 UCS + 20,2

ii) UCC = 0,63 DU + 37,0

iii) UCS = 1,253 UCC – 25,3

iv) UCS = 0,79 DU + 21,0

v) DU = 1,59 UCC – 59,0

vi) DU = 1,27 UCS – 27,0

A.2.5 Scheduling coefficient (SC)

A measure of uniformity specially designed for physical significance in turf or lawn irrigation. In these instances, even relatively small dry spot areas of inadequately watered turf show up with high visual impact. Turf managers often “water to the dry spot requirement,” 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 non-uniformity. The increase in irrigation time, unfortunately, has a negative effect on the application efficiency.

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 US, 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 % irrigated area 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 and the overlapping of individual sprinkler patterns to approximate field scale distribution patterns.

$$S_\mathrm{c} = \left[\frac{m}{m_\mathrm{crit}} \right]$$

where

S_C is the scheduling coefficient;

m is the average value = $\frac{1}{n}\left[\sum_{i=1}^{n} x_i \right]$;

x_i is the individual value of the depth of water within each collector in the array of values being analysed for uniformity;

n is the number of values in the array;

m_crit is the average of the values within the critical dry area.

The critical dry area is the contiguous area “dry spot” within the array being analysed 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.

Annex B
(informative)

Testing of part-circle sprinklers

Part-circle sprinklers are to be tested similarly to full-circle sprinklers, as described in the main body of this part of the standard, observing the following principles.

— Part-circle sprinklers should preferably be tested by the **full grid collector array** method (6.1).

— Part-circle sprinklers may be tested by the **radial collector array** method (6.2) if the manufacturer declares that the sprinkler is designed for uniform distribution of water across its intended application area, watching the following points:

  — This method of test is not applicable to sprinklers with non-contiguous application pattern (e.g. sprinklers having multiple discrete jets).

  — The radial line of collectors should be positioned near the centerline of the sector.

    — It is recommended to position additional radial lines of collectors near the sector boundaries.

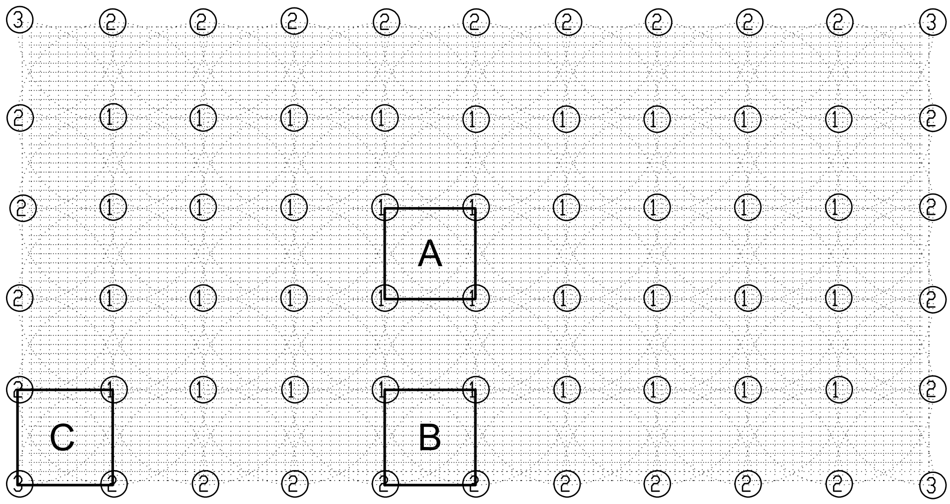
  — For a part-circle sprinkler declared as having multiple sectors with different distribution patterns or uniformity, at least one radial line of collectors should be tested in each sector.

Figure B.1 demonstrates the net of virtual sprinklers and collectors in the calculation procedure, taking into consideration the effect of multiple sprinklers positions, either full-circle or part-circle.

— The bordered square marked **A** represents typical sampling area for full-circle sprinklers.

— The bordered square marked **B** represents typical sampling area for full-circle and half-circle sprinklers.

— The bordered square marked **C** represents typical sampling area for full-circle, half-circle and quarter-circle sprinklers.



Key

1 full-circle sprinkler
2 half-circle (180°) sprinkler
3 quarter-circle (90°) sprinkler

Figure B.1 — Virtual collector array

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