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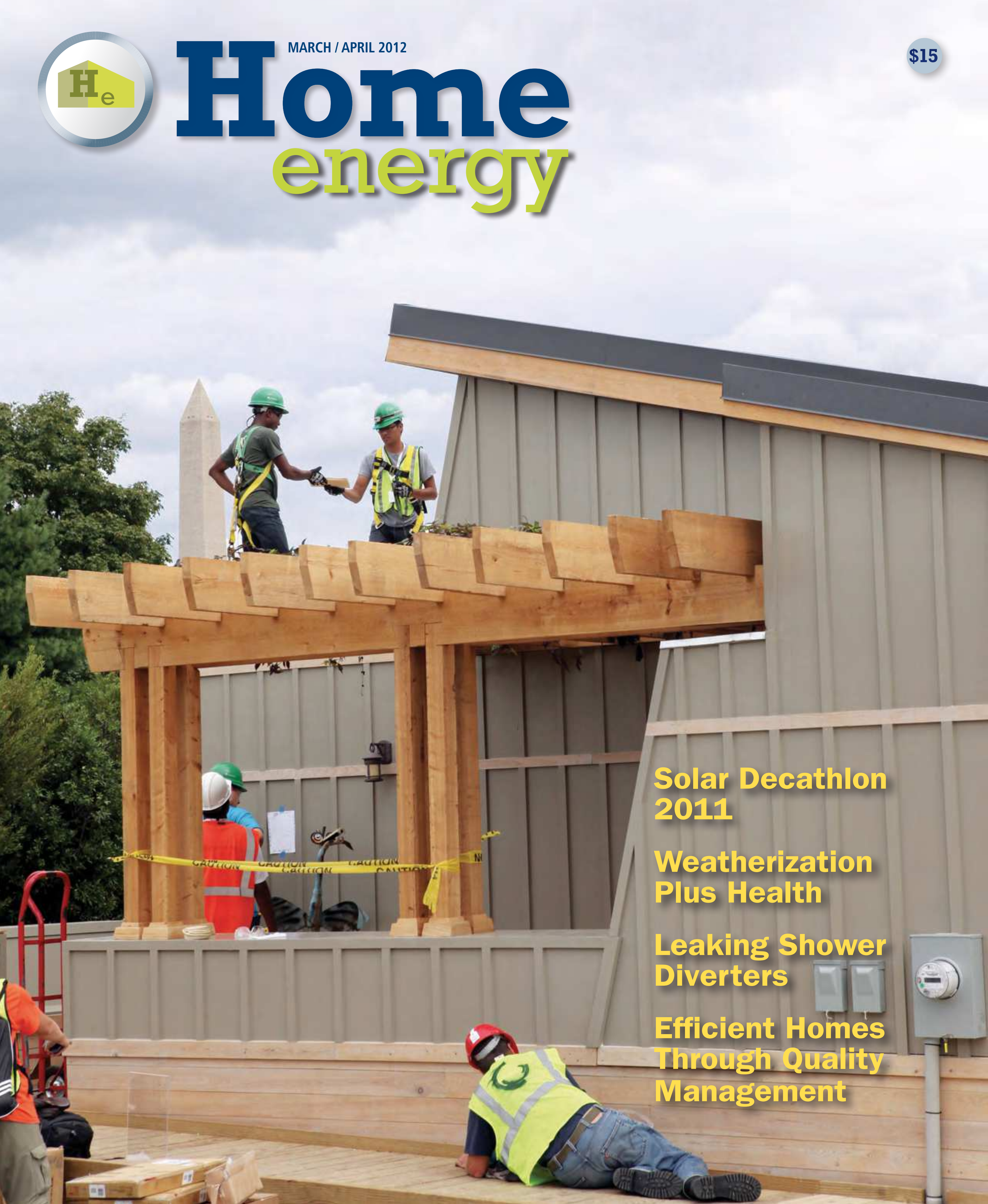

Solar Decathlon 2011

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Leaking Shower Diverters

Efficient Homes Through Quality Management

LEAKING SHOWER DIVERTERS
An *Overlooked* Energy Waster


WILLA VOGEL


BETH MIELBRECHT


IAN SHAPIRO

Some examples of plate diverters. Left to right: a lift on the tub spout diverter with a two-handle valve; a pull-down ring on the tub spout diverter with a single-handle valve; and a button on the valve plate with a single-handle valve.


IAN SHAPIRO

Here's a situation you want to avoid.

BY BETSY JENKINS

If a diverter valve leaks in shower mode, the water flowing out of the bathtub spout goes straight down the drain, wasting both water and the energy used to heat that water. It's like pouring money down the drain!

A diverter is used in combination bath/shower units to direct flow either to the bathtub spout or to the showerhead. Diverters like the one shown in the photo at right use a valve to direct the flow to the showerhead or the tub spout. Diverters like those shown in the photos above use a plastic or metal plate to stop the water from flowing out of the tub spout. The water is diverted to the showerhead instead. If the plate is located on the tub spout, it is called a tub spout diverter.


BETSY JENKINS

This diverter valve is part of a three-handle shower valve.

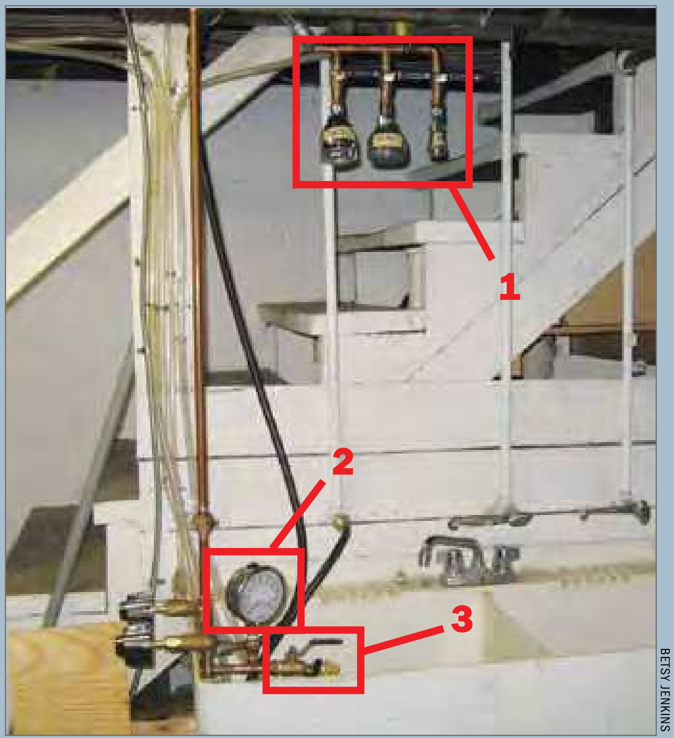
When a diverter is working properly, water flows out of either the tub spout or the showerhead, but not out of both. However, diverters very often leak, and when they do, water flows out of the tub spout even in shower mode (see photo top right). This leakage goes directly down the drain. Both the water and the energy used to heat the water are wasted.

Potential Savings

A team from the company I work for, Taitem Engineering, conducted a series of tests designed to determine how much energy and water leaky diverters waste. We surveyed approximately 130 apartments and houses, with a total of 120 combination bath/shower units with diverters. We found that 34% of the diverters leaked more than 0.1 gallons per minute (gpm). The largest leak we saw was 3.0 gpm, and the average of all leaks greater than 0.1 gpm was 0.8 gpm.

Further testing showed that when a leaking diverter is fixed, some of the water that had been leaking out the tub spout is forced out of the showerhead. This fraction of the water will not contribute to water or energy savings. However, even if we can claim only partial savings for fixing leaking diverters, the savings can still be substantial enough to justify the cost of the repair.

We also compared savings from fixing leaking diverters to savings from installing low-flow showerheads. In our data set of 130 homes, approximately 18% of the showerheads were high flow; these showerheads had a measured flow of 2.5 gpm or more, and an average flow of 3 gpm. If these showers were used for ten minutes per day, and we installed 2 gpm low-flow showerheads, water savings would total approximately 79,000 gallons of hot water per year. In the same dataset, 34% of the diverters leaked more than 0.1 gpm. Again assuming that the showers were used ten minutes per day, and assuming a savings factor of 0.7 for fixing the leaking diverters, water savings would total approximately 89,000 gallons of hot water per year. In other words, for the sample of homes we studied, savings from fixing diverters were higher than savings from installing low-flow showerheads!



Our test rig consisted of (1) multiple showerheads, each with its own shutoff valve; (2) a pressure gauge; and (3) a throttling valve to simulate tub spout leaks of various sizes.

Test Methods and Results

We constructed the test rig shown in the photo above to test how the flows through the showerhead and tub spout interact in various scenarios. We focused our testing on tub spout diverters and performed the three tests described below.

We installed three showerheads on our test rig to allow for easy switching between showerheads of various flows. We were also able to simulate a higher showerhead flow by opening two showerheads at once. We used a pressure-reducing valve (not shown in photo) at the main water supply for the building to vary the system pressure. Finally, for Test 1 and Test 2, we installed a ball valve in place of the tub spout diverter. This allowed us to simulate various leak flows.

Test 1. Our primary goal for this project was to determine a savings factor that energy auditors could use to calculate achievable savings from replacing a leaking diverter. Test 1 was designed to empirically determine the savings factor. To do this, we first measured the flow through the showerhead and the flow of the leak. Then we measured the flow through the showerhead when the leak was eliminated. We performed these measurements for each showerhead at six system static pressures and at five to ten leak flows per static pressure. Each flow measurement was taken for 60 seconds. We found that in general, at a given system pressure, the savings factor decreased as the original leak increased. We also found that the savings factor was almost always greater than 0.7, regardless of the showerhead, system pressure, or leak flow.

Test 2. In Test 2, we looked at what happened when we installed a low-flow showerhead and fixed a leaking diverter at the same time. We calculated the estimated savings by taking the difference between the actual existing flow and the rated flow of the new showerhead, and adding the total flow of the diverter leak (without multiplying by the savings factor). We then measured the flow through a high-flow showerhead, as defined above, and through the tub spout at a variety of leaks. Finally, we measured the flow through a showerhead rated at 2.25 gpm with no leak through the tub spout. We found that our calculated savings were lower than the achieved savings because in all cases, the actual flow through the low-flow showerhead was less than its rated flow.

Test 3. In Test 3, we investigated the different types of tub spout diverters available on the market. Our research was by no means exhaustive—we tested only 18 different spouts, and only one of each model. We labeled each tub spout with a unique identifier, starting with TS-1 and ending with TS-20. These tub spouts and their leak rates are shown in Table 1.

We found two patterns worth noting. First, the leak rate through most of the tub spouts increased as the system pressure decreased. This is because all of the tub spouts we tested use wa-

Table 1. Tub Spout Diverters Tested

Tag	Manufacturer	Model #	Price	Diverter Mechanism	Leak Rate (gpm) Low Pressure	Leak Rate (gpm) Medium Pressure	Leak Rate (gpm) High Pressure
TS-1	Danze	D606225	$24.00	Lift	0.02	0.01	0.00
TS-2	LDR	BT129/502 4250	$15.05	Lift	0.00	0.00	0.00
TS-4	American Standard	8888025.002	$19.25	Lift	0.02	0.03	0.03
TS-5	American Standard	8888055.002	$21.45	Lift	0.10	0.08	0.05
TS-6	Moen	391	$32.41	Lift	0.00	0.00	0.00
TS-7	Grohe	13 611 000	$30.00	Lift	0.00	0.00	0.00
TS-8	Moen	IPS 3830	$30.09	Lift	0.01	0.01	0.00
TS-9	Delta	RP 19820/ 33714	$21.63	Lift	0.01	0.16	0.06
TS-10	Unknown		--	Lift	0.01	0.00	0.00
TS-11	Kohler	389-CP/ Devonshire	$25.50	Lift	0.26	0.02	0.00
TS-12	Danco	34224CCB	$12.58	Lift	0.03	0.03	0.00
TS-13	Unknown	17463CV	--	Ring and spring	0.01	0.00	0.00
TS-14	Delta/Brass Craft	SWD0205/ RP17453	$20.38	Ring and spring	0.03	0.01	0.00
TS-15	Waxman/ Spray Sensations	24501	$7.95	Lift	0.01	0.01	0.01
TS-17	Waxman/ Spray Sensations	26629	$15.98	Lift	0.02	0.01	0.01
TS-18	Danco/ Universal	88703	$16.97	Lift	0.12	0.03	0.03
TS-19	Kohler	Coralais/ 15136-S-CP	$19.22	Lift	0.09	0.09	0.08
TS-20	BrassCraft/ OEM Mixet	SWD0411	$20.00	Positive pressure	0.00	0.00	0.00

NOTE: *TS-3 and TS-16 were old tub spouts that were not specifically purchased for this project. We did not include the test results from either spout in our analysis. All of the other spouts were new out of the box when we tested them. The results of our field survey imply that leaks worsen significantly over time.*

MYRON J WALTER

TS-20, the Mixet Positive Action Shut-off Diverter Spout by BrassCraft.

Table 2. Summary of All Tub Spout Tests

Leak (gpm)	Percentage of Spouts That Leaked Less Than Stated Leak at ALL Pressures
0.01	20%
0.02	45%
0.05	65%
0.10	75%

ter pressure to create the seal that prevents water from continuing to flow out of the tub spout when the diverter is in shower mode. Second, many of the tub spouts leaked significantly even though they were newly purchased. One manufacturer stated that a pencil-sized leak was normal. It may be normal, be we do not think it is acceptable! Also, our field survey results im-

ply that leaks increase as time passes, making this a good retrofit measure as well as an important issue to guard against in new construction.

The results of our testing are summarized in Table 2. This table shows the percentage of tub spout diverters that leaked less than a given leak rate at all system pressures. TS-2, TS-6, TS-7, and TS-20 performed best; these diverters leaked less than 0.01 gpm at all pressures. TS-2, TS-6, and TS-7 are standard models; we can identify no design feature that would make them perform better than any of the other spouts we tested. TS-20, however, has a different design: it is the Positive Action Shut-off Mixet diverter by BrassCraft. Like the pull-down ring-type diverters, it has a spring that holds the diverter plate in the open position. Instead of pulling up on a lift to engage the diverter, however, one pulls straight out, in line with the tub spout (see photo at left). When the water is turned on and the lift is pulled, water pressure causes the diverter to stay in the closed position. According to the product literature available from BrassCraft, the internal configuration of the spout was designed to make the seal very effective even at low pressures. Our testing showed that this tub spout diverter was the most effective; none of the other diverters performed so consistently well across all pressures.

Conclusions and Recommendations

Test 1. Most of the measurements we took in Test 1 showed a savings factor greater than 0.7. We therefore recommend that auditors use a savings factor of 0.7 to estimate the achievable savings from fixing a leaking tub spout diverter. We feel that this savings factor will result in a conservative estimate of savings without understating the savings to the point where the measure will no longer be cost-effective.

Test 2. Based on our results for Test 2, we conclude that auditors do not need to worry about overestimating the savings when replacing a showerhead and fixing a leaking diverter in the same bathroom. We recommend estimating the achievable savings by taking the difference between the existing measured showerhead flow and the proposed rated showerhead flow, and adding the total diverter leak flow. It is not necessary to multiply the leak flow by a savings factor. For example, if the flow through the existing showerhead is 3 gpm, the existing leak through the diverter is 0.2 gpm, and you are planning to install a 2 gpm low-flow showerhead, then a conservative estimate of the total savings from installing the new showerhead and fixing the leaking diverter is 1.2 gpm.

Test 3. We recommend using the BrassCraft Positive Action Shut-off Mixet tub spout diverter, or a diverter that has been specifically designed to minimize flow even at low pressure, whenever possible. This spout is currently available from several distributors on the Internet, and its price (approximately $25) is in line with those of the other spouts we tested. It is available in both threaded and slip-on configurations, in two lengths, and with a variety of finishes.

If for some reason the Positive Action Shut-off Mixet is not available, or is not appropriate for a given installation, we recom-

Calculating the Savings

Measuring flow rate in an existing diverter leak is straightforward. It requires a stopwatch, a bucket to collect the water, and a measuring device (for example, a measuring cup from your kitchen or a water bottle marked in milliliters or fluid ounces). Turn on the shower. Collect the water that leaks from the tub spout for 60 seconds, timed with the stopwatch. Be careful not to let any water from the showerhead collect in the bucket. Very carefully pour the water from the bucket into your measuring device. Note how many cups, fluid ounces, or milliliters you collected and convert this measurement into gallons. Since you measured the flow for one minute, you now have flow rate in gallons per minute.

CALCULATING POTENTIAL ENERGY SAVINGS

To calculate potential savings, multiply your measured flow rate by a savings factor of 0.7 to account for the water that gets forced through the showerhead when you fix the leak. Then multiply by the number of minutes per year that the shower is used to calculate potential savings in gallons of water per year. Finally, convert gallons per year of hot water into saved therms or kWh, depending on how you heat your water.

Using a sample measured flow rate of 1.1 gpm, here is how we calculate dollar savings per year.

1. Calculate the achievable savings by multiplying the measured flow rate by 0.7:
   Measured flow rate of 1.1 gpm x Savings factor of 0.7 = Achievable savings flow rate of 0.77 gal/min
2. Calculate the gallons saved per year by multiplying the achievable savings rate by the number of minutes per year the shower is in use. Assuming that one person lives in the apartment, and that he or she showers 10 minutes per day, that is 10 minutes per day times 365 days per year, or 3,650 minutes per year:
   Achievable savings flow rate of 0.77 gal/min x 3,650 min/yr = Annual savings of 2,810 gal/yr
3. Calculate how much energy it takes to heat 2,810 gallons of water up to the showering temperature by multiplying the gallons saved per year by the specific heat of water and by the required temperature rise in the water. Estimate that the cold water from the street enters the building at 50°F and that the person in the apartment showers at 110°F. This is a temperature rise of 60°F. It takes 1 Btu to raise 1 lb of water 1ºF. Water weighs approximately 8.3 lb per gallon:
   Annual savings of 2,800 gal x Specific Heat of water of 1 Btu/lb-°F x Weight of water of 8.3 lbs/gal x Temperature rise of 60°F = 1,400,000 Btu/yr saved
4. Calculate therms per year or kWh per year saved by dividing Btu saved per year by the appropriate conversion factor and then by the efficiency of the heater. One therm equals 100,000 Btu and 1 kWh equals 3,412 Btu. Assume that a natural-gas heater has an efficiency of 83% and an electric heater has an efficiency of 98%:
   Annual energy savings of 1,400,000 Btu ÷ Energy content of natural gas of 100,000 Btu/therm ÷ Efficiency of 0.83 = 16.9 therms/yr saved
   Annual energy savings of 1,400,000 Btu ÷ Btu/kWh electricity of 3,412 ÷ Efficiency of 0.98 = 419 kWh/yr saved
5. Calculate dollars saved per year by multiplying the therms or kWh saved per year by the cost of energy. In the following examples, we have assumed that natural gas costs $1.10 per therm and electricity costs $0.12 per kWh:
   Annual therms savings of 16.9 x $1.10/therm = $18/yr saved
   Annual kWh saved of 419 x $0.12/kWh = $50/yr saved

NOTE: *We have not included the cost savings achieved by reducing water consumption in this last calculation. Including those savings will improve the payback time for replacing a leaking diverter.*

mend testing any replacement spout after it is installed, and accepting it only if it leaks less than 0.02 gpm; if it leaks more than that, the spout should be returned to the manufacturer as faulty and a new spout should be installed.

Calculating Energy Savings and Payback

Using our results, it is easy for an auditor to calculate the annual savings that can be achieved by fixing a leaking diverter. (See "Calculating the Savings," p. 40 for full details.) Once auditors have calculated annual dollar savings, they must determine if the savings justify the cost of installing the new diverter. A new tub spout diverter costs approximately $25. If the installation is straightforward, it should take a plumber less than one hour to install. We therefore estimate a total installed cost of $50–100 per tub spout.

In general, it makes sense to install an energy conservation measure only if the replacement will save more than the installed cost over the lifetime of the replacement. We estimate a lifetime of 15–20 years for a tub spout diverter. Annual savings and payback for various leak flows are shown in Table 3. Depending on the cost of fuel, it will generally be cost-effective to replace a tub spout diverter that leaks more than 0.2 gpm.

Table 3. Annual Savings and Payback for Various Leak Flows

EXISTING LEAK (gpm)	HEATED BY ELECTRICITY		HEATED BY GAS	
	Annual Savings ($/yr)	Payback (Yr)	Annual Savings ($/yr)	Payback (Yr)
0.1	$4.60	21.7	$1.70	58.8
0.2	$9.20	10.9	$3.40	29.4
0.3	$13.80	7.2	$5.10	19.6
0.4	$18.40	5.4	$6.80	14.7
0.5	$23.00	4.3	$8.50	11.8
0.6	$27.60	3.6	$10.20	9.8
0.7	$32.20	3.1	$11.90	8.4
0.8	$36.80	2.7	$13.60	7.4
0.9	$41.30	2.4	$15.30	6.5
1	$45.90	2.2	$17.00	5.9

Note: *The savings in this table include a savings factor of 0.7 to account for the additional water that comes out of the showerhead when a leaking diverter is fixed. Electricity is assumed to be $0.12/kWh and gas is assumed to be $1.10/therm. We assume the shower is used for 10 minutes per day, and that a gas water heater has an efficiency of 83% and an electric heater has an efficiency of 98%. Payback is calculated based on an installed cost of $100 per diverter. Savings do not include the cost of water.*

Other Points to Consider

Here are a couple of other points to consider in deciding whether to install a new tub spout diverter. First, savings may be more permanent than would be the case if a low-flow showerhead were installed. Tenants frequently remove low-flow showerheads because they find the new flow too low. We predict that this will not be a problem with new diverters, both because tenants are unlikely to notice the change, and because it takes more skill and effort to replace a diverter than to replace a showerhead.

Second, leaking diverters can cause auditors to miss water and energy saving opportunities. This is because the leak reduces the flow from the showerhead. Showerhead flow should be remeasured after a leaking diverter is replaced and a new showerhead should be installed if the existing one has a flow higher than 2.5 gpm.

Fixing Leaking Diverters

It is relatively simple to replace a leaking tub spout diverter. However, especially in older showers, it is common for the tub spout to have become stuck to the water pipe. If the spout is stuck, be very careful to not break the pipe behind the wall of the shower. It may be impossible to replace the tub spout without opening up the shower wall and replacing some of the pipe. It may also be impossible to replace some kinds of diverter without opening the shower wall. A plumber or a building maintenance person with basic plumbing skills should be able to replace a tub spout diverter in less than an hour if the diverter is not stuck.

Whoever replaces the diverter should be extremely careful not to damage the shower wall or the pipe. It can take significant force to remove the existing diverter, especially if it is old and has rusted to the pipe. Protect the wall and pipe from damage. If those replacing the diverters can feel the pipe flex as they attempt to loosen the diverters, they should proceed only if they are willing to cut a hole in the shower wall to repair a broken pipe.

Betsy Jenkins *has worked on reducing the energy consumption of multifamily buildings in New York for 9 years. She can no longer take a shower without examining the diverter and thinking about how much money is flowing straight down the drain.*

The research described in this article was conducted by Taitem Engineering for the New York State Housing and Community Renewal Weatherization Assistance program. Many thanks to Bill King for building our test rig and lifting many buckets of water; to Rob Rosen for his last-minute testing efforts; to Fred Schwartz for hours of consulting; to Ian Shapiro for his enthusiasm for this project; and to Evan Hallas for recognizing that auditors everywhere are overlooking this issue.

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