Fixture Flow Rate Comparison Cross-Linked Polyethylene (PEX) Piping and Copper Tubing

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Table of Contents

List of Tables

List of Figures


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Executive Summary

In a typical single-family residential plumbing system, PEX and copper piping systems will deliver sufficient volumetric flow rates to the plumbing fixtures when using the same nominal size tubing. While PEX tubing has a smaller inside diameter than copper tubing, both tubing systems meet the farthest fixture demand, even with multiple fixtures flowing.

Laboratory testing was performed on identical configurations for both PEX and copper trunk and branch plumbing systems serving standard residential plumbing fixtures supplied at source pressures of 40, 60, and 80 psi for 60 and 100-feet of pipe to the furthest fixture. The flow rate of each plumbing fixture was virtually identical for both piping systems, except for minor differences in the water closet flow rate.

Background

In 2006, the NAHB Research Center conducted flow and pressure tests on PEX tubing systems configured as Trunk and Branch, Remote Manifold, and Home Run.[1] All of the PEX tubing systems used metal insert fittings. System pressure and flow rates were measured during the operation of actual household fixtures typically used in the residential market. A combination of fixture operation, of up to five simultaneous fixture flows, provided a range of flow rates in various sections of the piping system. One fixture, the primary Test Fixture, was monitored during each flow sequence. This Test Fixture was located the farthest from the source supply, both in distance and elevation. The flow rate and pressure at this fixture provided the basis for analyzing the performance data of each system design and with multiple fixtures operating simultaneously. A similar test system and procedure was used to perform identical tests on a system constructed with copper tubing and is reported here.

Test Setup – Copper Tubing

Based on the previous testing of PEX plumbing systems, a Trunk and Branch system design was constructed using Type M copper tubing and subjected to the same flow and pressure test regimen. The same test apparatus originally used for the PEX tubing tests was used to construct the copper system. The incoming water supply system, water heater, kitchen sink faucet, showerheads, lavatory faucet, and water closet were identical to the original PEX tests. The tub/shower valves were changed using the same brand/model, but only with different respective piping connections. The original test apparatus used ½" PEX barb connections. This test setup used ½" NPT threaded connections, as would be typical in actual practice. As in the original PEX tests, the copper tests were performed on 100-foot and 60-foot systems measured from the shutoff valves after the water heater to the furthest shower (Test Fixture). The test setup included a shower and kitchen sink located about 6 feet above the water supply, and a water closet, lavatory, and shower at about 15 feet above the water supply, as shown in Figures 1 and 2.

[1] Residential PEX Water Supply Plumbing Systems: Design Guide, 2006. http://www.toolbase.org/pexdesignguide.

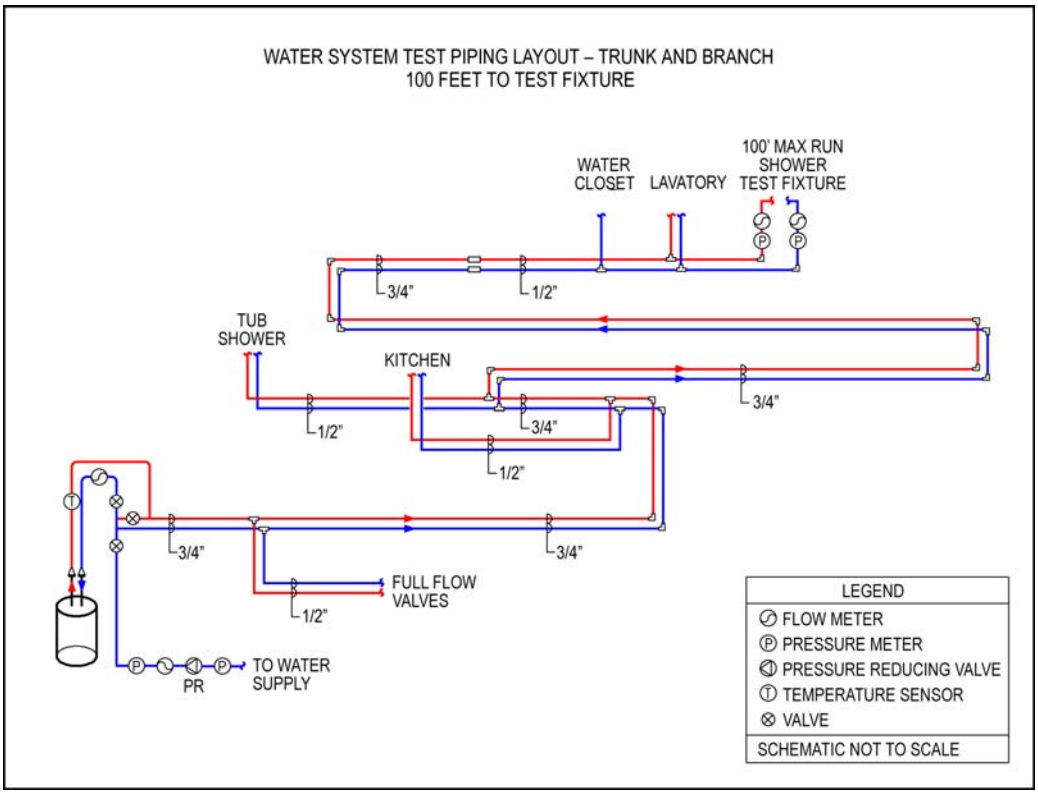

Figure 1 – *100' to Test Fixture*

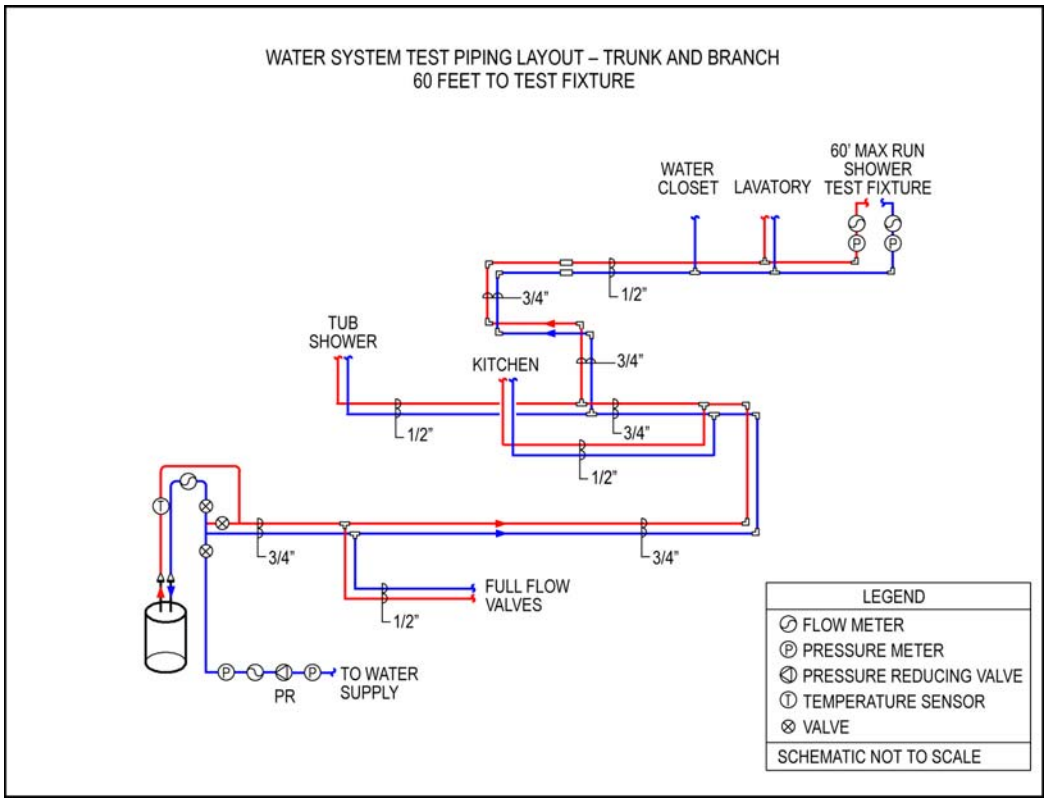

Figure 2 – *60' to Test Fixture*

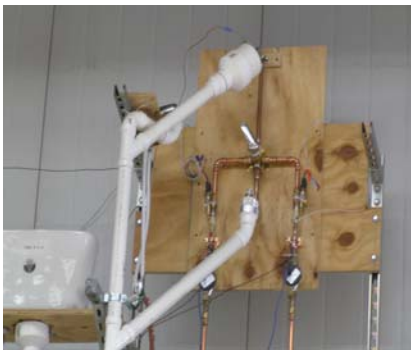

Figure 3 –
Test Shower Valve

The copper tubing layouts above were modified only to replace the sweep PEX 90 degree bends with 90 degree fittings. In the original 100-foot PEX setup, four of the seven 90 degree bends were metal insert fittings. In the 60-foot PEX setup, two of the five 90 degree bends were metal insert fittings.

The Test Fixture, shown in Figure 3, is located the furthest, by distance and elevation, from the source. It is a single handle, pressure balanced tub/shower valve that when on, is set to the highest temperature as regulated by the internal valve mechanism.

Test Method

A set of eight tests were performed for each of three source pressures of 40, 60 and 80 psi. The test set sequence and nomenclature is outlined in Table 1.

Table 1 – ***Pressure and Flow Test Set***

Test No.	Fixtures Operated	Nomenclature
1	Test Fixture (TF)	TF
2	TF and Lavatory	TF+Lav
3	TF and Water Closet	TF+WC
4	TF and Kitchen Faucet (mid-position)	TF+Kit
5	TF and 2nd shower (full on)	TF+Sh2
6	No. 5 and Kitchen	TF+Sh2+Kit
7	No. 6 and Lavatory	TF+Sh2+Kit+Lav
8	No. 7 and Water Closet	TF+Sh2+Kit+Lav+WC

For each test, the pressures and flow rates were recorded at the Test Fixture as well as at the inlet of the supply piping to the plumbing system.

A set of tests were also conducted to characterize the time-to-hot water for the copper piping system. The test method was similar to that as performed originally for the PEX tubing system and includes sequential steps. Only the Test Fixture is operated for the time-to-hot water test. For the testing sequence, the piping system to the Test Fixture is first flushed with cold water to stabilize the piping to the starting temperature. The bypass flush valve is then closed and the test begins when water is allowed to flow from the hot water tank to the Test Fixture. The time to exceed 100°F and 110°F at the Test Fixture is measured. As with the PEX tubing tests, the results are normalized on the basis of flow rate and hot water tank temperature.

Results and Discussion

Due to the minor differences in the tub/shower valves, the flow rate at the Test Fixture (TF) was slightly different between the PEX and copper systems. The PEX TF hot flow rate was measured at 1.7 gpm, while the copper TF hot flow rate was 1.5 gpm. On the cold side of the valve, the flow rates were 0.2 gpm and 0.5 gpm for the PEX and copper systems, respectively. All results are reported, including these small differences.

The major result of interest is the total system flow for each of the test systems using an identical test sequence. Even though the test fixtures blended the hot and cold-water supplies differently, the total flow rates through the valves were 1.9 gpm for the PEX system and 2.0 gpm

for the copper system. Therefore, the total flow for each pipe system through the test fixture was within an insignificant amount of 0.1 gpm. Figures 4, 5 and 6 report the total system flow for each test in the sequence for both the 60' and 100' runs to the Test Fixture at the three different supply pressures. The data shown in Figures 4, 5, 6, 7, and Tables 2 and 3, is the average of three tests.

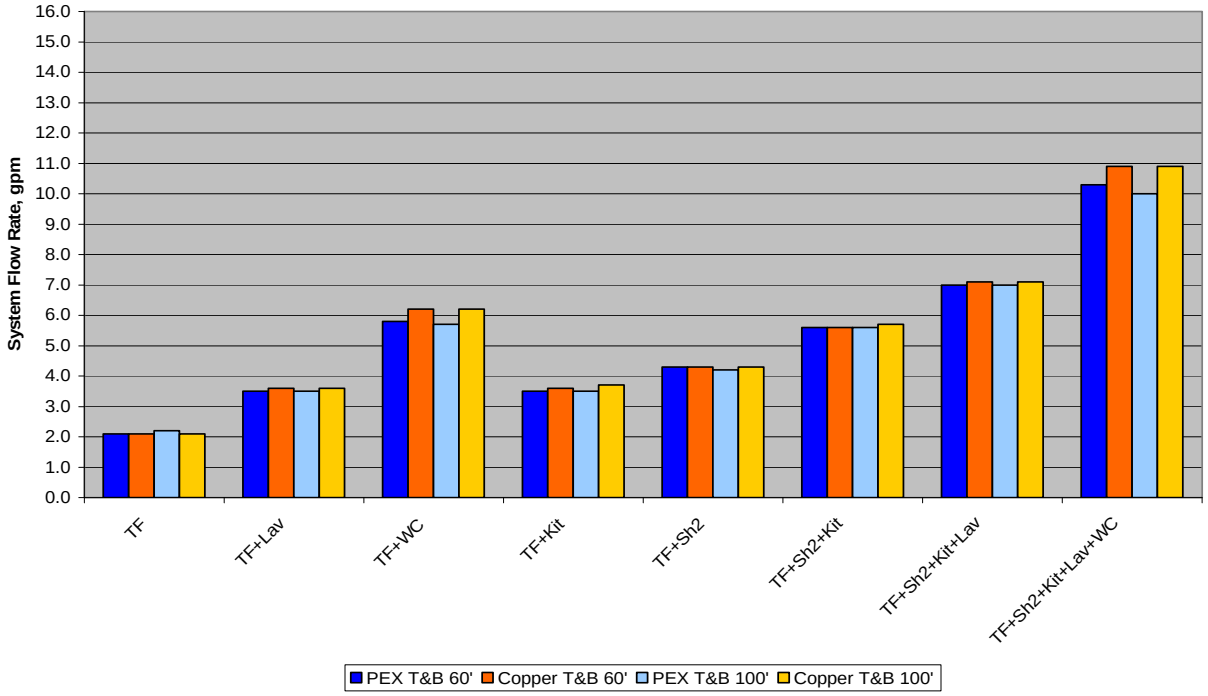

Figure 4 – *Total System Flow at 40 PSI*

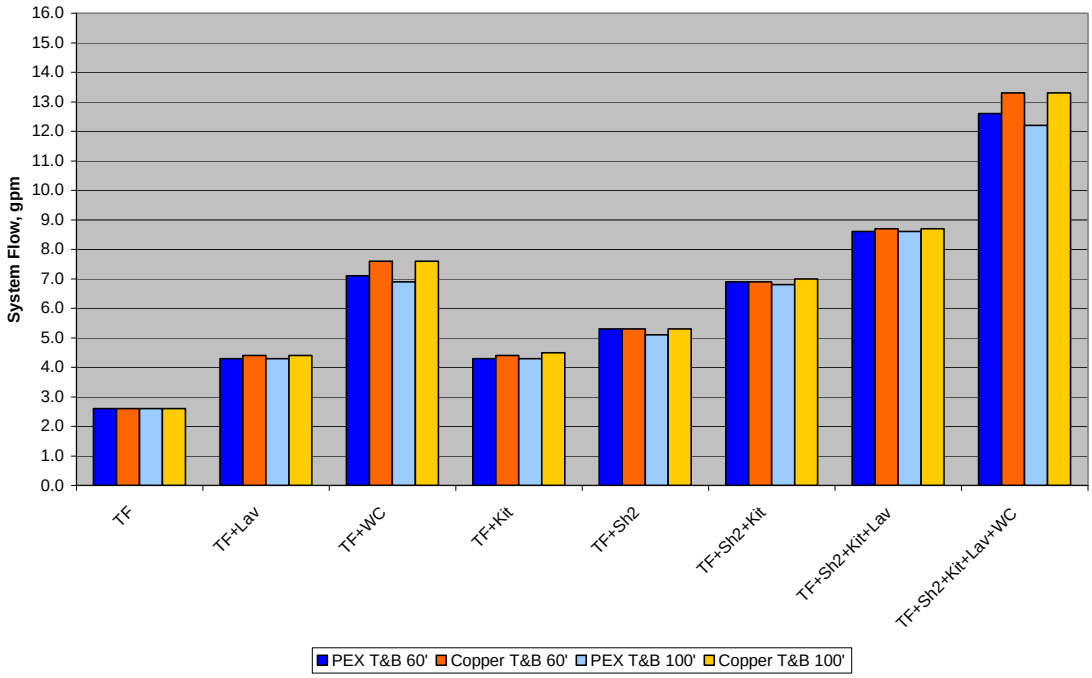

Figure 5 – *Total System Flow at 60 PSI*

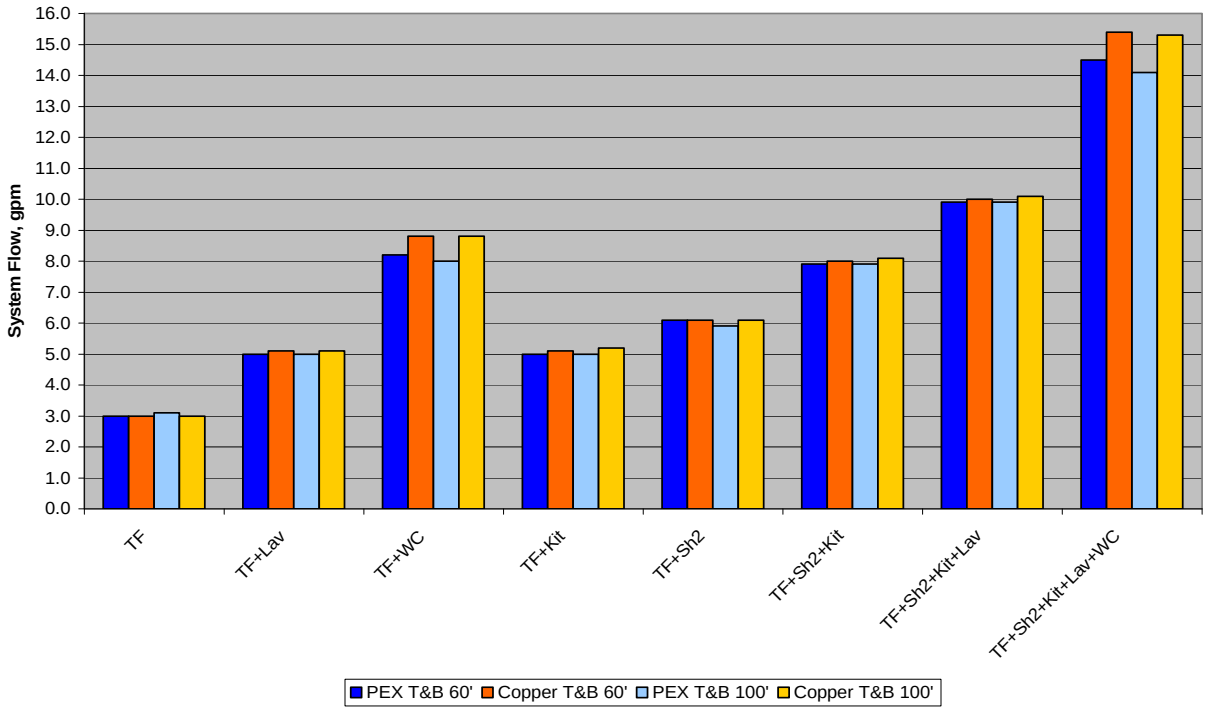

Figure 6 – *Total System Flow at 80 PSI*

The data indicates that the total system flows, which include both the hot and cold water, are virtually identical for the PEX and copper systems at all source pressures. A minor deviation, approximately 1 gpm from this result, is evident for the test sequences involving the water closet. The maximum difference of 0.9 gpm results in the increased tank fill time of approximately 7 seconds.

The data, also shown in tabular form for 40 psi source pressure, demonstrates that the piping systems perform similarly at the minimum recommended household source pressure of 40 psi.

Table 2 – *PEX 100-foot Flow Data*

Trunk & Branch 100' Flow and Pressure Test, Average Data - PEX Tubing								
T&B 100'	System	Cold Supply	Hot Supply	Main	Test Shower Fixture			
Fixture Flow Source Pressure	Flow gpm	Flow gpm	Flow gpm	Pressure Psi	TF Hot Flow gpm	Hot Pres. psi	TF Cold Flow gpm	Cold Pres. psi
T&B 100' - 40 PSI	0.0	0.0	0.0	40	0.0	34.0	0.0	35.2
TF	2.2	0.5	1.7	40	1.7	31.6	0.2	35.1
TF+Lav	3.5	1.6	1.9	40	1.7	31.2	0.2	34.2
TF+WC	5.7	4.0	1.6	40	1.7	31.9	0.2	29.5
TF+Kit	3.5	1.3	2.2	40	1.7	31.3	0.2	35.0
TF+Sh2	4.2	1.3	2.8	40	1.7	30.6	0.2	34.9
TF+Sh2+Kit	5.6	2.2	3.4	40	1.7	30.3	0.2	34.7
TF+Sh2+Kit+Lav	7.0	3.5	3.5	40	1.7	30.1	0.2	33.4
TF+Sh2+Kit+Lav+WC	10.0	5.8	4.2	40	1.7	28.6	0.2	29.3

Table 3 – *Copper 100-foot Flow Data*

Trunk & Branch 100' Flow and Pressure Test, Average Data - Copper Tubing - Threaded TF								
T&B 100'	System	Cold Supply	Hot Supply	Main	Test Shower Fixture			
Fixture Flow Source Pressure	Flow gpm	Flow gpm	Flow gpm	Pressure psi	TF Hot Flow gpm	Hot Pres. psi	TF Cold Flow gpm	Cold Pres. psi
T&B 100' - 40 PSI	0.0	0.0	0.0	40	0.0	33.5	0.0	34.6
TF	2.1	0.7	1.5	40	1.5	32.5	0.5	34.4
TF+Lav	3.6	1.7	1.9	40	1.5	32.1	0.5	34.1
TF+WC	6.2	4.8	1.4	40	1.5	32.9	0.5	32.3
TF+Kit	3.7	1.9	1.7	40	1.5	32.3	0.5	34.2
TF+Sh2	4.3	1.7	2.6	40	1.5	31.7	0.5	34.2
TF+Sh2+Kit	5.7	2.5	3.2	40	1.5	31.5	0.5	34.0
TF+Sh2+Kit+Lav	7.1	3.7	3.5	40	1.5	31.1	0.5	33.6
TF+Sh2+Kit+Lav+WC	10.9	6.9	4.0	40	1.5	30.9	0.5	31.5

In addition to the flow tests performed, a test procedure was used to characterize the time-to-hot water for the copper system. This is similar to the test performed for the PEX system. Figure 7 details the results for the copper system along with the previous PEX test results. The measured data for each test is averaged and then normalized to flow rate and temperature difference between the outlet and inlet.

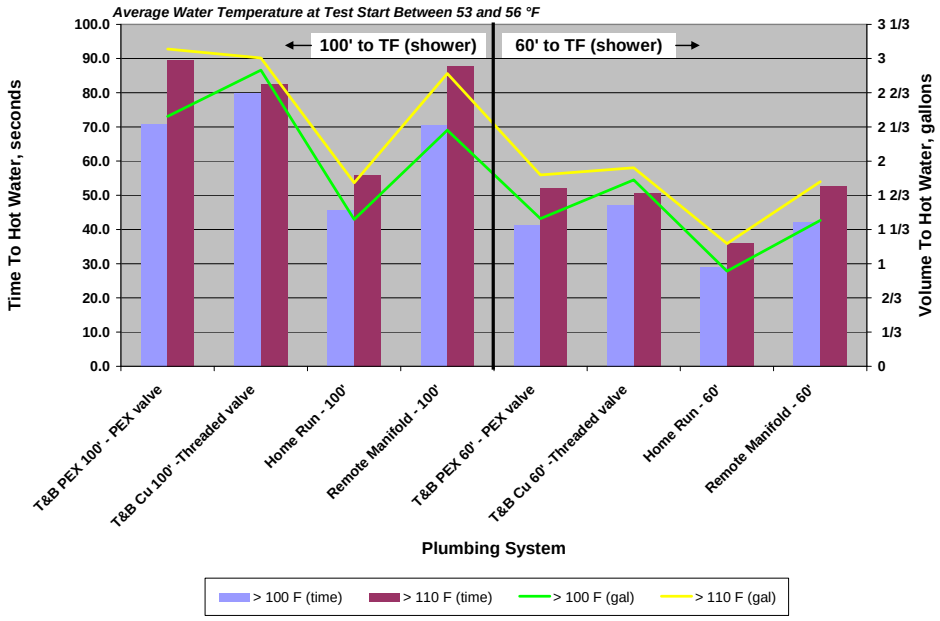

Figure 7– *Time to Hot Water*

Conclusion

In a typical single-family residential plumbing system, PEX and copper piping systems will deliver sufficient volumetric flow rates to standard residential plumbing fixtures when using the same nominal size tubing. While PEX tubing has a smaller inside diameter than copper tubing, at a given source pressure, both tubing systems meet the farthest fixture demand. This is the case even with multiple fixtures flowing.

Since plumbing fixtures are required to be flow limiting in most cases, both the PEX and copper piping systems of the same nominal dimension are capable of delivering the fixture demand. This includes instances where long piping runs to the outlet of 100 feet and with minimal source pressure of 40 psi.