Smart Water Application Technologies™ (SWAT)

Turf and Landscape Irrigation Equipment

Spray Head Sprinkler Nozzles Performance Characteristics

Equipment Functionality Testing Protocol

Version 3.2 (April 2015)

Developed by the

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1. Introduction

Historically, a major focus of landscape irrigation has been keeping plant material growing in an aesthetically pleasing manner. More recently, emphasis has been placed on keeping plant material healthy while using the minimum amount of water. Applying irrigation water efficiently, as it relates to plant-water requirements, is one way to achieve this goal. This protocol is specifically for nozzles that are intended for use in sprinkler bodies with replaceable or non-replaceable nozzles that are commonly referred to as spray heads. A sprinkler nozzle is the component of an irrigation system through which water is disbursed to the landscape. Sprinkler nozzles are designed and engineered to apply water in a specific pattern and distance of throw at specified water pressures. Understanding the application characteristics of the sprinkler nozzle contributes to the appropriate design of the irrigation system.

2. Scope

The sprinkler nozzles evaluated under this testing protocol include spray head sprinkler nozzles commonly used for landscape applications that are either fixed arcs (such as 90°, 120°, 180° or 360°) or the nozzle can be adjusted to any number of arcs up to and including 360 degrees. The testing protocol has two parts:

1) Testing the nozzles individually and comparing to the manufacturer claims of performance for flow and distance of throw.

2) Testing nozzles of various arcs as a group similar to a zone of sprinklers typically found in landscape applications in two standardized shapes: square and circular. The testing protocol will not evaluate nozzles that have specialty patterns.

Test results shall be posted with manufacturer's permission for a maximum of three years after which the product shall be retested. The updated test results will replace the previous test results. Nozzles may be tested at any time and have the results posted. Manufacturer observation of the test is subject to testing laboratory procedures.

Disclaimer

This protocol does not test material durability under specific stresses or environmental conditions. This protocol does not evaluate nozzle performance when installed on sprinkler bodies that have integral pressure regulation or check valves. The testing protocol will not evaluate specialty pattern nozzles such as side-strip, center-strip, end-strip nozzles or similar. Testing in windy conditions is also beyond the scope of this protocol.

3. Normative References

3.1. ASAE, S398.1 March 1985 (R2012). Procedure for Sprinkler Testing and Performance Reporting.

3.2. Landscape Irrigation Auditor, 3rd edition. Irrigation Association 2013. Falls Church, VA.

3.3. Irrigation Association Audit Guidelines Irrigation Association. Falls Church, VA. http://www.irrigation.org/uploadedFiles/Certification/CLIA-CGIA_AuditGuidelines.pdf

4. Terms and Definitions

For purposes of this testing protocol, the following terms and definitions apply:

4.1 Air temperature – Ambient air temperature indicated by a thermometer exposed to the air but sheltered from direct solar radiation.

4.2 Arc – Portion of a full-circle covered by a part-circle nozzle and can be fixed or adjustable.

4.3 Catchment device – Container used to collect water being dispersed by a nozzle or group of nozzles. All catchment devices shall be identical in size and shape and have a throat opening of at least 12.5 square inches (80.6 square centimeters) with a sharp edge and deep enough so water will not splash out. Catchment device shall hold a volume of water at least 6.75 ounces (200 mL) of liquid or a depth of water equivalent to at least 1 inch (2.54 cm).Volume or depth of water shall be measured with an accuracy of ± 3.0 percent.

4.4 Data logger – A device that records data electronically and automatically from a sensor/transducer/instrument.

4.5 Distance of throw (wetted area) – Distance from a nozzle to the furthest point of water application at least equal to 0.01 in./h (0.3 mm/h) as per ASAE 398.1. Also called throw or radius of throw for sprinklers with circular wetting patterns.

4.6 Dynamic pressure – Measure of water pressure with the water in motion. Also known as operating, residual or working pressure.

4.7 Manufacturer-advertised – Claimed performance listed in readily available manufacturer product or performance literature.

4.8 Nozzle – Final orifice through which water passes out to the atmosphere.

4.9 Over spray (OS) – water that drifts away or that is applied beyond the target area.

4.10 Percolation losses (PL) – Water applied beyond the 75th percentile application rate is considered excessive and assumed to be lost to deep percolation.

4.11 Precipitation rate (PR) – Rate at which water is applied to a given area measured in depth units over time. Also known as application rate.

4.12 Relative humidity – The amount of water vapor in the air relative to the amount that the air can hold at saturation.

4.13 Spacing arrangement – Sprinklers are arranged in a pattern so that each sprinkler throws water to the adjacent sprinklers

4.13.1 Square spacing arrangement: In-line sprinklers and rows of sprinklers are evenly spaced in a square pattern based on the manufacturer-advertised radius of throw. Full, half and quarter-circle nozzles are operating at the same time within the zone.

4.13.2 Circular spacing arrangement: The area of the circle shall be based on the manufacturer-advertised radius of throw of the full-circle nozzle located in the center and six part-circle sprinklers spaced equally around the circumference with all nozzles operating at the same time.

4.14 Sprinkler operational efficiency (OE_S) – term accounting for water applied to the target area less the percolation (PL) and overspray (OS) losses; expressed as a percentage.

4.15 Spray head sprinkler – A single unit assembly comprised of a sprinkler body and a nozzle.

4.16 Test lot – The total sample quantity of nozzles obtained for potential testing.

4.17 Test batch – A subsample quantity of nozzles from the test lot.

4.18 Uniformity – Term describing the evenness of water application by a sprinkler or a group of sprinklers over an area.

4.18.1 Distribution Uniformity of lowest quarter (DU_{lq}): Ratio of the average of the lowest one-fourth of measurements of irrigation water applied to the overall average measurement of irrigation water applied.

5. Symbols and Abbreviations

PR – Precipitation rate (in./h)
gpm – Gallons per minute
psi – Pounds force per square inch
DU_{lq} – Distribution uniformity lowest quarter
OE_s – Sprinkler operational efficiency
PL – Percolation losses
OS – Overspray losses

Note: U.S. customary units are used in this document with metric units in parenthesis

6. Test Specimen Selection

6.1 Nozzle Test Lots

Fifty percent of the nozzles shall be obtained from each of two different production runs by the testing lab. A nozzle test lot shall be provided for each distance of throw (or radii) as published in manufacturer literature and for the arcs needed to test in the standardized spacing arrangements. For fixed-arc nozzles the test lot will include: 20 quarter-circle (90°) nozzles, 24 one-third (120°) nozzles, 20 half-circle (180°) nozzles, and 10 (360°) full-circle nozzles; all with the same distance of throw. A test lot for adjustable or variable arc nozzles will be 70 nozzles (or 60 adjustable/variable arc nozzles plus 10 full-circle complementary nozzles if the adjustable/variable arc nozzles do not open sufficiently to cover a full-circle pattern). A nozzle test batch shall be randomly selected by the testing lab from the test lot for each described test. All nozzles used in the tests shall be retained by the testing laboratory for not less than three years.

6.2 Single Nozzle Testing

Three nozzles of each fixed arc and radii in the test lot shall be selected and installed on a compatible sprinkler body. Results will be reported for each nozzle radii individually and averaged. The results shall be compared to manufacturer advertised claims of performance. For nozzles that have multiple and distinct distance of throw settings, tests shall be performed at the minimum setting and the maximum setting and for any other distinct nozzle setting if those are features of the nozzles. Each distinct distance of throw setting shall be considered a unique nozzle and shall require the number of nozzles as listed in Item 6.1. For nozzles that have variable/adjustable arc settings, the tests shall be done with the nozzles adjusted to 90°, 120°, 180°, and 360° arcs similar to fixed arc nozzles.

All nozzles shall be tested at full distance of throw without using the adjustment features incorporated into the nozzle design by the manufacturer to modify distance of throw in field applications.

6.3 Defined Shape Testing

A square spacing arrangement (Schematic 11.3) and a circular spacing arrangement (Schematic 11.4) shall be used to evaluate how nozzles work together as a group. For each spacing arrangement, the specified quantity of nozzles shall be selected from the test lot to populate the arrangement. For the square spacing arrangement, four 90° nozzles, four 180° nozzles, and one 360° nozzle shall be selected from the test lot and shall comprise a test batch. For the circular spacing arrangement, six 120° nozzles and one 360° nozzle shall be selected from the test lot and shall comprise a test batch. Three test batches shall be selected and identified for each spacing arrangement. Each test batch shall be tested at each of the operating pressures listed for the respective nozzle types. The same procedure shall be done for variable/adjustable arc nozzles. The results shall be reported for each test batch and each operating pressure. No individual nozzle shall be used in more than one test batch.

All nozzles shall be tested at full distance of throw without using the adjustment features incorporated into the nozzle design by the manufacturer to modify distance of throw in field applications. Nozzles that have features to include distinct multiple distance of throw settings will be tested at the minimum setting, the maximum setting and any other setting as published in manufacturer literature as though they are distinct nozzles. Results for each setting shall be reported for the nozzle.

7. TEST FACILITY AND EQUIPMENT

7.1 Testing Facility

Testing will be performed on a level area (less than two percent slope) large enough to accommodate the spacing arrangements. Environmental conditions including air temperature, relative humidity, and wind speed shall be monitored and recorded at the beginning and at the conclusion of each test procedure. The water quality shall be checked prior to testing to confirm compliance with 7.2.7. The tests shall be conducted when wind speed is less than three miles per hour. All catchment devices shall be set at or just below the cap height of the sprinkler so that the nozzles will be a minimum of four inches (10 cm) above the catchment devices when fully pressurized.

Sprinkler bodies or risers with acceptable nozzle adapters with nominal 4-inch (10 cm) pop-up height in accordance with manufacturer's literature shall be utilized for all tests. For the purposes of evaluating nozzle characteristics, sprinkler bodies shall not have integral check valves or pressure regulating devices.

7.2 Environmental Monitoring and Water Quality

7.2.1 General Requirements

All instruments used for monitoring shall have protective shields and be protected from any dust or spray during testing which could influence readings. Calibrate the instruments for accuracy prior to testing as needed.

7.2.2 Data Logger

If data loggers are used to monitor and capture data, the data logger shall be able to collect data readings at least once every five seconds and average for the test run time for conditions listed below in paragraphs 7.2.3 through 7.2.5.

7.2.3 Air Temperature and Relative Humidity

Air temperature and relative humidity will be monitored by an instrument(s) capable of measuring temperatures ranging from 32 to 140°F (0 to 60°C) with an accuracy of ±1 degree and relative humidity ranging from 0 to 100-percent with an accuracy of ±3 percent over the range of 0-90 percent. During nozzle testing, acceptable temperature range shall be 50-86°F (10-30°C) and relative humidity 30-60 percent. Changes of temperature or humidity during the test shall not change more than 5 percent of the pre-test ambient conditions.

7.2.4 Wind Speed

During testing, wind speed shall be monitored by an instrument capable of measuring wind speeds ranging from 1 to 30 mph (1.6 to 48.3 kph) with an accuracy of ±3 percent of the reading. The anemometer shall be set at 3 to 6 feet (1 to 2 meters) above ground and upwind of the testing location but not more than 150 feet (45 meters) away. Maximum wind speed and average wind speed throughout the test period shall be reported.

7.2.5 Test Pressure

Pressure gauges or pressure transducers to monitor testing pressure shall be installed upstream of any nozzles being tested, but downstream of any water source, pump, pressure-regulating device, or valve. An additional pressure gauge or pressure transducer shall be located within the pipe network near the center of the spacing arrangement as shown in schematics 11.3 and 11.4. Pressure measuring device shall be accurate to within 0.50 psi (0.03 bar) in the range of the inlet pressures being tested. Water pressure shall not vary more than +/- 3 percent during test period.

7.2.6 Flow Measurements

The flow measuring device shall have a totalizer with a minimum resolution of 0.1 gallon (0.38 Liter). If a switch closure from the meter is connected to a data logger, it shall produce a pulse for each 0.1 gallon of flow. Measurement accuracy shall be +/- 1.5 percent for the range of flow measured. The measuring device shall meet manufacturer’s published installation requirements for optimal operation.

Flow rates through the tested nozzles shall be determined under the pressures specified in the test procedures. Flow meter readings will provide water volume measurements throughout the duration of the test. For nozzles that have variable radii of throw, the tests shall be performed at the minimum radius of throw and at the maximum radius of throw, as specified in manufacturer literature.

7.2.7 Water Quality

Acceptable water quality shall have a pH between 6.5-8.5, a water temperature less than 86°F (30°C) and suspended solids no greater than 200 mesh (74 microns) in size so as not to interfere with nozzle operation. Installation of a 200 mesh filter during testing is required as depicted in 11.3 and 11.4.

8. TESTING PROCEDURES

Each nozzle series will undergo four test procedures;

1.) Single nozzle distance of throw test
2.) Single nozzle flow and precipitation rate test
3.) Square spacing arrangement test
4.) Circular spacing arrangement test

The minimum test run time shall be based upon the Irrigation Association Auditing Guidelines to capture a measurable sample.

8.1 Single Nozzle Water Application Metrics

Tests for 8.1.1 and 8.1.2 shall be conducted at the same time.

8.1.1 Distance of Throw

A single sprinkler body with a test nozzle shall be arranged in a test facility to measure distance of throw and flow rate. The distance of throw will be evaluated for 90°, 120°, 180°, 270° and 360° arcs. Single nozzle distance of throw testing shall be conducted at the recommended dynamic pressure and 15 psi (1.04 bar) above the recommended operating pressure as listed in manufacturer's literature.

Distance of throw shall be measured from the sprinkler nozzle centerline using a multiple-leg arrangement to the most distant point of water catchment as shown in Schematic 11.1. For nozzles covering an arc of 90° or less, two legs shall be used. For nozzle arcs greater than 90° up to and including 180° shall use three legs and for nozzle arcs greater than 180° shall use four legs. The legs shall divide the arc evenly and shall not be placed along the extreme edges of the nozzle pattern.

Catch device placement shall be in-line on 1-foot (30 cm) increments, center-to-center, for nozzles with radius of throw less than 16 feet (4.88 meters) and in-line on 2- foot (60 centimeters) increments, center-to-center, for nozzles with a radius of throw 16 feet (4.88 meters) and greater. Catch devices shall extend a minimum of two increments further than the anticipated distance of throw.

The reported distance shall be the average of all of the radial-leg tests and reported in increments of ½-foot for nozzles that throw less than 16 feet and in increments of 1-foot for nozzles that throw 16 feet or more.

8.1.2 Precipitation Rate Comparison

Determine the precipitation rate for the nozzles based upon the data collected in 8.1.1.

Gross precipitation, expressed as inches per hour (in./h), will be determined by measuring the flow rate using a water meter and dividing by the area which shall be based on distance of throw as measured in 8.1.1 for a full-circle sprinkler (or equivalent) on square spacing and compared to manufacturer literature

$$PR_{gross} = \frac{96.3 \times flow(gpm)}{Area(square\ feet)}$$

8.2 Defined Shape Spacing Arrangements

Square (Schematic 11.3), and circular (Schematic 11.4) spacing arrangements of the test nozzles shall evaluate nozzle precipitation rates, sprinkler operational efficiency, and distribution uniformity.

Square and circular spacing arrangements of test nozzles shall be conducted at the recommended dynamic pressure and 15 psi (1.04 bar) above the recommended operating pressure as listed in manufacturer's literature. The spacing between the sprinkler heads in the arrangements shall be based on what is listed in manufacturer literature as the distance of throw for the nozzles operating at the manufacturer recommended pressure. Part-circle arcs shall be adjusted to minimize off-target application for each spacing arrangement.

Nozzles that have a specific distance of throw adjustment shall be tested at the minimum setting, the maximum setting, or any other distinct setting, as declared in manufacturer literature and reported as separate tests using a different lot of nozzles for each distinct setting.

The **maximum** spacing between catchment devices will be one-third of the sprinkler spacing for nozzles with a distance of throw less than 16 feet (4.88 meters) and one-fourth of the sprinkler spacing for nozzles with a throw equal to or greater than 16 feet (4.88 meters) arrayed in a grid pattern within the coverage area. One row of catchment devices shall be placed around the outside of the perimeter of the sprinkler spacing arrangement with the same spacing between catchment devices as within the sprinkler spacing arrangement. A minimum of 24 catchment devices shall be used within the test area of the sprinkler spacing arrangement.

Minimum test run times shall comply with Irrigation Association Auditing Guidelines and must be of sufficient time to capture a measurable sample.

8.2.1 Precipitation Rate Calculations

Gross precipitation expressed as inches per hour (in./h), shall be determined by measuring the flow rate using a water meter and dividing by the area which shall be based on distance of throw as measured in 8.1.1 for a full-circle sprinkler (or equivalent) on square spacing and compared to manufacturer literature

$$PR_{gross} = \frac{96.3 \times flow(\ gpm\ )}{Area(\ sq.\ ft.)}$$

Net precipitation rate (in./h) shall be calculated based upon the water measured in the catchment devices.

For volume measurements:

$$PR_{net} = \frac{3.66 \times Average\ catchment(\ mL)}{Test\ run\ time(\ \text{min.}) \times Catch\ device\ area(\ sq.\ in.)}$$

For depth measurements:

$$PR_{net} = \frac{Average\ depth}{Test\ run\ time(\text{min.})} \times 60$$

8.2.2 Nozzle Performance Characterization

Distribution Uniformity

These tests will characterize the areal distribution of water in the test area under the applied irrigation conditions, resulting in uniformity calculations across the spacing arrangements within the test areas.

Distribution Uniformity of Lowest Quarter (DU_{lq}): Ratio of the average of the lowest one-fourth of measurements of irrigation water applied to the overall average measurement of irrigation water applied.

$$DU_{lq} = \frac{Low\ \ quarter\ \ average\ \ measurement}{Overall\ \ average\ \ measurement}$$

Overspray Losses

This calculation considers water that is applied beyond the target area. It is measured in catchment devices that are outside of the perimeter of the target area and expressed as a percentage.

$$OS = \frac{total\ \ overspray\ \ catchment}{total\ \ of\ \ all\ \ catchments} \times 100$$

Percolation Losses

This calculation considers the depth or volume of water applied beyond the 75^{th} percentile application rate that is considered lost to deep percolation.

$$PL = \frac{water\ \ loss}{total\ \ water}\ \ x\ 100$$

Assume the catchment devices which contain water greater than 75^{th} percentile application rate are: #1, #2, #3, …., #n.

The catchment water in those cans are C_1, C_2, C_3, … C_n

$$Water\ Loss = \left(C_1 + C_2 + C_3 + ...C_n\right) - n \times C_{75}$$

$$Total\ Water = \left(C_1 + C_2 + C_3 + ...C_n\right)$$

Sprinkler Operational Efficiency
This calculation subtracts the losses (expressed as a decimal fraction) from the theoretical perfect sprinkler system and expresses as a percentage.

$$OE_S = 100\left(\left(1 - PL\right)\left(1 - OS\right)\right)$$

9. TEST REPORT

9.1 Single nozzle test report

1. Date of test, name of testing facility, location, environmental/climate conditions, test pressure, size of catchment device, test run time and if the test was done indoors or outdoors.
2. All pertinent information for the identification of the nozzles being tested including manufacturer, nozzle designation, flow rate, radius and arc of throw and precipitation rate as listed in manufacturer literature.
3. Test results for each individual nozzle and averaged for distance of throw and flow rate.
4. Net and gross precipitation rates for testing pressure and distance of throw.

9.2 Defined Shape spacing arrangements test report

1. Spacing arrangement and distance between sprinklers
2. Size of catchment device, test run time and distance between water catchment devices for uniformity tests.
3. Flow rates of all nozzles for sprinkler spacing arrangements and pressures tested.
4. Net and gross precipitation rates of nozzles for sprinkler spacing arrangements and pressures tested.
5. Lower-quarter distribution uniformity for each of the sprinkler spacing arrangements and pressures tested.
6. Losses: overspray losses and deep percolation losses based on adequacy at the 75^{th} percentile.
7. Sprinkler operational efficiency.

10. INFORMATIVE REFERENCES

ASABE/ICC-802-2014 Landscape Irrigation Sprinkler and Emitter Standard

Baum, Melissa C., Michael D. Dukes, and Grady L. Miller. 2003. Residential irrigation uniformity and efficiency in Florida. American Society of Agricultural Engineering Florida Section Meeting. Clearwater, FL.

Burt, C.M., A.J. Clemmens, and K.H. Strelkoff. 1997. Irrigation performance measurements: Efficiency and uniformity. Journal of Irrigation and Drainage Engineering. 123(6):423-442.

Christiansen, J.E. 1942. Irrigation by sprinkling. California Agricultural Experiment Station Bulletin 670. University of California, Berkley, CA.

Irrigation Association. 2010. Principles of Irrigation. Irrigation Association Water Management Committee. Falls Church, VA.

ISO 15336 Irrigation equipment – irrigation sprinklers Part 1: Definition of terms and classification

ISO 15336 Irrigation equipment – irrigation sprinklers Part 3: Characterizing of distribution and test methods

ISO 8026 Agricultural irrigation equipment – Sprayers – General requirements and test methods

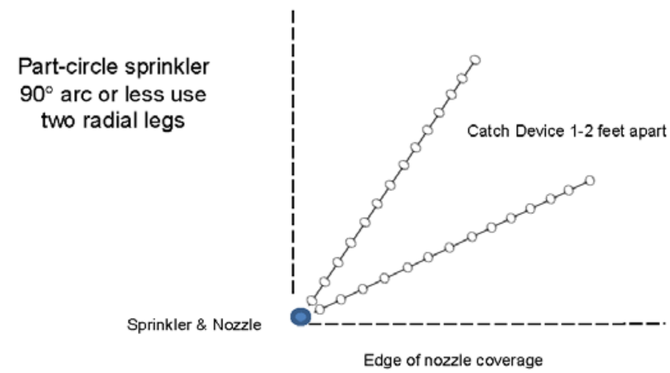
Kumar, R., Green, R., Vis, E. 2014. Distribution Uniformity of Multi Stream Multi Trajectory Rotary Nozzles Spaced Below Recommended Distance. Cal Poly University Pomona, CA.

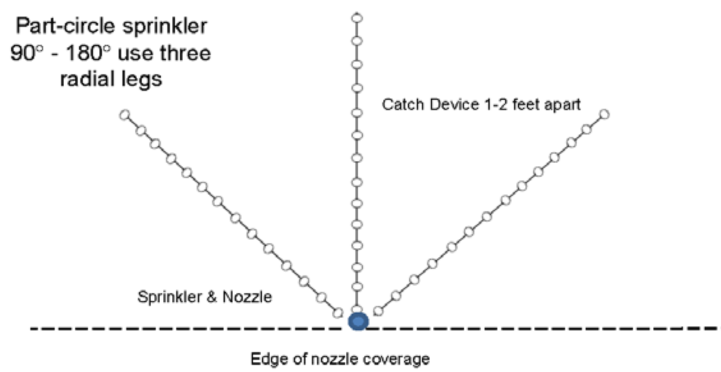
Mecham, Brent. 2004. Using distribution uniformity to evaluate the quality of a sprinkler system. Northern Colorado Water Conservancy District Report. Berthoud, CO.

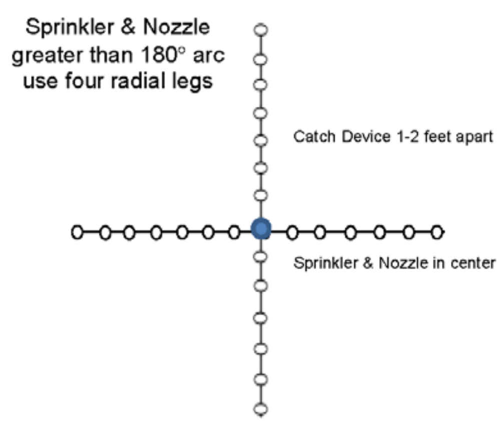
Solomon, Kenneth. 1988. A new way to view sprinkler patterns. Irrigation Notes. Center for Irrigation Technology, California State University, Fresno. Fresno, CA.

11. SCHEMATICS

11.1. Distance of throw measurement. Radial spokes as needed depending on the arc of coverage.

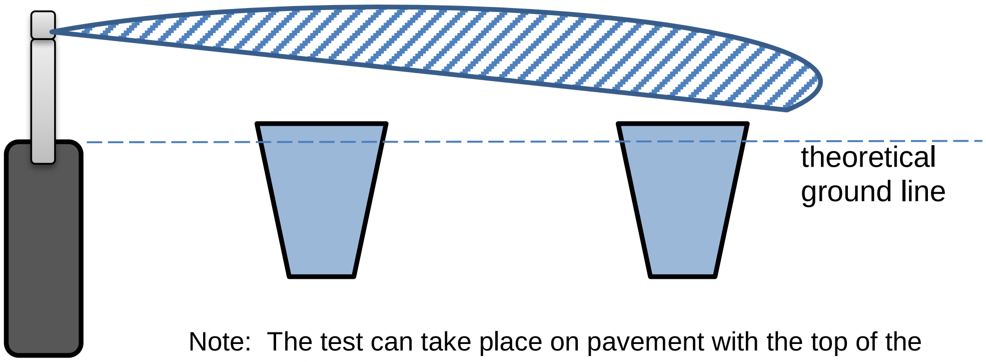






11.2. Catchment device

All catchment devices will be, approximately level with the cap of the sprinkler body and about 4 inches below nozzle discharge.

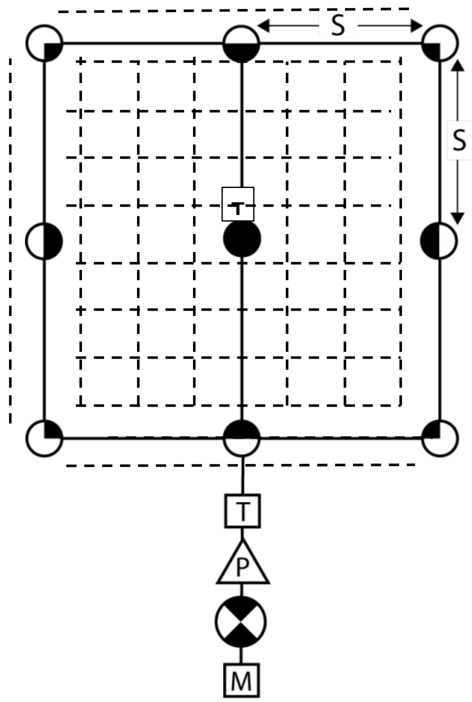


Note: The test can take place on pavement with the top of the catch devices nearly level and at the same height as the top of the sprinkler cap. Sprinkler stem will pop up approximately 4 inches above the catch device.

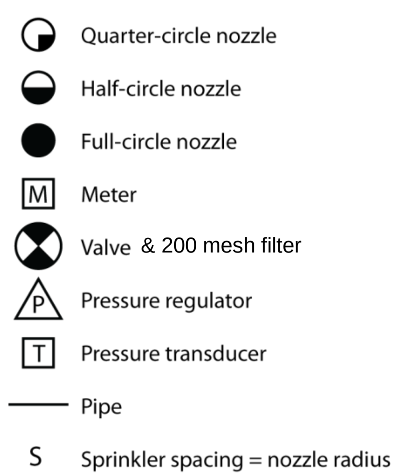
11.3 Square spacing arrangement

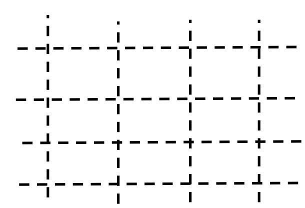
Catchment devices shall be placed in a grid pattern within the spacing arrangement to determine distribution uniformity.

Square Configuration



Legend





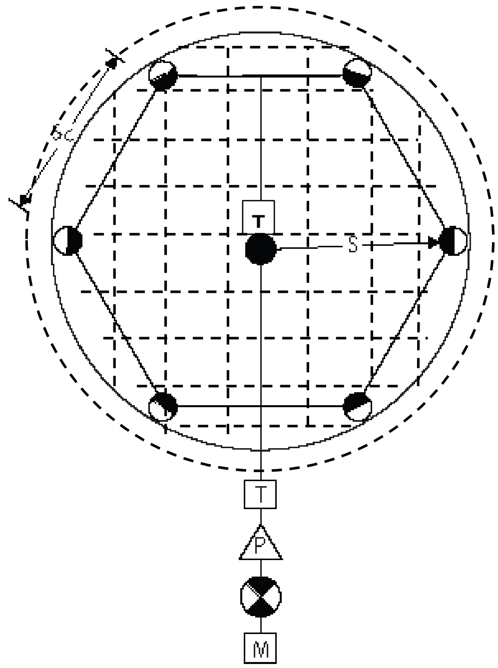
Indicates catchment devices arranged for testing

Note: Pipe sizing based on highest flow rate for tests.

Velocity < 3 fps   Friction loss < 5 percent.

11.4 Circular spacing arrangement

Catchment devices shall be arranged in a grid pattern within the target area to determine distribution uniformity.



Legend

Third-circle nozzle

Full-circle nozzle

M Meter

Valve & 200 mesh filter

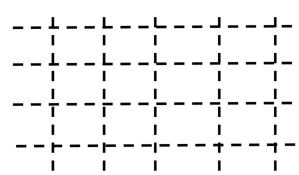
P Pressure regulator

T Pressure transducer

Pipe

S Sprinkler spacing = nozzle radius

S_C Spacing of sprinkler evenly around circumference nearly equal to nozzle radius



Indicates catchment devices arranged for testing

Note: Pipe sizing based on highest flow rate for tests.
Velocity < 3 fps Friction loss < 5 percent.