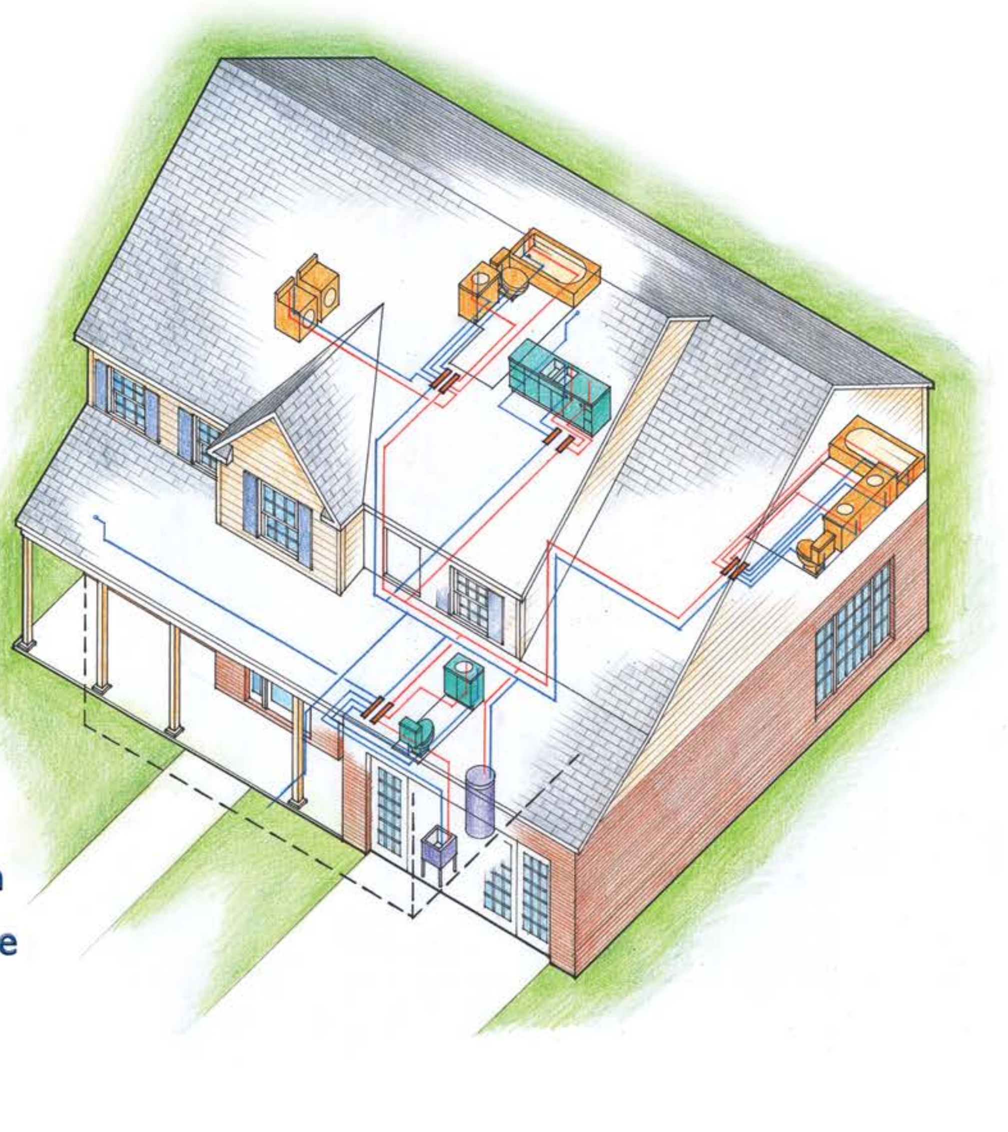
DESIGN GUIDE

Residential PEX Water Supply Plumbing Systems

Second Edition



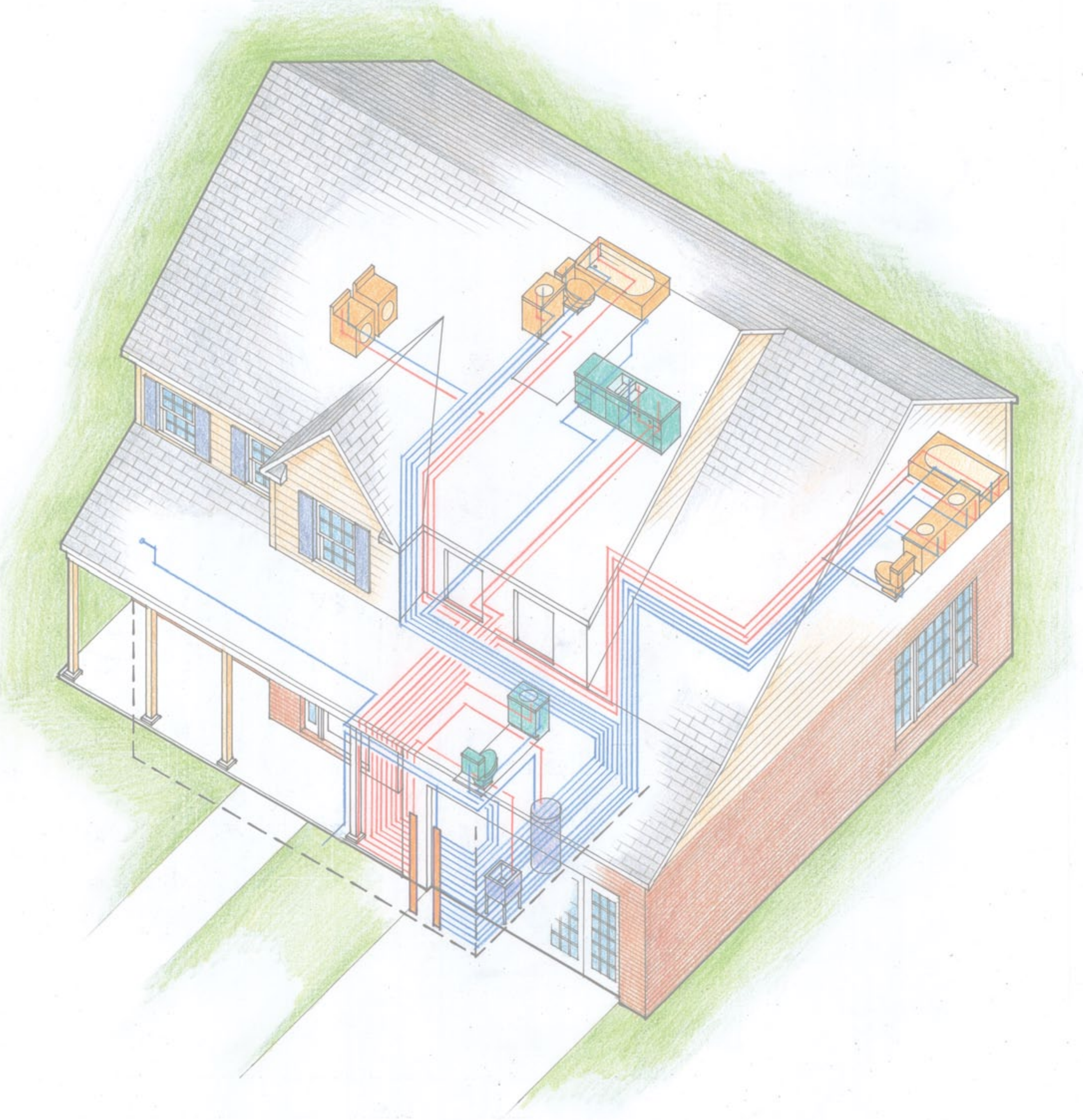
Applications
Advantages
Material Properties
Joining Methods
Code Acceptance
System Design
Installation
and more

PPFA Plastic Pipe and Fittings Association

ICC ES PMG

PLASTICS·PIPE·INSTITUTE™

Home Innovation RESEARCH LABS™



DESIGN GUIDE

Residential PEX Water Supply Plumbing Systems

Second Edition

Prepared for

PLASTICS·PIPE·INSTITUTE™

Plastics Pipe Institute, Inc (PPI)
105 Decker Court
Suite 825
Irving, TX 75062
www.plasticpipe.org

and

PPFA
Plastic Pipe and Fittings Association

Plastic Pipe and Fittings Association (PPFA)
800 Roosevelt Road, Bldg. C, Ste. 312
Glen Ellyn, IL 60137
www.ppfahome.org

Prepared by

Home Innovation RESEARCH LABS™

Home Innovation Research Labs
(formerly the NAHB Research Center, Inc.)
400 Prince George's Boulevard
Upper Marlboro, MD 20774
www.HomeInnovation.com

November 2013

This document was developed as the result of a consensus process involving the Plastic Pipe Institute, the Plastic and Plastic Pipe and Fitting Association, and representatives from numerous piping and fitting manufacturers. It was prepared by the Home Innovation Research Labs.

Acknowledgements

We would like to thank the following principal contributors to this Guide:

NIBCO, Inc.
Elkhart, Indiana

Tom Coe

Plastic Pipe and Fittings Association
Glen Ellyn, Illinois

Richard Church, Mike Cudahy

Plastics Pipe Institute
Irving, Texas

Randy Knapp

REHAU, Inc.
Leesburg, Virginia

Lance MacNevin

Uponor
Apple Valley, Minnesota

Kate Olinger, Mike Rivers

Viega, LLC
Wichita, Kansas

Gary Morgan, Christina Smith

Watts
Springfield, Missouri

Chris Haldiman

Zurn Plumbing Products Group
Commerce, Texas

Gary Runyan

ICC – ES
Whittier, California

Maribel Campos

NSF International
Ann Arbor, Michigan

Nasrin Kashefi

Home Innovation Research Labs
Upper Marlboro, Maryland

Joseph Wiehagen

Disclaimer

Neither the Home Innovation Research Labs, Inc., the Plastics Pipe Institute, the Plastic Pipe and Fitting Association, the U.S. Department of Housing and Urban Development, nor any person acting in its behalf, makes any warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this publication or that such use may not infringe privately owned rights, or assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this publication, or is responsible for statements made or opinions expressed by individual authors.

For Further Information:

Please consult the following websites for the latest version of this publication. Print on demand version available through ICC ES only.

Plastics Pipe Institute
http://www.plasticpipe.org/

Plastic Pipe and Fittings Association
http://www.ppfahome.org/

Home Innovation Research Labs
http://www.HomeInnovation.com

ICC Evaluation Service, LLC
www.icc-es.org

Table of Contents

List of Figures

List of Tables

8 PERFORMANCE DATA

Following the introduction of PEX plumbing systems in North America in the 1980's and the rapid growth of its usage in the 1990's, a significant amount of research on the performance of PEX plumbing systems has been conducted since 2000, with the objectives of determining the most efficient and effective plumbing designs for residential and light commercial applications.

For the reference of plumbing designers, installers, builders, plumbing engineers and inspectors, this chapter is intended to present and summarize the recent research, which demonstrates the high levels of performance from various PEX plumbing designs.

This chapter includes laboratory performance data on three common PEX plumbing design techniques – trunk-and-branch, parallel, zone (remore manifold) – and provides both objective and subjective ratings of each of these designs for various type of residences while considering numerous criteria.

Also included are studies to evaluate the ability of PEX plumbing systems to absorb pressure surges in residential plumbing systems, and to measure empirical performance data with fixture flow comparisons of PEX versus copper plumbing systems. The results of each study are summarized on page 74 and 75, respectively.

System Performance Comparison

Each of the three PEX plumbing configurations described in this guide can be installed in most homes with satisfactory performance. The different systems offer opportunities to optimize the performance of the plumbing system, reduce the installed cost, and increase overall customer satisfaction and acceptance. In order to quantify the differences between PEX system designs, each system was tested in the laboratory to provide a similar set of conditions under which the systems are installed and operated. Actual residential plumbing fixtures, piping layouts with fittings, and even elevation changes were installed and operated. This provided a consistent comparison between system designs, as well as an indication of the minimum performance characteristics of each system.

PEX piping was installed in each of the three configurations—trunk and branch, parallel, and zone—with overall results showing:

- All systems had similar flow characteristics at each of the fixtures when flowing independently
- All system designs responded in a similar manner to simultaneous flow events (more than one fixture flowing at once)
- Minor differences in the actual measured flow and pressure at a test fixture emerged when simultaneous flow events occurred

Test System Design and Set-up

A set of plumbing fixtures were installed in a laboratory setting to provide actual flow and pressure data during operation of the fixtures. These data provide assurance that the PEX plumbing system design is capable of supplying the required flow rates during operation of the fixture. In addition, the test results provide assurance that the plumbing system design will supply adequate flow and pressure to a remote test fixture while other fixtures are operated simultaneously. The test system was constructed and reconfigured for each type of PEX plumbing design, including the standard trunk and branch (T&B), the parallel (HR), and the zone (RM). A primary Test Fixture (TF), represented by a tub/shower unit, was installed and instrumented to measure flow rate and flow pressure on the hot and cold lines, as well as mixed water temperature. Figure 8.1 shows the laboratory system diagram for the T&B system. Other test system designs are shown in Appendix A. The TF was located the farthest from the source of all the fixtures, and was operated in shower mode during all tests. The operating performance of this test fixture represents the "worst case" characteristics of the full system, since all other fixtures were closer to the source. Figure 8.2 shows the laboratory set-up configured with the fixtures and the T&B system design with 100-foot distance to the TF. Figure 8.3 shows the TF with the sensors for pressure and flow installed.

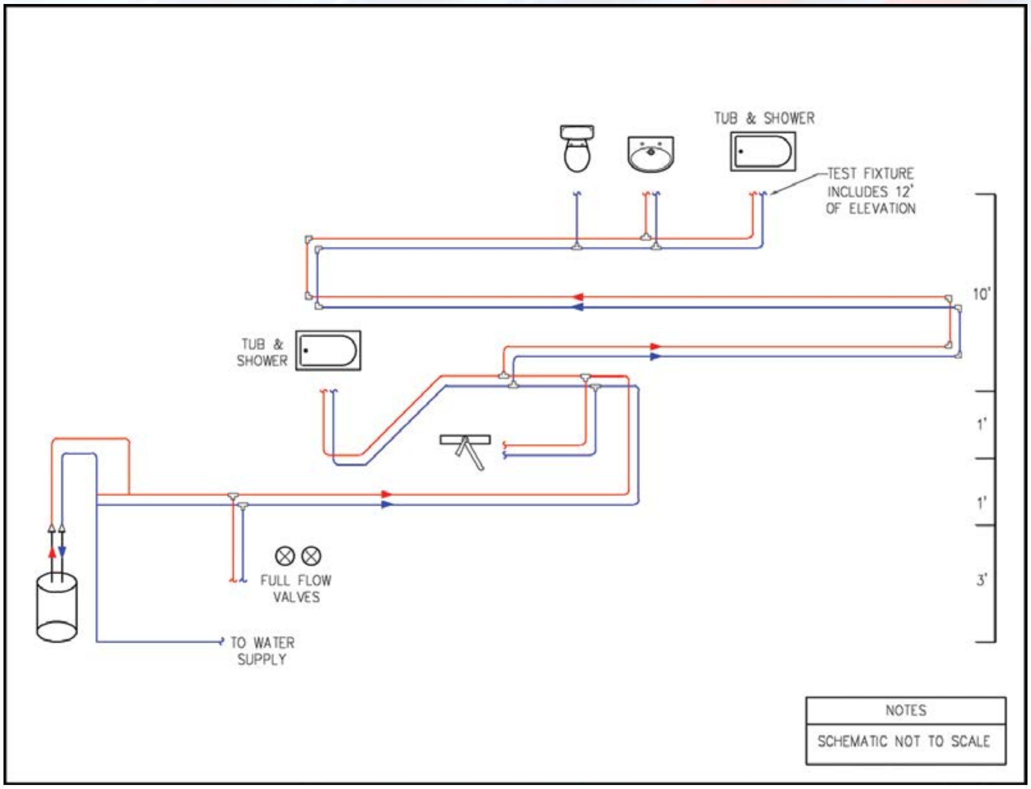


Figure 8.1 – Fixture Layout for Laboratory Testing

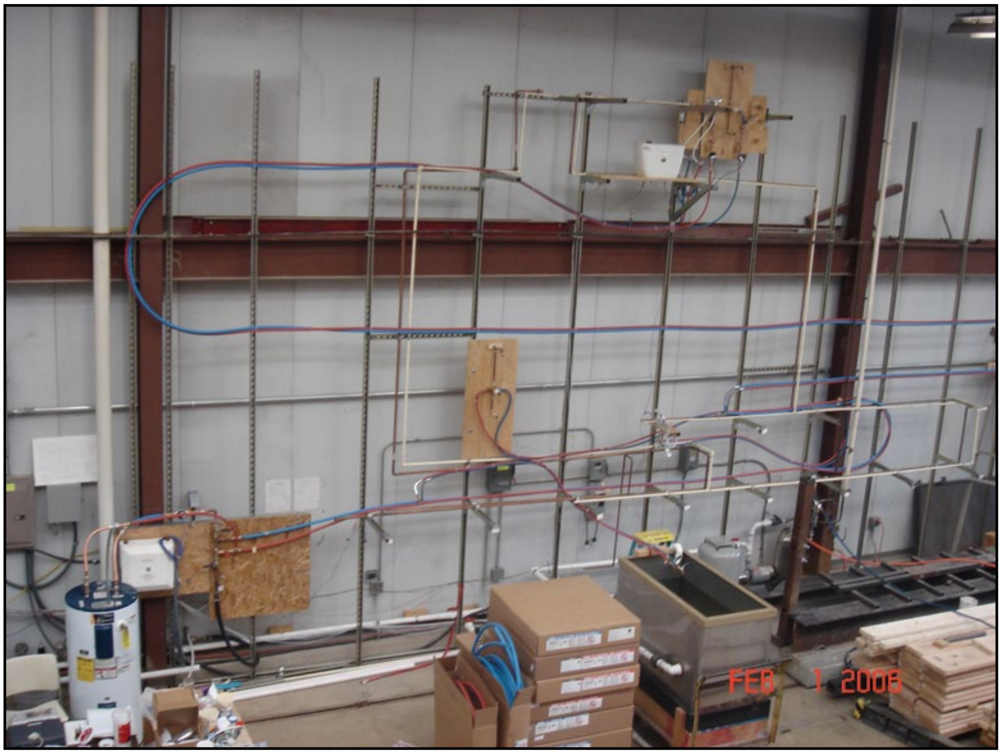


Figure 8.2 – Laboratory Test Set-up with Five Outlets, Hot Water Tank, and T&B System

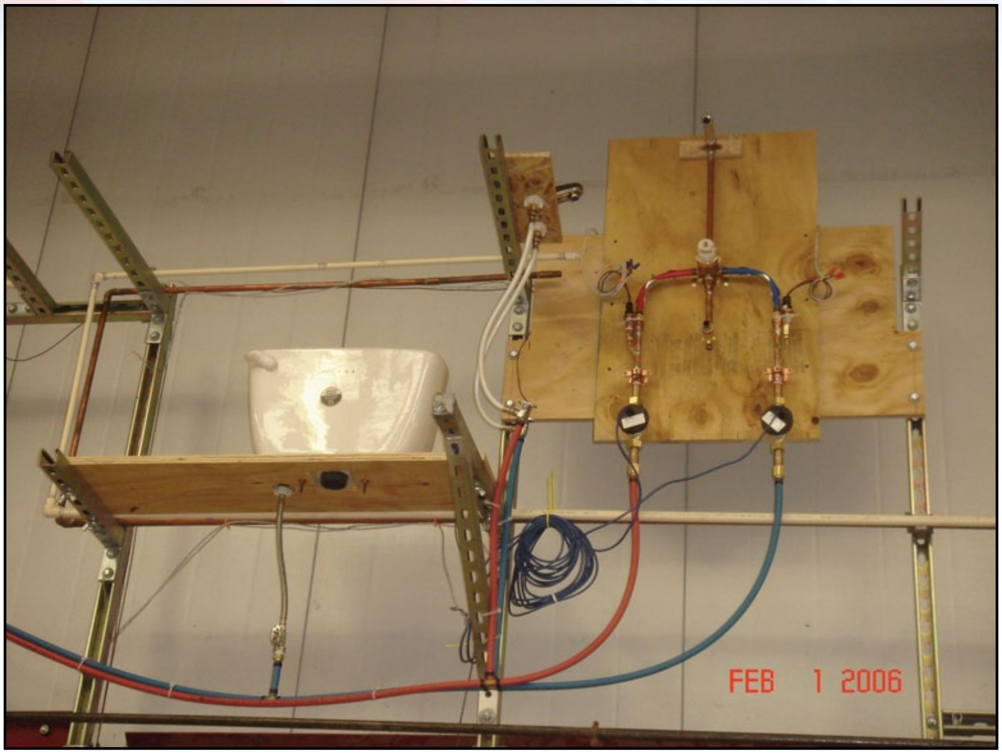


Figure 8.3 – The Test Fixture (Shower) with Flow and Pressure Sensors Installed

Table 8.1 shows the set of plumbing fixtures installed to represent specific residential outlets. These fixtures were connected to the three different PEX plumbing configurations. Tests included using two different total distances of pipe run to the farthest TF, 100 feet and 60 feet. The piping runs to the other fixtures were run in lengths that matched the type of piping system installed (i.e., if the HR system was being tested, all fixtures are plumbed with the HR system).

Table 8.1 – Plumbing Fixtures Installed in the Test Plumbing System

Fixture	Length from Source (feet)	Elevation Above Source	Operation During Test
Tub/Shower TF	60 or 100	15	Full-On Shower
Lavatory	60 or 100	15	Intermittent
Water Closet (tank type)	55 or 95	15	Intermittent
Kitchen Faucet	Less than 40	5	Intermittent
Tub/Shower 2	Less than 40	6	Intermittent

Diagrams of all the test piping arrangements are shown in Appendix A.

Two sets of tests were performed for each plumbing system. One test recorded pressure and flow data at the TF, while other fixtures were operated. A second set of tests was performed to measure the length of time it took for hot water to reach the TF. The test was started after the piping was stabilized to the incoming water temperature.

Plumbing System Pressure and Flow Test Results

For all pressure and flow tests, the farthest shower fixture (TF) was operated in the shower “full-on” mode. The flow pressure and flow rates for each of the hot and cold water supplies to the TF were recorded. During the operation of the TF, other simultaneous flows were added as described in Table 8.2. For this, the TF flow and pressure data were recorded as well as the total hot and cold water supply to the other fixtures and the pressure at the base of the riser.

Table 8.2 – Pressure and Flow Test Regime

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

Flow and pressure measurements were recorded for each of the tests and are recorded in Table 8.3. Each system was tested at three different static pressures measured at the base of the riser, 40, 60, and 80 psi. Table 8.3 shows the results of the TF flowing with no simultaneous fixtures operating.

Table 8.3 – TF Flow and Pressure Data for Each System

System Type, Distance to TF, Riser Pressure	Riser Pressure	TF Hot Valve Flow	TF Hot Valve Pressure	TF Cold Valve Flow	TF Cold Valve Pressure
	psi	gpm	psi	gpm	psi
T&B, 100', 40 psi	40.0	1.7	31.6	0.2	35.1
Zone, 100', 40 psi	40.0	1.7	31.6	0.2	35.0
Parallel, 100', 40 psi	40.0	1.7	29.3	0.2	35.0
T&B, 100', 60 psi	60.0	2.2	50.0	0.3	55.2
Zone, 100', 60 psi	60.0	2.2	49.7	0.3	54.9
Parallel, 100', 60 psi	60.0	2.1	46.4	0.3	54.8
T&B, 100', 80 psi	80.0	2.6	68.7	0.3	75.1
Zone, 100', 80 psi	80.0	2.6	68.7	0.3	75.1
Parallel, 100', 80 psi	80.0	2.5	63.6	0.3	75.0
T&B, 60', 40 psi	40.0	1.8	32.0	0.2	35.1
Zone, 60', 40 psi	40.0	1.8	32.1	0.2	35.0
Parallel, 60', 40 psi	40.0	1.7	30.8	0.2	35.0
T&B, 60', 60 psi	60.0	2.2	50.8	0.3	54.9
Zone, 60', 60 psi	60.0	2.2	50.6	0.3	55.0
Parallel, 60', 60 psi	60.0	2.2	48.8	0.3	54.9
T&B, 60', 80 psi	80.0	2.6	69.9	0.3	75.2
Zone, 60', 80 psi	80.0	2.6	70.2	0.3	75.1
Parallel, 60', 80 psi	80.0	2.5	66.9	0.3	75.1

Note 1: **T&B** = Trunk and Branch;
Note 2: Systems installed at either 100' or 60' to TF
Note 3: Nominal Pressures of 40, 60, and 80 psi are static pressures

The performance data for each of the three system designs shows very similar performance for both the 100-foot distance to the TF and the 60-foot distance to the TF. At 100 feet from the source, the TF flow rate on the hot side of the valve was the primary flow and was 1.5 gpm at a low pressure of 40 psi (static). The flow rate at the valve increased to 2.4 gpm for the 60-foot distance with a riser pressure of 80 psi (static).

Once the baseline flow performance was verified for the TF, additional tests were performed adding simultaneous flows in conjunction with the TF flowing. The performance measure of the system capability to supply the farthest fixture is the flow and pressure data at the TF. Table 8.4 shows the performance data for the 100-foot tests with a source pressure of 40 psi.

Table 8.4 – Simultaneous Flow Performance Data – 100' Maximum Length, 40 psi Source Pressure

Fixture Flow	Total System Flow	Cold Supply Flow	Hot Supply Flow	Main Pressure	Test Fixture (Shower)			
					Hot Flow	Hot Pressure	Cold Flow	Cold Pressure
	gpm	gpm	gpm	psi	gpm	psi	gpm	psi
Trunk and Branch 100' 40 psi Static	0.0	0.0	0.0	40.0	0.0	34.0	0.0	35.2
TF	2.1	0.5	1.6	40.0	1.7	31.6	0.2	35.1
TF+Lav	3.5	1.6	1.9	40.0	1.7	31.2	0.2	34.2
TF+WC	5.5	3.9	1.6	40.0	1.7	31.9	0.2	29.5
TF+Kit	3.5	1.3	2.2	40.0	1.7	31.3	0.2	35.0
TF+Sh2	4.2	1.3	2.9	40.0	1.7	30.6	0.2	34.9
TF+Sh2+Kit	5.6	2.2	3.4	40.0	1.7	30.3	0.2	34.7
TF+Sh2+Kit+Lav	7.0	3.5	3.5	40.0	1.7	30.1	0.2	33.4
TF+Sh2+Kit+Lav+WC	10.2	5.9	4.3	40.0	1.7	28.6	0.2	29.3
Zone 100' 40 psi Static	0.0	0.0	0.0	40.0	0.0	33.9	0.0	35.2
TF	2.1	0.4	1.7	40.0	1.7	31.6	0.2	35.0
TF+Lav	3.5	1.4	2.1	40.0	1.7	31.1	0.2	34.6
TF+WC	5.5	3.9	1.6	40.0	1.8	32.0	0.2	31.8
TF+Kit	3.5	1.3	2.2	40.0	1.7	31.3	0.2	34.9
TF+Sh2	4.2	1.5	2.7	40.0	1.7	30.6	0.2	34.9

Table 8.4 – Simultaneous Flow Performance Data – 100' Maximum Length, 40 psi Source Pressure *(continued)*								
Fixture Flow	Total System Flow	Cold Supply Flow	Hot Supply Flow	Main Pressure	Test Fixture (Shower)			
					Hot Flow	Hot Pressure	Cold Flow	Cold Pressure
	gpm	gpm	gpm	psi	gpm	psi	gpm	psi
TF+Sh2+Kit	5.6	2.4	3.2	40.0	1.7	30.5	0.2	34.7
TF+Sh2+Kit+Lav	7.0	3.6	3.4	40.0	1.7	30.0	0.2	34.0
TF+Sh2+Kit+Lav+WC	10.2	6.2	4.0	40.0	1.7	29.8	0.2	30.8
Parallel 100' 40 psi Static	0.0	0.0	0.0	40.0	0.0	34.0	0.0	35.2
TF	2.1	0.4	1.7	40.0	1.7	29.3	0.2	35.0
TF+Lav	3.5	1.2	2.3	40.0	1.7	29.2	0.2	35.0
TF+WC	5.5	3.7	1.8	40.0	1.7	29.4	0.2	35.0
TF+Kit	3.5	1.2	2.3	40.0	1.7	29.0	0.2	35.0
TF+Sh2	4.2	1.5	2.8	40.0	1.7	28.6	0.2	35.0
TF+Sh2+Kit	5.6	2.3	3.3	40.0	1.7	28.6	0.2	34.9
TF+Sh2+Kit+Lav	7.0	3.3	3.7	40.0	1.7	28.4	0.2	34.8
TF+Sh2+Kit+Lav+WC	10.2	6.3	3.9	40.0	1.7	28.7	0.2	34.6

TF = Test Shower Fixture, 15' elevation; **Lav** = Lavatory, both valves open, 15' elevation
WC = Water Closet, tank type, 15' elevation; **Kit** = Kitchen, mid-position, 4' elevation
Sh2 = 2nd Shower, full open valve, 5' elevation

Based on the simultaneous flow performance data, all systems continued to supply adequate pressure and flow to the remote TF located 100 feet from the source. With the source pressure of 40 psi, the maximum system flow rate was 8.0 gpm; 5.0 gpm to the cold supply fixtures and 3.0 gpm to the hot supply fixtures. Table 8.5 shows similar results with a system design of 60 feet to the TF.

Table 8.5 – Simultaneous Flow Performance Data – 60' Maximum Length, 40 psi Source Pressure								
Fixture Flow	Total System Flow	Cold Supply Flow	Hot Supply Flow	Main Pressure	Test Fixture (Shower)			
					Hot Flow	Hot Pressure	Cold Flow	Cold Pressure
	gpm	gpm	gpm	psi	gpm	psi	gpm	psi
Trunk and Branch 60' 40 psi Static	0.0	0.0	0.0	40.0	0.0	34.1	0.0	35.2
TF	2.1	0.4	1.7	40.0	1.8	32.0	0.2	35.1
TF+Lav	3.5	1.4	2.1	40.0	1.7	31.6	0.2	34.5
TF+WC	5.5	3.9	1.7	40.0	1.8	32.1	0.2	31.2
TF+Kit	3.5	1.3	2.2	40.0	1.7	31.7	0.2	35.0
TF+Sh2	4.2	1.4	2.8	40.0	1.7	30.9	0.2	34.9
TF+Sh2+Kit	5.6	2.2	3.4	40.0	1.7	30.5	0.2	34.7
TF+Sh2+Kit+Lav	7.0	2.9	3.5	40.0	1.7	30.4	0.2	33.7
TF+Sh2+Kit+Lav+WC	10.2	6.0	4.2	40.0	1.7	29.2	0.2	30.0
Zone 60' 40 psi Static	0.0	0.0	0.0	40.0	0.0	34.0	0.0	35.2
TF	2.1	0.3	1.7	40.0	1.8	32.1	0.2	35.0
TF+Lav	3.5	1.3	2.2	40.0	1.7	31.7	0.2	34.8
TF+WC	5.5	3.9	1.6	40.0	1.8	32.3	0.2	33.1
TF+Kit	3.5	1.1	2.4	40.0	1.7	31.7	0.2	35.0
TF+Sh2	4.2	1.4	2.8	40.0	1.7	31.1	0.2	34.9
TF+Sh2+Kit	5.6	2.3	3.3	40.0	1.7	30.7	0.2	34.8
TF+Sh2+Kit+Lav	7.0	3.4	3.6	40.0	1.7	30.4	0.2	34.3
TF+Sh2+Kit+Lav+WC	10.2	6.2	4.0	40.0	1.7	30.4	0.2	32.0
Parallel 60' 40 psi Static	0.0	0.0	0.0	40.0	0.0	34.0	0.0	35.1
TF	2.1	0.4	1.7	40.0	1.7	30.8	0.2	35.0
TF+Lav	3.5	1.2	2.3	40.0	1.7	30.7	0.2	34.9
TF+WC	5.5	3.9	1.6	40.0	1.7	31.6	0.2	34.8
TF+Kit	3.5	1.4	2.2	40.0	1.7	30.6	0.2	34.9
TF+Sh2	4.2	1.4	2.8	40.0	1.7	30.2	0.2	34.9

Table 8.5 – Simultaneous Flow Performance Data – 60' Maximum Length, 40 psi Source Pressure *(continued)*								
Fixture Flow	**Total System Flow**	**Cold Supply Flow**	**Hot Supply Flow**	**Main Pressure**	**Test Fixture (Shower)**			
					Hot Flow	**Hot Pressure**	**Cold Flow**	**Cold Pressure**
	gpm	**gpm**	**gpm**	**psi**	**gpm**	**psi**	**gpm**	**psi**
TF+Sh2+Kit	5.6	2.3	3.3	40.0	1.7	30.0	0.2	34.8
TF+Sh2+Kit+Lav	7.0	3.3	3.7	40.0	1.7	29.8	0.2	34.8
TF+Sh2+Kit+Lav+WC	10.2	6.5	3.7	40.0	1.7	30.3	0.2	34.5

TF = Test Shower Fixture, 15' elevation; **Lav** = Lavatory, both valves open, 15' elevation
WC = Water Closet, tank type, 15' elevation; **Kit** = Kitchen, mid-position, 4' elevation
Sh2 = 2nd Shower, full open valve, 5' elevation

The system performance with simultaneous flows was very similar to the previous 100-foot test but with slightly lower pressure drops. A static pressure of 40 psi is considered to be a minimum supply pressure. A summary of the results for the simultaneous flow system performance at 60 and 80 psi source static pressure is shown in Appendix A.

Comparing the flow pressure and flow rate is a good way to determine the performance of a plumbing system. The limitation is that the pressure at the base of the riser is dependent on the size of the service line, meter, and water utility supply pressure. In order to describe and compare the performance of each type of system, the pressure drop from the base of the riser to the farthest outlet (including elevation losses) can be evaluated. Figures 8.4 and 8.5 show the comparison of pressure drop based on various outlets in the system flowing with the resultant pressure drop at the farthest fixture. Both figures indicate that the parallel system, while having a higher pressure drop to the TF, has a more consistent pressure drop during simultaneous flow. The other systems, based on the trunk line feeding branch lines, continued to show increasing pressure drop as more fixtures were added to the system. In fact, when the full set of fixtures was operating simultaneously, the trunk and branch system pressure drop exceeded that of the parallel and the zone configurations. (The zone system is highly dependent on the system design, i.e., the location of the manifolds and the number of fixtures connected to the manifold).

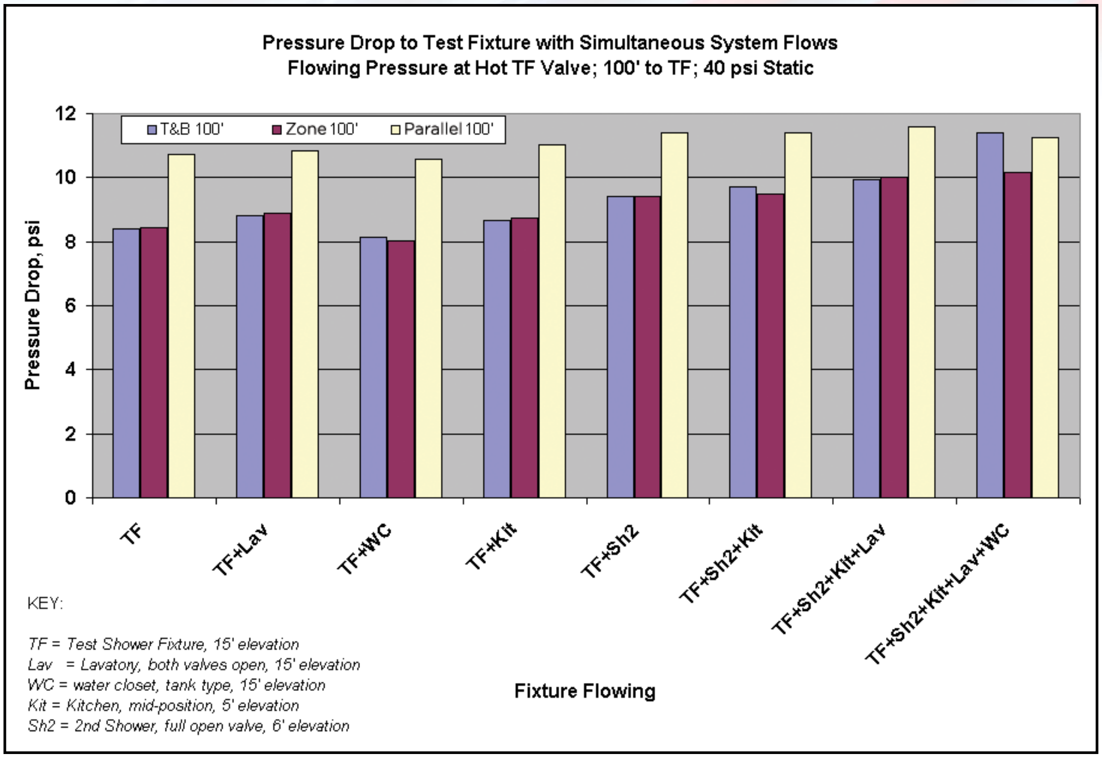


Figure 8.4 – Pressure Drop Comparison, 100' Distance to TF

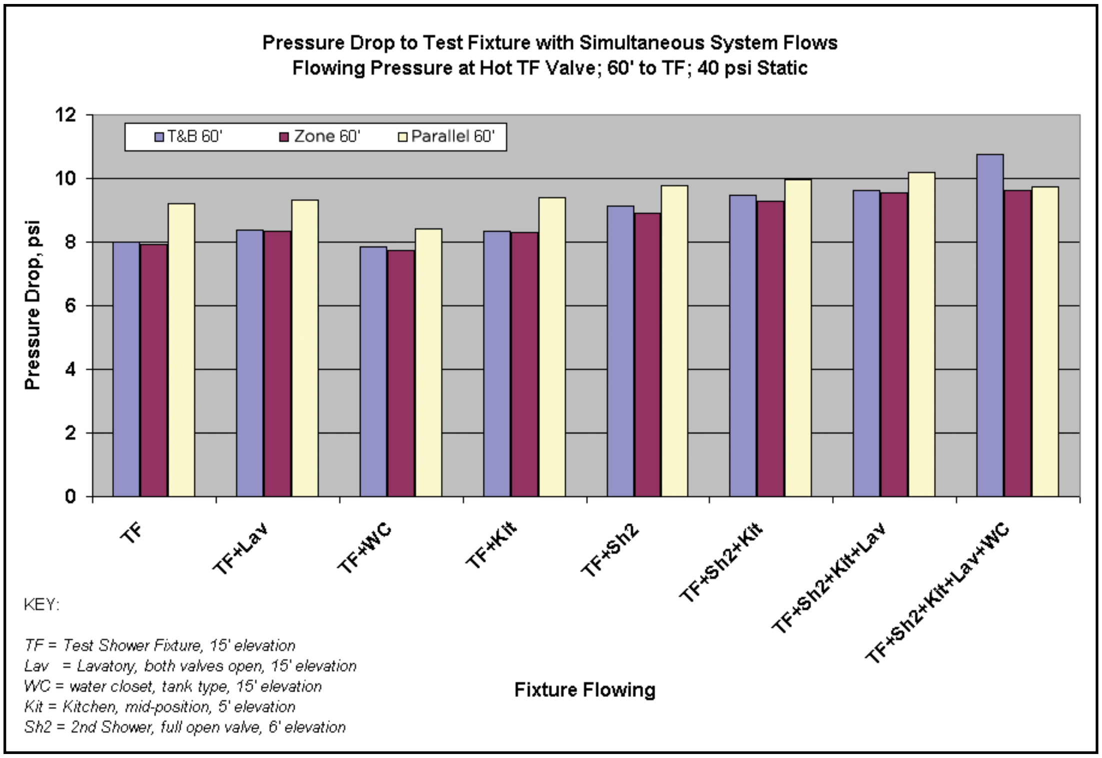


Figure 8.5 – Pressure Drop Comparison, 60' Distance to TF

Wait Time for Hot Water

A significant benefit of PEX piping systems is the opportunity to reduce water and energy waste by reducing the amount of time to deliver hot water to the outlet from the water heater. Though hard to quantify definitely, there are indications that hundreds of gallons of water per year are wasted while waiting for hot water to reach the outlet.

Tests were also performed on each of the three PEX system designs to compare the time it takes for hot water to be delivered to the test fixture (TF). Figure 8.6 shows the results of delivering hot water to the shower fixture after the pipes were flushed with cold (city) water. The results were normalized to keep the flow rates and temperature from the hot water tank constant for all systems.

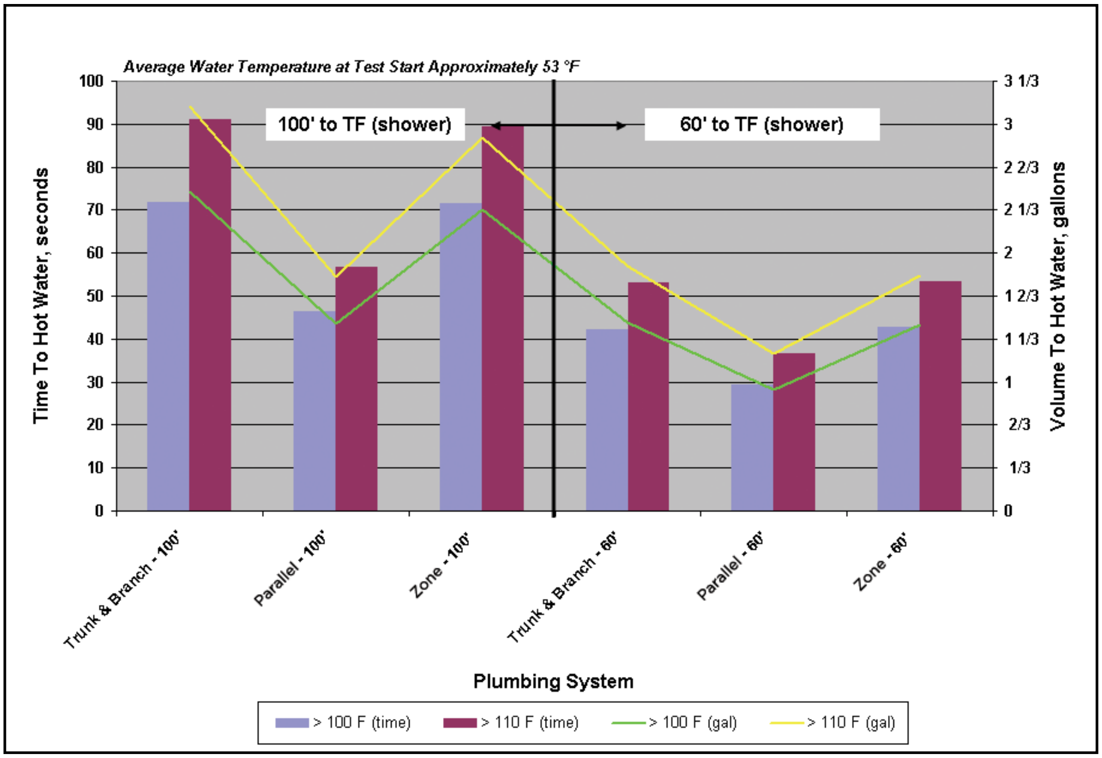


Figure 8.6 – Comparison of Hot Water Delivery Time

Water and time savings of between 30 percent and 40 percent were identified based on this analysis of the parallel system over either the trunk and branch or zone system designs.

Test Summary

A summary of the performance characteristics of each system is shown in Table 8.6. The data indicates:

- Trunk and branch and zone systems will supply one fixture at a higher pressure
- Parallel systems will supply a more stable pressure to each fixture when operating simultaneous fixtures
- Parallel systems will deliver hot water to the outlet quicker, especially when the pipes are at room temperature
- Trunk and branch and zone systems will deliver hot water quicker during sequential flows
- All three system designs will supply sufficient flow and pressure to the outlets even when the base riser pressure is 40 psi and the length to the farthest outlet is 100 feet.

Table 8.6 – Performance Summary, 100' Maximum Distance

System	Test Fixture Only		Test Fixture With Simultaneous		Test Fixture Only	
	Flow Rate Hot	Pressure Hot	Flow Rate Hot	Pressure Hot	Time to > 100°F Hot Water	Time to > 110°F Hot Water
	gpm	psi	gpm	psi	sec	sec
40 psi Static						
T&B - 100'	1.7	31.6	1.7	28.6		
Zone - 100'	1.7	31.6	1.7	29.8		
Parallel - 100'	1.7	29.3	1.7	28.7		
60 psi Static					**from 53°F**	
T&B - 100'	2.2	50.0	2.1	44.4	71.9	90.9
Zone - 100'	2.2	49.7	2.1	46.3	71.6	89.3
Parallel - 100'	2.1	46.4	2.1	45.6	46.3	56.8
80 psi Static						
T&B - 100'	2.6	68.7	2.4	61.6		
Zone - 100'	2.6	68.7	2.5	63.0		
Parallel - 100'	2.6	63.6	2.4	62.0		

PEX Pipe Response to Surge Pressure (Water Hammer)

A benefit of flexible piping systems is the ability to mitigate or absorb pressure surges in plumbing systems, such as what can occur when flowing water is stopped by a fast-acting valve. To quantify this benefit, a test apparatus was constructed and operated such that pressurized flowing water in a 20-foot straight length of pipe was abruptly interrupted by a fast-acting solenoid valve. Several rigid and flexible, metal and plastic, nominal one-half inch diameter pipe materials were subjected to a test regime that included flow rates as high as 6 gallons per minute, using cold and hot water supplies.

Results of the pressure measurements taken at the location of the fast-acting valve showed that plastic pipe materials exhibited lower peak pressure measurements than copper pipe at all flow rates. The results were consistent for both cold and hot water tests.[10]

For example, test results using nominal half-inch pipes with "cold" water at a typical flow rate of 2.5 GPM showed that peak pressures were reduced by up to 37% for PEX pipes as compared with copper pipes. Test results using nominal half-inch pipes with "hot" water at a typical flow rate of 2.5 GPM showed that peak pressures were reduced by up to 33% for PEX pipes as compared with copper pipes. Results are shown in Tables 8.7 and 8.8. At higher flow rates, the percentage of the surge pressure reduction increases.

Table 8.7 – First Peak Pressure for Each Piping Material and Flow Rate (Cold Water)

Pipe Material	Maximum Measured Pressure, psi				
Flow Rate, gpm	2	2.5	3	4	6
1/2 inch Type L Copper	194	239	266	318	422
1/2 CPVC	155	173	201	222	296
1/2 PEX-1	143	168	177	212	274
1/2 PEX-2	136	150	169	193	244
Note: Pressure response measurements include 60 psi static pressure					

Table 8.8 – First Peak Pressure for Each Piping Material and Flow Rate (Hot Water)

Pipe Material	Maximum Measured Pressure, psi				
Flow Rate, gpm	2	2.5	3	4	6
1/2 inch Type L Copper	149	181	204	250	306
1/2 CPVC	142	157	174	203	252
1/2 PEX-1	108	113	124	141	175
1/2 PEX-2	113	122	123	141	174
Note: Pressure response measurements include 60 psi static pressure					

PEX and Copper Pipe Flow Rates

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

Even though PEX tubing has a slightly smaller inside diameter than copper tubing of the same nominal dimension, both tubing systems satisfied the farthest fixture demand, even with multiple fixtures flowing. The following Table compares the two piping systems with a minimum source pressure of 40 psi, the most demanding scenario in the test Results of tests using higher pressures were consistent.

Results of this testing demonstrate that in a typical single-family residential plumbing system, both PEX and copper piping systems will deliver sufficient volumetric flow rates and pressures to the plumbing fixtures when using the same nominal size tubing.

Table 8.9 – Flow Performance Data, PEX and Copper, 100' Maximum Length, 40 psi Main Source Pressure

	Source						Farthest Test Fixture (Shower)							
	System Flow		Cold Supply		Hot Supply		Hot Water Flow		Hot Water Pressure		Cold Water Flow		Cold Water Pressure	
Unit of Measure	GPM		GPM		GPM		GPM		psi		GPM		psi	
System Type	PEX	Copper	PEX	Copper	PEX	Copper	PEX	Copper	PEX	Copper	PEX	Copper	PEX	Copper
T&B 100' Main Pressure									34.0	33.5			35.2	34.6
TF	2.2	2.1	.5	.7	1.7	1.5	1.7	1.5	31.6	32.5	.2	.5	35.1	34.4
TF + Lav	3.5	3.6	1.6	1.7	1.9	1.9	1.7	1.5	31.2	32.1	.2	.5	34.2	34.1
TF + WC	5.7	6.2	4.0	4.8	1.6	1.4	1.7	1.5	31.9	32.9	.2	.5	29.5	32.3
TF + Kit	3.5	3.7	1.3	1.9	2.2	1.7	1.7	1.5	31.3	32.3	.2	.5	35.0	34.2
TF + Sh2	4.2	4.3	1.3	1.7	2.8	2.6	1.7	1.5	30.6	31.7	.2	.5	34.9	34.2
TF + Sh2+Kit	5.6	5.7	2.2	2.5	3.4	3.2	1.7	1.5	30.3	31.5	.2	.5	34.7	34.0
TF + Sh2+Kit+Lav	7.0	7.1	3.5	3.7	3.5	3.5	1.7	1.5	30.1	31.1	.2	.5	33.4	33.6
TF+Sh2+Kit+Lav+WC	10.0	10.9	5.8	6.9	4.2	4.0	1.7	1.5	28.6	30.9	.2	.5	29.3	31.5

GPM=Gallons Per Minute, psi=pounds per square foot, TF=Test Shower Fixture, Lav=Lavatory (sink), WC=Water Closet, Kit= Kitchen, Sh2=Shower 2

GLOSSARY

ASTM: American Society for Testing and Materials

Corrosion: deterioration in metals caused by oxidation or chemical action

Crosslinked polyethylene: a polyethylene material which has undergone a change in molecular structure using a chemical or a physical process whereby the polymer chains are chemically linked. Crosslinking of polyethylene into PEX for pipes results in improved properties such as elevated temperature strength and performance, chemical resistance, and resistance to slow crack growth.

Elasticity: a measure of material stiffness or the ability of the material to stretch or deform temporarily under a load

Fitting: a device or connection that allows the PEX pipe to change direction or size, such as a tee, elbow, or coupling

Fixture: a device or appliance at the end of a water supply distribution pipe line. Example: lavatory, water closet, tub/shower, dishwasher

IAPMO: International Association of Plumbing and Mechanical Officials

ICC: International Code Council

IPC: International Plumbing Code

IRC: International Residential Code

Joint: the connection of the PEX pipe to a fitting, fixture, or manifold

Manifold: a device having a series of ports that are used to connect distribution lines for several fixtures

NSPC: National Standard Plumbing Code

Outlet: see fixture

Parallel: a plumbing design that utilizes a central manifold and distribution piping to each hot and cold water fixture

pH: a scale ranging from 0 to 14 that ranks how acidic or alkaline a liquid is; water with a pH below 7 is considered acidic and water with a pH above 7 is considered alkaline

PPFA: Plastic Pipe and Fittings Association

PPI: Plastics Pipe Institute

Scaling: process of mineral buildup on the interior of a pipe

Test fixture: the tub-shower unit farthest from the water source that was instrumented to measure flow rate, flowing pressure, and mixed water temperature in the lab tests

Thermoplastic: having the property of becoming soft when heated and hard when cooled

Thermoset: having the property of becoming permanently hard and rigid when heated or cured

Trunk and branch: a plumbing design that has a large main line that feeds smaller pipes to each fixture

Ultraviolet: high energy light waves found in sunlight that lead to the degradation of many plastics and materials (UV)

UPC: Uniform Plumbing Code

Wait time: the time it takes for hot water to be delivered to the Test Fixture; delivery time

Water hammer: a banging noise heard in a water pipe following an abrupt alteration of the flow with resultant pressure surges

Zone: a plumbing system that uses trunk lines from the water source to small manifolds at grouped fixtures, such as a bathroom; can be flow-through or closed end