PPI TN-26/2005

Erosion Study on Brass Insert Fittings Used in PEX Piping Systems

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October 2005

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Background:
Most PEX plumbing systems are installed using some form of insert fitting. These fittings are usually made from brass or some other copper alloy. Because the insert portion of the fitting has a smaller diameter than the tube, the velocity of the water through the fitting is higher than the velocity of the water in the tube. PEX systems, delivering the same volume of water will have higher flow velocities in the tube and fittings than copper systems of the same nominal size. Many plumbing codes have maximum recommended flow velocities for copper or copper alloys in plumbing systems to prevent erosion of the system from the flowing water. Millions of brass insert fittings have been installed in PEX plumbing and heating systems over the past 20 or more years in Europe and the United States. In that time, we are unaware of any erosion induced failures of PEX piping systems

In order to more fully evaluate this subject, the High Temperature Division of the Plastics Piping Institute funded a test program at Materials Performance Inc. in College Station, TX.

Objective:
The objective of this test program was to subject different brass insert fittings for PEX plumbing systems to flow rates that represented the maximums that could occur if a plumbing system was sized according to the 2000 version of the Uniform Plumbing Code and then flowing enough hot, chlorinated water through them to be equivalent to 40 years of service in typical single family residence.

Results:
None of the brass insert fittings for PEX systems failed during this test. Weight losses were less than 3% for all fittings. Internal diameter increases due to erosion were less than 1%. ¾” copper sweat elbows with straight pieces of copper tube attached were subjected to the same condition as the ¾” brass insert fittings for PEX and these did not fail either.

Conclusions:
The results indicate that very little erosion occurs at the test conditions chosen. The water conditions chosen were at the severe end of normal potable water conditions and the water flow rates were the maximum that should be experienced when all fixtures on a given line are open and flowing at capacity.

No failures occurred and based on these results, failures due to internal erosion of brass insert fittings in PEX plumbing systems would not be expected over a normal lifetime of a plumbing system. PEX piping systems with brass insert fittings can be sized following the tables published in the model codes without undue concern for erosion of the fittings in normal plumbing applications.

Discussion:

The test program given to the lab is listed in Appendix A. It is considered to be aggressive relative to most plumbing installations for the following reasons.

1. The water temperature was maintained at 140F for the duration of the test. In a normal residential plumbing system, some flows occur at lower temperatures on the hot water side of the system because the water-cooled off when the line was not in use.
2. In the test, the total volume water was flowing at the elevated temperature. In a normal residential system, the total flow for the structure is divided between the hot and cold sides of the system. The only fittings that actually have the total volume of the water being used by a residence passing through them are the fittings on the cold-water inlet line before flow splits at the water heater.
3. The pH of the water was maintained between 6.5 and 6.7. This is corrosive and much lower than the 6.9 to 7.1 range that is common for water systems.
4. The water velocity for the entire life of the test was at a velocity that assumed all fixtures on a line would be open to their maximum at the same time. In normal systems, usually only a small percentage of the maximum possible flow is experienced at one time so most of the water flows at velocities that are much lower than the possible maximum.
5. The chlorine level of the water was maintained between 2.5 and 3.0 ppm for the duration of the test. The average chlorine level for water systems in the U.S. is about 1.0 ppm. It would be an unusual circumstance for a residence to experience chlorine levels equal to the test condition for an extended period of time.

Three different fitting types were tested.

A. Fittings machined from brass rod, Alloy C36000, to ASTM F1807
B. Fittings machined from forged brass, Alloy C37700, to ASTM F1807
C. Fittings machined from forged brass, Alloy C37700, to ASTM F1960

Note 1: Brass fittings made to ASTM F 2080 were not included in the study reported in this TN. However, brass fittings made to ASTM F 2080 have the same inside diameter and are produced from the same brass alloys as are used for ASTM F 1960 brass fittings. Therefore, the conclusions based on test results for F 1960 fittings would be expected to be the same for F 2080 fittings.

The total water flow through each size fitting during the test is listed below.

Size	Water Flow
3/8”	700,125 gallons
½”	1,400,250 gallons
¾”	4,200,750 gallons

The water velocities for each type of fitting are listed below.

Size	ASTM F1807	ASTM F1960
3/8	19.3 ft/sec	13.8 ft/sec
½”	16.7 ft/sec	13.4 ft/sec
¾”	21.8 ft/sec	16.7 ft/sec

The results are tabulated and illustrated in the following tables and graphs.

Table 1	Weight loss of ¾” fittings at end of test.
Table 2	Weight loss versus gallons of flow through ¾” elbows.
Table 3	Weight loss of ½” fittings at end of test.
Table 4	Weight loss of 3/8” fittings at end of test.

Because the ¾” fittings had the highest flow velocities, the ¾” elbows were selected to be checked for weight change at 1,000,000 gallon intervals during the test. As would be expected, the weight loss did trend up as the amount of water flowing through the fittings increased.

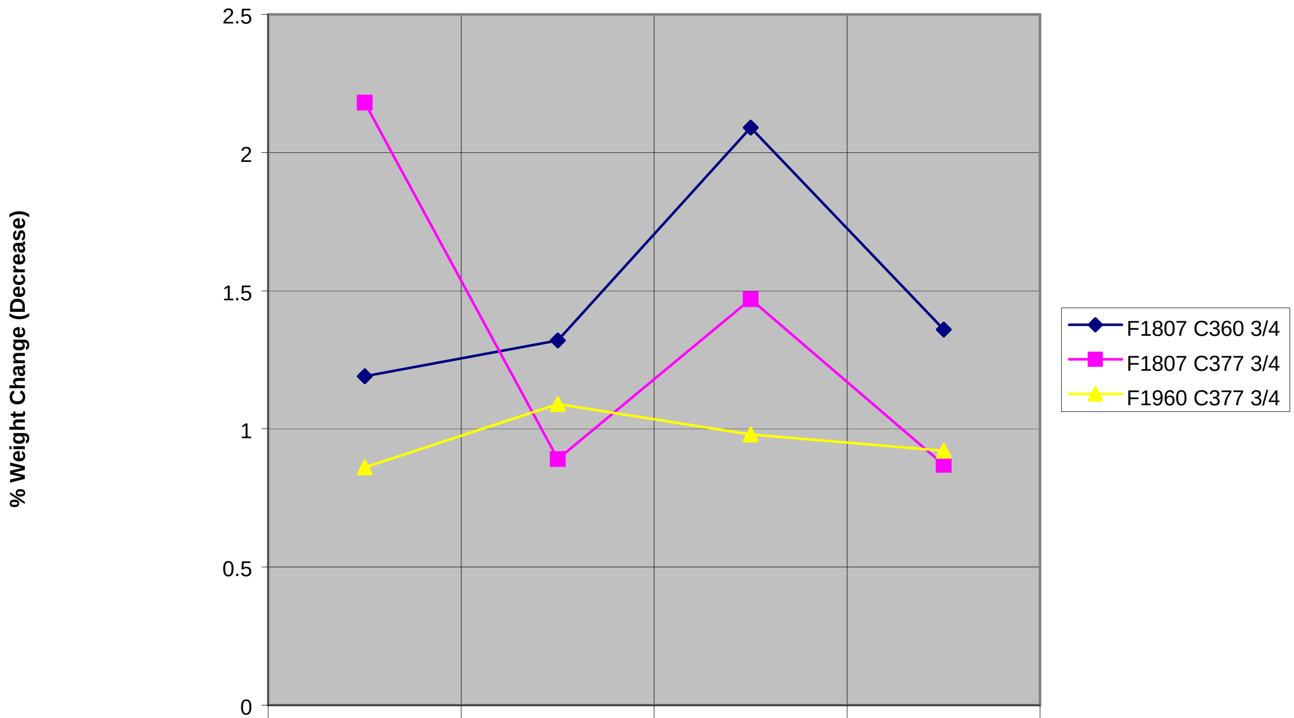
Table 4 does not have any 3/8” fitting data from F1960 type fittings because they were not available at the time of the test.

The fittings of each type with the largest weight loss were sectioned and examined for signs of pitting. There were no signs of localized pitting that would indicate a probability of early fitting perforation due to localized material loss.

Because of the very aggressive conditions during the test, a section of ¾” PEX tube was also evaluated for any dimensional changes at the end of the test. There was no measurable change in the PEX tube.

Based on these results, it seems unlikely that PEX plumbing systems using brass insert fittings, sized according to the tables in the Uniform Plumbing Code for copper tubing, will fail from erosion of the fittings caused by high water velocities in normal residential applications.

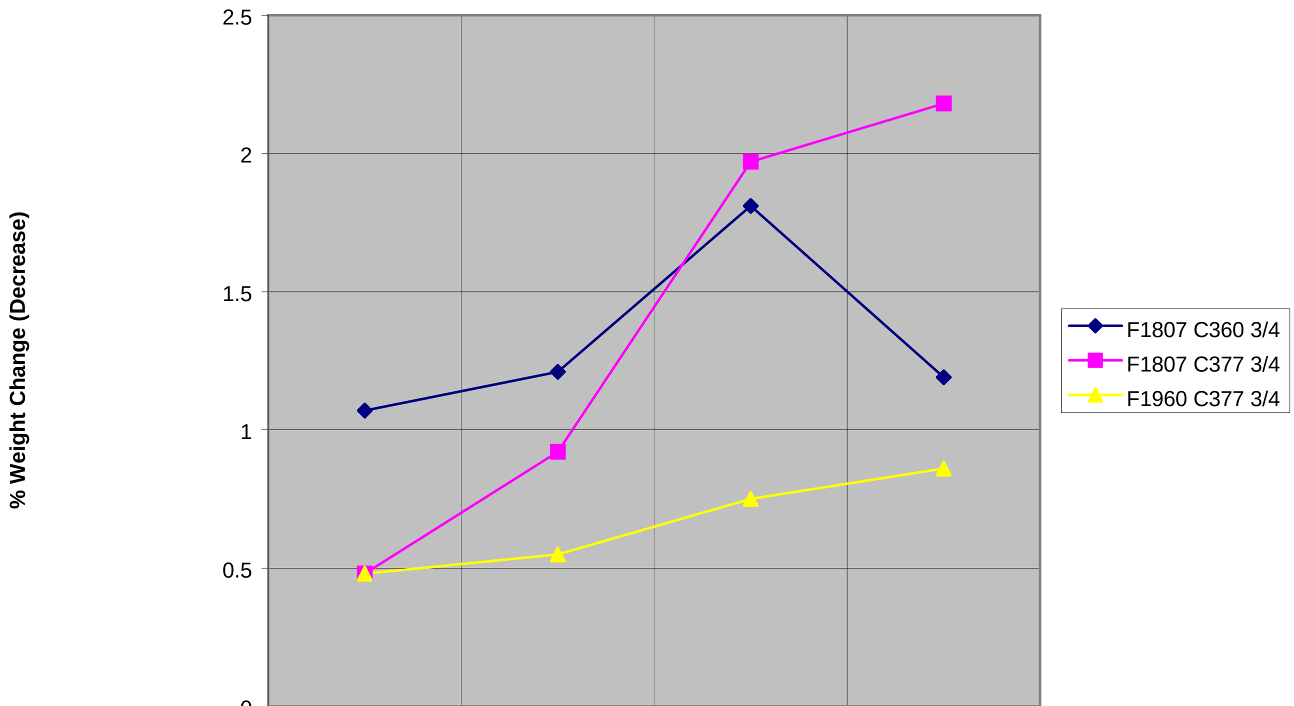
% Weight Loss vs Fitting Type 3/4" 4200750 Gallons - Table 1



	Elbow	Tee1	Tee2	Coupling
F1807 C360 3/4	1.19	1.32	2.09	1.36
F1807 C377 3/4	2.18	0.89	1.47	0.87
F1960 C377 3/4	0.86	1.09	0.98	0.92

Fitting type

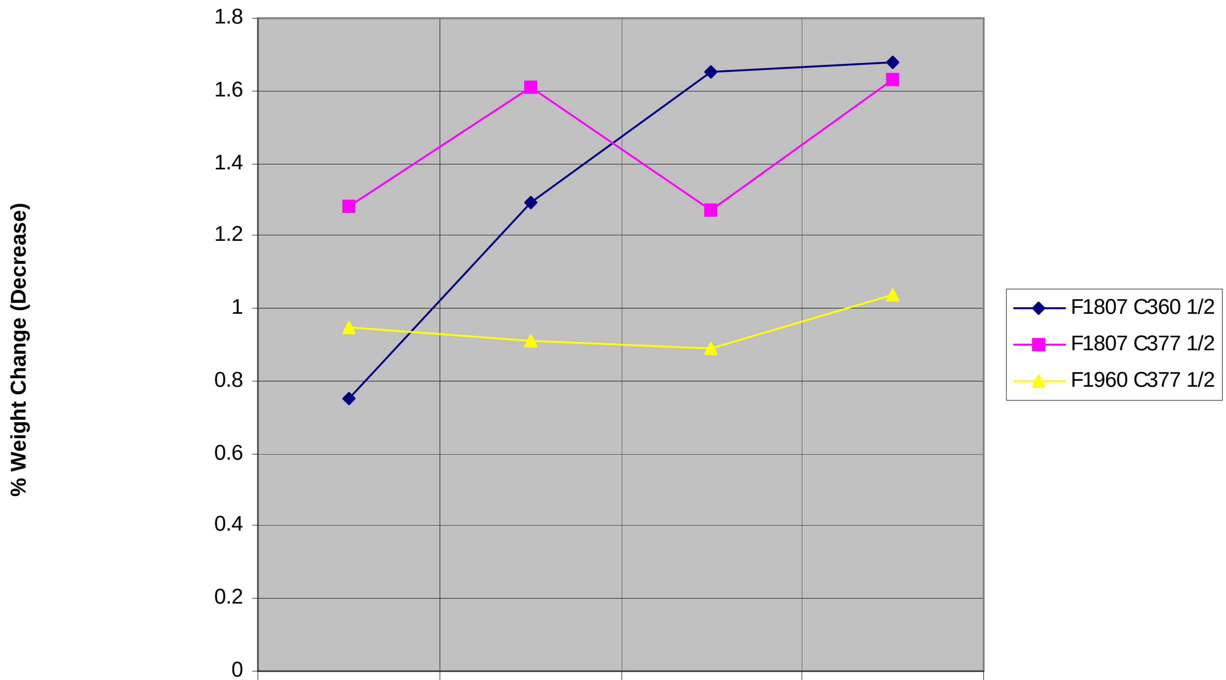
% Weight Loss vs Gallons Through 3/4" Elbows - Table 2



	1E+06	2E+06	3E+06	4E+06
F1807 C360 3/4	1.07	1.21	1.81	1.19
F1807 C377 3/4	0.48	0.92	1.97	2.18
F1960 C377 3/4	0.48	0.55	0.75	0.86

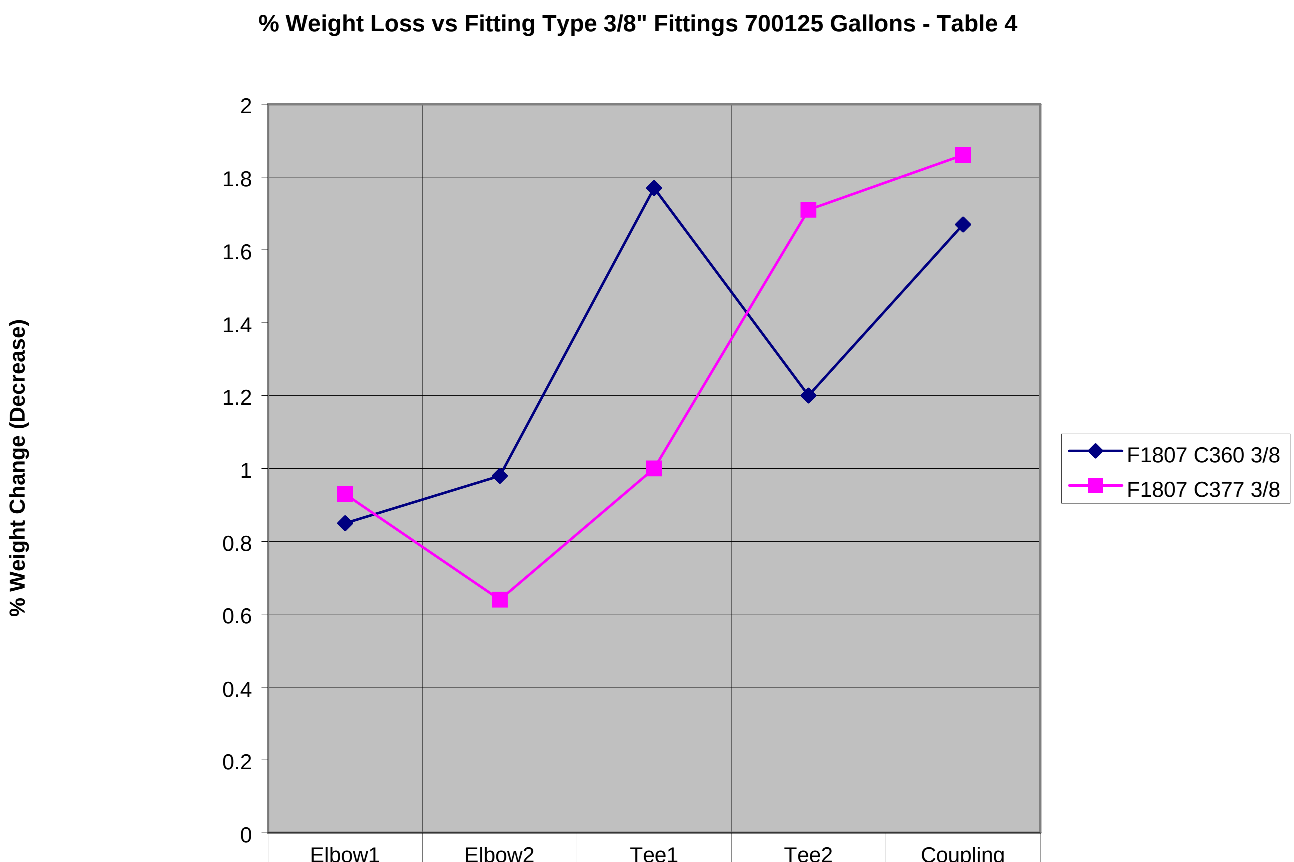
Gallons of Water

% Weight Loss vs Fitting Type 1/2" 1400250 Gallons - Table 3



	Elbow	Tee1	Tee2	Coupling
F1807 C360 1/2	0.75	1.29	1.65	1.68
F1807 C377 1/2	1.28	1.61	1.27	1.63
F1960 C377 1/2	0.95	0.91	0.89	1.04

Fitting Type



	Elbow1	Elbow2	Tee1	Tee2	Coupling
F1807 C360 3/8	0.85	0.98	1.77	1.2	1.67
F1807 C377 3/8	0.93	0.64	1	1.71	1.86

Fitting Type

Appendix 1

Plastics Pipe Institute HTD Project 97-03   Revision 1 10-8-99

Flow Erosion Test For PEX Fittings

Objective:

The objective of this test procedure is to see if the water flow that might be experienced in a typical, non-recirculating plumbing system will cause failure of the metal fittings that are used in PEX plumbing systems in a reasonable lifetime. We will also check to see if there is any erosion evident in the PEX tube during this test.

Test Description:

A system will be set up with fittings of all sizes and common geometries. Hot water will be circulated through the fittings at flow rates that result from sizing a plumbing system according to the Uniform Plumbing Code. The amount of water circulated will be equivalent to the average household usage for 40 years based on most recent usage information from AWWA and household population information from the U.S. Census Bureau. After testing, the fittings will be examined for signs of erosion and weighed to determine the percentage weight loss.

Water Temperature:

The circulating water temperature will be 140F at the inlet to the system. The exit temperature for any loop will not be below 135F.

Water Quality:

The pH of the water will be maintained between 6.5 and 6.7. The chlorine level will be maintained between 2.5 and 3 ppm. These values may be converted to ORP values for control purposes. The water shall be “Moderately Hard” as determined by one of the following measures. The hardness shall be between 3.6 and 7 grains per gallon, or the $CaCO_3$ shall be between 75 and 150 mg/l. The water shall be filtered using a potable water sediment filter. The filter shall have a nominal rating of 50 microns. To minimize the possibility of unexpected changes in water quality due to mineral or other chemical build ups, 5 gallons per hour of the circulating water should be replaced with make-up water.

Water Flow Rates:

The water flow rates are taken from Table 6-4 in the Uniform Plumbing Code that gives the capacity of tubes of various lengths in Fixture Units. The maximum value shown for a size is the value that is used. 3/8” is not covered in this table. For 3/8”, we used the maximum Fixture Unit device that is shown to be acceptable for connection to a 3/8" tube which is 3 for a flush tank toilet in Table A-2. All values for fixture units are for private use. The Fixture Unit values were then converted to gpm by using Chart A-3.

Tube Size	WSFU	gpm
3/8	3	2.5
½	7	5
¾	20	15

Water Volume:

The volume of water to be passed through the fittings must be enough to simulate 40 years of service. The WaterWiser web page of the AWWA , updated in 1999, gives the average daily use per person as 72.5 gallons. The U.S. Census Bureau shows that the average household has slightly less than 3 people in it. To be conservative, we will assume a household with 4 people. This gives a total volume of 4,234,000 gallons used in 40 years. This will be the amount of water that must be passed through the ¾" fittings.

With a flow rate of 15 gpm, 24 hours a day, 7days a week, it will take 28 weeks for 4,234,000 gallons of water to pass through ¾" fittings.

Using this length of time, the following amount of water will be passed through the 3/8" and ½" fittings at their target flow rates.

3/8"	705,600 gallons
½"	1,411,200 gallons

Water Velocities:

Using the minimum ID's published in the fitting standards, the following water velocities (ft/sec) will occur in the fittings at the flow rates required by this test.

Size	F1807-Brass	F1807-Copper	F1960-Brass
3/8	19.3	19.3	13.8
½	16.7	16.7	13.4
¾	21.8	21.8	16.7

Data To Be Taken At Start Of Test:

For each fitting tested, the following information will be recorded.

1. The ID of each insert portion of the fitting in thousandths of an inch.
2. The weight of each fitting to the hundredths of a gram.
3. Note if there is a smaller ID other than the insert portion of the fitting.

Other information to be recorded for each system.

1.The weight of the copper assembly

2. Wall thickness in 4 places on each end of a piece of ¾” tube. Make a 3 inch long mark along the tube length at the location of each measurement. This tube will be cut out at the end of the test and the wall thickness will be checked at these marks.

Installation Requirements:

Each fitting shall be installed in PEX tube according to the manufacturer’s instructions. The distance between any fitting and the next one must be at least 30 tube diameters except for the two 3/8” elbows. These two fittings should only have a distance of 2” between the insert portion of the fittings. If the PEX tubing is bent or curved, no fitting shall be closer than 30 tube diameters downstream of the bend. The direction of flow through each fitting shall be marked on the fitting. A schematic of a typical set-up for a fitting system is shown in Figure 1. Other arrangements could be used.

Fittings To Be Tested:

At a minimum, two tees, an elbow and a coupling of each size, from each material from each standard shall be tested. One of the tees will be tested with flow in the straight through direction and the other will be tested with flow coming in the straight through direction and out the branch. For the ¾” size, 3 additional elbows will be installed in the system. One of these will be removed after 1 million gallons of water flow and the others will be removed at 2 and 3 million gallons of water flow. If other fittings are required for plumbing the system and they will experience the flows, they will be included in the test. They should be kept in “systems”. With flow metering valves and flow meters it is possible to have flow through the ¾” fittings first with some diverted to flow through ½” fittings and some diverted to flow through the 3/8” fittings.

In addition to the fittings for PEX, we will test a ¾” copper elbow assembly in each system. The assembly will consist of a ¾” sweat x sweat elbow with 24” long pieces of Type M copper sweated into the fitting. The tube ends shall be reamed as recommended by the Copper Development Association and a flux and solder suitable for potable water applications shall be used. To connect this assembly to the PEX tube, sweat adapter fittings shall be used that are the same type as the other fittings in the system.

Data To Be Taken During And At The End Of The Test:

If any fitting starts to leak because of a hole being eroded through the fitting, remove the fitting from the test and record the amount of water that had passed through the fitting to that point. Continue to test the other fittings to the completion of the test.

After the required amount of water has flowed through the fittings, carefully remove each fitting from the system. If saws are used, care must be taken not to nick or cut the fitting since this will affect the weight after testing. Record the following information.

1. The ID of each insert portion of the fitting in thousandths of an inch.
2. The weight of each fitting to the hundredths of a gram.
3. Calculate the percentage weight change for each fitting.
4. Visually inspect each fitting for signs of erosion. Record any signs observed.
5. For each system, section the fitting with the highest percentage weight loss and check for localized pitting. Take photos of each half of the fitting. This step is only at the end of the test.
6. The weight of the copper assembly.
7. The wall thickness of the ¾ PEX tube at the locations marked at the start of the test after cutting off the portion that had been attached to the fitting.

Remove fittings at the following times.

1. After 1 million gallons – one ¾" elbow
2. After 2 million gallons – one ¾" elbow
3. After 3 million gallons – one ¾" elbow
4. At end of test – all other fittings.

When fittings are removed for weights at the intermediate points, they should be replaced by like fittings of the same style.

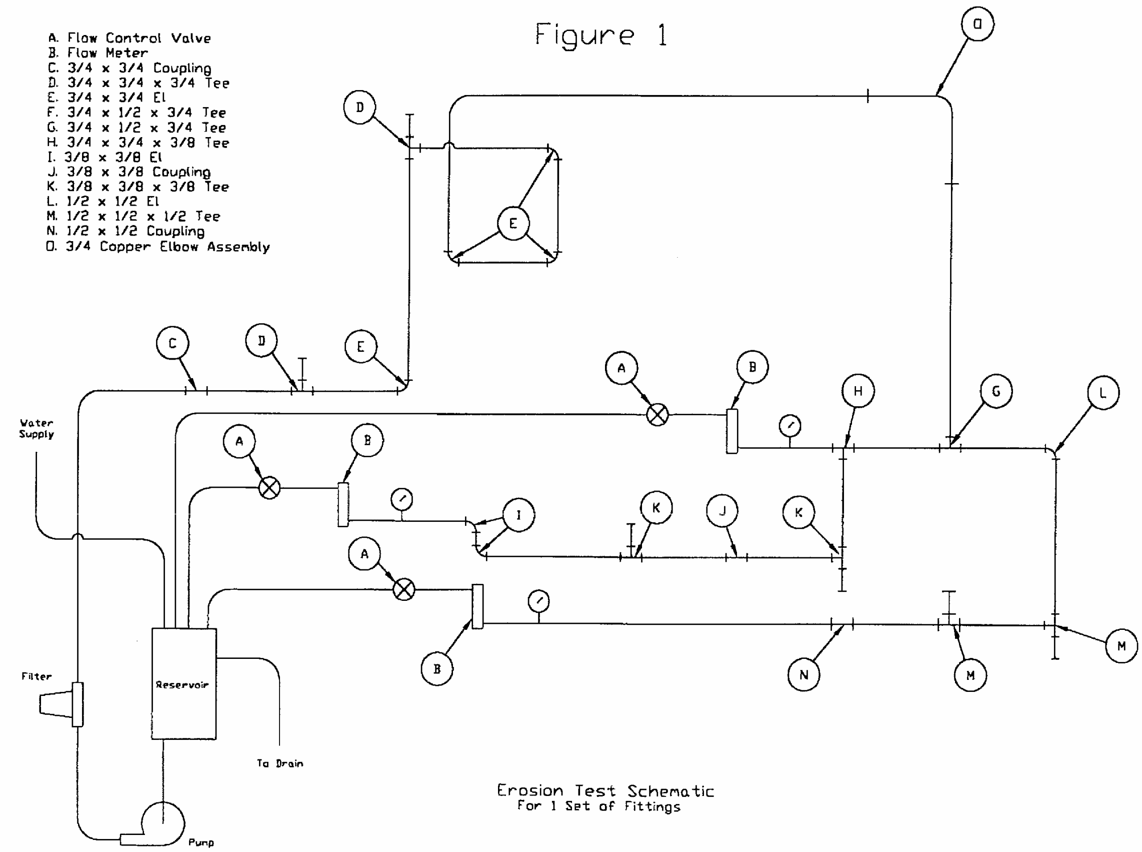
Report:

The report shall contain the following information.

1. Description of test set-up including temperature controls, water quality controls and the source of the water.
2. A schematic of the test set-up.
3. Tables of all measurements and weights taken.
4. Tables of all calculated weight change percentages.
5. Photos of the sectioned fittings
6. If no fittings leak because of erosion, a statement to that effect.

Table of Fittings to Be Tested
For One System

Quantity	Description
1	¾ X ¾ Coupling
2	¾ X ¾ X ¾ Tee
4	¾ X ¾ Elbow
1	¾ X ½ X ¾ Tee
1	¾ X ¾ X 3/8 Tee
1	½ X ½ Elbow
2	½ X ½ X ½ Tee
1	½ X ½ Coupling
2	3/8 X 3/8 X 3/8 Tee
2	3/8 X 3/8 Elbow
1	3/8 X 3/8 Coupling
1	¾ Copper Assembly



Erosion Test Schematic
For 1 Set of Fittings