The Amazing Heat Scavenger Experiment

For months I have been thinking and day-dreaming about ways to conduct a valid experiment to recover waste heat from the grey water outlet of a domestic shower. Original plans involved setting up a shower base and shower screen on a platform in the back yard. My neighbours are probably grateful that I failed to obtain the necessary equipment as ReNew's copy deadline rapidly approached. So one cool Melbourne afternoon in late July I was able to remain fully clothed as I ran two experiments that show great promise for significant heat recovery at a very affordable price.

The experiment involved setting up a very cheap ***countercurrent heat exchanger***: I bought a 6 metre length of 50mm UPVC waste water pipe for $17, and a 6 metre length of "half inch" hard drawn copper pipe for $24. I reasoned that if I put the copper pipe inside the PVC pipe, I could run warm water down the PVC pipe, while simultaneously running cold tap water up the copper pipe. The warm water - representing grey water from my bathroom shower - would then transfer its heat quite efficiently to the incoming cold water, with the potential for massive savings in my water heating bills.

During the experiment's planning phase there were four important considerations:

1. *What is the temperature of the cold tap water (mid-winter)?* The answer this winter in Melbourne is 12 degrees Celsius. Interestingly, forty years ago in another Melbourne suburb, I used to do B&W photography, and routinely measured the July water temperature of tap water at only 10 degrees C - possibly an indicator of global warming's effect over the years.

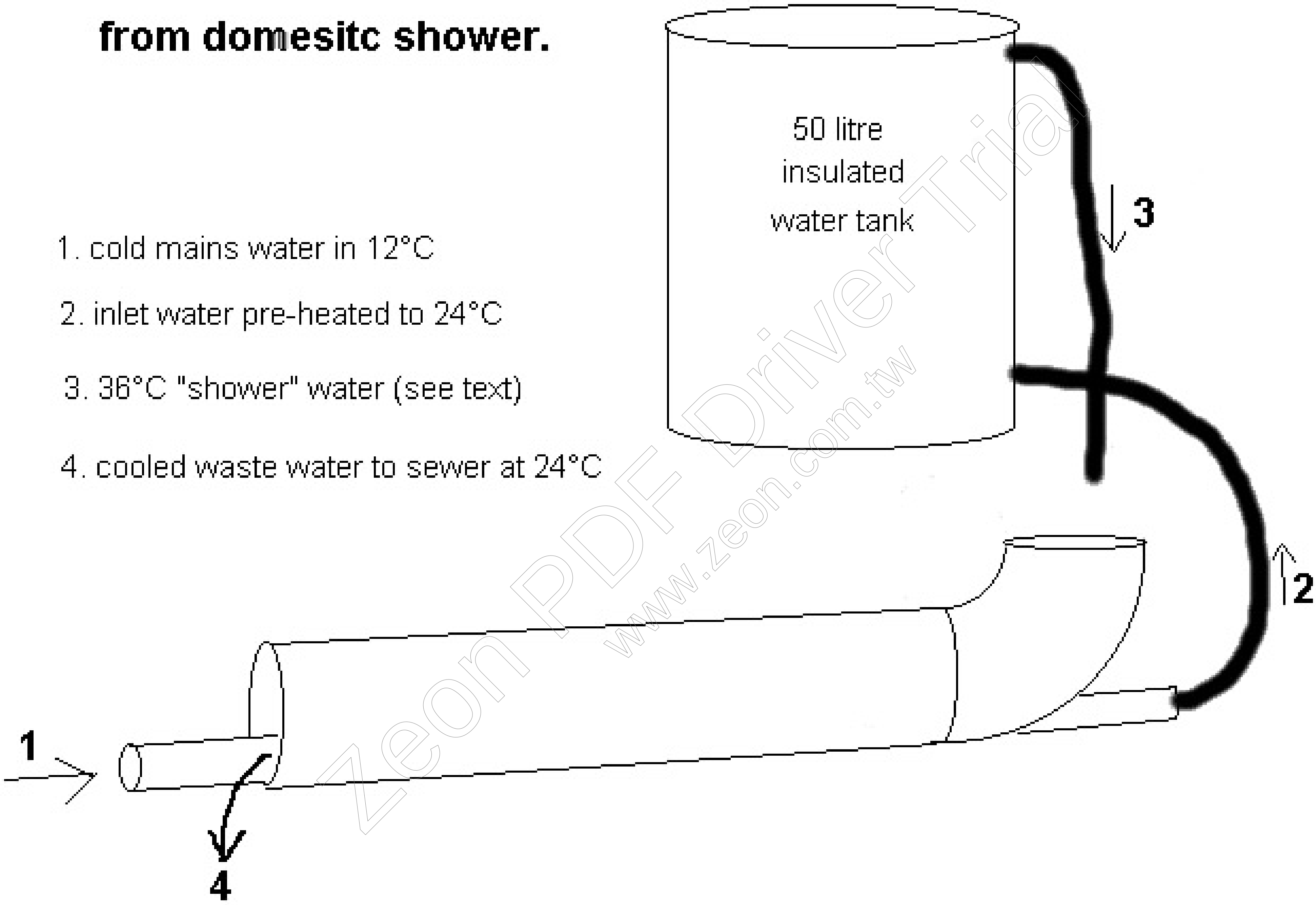
2. *What is the outlet temperature of my home's shower?* A thermometer in the plug hole showed a reading of about 30 degrees C. This is probably quite low compared to the average domestic shower, as my shower base is in fact a very heavy cast iron bath, which itself sucks heat from the shower water (and from my feet!). I chose to do the experiment with waste water entering the pipe system at 35 degrees C.

3. *What is the water flow rate?* When I am being especially frugal, the shower flow was measured at three litres per minute. Four litres per minute is probably more "normal" for a conscientious water user, and even higher flow rates are useful for rinsing soap off one's body at the end of a soapy showering session. I rather arbitrarily chose 4 litres per minute as the target flow rate for my heat-exchanger.

4. *Given the chosen flow rate, what "slope" should the pipe(s) have* so that the inner copper pipe is just submerged in the outer pipe's water flow? This is very important to maximise the effective area of copper used in the heat-exchange process. Trial and error showed that a very small drop of 1:300 was best. The pipe was kept straight over its entire six metre length, with a drop of only 20mm over that distance.

Experimental setup to show potential heat recovery from domesitc shower.

1. cold mains water in 12°C
2. inlet water pre-heated to 24°C
3. 36°C "shower" water (see text)
4. cooled waste water to sewer at 24°C



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Other considerations in this simple heat-exchanger design are that 0.9mm copper conducts heat so much faster than 2.5mm of PVC that I decided not to bother insulating the outer plastic pipe at all. Another real-world problem is that grey water will very quickly coat the copper pipe in foul slime, thus insulating the cold feed water from the warm grey water. Perhaps some sort of giant pipe cleaner could be rammed down the plastic pipe every few weeks if the slime became too thick. Better would be to blow warm dry solar heated air into the PVC pipe every sunny day, because the slime curls up, and peels off the copper pipe as it dries: this would be a self cleaning system. Fouling with hairs could also be a big issue affecting efficiency.

The test rig was completed with a 50 litre insulated hot water tank: it simultaneously provided the 35 degree C "waste" water to be poured down the PVC pipe, and was fed by the fresh water supply coming up the inner copper pipe. This simple system accurately simulates a real-world showering setup, and ensures roughly equal water flow rates in both directions along the piping system. Data monitoring was with a DataTaker DT50 data logger and four "type T" thermocouple temperature sensors, taking readings every five seconds. Two runs were made, each involving about 30 litres of total waterflow over a ten minute period.

As expected, both data series showed significant pre-heating of the water coming up the copper pipe. In the first run, what started in the garden hose at 12.5 degrees was heated to 25.5 degrees before entering the bottom of the hot water tank. And of course the waste water temperature dropped from 36.7 degrees to 24.9 degrees. The flow rate was only about 3 litres per minute on average, as it was impossible to get a steady flow rate from the garden tap with its expanding tap washer. The second run gave similar results: cold water pre-heated from 13.1 to 24.1 degrees, with the warm water surrendering its heat to go from 36.6 to 24.1 degrees. The fact that we gained only 11 degrees of heating from 12.5 degrees of cooling suggests that the un-insulated PVC pipe was losing some heat to the surrounding cold air.

It is interesting to note that the temperature gradient along each water stream is linear, but the efficiency of a countercurrent heat exchanger is *exponentially* related to it's length: This setup achieved 50% heat recovery. If we double the length to 12 metres, we don't get 100% heat recovery, we "only" get 75% heat recovery. Taking insanity to new lengths, we could have a 24 metre long heat exchanger, and it should recover 87.5% of the heat from the waste water. Crazy as it may seem, if it costs only $200 in materials, maybe this is still an economically rational heat exchanger?? How much do you have to spend on a solar water heater to reduce your showering bills by 87.5 per cent? - probably $2000 or more!

This article reports experimental results, and readers wanting to copy this experiment should note that – as with lots of environmentally "cool" things we could be doing to reduce greenhouse gas emissions – it is probably not covered by existing plumbing regulations.

Hypothetically speaking, a shower system designed to make optimal use of this heat scavenger would have the following features:

The hot water storage tank would be located beside your shower cubicle. The shower cubicle would be a modular fibreglass unit with a perspex door (for minimal thermal mass). It would be unventilated during your Government-regulated 3-minute shower, to reduce heat loss from evaporation. The hot water tank would be solar heated with gas boosting to only 42-45 degrees, so that the user would not need to add any cold water to get a pleasant showering temperature. The user should be able to dial-up a flow rate of 4 litres per minute, or whatever is the chosen flow rate at which the heat-exchanger performs optimally (i.e. the slope at which the heat exchanger pipes have been set).

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Finally I should mention that this system works best in very cold climates, such as ski resorts, Antarctic bases, anywhere in Tasmania in mid-winter, etc. so it has great advantages to reduce greenhouse gas emissions during long cold dark winter nights. Yes Tasmanians, Basslink means that very soon your off-peak electric water heating will have a heavy greenhouse cost, just like mainland Australia.

Water flow of 3 litres per minute, with the water being heated by 11 degrees can be translated to a "wattage" rating. Each millilitre of water takes 4.18 joules of energy to heat by one degree C. A Joule is a watt-second. (3000 ml x 11 degrees x 4.18 watt-seconds) every 60 seconds equates to 2,300 watts of free water heating. This is a truly amazing amount of free water heating from a $50 investment. If you are paying 15 cents per kilowatt-hour for electric heating of your shower water, it will take a family of four (each of whom showers for 5 minutes daily) only 15 months for this heat exchanger to fully pay for itself.

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Melbourne, July 2004

Opposite: Adjusting the inflowing water flow rate prior to the countercurrent test run (see text)