Pressure Regulating Spray Sprinkler Body Final Test Report

Submitted to:

EPA WaterSense Program

By:

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Introduction

The EPA WaterSense program engaged Dr. Michael Dukes of the University of Florida, Agricultural and Biological Engineering Department to perform validation testing for Spray Sprinkler Bodies (SSBs). Testing of the SSBs focused on their pressure regulation characteristics. Testing occurred October 2016.

The purpose of the testing was as follows:

1. Validate the repeatability and consistency of the draft test procedure.
2. Determine performance of pressure regulating (PR) SSBs compared to non-PR SSBs.

Models Tested

A total of 11 different SSB models were tested (arbitrarily labeled brands A-H). Each model had three replicate samples tested. The testing included three brands (A-C) with both pressure regulating and non-pressure regulating bodies to determine water savings potential. Other bodies tested had a range of features including one brand with a check valve and two with flow reduction capability. Regulation pressure ranged from 30 psi to 45 psi depending on brand and model tested. Maximum operating pressure ranged from 70 psi to 100 psi. The SSBs tested were obtained from commercial irrigation equipment distributors.

Procedure

The test procedure was performed based on a modified version of the ASABE/ICC 802-201 Landscape Irrigation Sprinkler and Emitter Standard as follows:

1. Test conditions
   - (a) All tests shall be conducted at an ambient air temperature between 40 and 120°F (3 and 49°C) and the water supply temperature shall not exceed 78°F (25.5 °C). The water supplies shall be filtered in accordance with the specifications of the manufacturer.
   - (b) Test samples shall be stored at ambient laboratory conditions for a minimum of 12 hours prior to testing. Test samples shall be flushed prior to testing.
2. Pressure regulation test
   - (a) Testing of spray devices with integral pressure regulators shall be conducted so that the flow is 1.5 +/- 0.1 gpm (5.7 +/- 0.4 lpm) for the low flow rate test and 3.5 gpm +/- 0.1 gpm (13.2 lpm +/- 0.4 lpm) for the high flow rate test at the manufacturer's stated regulation pressure. The flow rate shall be controlled by a needle valve. Both low and high flow rate tests will be performed on each test specimen. The test specimen shall be tested at six inlet pressures: manufacturer's stated regulation pressure, 10 psi above the regulated pressure, 60 psi, 70 psi (or the maximum operating pressure, whichever is greatest), 60 psi, and 10 psi above the regulation pressure.
   - (b) For all pressure test points, the pressure shall be adjusted to within 1.0 psig (6.9 kPa) of the specified test point (e.g., 40 psi, 60 psi, etc.) and stabilized. Stabilization is considered achieved when 3 consecutive pressure readings are within +/- 1 psi (+/- 6.9 kPa) of the specified test point.

(c) Testing shall be conducted beginning with the lowest test point, and increased incrementally to the highest test point. Upon reaching the highest test point, the inlet pressure shall then be reduced incrementally to the lowest test point. After testing a sprinkler under one pressure, the inlet pressure shall be reduced to 0 psi prior to starting the next test. At each test point, the pressure at the inlet and outlet of the test specimen shall be measured and recorded. Inlet and outlet pressures shall be logged at no greater than 30 second intervals and the data collection duration at each test pressure shall be a minimum of 3 minutes, not to exceed 5 minutes. Inlet pressure shall be measured at the inlet to the sprinkler body. Outlet pressures shall be measured downstream of the pressure regulation device as close as practical to the orifice.

(d) Test specimens shall be supplied by straight, smooth piping that is free of fittings, except compliant pressure taps, for a minimum length of 20 times the inlet diameter of the nozzle test specimen. Supply piping shall be ¾" nominal diameter SCH 40 PVC. All pressure taps shall comply with ASME PTC 19.2. The average of the readings, minimum, maximum values and standard deviation shall be recorded.

(e) Where flow metering devices are utilized, the flow shall be conditioned in accordance with manufacturer instructions and shall be installed in accordance with ASME PTC 19.5. Flowrate shall be measured at no more than 30 second intervals and the test duration shall be a minimum of 3 minutes, not to exceed 5 minutes.

Test Equipment and Setup

1. Equipment
    a. Two pressure transducers capable of measuring pressure from 0 to at least 150 psi with at least 0.1 psi resolution. Accuracy (including linearity and hysteresis and repeatability) shall be within 0.50 psig (3.4 kPa) in the range of inlet pressures tested.
    b. Data logger capable of measuring the pressure transducer and flowmeter inputs.
    c. Flow meter capable of resolving at least 0.05 gpm (0.189 lpm) within a range of at least 1.5 to 15 gpm and accuracy of 100% +/- 1.5% for the range of flow measured.
    d. Piping to allow necessary straight pipe runs for the flow measurement and necessary pressure taps as described previously.

The test apparatus (Figure 1) was constructed as described in the ASABE/ICC 802-210 standard with a few modifications. The original specification called for ¾" SCH40 PVC piping; however, ½" SCH40 PVC was used. In addition, the test procedure was silent on the connection of a needle valve (1.5 gpm test, Parker MV400s, Cleveland, OH; 3.5 gpm test, Hayward NVA 1050T, Clemmons, NC) to the sprinkler stem. An adapter was fashioned consisting of a female threaded sprinkler stem that was bonded to a PVC union fitting. Sprinklers were tested with no filters except where necessary for features such as flow reduction to function. Potable water was used as the water source. Since the supply pressure was not adequate to meet the maximum test pressures, a high pressure, low volume centrifugal pump was used to achieve adequate maximum test pressure. In addition, the pressure transducers used had a full scale measurement range of 0 to 145 psi which was deemed adequate for the test.

A Campbell Scientific (Logan, UT) CR1000 datalogger was used to record measurements from the flowmeter and the pressure transducers. The flowmeter was a Seametrics (Kent, WA) PE202-075 low flow magmeter (Figure 2) with resolution of at least 0.01 gpm and accuracy of +/- 1% plus 0.005 gpm of reading across rated range. The pressure transducers were Campbell Scientific model CS451 (Figure 3) with a resolution of 0.0035% full scale and accuracy of +/- 0.1% full scale range. An adjustable pressure regulator (Watts LF26A, North Andover, MA, Figure 4) was used to set the various pressure test levels. The two manual pressure gauges were used only to assist the getting near the proper test pressure but all final test conditions were determined with the pressure transducers.

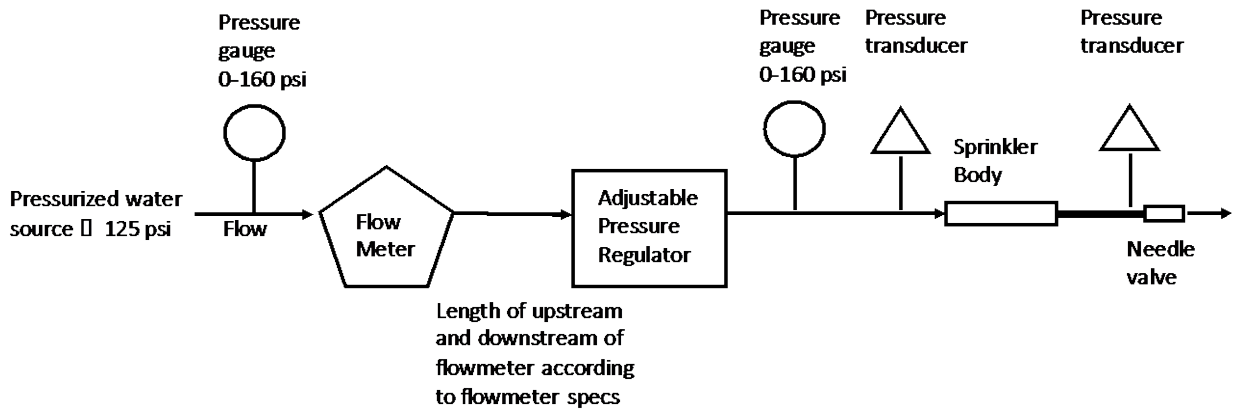


Figure 1. Test equipment schematic

Figure 2. Test apparatus showing flowmeter (credit Michael Gutierrez UF/IFAS)

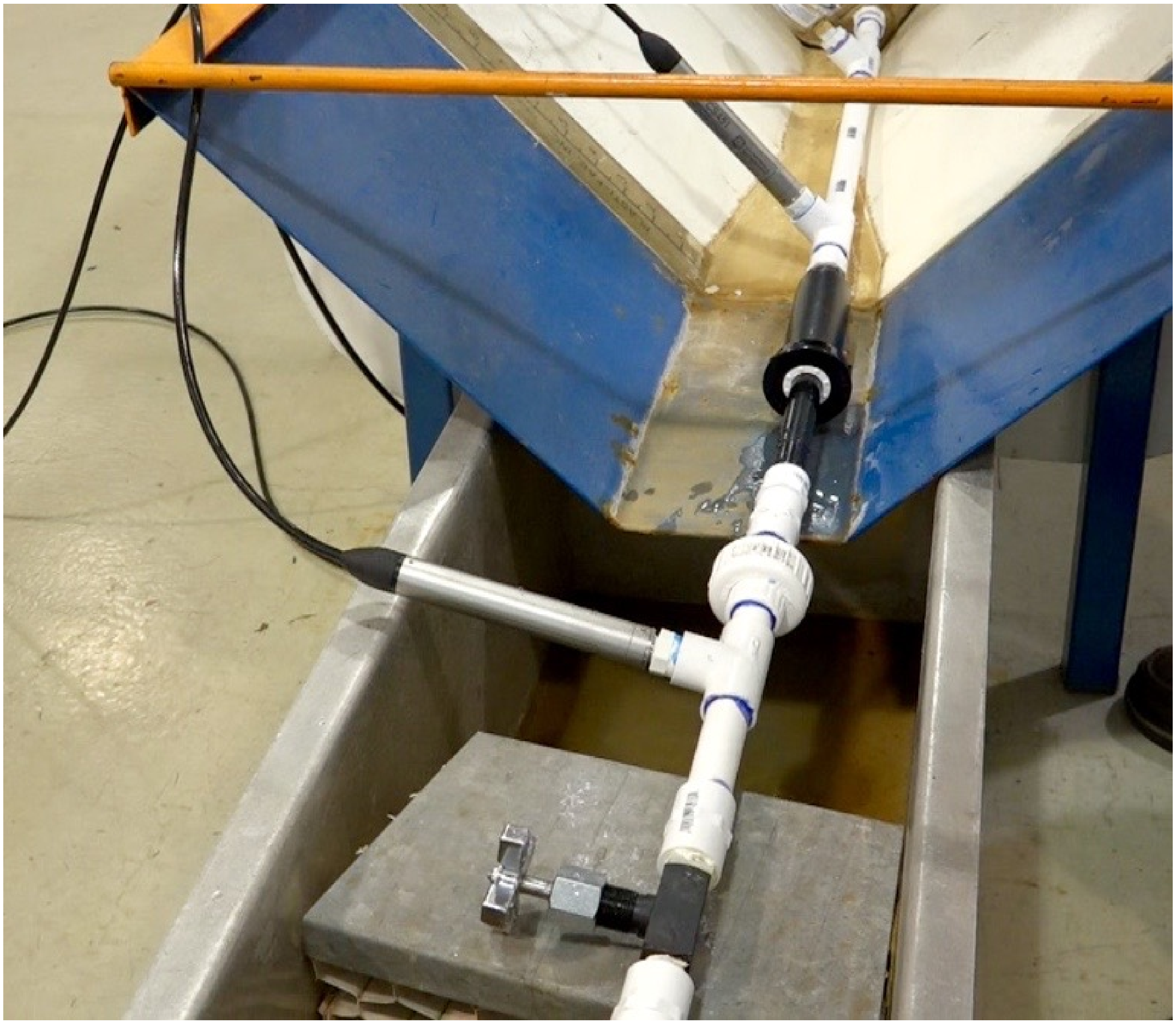


Figure 3. Testing of a sprinkler body with inlet and outlet pressure transducers, needle valve and associated fittings (credit Michael Gutierrez UF/IFAS)

Figure 4. Adjustable pressure regulator and pressure gauges (credit Michael Gutierrez UF/IFAS)

Results and Discussion

Test Consistency

The outlet flowrate and pressure response for models A through C with both non-PR and PR SSBs is shown in Figures 5 through 10. Each figure shows the outlet flowrate and outlet pressure response as a function of the test inlet pressure for the three samples tested on each brand. Inlet pressures are an average of eight pressure readings taken every 30 seconds over four minutes. Across most brands outlet pressure was very consistent comparing replicate samples across the test points. The exception is brand B which had some variation in pressure across samples at the 3.5 gpm flowrate (Figure 8). In contrast, all brands had at least small to moderate variability in outlet flowrate with some such as brand B varying as much as 0.5 gpm in the 1.5 gpm test (Figure 7). Figures 11 and 12 show model D which has the same 30 psi regulation pressure as models A through C; however only the pressure regulating SSB was tested for this brand. In general, results were consistent among replicate bodies with some inconsistency in flowrate as seen previously. Thus, measurement of outlet pressure or flowrate is necessary to determine sprinkler performance. Flowrate provides the most direct measurement of performance and incorporates effects due to manufacturing variation.

Although initially the main interest was testing replicate products within a brand, it was decided to test one sample SSB two additional times to verify the consistency of the test outcomes. Sample #1 model A with pressure regulation was tested in this manner (Figures 13 and 14).

Though not shown, the model with a check valve had results consistent with other test results where individual sprinklers had consistent flowrate and outlet pressure when compared to one another and across the input pressure range. This test verified that the test procedure could produce consistent results with additional features such as a check valve. Additionally, two models with flow reduction features in addition to pressure regulation were tested in the pressure regulation test. We were unable to successfully test one of these models due to the construction of these SSBs with a stem connected to the nozzle and filter. The custom adaption of the needle valve in future testing of these devices will need to account for the particular way these devices provide flow reduction in the event of a missing nozzle or broken stem. The other model with flow reduction was tested successfully and had outlet pressure and flowrate responses similar to brands A-D shown previously.

Note that in the flowrate and pressure response graphs there appears to be much greater variability in flowrate compared to outlet pressure due to the difference in y-axis scales with more than five times the range on the pressure figures (e.g. 30-70 psi) compared to flowrate (e.g. 1.5-2.2 gpm) for the 1.5 gpm test for example.

In summary, the testing across sample replicates and reproducibility across the same replicate in multiple tests was remarkably consistent. This outcome ensures repeatability when the test is implemented among different test labs. The exception to this result is one product with the flow reduction feature. Future tests of this product and others with similar construction will need to use a modified needle valve attachment adapted to this type of flow reduction feature.

Flowrate Reduction

Flowrate was reduced at each pressure test level across all three brands and at both test flowrates and as expected the amount of reduction increasing with increasing test pressure (Figure 15). Though there was some variation among the three brands, for example with Brand C having the highest flowrate reduction at the 60-70 psi test points at 1.5 gpm, no clear trends emerged across brands. In addition, the response of these SSBs on the rising and falling limbs of the pressure test points was reasonably consistent. When flowrate reduction is averaged across the rising and falling test points, the 1.5 gpm and 3.5 gpm test flowrates produce similar results (Figure 16).

Outlet Pressure Variation

Brands A through D had regulated outlet pressure of 30 psi as declared by the manufacturers. However, measured outlet pressure across the brands varied from 22 to 34 psi at the 1.5 gpm test flowrate and 20 to 33 psi at the 3.5 gpm flowrate. Most of the variation was due to brand rather than test pressure as seen in Figure 17. During initial testing of the pressure regulating SSB's, WaterSense determined that there was hysteresis in the test with the rising test limb not matching the falling limb and the falling limb having unrealistic results. In response, it was decided that the test would be brought to zero pressure in between each test point. This modification seems to have alleviated most of the hysteresis issue; however, there may still be some effect as seen in brand B at both test flowrates.

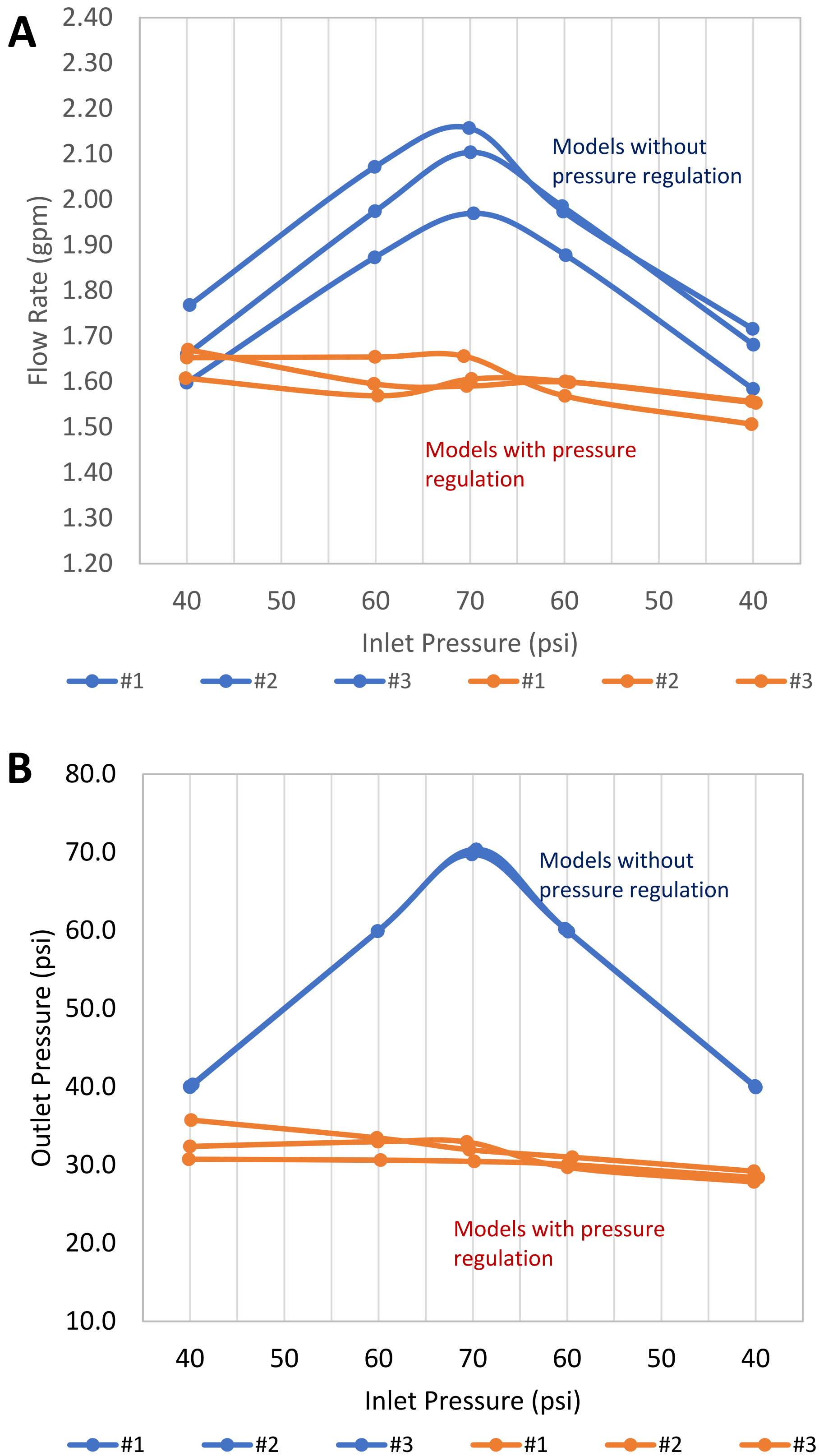


Figure 5. Brand A outlet flowrate (A) and outlet pressure (B) at nominal flowrate of 1.5 gpm

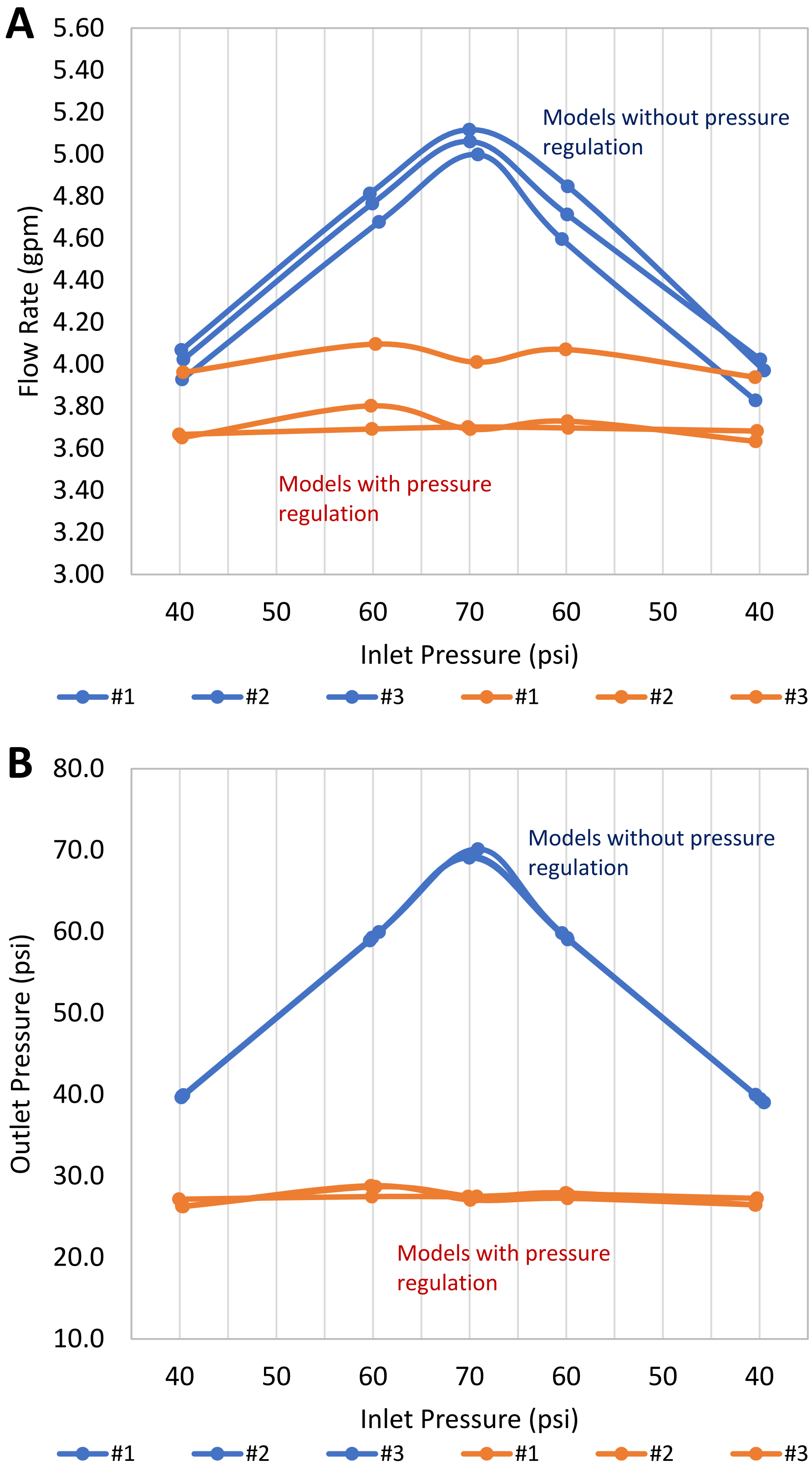


Figure 6. Brand A outlet flowrate (A) and outlet pressure (B) at nominal flowrate of 3.5 gpm

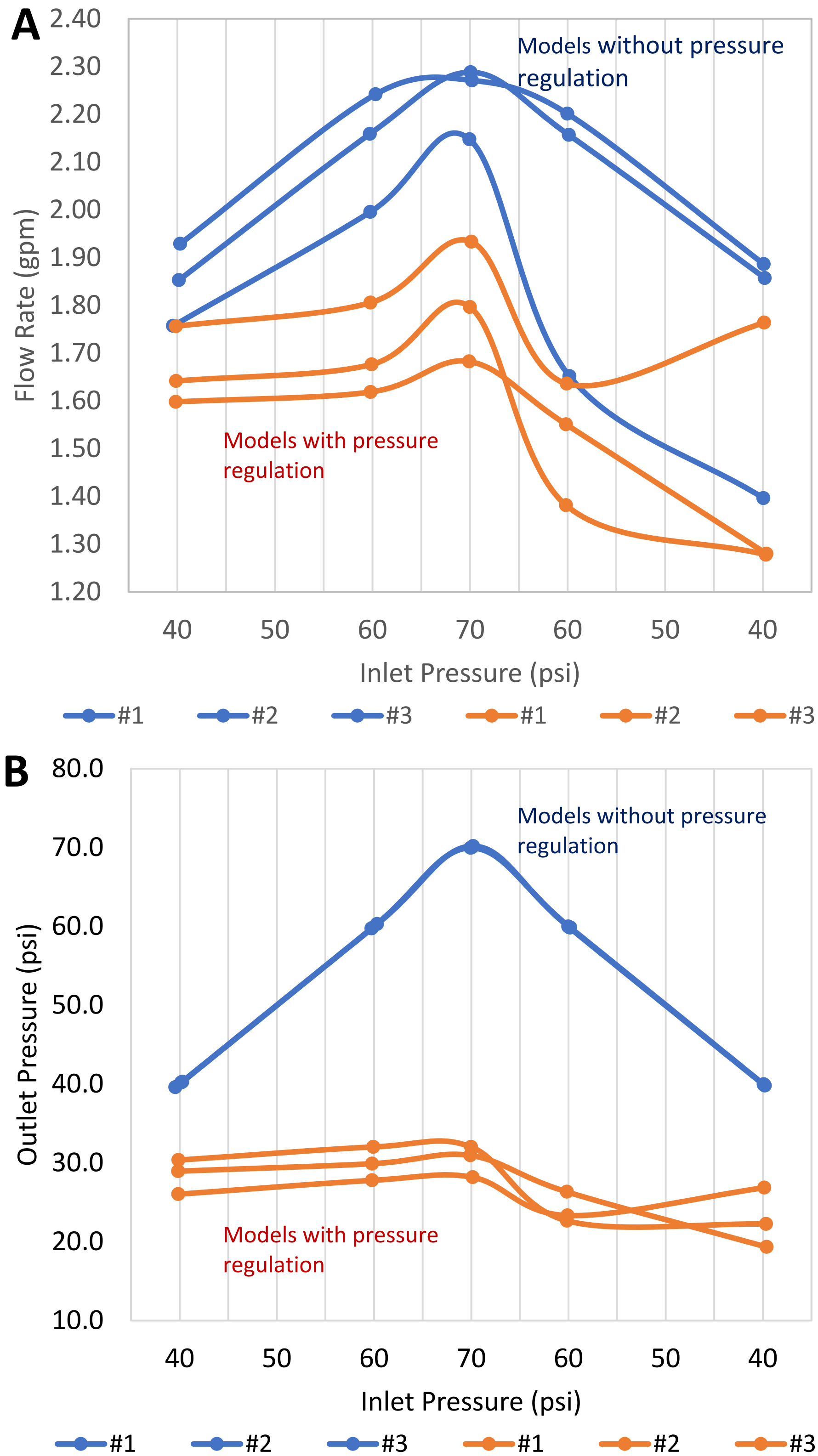


Figure 7. Brand B outlet flowrate (A) and outlet pressure (B) at nominal flowrate of 1.5 gpm

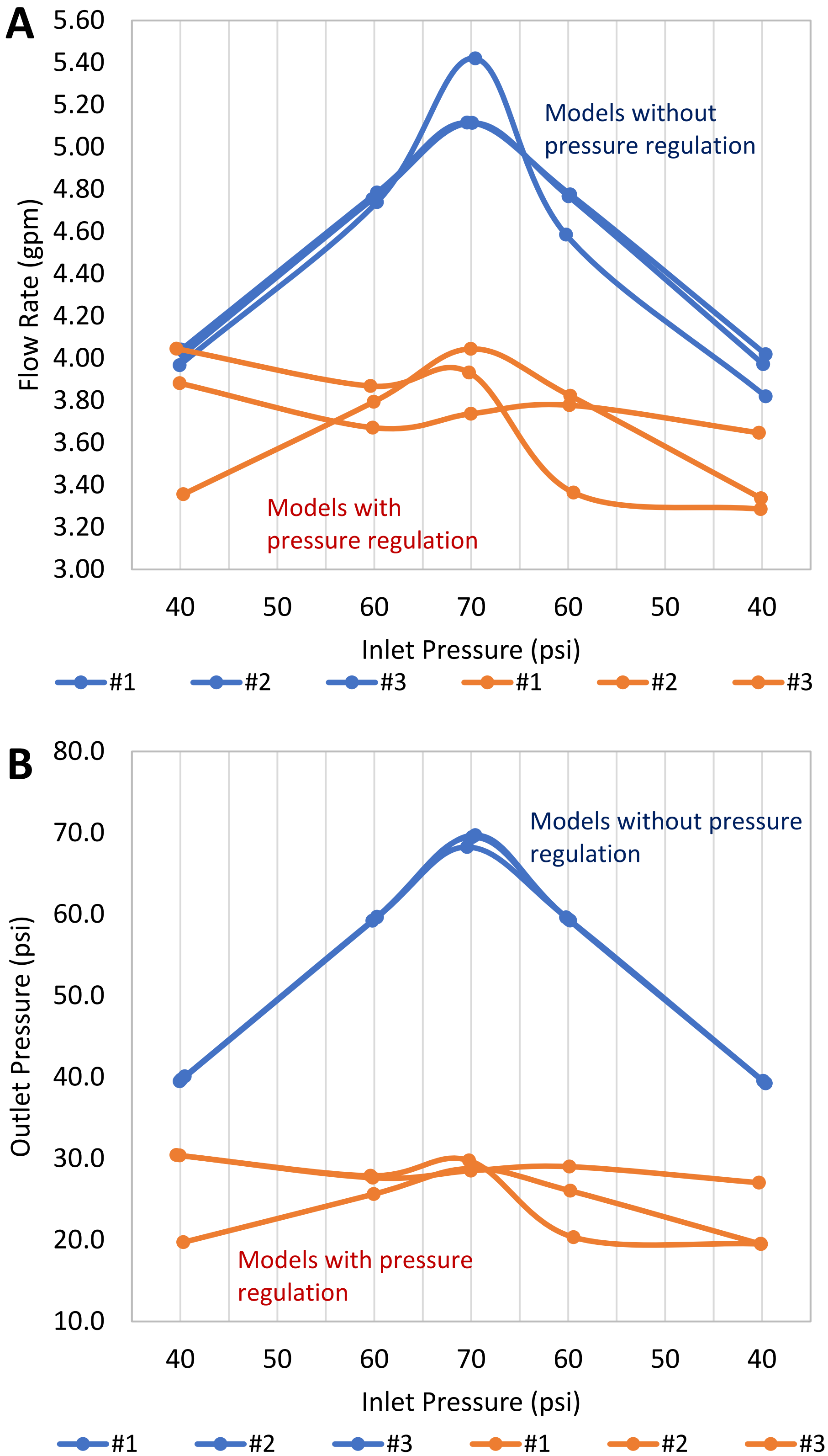


Figure 8.Brand B outlet flowrate (A) and outlet pressure (B) at nominal flowrate of 3.5 gpm

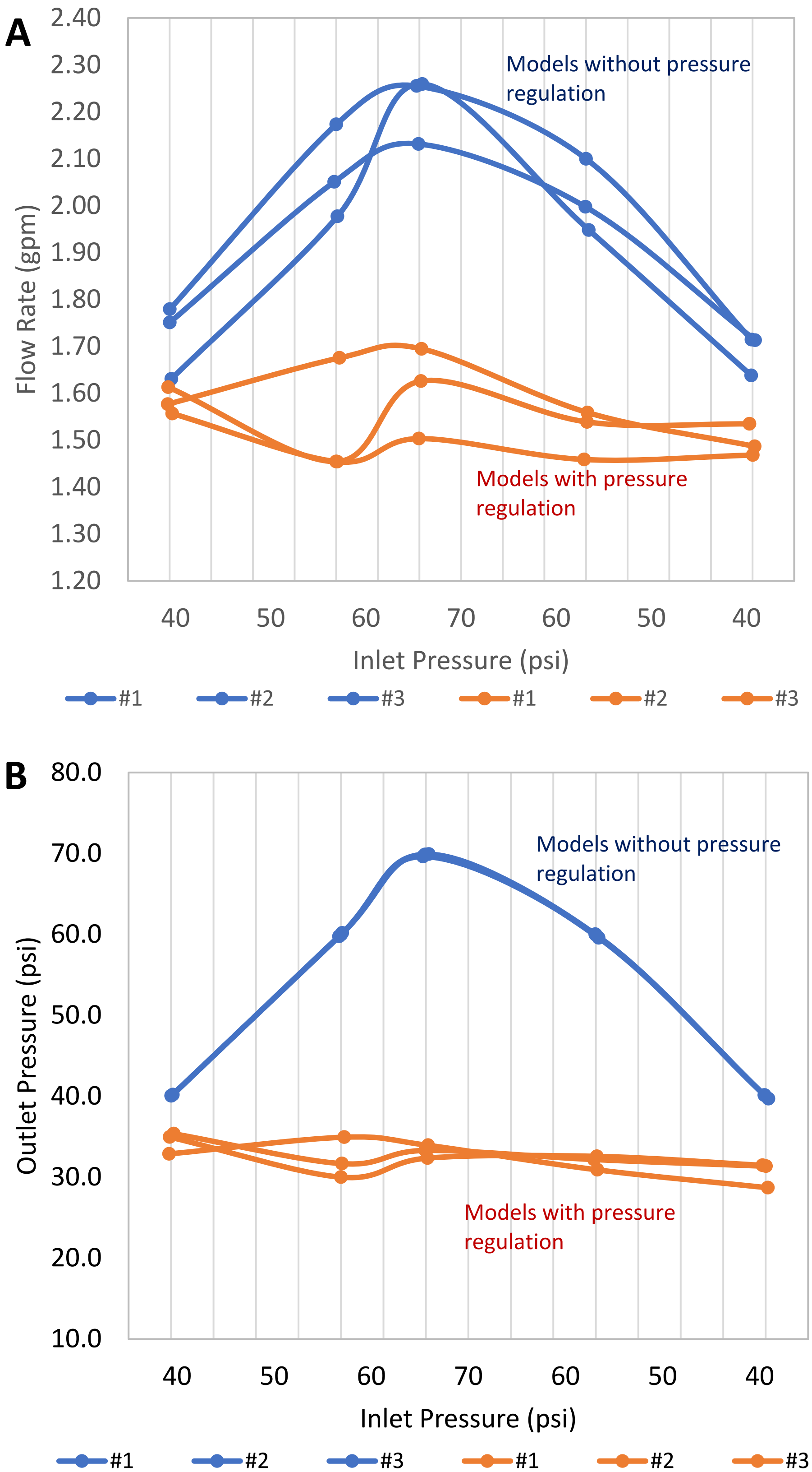


Figure 9. Brand C outlet flowrate (A) and outlet pressure (B) at nominal flowrate of 1.5 gpm

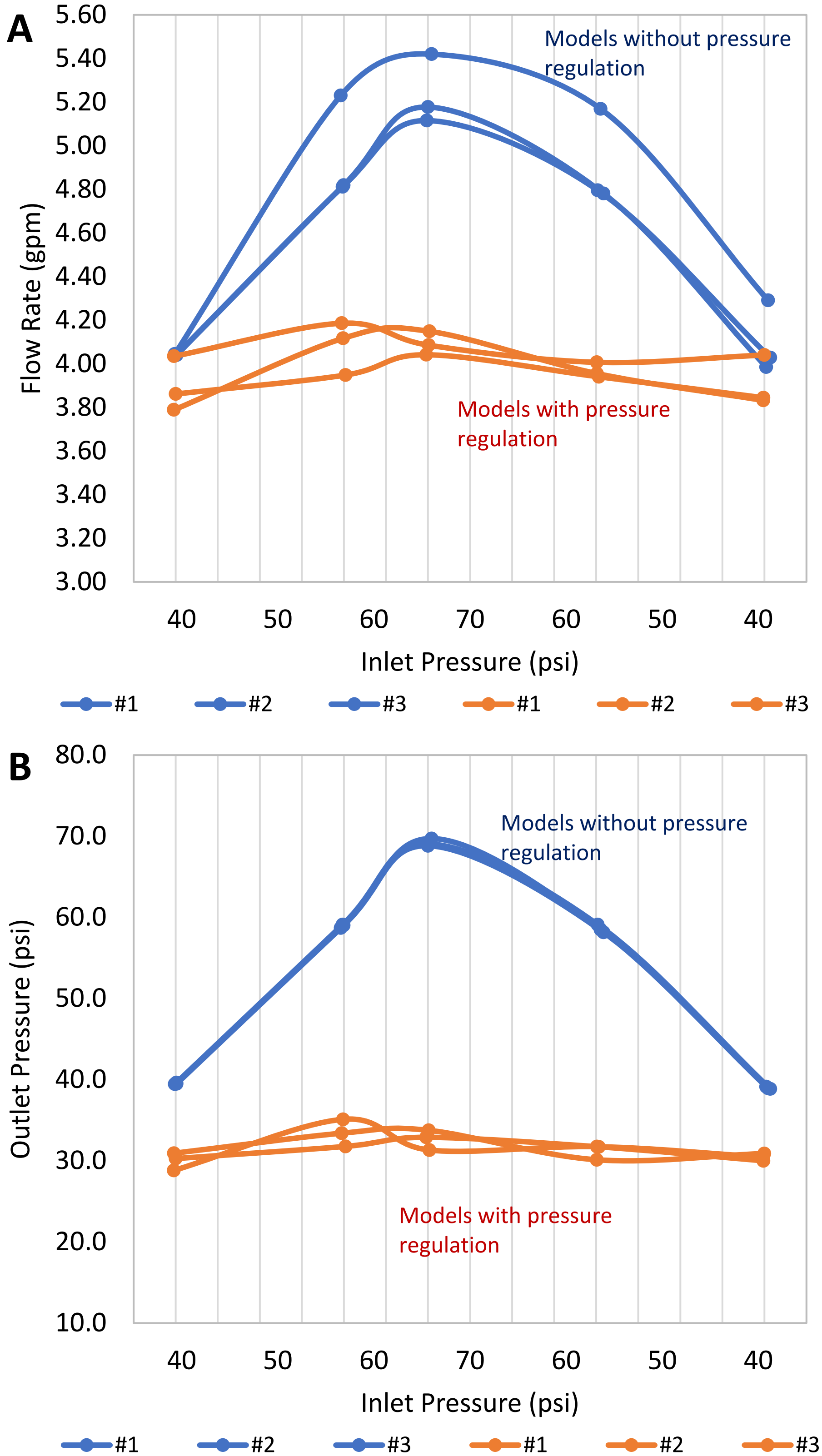


Figure 10. Brand C outlet flowrate (A) and outlet pressure (B) at nominal flowrate of 3.5 gpm

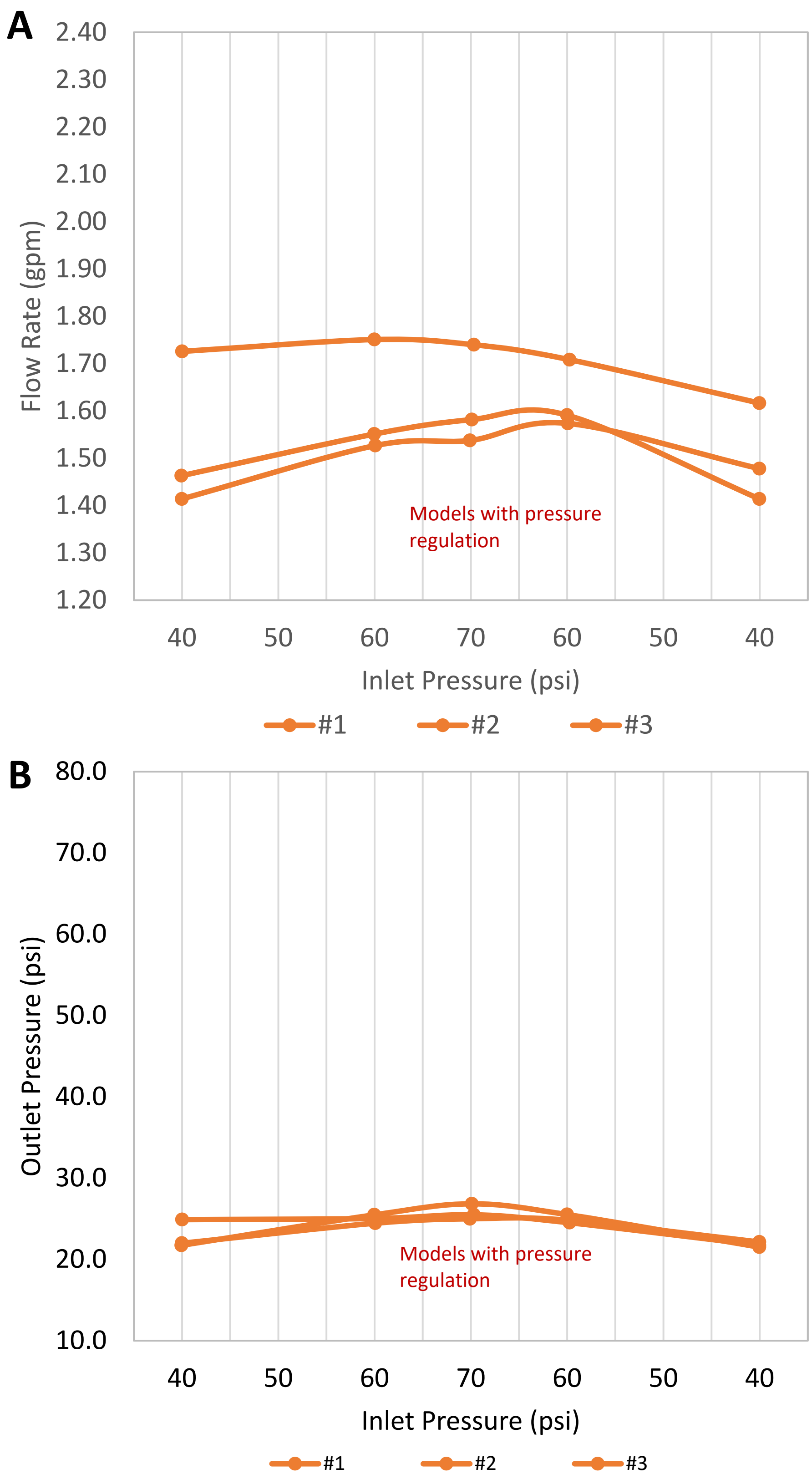


Figure 11. Brand D outlet flowrate (A) and outlet pressure (B) at nominal flowrate of 1.5 gpm

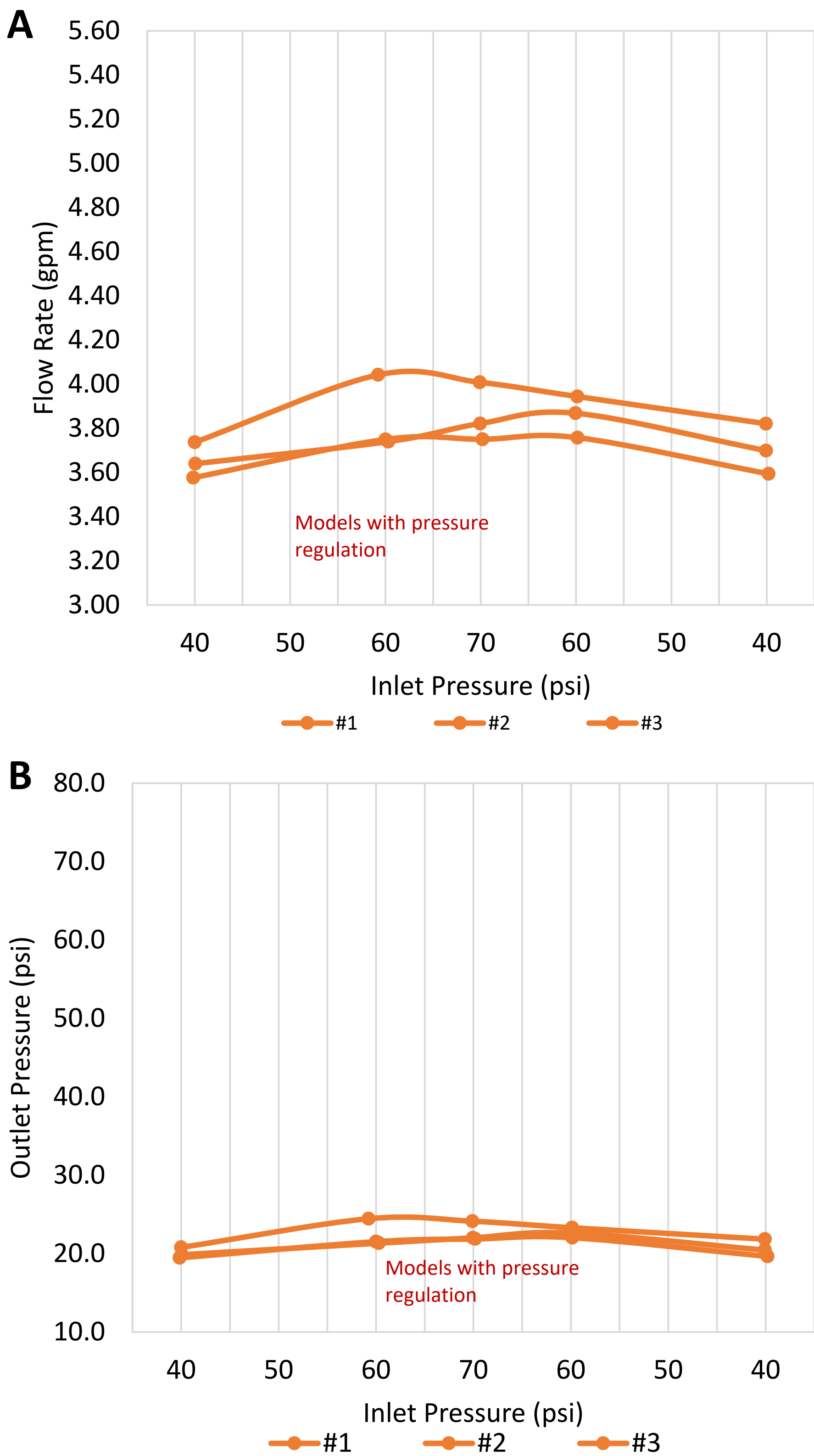


Figure 12. Brand D outlet flowrate (A) and outlet pressure (B) at nominal flowrate of 3.5 gpm

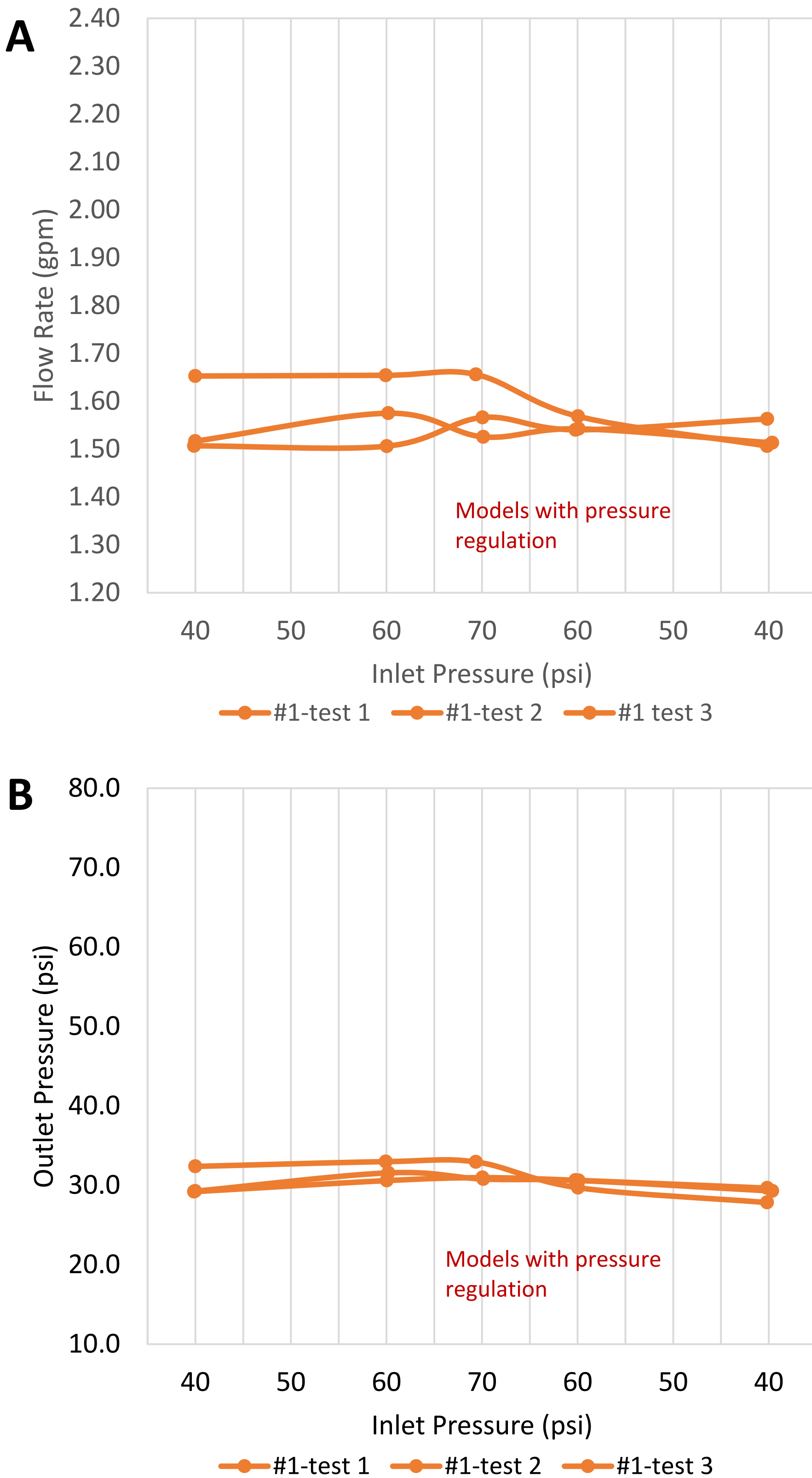


Figure 13. Brand A sample #1 outlet flowrate (A) and outlet pressure (B) at nominal inlet flowrate of 1.5 gpm

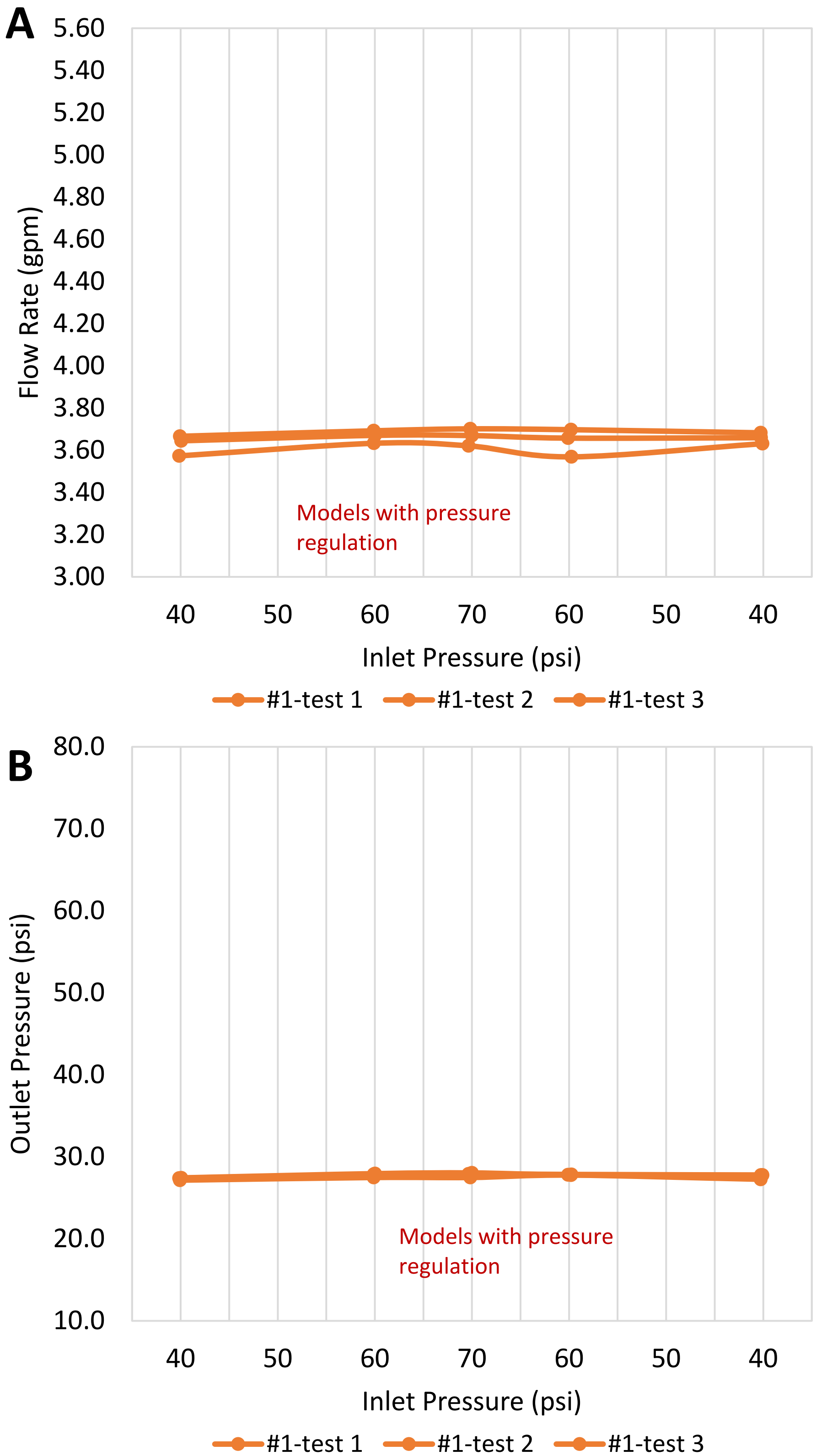


Figure 14. Brand A sample #1 outlet flowrate (A) and outlet pressure (B) at nominal inlet flowrate of 3.5 gpm

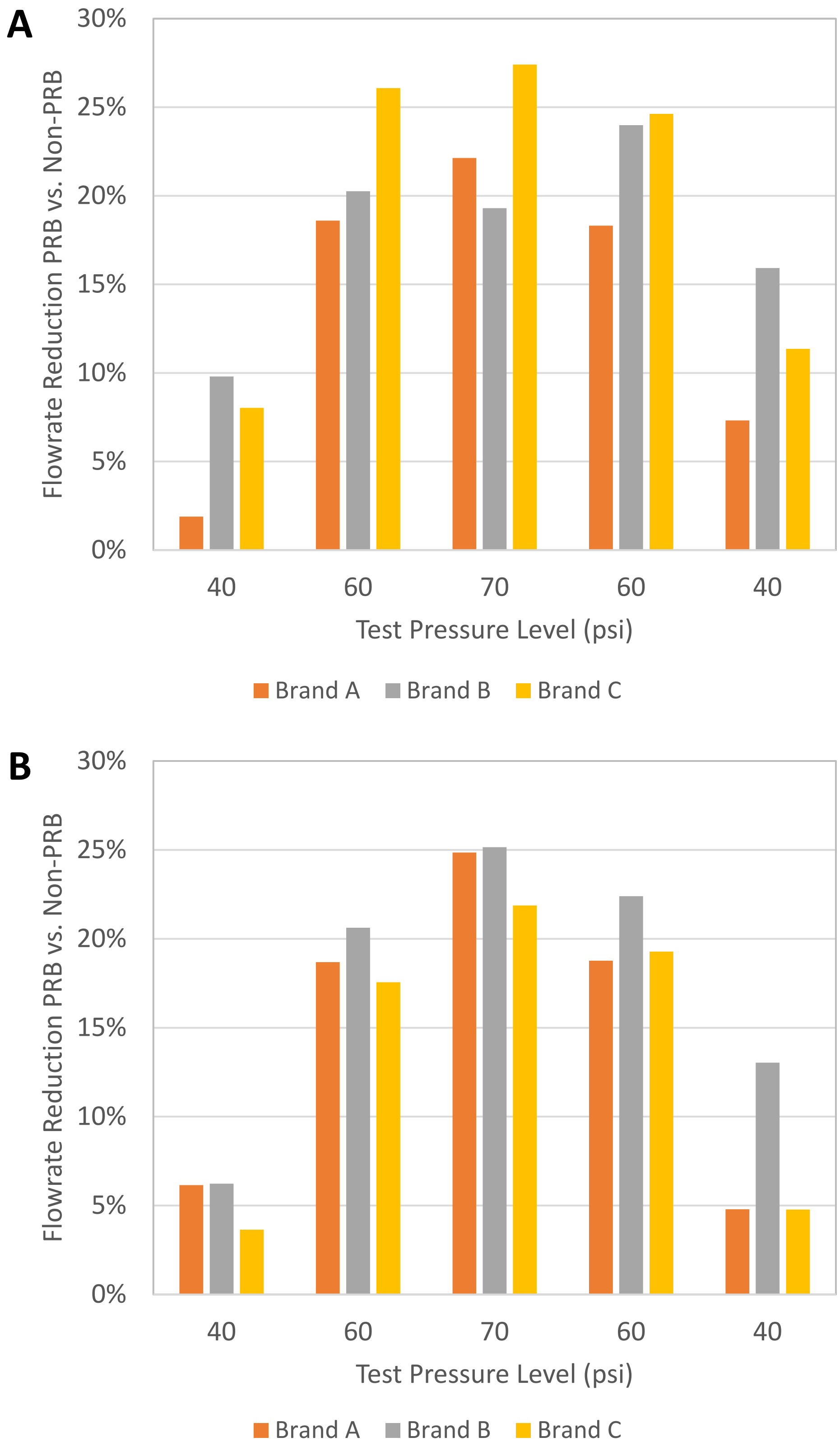


Figure 15. Flowrate reduction of pressure regulating SSBs compared to non-pressure regulating at 1.5 gpm (A) and 3.5 gpm (B) nominal flowrate

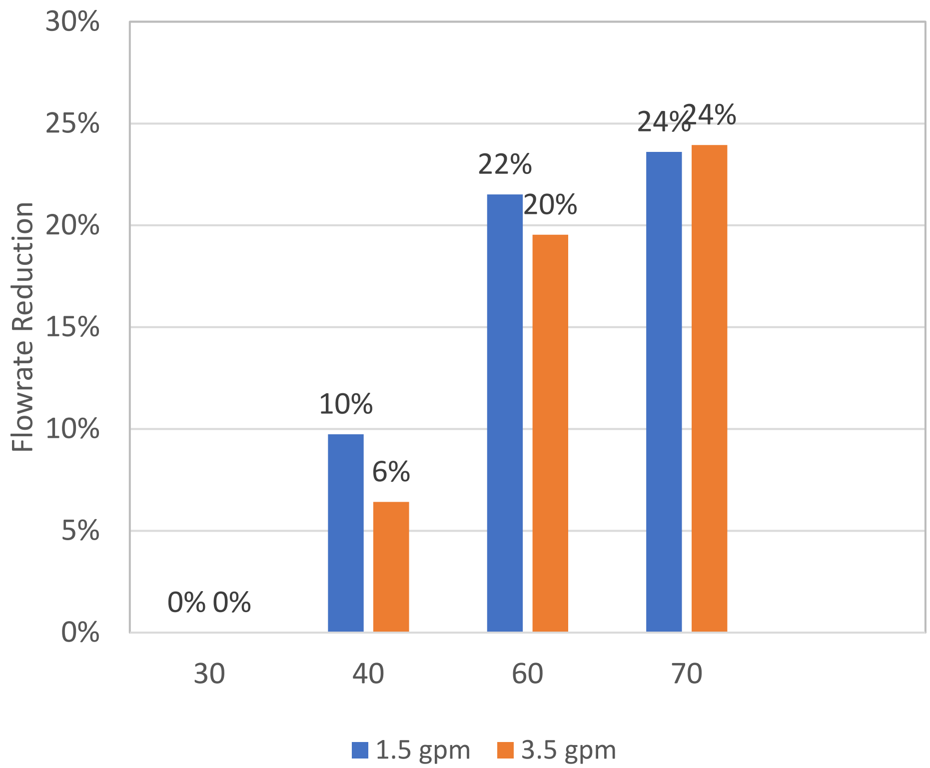


Figure 16. Average flowrate reduction of pressure regulating SSBs compared to non-pressure regulating (models A through C)

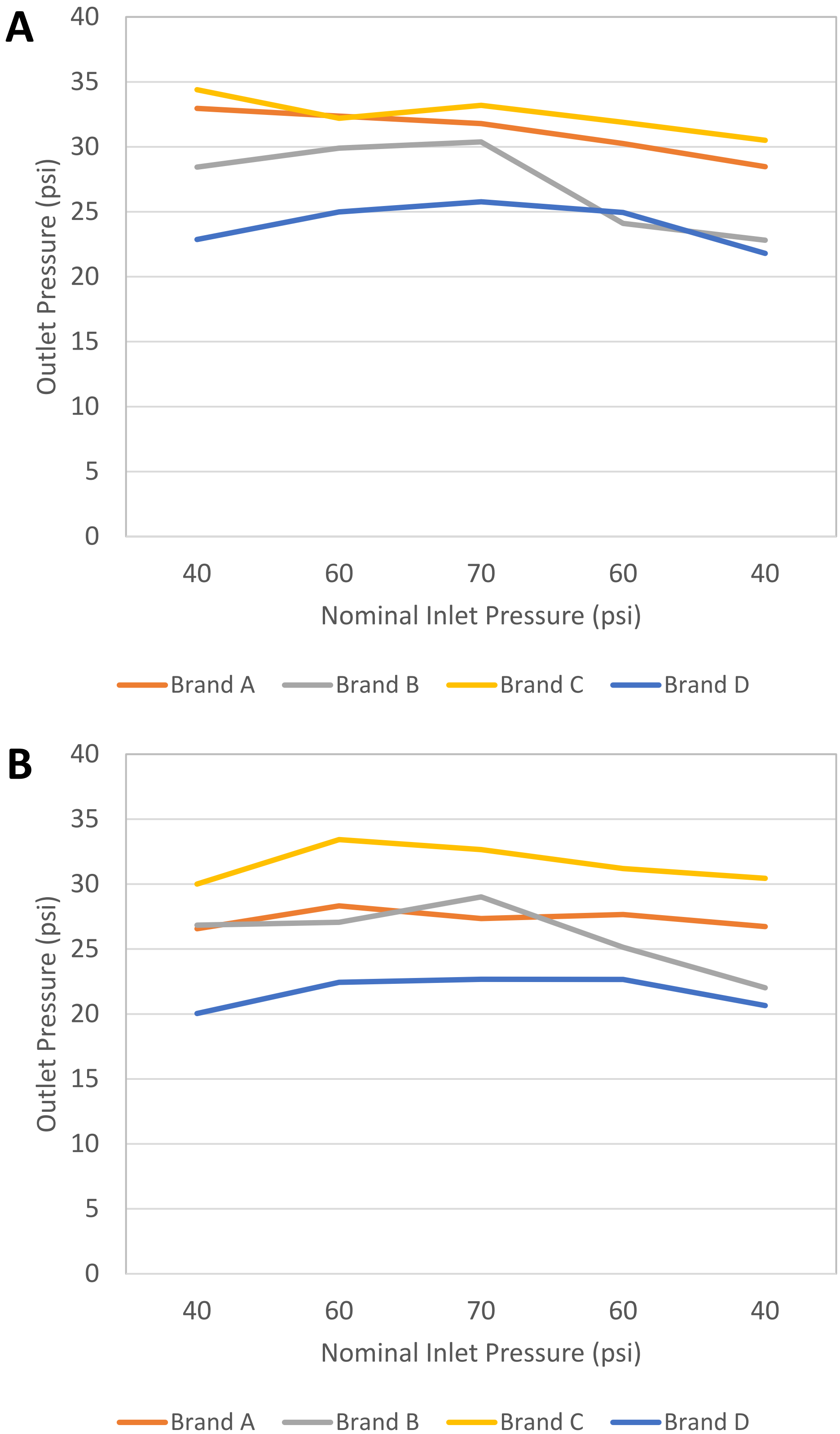
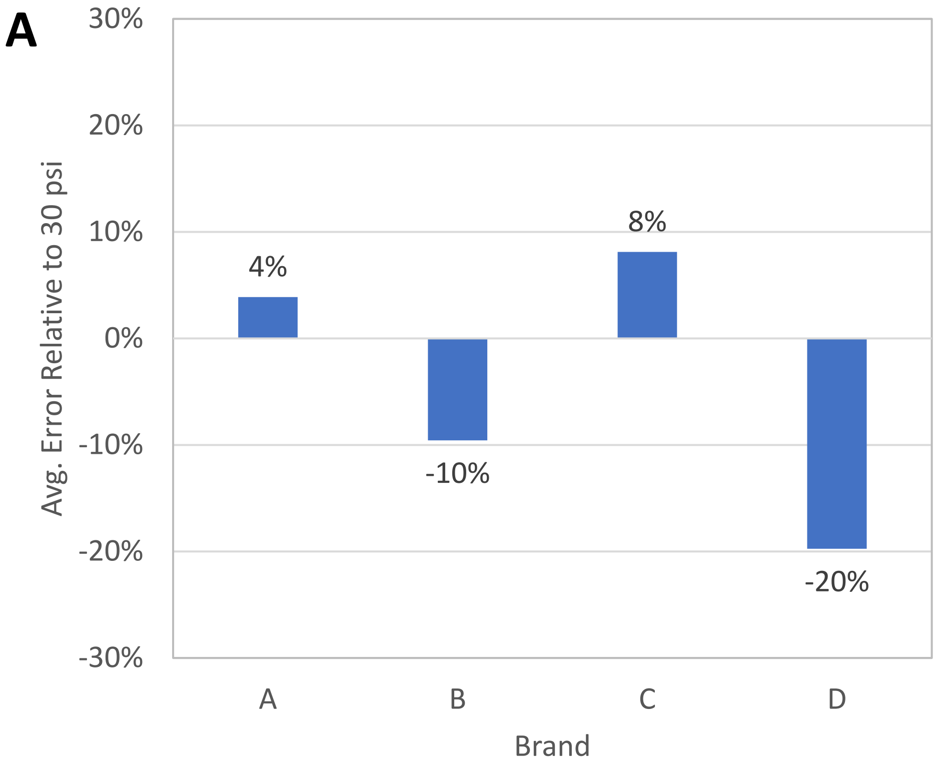


Figure 17. Outlet pressure across test range at 1.5 gpm (A) and 3.5 gpm (B) nominal flowrate

Pressure and Flowrate Deviation

Deviation from test flowrate and regulated pressure was examined to help determine potential criteria for a WaterSense specification. Figure 19 shows average deviation across all test pressures in measured outlet pressure relative to the manufacturer declared 30 psi regulation pressure and deviation relative to initial calibrated test flowrate for brands A through D. Figure 19 shows the same deviation for only the rising limb test pressures (i.e. 40, 60, and 70 psi). Deviation in pressure was highest in brand D with -18% to -20% deviation in outlet pressure relative to 30 psi. The other three brands had deviation ranging from -10% to 11% depending on brand and averaged across all or just rising pressure test limb. Though results vary numerically somewhat, trends are similar for all test pressures and rising limb test pressures. Similarly, Figures 20 and 21 show deviation results for the 3.5 gpm test flowrate. Again, trends are similar as was seen at the 1.5 gpm test flowrate. Flowrate deviation compared to actual measured initial test flowrate (e.g. 1.5 +/- 0.1 gpm) was compared for the rising limb of test pressures and the maximum test pressure for all SSBs (Figure 22). All but two brands had flowrate error less than 10% compared to the average of the rising limb and all but one compared to the maximum test pressure point.



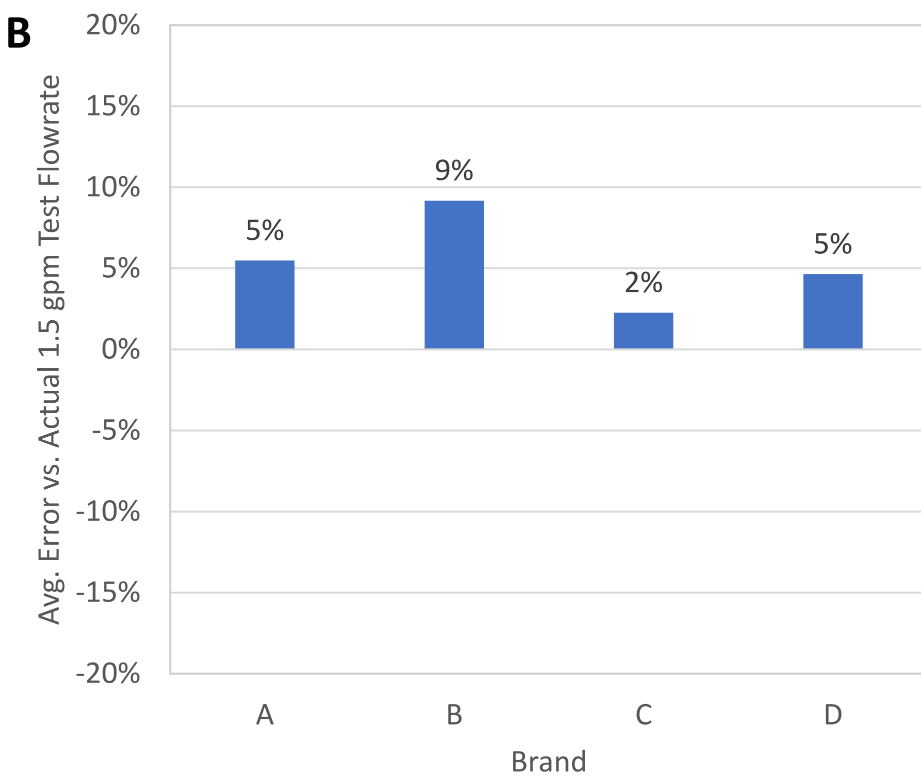


Figure 18. Average SSB outlet deviation from 30 psi regulated pressure (A) and relative to initial calibrated test flowrate (B) across all test pressures at 1.5 gpm nominal flowrate

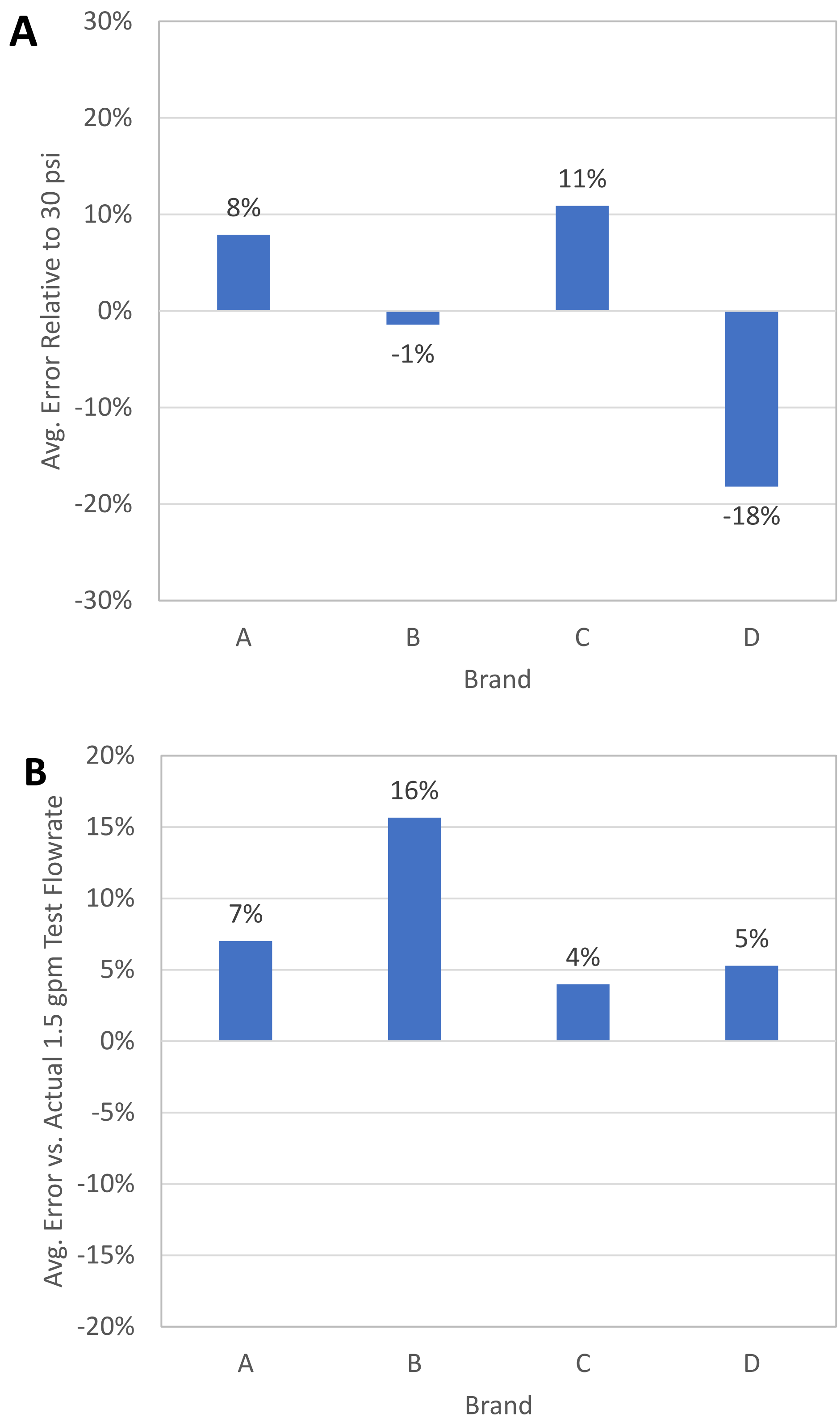


Figure 19. Average SSB outlet deviation from 30 psi regulated pressure (A) and relative to initial calibrated test flowrate (B) across rising test pressures at 1.5 gpm nominal flowrate

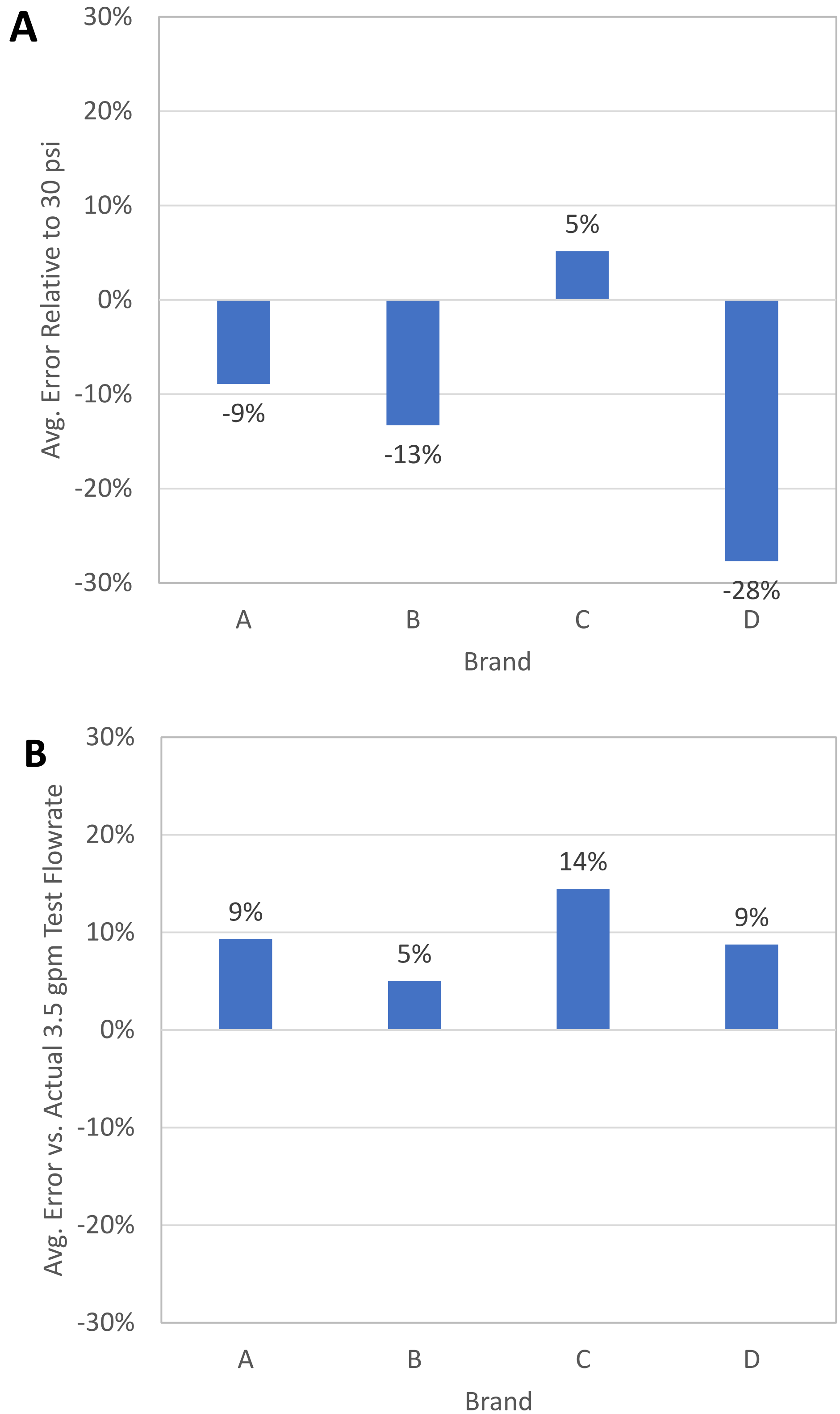


Figure 20. Average SSB outlet deviation from 30 psi regulated pressure (A) and relative to initial calibrated test flowrate (B) across all test pressures at 3.5 gpm nominal flowrate

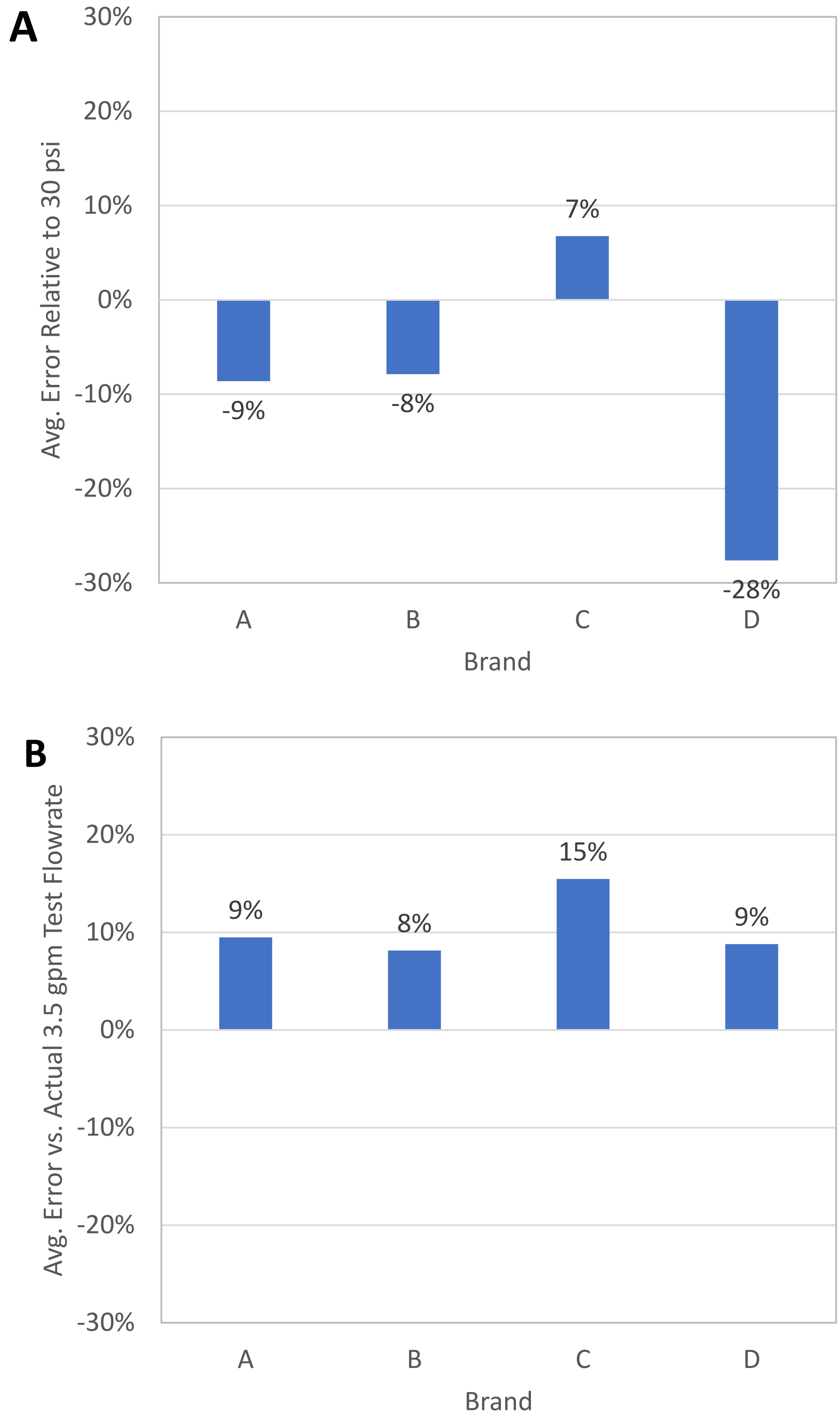


Figure 21. Average SSB outlet deviation from 30 psi regulated pressure (A) and relative to initial calibrated test flowrate (B) across rising test pressures at 3.5 gpm nominal flowrate

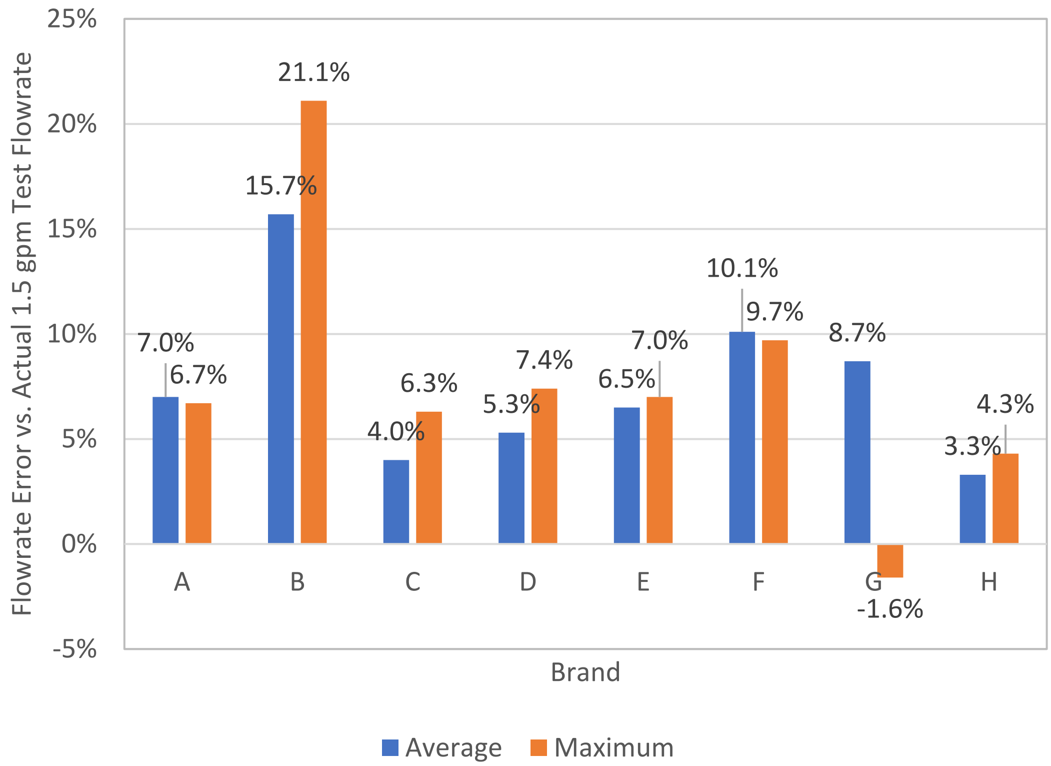


Figure 22. Flowrate deviation of tested SSBs compared to initial calibrated test flowrate at regulated pressure averaged across the rising test pressures (average) and at the maximum test pressure (maximum)

Conclusions and Recommendations

In summary, the SSB test is consistent and repeatable when implemented as done in this work. One can expect consistency in results across the range of products tested here as well as when product testing is repeated in time. The one exception for the products tested is one of the SSBs with flow reduction technology. This product could not be tested with the needle valve as constructed in this work. However, we believe the manufacturer could assist test labs with construction of a device to make testing possible.

Since the falling test limb had consistent results with the rising limb and there may be slight evidence of hysteresis in the falling limb, it is recommended that the falling limb be eliminated for simplicity. In addition, the two test flowrates of 1.5 gpm and 3.5 gpm produce similar outcomes and one could be eliminated.

Testing the pressure regulating SSBs and non-regulating family of models resulted in flowrate reduction of 10 to 24% at 1.5 gpm and 6 to 24% at 3.5 gpm. This result indicates that substantial irrigation savings can be achieved at these pressures and likely more at higher supply pressures.