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January 6, 2005

To: Water Team
From: Mark Sevier
RE: Report on Waste & Wait testing of D.R. Horton Beta home

While it seems to me like just yesterday that we were all out in CA testing the Beta home, much time has passed, and I apologize for the delay with the following information.

The results show significant water and time savings for the demand re-circ system in a 'cold start' mode, as was expected. The time to prime the loop with the larger return pipe size is still greater than our goal of 30 seconds, and should be reviewed to bury this time in some other function for quicker apparent response. Overall, the testing was a great success, and the system performed very well.

Once you get a chance to look over this information, please feel free to call or email (mark@buildingscience.com) with any questions.

Sincerely,

Mark Sevier, PE

cc: Betsy Pettit, AIA
Dr. Joe Lstiburek, PhD, P.Eng

Wait and Waste Testing of D.R. Horton Beta Home

To establish the relative difference in water waste between typical house plumbing and using a demand re-circulation system, the Beta home was tested first without the demand re-circ system operating, and secondly with it in operation. The difference in performance is striking, and encouraging for homeowner satisfaction and water conservation. While the usage pattern will determine how frequently the water and time savings will occur, for single or initial draws, the reduction is significant. Insulating the supply piping lines will reduce the clustered use energy consumption, as well as allow the water heater to be set at a lower temperature, and deliver hotter water sooner than without insulation.

Unfortunately, the system did not meet the intended wait time for priming of the re-circulation line, even after installing the ¾" piping for the re-circulation line. While this deficiency seems small in relation to the potential water savings and convenience improvement, it is important to consider how to reduce the priming time or market the use to avoid the homeowner waiting for this time period.

Testing Method:

The objective of the test was to record the volume of water to first temperature rise, to useful temperature (selected to be over 100F due to the granularity of the data), and to final temperature, while recording the minimum and maximum temperature, and time to each volume with the fixture at maximum flow (full open). These parameters were taken both by hand, and with datalogging equipment. For the manual measurements, a thermometer was placed in the water stream right at the discharge from the fixture, and the water flow was directed to separate containers for each desired volume measurement. For the datalogger measurements, a Hobo datalogger in a funnel was used to measure time and temperature, while a separate datalogger on the water meter took volume information. While the data don't correlate exactly, it was valuable to back check one method with the other.

As a preparatory step, a bypass line was installed in the hot water feed from the hot water tank to the house, such that the hot water line could be flushed with cold water after each test. This was necessary to allow sequential wait and waste tests of the typical system, but was not used in the re-circulation system tests.

Water Temperature Adjustment:

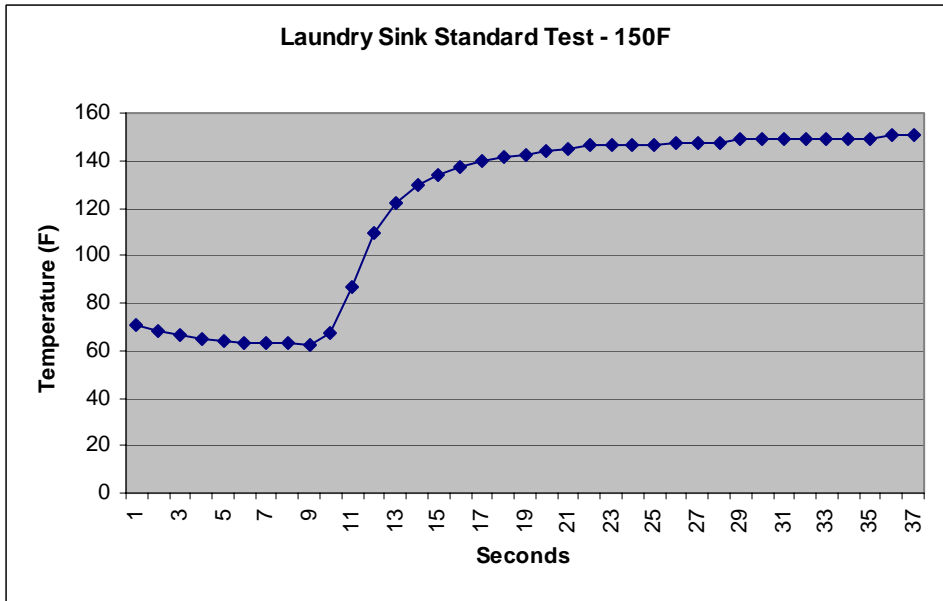
Once the bypass line was in place, a test was run at the fixture nearest to the hot water tank – the laundry sink. Co-ordination of moving the faucet & thermometer over the appropriate bucket at the appropriate temperatures created some difficulty especially at the high flow rate of the laundry faucet. During the first test at the laundry sink, the hot water temperature was found to be much higher than desired – 150F. Due to the risk of scalding, and desire to test at 120F, the testing was suspended while cold water was introduced into the hot water tank until the burner came on. After a couple iterations, the desired 120F water temperature was achieved, and testing could resume.

Standard Plumbing Baseline Testing:

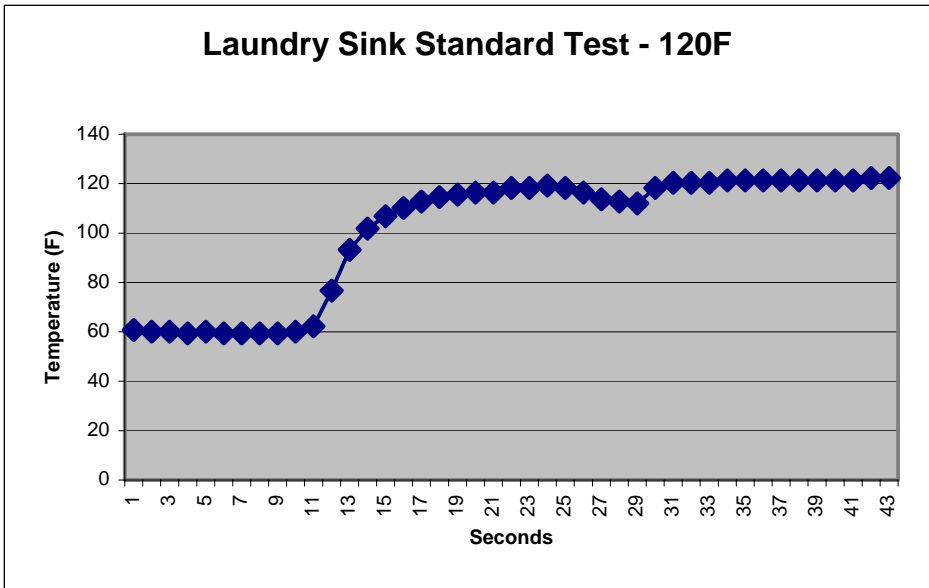
For the standard plumbing testing, the fixtures were tested in order of how close they were to the water heater, the laundry sink being nearest, and BR2 tub spout being furthest. For the re-circulation system testing, the process was reversed starting at the BR2 tub spout, and finishing with the laundry sink.

The following are the graphs and volumes of the datalogged flow tests on the standard (non-re-circ) system. As can be seen, the wait times and wasted volumes are significant. Note that these times and volumes are from a cold start condition, and wouldn't occur during 'clustered' use, when fixtures are used within the time that the trunk line is still warm.





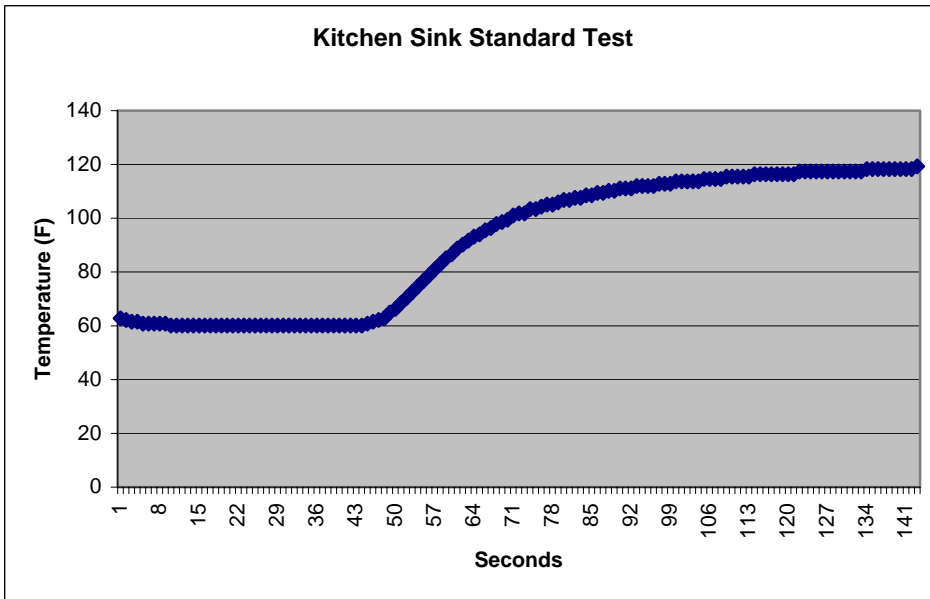
	Seconds	Gallons
First rise	10	0.79
Useful	12	0.95
Maximum	36	2.83



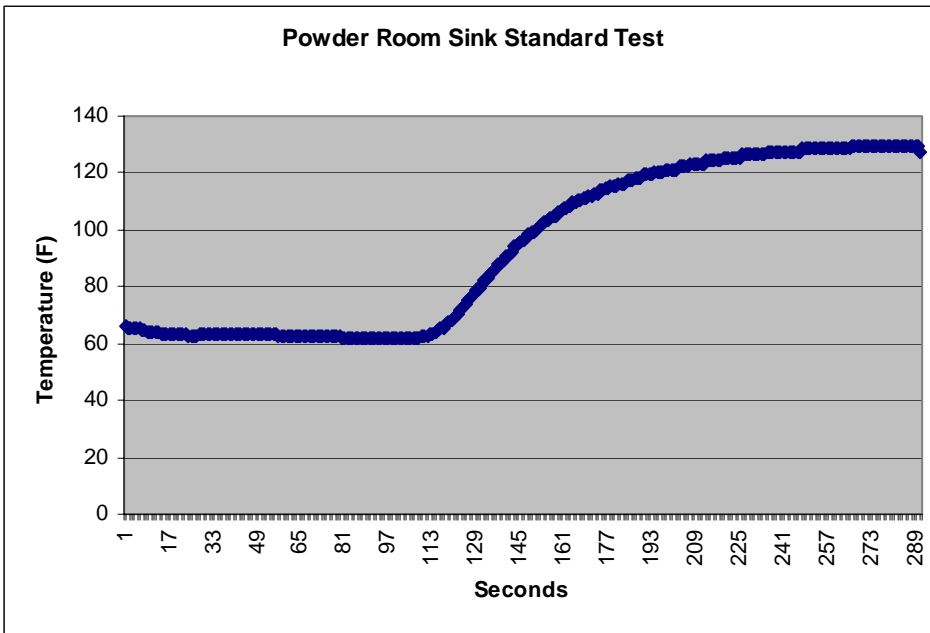
	Seconds	Gallons
First rise	10	0.81
Useful	14	1.12
Maximum	42	3.30

Nearest fixture – 14 second wait and more than a gallon of wasted water!



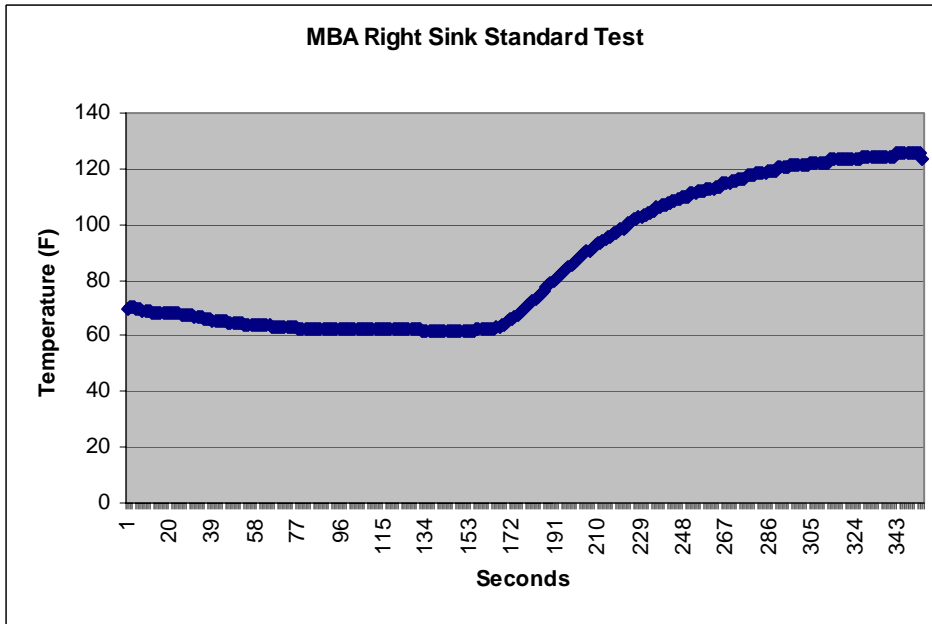


	Seconds	Gallons
First rise	44	0.98
Useful	70	1.56
Maximum	142	3.19

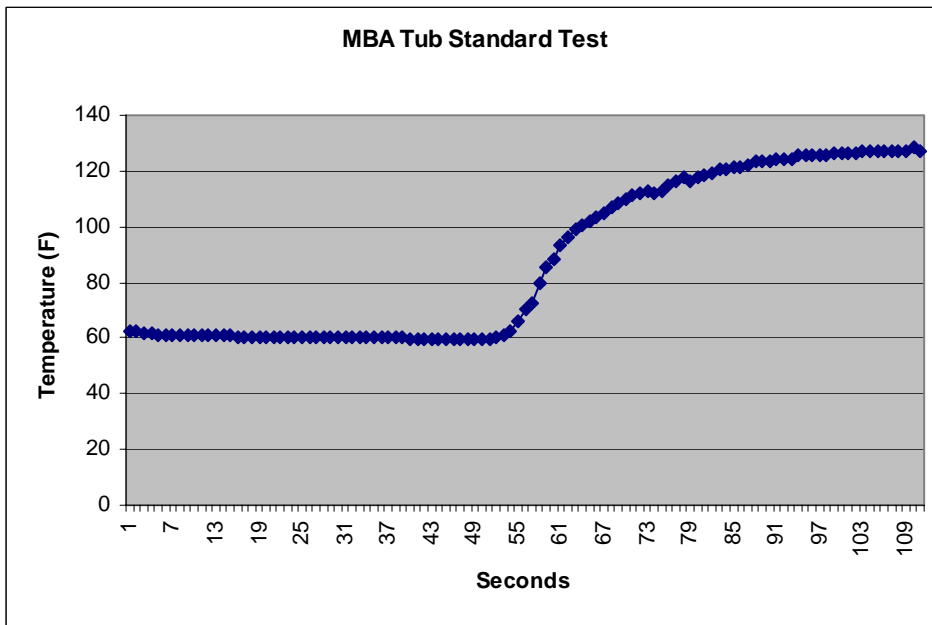


	Seconds	Gallons
First rise	113	2.33
Useful	150	3.13
Maximum	265	5.63



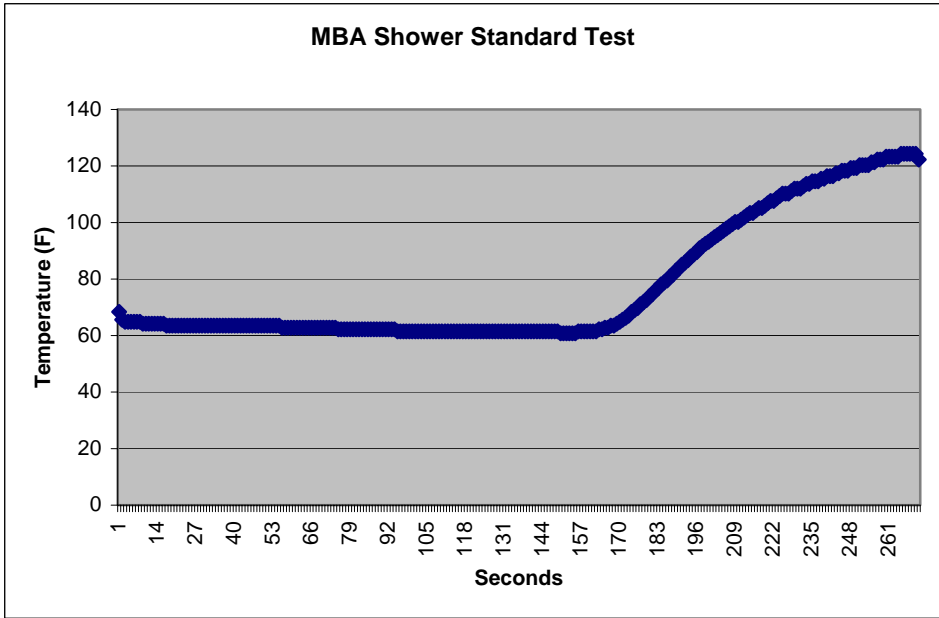


	Seconds	Gallons
First rise	165	3.67
Useful	223	4.96
Maximum	342	7.61

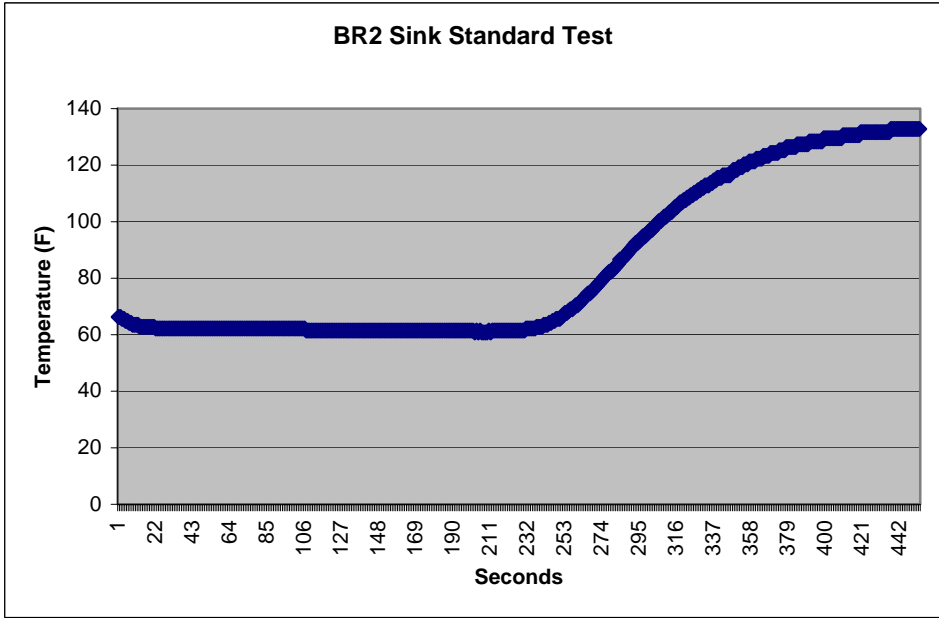


	Seconds	Gallons
First rise	52	3.76
Useful	64	4.62
Maximum	103	7.46





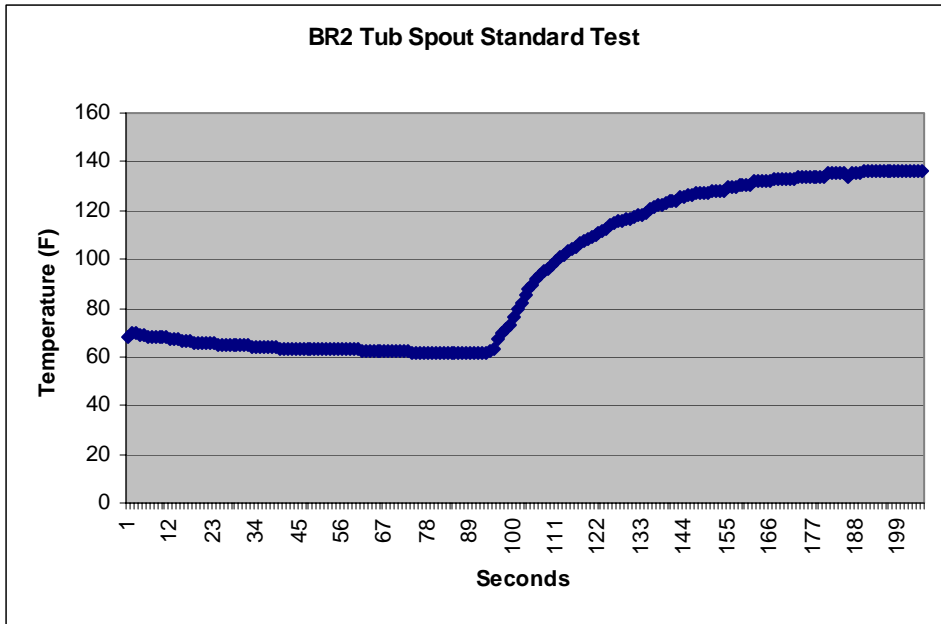
	Seconds	Gallons
First rise	169	4.61
Useful	209	5.71
Maximum	265	7.26



	Seconds	Gallons
First rise	241	5.16
Useful	306	6.56
Maximum	437	9.41

Furthest fixtures (BR2): Sink – 5+ minute wait & 6.5+ gallons of wasted water!



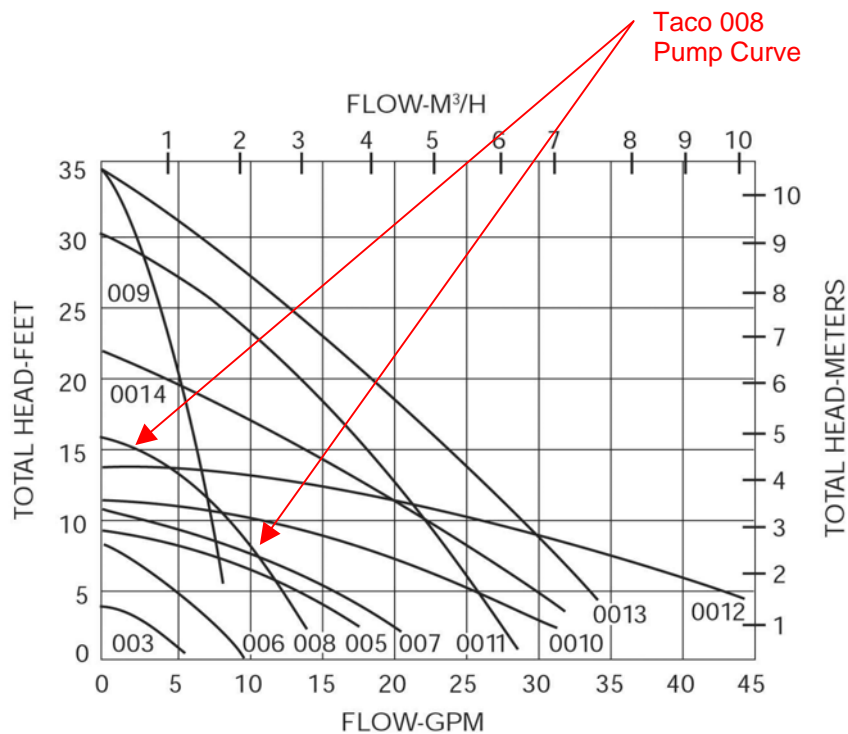


	Seconds	Gallons
First rise	93	5.21
Useful	111	6.21
Maximum	189	10.55

Re-Circulation System testing:

After testing the baseline for all the fixtures, the wait and waste using the demand re-circulation system was tested. The first test was to measure how long it took for the re-circulation pump to fill the re-circulation loop with hot water. The goal for priming the loop had been 30 seconds or fewer, but it soon became clear that it would be significantly longer.

The re-circ pump is designed to 'time-out' after 3:30 mins, to prevent ruining a pump from any system problems, and the pump at the Beta home initially turned off due to the 'time-out', as opposed to the loop getting up to temperature. The pump ran for an additional 15 seconds after pressing the button again, yielding a total of 3:45 to prime the loop. The re-circ line had been piped in 1/2" pipe, as opposed to the 3/4", and therefore it was hard to tell what the timing would be at the correct size. Using this priming time, the estimated volume of 6 gallons of the system, and the pump curve for the re-circ pump (Taco 008), the head loss through the system can be estimated. It would appear that the system configuration led to a flow rate of ~1.5 gpm, corresponding to a head loss of over 15 feet – nearly the entire head capacity of the pump.



Taco Pump Curves – Model #008 is the installed re-circulation pump

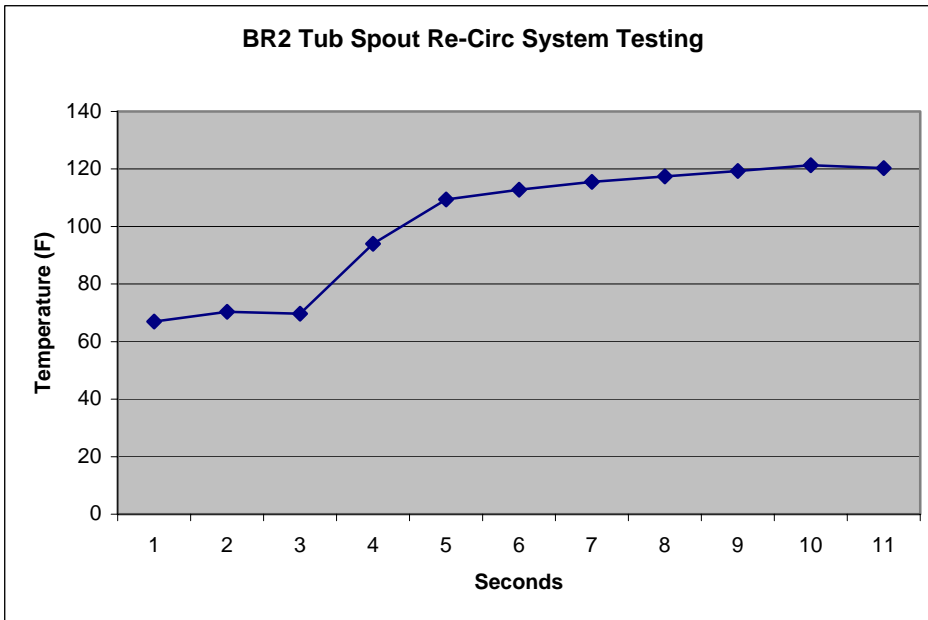
Subsequently some system trouble shooting was done, and the re-circ line was re-configured in $\frac{3}{4}$ " piping, which resulted in a 1:30 loop priming time. With these improvements, the flow rate rose to ~4 gpm, and head loss dropped to ~14 feet. The exponential relationship shows the change in performance with change in pressure and flow, and suggests that the performance improvement of using a larger pump will not reach the goal of a 30 second loop filling time.

Fixture Testing using Demand Re-Circulation System:

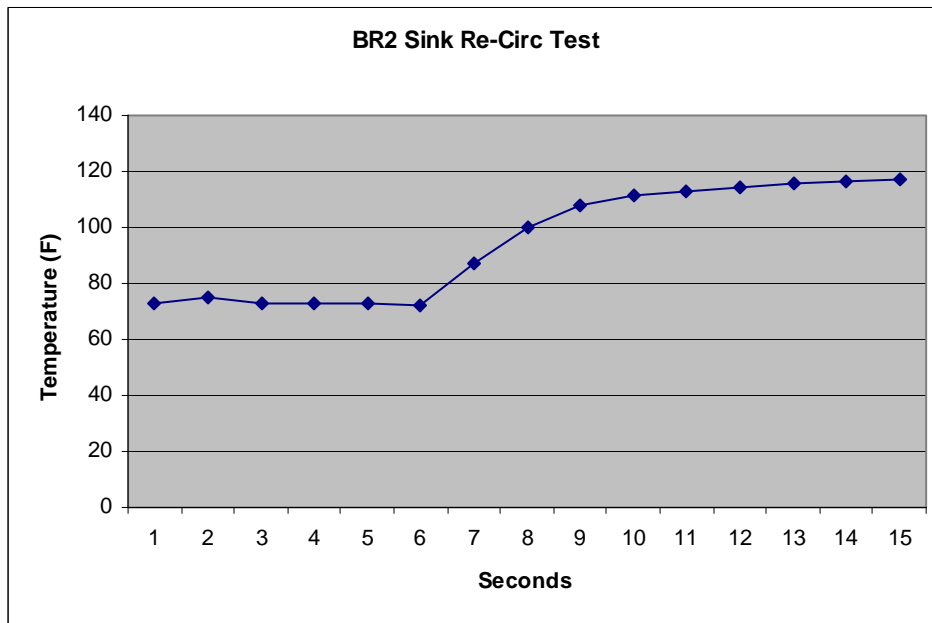
Once the re-circulation loop had been primed, the individual fixtures were tested in a similar manner to the standard plumbing testing. While the intention was to use both manual and datalogging techniques, the temperature change was so rapid that there was not time for the manual thermometer measurement, which instead was taken by touch. The wait and waste results were impressively better than those taken without the re-circulation system in operation.

The following graphs show the improved performance, while the charts below each graph compare the wait and waste volumes and times with and without the demand re-circulation system. Across the board, the re-circ system saved nearly 90% of the water wasted with the standard plumbing. The wait times were similarly impacted.



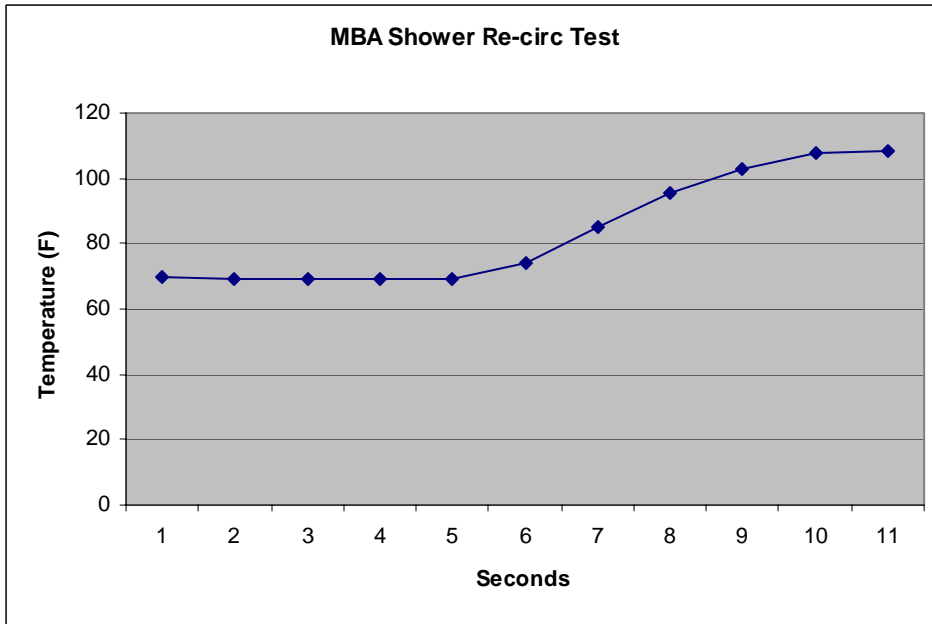


	Re-circulation		Standard		Savings		Water
	Seconds	Gallons	Seconds	Gallons	Seconds	Gallons	Savings
First rise	1		93	5.21	92	5.21	
Useful	4	0.23	111	6.21	107	5.98	96%
Maximum	9	0.46	189	10.55	180	10.09	96%

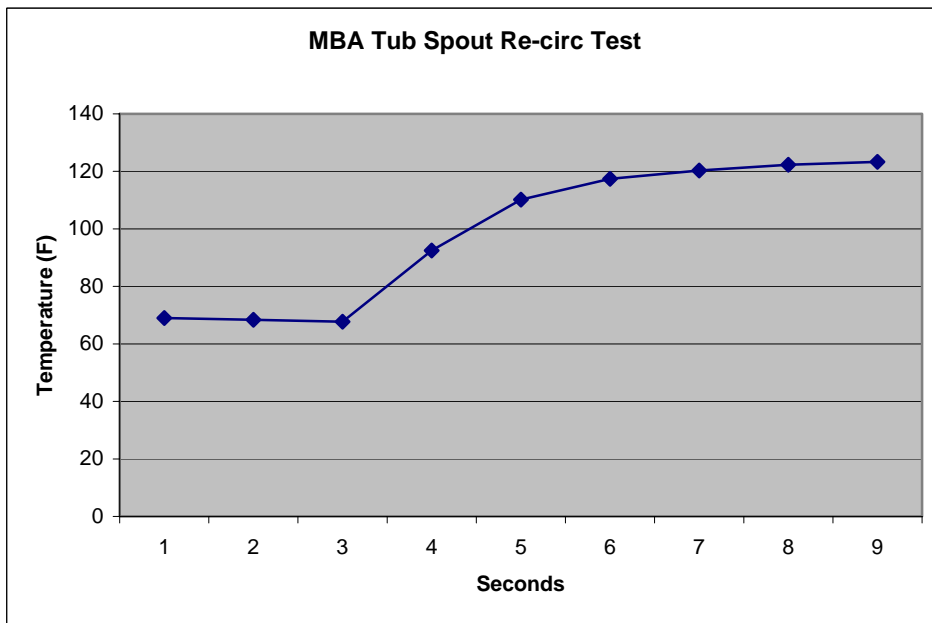


	Re-circulation		Standard		Savings		Water
	Seconds	Gallons	Seconds	Gallons	Seconds	Gallons	Savings
First rise	7	0.16	241	5.16	234	5.00	97%
Useful	8	0.18	306	6.56	298	6.38	97%
Maximum	15	0.35	437	9.41	422	9.06	96%



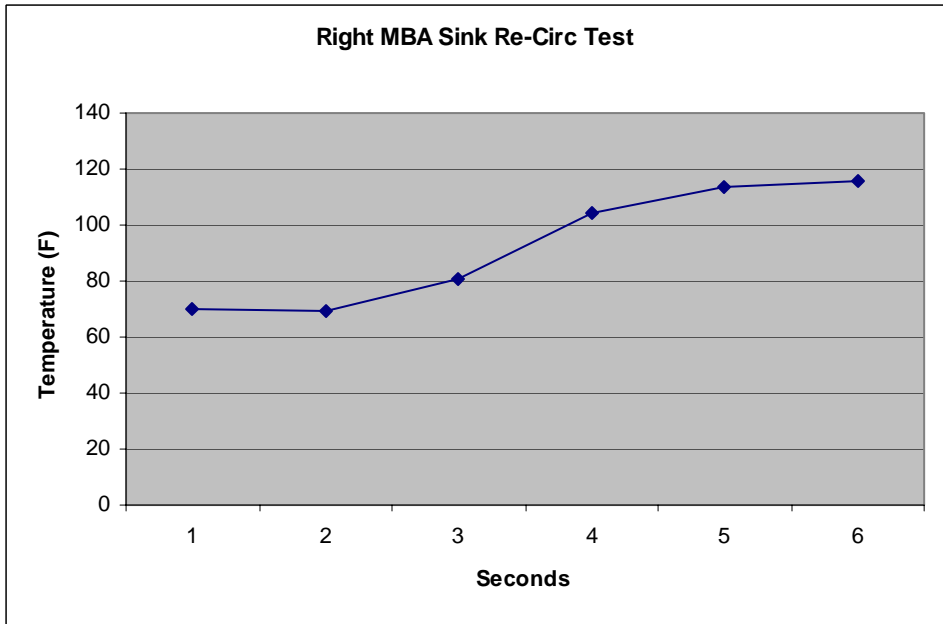


	Re-circulation		Standard		Savings		Water
	Seconds	Gallons	Seconds	Gallons	Seconds	Gallons	Savings
First rise	6	0.24	169	4.61	163	4.37	95%
Useful	9	0.28	209	5.706	200	5.42	95%
Maximum	11	0.30	265	7.2572	254	6.96	96%

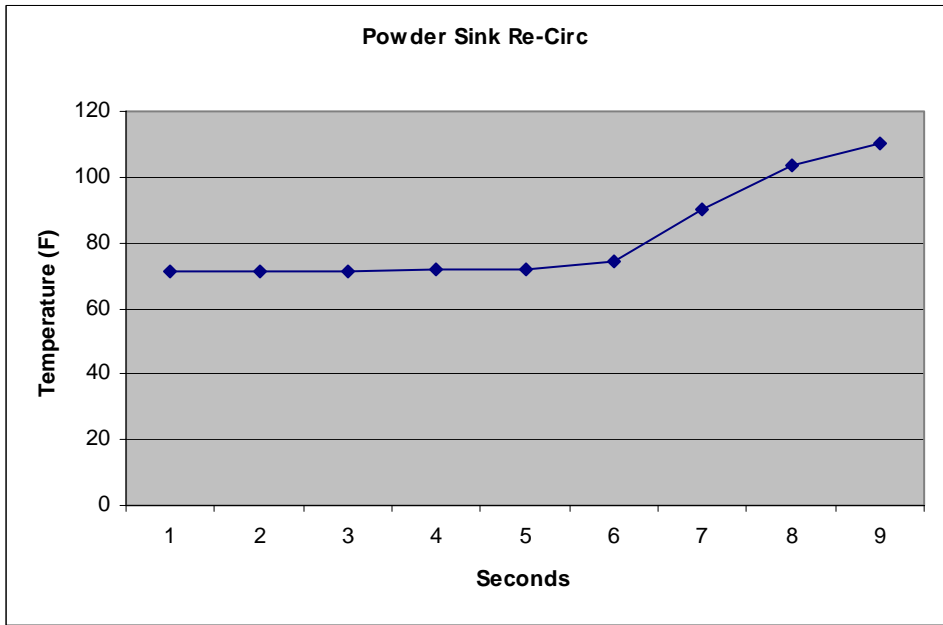


	Re-circulation		Standard		Savings		Water
	Seconds	Gallons	Seconds	Gallons	Seconds	Gallons	Savings
First rise	4	0.48	52	3.76	48	3.28	87%
Useful	5	0.55	64	4.62	59	4.07	88%
Maximum	9	0.64	103	7.46	94	6.82	91%





	Re-circulation		Standard		Savings		Water
	Seconds	Gallons	Seconds	Gallons	Seconds	Gallons	Savings
First rise	3	0.08	165	3.67	162	3.59	98%
Useful	4	0.09	223	4.96	219	4.87	98%
Maximum	6	0.11	342	7.61	336	7.51	99%

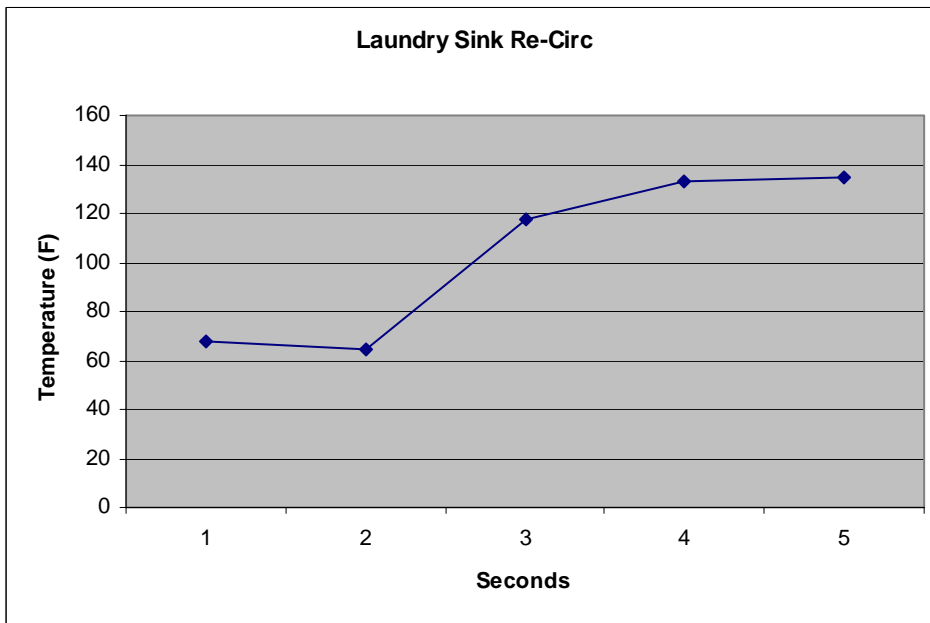


	Re-circulation		Standard		Savings		Water
	Seconds	Gallons	Seconds	Gallons	Seconds	Gallons	Savings
First rise	6	0.13	113	2.33	107	2.20	94%
Useful	8	0.16	150	3.13	142	2.97	95%
Maximum	10	0.18	265	5.63	255	5.45	97%



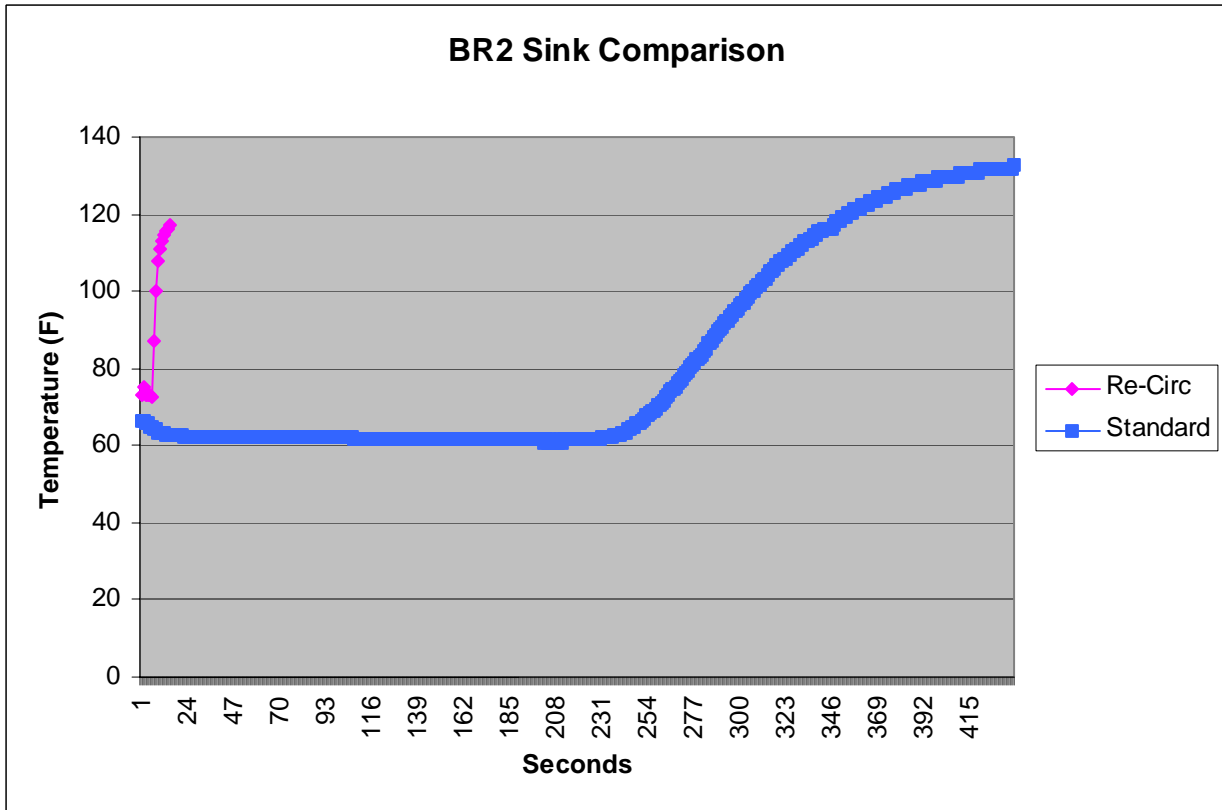


	Re-circulation		Standard		Savings		Water
	Seconds	Gallons	Seconds	Gallons	Seconds	Gallons	Savings
First rise	9	0.21	44	0.98	35	0.77	79%
Useful	11	0.24	70	1.56	59	1.33	85%
Maximum	13	0.27	142	3.19	129	2.92	92%



	Re-circulation		Standard		Savings		Water
	Seconds	Gallons	Seconds	Gallons	Seconds	Gallons	Savings
First rise	3	0.09	10	0.81	7	0.72	89%
Useful	3	0.09	14	1.12	11	1.03	92%
Maximum	5	0.15	42	3.30	37	3.15	95%





Graphical comparison of Wait Time for Hot Water – BR2 sink

Summary:

As can be seen from the preceding information, there is a significant reduction in water waste, and wait time for the demand re-circulation system. Gallons of water waste become cups, and hot water delivery times drop from minutes to seconds. Demand re-circulation systems show significant performance improvement over typical systems.

The demand re-circulation system walks the fine line between water and energy savings, in that there is some waste in one or the other when using traditional plumbing systems (closed, pressurized). A traditional trunk and branch system can minimize energy waste (as long as the user is present when the water becomes hot at the fixture), but maximizes water waste. Continuous re-circulation systems minimize water waste by keeping a loop of hot water throughout the building, but maximize energy waste by keeping the loop hot when there is no call for hot water. Demand re-circulation systems have the good characteristics of both systems, without the most of the adverse effects: they fill the re-circulation loop with hot water only when desired, yielding energy savings, and minimize water waste by bringing hot water to the end of the branch piping.

It is worth mentioning several side benefits to the demand re-circ system, aside from the water savings. Performance for the homeowner is perhaps the most notable, since a majority of homes have noticeable waits for hot water. Convenience and comfort (no longer washing hands w/cold water, or waiting) will rate favorably with most homeowners. Further, having a predictable time for the arrival of hot water can also reduce energy and water waste due to hot water running down the drain without being noticed. Finally, strain on municipal water supplies and water processing energy and chemicals can be reduced through conservation.

