Secondary Regulator Testing

SUMMARY

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Summary

Evaluating the Role of Secondary Regulators in the Draught Beer System

Often, we don't give secondary regulators much thought. Their job is simple: provide CO2 or mixed gas to the keg at the right pressure, as needed. The service calls and troubleshooting experiences we've had left us wondering if some challenges could be related to regulator performance. We decided to do some testing. The suspicion was that many of the secondary regulators used in beer dispense may not be as sensitive as the job requires.

The following are the tests we ran: Test #1, Pressure Drop vs. Flow Rate; Test #2, confirmation of Test #1 on the test rig (see full report for more details); Test #3, Critical Pressure Test; Test #4, Busy Bar Simulation with water; Test #5, Busy Bar Simulation with Beer; Test #6, Overnight testing with Regulator E. These 6 tests were designed to give us a different view of the performance or efficiency of the main regulators used today in beer coolers. We started with straightforward laboratory gas flow testing and finished up by pouring beer in the beer cooler where the temperature was always nearly perfect. The result was a 56-page report. This is the summary. If you would like to see the full report, let us know.

The brands in our full report are hidden, with one exception, but are the most common used today. In most tests, the best performing one was the Cornelius regulator which we labeled "A". The second best one, labeled "B" is the regulator we are introducing under the brand TruRegs™. There were two other regulators not included in the report that were less common and in both cases were worse performers than the ones tested.

Each test series required quite a bit of time and the last tests used a substantial amount of beer, so we limited the candidates for the final round of testing with beer to two: Reg B (ours) and Reg E (the worst one we tested).

There are many design elements that affect regulator performance. We have considerable experience with this challenge as our blenders use 2 types of pressure regulating valves that must balance the pressure to .004 psi.

Notes on Hydraulic Pressure and Draught Beer.

After years of service call mysteries, philosophical theorizing, and careful observation, we've concluded that whenever the hydraulic pressure exerted on the beer in the line is less than the ideal keg pressure for 100% CO2, bubbles will begin to form in the beer line. This eventually causes excess foam at the faucet and the glass. Lowering of hydraulic pressure is caused by a variety of issues, including:

- Beer lines higher than the beer keg or tank.
- Restriction losses while flowing.
- Temperature increases the beer line may be exposed to.
- Inability of the regulator to maintain pressure under flow conditions.

Hydraulic pressure issues are the driving force behind the testing. The ability of a regulator to maintain its set pressure under the constantly changing flow requirements is exactly what a perfectly functioning draught system requires.

Test #1, Pressure Drop vs. Flow Rate

Summary/Purpose:

Initially, we wanted to see how far the pressure, on the regulator, drops below the set pressure as gas flow is increased. Knowing that, for Helena, MT, ideal conditions for a keg using 100% CO_2 is 13 psig (4,000 feet above sea level, 38 ˚F., 4.8% alcohol, 2.5 vol/vol CO_2 content), all our testing used 13 psig as the regulator “set point”.

Experiment:

Testing was completed in our lab with calibrated and certified test equipment, which included: mass flow meters, needle valve, and digital gauges. Our metrics for the equipment were as follows:

- Inlet Pressure: 50 psig (Higher Inlet pressures to the regulator improve efficiency and performance)
- Test Regulator set to 13 psig

Tracking the pressure drop, we opened the needle valve until we reached 12 psig, then recorded the flow through the mass flow meter. The regulator was re-pressurized to 13 psi, then the needle valve was opened until the gauge read 11 psig, and the gas flow recorded. This process was continued for gauge pressure drops of 10, 9, and 8 psig.

Conclusion:

The graph below shows how much the outlet pressure drops as flow increases. “Taps open” is our flow increment for these first tests. This is the flow rate that would be required to pour multiple glasses or pitchers and growlers from kegs supplied by one regulator. “Taps open” is right around 9 slpm or 19 scfh.

Regulators A and B drop about 1 psi at one tap open (1 gallon per minute) from the set point of 13 psig while regulators C and D drop just over 2 1/4 psi at the same flow rate. Regulators E and F both drop over 4 psi (30%) at 1 tap open. The numbers on the right indicate the pressure from the regulator and the numbers on the left show how far the pressure has dropped from the set point of 13 psig.

Test 1 clearly shows how regulator performance varies from model to model even under conditions every regulator in a draught system can be exposed to.

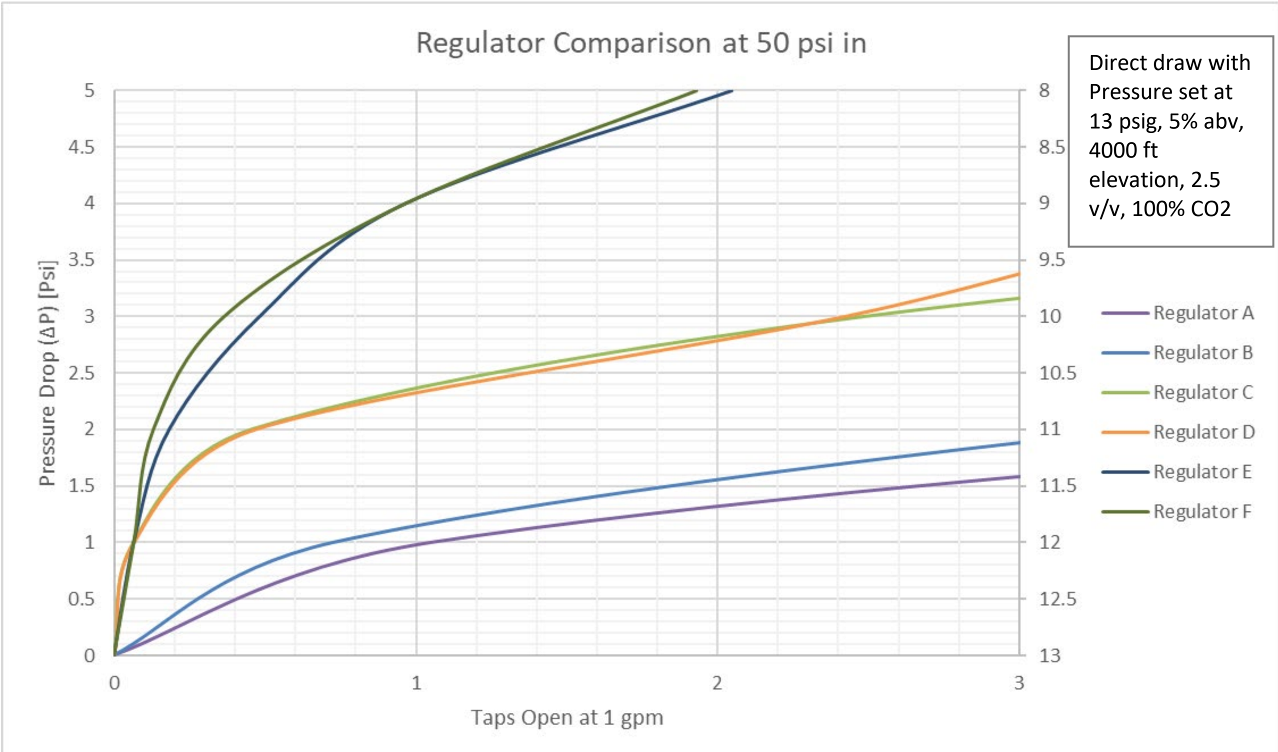

Figure 1: Pressure Drop vs. # of Taps Open (Figure 1.7 in full report)

Test #3, Critical Pressure Test

Note: Test #2 was a confirmation of Test #1 and is in the full report.

Summary/Purpose:

In this test, we wanted to measure each regulators' critical pressure. When the tap is opened on a full keg and run constantly, the critical pressure is the outlet pressure where the regulator stabilizes. This tells us the bottom point (lowest pressure) the regulator can get to when constantly pouring from a tap.

Experiment:

Testing was completed in our lab with calibrated and certified test equipment, which included: mass flow meters, DAQ (a data acquisition system, sampling twice per second), pressure transducers, and digital gauges (to verify our pressure transducers were accurate.) Our metrics for the equipment were as follows:

- Inlet Pressure: 50 psig (Higher Inlet pressures to the regulator improve efficiency and performance)
- Test Regulator set to 13 psig

Using a 10L Keg filled with water, we connected Regulator A to the test fixture. With the gas turned on we opened the tap and let the 10L keg run out. The DAQ recorded pressures and flow rate every 0.5 seconds. This process was repeated for each Regulator.

Conclusion:

We are including the individual charts for each regulator as it would be confusing to put all the results on one chart. This series of tests shows several very important pieces of the regulator puzzle:

1. The pressure drop affects the final flow rate. The lower the critical pressure, the lower the flow rate will be. This matters a great deal when designing and setting up a draught system because, as the pressure drops, so does the flow rate of the beer. If it becomes necessary to increase the outlet pressure of the regulator to maintain the beer flow at 2 oz/sec., the beer will be at too high a pressure when beer is not pouring and will over-carbonate!
2. These test results show that the pressure from the secondary regulator is higher than the pressure in the keg itself. This is caused by the Thomas or check valve in the keg coupler. The force required to push gas through this valve uses the pressure from the regulator, nearly a full psi, further reducing the pressure the beer is exposed to. This also confirms the results from Test #1. The best regulator has a pressure drop of a bit over 1 psi and the worst just over 4 psi.

A consideration not tested in this series of tests is the impact of the check valve on the outlet of the regulator (if there is one.) The higher cracking pressure of that check valve will, like the one in the keg coupler, further reduce the pressure to which the beer is exposed .

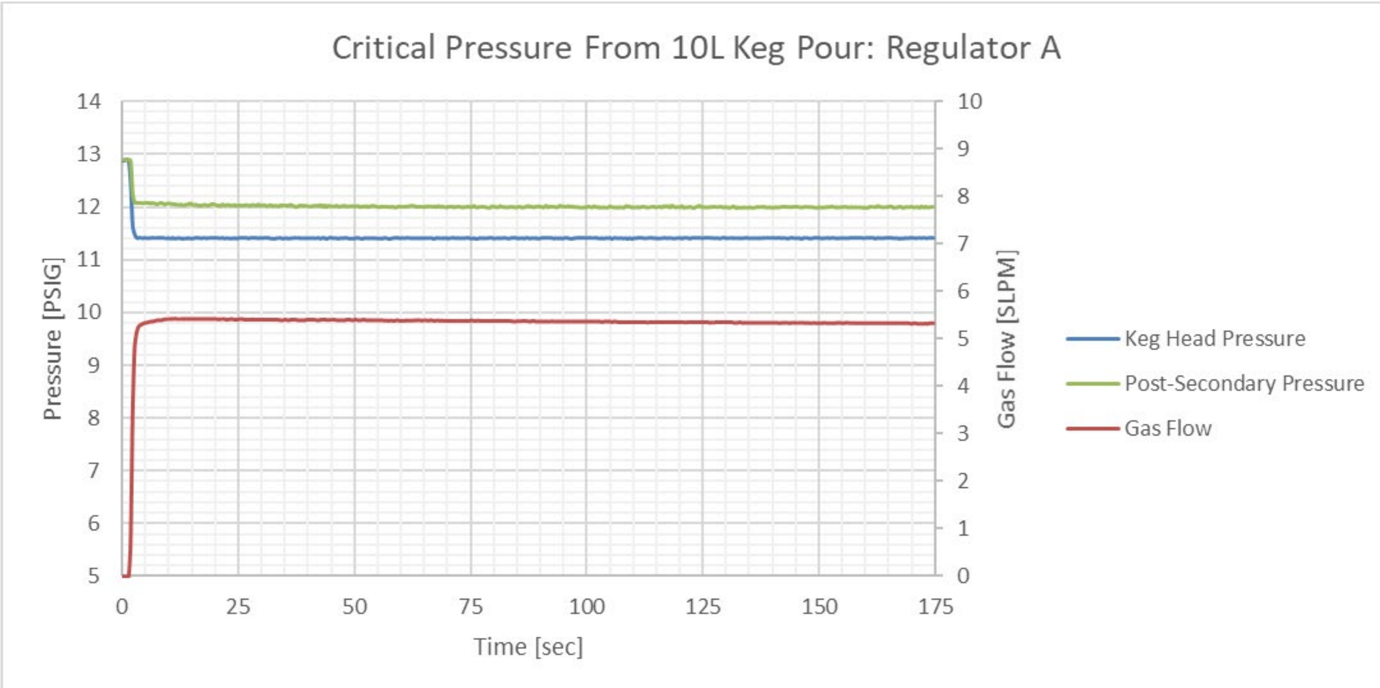

Figure 2: Regulator A Critical Pressure Drop (Figure 3.1 in the Full Report)
Critical pressure drop of 1.48 psig

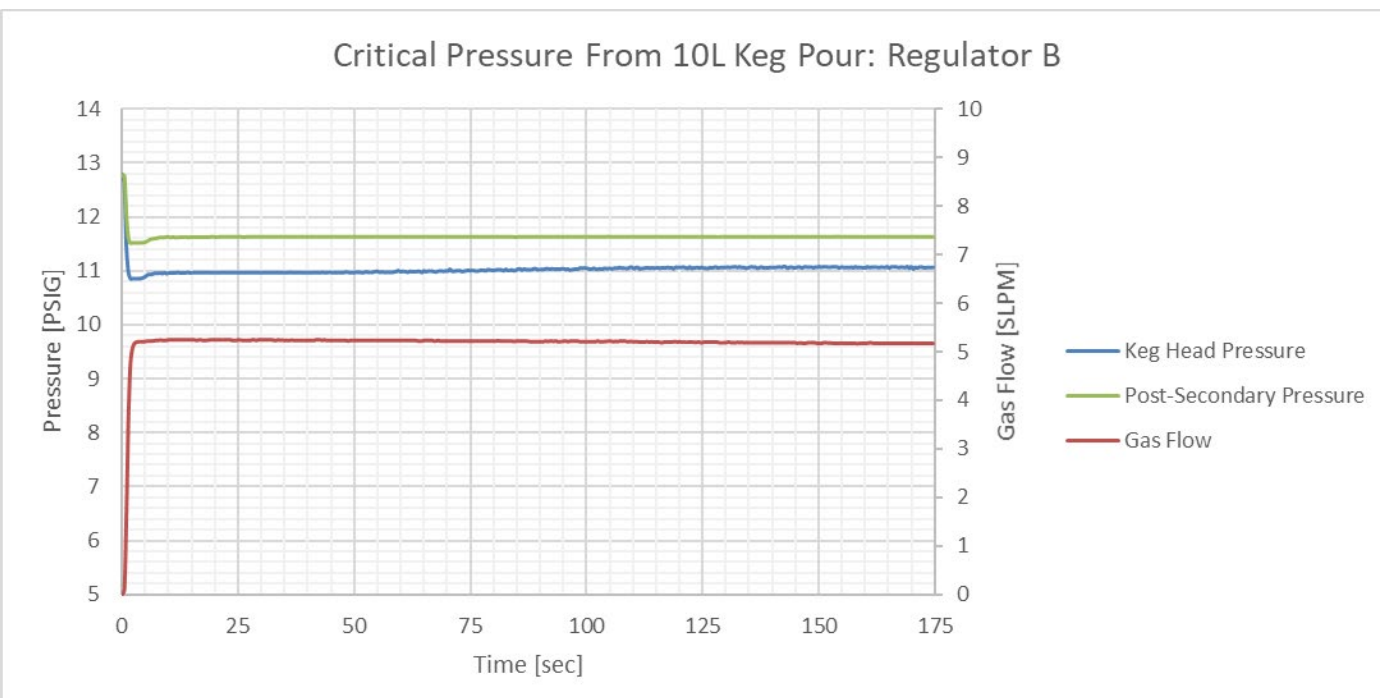

Figure 3: Regulator B Critical Pressure Drop (Figure 3.2 in the Full Report)
Critical pressure drop of 1.8 psig

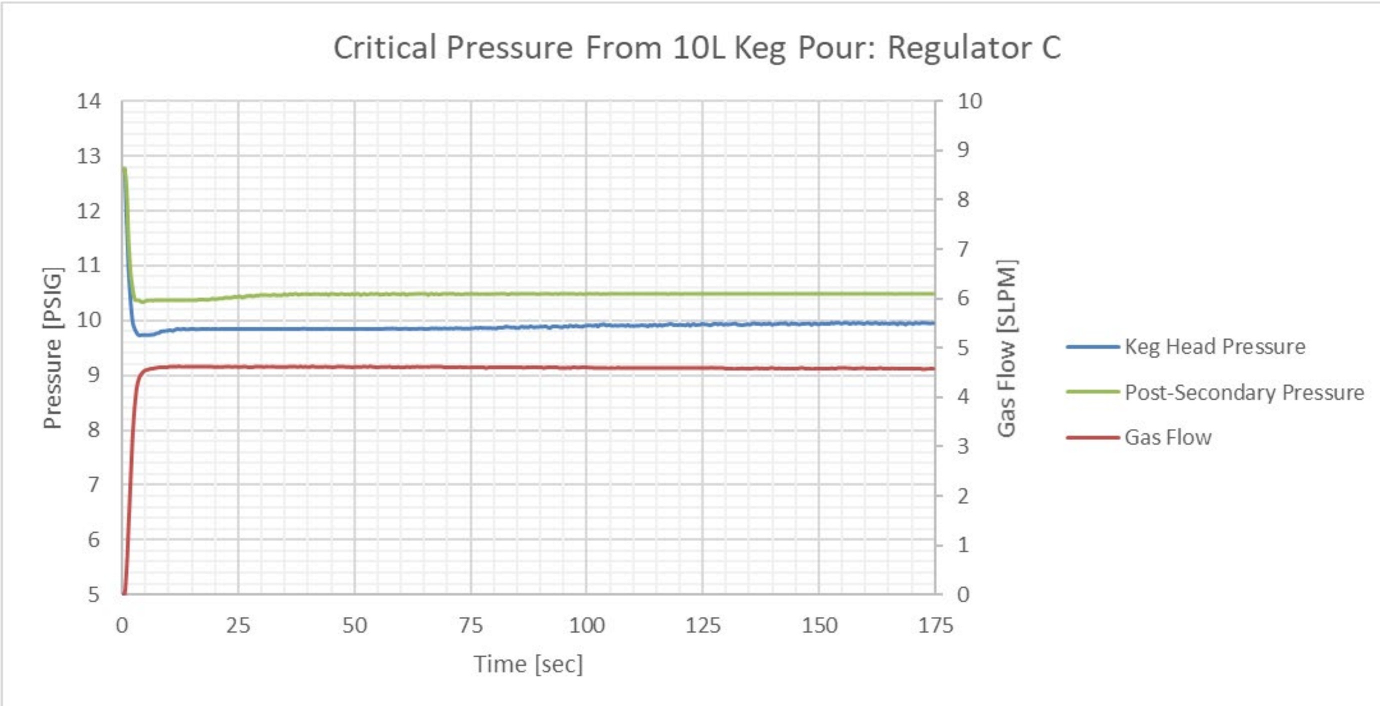

Figure 4: Regulator C Critical Pressure Drop (Figure 3.3 in the Full Report)
Critical pressure drop of 2.91 psig with a low point of 9.9 psig

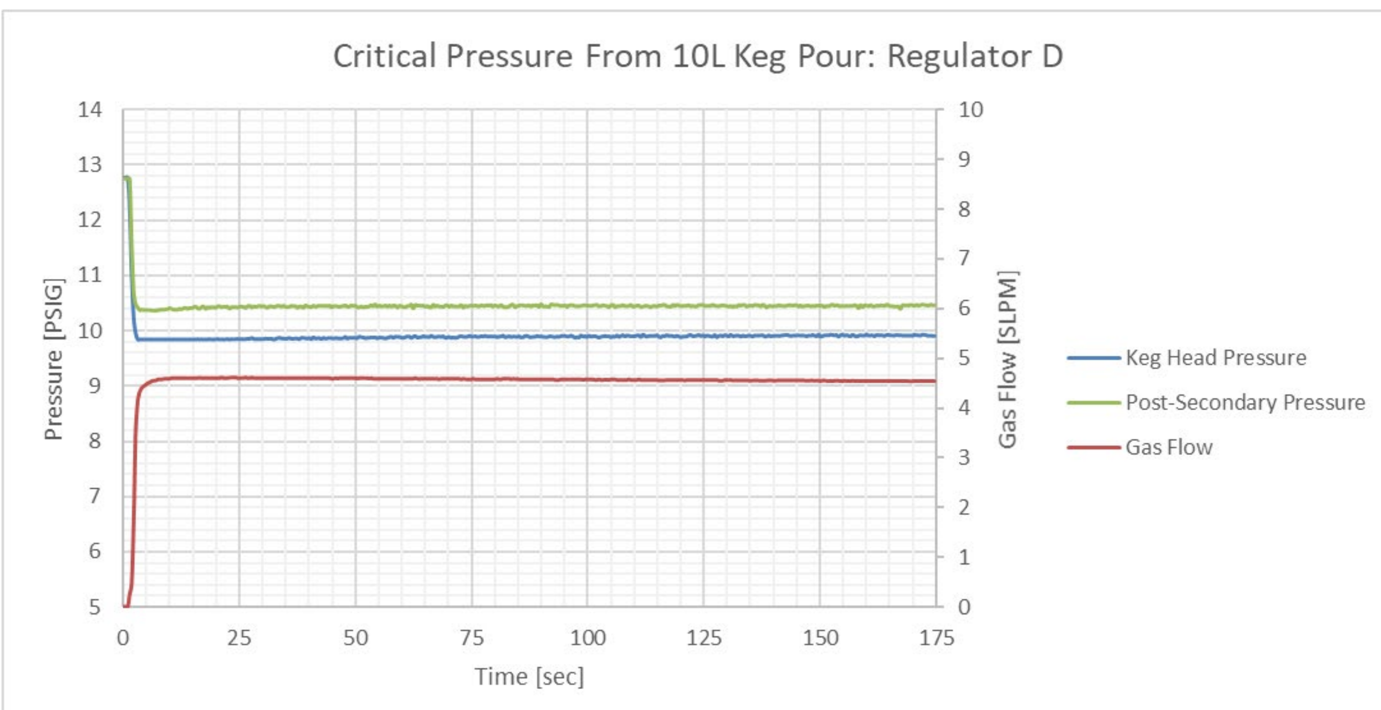

Figure 5: Regulator D Critical Pressure Drop (Figure 3.4 in the Full Report)
Critical pressure drop of 2.9 psig with a low point of 9.85 psig

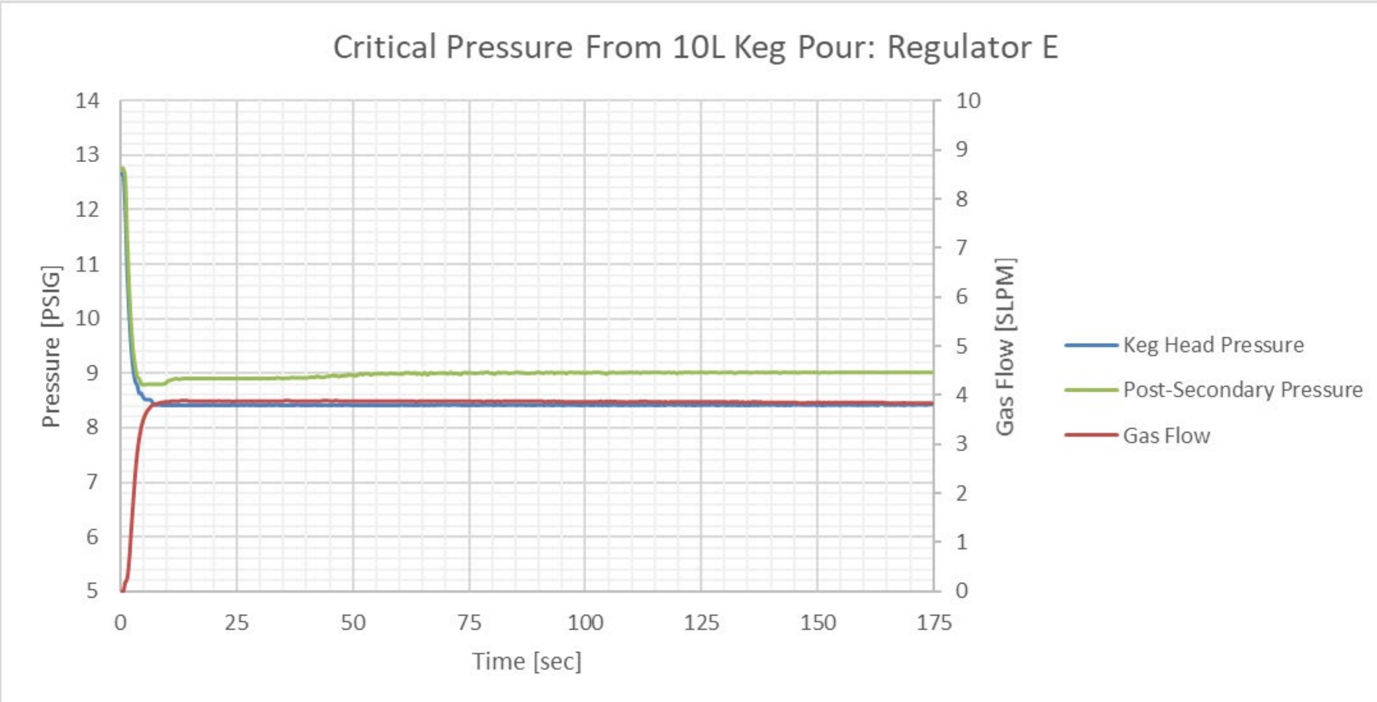

Figure 6: Regulator E Critical Pressure Drop (Figure 3.5 in the Full Report)
Critical pressure drop of 4.24 psig with a low point of 8.4 psig

Test #4, Busy Bar Simulation with water

Summary/Purpose:

Now that we know the pressure drop to open each regulator and critical pressures, we came up with a hypothesis. This hypothesis is: demand on the regulator changes with the keg level, or more specifically with gas volume in the keg. We wanted to run tests simulate a busy bar with water, so that we could prove this hypothesis and so that no excess beer would be lost.

Experiment:

Testing was completed in our lab with calibrated and certified test equipment, which included: mass flow meters, DAQ (a data acquisition system, sampling twice per second), pressure transducers, and digital gauges (to verify our pressure transducers were accurate). Our metrics for the equipment were as follows:

- Inlet Pressure: 50 psig (Higher Inlet pressures to the regulator improve efficiency and performance)
- Test Regulator set to 13 psig

A 50L keg was filled with water. Each regulator was connected to our test fixture, individually. Pours were done every 30 seconds for a total of 10 pours. This was done 3 times for each regulator: the half barrel keg full, ½ full, and ¼ full. This test was done for each regulator simulating a busy bar. Results were recorded with the DAQ.

Conclusion:

You can see in the chart(s) that follow (Fig. 7 and Fig. 8,) the full keg creates a flow which is higher flow for a shorter time. This contrasts greatly with the last 1/4 of the keg where the demand requires of lower flow for a longer time.

This matters in part because this is exactly what happens in real draught systems every day. It also matters because it creates a different challenge for the regulator. The full keg necessitates a quick opening higher flow and the 1/4 keg necessitates a more sensitive regulator, opening with a small pressure change.

This test compares one of the better regulators to the worst one we tested fully and shows that, under simulated pouring conditions with water, the performance difference is significant. The failure of Regulator E to return the keg to the original set pressure creates a condition which allows CO_2 to come out of solution, causing foam in some conditions.

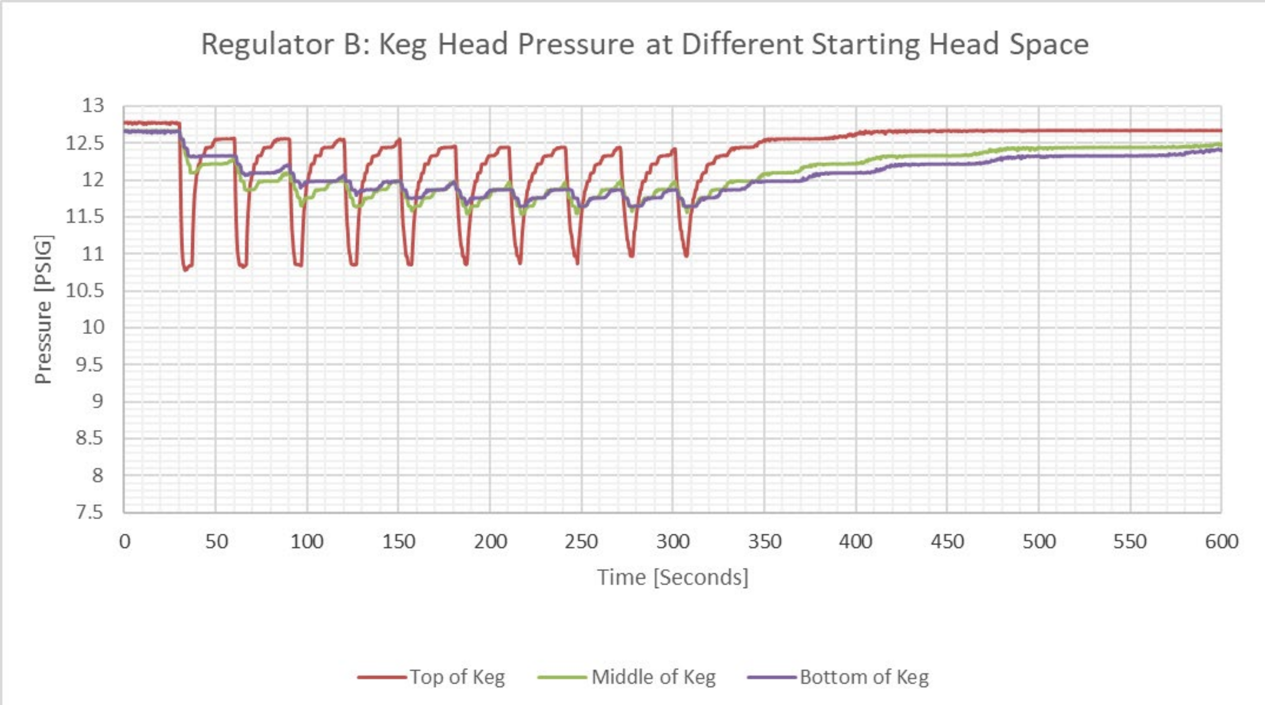

Figure 7: Regulator B Pressure inside the Keg (Figure 4.8 in the Full Report)

Note the different flow rates required to meet the demands on the regulator depending on the level of beer in the keg. More importantly, notice how much less pressure drop Regulator B needs to meet the demand and how much quicker the keg pressure returns to the set pressure. Notice, especially the in the case of Regulator E, after 5 minutes the keg pressure is still 2 1/4 psi below the desired set pressure.

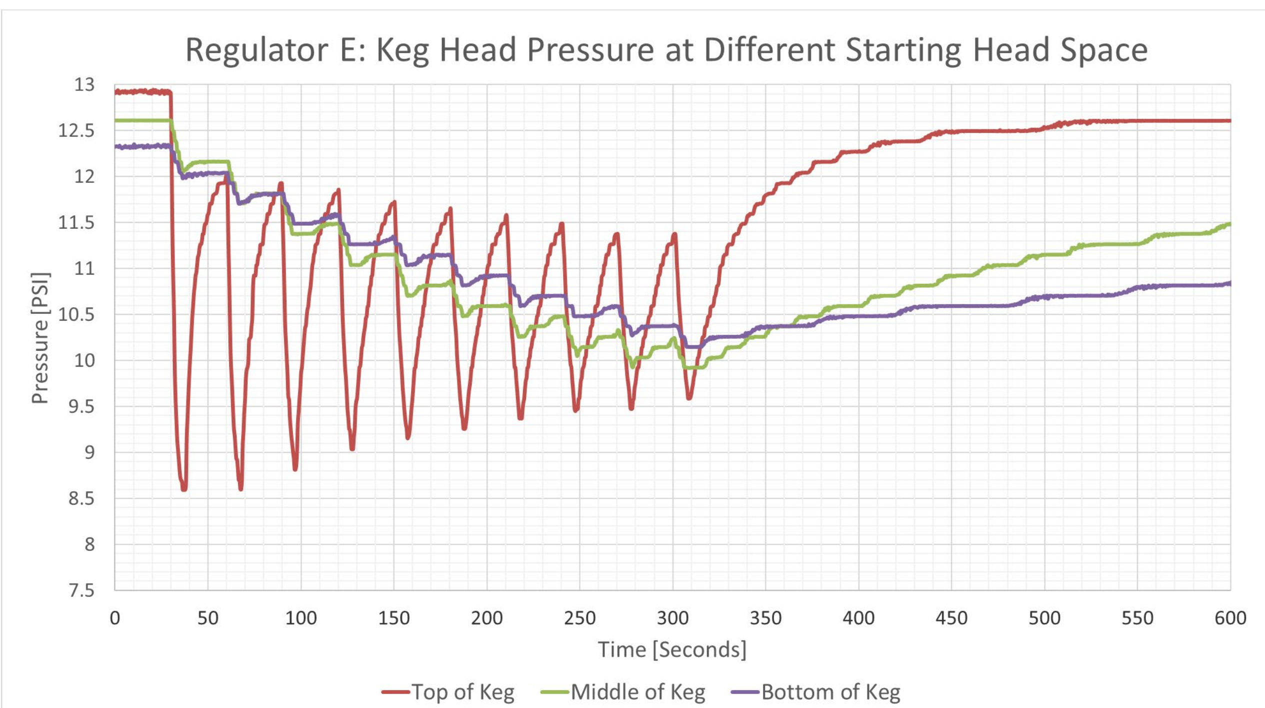

Figure 8: Regulator E Pressure inside the Keg (Figure 4.20 in the Full Report)

Test #5, Busy Bar Simulation with Beer

Summary/Purpose:

Since our hypothesis in Test #4 was proven accurate, we wanted to run a test with beer. We wanted to see how the pressure drop affected CO2 coming out of beer in the line. Due to the nature of this test, we only used Reg B and Reg E (our reg and the worst reg, respectively.)

Experiment:

Testing was completed with the test fixture outside the cooler (with the gas components.) The keg/tap was set up inside the cooler to eliminate any problems that might be caused by warm shanks or faucets. The equipment used was calibrated and certified test equipment, which included: mass flow meters, DAQ (a data acquisition system, sampling twice per second,) pressure transducers, and digital gauges (to verify our pressure transducers were accurate.) Our metrics for the equipment were as follows:

- Inlet Pressure: 50 psig (Higher Inlet pressures to the regulator improve efficiency and performance)
- Test Regulator set to 13 psig

50L kegs filled with beer were used. We ran 30 feet of 3/8" vinyl tube and 3/16" vinyl choker to create 12.6 pounds of restriction. The line was coiled on a flat surface 1 foot above the keg equal to the height of the faucet as well (one-foot total lift from top of keg.) Regulator B was connected to our test fixture. 64 oz growlers were poured every 30 seconds and the pressures and gas flow rates recorded via the DAQ. This test was then run with Regulator E, starting with a fresh keg.

Conclusion:

Regulator E dropped 3.5 psi from the set point over 3 times the drop from Regulator B. At times, bubble formation was seen in the beer line with Regulator E pointing out the importance of regulator performance in a beer system.

[(Almost) No beer was harmed in the testing process; it was poured into growlers and given away. Certified by the IFTPOCTB. (Institute for the Prevention of Cruelty to Beer)]

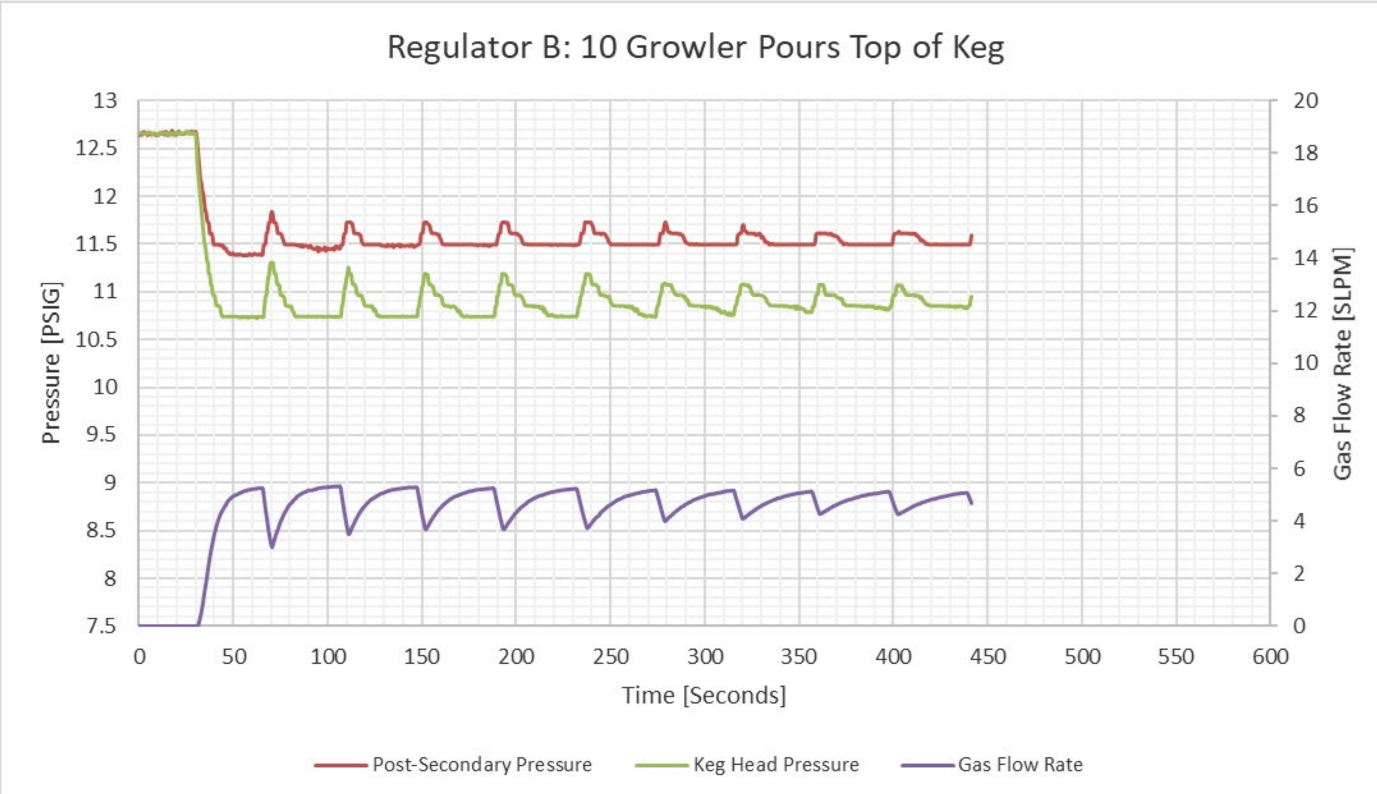

Figure 9: Regulator B, Growler pours, Top of Keg (Figure 5.9 in the Full Report)
Note that the regulator outlet pressure drops from a 12.6 psig set point to 11.5 psig under the test conditions and the keg pressure is 1.2 to 1.5 psi lower than the regulator outlet pressure due to the Thomas valve cracking pressure. The regulator outlet pressure is actually 1.1 psi lower than the starting keg pressure of 12.6 psig.

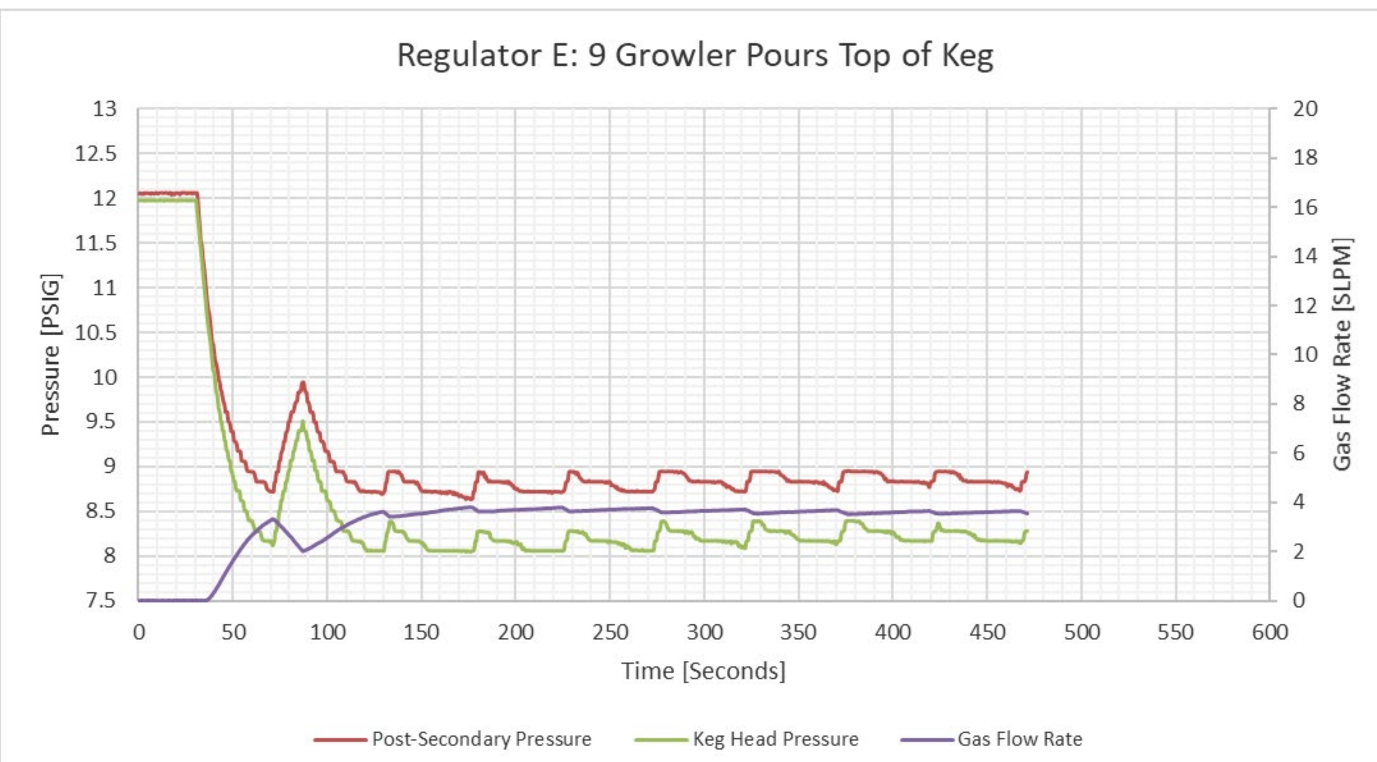

Figure 10: Regulator E, Growler pours, Top of Keg (Figure 5.2 in the Full Report)
Note the regulator outlet pressure drops from the set point of 12.2 psig to 8.7 psig under the test conditions and the actual keg pressure drops an additional 1.1 psi. The regulator outlet pressure is 3.5 psi lower than the starting pressure of 12.2 psig.

Test Series 6, Overnight testing with Regulator E

Summary/Purpose:

It was noticed that Regulator E did not readily return to the set point. We wanted to see if the regulator would return to its set pressure at different intervals.

Experiment:

Testing was completed with the test fixture outside the cooler (with the gas components.) The keg/tap inside the cooler to eliminate any problems that might be caused by warm shanks or faucets. The equipment used was calibrated and certified test equipment, which included: mass flow meters, DAQ (a data acquisition system, sampling twice per second,) pressure transducers, and digital gauges (to verify our pressure transducers were accurate.) Our metrics for the equipment were as follows:

- Inlet Pressure: 50 psig (Higher Inlet pressures to the regulator improve efficiency and performance)
- Test Regulator set to 13 psig

This test was done by letting the system sit unused overnight, then pouring 3 pint glasses of beer, and waiting 2 hours. This was done 5 times in sequence, then the system sat unused overnight.

Conclusion:

Notice the pressure did not return to the set point of 12 psig once the test started, and after the last pour, the regulator only returned to 11.5 psig which took over 10 hours.

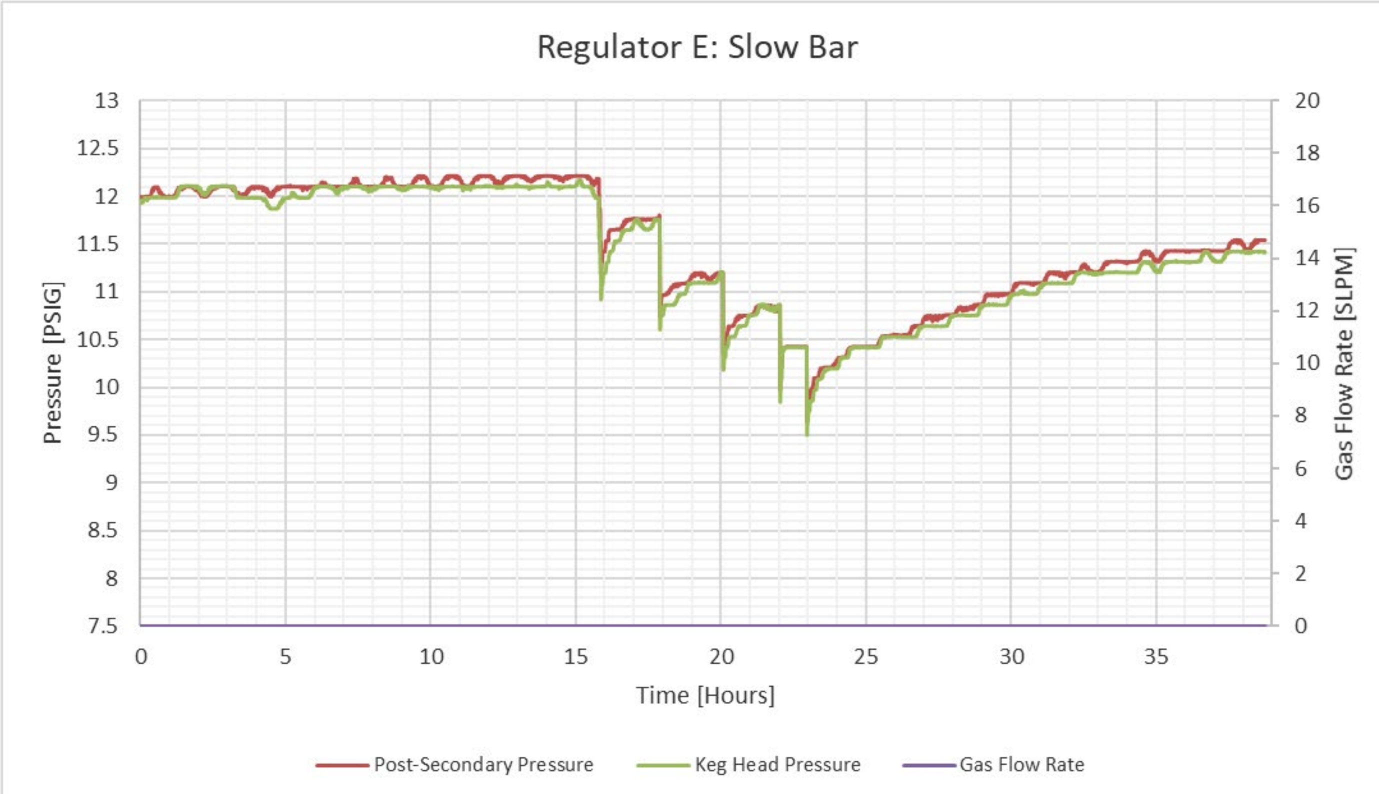

Figure 11: Regulator E, Slow Bar Overnight Test (Figure 6.1 in the Full Report)
This shows that poor performing regulators not only drop pressure excessively, but their lack of sensitivity means that they can take hours to return to the original set pressure. In a system with any type of lift or other challenges, the lowered pressure would translate into bubbles building up in the line and foam in the glass.

Conclusions

We were surprised to see the performance of several of the regulators in common use today and believe these results may make clear some of the small mysteries in troubleshooting draught problems. If we design systems with the assumption that setting the regulator to 13 psig will assure a keg pressure of 13 psig under flow conditions, we are, in many cases, mistaken.

This information has helped us improve or resolve several challenges in three of our local breweries already.