RESEARCH HIGHLIGHT

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Drainwater Heat Recovery Performance Testing at CCHT

INTRODUCTION

Drainwater heat recovery (DWHR) is a relatively simple technology to reduce household hot water energy consuption and to prolong the availability of hot water during periods of high demand or continuous use. Drainwater heat recovery units take advantage of the fact that as water drains it clings to the sides of vertical drainpipes due to surface tension. This creates a very high surface-contact-to-volume ratio, allowing heat to be recovered from the drainwater by wrapping the incoming cold water supply pipe around the vertical drain line. A number of proprietary DWHR units currently exist. A research program to assess the extent to which they can recover energy was initiated at the Canadian Centre for Housing Technology (CCHT)[1].

Six standard manufactured units were tested in two studies in 2005 and 2006. These units consist of various lengths of 3-in. (76.2 mm), nominal diameter copper drainpipe, wrapped with a soft copper tube, either 1/2 in. (12.7 mm) nominal or 3/8 in. (9.5 mm) nominal. Cold water circulates in the smaller tubes to recover the heat from the drainwater, as shown in figure 1. The various units have different patterns for winding the tube pipe around the drainpipe and the tubes are formed in slightly different shapes.

In most homes, there are drainwater “events” that include only cold water (toilets), both hot and cold water (sinks, clothes washing and showering) and hot water only (dishwashers).

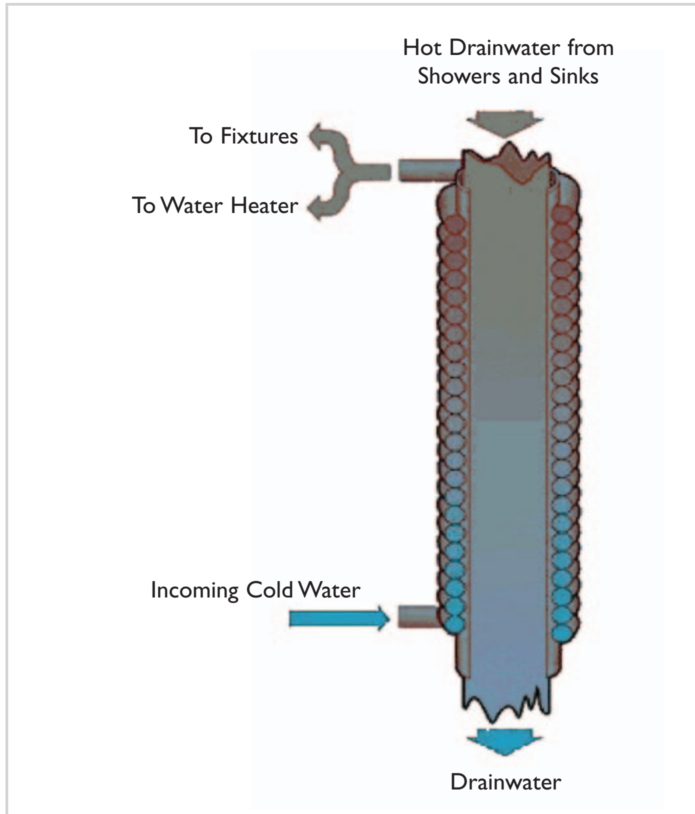

Figure 1 Schematic of cross-section of a typical DWHR unit

[1] The Canadian Centre for Housing Technology (CCHT) is a research facility dedicated to the evaluation of technical innovations for housing.. The Centre is jointly operated by the National Research Council (NRC), Natural Resources Canada (NRCan) and Canada Mortgage and Housing Corporation (CMHC). The CCHT research and demonstration facility features two highly instrumented, identical, two-storey houses with full basements. The houses, each 210 m^2 (2,260 sq. ft.), are built to R-2000 standards and use simulated occupancy to evaluate the whole-house performance of new technologies in side-by-side testing. The CCHT also has an Info Centre that includes a demonstration of FlexHousing™. For more information about CCHT, go to http://www.ccht-cctr.gc.ca

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Some events involve simultaneous hot water draws and warm waste water flows (sinks and showers) and some involve delays between hot water draws and warm waste water flows (clothes washers, dishwashers and baths). The distinction between these events is important, because the type of DWHR device tested has very little storage and works best with long, simultaneous flows, such as showers.

RESEARCH PROGRAM

The CCHT researchers started studying the effectiveness of drainwater heat recovery units in 2005 by measuring the daily natural gas savings from three different units in two plumbing configurations and four daily schedules of hot and cold water draws.

Effectiveness testing was also done on a total of five units. One of the objectives of this study was to determine whether non-simultaneous flows have an impact on energy savings offered by the DWHR units tested and whether they should be considered in future modelling efforts.

The 2005 study confirmed that the heat recovered from non-simultaneous flows was inconsequential. A follow-up to the initial study in 2006 tested the performance of six units, including the five models first tested in 2005.

The 2006 study created a more accurate effectiveness model, combining principal data from shower-only flow tests with mathematical modelling to develop an energy savings calculator; flow vs. drop in water line pressure curves for each unit, and a test procedure for future performance testing of DWHR units.

All testing and monitoring for this research took place at the Canadian Centre for Housing Technology (CCHT).[1] The 2005 tests were performed in the CCHT test house and the 2006 tests were performed in the FlexHouse™ unit of the CCHT Info Centre building. These tests did not involve the usual CCHT twin-house, side-by-side house testing.

METHODOLOGY

Two different installation configurations were used in the two studies. In some tests, these configurations were compared to a benchmark configuration. All units had a 3-in. inner drainpipe diameter.

- Benchmark: No heat recovery, the unit is isolated.
- Configuration A: Water to the hot water tank (HWT) is preheated by the DWHR unit.
- Configuration B: Cold Water to HWT and cold water to the shower is preheated by the DWHR unit.

Tables 1 and 2 show the general characteristics of the units tested and which units were tested in each study.

Table 1 DWHR units tested

Unit	Unit Length		2005 Tests		2006 Tests	
	Actual length (in.)	Coiling length (in.)	Daily water draws	Effectiveness	Configuration A	Configuration B
PowerPipe R3-60	60	55.5	√	√	√	√
PowerPipe R3-36	36	31		√	√	√
GFX, G3-60	60	60.25	√	√	√	√
GFX, G3-40	40	36		√	√	√
ReTherm S3-60	60	2@28	√	√	√	√
ReTherm C3-40	40	36			√	√

Table 2 DWHR tube characteristics

Unit	Unit Length		Tubing			
All units with 3 in. inner pipe diameter	**Actual length (in.)**	**Coiling length (in.)**	**Tubing diameter (in.)**	**Tube passes**	**Winding**	**Squareness**
PowerPipe R3-60	60	55.5	0.375	Quadruple pass	Single sections	Squarest
PowerPipe R3-36	36	31	0.375	Quadruple pass	Single sections	Squarest
GFX, G3-60	60	60.25	0.5	Single pass	Single sections	2nd squarest—nearly square
GFX, G3-40	40	36	0.5	Single pass	Single sections	2nd squarest—nearly square
ReTherm S3-60	60	2@28	0.5	Single pass	Two equal sections	3rd squarest—nearly square
ReTherm C3-40	40	36	0.5	Single pass	Single sections	3rd squarest—nearly square

Figure 2 Three units from Phase 1 report. From top to bottom: ReTherm S3-60, GFX G3-40, PowerPipe R3-36.

INSTALLATION

Phase One Study, 2005

For the daily draw testing, each DWHR unit was installed and fitted with five valves to allow the three modes of operation—Benchmark, Configuration A, Configuration B. A mixing valve maintained the shower temperature at about 46°C (114°F). A 100 L (22 U.K. gal.) reservoir simulated the storage of water in baths, clothes washers and dishwashers, while a motorized damper was used to flush the toilet automatically .

A pulse-generating natural gas meter connected directly to the hot water tank (HWT) measured fuel consumption. Three pulse-generating water meters measured flows of cold, hot and warmed water. Eight thermocouples evaluated the performance of the system and the effectiveness of the DWHR. Data was logged in 10-minute intervals for daily water draws and at one-minute intervals for the long-shower tests for effectiveness.

Phase Two Study, 2006

The DWHR units were installed the same as in the initial study, with pressure transducers installed at the inlet and the outlet to measure the pressure lost in the outer coil at various flows. Thermocouples were installed on the top and bottom connections and at the inlet and outlet of the outer coil. To compensate for variations in temperature of the cold water supply, a 2 kW (2.68 hp) chiller was used to chill two reservoirs in a closed-loop arrangement powered by a circulating pump. A cold-water mixing valve was installed between the cold and city flow to ensure better temperature control. This set-up maintained cold water temperature at 8°C (46°F).

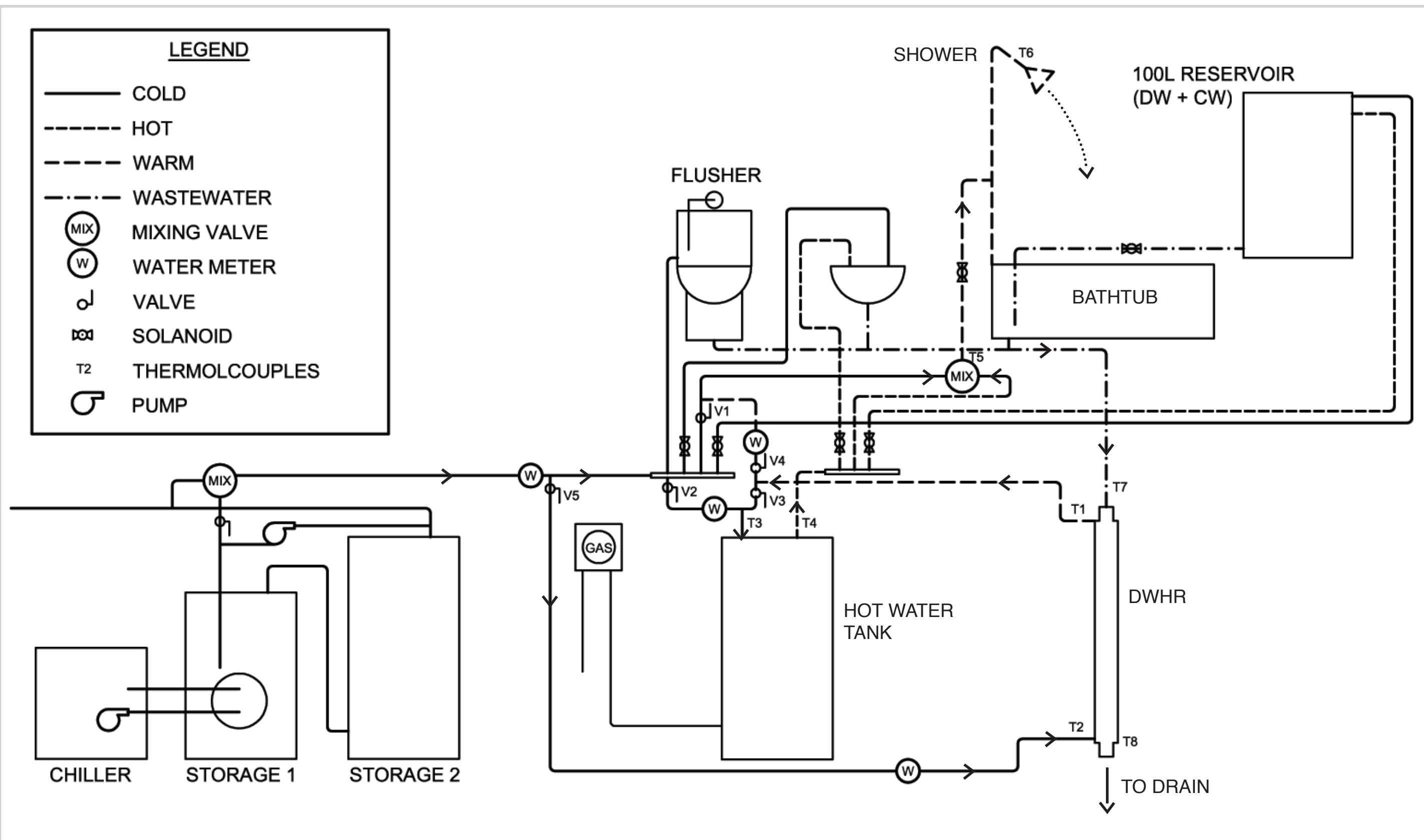

Figure 3 Schematic layout of the DWHR device testing configuration.

TESTING

Phase One Study, 2005

Two types of tests were performed in the initial study. The first test quantified the energy savings possible in a typical home with two, three and four occupants. Each unit was tested in eight combinations of configurations and schedules. Daily draws used in the study were similar to those used to evaluate water heaters at the CCHT.

To estimate the importance of non-shower savings, a comparison was made between the benchmark and testing data from 8:30 a.m. on (after the hot water tank had time to recover from the last shower). The second test was to determine the effectiveness of the DWHR units. The "in situ"[2] effectiveness tests consisted of running the shower until the water temperature dropped from 46°C (114°F) to below body temperature (37.0°C— 98.6°F) for each unit in each configuration.

Phase Two Study, 2006

The testing focused on shower flows and inlet–outlet temperatures of six DWHR units for Configuration A (preheat to hot water tank) and Configuration B (preheat to shower and hot water tank).

Energy recovery and performance were measured for shower flows of 6.5, 8.5 and 10 L (1.4, 1.8 and 2.2 U.K. gal.) per minute at shower temperatures of 37, 41 and 45 degrees Celsius (98.6, 105 and 113 degrees Fahrenheit). Cold water was fixed at 8 °C (46°F). Reduction in water line pressure was measured across each pipe at the three flow rates noted above.

After initial testing of all parameters on two units (18 tests per pipe), trends in calculated NTU (number of thermal units)[3] curves allowed the number of tests required per unit to drop to between 8 and 10. The only relevant parameter in evaluating the NTU for each heat exchanger was the flow rate.

FINDINGS

Phase One Study, 2005

There were 33 days of benchmarking and 72 days of testing between September, 2005 and February, 2006. The results represent the natural gas savings with a range of cold water temperatures (daily minimums of 19.4°C [66.92°F] to 9.5°C [49.10°F]) and adjusted water draws. As a result, annual savings cannot be projected through simple multiplication. Theoretically, some savings should be provided by non-simultaneous flows due to the storage of heat in the water contained in the outer tube and in the mass of copper. Testing showed that non-shower savings during the day were negated by a single cycle of the HWT burner caused by tank losses at times when there were no hot water draws.

The in situ effectiveness testing looked at how long the shower could be run before the water temperature dropped below 37°C (98.6°F). All DWHR devices resulted in significantly longer hot water availability times than the benchmark time of 28 minutes.

Configuration A results ranged from 39 minutes to 62 minutes. Configuration B results ranged from 53 to over 75 minutes.

The overall thermal effectiveness in terms of the length and mass of each unit ranged from 46 per cent to 67 per cent. Configuration A was more thermally effective than Configuration B during the shower-only testing, due to the lower flow rate of cold water, which allows the temperature of the water exiting the DWHR unit to get closer to the temperature of the drain water flowing through the unit. However, during the full-day tests, more natural gas was saved in Configuration B, as the larger volume of water flowing through the DWHR unit compensates for the lower effectiveness.

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2 The results are called "in situ" effectiveness because the testing conditions were not as effectively controlled as in a laboratory.

3 NTU=number of heat transfer units. The NTU is a measure of the heat transfer size of the heat exchanger: the larger the NTU, the closer the heat exchange approaches its thermodynamic limit. The NTU-effectiveness method gives the ratio of the actual rate of heat transfer to the maximum possible rate of heat transfer in a heat exchanger. This method is particularly useful when outlet temperatures are not given.

Phase Two Study, 2006

Effectiveness

There were some performance differences observed in the six DWHR units tested that related to the length of the unit and the way in which the soft copper tube was shaped and wound around the drainpipe. It was found that there is an optimal balance between performance and size: as the pipes get longer, they tend to add only marginal benefits to the performance. Shorter pipes generally perform best on a per-foot basis.

Reduction in Water Line Pressure

Different patterns of wrapping the soft copper tube around the drainpipe were shown to impact on the water pressure loss in the water line. The longest DWHR unit created the greatest pressure loss, while units where water travels through multiple tubes in parallel or sections had much smaller pressure loss. Homes with low-pressure systems, such as a deep well pump, might find the DWHR unit significantly affects shower pressure when other draws are being made on the system at the same time. Units that feature design considerations to minimize the reduction in water line pressure will be best suited for these situations.

Energy Savings Calculator

An energy savings calculator was developed from the performance modelling and testing. The on-line calculator (http://www.ceatech.ca/calculator) includes a correction for seasonal temperature changes in cold water supply. Users input the following data to determine which, if any, DWHR device is most effective at saving energy in their household.

- Shower temperature (3 options)
- Length of shower
- Number of showers per day
- Type of showerhead (4 options)
- Type of hot water tank in the home (pull-down list)
- Type of DWHR unit (pull-down list, will be expanded as other units are tested)
- Closest city (for cold water supply temperature)
- Configuration Type (A or B)

Table 3 shows the calculator results from six tested units. The default parameters used as the basis were: four, seven-minute showers a day with a standard flow (9.5 L/min [0.03 U.K. gal./min.]) shower head, and a warm temperature (41°C [105°F]). Ottawa was used as the location, and fuel prices are as shown (annual savings rounded to the nearest dollar).

Testing Procedure

A simplified test procedure can be developed by keeping the configurations and shower temperature constant while changing the flow rates. Initially the test showers were run for 30 minutes, but it was then found that this could be reduced to 15 minutes for the test to go through the transient stage to the steady state. A national testing facility is being contemplated.

Table 3 Calculated annual savings for six tested DWHR devices

	Configuration A						Configuration B					
DWHR unit	**Gas @ 48.5¢/m³**		**Elect. @ 12¢/kWh**		**Oil @ 78¢/L**		**Gas @ 48.5¢/m³**		**Elect. @ 12¢/kWh**		**Oil @ 78¢/L**	
	m³	**$**	**KWh**	**$**	**L**	**$**	**m³**	**$**	**KWh**	**$**	**L**	**$**
PowerPipe R60	142	69	1,145	137	137	107	171	83	1,385	168	106	130
PowerPipe R36	100	49	810	97	97	76	117	57	942	113	113	88
GFX G3-60	133	64	1,073	129	129	100	160	77	1,290	155	155	121
GFX G3-40	126	61	1,017	122	122	95	151	73	1,218	146	146	114
ReTherm S3-60	118	57	956	115	115	89	142	69	1,153	138	138	108
ReTherm C3-40	113	55	911	109	109	85	132	64	1,071	128	128	100

Limitations of this Study

Phase One Study, 2005

Due to the variation in cold water supply temperatures during the testing period, the daily gas savings could not be directly compared or used to extrapolate annual savings. The results of the effectiveness tests have only relative or comparative meanings, as the actual length of a shower depends on several factors outside of the DWHR device make and model (such as hot water temperature, shower flow rate, hot water tank specifications and groundwater temperature).

The pressure drop through each unit was measured during the long shower tests. However, the relatively small differences between the pipe and the accuracy of the pressure gauges (±2 psi [±13,789 Pa]) required more sophisticated gauges to determine and compare pressure drops.

Phase Two Study 2006

After it was determined that each DWHR unit could be characterized by an NTU vs. flow rate curve, the uncontrolled variables did not have significant effect due to the fact that flow rates, inlet temperatures and outlet temperatures were the important variables.

Uncontrolled variables:

- Shower flow rate was subject to fluctuations due to city water pressure and variation as other buildings on the NRC complex—where the CCHT houses are located— drew large amounts of water during the tests.
- As available water meters only generate one pulse per liter, an error of ±0.5L/min (±0.11 U.K. gal./min.) was expected.

Shower temperature was controlled using a manually adjusted thermostatic mixing valve, leading to some slight variations.

Conclusions and Implications for the Housing Industry

Although the devices are very similar, the performance of comparable units can vary widely based on the way in which the soft copper tube is shaped and then wrapped around the drainpipe section.

The efficiency and effectiveness of DWHR units is lifestyle-dependent. Households with high shower use will obtain more benefit from installing a DWHR unit than households where baths are more prevalent. Households in rural areas without access to a municipal water supply will need to look at units that have designs that minimize reductions in water line pressure.

The project team developed an on-line energy savings calculator (http://www.ceatech.ca/calculator) and a simplified standard performance test that will be part of the foundation of a CSA standard. Energy savings calculations are restricted to simultaneous shower flows. To ensure both the calculator and performance testing calculations are comparable, a correction to the cold water supply temperature has been incorporated to accommodate seasonal changes.

A full report on this project is available from Natural Resources Canada and CCHT.

The Canadian Centre for Housing Technology (CCHT)

Canada Mortgage and Housing Corporation (CMHC), The National Research Council (NRC) and Natural Resources (NRCan) jointly operate the Canadian Centre for Housing Technology (CCHT). CCHT is a unique research, testing and demonstration resource for innovative technology in housing. CCHT's mission is to accelerate the development of new housing technologies and their acceptance in the marketplace. CCHT operates a Twin-House Research Facility, which offers an intensively monitored, real-world environment. Each of the two identical, two-storey houses has a full basement. The houses, 210 m^2 (2,260 sq. ft.) each, are built to R-2000 standards. For more information about the CCHT Twin-House Research Facility and other CCHT capabilities, visit http://www.ccht-cctr.gc.ca

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Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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