REGION OF WATERLOO

Residential Water Softener Performance Study

Testing Report

October 5, 2012

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1.0 Introduction

The Region of Waterloo and the City of Guelph, Ontario, supply their customers with some of the "hardest" groundwater in Canada – as high as 960 ppm or 56 grains per U.S. gallon. Approximately 72% of the homes in the Region of Waterloo and the City of Guelph have ion exchange water softeners. In the Region of Waterloo it is estimated that 134,723 household water softeners use at least 2,753,738 m^3 of potable water and 44,700 tonnes of salt per year for softener regeneration.

Initial research by the municipalities found no independent test results on water softener performance that could be passed on to local consumers. As such, the two municipalities partnered to construct a water softener test rig at William Street Pumping Station in the Region of Waterloo. Ongoing testing has been conducted on several residential ion exchange water softeners since late 2009. The majority of softeners tested had regeneration cycles based on throughput (demand initiated regeneration or DIR) and one test softener used a sensor to determine when resin beds needed to be recharged. Softeners using simple timers to trigger regenerations were deemed to be obsolete and were, therefore, not tested[1]. This report (found at www.watersoftenerfacts.ca) presents the cumulative results of these water softener tests.

To make the testing as real as possible, automated flow control valves on the water supply piping to each softener simulated typical residential water demand profiles – a separate demand profile for each day of the week based on residential water demand data provided by the Region of Waterloo.

The parameters monitored as part of this program were:

- volume of water softened,
- volume of water wasted to drain during regeneration,
- weight of salt used during regeneration,
- hardness of water before and after softening,
- frequency of regeneration, and
- the energy used per volume of water softened (kWh).

The most common type of regeneration media in the Region of Waterloo and the City of Guelph is sodium chloride (salt). This was the media used to regenerate the softeners in this study.

2.0 Water Softeners Tested

Most of the water softeners tested in this study are widely available in Waterloo Region and Guelph areas. The residential softeners tested were "installed" by the retailer or manufacturer's representative and adjusted based on a water hardness of 580 ppm[2] (34 grains per U.S. gallon[3]) and a household occupancy of 3 persons. One water softener was purchased "off the shelf" from

[1] Most softeners available in the marketplace today use DIR.

[2] The hardness of the water supply to the test rig is 580 ppm (34 grains per U.S. gallon). The average water hardness in the Region of Waterloo is approximately 400 ppm, though values can reach 960 ppm. The average water hardness in the City of Guelph is 460 ppm, with a range of between 340 to 580 ppm. Another way to express ppm is mg/l.

[3] 1 grain = 0.0648 grams; 1 grain per U.S. gallon = 17 mg per litre (or ppm) of hardness (calcium & magnesium)

a local big box store and installed by a certified plumber. In each case, the installer was told to set the softener up as they would in a normal household with appropriate efficiency settings.

Residential water softeners employ an ion exchange process where calcium and magnesium ions in the water are replaced (exchanged) with sodium ions contained in the softener's resin bed – essentially a mass of small plastic beads. Unlike calcium and magnesium, sodium does not precipitate in pipes, water heaters, appliances, or cause soap scum – thus water containing no calcium or magnesium ions is deemed to be "soft". Once all of the sodium ions have been removed from the resin bed and replaced with calcium or magnesium ions, the bed must be regenerated. Regeneration involves flushing the resin bed with a strong brine solution. The sodium in brine replaces the calcium and magnesium ions that have built up in the resin bed with sodium ions. After regeneration the softening process is ready to begin again. The remaining brine, as well as the calcium and magnesium removed from the water, is discharged to drain during the regeneration process. An efficient softener will discharge a minimum volume of brine (water) to drain and use a minimum amount of salt during regeneration.

Most of the water softeners tested to date contain approximately one (1) cubic foot of resin. One cubic foot of resin is often reported as having the capacity to remove a maximum of 30,000 grains (464,396 grams) of hardness before reaching exhaustion. These demand initiated regeneration (DIR) water softeners are considered the typical size required for a family of three people in Waterloo Region and Guelph. Retail purchase prices of the tested water softeners ranged from approximately $800 to $3,000.

3.0 Methodology

A computer-controlled test rig capable of automating three water softeners at once was constructed at William Street Pumping Station in Waterloo in the fall of 2009.

The primary components of the test rig are as follows:

- Hard water supply
- Weigh scale, to measure salt use
- Water meter to measure volume of soft water produced
- 1.5 inch automated butterfly control valve used to simulate typical residential demands
- Soft water drain line
- Water meter to measure volume of water used during regeneration
- Automatic hardness analyser: Hach Aquatrend APA 6000 Analyser
- Power monitor to record energy usage: P4460 Kill A Watt*EZ*, Electricity Usage Monitor

To keep the water hardness analyzer used in this study functioning accurately, a constant flow of water from a separate (not tested) water softener was maintained. Accuracy of the hardness analyzer was routinely checked and verified through sampling and analysis by Region of Waterloo's Laboratory Services.

Accuracy of the following test rig components was certified:

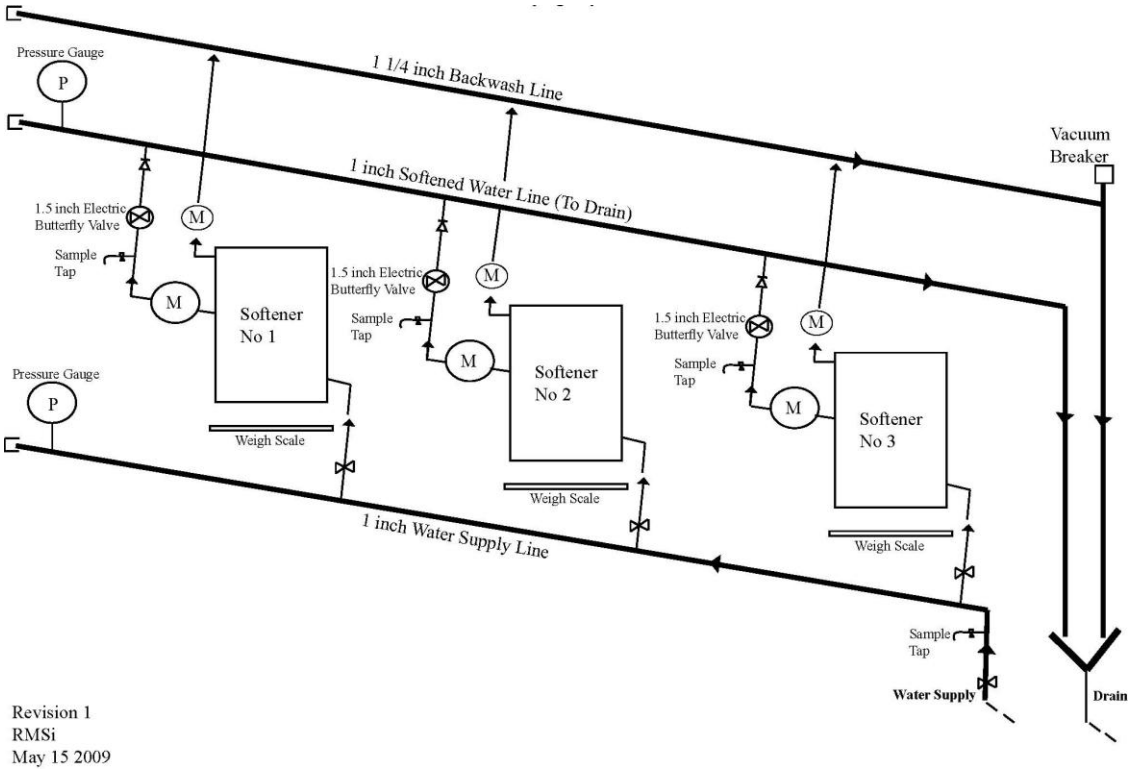
- Seametrics 20mm disc flow meters +/- 2% (measures wastewater from regeneration)
- Burkett Type 8081 instant flow meters +/- 2.5%
- Force Flow model PVC150KHA17 high accuracy carboy scales +/- 2.5%
- Hach model APA6000 hardness analyser 10-1000 ppm +/- 2.5%

Water softeners purchased for testing were "off the shelf" models and not modified. Each supplier was asked to install and set up their own softener on the test rig as if it were supplying a typical household of three people using a raw water hardness of 580 ppm (34 grains per U.S. gallon).

During softener test cycles, salt was loaded into brine tanks sitting on electronic weigh scales. Flow and weigh scale data were downloaded to computer by Region staff regularly. An independent consulting engineer was contracted to analyse, verify and summarize results.

Each of the test softeners were operated for a minimum of seven (7) days with the established test flow profile before the official test began. This ensured that the resin had been sufficiently conditioned and regenerated prior to the official reporting period. In most cases, test softeners were operated for more than seven days before the official test began.

Schematic of Test Rig



The photograph below shows the test rig and three water softeners being tested. The hardness analyser can be seen on the right side of the photo.

4.0 Water Use Profiles

As mentioned earlier, the water demands used in this study were meant to simulate typical household water demands. The demand patterns used in this study were based on the results of a household monitoring program completed in Waterloo Region[4]. A separate demand profile was used for each day of the week, which recreated typical water uses for a family of three in a detached home. The demand profile called for an average of 700 litres per household per day to flow through the test softeners. Flow rates through the softeners were (4, 17 and 33 litres per minute (lpm) for varied lengths of time, depending on the simulated time of day and day of the week. The source water pressure flowed at 565 kPa (82 psi).

The tables below detail the test flow profiles for the seven day test cycle. The 10 per cent "make up" water includes 25 litres per day of trickle flow to an automated hardness analyzer, plus a small amount of additional water to make sure daily volume targets were achieved.

Average Household Monday		
Flow Rate	Duration	Volume
lpm	minutes	litres
4	**2.92**	**11.68**
33	**6.60**	**217.89**
17	**20.00**	**178.09**
sub total	29.52	407.66
	10% make up	**45.30**
	Total	452.96

[4] Residential End Uses of Water, American Water Works Association Water Research Foundation, 1999; Region of Waterloo Water Efficiency Master Plan Update, data logging, 2005

Average Household Tuesday		
Flow Rate	Duration	Volume
lpm	minutes	litres
4	**3.70**	**14.80**
33	**12.15**	**400.86**
17	**20.02**	**340.33**
sub total	35.87	755.99
	10% make up	**84.00**
	Total	839.99

Average Household Wednesday		
Flow Rate	Duration	Volume
lpm	minutes	litres
4	**3.55**	**14.18**
33	**12.27**	**405.01**
17	**18.64**	**316.88**
sub total	34.46	736.07
	10% make up	**81.79**
	Total	817.86

Average Household Thursday		
Flow Rate	Duration	Volume
lpm	minutes	litres
4	**17.69**	**70.77**
33	**10.29**	**339.55**
17	**11.97**	**203.44**
sub total	39.95	613.76
	10% make up	**68.20**
	Total	681.96

Average Household Friday		
Flow Rate	Duration	Volume
lpm	minutes	litres
4	**8.96**	**35.83**
33	**15.46**	**510.08**
17	**9.58**	**162.89**
sub total	34.00	708.80
	10% make up	**78.76**
	Total	787.56

Average Household Saturday		
Flow Rate	Duration	Volume
lpm	minutes	litres
4	**7.86**	**31.44**
33	**6.65**	**219.38**
17	**18.80**	**319.53**
sub total	33.31	570.35
	10% make up	**63.37**
	Total	633.72

Average Household Sunday		
Flow Rate	Duration	Volume
lpm	minutes	litres
4	**3.21**	**12.83**
33	**11.19**	**369.42**
17	**14.10**	**239.78**
sub total	28.50	622.03
	10% make up	**69.11**
	Total	691.14

The six parameters logged for each water softener are as follows:

- Instantaneous flow rate (lpm) logged every 2 minutes
- Cumulative volume (litres) logged every 30 minutes
- Wastewater flow rate (US gpm) logged every minute
- Weight of salt (kg) logged every hour
- Water hardness (ppm) logged every 5 minutes
- Kwh per day of energy use

Both the volume of softened water, and the volume of water used to regenerate (wastewater), are each recorded by a water meter. The data logger takes a reading of the water meter register, which records the total volume of water passed through the meter. The daily total volumes are calculated by taking the register (and data logged) reading at the start and the end of the 24 hour period – this gives the daily total of water passed through each respective water meter.

5.0 General Test Results

The water softener testing conducted to date is considered preliminary, and the Region of Waterloo and City of Guelph have decided not to publish details on the performance of individual water softeners at this time. The project team is currently reviewing the results to finalize suggested changes to the test protocol. Following a peer review of the revised test protocol and approvals by Region of Waterloo and City of Guelph, water softener performance testing and reporting is expected to continue. At that time, any softeners tested with the earlier protocol must be retested.

Most single tank water softeners are set to regenerate when the resin tanks have used up about 75% of capacity in order to prevent household water from getting hard during higher demand *days. Water softeners are typically set to regenerate over night when water is not being used, and* the buffer helps to provide soft water until the evening regeneration time arrives. Water softeners will also use salt more efficiently if they regenerate before resin beds become exhausted.

Two units tested to date recharged at any time during the day or night. These units contain two smaller resin tanks, so that when one tank is exhausted and recharging, water continues to be softened through the second tank. These systems ensure that soft water is supplied at all times.

The preliminary test results reported how much salt and water each softener used per cubic meter (m^3) of softened water produced[5]. Energy consumption was reported in kWh per day consumed. In several cases, water softeners consumed such little power that usage could not be detected. Of the softeners tested, only the Kinetico, which is completely mechanical, uses zero power. Estimated annual operating costs for the nine softeners listed in Appendix A are summarized below. The estimates are based on a year of operation at the William St. Pumping Station. Operating costs are mainly affected by salt consumption, because this is the most costly input.

Performance Level	**Salt kg per m^3 Water**	**Litres Regeneration per m^3**	**kWh Per Day Energy**	**Estimated Annual Operating Cost**
Lowest Salt Usage	0.8	49	0.00	$125
Lowest Water Usage	0.8	49	0.00	$125
Average Salt/Water Usage	1.0	76	0.00	$192
Highest Water Usage	1.0	105	0.11	$194
Highest Salt Usage	1.7	82	0.00	$248

In several cases, test water softeners were unable to produce continuously soft water and the original installers would be called to adjust or repair the units. This caused significant delays in the research. When the units stopped producing soft water, even if for one day, data collected to that point in the test was not considered valid. The test results reported are for periods when water softeners were producing softened water continuously for a minimum of 20 days.

If the softeners were operated at the William Pumping Station in Waterloo for one year, operating costs would range from $125 to $248 per year. The most expensive part of operating a water softener is the cost to purchase salt; therefore, the best way to control costs is to reduce salt consumption.

[5] 1 cubic metre (m^3) = 1,000 litres

6.0 NSF/ANSI 44 Performance Standard

The project team compared test results in this study with a voluntary water softener performance standard established jointly by the American National Standards Institute (ANSI) and the National Sanitation Foundation (NSF). The NSF/ANSI Standard 44 for "Cation Exchange Water Softeners" was first published in 1987 following an examination of the U.S. Water Quality Association (WQA) S-100 test criteria. Products passing the NSF/ANSI Standard 44 are certified for the removal of hardness (calcium and magnesium). Table 5 below quantifies the performance standard in both U.S. units of measure, and in metric units of measure.[6]

Table 1 – NSF/ANSI Standard 44 for Cation Exchange Water Softeners

	Notes
Minimal removal capacity of 3,350 grains per pound of regenerant salt consumed	U.S. measures
1,000 grains hardness removal capacity per 5 U.S. gallons of regeneration water discharged	U.S. measures
477 grams hardness removed per 1 kilogram regenerant salt consumed	Metric measures
64.8 grams hardness removed per 18.9 litres regeneration water discharged	Metric measures

Although the results in this study were used to compare against the performance benchmarks established in the NSF/ANSI Standard 44, it should not be construed that the softeners pass or fail against the standard. The tests in this study were not refereed by NSF/ANSI, and test methodology used in Waterloo is not the same as that used by NSF/ANSI.

All the water softeners tested in Waterloo exceeded NSF/ANSI 44 performance standards for water efficiency. In some cases, the softeners used half to one-third the regeneration water allowed in the standard.

Three of the water softeners tested to date may not have been able to meet the NSF/ANSI 44 performance standard for salt usage. Future reporting will provide more details regarding performance standards and how softeners may be adjusted or modified to perform more efficiently in Waterloo Region and Guelph.

7.0 Conclusions

1. Many of the water softeners tested to date had difficulty producing soft water at all times. Technicians were called frequently to adjust controllers to try and resolve the problems. Softeners were required to produce softened water continuously during the test period for results to be considered valid. Thus, reporting periods were for as little as 20 days. It has been suggested by some suppliers that "break through" hardness may occur in single tank units when peak water demands exhaust the resin before the scheduled evening regeneration, especially during the first 30 days of operation. Following the first 28-30 days of operation,

[6] 1 grain = 0.0648 grams; 1 grain per U.S. gallon = 17 mg per litre (or ppm) of hardness (calcium & magnesium)

some controllers reportedly adjust regeneration scheduling automatically based on actual water consumption patterns. The project team is now reviewing the duration that water softeners should be tested and how results will be recorded in the future.

2. In recent consultation with water industry stakeholders, consensus has grown regarding the need to condition the resin prior to commencing water softener testing. Stakeholders have advised that new softeners come with "supercharged" resin that should be operated for a length of time before any official performance data is collected. In consideration of these varying approaches, the appropriate duration of the resin conditioning period has not yet been finalized.

3. When functioning according to manufacturer design, the water softeners removed nearly all of the hardness[7]. With the exception of testing one water softener with hard water blending turned on, test softeners produced water with hardness ranging from 0 – 34 ppm (0 – 2 gpg)[8]. According to Canadian Water Quality Association Executive Director Kevin Wong, household water users cannot tell the difference between 17 ppm (1 grain per U.S. gallon) and 51 ppm (3 grains per U.S. gallon) of hardness. The water still "feels" soft to humans at 51 ppm of hardness.

4. The results indicate that the most water efficient water softeners are not necessarily the most salt efficient and vice versa.

5. This study did not measure long term maintenance costs or performance. Softener reliability and longevity would require further study.

6. DIR water softener controllers are typically adjustable and may be set to regenerate at various "salt dosages." At lower salt consumption settings, regeneration cycles are more frequent. More frequent regeneration usually means less overall salt consumption but potentially higher water wastage for backwash and brining purposes.

7. Despite the different test protocol and different source water used in the Waterloo Region study, most DIR softeners tested would pass the NSF/ANSI 44 performance standard. As such, NSF/ANSI 44 could be considered a minimum performance standard. Moving beyond NSF/ANSI 44, there is an opportunity to establish higher performance benchmarks for water softeners that could help consumers choose water softeners that use significantly less salt and water than the average unit

8. The water softeners tested to date are considered a "convenience sample" of DIR units available. There are many more brands of water softeners available on the market that could be tested in the future to form a more representative sample.

[7] The Water Quality Association-reported ranges of hardness are: soft < 17 ppm; slightly hard 17–60 ppm; moderately hard 60–120 ppm; hard 120–180 ppm; very hard >180 ppm.

[8] Note: To fully soften water at William Street Pumping Station in Waterloo, test softeners would need to remove 565 grams of total hardness from 1 m^3 of supply water. This would bring hardness to 15 ppm, which is just below 1 grain of hardness per U.S. gallon.

9. Researchers have found that water softeners with the same components and specifications are often sold under different brand names by authorized dealers. In order to avoid confusion, water softeners tested in this study were identified according to the brand name they were sold under.

10. Aside from using more efficient water softeners, there is also an opportunity to achieve both water and salt conservation by installing water softeners on the hot water supply only. Jurisdictions wishing to promote the reduction of salt and wastewater discharges may wish to pursue greater compliance with this building practice.

11. Another way to reduce wastewater and salt usage is to blend hard water with softened water using a valve to produce slightly hard water as is possible with the German manufactured unit tested. A hardness level of 85 to 136 ppm (5-8 grains per gallon) is considered sufficient for household use.

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Appendix A - Water Softeners Tested and Resin Volume (Not ranked according to performance)

Softener Brand Name	Valve & Controller	Resin Volume ft^3	# Resin Tanks
Culligan Medallist Plus 30	**Culligan Medallist (30&45) Gen2 Soft-Minder, Part No: 01016379D**	1.00	1
Ecowater GS6225D	**3/4" Ecowater 500 Series valve & Controller, Part #7246738**	0.75	1
Novatek NT32SE	**Metermatic SE, Model 7500 EM**	1.00	1
Kinetico 2040	**0.3-25.0 polypropylene turbine Kinetico Mach**	0.80	2
762 Metered Softener Logix	**Autotrol 255 valve with 762 Logix controller**	1.00	1
Culligan Sensor Gold 9"	**Culligan Gold 1"**	1.00	1
General Electric GXSF30H	**General Electric GSF30H, 3/4" valve, Part #7231929**	0.78	1
Petwa CL Series Crystal Vision WS1CS30	**Clack WS1**	1.00	1
Aqa Perla 11299	**Item #950000020**	0.38	2

Notes:

The above list only includes softeners tested that produced comparable results when tested against the test protocol

Suppliers often quote a softener with $1ft^3$ of resin has a hardness removal capacity of about 30,000 grains by weight before exhaustion

The Aqa Perla removal capacity is certified under German and UK Standards, but is purported comparable to 1 ft^3 resin units