Smart Water
Application Technologies™
(SWAT)

Turf and Landscape Irrigation Equipment

RAINFALL SHUTOFF DEVICES

Testing Protocol Version 3.0 (October 2009)

Equipment Functionality Test

Developed by the

Irrigation Association™

SWAT Committee
8280 Willow Oaks Corporate Drive, Suite 400
Fairfax, VA 22031
www.irrigation.org

1. PROTOCOL SUMMARY

Rain sensors (RSs) appear to be a useful tool for water conservation at household or commercial sites, at a relatively low cost. However, little evidence related to RS performance and/or reliability exists. This protocol provides a standard procedure for evaluating the performance and reliability of RSs, with respect to the rainfall depth before RSs switch to interrupt mode, and the accuracy, precision, and variability of their set points.

2. STATEMENT OF WORK

2.1. Relevance and Importance

A rain sensor (RS), also called rain shut-off device or rain switch, is a device designed to interrupt a scheduled cycle of an automatic irrigation system controller (i.e. timer) when a certain amount of rainfall has occurred. By eliminating unnecessary irrigation, RSs can improve irrigation efficiency, conserve water, reduce wear on the irrigation system, reduce disease and weed pressure on turfgrass/landscapes, and reduce the runoff and/or deep percolation that carry pollutants–such as fertilizers and pesticides–into storm drains and groundwater. In addition, RSs could reduce utility bills and turf maintenance costs by minimizing over-watering.

Several types and models of RSs, which differ in method of operation, have been developed by the irrigation industry. Some of them have a receptacle to weigh the amount of water. Other models also use a receptacle but, instead of weight, they detect the water level with a set of electrodes. However, the most widely used method employs a hygroscopic expanding material to sense the amount of rainfall. A recent development of these devices is a radio-controlled or wireless rain sensor, which comprises a sensor and a receiver unit. In some new versions, the receiver unit also acts as a controller, where different settings are allowed (delay time, soil type, custom interrupt, etc.).

2.2. Problem Statement and Project Need

A number of municipalities and states are requiring rain sensors or rainfall shut off devices or technologies as part of new irrigation systems. Some municipalities require older systems to be retrofitted with rain shut-off switches. Moreover, there are mandates for the use of RSs in various municipalities in North and South Carolina, Georgia, Texas, Minnesota and Connecticut (Dewey 2003). In spite of these mandates and laws, little scientific evidence related to RS performance and/or reliability existed until Cardenas-Lailhacar and Dukes (2007) conducted a study on two expanding-disk RS models.

2.3. Scope and Objectives of the Protocol

The scope and objectives of this protocol are to provide standardized testing procedures for evaluating the performance and/or reliability of commercially available RSs. As a standard from which to judge the RSs performance, the following parameters will be quantified: a) rainfall depth before RSs switch to interrupt mode, and b) accuracy, precision, and variation of their set points.

2.4. Exclusions

This protocol does not consider RSs connected to an actual automatic irrigation system. In addition, some features that could impact their market acceptance will be out of the scope of the protocol, like:

- adequacy of the RSs to maintain an acceptable turfgrass/landscape quality,
- improvement on the irrigation system's uniformity or other hardware aspects to conserve water,

- measurements of longevity, durability and/or mean time between failure (all parts of an irrigation system are subject to varied performance characteristics over time),
- dry-out period under different vent-ring settings and/or environmental conditions,
- placing rain sensors in different locations, angles, obstructions, etc.,
- resistance to debris,
- wireless RSs capability to communicate between sensor/emitter and receiver units,
- electrical performance under a specific load,
- tipping bucket and other similar sensors, which find their most common use as part of weather stations, or more sophisticated/expensive situations.

3. METHODS, PROCEDURES, EQUIPMENT AND TASKS

Different RS models differ in their method of measuring the amount of rainfall (weight, electrodes, hygroscopic expanding discs, etc.). Also, many RSs typically have some type of adjustment so that they can be set to react after a specific amount of rainfall. For example, some of the hygroscopic expanding disk-types have five different settings that are intended to interrupt an irrigation cycle after rainfall quantities of 3, 6, 13, 19, or 25 mm (⅛, ¼, ½, ¾, or 1 inch). However, this is not the case of some models, where a quick shut down of the irrigation system occurs after rain begins (without preset adjustments for a certain precipitation amount). Therefore, different approaches must be taken to test singular models/set points.

3.1. Test Set-Up

The units to be tested will be purchased by the testing agency from a random irrigation dealer, and installed and set by testing agency personnel. Every sensor will be placed in the same testing area at the testing facility. Each RS model test will require eight identical devices[1], which will be connected to a datalogger.

3.2. Rainfall

The standard test will use a rainfall simulator, because natural rain:

- Has different intensities during the same event. Sometimes it drizzles for a long time and sometimes it rains at high intensities for short periods of time.
- Instruments (RSs and/or rainfall measurement devices) could be affected by rain intensity associated with wind.
- Sometimes during a rain event, rain stops for some time, and then continues again. Depending on the elapsed time during the break, it could be considered one rain event or two separate events (e.g. 2 hr apart or more than 5 hr apart, respectively). During the break, part of the rain that fell is evaporated, increasing the testing error.
- Based on past experience testing rain sensors in Florida, the 25 mm (1 inch) set point probably could not be tested under natural rain conditions in less than a year. Also, it is desirable to achieve replicate storm events to test the repeatability of the results and doing so with real rain events would be unlikely in a reasonable amount of time.

3.3. Rainfall Simulator

A rain simulator will be constructed to allow faster data collection under controlled and uniform (standardized[2]) rain events. The frame and hydraulic design will be similar to that recommended by the Agricultural Research Service (ARS) of the USDA, following the design of Miller (1987), and as described by Humphry et al. (2002). The device will

---

[1] Due to variability observed in current testing.
[2] The accuracy and precision of a measurement process is usually established by repeatedly measuring some traceable reference standard.

be calibrated and pressure regulated at 138 kPa (20 psi) to produce uniform rainfall events. The nozzle commonly used in rain simulation experiments is the Spraying Systems square full cone nozzle TeeJet™ ½ HH-SS50WSQ. However, a nozzle with a spinning deflector, made by Water Whizzer, and previously tested by the University of Florida, will be used instead. These nozzles produce a realistic drop diameter (1.44 mm or 0.06 in, on average), and, most importantly, a lower intensity rainfall can be simulated (20 mm/hr compared to 60 mm/hr, or 0.8 in/hr compared to 2.4 in/hr).

The amount of rainfall applied per test will be checked against three calibrated tipping bucket rain gauges positioned across the testing area, which will be connected to a data logger. Precipitation data will be recorded at intervals of 0.25 mm (0.01 in) of rainfall; and day, hour, minute and second will be logged. Uniformity across the testing area shall fall within the 95% confidence interval of the average.

3.4. Sensor Dry-Out

The time that it takes RSs to reset for normal sprinkler operation after the rain has stopped–dry out period–is determined by weather conditions (temperature, wind, sunlight, relative humidity, etc.). Since the primary goal of this protocol is to test the accuracy and precision of the RS set points, the dry-out period will be normalized. The natural dry-out period will be accelerated by using on oven set at 30 °C to reduce the total testing time. Complete dry out is anticipated to take less than 24 hours. The indoor The dry out period is not critical to the accuracy and precision of the sensors, but ensuring the dry out period is expeditious will reduce testing time. Measuring the dry out period under natural conditions is relevant for the water conservation potential of these devices and is beyond the scope of this protocol.

3.5. Data

Each time a rain sensor changes status (from allowing irrigation, to interrupt mode, or vice versa), the date and time will be automatically recorded, at a one-second sampling interval, by means of a datalogger. Each set point test will be repeated 8 times to determine the variation inherent in individual sensors.

Additional data collection during the test include relative humidity, incoming solar radiation, and temperature from a nearby weather station.

3.5.1. Rainfall before interrupt mode

The depth (mm or inches) of rain applied before each RS unit switches to interrupt mode will be calculated. This will characterize the sensitivity of RS models with no explicit set point. The rain applied to the RS models with specific set points will be, at least, three times the amount needed to meet each set point.

3.5.2. Accuracy

The accuracy of an instrument refers to its ability to indicate an exact true value. Accuracy is related to absolute error, ε , which is defined as the difference between the true value of a measurement and the indicated value of the instrument:

$$\varepsilon = \text{true value} - \text{indicated value} \quad [1]$$

from which the percent accuracy, A , is found by (Figliola and Beasley, 2000):

$$A = \left(1 - \frac{|\varepsilon|}{true\ value}\right) \times 100 \quad [2]$$

where $|\varepsilon|$ is the absolute value of ε (without regard to its positive or negative sign).

3.5.3. Precision

Precision, also called reproducibility or repeatability, is the degree to which further measurements or calculations will show the same or similar results. Precision is usually characterized in terms of the standard deviation of the measurements, and it is defined as the square root of the variance. In other words, the standard deviation is the root mean square (RMS) deviation of values from their arithmetic mean as follows:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2} \qquad [3]$$

where σ is standard deviation of the population, N is the number of samples taken, x is the value of each sample, i is the number of the sample, and $\bar{x}$ is the mean value of the samples.

The reported standard deviation of a group of repeated measurements should give the precision of those measurements. A large standard deviation indicates that the data points are far from the mean and a small standard deviation indicates that they are clustered closely around the mean.

3.5.4 Coefficient of variation

The coefficient of variation (CV) for each device tested will be calculated for each set point. The CV is a measure of dispersion of a probability distribution, and it is defined as the ratio of the standard deviation σ to the mean, $\bar{x}$.

$$CV = \frac{\sigma}{\bar{x}} \qquad [4]$$

The CV is a dimensionless number that allows comparison of the variation of populations that have significantly different mean values, with the standard deviation significantly less than the mean.

3.6. Test Duration

A minimum of 8 shut-off/allow irrigation cycles will be considered for a valid RS evaluation, at one rain intensity. Thus, for a sensor with 5 thresholds testing would be performed along the following timeline: 5 thresholds x 8 replications / 2 tests per week = 20 weeks + 4 weeks for report preparation. Under this scenario, the total testing period would be 24 weeks per sensor brand/type; however, multiple brand/types can be tested concurrently. On the other hand, for RSs with no specific set point, the timeline should be 4 weeks for the test + 2 weeks for the report preparation.

4. TEST REPORT

A test report will be completed for each brand/model/set point. The test report is not meant to criticize the different brands, models or set points; neither to compare them. If some specific values are adopted as the minimum accepted by the industry, the final report may mention whether or not these values were achieved by the tested units. In addition, in concordance with SWAT testing procedures, manufacturers will have an opportunity to review test results prior to them being considered for posting on the website. The manufacturer will have the final choice to post test results. This test review process will be the same as for other products SWAT tested.

The test report will include the following:

- Weather conditions during the test including: relative humidity, temperature, solar radiation.
- Measured rain simulator application intensity for all tests
- Depth of rainfall before shut off (mm and inches), average
- Accuracy (%), average and standard deviation
- Depth of rainfall precision (σ from the mean)
- Coefficient of variation (%), average
- Rainfall events not detected (#, and %), if any[1]
- Shut off in absence of rainfall (#, and %), if any[1]

---

1 Cardenas-Lailhacar and Dukes (2007) reported this behavior for some hygroscopic expanding disk models.

5. REFERENCES

Cardenas-Lailhacar, B. and M. D. Dukes. 2007. Expanding disk rain sensor performance and potential irrigation water savings. *Journal of Irrigation and Drainage Engineering (in press)*

Dewey, C. 2003. “Sensors at work.” *Irrigation and Green Industry*, September 2003. <http://www.igin.com/Irrigation/0903sensors.html> (4 December 2006).

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

Humphry, J.B., T.C. Daniel, D.R. Edwards, and A.N. Sharpley. 2002. A portable rainfall simulator for plot-scale runoff studies. Applied Eng. in Agric. 18:199-204.

Miller, W.P. 1987. A solenoid-operated, variable intensity rainfall simulator. Soil Sci. Soc. Am. J. 51:832-834.