STRUCTURED PLUMBING (JFFERS REAL BENEFITS

Because there is a clear link between water use and energy consumption, saving can also save energy. The search is underway to find more efficient ways of delivering water to limit energy and water loss.

f the basic structure of the plumbing system In a home Is not efficient, then the efficiency of appliances connected to It is not going to be maximized.

Ideally, plumbing systems should be deslgned Instead of merely 'roughed In', Movtng tcwards more centralized system design offers a better chance of achieving optlmum efflclenoy

But the question then arises as to how thls can be effectively conveyed to stakeholders Includlng plumblng suppliers, hydraulic designers, contractors and regulators.

The entrenched culture or the plumbing market would need to change.nnd greater collaboration would have-to occuroetween various market sectors such as fixtures, piplng, water heaters, pumps and valves.

In an earlier life Gary Klein "an a plumbing and electrical contracting business In Lesotho (southern Africa), and more recently he has worked as an energy specialist with the California EnergyCornmtsslon,

Klein is now presloent ot the California-based consuttancy Afflilated International Management He says one key to conserving water andsnergy is to minimize the time It takes to deliver hot water,and this can be achieved by the design of What he calls structured plumbing systems,

Klein bel1eves the best way to achieve an efficient structured plumbing system Is to build back-to-back and stacked bathrooms and kitchens so that a plurnblngcore can be created.

"Water heating is a big user of residential energy, at 15-30% of a dwelling's total energy consumption, About 20% of stationary energy in the United States goes to water In some form.

"At the cutset;questlons need to be asked and conventlonal ways of thinking challenged, For example, have you measured the hotwater demand in the facllities you

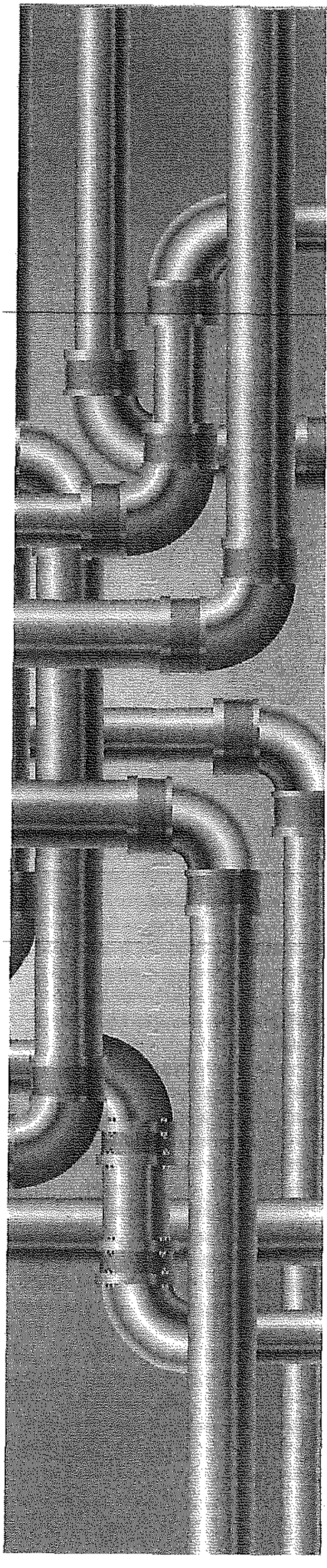
The aim should be to give.people what they want (hotwater) and what they expect (safety, raltabllty and convenience) as efficiently as possible.

"However, there are several potentially conflicting trends that have to be taken Into account. Larger houses are being built While city water pressures *are* reducing, and more plumbing fittings are being installed but with lower- flow rates.

"The result Is a longer wait for hotwater, less pressure, lower performance, customers who are less satisfied and increased complaints."

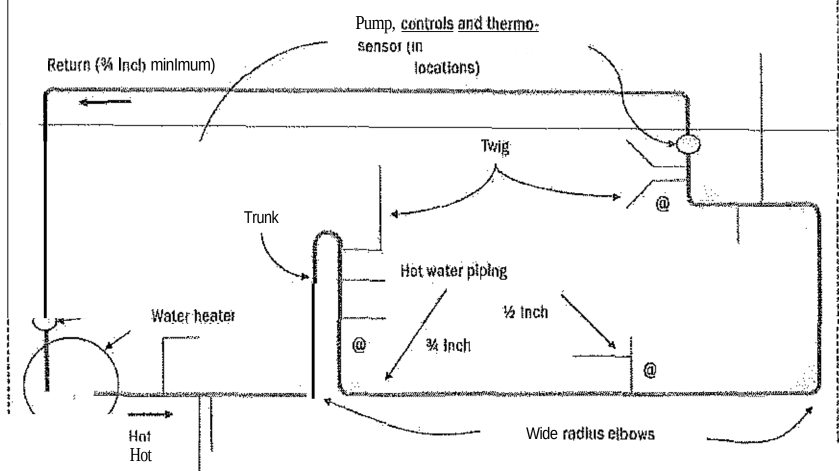
The elements in a bullding that can affect the efficiency of a hotwater system include the water heater, piping, fixtures, fittings, appliances and behavior, Interactions between them can have a dlrect effect on the system performance,

"There should be a focus on reducing structural and behavioral waste. by increasing the efficiency of the system and improving the use of water.



Structured plumbing layout

Using a dedicated return line



tocatn acuvauonmechantsms in hotwater locations - @

"System designers.should begin with the deslred end in mind bycareful consideration of appropriate flow ratesfor fixtures and apptanoes. pipe_sizing, water heatersizing and energy supply sizing.

'Forresldentlal water pressure upto 50psi tne rnexlmum allowableveloelty dlctates-plpe sizing, and forpressure below 35psi friction loss Inthe pipe dominates pipe sizing.

because the need to accommodate a high now rate leads to a larger plpe slze, which Inturn means greater volume Inthe plpe and'lncreesed energy waste during the use and cool down phases of a notweter event.

"If thepipes are sized forincreased flow, and alower flow rate fixture is used, this can also resuttfn energy waste during thedelivery phase.'

Klein says the ideal hot water distribution system has thesmanestvoume of pipe (comblnatlon of length and smallest practical diameter) from the source of hotwater to thefixture. The source IstheWater heater, or sometimes thetrunk line.

"For a glven layout orfloorplan of hot water outletjoceuons, the ideal system will have- the shortest bullrlable.trunk line, few ornobranches, theshortest bulldable tWigs, thejewest plumbing restrictions, and insulation on all hot water pipes.

"Insulation wilireduce heat loss, which is particularly Important for low-flow fixtures and appliances, and it will also Increase the time pipes stay hotbetween events.

"A few years ago my colleagues and I gave ourselves a challenge, How would you deliver hotwater to every fixture and appliance, wasting no more energy thanwe currently waste and wasting no more thanone cupful waiting for the hotwater to arrive?

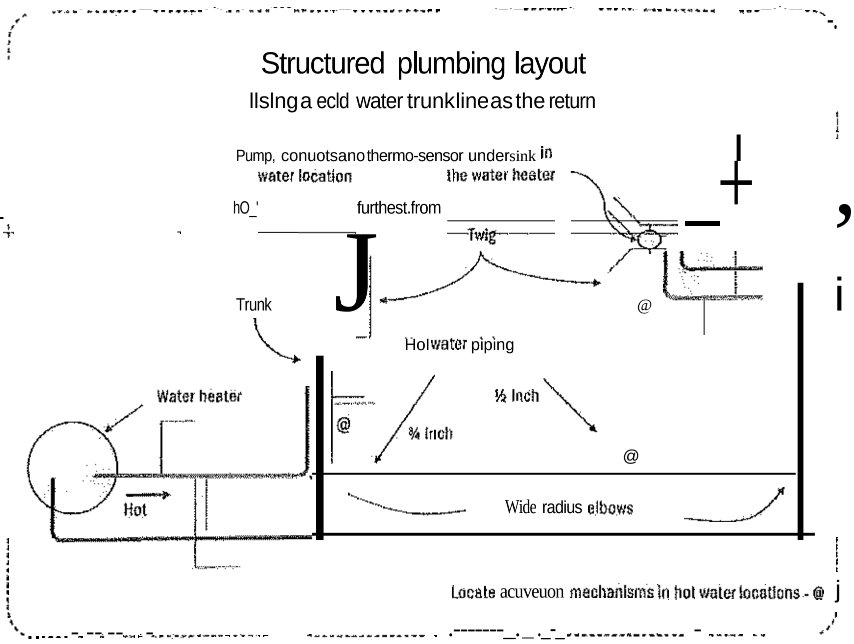
structured plumblng -fs themostpracuca! We also-learned Inthe process thatwasting no more than one cupful whlle waltlng at all fixtures is a tcugb geal to meet. Two cups is more practical,

"Inother words; the aim is to unprovethe deflvery phase toprovlde hotter water sooner by minimizing thewaste of water, energy and time."

When looking to lmprove the cool-down phase between hotwater events, several factorsshculd be considered, They include where the event is Inreletlon to thesource of hotwater, time until the next event; temperature of the hotwater needed forthatsubsequent event, andvolume otwater Inthepipe that eventually cools down.

Pipe insulation is essentlelfor lmpmvlng tne use and cool-down phases of a hotwater event.

Atypical structured plumbing system includes a circulation loop close to the fixtures and appliances. This can be a fully he-ated or half-heated loop, with a dedicated (three-pipe) or a cold water ttwo-pipe) return line, depending on the floor plan.



Energy specialist and **president of** the California-**based consultancy Affiliated International Management, says the key to conserving water and energy is** to mlnlmae the ttlTleit **takes to deliver** hot**water.**

"The system would also Include small-volume twig lines no larger.tnan half-Inch (13mm) diameter! although a larger dIameter would be needed tor fittings and appliances with a high ilow rate," Klein says.

"The-twiglines should be no more than 10 plumbing feet(3m) long, or two cups In volume, but some exceptions could Include garden tubs, washing·machlnes;,and·sinksor·appllanceson an island on a concrete slab.

"A demand-controlled pumping system would also be Installed with wired or wireless buttons -or motion sensors. The pump Would be activated to pre-heat the Insulated line, and It would shut ott automstcelly, usually In much less than a minute.

"Minimum Rcl Insulatlon en all hotwater plpes should ensure that waterInthe pipes stays hot 30-40 mlnutes after the last hotwater event."

Such a system wlll minimize the waste of water; energy and time, and will provide the most flexible and cost-effective solution for today's floorplans, resulting in high customer sansractron

People generally want convenience, but some crucial questions should be asked. How many water heaters are needed in a home?

"Most people thlnk they use hotwater several hours a day when the reality is under one hour. Customers can have the floor plan they want, and the plumbing system can be designed as efficiently as possible given that layout." Klein says several changes are proposed for the 2009 version of the Uniform Plumbing Code, and in Callfornla and North Carollna, seeking to improve tne perrormance otdomestlc hotwater distributlon systems in all buildings.

Changes being consldered to the code Include defining-plplng,suitable for-hot-water rllstrlbutlon, enabling use of smaller-diameter plplng forfixtures with lower flow rates, requiring Insulation of all hotwater dlstrlbutlon piplng and requiring buried potable distribution piping to be Installed in a conduit.

There are also lnoentlve programs sponsored by water and energy utilitles that provide a financial incentive for installation of structured plumbing. In addition, the OalltornleEnergy Commission, whiCh provides bulJding and appliance Standards, is developlng clearer guidelines on how to structure efficient plumbing.

Klein bellaves greater uptake of structured plumbing systems would be achieved through lncentlees rether than mandatory' requlrements,

"Incentive polnts are preferable to legislation, at least Initially, and once the benefits become more wldely recognlzed the uptake should escalate. Increases in the cost of energy and water will also help. The costcr energy per annum in the average home in the US Is about $300, and $100 for water – which Is too 0W and does not encourage efficient use oi these resources.

"The cost/benefit of structured plumbing can vary substantially from project to project. Actions such as chenglng the locatlon otuunk nnes, rerouting the plumbing and keeping the twigs' as small as possible can result In sUbstantlal··costsavings.-··illsome-:lnstances customers can recoup pumping costs Ih a few months.

"Projects I have been Invoived with have resulted in the footage of pipe being cut-by up to n factor of five. Consumers are better off In all cases when water/sewer and energy costs are taken into account."

Klein says payback of costs can generally be achieved wlth1nflveyears and in some cases within six months, particularly where the system Is Installed In a new constructlon, The benefit stream can be bullttntc the mortgage, and the savings can be more than the marginal cost of the mortgage.

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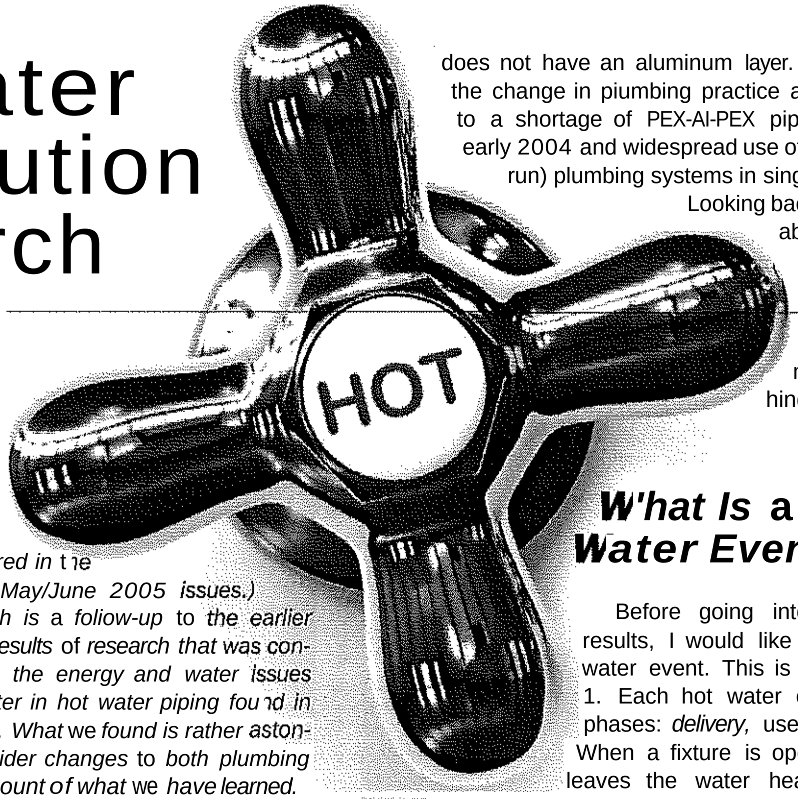
Hot ater Distribution Research

By Gary Klein

Starting in the January/February 2005 issue of Official, we ran a series of three articles on hot water distribution systems. (The other two articles appeared in the March/April 2005 and the May/June 2005 issues.) In the following article, which is a follow-up to the earlier series, we will document the results of research that was conducted to better understand the energy and water issues related to the flow of hot water in hot water piping found in typical residential applications. What we found is rather astonishing: we may want to consider changes to both plumbing and energy codes to take account of what we have learned.



Background

The California Energy Commission funded a project to study the performance of hot water distribution piping. That research was conducted by Dr. Carl Hiller. RE.. of Applied Energy Iechnology.*

The purpose of the research was to compare the performance of hot water flowing through insulated and unlnsulated pipes of various diameters. Before we began the tests we developed a matrix of test conditions that was quite large. We decided to start with 112- and 3/4-inch nominal diameter piping since our observation was that these two sizes were the most commonly used in single-family residences, both in California and around the country. These pipe diameters are also commonly found in multi-family, commercial and industrial applications and what we learned is applicable to these situations, too. The tests were to be conducted in air! with the temperature surrounding the pipes in the 65-70°F range.

We also decided to test copper and PEX-Aluminum-PEX (PEX-Al-PEX): copper because of its historically wide-spread use, and PEX-Al-PEX, because it was in common use in California at the time we began the tests. Since that time. we have seen a rapid shift to PEX piping that does not have an aluminum layer. The reasons for the change in piumbing practice appear to be due to a shortage of PEX-Al-PEX piping beginning in early 2004 and widespread use of manifold (home run) plumbing systems in single-family homes. Looking back, it would probably have made better sense to test PEX -rinstead-r-ot- PEX-Al-PEX; so much for 20/20 hindsight!

What Is a Hot Water Event?

Before going into the research results, I would like to define a hot water event. This is shown in Figure 1. Each hot water event has three phases: *delivery,* use and cool down. When a fixture is opened, hot water leaves the water heater and heads throug water piping toward the fixture. Ideally, we want this delivery time to be as short as possible. In practice there are probably two parts to the delivery phase. The first part is technical or structural and depends on: the plumbing system configuration; the location of the pipes; the volume of the water in the pipes between the water heater and the fixture; whether the piping is insulated; the fixture flow rate; the temperature of the water in the pipes compared to the temperature in the water heater, etc.

The second part is behavioral and depends on when the occupant decides the water is hot enough to use and "get in." As discussed in the first series, the behavioral waste can be significantly greater than the structural waste. The delivery phase may be short at some fixtures and long at others. It may be short or long at the same fixture, depending on when hot water was last needed somewhere else on the same line that serves the fixture. Some people *hover* near the fixture, checking to see when the water is hot enough, while others know from experience that it takes a long time, so they leave, returning when they are good and ready! From the occupant's point of *view,* this may appear to be totally random and hard to "learn," in which case I suspect their behavior defaults to the worst case condition at all fixtures.

In the articles that appeared in 2005, we showed how it is possible to deliver hot water! wasting no more than one cup, At flow rates between 0.5 and 2.5 gpm, this means the water will be delivered in 7.5 down to 1.5 seconds, which is pretty darned fast.

(*Hiller, Dr. Carl, RE., 2005. Hot Water Distribution System Research - Phase 1, California Energy Commission, Sacramento, California, November 2005, CEC 500-2005-161. The full report can be found at: http://www.energy.ca .gov/pierlfinal project reports/CEC-500-2005-161.html)

The use phase needs to be whatever length it takes to perform the task for which hot water is desired, The cool down phase begins the moment the fixture is turned *off,* If the time until the next hot water event is short enough, the water in the pipes all the way back to the water heater will be hot enough to use. If it is too long, water coming from the water heater will be run down the drain until water hot enough to use *arrives* at the fixture.

hot water temperature. The
ieeds to be set high enough

From our research, we have learned about all three phases of this process,

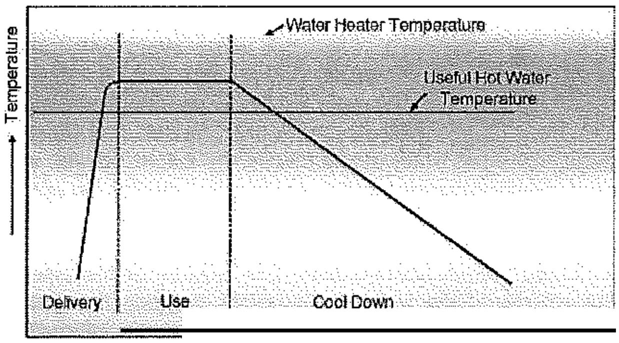


Figure 1. *Hot* Water *Event* Schematic

Figure 2. *Serpentine* Test *Rig* Schematic

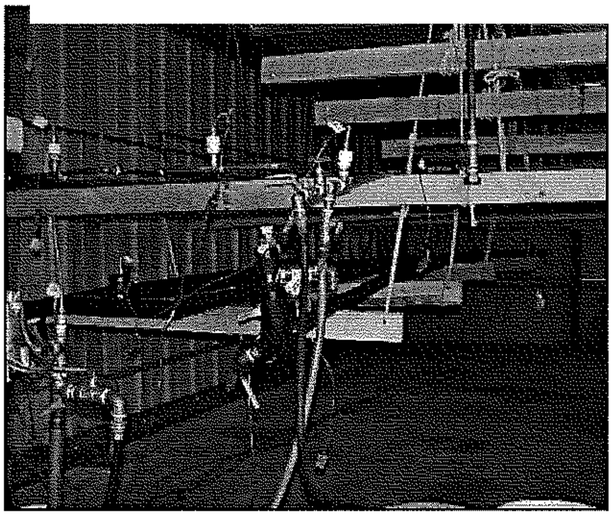


Figure 3. Test *Rig for Uninsulated (Top) and* Insulated (Bottom) *Copper Piping*

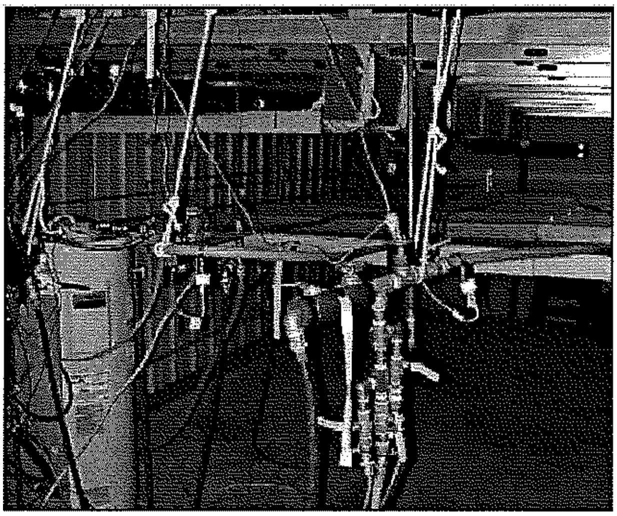


Figure 4. Test *Rig for Uninsulated PEX-Al-PEX*

The Test Rig

We set up a test rig to measure the performance. This is shown schematically in Figure 2 and in pictures in Figures 3 and 4,

Calculations and observations helped us decide to test roughly 120 foot-long sections of pipe. Since our lab was only 40 feet long, we needed to create a serpentine piping layout. When we used hard copper pipe, the long legs were nominally 20 feet long (the pipe is actually a bit longer) and the short legs were roughly 18 inches long, Temperature sensors were located at the beginning and end of the serpentine shape and at the center of each short leg,

We thought these two layouts, one for hard pipe and one for flexible pipe, were essentially identical. It turns out that they weren't identical and we learned a great deal from this mistake.

The Delivery Phase

We learned three things from our research about the delivery phase:

1. During the delivery phase, hot water acts differently than cold water.

2. Low flow rates « 1 gpm) waste much more water than high flow rates (> 4 gpm).

3. At typical fixture flow rates (1-3 gpm), sharp (standard) 90-degree elbows increase turbulence, heat loss and water waste.

Perhaps one of the most surprising things that we learned is that it is possible for significantly more water to come out of the pipe before hot water gets from the water heater to the fixture than is actually in the pipe. During the tests, our researcher found that the temperature sensor on the first turn was getting hot sooner than was theoretically possible assuming perfect plug flow, The difference in time was significant – otherwise he probably wouldn't have noticed it. To figure out what was going on, he used his hands to feel the pipe and found that there was a thin stream of hot water riding on top of the cold water that was running many feet ahead of the plug of hot water coming from the water heater. After some time, mixing would occur, but until that happened, there was a much greater surface area of hot water touching both the cold water and the relatively cold pipe than would normally have been expected.

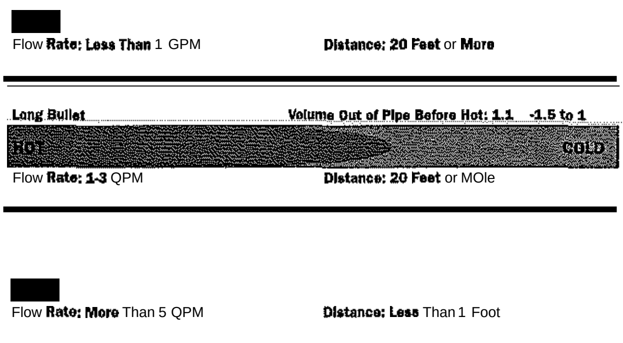


Figure 5. *Delivery* Phase *Schematics (drawings* not to scale)

This is depicted in the top portion of Figure 5. At the beginning of a hot water event, the cold water is much more viscous than the hot water. The length of the thin stream of hot water could be more than 20 feet long and would go around the elbows. The volume of water that would come out of the pipe (or past a given temperature sensor) before hot water arrived could be twice the volume that was in the pipe.

We found this condition most prevalent at flow rates less than 1 gpm. These flow rates are typical of commercial lavatory sinks, low flow showers and the hot water portion of the flow in a single lever sink when the valve is opened halfway between hot and cold.

As the flow rate increased into the range typical of many sinks and showers (1-3 gpm), the thin stream gave way to a more normal mixing front, which we have depicted as a long bullet. The length of the bullet was several feet ahead of the hot water plug. The extra volume of water that came out of the pipe before hot water arrived was generally 10 to 50 percent more than the volume of water in the pipe. The waste was larger for a given flow rate in the hard-piped test rig that had standard elbows than it was in the flexible pipe test rig that used wide-radius bends in the pipe itself to make the 180-degree turns.

At higher flow rates, typical of those found in garden or Jacuzzi tubs, some laundry sinks, washing machines and dishwashers, we saw what looked like plug flow – the idealized type of flow I heard described in engineering school. In these cases, the length of the much shorter bullet was only a very short distance ahead of the hot water plug. The extra velume of water that came out of the pipe before hot water arrived was generally much less than ten percent more than the volume of water in the pipe. We found this condition some of the time at high flow rates in the hard-pipe test rig with hard elbows. We found it much more often and at lower flow rates in the flexible test rig with wide-radius bends.

If you recall from the first article in the series, I had delivery problems when I measured my house. Looking back, I had installed a low flow showerhead (1 gpm) specifically to save water. However, both the low flow rate and the elbows in the copper piping created conditions that wasted a significant amount of water before the hot water arrived (more than twice what was in the pipe). This was certainly an unintended consequence of my attempt to save water! The extra water that came out had to be heated by the water heater and so my energy consumption was increased during the delivery phase. As we will see in the next section, the low flow rate fixture also frustrated my attempt to save energy during the use phase, too.

The Use Phase

We learned four things about the use phase:

Uninsulated PEX-AI-PEX piping has a greater ternperature drop at a given flow rate than does copper piping of the same nominal diameter. Insulating the pipes minimized the difference.

The temperature drop at a given flow rate is less in 1/2-inch piping than in 3/4-inch piping.

The temperature drop over a given distance is greater at low flow rates than at high flow rates. There is a significant difference in the rate of change of the temperature drop at flow rates below 1 gpm.

Insulation decreases the temperature drop at a given flow rate.

Figure 6 shows the comparison between nominal 3/4-inch PEX-Al-PEX and 3/4-inch copper piping over a length of 100 feet. The figure is based on steady state flow rates with the hot water entering the pipe at 135'F and the ambient air temperature surrounding the pipe at 67.5°F. The water in the uninsulated PEX-Al-PEX pipe lost more temperature at the same flow rate than aid the water In the copper pipe, We suspect that this additional heat loss ts due to a combination of two effects: the nominal 314-inch PEX-Al-PEX pipe has a larger surface area than the nominal 3/4-inch copper pipe - once it is hot there is more surface area to lose heat; and because the PEX-Al-PEX has a larger internal diameter than the copper piping, the face velocity of the water in the PEX-Al-PEX is slower and the rate of heat loss is greater than it is in copper. Once the pipes were insulated, the difference in temperature drop essentially disappeared,

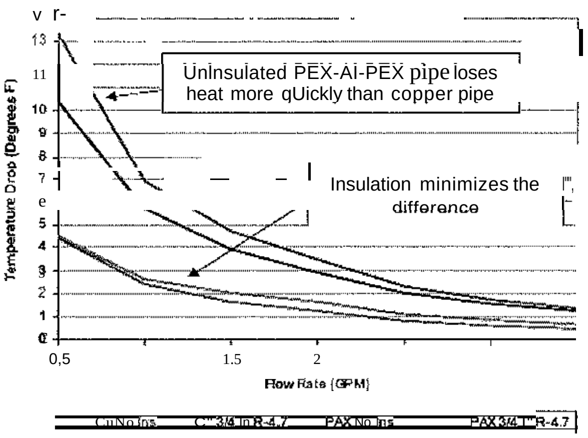


Figure 6. *Comparison of Nominal 314-Inch PEX-Ai-PEX and 3/4-Inch Copper Piping*

We did not have enough funding to run tests on 1/2-inch PEX-Al-PEX. Based on the fact that uninsulated copper performed better than PEX-Al-PEX and, with insulation, the performance was very similar, we think we can use the performance of copper pipe at 1/2- and 3/4-inch, with and without insulation, as a reasonable first order proxy to better understand what generally happens in hot water piping.

Figure 7 compares the performance of nominal 1/2- and 3/4-inch diameter copper piping, both insulated and uninsulated. As in the prior figure, the graph is based on steady state flow rates with the hot water entering the pipe at 135°F and the ambient air temperature surrounding the pipe at 67.5'F over a length of 100 feet.

At a given flow rate, the temperature drop in 1/2-inch nominal piping is less than in 314-inch nominal piping. This is due to the increased face velocity of the water, which reduces the heat loss rate. While from a thermal perspective it is beneficial to use the smallest pipe diameter possible, frictional losses increase exponentially with increased face velocity and result in increased pressure drop over a given length. We did not measure pressure drop during the tests. Future tests should do this so as to better understand its impacts.

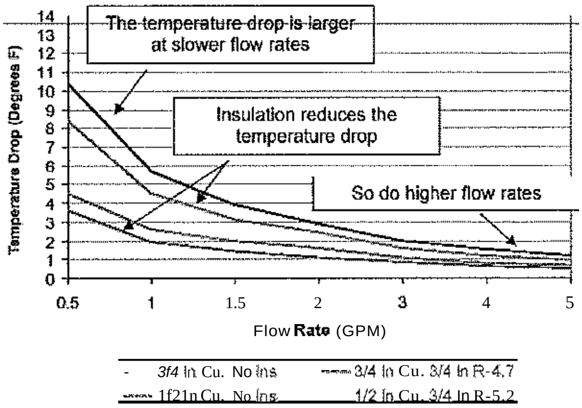


Figure 7. *Comparison of Nominal* 1/2- *and 314-Inch Copper Piping*

The temperature drop over a given distance is greater at low flow rates than at high ftow rates. At 2.5 gpm, the highest flow rate allowed for showerheads, the temperature drop in uninsulated copper piping is between 2°F and 2.5'F. At 1 gpm, the temperature drop in uninsulated pipe climbs to between 4.5'F and 5.5'F. At 5 gpm, the temperature drop goes down to roughly 1°F, and the difference between 1/2- and 3/4-inch diameter goes away.

There is a significant difference in the rate of change of the temperature drop at ftow rates below 1 gpm. At 0.5 gpm, the temperature drop almost doubles, The curve will get even steeper if the ftow rate is reduced still further and, for a given length at some low flow rate, hot water will never reach the fixture. The same thing would happen if length was increased while flow rate was held constant, or if the piping was located in a higher heat loss environment, say in damp soil under a slab or between buildings in a campus situation.

Insulation reduces the heat loss overall and, for a given flow rate, the temperature drop is cut roughly in half. Insulation also reduces the difference in temperature drop between 1/2- and 3/4-inch diameter piping,

The Cool Down Phase

We learned three things about the cool down phase:

1. If the time between hot water events is long enough, the pipes cool down to below the useful **hot water temperature for the next hot water event.**
2. Larger diameter pipes cool down more slowly than **smaller diameter pipes.**
3. Insulation extends the time it takes for the pipes to **cool down to a given temperature.**

The first point seems obvious, since if you wait long enough, the temperature of the water in the pipes will *even*-tually reach equilibrium with the ambient temperature surrounding the pipes. The real question is: how long does it take **to cool down to a non-useful hot water temperature? This** depends upon the starting temperature of the water in the pipes, the diameter of the pipes, the amount of pipe insula**tion, the environmental conditions in which the pipes are** located, and the temperature of water needed for the next **hot water event.**

Figure 8 compares how long it took for the water in 3/4-inch diameter copper pipes to cool down from a given starting temperature to 105°F. The ambient temperature surrounding the pipes was between 65°F and 70°F and the pipes **were located in air. Without insulation, it took between 5 and** 22 minutes for the temperature to reach 105°F. The hotter the water began, the longer it took.

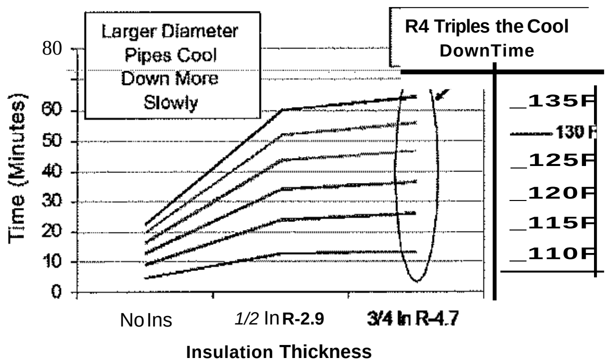


Figure **8.** *Time Required for 3/4-Inch Diameter* Pipes to *Cool Down* to *105°F With and* Without *Pipe Insulation*

When 112-inch wall thickness and 3/4-inch wall **thickness insulation were added, it took significantly longer** for the water to cool down to 105°F. Use of the 3/4-inch thick insulation (>R-4) roughly tripled the cooi down time. The 112-**inch wall thickness insulation did almost as well.**

Figure 9 compares how long it took for the water in 112-inch diameter copper pipes to cool down from a given starting temperature to 105°F. As with the tests on 314-inch diameter pipe, the ambient temperature surrounding the pipes was between 65°F and 70°F and the pipes were located in air. Without insulation, it took between 5 and 20 minutes for the **temperature to reach 105°F, almost exactly the same as for** the uninsulated 3/4-inch piping. Use of the 3/4-inch thick insulation (> R-4) roughly doubled the cool down time. The 1/2-inch wall thickness insulation did almost as well.

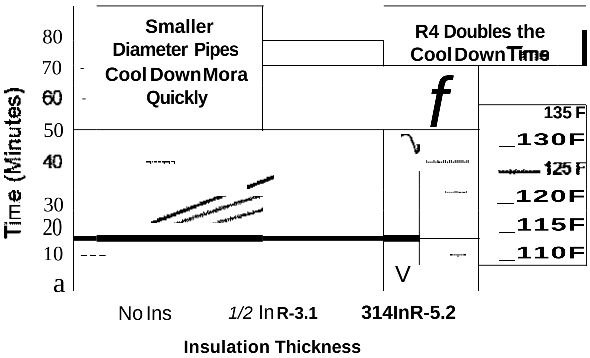
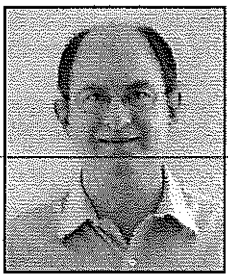


Figure **9.** *Time Required for 1/2-Inch Diameter Pipes* to *Cool Down* to *105°F With and* Without *Pipe Insulation*

Although the time it took the water in the uninsulated pipes to cool down was very similar for the 112-inch and 3/4-inch diameter pipes, when insulation was added, the water in the 314-inch pipes took roughly 1.5 times as long to **reach the same temperature as the 1/2-inch pipes.**

If the pipes were located in a colder environment, such as in a crawl space or an attic, used at night or early in the morning, or throughout much of the winter, they would *have* cooled down much more quickly. If the pipes were in a **high heat loss environment, such as in the damp soil under a** concrete slab, they would cool off even faster. If the ambient **temperature were higher, such as in an attic in the middle of a summer afternoon, the pipes would take much longer to** cool down. (On the other hand, the water in the cold water pipes might be too hot to usel)

In future articles in this series,* we *will apply the lessons learned to improving the performance* of *hot water *distribution* systems. We *will* also *look* at *possible* changes *that might* be *made* in *plumbing and energy codes* to *take* ***advantage* of *what we have learned and identify* some *additional research that should be done. Finally,* we *will look at the implications* of *making these improvements* on *the aver-*** a" ***connection*** *betweer:* ***water and energy use.***



About the Author: Gary Klein

Gary Klein has been intimately involved in energy efficiency and renewable energy since 1973. One fourth of his career was spent in Lesotho, the rest in the USA. Gary has a passion for hot water: getting into it, getting out of it, and efficiently delivering it to meet customers' needs. He currently helps administer California's Public Interest Energy Research program and chairs the recently formed Task Force on Residential Hot Water Distribution Systems. He can be contacted at Gklein@energy.state.ca.us

In House Testing

Location: Mount Martha, Vic.
Home Size: Two Story Approx. 400 sq meter
Home age: 4 years
Owner: Mr. Paul Felix,
Date conducted: March 2005

Previous Water Usage.
Before an On Demand Pumping System was installed it took a minimum 2 ½ minutes for Hot Water to arrive at the Kitchen Sink on a warm day. (Wintertime over 3 minutes)

Products and material specifications used in the supply of Hot Water to the Home.

(a) Hot Water Heater Rinnai Infinity 26 Tankless gas.
(b) Piping, 15 mm outside diameter poly/plastic.
(c) Pipe inside diameter 12 mm.
(d) 8.84 metres of 12 mm inside diameter pipe will hold one litre of water.
(e) 9 litres/minute low flow tap and shower ware, throughout the house restrict rapid flow of Hot Water creating additional thermal heat loss to the pipes during Hot Water Delivery.
(f) As the piping was not visible the estimated Hot Water piping length is in excess of 40 metres, holding a minimum of 4.5 litres. This estimate was based on the location of the Wet areas and House design and based on the knowledge of how Plumbers currently plumb homes.
(g) No insulation or lagging on the hot water piping was present or visible.

Water Loss.
The Dead or Standing Water lost through the hot water outlet waiting for hot water to arrive was on average 20 litres per usage.

Contributing factors to water loss.
This was due to the fact that the piping was not insulated and the Dead or Standing Water in the heat exchanger of the Rinnai unit also had to be heated. As well as an additional 2 plus Pipe volumes of water was lost due to thermal heat loss through the pipes.

Water and Energy Savings.
After an On Demand Pumping System was installed there was a vast improvement in the Hot Water Delivery.
The On Demand Pump was installed at the furthest point in the Plumbing layout and a dedicated return line was installed back to the Cold Water inlet to the Rinnai HWS.
Note,
This installation was not Structured Plumbing, but the closest that can be achieve when retro fitting an existing home, it will give about 80% of the savings that are achievable when Structured Plumbing is correctly installed.

An important fact in this installation is the pipe size used in the dedicated return line, it was 20 mm outside diameter poly/plastic this pipe diameter gives a better return flow.
The activation of the On Demand Pumping System was by a Wireless Remote Control unit that required no wiring to be run simplifying the installation.

The Savings,

(a) Time, the average time to receive Hot Water in the home is now only 30 seconds.
(b) This reduced the initial Gas Burning by 2 minutes minimum every time Hot Water is required, average household use of Hot Water for this home is 10 times a day.
Reducing daily Gas Burning by 20 minutes or 121.666 hours per year.
The Infinity 26, uses 199 Mj/hour of gas on maximum load, start-up is max load.
At a start-up of only 180 Mj/hour, the energy saved per year would be 21,899.88 Mj.
(c) The water that was not hot and run off at every tap in the house was reduced to less than 2 cup fulls around 400 ml, this is a saving of over 19 litres per use.
(d) Based on the 10 Hot Water Events every day the saving for this home is 190 litres of water a day or 69,350 litres per year.

Only initial test were carried out at this location on water saving per use and time of delivery when installation was carried out. The figures are based on the standard water usage of the home over a 12 Month period.

Greenhouse Emission reductions,

By just reducing the Gas burning by 20 minutes a day based at a lower than maximum Gas burning rate of 180 Mj/hour, the use of the On Demand Pumping System has reduced Green House Emissions in this home.

Allowing, 10 uses a day of 2 minutes of Gas Burning or 121.666 hours per year.
At 180 Mj/hour x 121.666 Hours > 21899.88 Mj. Of Gas saved per year.

Greenhouse equation, 21,899.88 Mj of Gas x 0.0719 kg C02_e = 1,574.60 kg of CO

1,574.60 kg of CO Emissions have been reduced from entering the atmosphere by efficiently delivering Hot water to the point of use.

This example does not take into account the Energy saved by the Water and Sewage Companies that do not have to pump or treat the water that has been saved.

Conclusion / Assumption

This is just one home in an Estate of many large homes of similar design and many had Instantaneous Hot Water Heaters.

The figure for this home could be considered high, but on investigation it is found to be average.

If you were to take a cross section of these homes say 100 and apply the figures in this test and then subtract 1/3 of the result you would get an annual saving of.

Water Saved, 4,623,333.3 litres

Energy Saved, 1,459,992 Mj of Gas

Greenhouse Gases, 104,973.3 kg of CO emissions

These figures are the result of efficient Hot Water Delivery and based on only 2 thirds of the overall assumption of 100 homes in the Estate where Mr. Felix lives.

If we take the figures for, 1,000 and 10,000 homes it is staggering.

For, **1,000 Homes.**

Water Saved, 46,233,333 litres

Energy Saved, 14,599,920 Mj of Gas

Greenhouse Gases, 1,049,733 kg of CO emissions

For, **10,000 Homes.**

Water Saved, 462,333,330 litres

Energy Saved, 145,999,200 Mj of Gas

Greenhouse Gases, 10,497,330 kg of CO emissions

Hot Water Delivery Design Requirements to save both Water and Energy during Hot Water Delivery in New Homes

Back Ground History of Structured Plumbing Concept.

- 1993 Larry Acker a Director of the US Department of Energy's e3Energy Committee and Gary Klein Head advisor to Commissioner Geesman of the California Energy Commission (CEC) began collaboration on improving Hot Water delivery and saving energy.
- 2003 Mr. Brod Street of the Victorian Governments DSE, Environment Policy & Climate Change Division and Mr. Tom Rendall of ACT Aust Pty. Ltd began working with Masseurs Acker and Klein.
- 2008 to this date these 4 individuals have shared findings in the many differences in how new home plumbing is installed.
- This information assisted in the development of the Test Program that was undertaken by the CEC that resulted in the full Environmental Report on Structured Plumbing **in** 2005.
- This 2005 CEC Report is the first real report to map and model the characteristics that are associated with the travel of hot water throughout the piping during the delivery stage of the hot water.
- To this day there is no more accurate way to determine water and energy losses during residential hot water delivery.
- It is with this modelling provided by the CEC 2005 Report that the following assumptions have been calculated.

Method of Calculation of average Water and Energy Losses for New Homes.

- Firstly the medium home size was worked to be 22 squares in size with potentially 10 hot water outlets this is the average amount for a home of this size.
- By working from Builders plans for standard homes of this size a basic length of hot water piping was established and by applying the CEC model to this piping a Water Volume was determined based on 15mm Pex Piping.
- The wasted volume determined is 40 litres per day average over all homes and Commercial Structures in Australia.
- Number of occupants was determined at 3, some Government Statistics show that the average household has 2.68 persons living in them.
- 2.68 is a very misleading figure because the 0.68 person will waste the same amount of water and energy in hot water delivery, the water volume wasted does not alter it is always a constant number of litres.
- So previous Government Modelling on water wastage has been calculated incorrectly when using only part of a person.
- All figures used in this Assumption are in fact less than the realistic wastage that occurs in most new homes, this is only a base number or a minimum wastage figure the true figure is more likely to be twice this number.
- Energy Consumption based on CEC findings that for every 16 litres of water wasted during hot water delivery One kWh of energy is lost or

consumed, the base figure for this assumption is 20 litres = 1 kWh of energy consumed.

The Assumption for Existing Home Construction within Australia.

At 40 Litres per day by 365 days allowing for only 4 million homes the water and energy wasted in Australia annually while waiting for hot water to arrive is.

- 292 Giga Litres of water wasted.
- While 14,600,000,000 kWh of energy is consumed by that lost water.
- As a result of the CEC and US DOE findings that equates to around 4 million Tons of Greenhouse Emissions.

New Home Construction based on this assumption.

With approximately 150,000 new dwellings per year being built annually the following figures apply.

- 10.95 Giga Litres of water wasted.
- 547,500,000 kWh of Energy Consumed unnecessarily.
- 150,000 Tons of Carbon Emissions emitted to the Atmosphere annually.
- Accumulatively in 2 years 450,000 Tons of CO would be emitted.
- With in 10 years the accumulative figure would be 1,400,650,000 Tons of CO emissions.

This assumption is based on minimum volumes of water wasted and the energy consumed calculated from field data and research and the modelling developed by the CEC in their comprehensive testing into Hot Water Delivery.

It is not proposed that I prove this information correct but the opposite that you prove it wrong.

The solution to this Water and Energy Consumption problem is very simple, change the Building Regulations to limit the amount of water wasted during hot water delivery to 500ml or 2 Cups of Water, but without using more energy than running the water down the drain.

By doing this it puts the responsibility back on to the Building Industry to construct Sustainable Homes.

To achieve this set goal the solution is the CEC developed and proven concept of Structured Plumbing.

- All home have to have plumbing but it needs to be constructed smarter.
- Standardize the delivery pipe size to ¾" or 20mm to assist water flow.
- Limit the number of Hard Elbows used in 90° direction changes bend or curve the pipe in a wide radius.
- Insulate all Hot Water delivery piping to assist in retaining heat energy lost during delivery.
- Limit the lengths of the Dropper or Twig Pipes to fixtures to 3 meters.

- Structure a Flow and return piping layout and connect an On Demand pumping system to circulate the unwanted cooled water from the hot water piping and return it back to the Hot Water System.
- It is very important that only recognised on demand pumping systems that operate using the Delta "T" temperature sensing method of monitoring the water temperature are used and to maximize the energy saving in Structured Plumbing.
- All Builders must provide an Environmental plumbing plan for all the homes they build and specifying the technical aspects and specifications of the materials and products used in the construction of the plumbing.
- These simple alterations to the way that new home plumbing is carried out instead of allowing the Plumber to just rough out their own plumbing design is very important to achieving the sustainability that the Governments are requiring from new home construction.

Retro Fitting existing Homes.

- The On Demand Pumping Systems is also the solution to the on going problem of the water and energy wastage in existing homes, because of the most important technical advancement in hot water delivery the on demand pumping system can be installed in Retro Fit.
- With a vast number of homes in Australia wasting water and energy the Retro Fitting of an on demand pumping system that can utilise the cold water supply pipe as a return will effectively solve this water and energy issue within the existing home area.
- Once again it is extremely important that only a true on demand controlled pumping system that is temperature controlled by the Delta "T" on demand electronics sensing device is used, otherwise hot water crossoVer Can occur into the cold water pipe. Also energy and water savings are not maximized, if hot water enters the cold water pipe then people will flush out the cold water line until the water is cooled a reverse problem.

Note: In most cases the average home constructed today is around the 32 plus square size with between 12 to 15 hot water fixtures and the length of plumbing doubled to that of a 22 square home. Water and Energy consumption is extremely high within these much larger homes.