



REGION OF WATERLOO

Residential Water Softener Performance Study

Testing Report #1

April, 2011

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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 m³ 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 or satisfactory benchmarks 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. From late 2009 to the end of 2010, nine different water softener models were tested. Eight of the softeners 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 tested¹. This report 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

Eight of the nine water softeners tested in this study are widely available and are of similar capacity. Each residential softener was “installed” by the manufacturer’s representative and adjusted based on a water hardness of 580 ppm² (34 grains per U.S. gallon³) and a household

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.

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

occupancy of 3 persons. One of the water softeners tested is manufactured in and imported from Germany, and is not currently available through local retail outlets.

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. Water softeners must regenerate more frequently as the hardness of the supply water increases. The sodium in brine relaces 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.

The water softeners tested through this study include:

1. Culligan

- Medallist Series Automatic Water Conditioner, Model: Plus 30
- Exchange capacity at Salt Dosage Per Recharge = 27,700 grains @ 12 lb.
- Controller: Medallist (30 & 45) Gen2 Soft-Minder. Part No: 01016379D

2. Ecowater

- Automatic Water Conditioner, Model: GS6225D
- Exchange capacity at Salt Dosage Per Recharge = 28,700 grains @ 12 lb.
- Controller: 500 Series valve and controller. Part No: 7276759

3. Novatek

- Automatic Water Softener, Model: Model NT32SE
- Exchange capacity at Salt Dosage Per Recharge = 30,000 grains @ 10 lb per cu ft.
- Controller: Metermatic SE, Model 7500EM

4. Kinetico

- 2040S Mach Series – twin tank
- Capacity 5,222 grains @ 1 lb. salt
- Controller: 0.3-25.0 polypropylene turbine Kinetico Mach

5. General Electric

- Smart Water™ Softening System
- Model: GXSF30H
- 30,200 grains @ 12.5 lb. salt
- Ecowater high flow valve and electronic controller

6. Culligan Sensor

- 9" QH Gold Series Model 30
- 27,700 grains @ 12lb. salt
- Controller: Culligan Gold 1"

7. Ontario Soft Water

- 255 Performa Series
- 25,460 @ 7lb salt
- Controller: Logix 762

8. Crystal Clear

- CL Series, Model: 01-8301 ES1CS-30
- 32,000 grains @ 10 lb. salt
- Controller: CLACK WS1CS, 1" valve

9. Aqa Perla

- PNR 6-500050/11299
- Twin resin tanks BNC-0521-A8E
- Total grain capacity 3,692 (1,846 per tank) @ 250 grams salt per tank regeneration
- Item #950 000 020

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 WattEZ, 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 through sampling and analysis by Region of Waterloo's Laboratory Services.

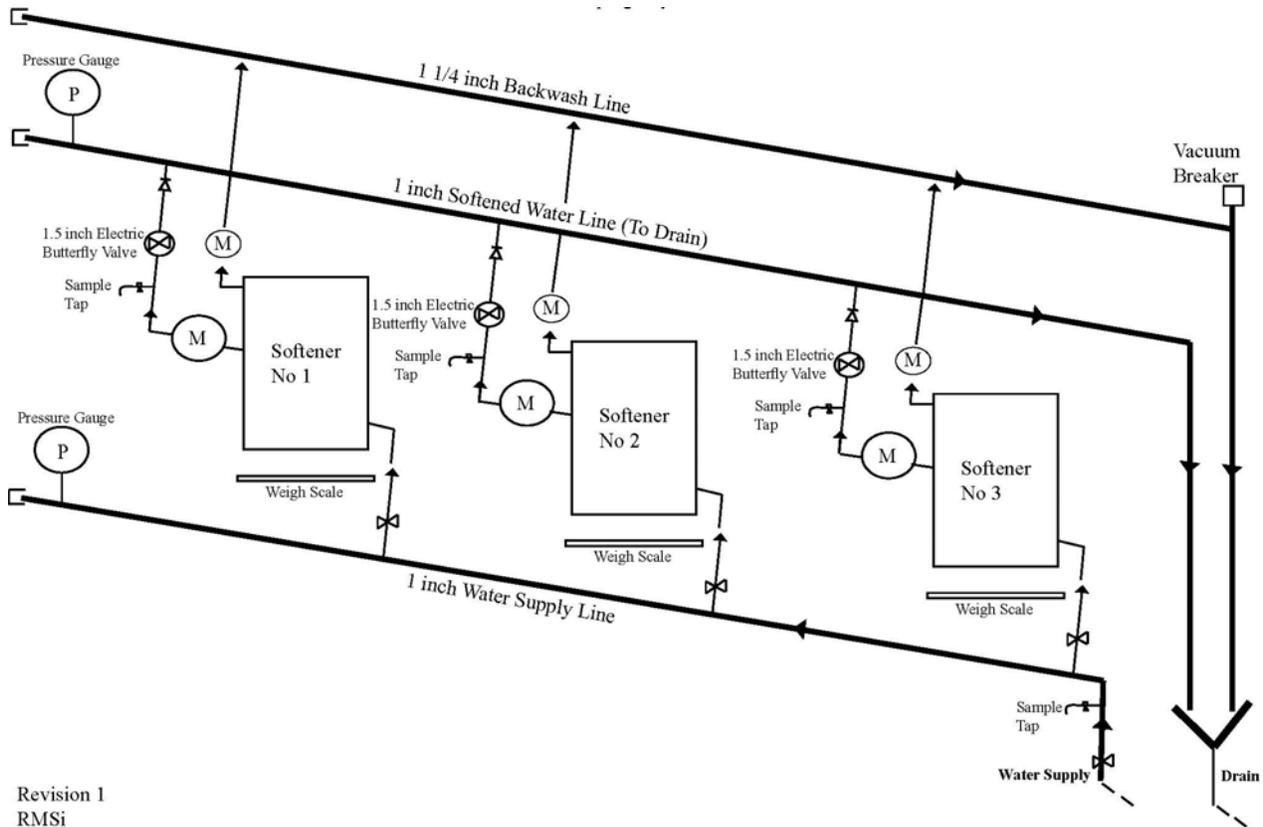
Accuracy of the following test rig components was certified:

- 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.

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.

Schematic of Test Rig



Revision 1
RMSi
May 15 2009

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. 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. Occasionally, the instrumentation failed to keep flow rates and daily volumes within 5-7% of target values. These data were not included in the analysis.

Each softener remained on the test rig for at least 30 days. However, results detailed in this report reflect only those days when flow rates and daily volumes were within target parameters. Reported results range from 14 - 42 days of testing.

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

5.0 Test Results

For ease of comparison, regeneration water and salt usage data has been reported on a per cubic meter (m^3) of softened water produced.⁴ Table 1 below indicates how many litres of regeneration water went to drain (waste) for every m^3 soft water produced. Table 2 indicates how many kilograms (kg) of salt were used to produce every m^3 of soft water. Table 3 reports energy demands in kilowatt hours (Kwh) per day.

5.1 Regeneration

Table 1 - Volume of Water Used for Regeneration Per 1,000 litres (m^3) of Softened Water

Softener	# Test Days	Regeneration: Litres per m^3 Produced	Approx. Regeneration Frequency in days
GE	14	43	2.8
Kinetico	42	57	1.0
Ont. Soft Water	42	69	3.3
Novatek	23	80	4.0
Aqa Perla	14	83	2.8
Crystal Clear	14	89	3.4
Culligan Sensor	37	91	3.0
Ecowater	20	98	1.3
Culligan	20	105	3.3

Most 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 25% buffer helps to provide soft water until the evening regeneration time arrives.

The Kinetico and Aqa Perla softeners were the only units tested that recharge 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 may allow for better utilization of resin capacity and ensure that soft water is supplied at all times.

⁴ 1 cubic metre (m^3) = 1,000 litres

5.2 Weight of Salt Used

Table 2 - Kilograms of Salt Used per m³ of Softened Water Produced

Softener	Number of Test Days	Kg Salt per m ³ soft water produced
Kinetico	42	0.8
Culligan	20	1.0
Novatek	23	1.2
Ecowater	20	1.3
Culligan Sensor	37	1.3
GE	14	1.3
Crystal Clear	14	1.5
Ontario Soft Water	42	1.6
Aqa Perla	14	1.9

5.3 Power Used

Energy use is not considered to be a big operating factor for residential ion exchange water softeners. The Kinetico softener is the only unit tested to date that operates on a strictly mechanical (kinetic) basis and requires no electricity. The other units tested use very little energy. In three cases, energy consumption was so low that it was not detectable by the instrumentation used. Table 3 summarizes the energy consumption in kilowatt hours (kWh) per day.

Table 3 – Energy Consumption, kWh Per Day

Softener	Number of Test Days	kWh/Day Energy Use
Kinetico	42	0.00
Ecowater*	20	0.00
GE*	14	0.00
Crystal Clear*	14	0.00
Aqa Perla	14	0.01
Ontario Soft Water	42	0.06
Culligan	20	0.11
Novatek	23	0.11
Culligan Sensor	37	0.16

* equipment not able to measure the low energy demands; no data available

5.4 Estimated Operating Costs

For comparison purposes, annual operating costs were calculated for each water softener tested. Assumptions were that the average household uses 251 m³ per year of water; a 20 kg bag of salt, delivered to the home, costs \$9.44; the combined water/sewer rates are \$3.26 per m³ and energy costs \$0.11 per kW-h.⁵

⁵ Based on 2010 costs in the City of Kitchener.

Table 4 – Estimated Water Softener Annual Operating Costs

Softener Name	\$ Water/sewer	\$ Salt	\$ Power	Tot. Cost/yr
Kinetico	46.63	94.70	0	\$141
Gen. Electric	35.17	153.90	0	\$189
Culligan	85.89	118.38	4.42	\$209
Novatek	65.44	142.06	4.42	\$212
Ecowater	80.17	153.90	0	\$234
Culligan Sensor	74.44	153.90	6.43	\$235
Ont. Soft Water	56.44	189.41	2.41	\$248
Crystal Clear	72.80	177.57	0	\$250
Aqa Perla	67.90	224.92	0.40	\$293
			Average	\$224

5.5 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 5 – 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
478 grams hardness removed per 1 kilogram regenerant salt consumed	Metric measures
342 grams hardness removed per 100 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.

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

Six of the nine water softeners tested 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.

6.0 Conclusions

1. When functioning according to manufacturer design, test water softeners removed virtually all the hardness⁷, with the resulting water having hardness levels below 17 ppm. Any level below 17 ppm, or one grain per gallon, is considered soft⁸. 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.
2. The results indicate that the most water efficient water softeners are not necessarily the most salt efficient and vice versa.
3. Although water softener controllers are adjustable, suppliers installed and set test units to factory settings. This proved beneficial for the purposes of this study, but may be the reason that some showed weak results when compared to the NSF/ANSI benchmark for salt consumption. Further testing is warranted.
4. There is an opportunity to share this water softener test data with the U.S. Environmental Protection Agency (EPA) “WaterSense” benchmarking initiative. The EPA issued a “Notification of Intent” to establish performance standards for cation exchange water softeners on November 10, 2010. The goal of EPA is to establish higher performance benchmarks for water softeners than those established by NSF/ANSI. Water using appliances passing the WaterSense benchmark are at least 20 percent more water-efficient than conventional models, and are given the WaterSense label. WaterSense labelling is visible across the United States and is in the process of being recognized in Canada.
5. There is a need to continue measuring the performance of residential ion exchange water softeners of varying capacity and design to build a larger database for comparison and reporting purposes.
6. Preliminary short-duration testing was done on three softeners with potassium chloride in place of sodium chloride salts. Although results were not conclusive, indications were that softeners may perform significantly differently when potassium chloride is used instead of sodium chloride. Further testing is required.

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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 soften water at William Street Pumping Station in Waterloo, test softeners would need to remove 565 grams of total hardness from 1 m³ of supply water. This would bring hardness to 15 ppm, which is just below 1 grain of hardness per U.S. gallon.