# Smart Water Application Technologies™ (SWAT)

**Turf and Landscape Irrigation Equipment**

# PRESSURE REGULATING SPRAY HEAD SPRINKLERS

## Equipment Functionality Test

**Testing Protocol Version 3.0 (May 2012)**

**Developed by the**

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# 1. Introduction

Many irrigation systems have excessive pressure for the type of equipment that has been installed. Excessive pressure will cause higher flow rates and over-pressurization can lead to water losses and contribute to poor distribution uniformity. Fixed spray or multi-stream, multi-trajectory (MSMT) nozzles that fit spray head sprinklers (sprinklers that have non-rotating pop-up stems or turrets) are designed to operate within a specified pressure range and usually have a manufacturer suggested pressure for optimal performance. To address the potential problem of over-pressurization, several manufacturers have designed and manufactured sprinklers that regulate pressure to the nozzle over a range of inlet pressures. Pressure regulation is achieved within the internal parts of the spray head sprinkler. This protocol describes the testing procedure for pressure regulating spray head sprinklers.

# 2. Scope

The protocol described herein seeks to measure and evaluate the pressure regulating performance of pressure-regulated spray head sprinklers against the manufacture-advertised performance. Spray head sprinklers included under this protocol include sprinklers with a non-rotating stem or turret, threads to accept a nozzle that retracts into the sprinkler body when not operating and has an automatically actuated pressure regulator that is integral to the sprinkler. The measure of performance is based upon measured outlet pressure (pressure in the sprinkler stem downstream of regulation and upstream of the nozzle) under various inlet pressures. In addition, the protocol is designed to evaluate the water saving potential of pressure regulating spray head sprinklers when the nozzle is missing (simulating a sheared-off nozzle). The scope of this protocol does not include rotary sprinklers; including impact style or closed-case gear-driven sprinklers that have a stem or turret that rotates.

***Disclaimer***

This protocol does not attempt to evaluate any other measure of sprinkler or nozzle performance regarding flow rates at specified pressures or application uniformity, nor does it set criteria for optimal sprinkler performance. No implication is made that pressure regulation to the manufacture-advertised level results in optimal sprinkler performance. This protocol does not test material durability under specific stresses or environmental conditions.

## 3. Terms and Definitions

Accuracy – Degree of closeness of a measurement to a true value. In this protocol the accuracy is defined in terms of percent error , δ (Figliola, R. S. and Beasley, D. E. 2000. *Theory and design for mechanical measurements*, 3rd Ed., John Wiley and Sons, Inc., N.Y.:

$$\delta = \eta \times 100 \tag{1}$$

Where η is relative error:

$$\eta = \frac{|v - v_m|}{v} \tag{2}$$

and v = true (manufacturer-advertised) value and $v_m$ is the measured value.

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

Manufacturer-advertised – Claimed performance, e.g., manufacturer-advertised regulated pressure of 30 psi.

Precision – A measure of repeatability of a measurement over a number of trials. In this protocol, precision is measured by the standard deviation (the inverse of precision, i.e. variability) and coefficient of variation (CV). The coefficient of variation is a measure of variability normalized by the mean:

$$CV = \frac{s}{\bar{x}} \tag{3}$$

where s and $\bar{x}$ are sample standard deviation and sample mean respectively:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}$$

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{4}$$

Replicate – Experimental unit: for this protocol, an individual sprinkler

Specified test inlet pressure – The target inlet pressure, as distinguished from the actual testing pressure.

Sprinkler – Emission device with a body, internal parts and one or more nozzles to convert irrigation water pressure to high velocity water discharge through the air

Nozzle – The actual orifice(s) that water passes through
Spray head – Sprinkler with a nozzle that continuously applies water in a pattern over an area.
Rotor head – Sprinkler with a nozzle that applies water in a pattern over an area by means of one or more moving streams.

Test lot – the total sample of sprinklers obtained for potential testing

Test batch – a subsample of the test lot upon which testing will be performed

# 4. Symbols and Abbreviations

psig – pounds force per square inch gauge.
gpm – gallons per minutes
Note: U.S. customary units are used in this document

# 5. Test Specimen Selection

One dozen sprinklers of each tested sprinkler model with four-inch pop-up stems from three different manufacturer date codes shall be obtained as “off-the-shelf-purchases” from authorized irrigation distributors for a total of 36 samples (test lot). Three sprinklers shall be selected at random from each manufacture date code lot, for a total of nine sprinklers of the same model (test batch) to be subject to the continuous and step test procedures. The stability test and missing nozzle test procedures will use other sprinklers drawn from the test lot.

# 6. Test Method

## 6.1. Testing Device

The testing device shall be constructed to supply a pressure range as indicated in manufacturer literature usually between 15.0 and 100.0 psig. Inlet pressure provided to replicate heads (either simultaneously run or replicated in another trial) shall not differ by more than +/-1.0 psig from specified test pressure.

## 6.2. Location of Pressure Measurement

Pressure shall be recorded at the entrance to the sprinkler body (inlet) and at the sprinkler stem (outlet). Pressure taps shall not intrude into the tapped sections and any burrs or irregularities caused by provision of a pressure tap shall be removed. Pressure tap openings shall not exceed 1/10 of inside diameter of section tapped.

## 6.3. Measuring Equipment

### 6.3.1. Pressure Measurement

Pressure measuring device shall be a transducer capable of being logged with a datalogger. Accuracy (including linearity and hysteresis and repeatability) shall be within 0.50 psig in the range of inlet pressures tested. Precision resistors (0.1% tolerance) shall be used in any application (e.g. completion resistors at logger) that converts current to voltage for logging purposes. If using a multiplexer, power and ground leads from the pressure sensors are to be connected to a common power and ground source rather than routed through the independent multiplexer channel contacts, and sufficient warm-up time shall be allowed prior to querying sensors.

### 6.3.2. Flow Measurement

The flow measuring device shall be capable of being logged with a datalogger. The minimum resolution shall be 1 gallon, e.g. 1 gallon per pulse if using a reed switch type pulse count meter. Other meter output for logging purposes may include electrical signal (mA or volts) or frequency (Hz). Meter accuracy shall be (100% +/- 1.5%) for the range of flow measured. The water meter shall be located upstream of any pressure regulating device, at least 10 pipe diameters downstream of any valve, and at least five pipe diameters upstream of any elbow, tee or junction. Minimum meter size shall be one-inch.

## 6.4. Testing Procedure

Each model submitted for testing will undergo four test procedures;

1.) continuous test;
2.) step test;
3.) stability test:
4.) missing nozzle test.

### 6.4.1. Continuous Test

For the continuous test, the nine sprinklers selected will undergo a “low flow” trial achieved by using half-circle spray nozzles. A “high flow” trial will utilize three sprinklers from the testing lot with a full-circle nozzle.

#### 6.4.1.1 Continuous Low Flow Test

Sprinklers shall be tested with a 12-foot half-circle spray nozzle at inlet pressures ranging from the manufacturer-advertised regulated pressure to the maximum inlet pressure declared in manufacturer operating specifications. Specified test inlet pressures shall be in 5.0 psig increments up to at least 20.0 psig above the advertised pressure and then in 10.0 psig increments at even numbers of 10 to the maximum manufacturer specified inlet pressure. . For example: with sprinklers regulated to a pressure of 30.0 psig, the specified test pressures would be as follows:

- 30.0, 35.0, 40.0, 45.0, 50.0 psig and in 10.0 psig increments thereafter up to the maximum pressure indicated in the manufacturer operating specification.

For sprinklers that are regulated at 45.0 psig the tests pressures would be as follows:

- 45.0, 50.0 55.0, 60.0, 65.0, 70.0 psig and in 10.0 psig increments thereafter up to the maximum pressure indicated in the manufacturer operating specification.

For sprinklers specified with a maximum pressure not at an even number of 10, the maximum specified test pressure shall be the manufacturer-advertised maximum inlet pressure.

The test shall be run continuously throughout the pressure range, increasing pressure, then decreasing pressure to obtain the required specified test pressures, so that there will be two sets of readings per sprinkler at each pressure (inlet and outlet), except for the maximum pressure tested. Inlet (test) pressures shall be measured at the sprinkler body. Inlet pressure shall be adjusted to within 1.0 psig of the specified testing pressure and stabilized prior to test initiation. Stabilization is considered achieved when three consecutive pressure readings are within +/- 1.0 psig of the specified test pressure. Upon inlet pressure stabilization, inlet and outlet pressures shall be logged at 30 second intervals and the test duration shall be a minimum of three minutes to obtain six pressure sample pairs (inlet and outlet) within 1.0 psig of the specified test pressure.

#### 6.4.1.2 Continuous High Flow Test

Three randomly selected sprinklers from the test batch used in the low flow trial in 6.4.1.1 will then be tested with a 15-foot full-circle spray nozzle to evaluate how it performs with a higher flow rate through the same pressure range and levels conducted in the low flow trial of 6.4.1.1.

### 6.4.2. Step Test

All nine heads in the test batch shall undergo the step test fitted with 12-foot half-circle nozzles. The step test procedure shall be conducted at the same specified test pressures as the continuous test procedure. After each specified test level trial, the testing apparatus shall be depressurized (to atmospheric pressure) and the next trial initiated after re-pressurization and pressure stabilization as defined in 6.4.1.1. Each trial shall have minimum duration, sampling frequency and number of recorded sample pairs as in 6.4.1.1. Only one trial shall be done at each specified test pressure, i.e., there will not be a descending pressure mode as in the continuous test.

### 6.4.3. Stability Test

Three randomly selected sprinkler heads not previously tested fitted with 12-foot half-circle nozzles will be subjected to a stability test. The test comprises a continuous run of 30 minutes at a specified test pressure of 20 psig above the manufacturer-advertised regulated pressure rating. Pressure readings shall be taken at 30 second intervals (for a total of 60 inlet/outlet pressure pairs) to evaluate how well the regulator controls pressure over a longer period of operation. The test shall commence by increasing the pressure to the manufacturer-advertised maximum operating pressure, then reducing to +20.0 psig above the manufacturer-advertised regulated pressure. Pressure recording will be initiated after pressure stabilization (three consecutive pressure readings taken at 30 second intervals within +/- 1.0 psig of +20.0 psig above the specified test pressure).

### 6.4.4. Missing Nozzle Test

Three randomly selected pressure regulating sprinklers not previously tested and one non-pressure regulated sprinkler of the same size and make both fitted with 12-foot half-circle nozzles will be subjected to a missing nozzle test. Only one sprinkler shall be tested at a time and all sprinklers shall be located at the same position on the test stand. Pressure measurement at the inlet to the sprinkler and flow rate measurement is required. The tests shall be conducted at sprinkler inlet pressures (test pressures) equal to the manufacturer-advertised regulated pressure, 15 psig above the manufacturer-specified regulated pressure, and 30 psig above the manufacturer-specified regulated pressure. The stipulated test pressures are for conditions with the nozzle on. The test shall commence by increasing the pressure to within +/-1.0 psig of the specified test pressure and stabilizing as defined in 6.4.1.1 then removing the nozzle.. A minimum of 10 seconds shall be allowed for flow stabilization, then flow rate shall be measured by either of two methods: for pulse type output record seven pulse counts (six intervals) with time stamps having a minimum one second resolution for

computation of six flow rates. For electrical signal (mA or volts) or frequency (Hz) output, record six flow rates at 10 second intervals.

# 7. Test Report

The test report shall include information by test as follows:

## 7.1. Continuous, Step, and Stability Tests

For each sprinkler tested at each specified test pressure (inlet) record elapsed time, measured inlet pressure, measured outlet pressure, and accuracy of outlet pressure (percent error) for each pressure pair measurement (Appendix 1, Tables A-1 to A-4). This is referred to as a "data collection form". Mean, standard deviation, and CV of these measures will also be reported and subsequently used to calculate statistics of the summary tables. There will be one table for each specified test pressure and replicate.

For each set of replicates at a specified test pressure (inlet), record means (across reps) of: accuracy (percent error), standard deviation, and CV (coefficient of variation) of outlet pressure. One table covers the range of specified test pressures. This is referred to as a "summary table". Data for this table is forwarded from the appropriate data tables. The table shall also provide the grand means (across reps and pressures) of accuracy, standard deviation, and CV, computed with data in the body of the summary table. See Appendix, Example Summary Report Tables 1 to 5.

## 7.2. Missing Nozzle Test

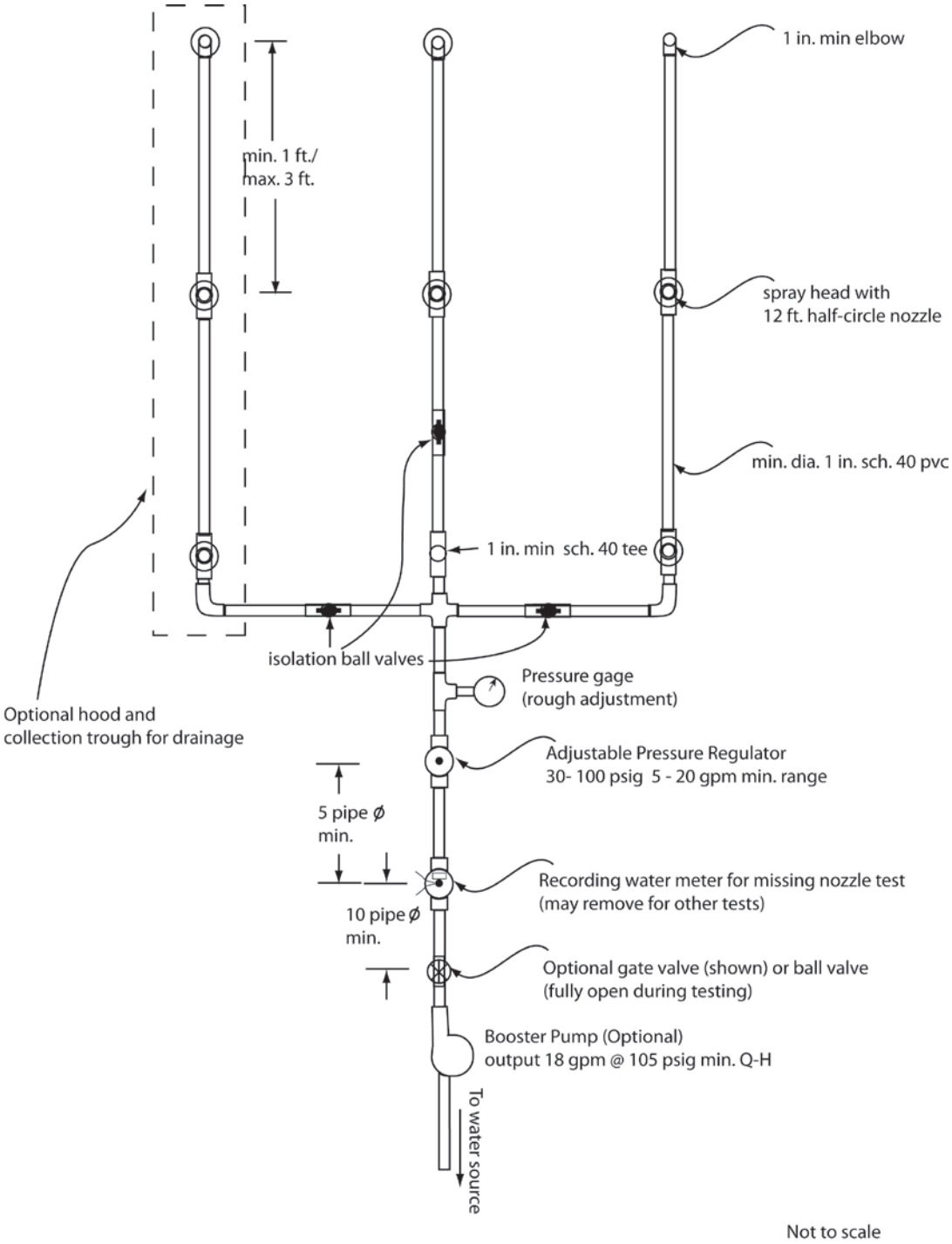
For each sprinkler head tested; record measured inlet pressure with nozzle on, elapsed time, total flow (gallons), average flow rate (gpm) over the tested period, and percent flow reduction. Record means (over regulated head reps) of elapsed time, average flow rate, and percent flow reduction for each specified test inlet pressure. See Appendix, Table A-5 for an example data collection form report. Forward mean values for each specified test inlet pressure from the data collection form into a summary table that will provide grand means (across reps and pressures). See Appendix, Example Summary Report Table 5.

# 8. References

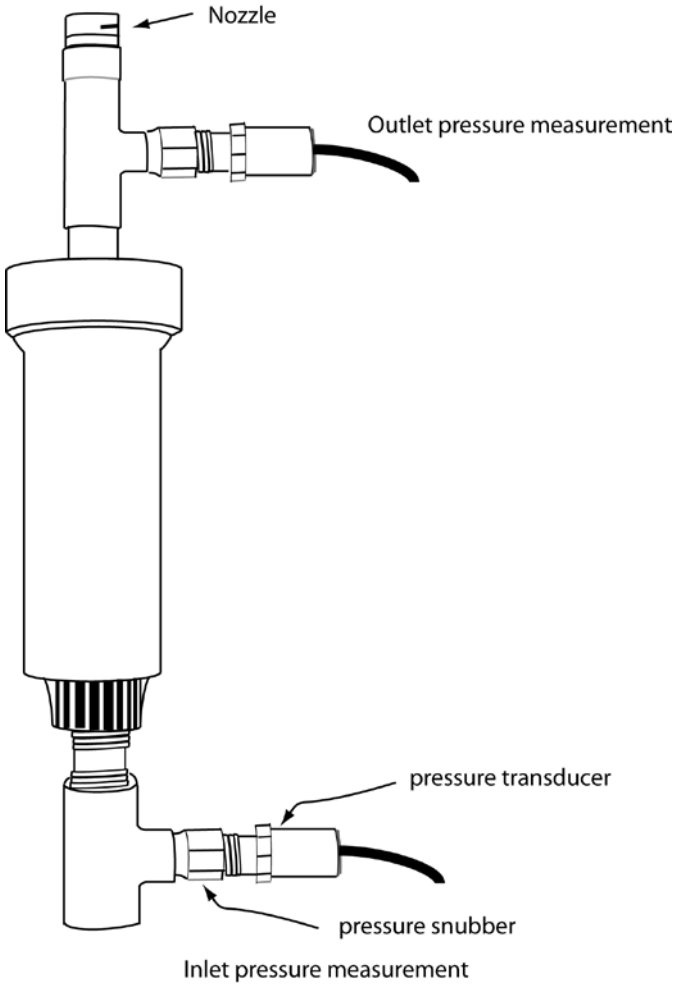
Figliola, R.S. and Beasley, D.E. 2000. *Theory and design for mechanical measurements*, 3rd Ed., John Wiley and Sons, Inc., N.Y.

# 9. Schematics

## 9.1. Example Test Stand



## 9.2. Example Pressure Sensing



## 1. Example Data Collection Form
## Half-circle nozzle (low flow) operation

**Table A-1. Example data report for low flow continuous test[1]**

Sprinkler Manufacturer: _____ Sprinkler Model: _____

Advertised Regulation (psig)_____ Sprinkler ID (Rep) _____

Specified Inlet Pressure, psig _____ Mode: Increasing / Decreasing Pressure

| Time | Measured Inlet Pressure, psig | Measured Outlet Pressure,psig | Percent Error (Outlet) |
|---|---|---|---|
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| | | | |
| Mean[2] | | | |
| Std. Dev.[2] | | | |
| CV[2] | | | |
| Repeat table for each specified pressure and sprinkler up to a maximum psig, then decrease to manufacturer designated nominal psig. Minimum of 6 readings at each pressure taken at a time interval of 30 seconds | | | |

Date: _____

Begin Test _____ am/pm

End Test _____ am/pm

Testing Agency:

_____

Name(s) of person(s) performing test

_____

_____

[2] Mean, Std. Dev. And CV from each rep and pressure used in calculation of Mean, Std. Dev. And CV in subsequent summary reports.

[1] Note: Pressure and time data collected by data logger and not manually recorded.

## 2. Example Data Collection Form
## Full-circle nozzle (high flow) operation

**Table A-2. Example data report for high flow continuous test**

Sprinkler Manufacturer: _____ Sprinkler Model: _____

Advertised Regulation (psig)_____ Sprinkler ID (Rep) _____

Specified Inlet Pressure, psig _____ Mode: Increasing/Decreasing Pressure

| Time | Measured Inlet Pressure, psig | Measured Outlet Pressure,psig | Percent Error (Outlet) |
|---|---|---|---|
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| Mean[2] | | | |
| Std. Dev.[2] | | | |
| CV[2] | | | |
| Repeat table for each specified pressure and sprinkler up to a maximum psig, then decrease to manufacturer designated nominal psig. Minimum of 6 readings at each pressure taken at a time interval of 30 seconds | | | |

Date: _____

Begin Test _____ am/pm

End Test _____ am/pm

Testing Agency:

_____

Name(s) of person(s) performing test

_____

_____

[2] Mean, Std. Dev. And CV from each rep and pressure used in calculation of Mean, Std. Dev. And CV in subsequent summary reports.

## 3. Example Data Collection Form
## Step test with half-circle nozzle operation

**Table A-3. Example data report for step test**

Sprinkler Manufacturer: _____ Sprinkler Model: _____

Advertised Regulation (psig)_____ Sprinkler ID (Rep) _____

Specified Inlet Pressure, psig _____

| Time | Measured Inlet Pressure, psig | Measured Outlet Pressure,psig | Percent Error (Outlet) |
|---|---|---|---|
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| Mean[2] | | | |
| Std. Dev.[2] | | | |
| CV[2] | | | |
| Repeat table for each specified pressure and sprinkler up to a maximum psig. Minimum of 6 readings at each pressure taken at a time interval of 30 seconds | | | |

Date: _____

Begin Test _____ am/pm

End Test _____ am/pm

Testing Agency:

_____

Name(s) of person(s) performing test

_____

_____

[2] Mean, Std. Dev. And CV from each rep and pressure used in calculation of Mean, Std. Dev. And CV in subsequent summary reports.

## 4. Example Data Collection Form
## Stability test with half-circle nozzle operation

**Table A-4. Example data report for stability test**

Sprinkler Manufacturer: _____ Sprinkler Model: _____

Advertised Regulation (psig)_____ Sprinkler ID (Rep) _____

Specified Inlet Pressure, psig _____

Date: _____

| Time | Measured Inlet Pressure, psig | Measured Outlet Pressure,psig | Percent Error (Outlet) |
|---|---|---|---|
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| Mean[2] | | | |
| Std. Dev.[2] | | | |
| CV[2] | | | |
| Repeat table for each tested sprinkler. Minimum of 6 readings at each pressure taken at a time interval of 30 seconds | | | |

Begin Test _____ am/pm

End Test _____ am/pm

Testing Agency:

_____

Name(s) of person(s) performing test

_____

_____

[2] Mean, Std. Dev. And CV from each rep and pressure used in calculation of Mean, Std. Dev. And CV in subsequent summary reports

## 5. Example Data Collection Form
## Missing Nozzle Test

**Table A-5. Example data report for missing nozzle test**

Sprinkler Manufacturer: _____ Sprinkler Model: _____

Advertised Regulation (psig)_____ Sprinkler ID (Rep)_____

Date: _____

Begin Test _____ am/pm

End Test _____ am/pm

Testing Agency:

_____

Name(s) of person(s) performing test

_____

_____

| Measurment No. | Measured Inlet Pressure, psig | Time or Elapsed Time, min.[1] | Flow Rate, gpm[2] |
|---|---|---|---|
| 1 regulated | advertised | | |
| 2 “ | “ | | |
| 3 “ | “ | | |
| 4 ” | “ | | |
| 5 “ | “ | | |
| 6 “ | “ | | |
| Mean | | ---------- | |
| 1 unregulated | advertised | | |
| 2 “ | “ | | |
| 3 “ | “ | | |
| 4 ” | “ | | |
| 5 “ | “ | | |
| 6 “ | “ | | |
| Mean | “ | ---------- | |
| Flow reduction, %[3] | | | |

[1] For mAmp, voltage or frequency output record time, for pulse count output record elapsed time between pulses
[2] if pulse count output Flow rate = Volume (gal) divided by elapsed time (min)
[3] (1-(mean regulated flow rate/ mean unregulated flow rate)) *100

Note: repeat form for inlet pressures of advertised +15 psi and advertised +30 psi

# 6. Example Summary Report

## Low flow test

**Table 1. Accuracy and Precision by pressure (across replicates) and overall (across replicates and pressures).**

| Specified Inlet Pressure | Percent Error[1] | Standard Deviation (Std. Dev.), outlet pressure[1] | Coefficient of Variation (CV), outlet pressure)[1] |
|---|---|---|---|
| 30 | | | |
| 35 | | | |
| 40 | | | |
| 45 | | | |
| 50…… | | | |
| Grand Mean | | | |

[1] Calculated using Mean, Std. Dev., and CV from data collection forms

## High Flow Test

**Table 2. Accuracy and Precision by pressure (across replicates) and overall (across replicates and pressures).**

| Specified Inlet Pressure | Percent Error[1] | Standard Deviation (Std. Dev.), outlet pressure[1] | Coefficient of Variation (CV), outlet pressure)[1] |
|---|---|---|---|
| 30 | | | |
| 35 | | | |
| 40 | | | |
| 45 | | | |
| 50……. | | | |
| Grand Mean | | | |

[1] Calculated using Mean, Std. Dev., and CV from data collection forms

## Step-Test

**Table 3. Accuracy and Precision by pressure (across replicates) and overall (across replicates and pressures).**

| Specified Inlet Pressure | Percent Error[1] | Standard Deviation (Std. Dev.), outlet pressure[1] | Coefficient of Variation (CV), outlet pressure)[1] |
|---|---|---|---|
| 30 | | | |
| 35 | | | |
| 40 | | | |
| 45 | | | |
| 50……. | | | |
| Grand Mean | | | |

[1] Calculated using Mean, Std. Dev., and CV from data collection forms

## Stability Test

**Table 4. Accuracy and Precision by replicate (across sampling times) and overall (across replicates and sampling times).**

| Sprinkler ID (Rep) | Percent Error[1] | Standard Deviation (Std. Dev.), outlet pressure[1] | Coefficient of Variation (CV), outlet pressure)[1] |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| Grand Mean | | | |

[1] Calculated using Mean, Std. Dev., and CV from data collection forms

## Missing Nozzle Test

**Table 5. Mean flow reduction (%) by specified test inlet pressure (across replicates) and overall (across specified test inlet pressures and replicates).**

| Sprinkler ID (Rep) | Inlet Pressure[1] | Average Flow Rate gpm[1] | Flow Reduction %[1] |
|---|---|---|---|
| Advertized | | | |
| Advertized + 15 psi | | | |
| Advertized + 30 psi | | | |
| Grand Mean | | | |

[1] Calculated using means from data collection forms