Landscape Irrigation Sprinklers: WaterSense® Specification Update

I. Introduction

In July 2014, WaterSense published a Notice of Intent (NOI) to develop a draft specification for landscape irrigation sprinklers. Since that time, WaterSense has received public comments on the NOI, conducted additional research, and determined a path forward for this product category. This report serves to update stakeholders and interested parties on the feedback received, data collected, and decisions and progress made since the release of the NOI.

II. NOI Overview

In the NOI, WaterSense defined a landscape irrigation sprinkler according to the draft American Society for Agricultural and Biological Engineers and International Code Council (ASABE/ICC) 802-2014 *Landscape Irrigation Sprinkler and Emitter Standard*:[1] "A sprinkler is a device consisting of a sprinkler body with one or more orifices (i.e., nozzles) to convert irrigation water pressure to high-velocity water discharge through the air, discharging a minimum of 0.5 gallons per minute (gpm) at the largest area of coverage available for the nozzle series when operated at 30 pounds per square inch (psi) or more with a full-circle pattern."

The NOI discussed two main components that influence the efficiency of a sprinkler: the nozzle and the body. The nozzle provides the pattern of water emitted from the sprinkler, either in a fan-like pattern (i.e., a spray nozzle) or by means of one or more moving streams [e.g., multi-stream, multi-trajectory (MSMT)]. The nozzle influences the uniformity of how water is applied. The body of the sprinkler, which houses the nozzle, provides pressure regulation if applicable and can compensate for changes in inlet pressures. These two components are generally sold separately and are interchangeable between brands in some cases.

WaterSense initially recommended that its draft specification apply to both high-efficiency nozzles and pressure-regulating bodies of landscape irrigation sprinklers. It was the U.S. Environmental Protection Agency's (EPA's) intent to develop one specification that included separate criteria for each component (i.e., a set of nozzles criteria and a set of bodies criteria). Each component would be certified and labeled separately and could either be purchased and used separately, or packaged and sold together as a WaterSense labeled landscape irrigation sprinkler.

[1] ASABE/ICC. 2014. Draft ASABE/ICC 802-2014 *Landscape Irrigation Sprinkler and Emitter Standard*. www.iccsafe.org/cs/standards/IS-IEDC/Pages/default.aspx.

Regarding high-efficiency nozzles, WaterSense proposed distribution uniformity (DU) as the appropriate performance measure. DU, as defined by the draft ASABE/ICC 802-2014 *Landscape Irrigation Sprinkler and Emitter Standard*,[2] is the measure of the uniformity of irrigation water applied to a defined area. DU low quarter (DU_{LQ}) is typically the DU metric used in the field (i.e., measured in a landscape) and is defined as the ratio of the average of the lowest one-fourth of measurements of irrigation water to the average of irrigation water captured by collection devices, expressed as a dimensionless number with two decimal places.[3] Because field studies were lacking, the WaterSense NOI suggested calculating theoretical savings instead of actual savings by incorporating DU into the irrigation schedule.

Regarding pressure-regulating bodies, the NOI proposed setting a performance threshold by developing an acceptable outlet pressure variance across a range of inlet pressures and using the test method for pressure regulation as outlined in the draft ASABE/ICC 802-2014 *Landscape Irrigation Sprinkler and Emitter Standard.*[4] WaterSense suggested calculating savings based on the reduction in flow when pressure regulation is in place and potentially capturing additional savings from devices that reduce flow when a nozzle is damaged or missing.

EPA listed several outstanding issues in the NOI regarding both nozzles and bodies and requested feedback during the public comment period on a variety of topics.

III. Public Comment Feedback

EPA received more than two dozen public comments on the NOI and has published a comment compilation document on the WaterSense website. In general, commenters supported moving forward with pressure-regulating bodies but expressed concern about high-efficiency nozzles and the use of DU as a performance measure. Specifically, commenters had concerns with WaterSense developing a specification for a product category based on theoretical savings. As discussed in the NOI, WaterSense identified two field studies examining high-efficiency nozzles and savings in the field. While both studies measured an increase in DU with high-efficiency nozzle retrofits, neither resulted in the expected water savings.

For example, in late 2008, the Southern Nevada Water Authority (SNWA) initiated a research study designed to evaluate the water efficiency potential of sprinklers with increased DU_{LQ}. In this study, a total of 163 systems at occupied, single-family homes had been retrofitted with multi-stream rotational spray heads and similar products from various manufacturers. By late 2009, it had been observed that DU_{LQ} improvements were statistically significant among the sites. However, when researchers conducted audits at the sites between late 2012 and spring 2013, analysis revealed no post-retrofit water savings for the study sites.

[2] *Ibid.*
[3] *Ibid.*
[4] *Ibid.*

In addition, as part of its public comment submission, San Antonio Water System (SAWS) submitted information on a program review of a multi-stream nozzle rebate program the utility conducted. The utility was interested in understanding the efficiency provided by those nozzles at residential and commercial sites. An evaluation of 12-month water consumption after the retrofits suggested that on average, the commercial sites increased their water usage. Although modest savings was observed among residential sites, the program was discontinued due to the fact that water savings were not able to offset the cost of the retrofits. The program review highlighted that the challenge of managing irrigation controller settings easily interferes with savings that might otherwise be achieved.

In the NOI, WaterSense also acknowledged a data gap between DU measured in the laboratory and DU measured in the field. While both metrics can be reliably measured, high laboratory DU does not translate to correspondingly high field DU. WaterSense identified a phased approach to try to develop this relationship. If existing data could not be collected during the NOI phase to support this relationship, WaterSense proposed a field study (see Appendix A of the NOI).

IV. A Path Forward

Based on the lack of field studies demonstrating savings and the public comments received discouraging WaterSense from basing savings on theoretical calculations based on DU, EPA has decided to put specification development for high-efficiency nozzles on hold. WaterSense continues to collect data and would be interested in collaborating with the industry on field studies or other research that would assess tangible savings, develop consensus around a new performance measure, or demonstrate DU as a viable performance measure for high-efficiency nozzles.

However, WaterSense is moving forward with specification development for pressure-regulating bodies, based on the comments received and also potential savings that can be achieved by these products. Sprinklers are usually designed to operate within a range of pressures and have an optimum pressure under which the nozzle reaches its best performance. Most sprinkler models available on the market have an operating pressure range between 15 and 75 psi, with an optimum pressure between 30 and 45 psi. In many cases, sprinklers are installed at sites where the system pressure is above its operating range, resulting in wasted water.

High operating pressure can result in inefficiencies for a variety of reasons, including excessive flow rates, misting, fogging, and uneven distribution. By regulating system inlet pressure to an optimum level, a sprinkler with pressure regulation can increase efficiency in the irrigation system. The pressure-regulating feature, usually achieved by a device built in the stem, compensates high inlet pressure and maintains the pressure at a relatively constant level. As a result, the flow through a sprinkler is also constant across a range of inlet pressures. Additionally, by maintaining the pressure within a nozzle’s operating range, the nozzle generates appropriate water droplet size and performs with high uniformity.

WaterSense is specifically focusing on the potential savings from the reduction in flow. This reduction can be calculated by determining the difference in flow rate before and after pressure regulation. (Note: The difference in flow rate is also proportional to the difference in pressure). For example, as calculated using Equations 1 and 2 below, in a system with an inlet pressure of 50 psi and sprinklers pressure regulated to 30 psi, water savings, in theory, is about 22 percent. If the inlet pressure is 70 psi, water savings would be approximately 34 percent. Therefore, irrigation systems that experience high pressures could realize significant water savings if retrofitted with pressure-regulating sprinklers.

Equation 1: Bernoulli's Equation

$$\frac{Flow}{Flow_{PR}} = \sqrt{\frac{P}{P_{PR}}}$$

Where:
$Flow$ = Flow rate without pressure regulation
$Flow_{PR}$ = Flow rate with pressure regulation
P = System pressure without pressure regulation
P_{PR} = Sprinkler operating pressure with pressure regulation

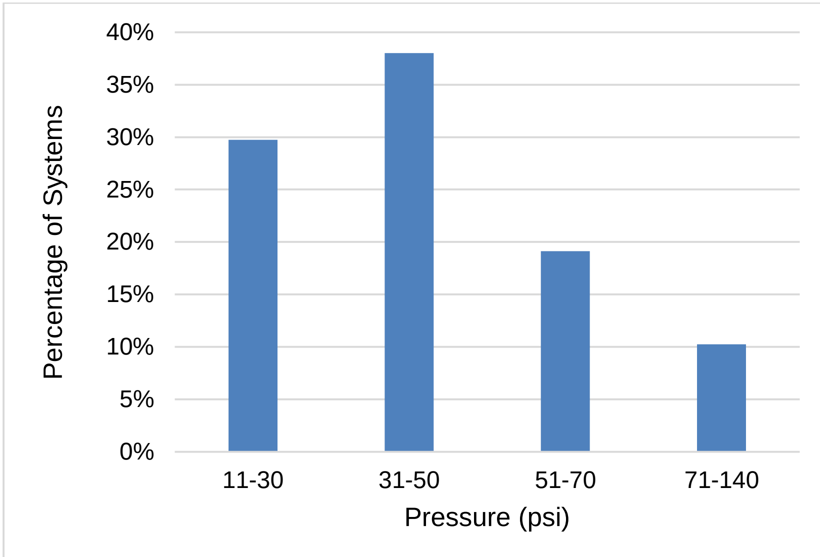
Equation 2: Solve Bernoulli's Equation for Water Savings

Water Savings = $Flow$- $Flow_{PR}$=1-($\sqrt{\frac{P_{PR}}{P}}$)

Examples:
If P=50 psi, P_{PR}=30 psi, Water Savings = 22%.
If P=70 psi, P_{PR}=30 psi, Water Savings = 34%

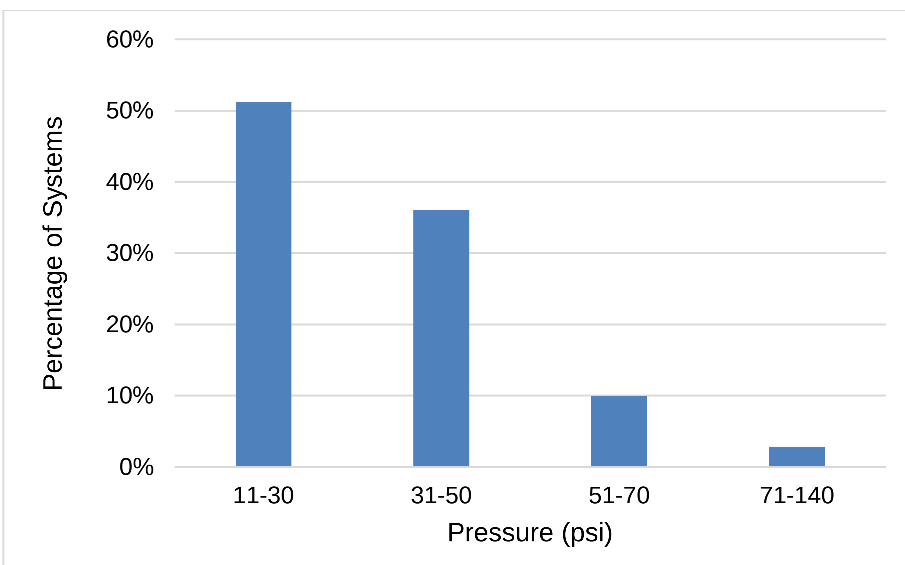
Although system pressure varies from site to site, high system pressure is not uncommon. Researchers from Utah State University have been conducting a landscape irrigation system evaluation program since 1999. In this program, researchers visit homes and commercial, industrial, and institutional sites to evaluate outdoor irrigation systems. During the visits, researchers collect system pressure at each site. The dataset currently holds 6,462 records, 29 percent of which have a pressure of higher than 50 psi, including 10 percent that have pressures above 70 psi (see Figure 1).

Figure 1. Irrigation System Pressure Data, Utah State University



Similarly, the Center for Resource Conservation in Boulder, Colorado, offers free onsite sprinkler consultations for residential properties. Trained irrigation auditors visit each property to conduct irrigation system inspections. During this process, sprinkler operating pressure is measured. According to the data gathered during these inspections (7,744 records in total), 13 percent of them have a pressure of higher than 50 psi, including 3 percent higher than 70 psi (see Figure 2).

Figure 2. Irrigation System Pressure Data, Center for Resource Conservation



Additionally, the American Water Works Association Research Foundation published a table of water pressures in distribution systems for 15 cities across the United States and Canada in its *Residential End Uses of Water Study*.[5] Pressures ranged from 20 psi to 500 psi (see Table 1).

Table 1. Water Pressure Ranges in Distribution Systems

Utility/Provider	What are the range of pressures in your water distribution system?
Boulder, Colorado	80-160 psi
Cambridge, Ontario	20-100 psi
Waterloo, Ontario (Canada)	20-100 psi
Denver, Colorado	40-110 psi
Eugene, Oregon	40-80 psi
Las Virgenes Municipal Water District (California)	30-500 psi
Lompoc, California	85-120 psi
Phoenix, Arizona	60-120 psi
Municipal Region of Waterloo (Ontario)	50-70 psi
San Diego, California	40-85 psi
Scottsdale, Arizona	40-120 psi
Seattle, Washington	40-80 psi
Tampa, Florida	20-65 psi (typical = 45 psi)
Tempe, Arizona	50-90 psi
Walnut Valley Water District (California)	40-180 psi

With the prevalence of high system pressure, as demonstrated above, WaterSense anticipates that labeling and promoting pressure-regulating sprinkler bodies can improve outdoor water efficiency in a wide range of climates.

V. Recent Developments

WaterSense has made significant progress on the research proposed in the NOI for the pressure-regulating body product category. Appendix A of the NOI described the data gaps that needed to be filled prior to draft specification development and identified two research objectives for pressure-regulating bodies.

1. Determine if the selected protocols to test pressure regulation are repeatable and reproducible, including when flow is reduced due to a damaged or missing nozzle.

[5] Mayer, Peter W. and William B. DeOreo. American Water Works Association Research Foundation. 1999. *Residential End Uses of Water*.

2. Once a protocol(s) for the above performance measures are determined to be repeatable and reproducible, determine the performance threshold that defines an effective pressure-regulating body.

Regarding the first objective, WaterSense is moving forward with adopting the test methods for pressure regulation and missing nozzles as defined in the ASABE/ICC 802 *Landscape Irrigation Sprinkler and Emitter Standard*.[6] (Note: The draft standard referenced in the NOI was finalized shortly after the NOI was released. No changes to the test methods were made.) The purpose of the pressure regulation test is to determine if a sprinkler can maintain a relatively constant flow rate and outlet pressure across a range of system inlet pressures. The step test is designed to run a sprinkler from a minimum inlet pressure and increase the inlet pressure incrementally until it reaches the sprinkler's maximum operating pressure, then decrease the inlet pressure back to the initial minimum pressure. For example, a sprinkler with pressure regulation at 30 psi and maximum operating pressure at 70 psi would undergo a pressure regulation test requiring the sprinkler to be tested under the following pressures in a continuous process: 30 psi, 35 psi, 40 psi, 45 psi, 50 psi, 60 psi, 70 psi, 60 psi, 50 psi, 45 psi, 40 psi, 35 psi, 30 psi. WaterSense is developing a separate missing nozzle test to determine if a sprinkler can maintain a relatively low flow rate when the nozzle is removed (e.g., damaged or missing in the field).

To meet the first research objective, WaterSense is currently collaborating with several manufacturers and three independent testing laboratories (i.e., International Association of Plumbing and Mechanical Officials, Texas A&M AgriLife Extension Service, and QAI Laboratories) to determine if the test methods identified in the ASABE/ICC 802 standard are repeatable and reproducible. Early in 2015, WaterSense developed a scope for performance testing that was heavily based on the ASABE/ICC 802 standard with a few modifications. First, stakeholders requested through public comment that a low and a high flow be tested. The standard only requires testing at one flow rate, so WaterSense incorporated testing at a high and low flow rate. Second, stakeholders requested that outlet flow be measured in addition to outlet pressure, so WaterSense incorporated that as well.

Two of the laboratories began testing in spring 2015. In April 2015, the laboratories conducted an initial pressure regulation test on two models randomly selected from the products supplied by various manufacturers to determine whether a standard orifice needed to be used or if another method could be used to control flow (e.g., variable arc nozzle or needle valve). Testing results determined that either method to control flow could be used and also demonstrated that a pressure regulation feature is able to reduce outlet pressure (and flow) across a range of inlet pressures.

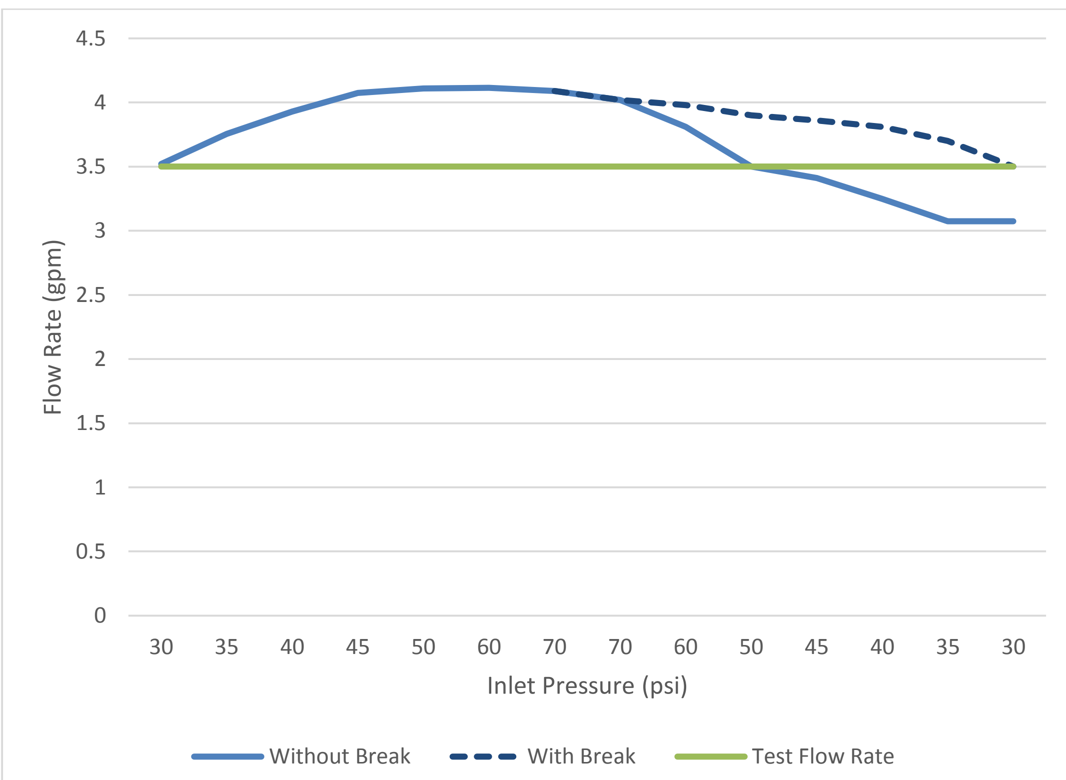
While the water-saving potential of pressure-regulating bodies is promising, the laboratories observed hysteresis (i.e., the influence of the previous history or treatment of a body on its subsequent response to a given force or changed condition) between inlet and outlet pressure as the inlet pressure was reduced from the highest pressure to

[6] ASABE/ICC. 2014. ASABE/ICC 802 *Landscape Irrigation Sprinkler and Emitter Standard*. www.iccsafe.org/cs/standards/IS-IEDC/Pages/default.aspx.

the minimum pressure. For example, at the beginning of the test, when inlet pressure was 35 psi, the outlet pressure measured at about 30 psi. When inlet pressure climbed to 50 psi, the outlet pressure measured at about 33 psi. However, when inlet pressure decreased down to 50 psi after reaching its maximum at 70 psi, the outlet pressure measured at approximately 28 psi. When the inlet pressure finally returned to 30 psi, the corresponding outlet pressure measured at nearly 20 psi, which was below the pressure regulation level 30 psi.

To resolve the hysteresis problem, the method was redesigned to introduce a reduction to 0 psi between each pressure level. In theory, if the sprinkler is allowed to return to the state without pressure, any temporary physical change may disappear. A trial test demonstrated that hysteresis can be significantly reduced by introducing short-duration breaks in pressure as the testing sequence moves from high pressure to low pressure (see Figure 3). These reductions in pressure were also introduced to more closely simulate conditions in the field. Most sprinklers operate a few times a week. When a sprinkler is operating, the system inlet pressure is relatively constant. It is rare to see a system with variances in pressure as much as 40 psi in one cycle, which was the case in the original test. It is more common for a sprinkler to operate under a constant pressure and stop, which is essentially a long reduction in pressure. Therefore, WaterSense believes it is reasonable to adjust the pressure regulation test procedure according to these test results.

Figure 3. Flow Rate With and Without Pressure Breaks between Pressure Levels



WaterSense has made one additional change to the methodology in the scope since testing began. The original test in the ASABE/ICC 802 standard required testing at the minimum operation pressure, then in increments of five, then 10 psi up to the maximum operating pressure and back down. This process could result in testing 12 or more pressure levels, creating a labor-intensive and long test period. To reduce the workload on the laboratories and bring down the testing cost, WaterSense is proposing to reduce the required pressure levels down to three, resulting in conducting the test for five pressures instead of 12. For example, a sprinkler with pressure regulation at 30 psi and maximum operation pressure at 70 psi would undergo a test with the following inlet pressures: 40 psi, rest, 60 psi, rest, 70 psi, rest, 60 psi, rest, 40 psi, where the rest period is 1 minute or more of zero pressure.

VI. Moving Forward

In the coming months, WaterSense will continue analyzing initial test results for pressure-regulating bodies, modify the testing scope as needed, test additional models, and evaluate product performance under a missing nozzle test. The completed performance testing will provide WaterSense with a dataset that can be used to meet the second objective discussed above, determining the performance threshold that defines an effective pressure-regulating body, a key aspect of specification development. Once the test method is solidified and a draft threshold set, WaterSense will release a draft specification for this product category, likely in mid-2016, to all interested parties. A public comment period and public meeting will follow.

While WaterSense has placed any plans for a high-efficiency nozzle specification on hold, the program will continue to consider how to define performance for the product. If stakeholders can provide additional data (e.g., field studies) and/or an alternative performance measure to DU, please submit that information to WaterSense at watersense@epa.gov.

EPA appreciates the continued interest in a WaterSense specification for pressure-regulating sprinkler bodies and will keep the public and stakeholders informed of its progress throughout the specification development process.