Designer's Guide

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Hot Water Temperature Maintenance and the Codes

I have been attending meetings of the Plumbing Code Study and Development Committee of Southeastern Michigan started by John Nussbaum, executive vice-president of the Plumbing & Mechanical Contractors of Detroit. Since 1988, John has pulled together a consensus group of people in the plumbing industry to draft new code language and review proposed code changes. In the fall of each year, the group assembles to review the code and propose new code text prior to the deadline for submissions for code changes. When the code change monographs are printed and distributed, John assembles this group of volunteers to review the proposed changes and formulate positions for or against. In some cases the committee may decide to propose a minor amendment to the text. The committee selects a few representatives to attend the code hearings and testify on its behalf. The committee has 24 members who are master plumbers, inspectors, contractors, manufacturers representatives, engineers, design professionals and a member of the general public.

This code committee is a local code committee whose members want their voices to be heard at the model code hearings. In Michigan they reviewed the two model codes in 1998 and chose the International codes because they offered a full family of codes. At the time, the *Uniform Plumbing Code* was favored by many, but there was not a building code to go with the Uniform Codes. Recently, the International Association of Plumbing and Mechanical Officials formed an alliance with the National Fire Protection Association to develop a building code so in the near future, they will have a family of codes. Because Michigan has selected the International Codes, the Southeast Michigan Code Study and Development Committee is for now only reviewing and working on the *International Plumbing Code*.

The Southeast Michigan code committee has proposed several code changes. One of them will deal with the distance from the source of hot water to the point of use. Currently the code says:

> **607.2 Hot water supply temperature maintenance.** Where the developed length of hot water piping from the source of hot water to the farthest fixture exceeds 100 feet ,the hot water supply system shall be provided with a method of maintaining the temperature of hot water to within 100 feet of the fixtures.

The committee proposed a code change to reduce the "100 feet" distance to "50 feet." As strange as it may seem, this code change will not be heard in the plumbing code hearings. The International Code Council has a Code Correlation Committee that decided this code change is under the jurisdiction of the *International Energy Code*. The proposed change will be heard during the *International Energy Code* hearings and, if the code change is successful, it will automatically appear in the plumbing code.

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The reason for the proposal

This proposed change is intended to address the waste of water and energy associated with systems with up to 100 feet of hot water piping from the water heater to the farthest fixture. In the *Domestic Water Heating Design Manual*, recently published by the American Society of Plumbing Engineers (ASPE), chapters 10 and 11 describe how to promptly deliver hot water to all fixtures, depending on the type of facility. The manual recommends a minimum of 25 feet or 30 seconds as minimally acceptable.

Previous guidelines indicate that, when the distance from the water heater to the farthest outlet exceeds 100 feet, the water should be circulated. The 100-foot recommendation appears to be subjective, and some engineers and contractors use the 100-foot criterion as the maximum length for all uncirculated, uninsulated, dead-end hot water branches to fixtures. When the 100-foot criterion in the current code is followed, it creates considerable problems, such as lack of hot water at fixtures, insufficient water heater capacity and thermal temperature esca-

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Nominal Diameter (in.)	Copper Pipe Type L		Copper Pipe Type M		Steel Pipe Schedule 40		CPVC Pipe Schedule 40	
	Water (gal./ft.)	Wgt. (lb./ft.)	Water (gal./ft.)	Wgt. (lb./ft.)	Water (gal./ft.)	Wgt. (lb./ft.)	Water (gal./ft.)	Wgt. (lb./ft.)
1/2	0.012	0.285	0.013	0.204	0.016	0.860	0.016	0.210
3/4	0.025	0.445	0.027	0.328	0.028	1.140	0.028	0.290
1	0.043	0.655	0.045	0.465	0.045	1.680	0.045	0.420
1-1/4	0.065	0.884	0.068	0.682	0.077	2.280	0.078	0.590
1-1/2	0.093	1.140	0.100	0.940	0.106	2.720	0.106	0.710

Table 1 — Water Contents and Weight of Tube or Piping per Linear Foot (English units)

lation in showers.

The 100-foot length criterion was developed in 1973 after the Middle East oil embargo, when energy costs were more important than water conservation. Because the circulation of hot water causes a very minor loss of energy due to radiation and convection, the current 100-foot distance was chosen. The energy loss is minor when compared to the energy loss of water that was heated and poured down the drain and the lack of hot water at the fixtures, especially the intermittent use fixtures such as lavatories. The previous guidelines apparently compromised and developed the 100-foot maximum length criterion.

Length and time criteria

The latest edition of the ASPE *Domestic Water Heating Design Manual* recommends changes to the 100-foot length criterion. Water that is wasted because of the long delay in obtaining hot water at the fixtures has become a more critical issue than the energy losses caused by hot water temperature maintenance systems. To significantly reduce the wasting of cooled hot water, the engineering community has reevaluated the permissible distances for uncirculated, dead-end branches to periodically used plumbing fixtures. The existing 100-foot allowable distances for uncirculated, dead-end branches represent a trade-off between the energy used by the hot water temperature maintenance system and the cost of the insulation, on the one hand. On the other hand, with long dead-end branches there is the cost of energy to heat the excess cold water makeup, the cost of wasted potable water, decreased capacity of the water heater and extra sewer surcharges added to the water meter reading. For those concerned about energy losses there would be no nighttime energy losses, if the energy to the self-regulating heater cable or circulating pump were to be controlled by a timer during night time hours. Furthermore, engineers and contractors should be aware that there is a potential for liability if an educated owner questions the ade-

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Nominal Diameter (mm)[a]	Copper Pipe Type L		Copper Pipe Type M		Steel Pipe Schedule 40		CPVC Pipe Schedule 40	
	Water (L)	Wgt. (kg)	Water (L)	Wgt. (kg)	Water (L)	Wgt. (kg)	Water (L)	Wgt. (kg)
DN15	0.045	0.129	0.049	0.204	0.061	0.390	0.061	0.099
DN20	0.095	0.202	0.102	0.328	0.106	0.517	0.106	0.132
DN25	0.163	0.297	0.170	0.465	0.170	0.762	0.170	0.191
DN32	0.246	0.401	0.257	0.682	0.291	1.034	0.295	0.268
DN40	0.352	0.517	0.379	0.940	0.401	1.233	0.401	0.322

[a]*Pipe sizes are indicated for mild steel pipe sizing.*

Table 2 — Water Contents and Weight of Tube or Piping per Meter (metric units)

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quacy of their hot water delivery system even if it meets the code.

What are *reasonable delays* in obtaining hot water at a fixture? The *Domestic Water Heating Design Manual* describes a reasonable delay as follows: For anything beside very infrequently used fixtures (such as those in industrial facilities or certain fixtures in office buildings), a delay of zero to 10 seconds is normally considered acceptable for most residential occupancies and public fixtures in office buildings. Adelay of 11 to 30 seconds is marginal but possibly acceptable, and a time delay longer than 31 seconds is normally considered unacceptable and a significant waste of time, water and energy. Therefore, when designing hot water systems, *it is prudent for the codes to provide some means of getting hot water to the fixtures closer to or within these acceptable time limits*. This means that there should be a maximum distance of approximately 25 feet (7.6 meters) between the hot water maintenance system and each of the plumbing fixtures requiring hot water. The distance should depend on the water flow rate of the plumbing fixture at the end of the line and the size of the line (see Tables 3 and 4). Additional delays in getting hot water to the fixture may be caused by the rerouting of the pipes for structural conditions or other flow related problems. The tables support the 25-foot distance, although past experience shows the industry may resist such a drastic change. Therefore the committee suggested a maximum of 50 feet because it

Maximum Flow Rates [a]		
Fittings	GPM	L/Sec
Lavatory faucet	2.0	0.13
Public non-metering	0.5	0.03
Public metering	0.25 gal./cycle	0.946 L/cycle
Sink faucet	2.5	0.16
Shower head	2.5	0.16
Bathtub faucets		
Single-handle	2.4 min.	0.15 min.
Two-handle	4.0 min.	0.25 min.
Service sink faucet	4.0 min.	0.25 min.
Laundry tray faucet	4.0 min.	0.25 min.
Residential dishwasher	1.87 avg.	0.12 avg.
Residential washing machine	7.5 avg.	0.47 avg.

[a]*Unless otherwise noted.*

Table 3 — Approximate Fixture and Appliance Water Flow Rates

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		Delivery Time (sec.)											
Fixture Flow Rate (gpm)		0.5 gpm			1.5 gpm			2.5 gpm			4.0 gpm		
Piping Length (ft.)		10	25	50	10	25	50	10	25	50	10	25	50
Copper Pipe	1/2 in.	25	63[a]	125[a]	8	21	42[a]	5	13	26	3	8	16
	3/4 in.	48[a]	119[a]	238[a]	16	40[a]	80[a]	10	24	48[a]	6	15	30
Galv. Stl. Pipe, Sched. 40	1/2 in.	63[a]	157[a]	314[a]	21	52[a]	104[a]	13	31	62[a]	8	20	40[a]
	3/4 in.	91[a]	228[a]	456[a]	30	76[a]	152[a]	18	46	92[a]	11	28	56[a]
CPVC Pipe, Sched. 40	1/2 in.	64[a]	159[a]	318[a]	21	53[a]	106[a]	13	32	64[a]	8	20	40[a]
	3/4 in.	95[a]	238[a]	476[a]	32	79[a]	158[a]	19	48[a]	96[a]	12	30	60[a]

Note: Table based on various fixture flow rates, piping materials, and dead-end branch lengths. Calculations are based on the amount of heat required to heat the piping, the water in the piping, and the heat loss from the piping.

[a]*Delays longer than 30 seconds are not acceptable according to ASPE's Domestic Hot Water Design Manual.*

Table 4 — Approximate Time Required to Get Hot Water to a Fixture

would be a vast improvement and most homes and small businesses can deliver hot water from a centrally located water heater without having a temperature maintenance system (see Table 4).

Low flow fixture requirements

With the low fixture discharge rates now mandated by national and local laws, it takes considerably longer to obtain hot water from non-temperature maintained hot water lines than it did in the past, when fixtures had greater flow rates. For example, a public lavatory with a 0.50 or 0.25 gallon per minute (0.03 or 0.02 liter per second) maximum discharge rate would take an excessive amount of time to obtain hot water from 100 feet (30.48 meters) of uncirculated, uninsulated hot water piping. Tables 1 through 6 give conservative approximations of the

		Approximate Delivery Time (sec.) of Hot Water From Source to Fixture							
Fixture Flow Rate		0.5 gpm		1.5 gpm		2.5 gpm		4.0 gpm	
Piping Length (ft.)		100[b]	50	100	50	100	50	100	50
Copper Pipe	1/2 in.	250[a] (4.1 min.)	125[a]	80[a]	40[a]	50[a]	25	30	15
	3/4 in.	480[a] (8.0 min.)	240[a]	160[a]	80[a]	100[a]	50[a]	60[a]	30
Galv. Stl. Pipe Sch. 40	1/2 in.	630[a] (10.5 min.)	315[a]	210[a]	105[a]	130[a]	65[a]	80[a]	40[a]
	3/4 in.	910[a] (15.1 min.)	455[a]	300[a]	150[a]	180[a]	90[a]	110[a]	55[a]
CPVC Pipe Sch. 40	1/2 in.	640[a] (10.6 min.)	320[a]	210[a]	105[a]	130[a]	65[a]	80[a]	40[a]
	3/4 in.	950[a] (15.8 min.)	475[a]	320[a]	160[a]	190[a]	95[a]	120[a]	60[a]

Note: Table based on various fixture flow rates, piping materials, and dead-end branch lengths of 50 and 100 feet. Calculations are based on the amount of heat required to heat the piping, the water in the piping, and the heat loss from the piping.

[a]Delays longer than 30 seconds are not acceptable according to ASPE's Domestic Hot Water Design Manual.

[b]Current code text allows 100 ft. from hot water source. Delay in seconds (min.) are listed in this column.

Table 5 — Comparison of Time Delays for Current Code Text of 100 Feet vs Proposed Code Text of 50 Feet

amount of time it takes to obtain hot water at a fixture based on the size of the line, the fixture flow rate, and the times required to replace the cooled-off hot water, to heat the pipe, and to offset the convection energy lost by the insulated hot water line.

Results of delivery delays

As mentioned previously, and shown in Table 5, when there is a long delay in obtaining hot water at the fixture, there is significant waste of potable water as the

cooled hot water supply is simply discharged down the drain unused. Furthermore, plumbing engineers concerned about total system costs have realized that the cost of this wasted, previously heated water includes:

1. The original cost for obtaining potable water.
2. The cost of fuel used to previously heat the water.
3. The final cost of the waste treatment of this excess potable water, which results in larger sewer surcharges.
4. The cost of heating the incoming cold water that is replacing the wasted water to bring it up to the required temperature.

When there is a long delay in obtaining hot water at the fixtures, the faucets are turned on for long periods of time to draw the hot water from the water heater to the fixture to get the hot water up to the desired temperature. This can cause the water heating system to run out of hot water and make the water heater sizing inadequate. The water heater may be unable to heat all the extra cold water brought into the system because of the ambient temperature water being discharged down the drain. This extra cold water entering the hot water system reduces the hot water supply temperature. This increases the problem of insufficient hot water because to get a proper blended temperature more lower-temperature hot water will be used to achieve the final mixed water temperature. (See Chapter 1, Table 1.1 in the *Domestic Water Heating Design Manual*.) Additionally, this accelerates the downward spiral of the temperature of the hot water system.

The 100-foot distance also results in long delays in getting hot water to the fixtures and the fixtures operate for longer than expected periods of time. That means the actual hot water demand period is greater than the peak demand period normally designed for. Therefore, when sizing the water heater and the hot water piping distribution system, the designer should be aware that the lack of a proper hot water maintenance system will seriously affect the required size of the water heater.

Prompt hot water supply

Hot water maintenance systems are as varied as the imaginations of the plumbing engineers and contractors who create them. They can be grouped into three basic categories, though any actual installation may be a combination of more than one of these types of system. The three basic categories are:

1. Circulation systems.
2. Self-regulating heat trace systems.
3. Point of use water heaters (locating the water heater within 50 feet of the fixtures). □

Note: Tables 2, 3 and 6 are taken from the ASPE *Domestic Hot Water Heating Manual*; Table 4 is also from the manual with the addition of interpolated values for 50-foot pipe lengths. Table 5 is derived from data in other tables in this article.

		Approximate Delivery Time (sec.) of Hot Water From Source to Fixture							
Fixture Flow Rate		0.03 LPS		0.10 LPS		0.16 LPS		0.25 LPS	
Piping Length (m)		3.1	7.6	3.1	7.6	3.1	7.6	3.1	7.6
Copper Pipe	DN15	25	63[a]	8	21	5	13	3	8
	DN22	48[a]	119[a]	16	40[a]	10	24	6	15
Galv. Stl. Pipe Sch. 40	DN15	63[a]	157[a]	21	52[a]	13	31[a]	8	20
	DN20	91[a]	228[a]	30	76[a]	18	46[a]	11	28
CPVC Pipe Sch. 40	DN15	64[a]	159[a]	21	53[a]	13	32[a]	8	20
	DN20	95[a]	238[a]	32[a]	79[a]	19	48[a]	12	30

Note: Table based on various fixture flow rates, piping materials, and dead-end branch lengths. Calculations are based on the amount of heat required to heat the piping, the water in the piping, and the heat loss from the piping.

[a]Delays longer than 30 seconds are not acceptable according to ASPE's Domestic Hot Water Design Manual.

Table 6 — Approximate Time Required to Get Hot Water to a Fixture (metric)