Property Risk Consulting Guidelines

A Publication of AXA XL Risk Consulting

PRC.14.1.2.3

TESTING AND ANALYZING LOOPED WATER SUPPLIES

INTRODUCTION

Looped underground piping has many advantages over dead end connections. Loops:

- Reduce the frequency and severity of impairments because water can flow through an alternative path if one path is out of service for maintenance or because of a malfunction.
- Reduce overall friction loss since part of the flow is carried in each leg.
- Ensure adequate protection of the facility by allowing proper placement of hydrants and sprinkler risers around buildings.

Looped piping creates multiple flow paths. Water tests must be performed on each leg to ensure all valves are open and each path is clear of obstruction.

POSITION

When looped piping systems are encountered, conduct water supply testing close to the building being analyzed with all legs in service. In addition, conduct water flow tests on each leg of a looped underground system at 5 yr intervals. In setting up this test, flow the strongest leg first with subsequent legs tested in the order of decreasing anticipated effectiveness. When the “combined” test is run with all valves open, a noticeable increase in both volume and residual pressure is usually observed.

Select a single location for reading static and residual pressures as hydraulically close to the flow location as possible. The actual point of pressure reading is where the flowing water joins the non-flowing pipe feeding the gauge. Avoid placing the residual gauge where false pressures may be trapped by check valves.

When proposed construction is involved, the underground mains may not be in place. It may be necessary to determine projected flows at the proposed facility. When looped piping systems are involved, the combined flow can be determined by estimating the flow and pressure drop in each of the legs.

DISCUSSION

Water system piping consists of essentially three types: piping in series; piping in parallel; and branched piping. Piping in series are those connected end-to-end. The water that flows into one end comes out the other. Since the diameter of the pipe and the pipe elevation can vary, the velocity of the water flowing and the internal pressure in the pipe may change as well. However, friction loss along the pipe increases, starting at the entrance point and continuing along the pipe in the direction of the flow.

Pipes in parallel experience the same effect as series pipes in the individual legs. At the point were multiple legs are formed, only one residual pressure can exist. Similarly, at the point where these same legs come back together, only one residual pressure can exist. Therefore, the pressure drop in each of the legs is the same. In addition, the flow through the individual legs is equal to the total flow entering and leaving the parallel pipes.

Branched piping systems are those that split flow into pipes that do not rejoin or take water from several sources into a single major supply. The algebraic sum of the flow at any point or node is zero.

Complex piping systems are made up of a wide variety of these simpler types. Being able to predict flow at any point in a system requires a thorough knowledge of the system layout and interconnections, as well as the pipe characteristics necessary to do the calculations. Periodic testing to determine the adequacy of water supplies is essential when analyzing the availability and reliability of water for fire protection needs.

The following discussion includes a procedure for conducting a flow test on a simple looped system, a method of calculating flows in the individual legs of a simple loop, and an alternate graphical method of determining flows. Figure 1 represents a typical loop around an industrial facility used in the following example.

Conducting A Looped System Flow Test - In this example, there are two legs to be tested - the longer, smaller-diameter west leg and the shorter, larger-diameter east leg. The most logical test point, due to its proximity to the junction of two valved sections of the loop, would be to flow H-4 and take static and residual pressures at H-3.

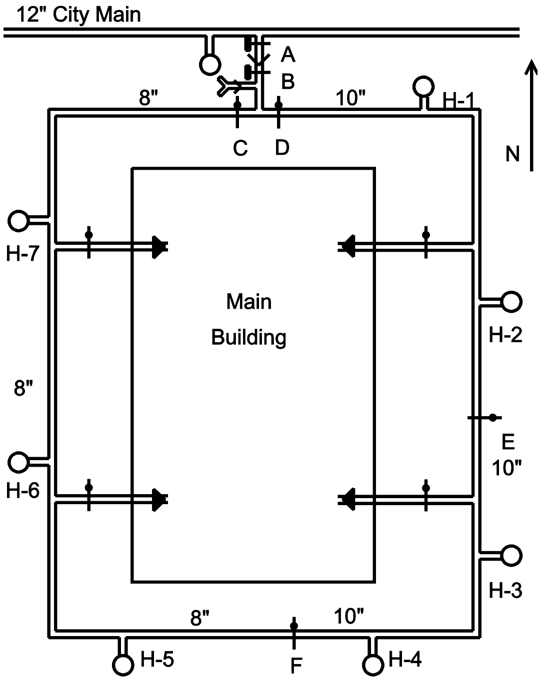

Figure 1. Facility Layout Showing Underground Water System.

Conduct a preliminary flow test with all control valves open. Although the pressure gauge is located on hydrant H-3, the point for the residual pressure reading is at the junction of the loop main and the connection feeding H-3. In hydraulics the point where the actual pressure reading occurs is referred to as the “common” point.

Next, test the strongest leg. Since the east leg is shorter and uses larger pipe, it is anticipated that this would be the strongest leg. This can be accomplished by numerous valve closure scenarios.

However, by shutting valve “C,” all water discharging from H-4 must come through the east leg. The common point for the residual pressure reading is at the junction of the loop main and the connection feeding H-3.

After this test is made, open valve “C,” and then shut valve “D.” Now all the water discharging from H-4 must come from the west leg. Note that the common point from a residual pressure standpoint is now at the junction where the H-4 connection meets the loop. The results from this test should be less than the test previously made on the west leg.

Finally, open valve “D” and rerun the combined test. This combined test would normally be considered as an adequate test of the public water supply. It should be equal to or greater than the test of the best individual leg. With both legs feeding H-4, the common point for the residual pressure reading is at the junction of the loop main and the connection feeding H-3.

Calculating Flows In Individual Legs - When water flows through a simple looped system, a certain amount of water goes through each leg.

$$Q_t = Q_e + Q_w$$

where:

$Q_t =$ total flow

$Q_e =$ flow in east leg

$Q_w =$ flow in west leg

The pressure loss in parallel legs is the same. A pressure drop for each leg can be calculated, based on an estimated flow in each leg and by taking into account the actual length of the leg and the additional length equivalent to piping fittings.

Where individual flow tests of each leg of a loop have not been measured or where installation of the underground is pending, it is possible to determine Q_e and Q_w, and thus Q_t, using a trial-and-error calculation. The pressure at the common point will be the same for both legs. By knowing the size and length of pipe, a flow for each leg can be assumed. If the calculated friction loss in each leg is not the same, new flows can be assumed and the friction loss recalculated until they are the same.

As an alternative to this trial-and-error method, it is possible to calculate the flow through each leg of a loop directly. The following is a description of a simple calculation method.

First, assume a flow through each leg and determine the amount of friction loss. Then, using a simplification of the Hazen/Williams formula, find K_e and K_w for each respective leg.

The Hazen/Williams formula can be simplified as follows:

$$Q = KP^{0.54}$$

where:

Q = flow in gpm

P = pressure loss due to friction in psi

K = constant

This equation looks similar to the orifice equation $Q = K\sqrt{P}$ but is based on friction loss rather than the normal pressure at an orifice and the K is different as well.

If a flow of 1000 gpm (3785 L/min) and a roughness coefficient of $C = 100$ is assumed for each leg, a K factor for the east and west legs can be calculated. It should be noted that if the same assumed flow is put through each leg, the pressure drops will most likely not be the same. This is done only to establish appropriate K factors for each pipe assembly. Note the subscript “a” will be used below to indicate “assumed” conditions.

For the east leg, assumed flow (Q_{ea}) = 1000 gpm (3785 L/min) through the 10 in. (250 mm) main. Total equivalent length (L_e) = 1000 ft (304.8 m). Friction loss factor as determined by the Hazen/Williams formula based on the appropriate flow, C Factor and pipe size is (F_{pe}) = 0.00427 psi/ft (0.000966 bar/m)

$$P_{ea} = F_{pe} \times L_e = 0.00427 \times 1000 = 4.27 \text{ psi} \quad (P_{ea} = 0.000966 \times 304.8 = 0.294 \text{ bar})$$

where:

P_{ea} = pressure loss in east leg

F_{pe} = friction loss per ft in east leg

L_e = equivalent length of east leg

$$K_{ea} = \frac{Q_{ea}}{P_{ea}^{0.54}} = \frac{1000}{4.27^{0.54}} = 56.6 \text{ gpm/psi}^{0.54} \quad \left(K_{ea} = \frac{3785}{0.294^{0.54}} = 7385 \text{ L/min/bar}^{0.54}\right)$$

For the west leg, assumed flow (Q_{wa}) = 1000 gpm (3785 L/min) through the 8 in. (200 mm) main. Total equivalent length (L_w) = 1200 ft (365.8 m). Friction factor (F_{pe}) = 0.01294 psi/ft (0.002927 bar/m)

$$P_{wa} = F_{pw} \times L_w = 0.01294 \times 1200 = 15.53 \text{ psi} \quad (P_{wa} = 0.002927 \times 365.8 = 1.071 \text{ bar})$$

$$K_{wa} = \frac{Qwa}{P_{wa}^{0.54}} = \frac{1000}{15.53^{0.54}} = 227.3 \text{ gpm/psi}^{0.54} \quad \left(K_{wa} = \frac{3785}{1.071^{0.54}} = 3649 \text{ L/min/bar}^{0.54}\right)$$

Since only one pressure can exist at a given point, the following applies for the actual flow conditions:

$$\frac{Q_e}{K_e} = \frac{Q_w}{K_w}$$

Since K_{ea} and K_{wa} were arrived at by assuming a flow, these K factors only hold for the particular flow and pressure conditions. However, the ratio of K_{ea} to K_{wa} remains constant since flow is a function of pressure, therefore:

$$\frac{K_{ea}}{K_{wa}} = \frac{K_e}{K_w}$$

$$Qe = \frac{K_e}{K_w} \times Q_w = 2.01\ Q_w$$

Based on a combined flow of (Q_t) 1500 gpm (5678 L/min) at the entrance of the loop:

$$Q_e + Q_w = Q_t$$

then,

$$2.01\ Q_w + Q_w = Q_t$$

$$Q_w = \frac{1500}{3.01} = 498.3 \text{ gpm} \quad \left(Q_w = \frac{5678}{3.01} = 1886 \text{ L/min}\right)$$

$$Q_e = 1500 - 498.3 = 1002 \text{ gpm} \quad (Q_e = 5678 - 1886 = 3792 \text{ L/min})$$

These figures can be checked by calculating the friction loss in each of the legs using their respective flows. The pressure loss in each leg should be equal.

East leg, based on Q_e, C, and L_e;

$$F_p = 0.00429 \text{ psi/ft } (0.00970 \text{ L/min/m})$$

$P_e = 0.00429 \times 1000 = 4.29$ psi ($P_e = 0.00970 \times 304.8 = 0.296$ bar)

West leg, based on Q_w, C, and L_w;

$F_p = 0.00357$ psi/ft (0.000808 L/min/m)

$P_w = 0.00357 \times 1200 = 4.28$ psi ($P_w = 0.00082 \times 365.8 = 0.296$ bar)

Graphical Method Of Determining Flows - The following is a description of the same problem solved graphically:

Similar to the previous calculation method, a flow is assumed for each leg.

For the east leg, assumed flow (Q_{ea}) = 1000 gpm (3785 L/min) through the 10 in. (250 mm) main. Total equivalent length (L_e) = 1000 ft (304.8 m). Friction factor (F_{pe}) = 0.00427 psi/ft (0.000966 bar/m)

$P_{ea} = F_{pe} \times L_e = 0.00427 \times 1000 = 4.27$ psi ($P_{ea} = 0.000966 \times 304.8 = 0.294$ bar)

For the west leg, assumed flow (Q_{wa}) = 1000 gpm (3785 L/min) through the 8 in. (200 mm) main. Total equivalent length (L_w) = 1200 ft (365.8 m). Friction factor (F_{pe}) = 0.01294 psi/ft (0.002927 bar/m)

$P_{wa} = F_{pw} \times L_w = 0.01294 \times 1200 = 15.53$ psi ($P_{wa} = 0.002927 \times 365.8 = 1.071$ bar)

These two friction loss points can be plotted respectively as point “A” and point “B” on $N^{1.85}$ semi-log hydraulic paper. Refer to Figure 2. Losses in the two legs can be plotted since both curves would pass through the “origin” of the graph at zero flow rate. The two curves can be graphically combined by selecting a common friction loss pressure on both curves and algebraically adding their respective flows. Points “C” and “D” correspond to similar pressure losses. Point “E” is found by combining the flow at point “C” and “D.” The combined curve is again drawn through the “origin.”

At the known total flow on the combined curve, point “F” can be plotted, and a horizontal line can be drawn at constant pressure loss. Since each leg will experience the same pressure loss, point “G” locates the flow through the east leg and “H” locates the flow through the west leg. By observation it can be seen that the flow for each leg is similar to those calculated in the previous example.

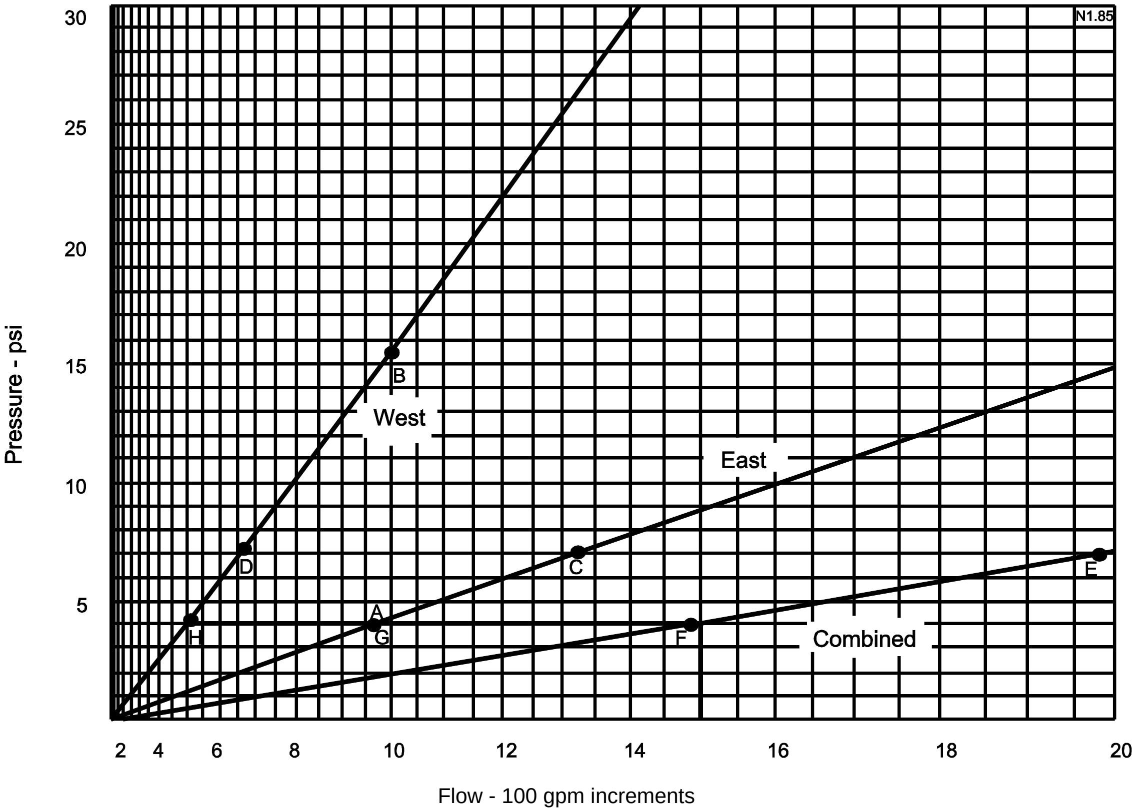

Figure 2. Graphical Solution Of Flow In Individual Legs Using $N^{1.85}$ Semi-Log Hydraulic Paper.

Other Uses For Estimating Loop Flow - When water tests are conducted it is possible to analyze the results by comparing the actual results with the anticipated.

If the measured pressure drop far exceeds the calculated pressure drop, this may be indicative of an obstruction in that leg requiring further testing to pinpoint the problem. It is possible to make a thorough examination of an affected portion of the underground by performing a hydraulic gradient. While flowing water through an isolated portion of the underground, static and residual pressures are recorded along the pipe at as many points as possible. Knowing the pipe and fitting data, it is possible to calculate the theoretical pressure loss in the questionable underground section. A comparison between the actual and the theoretical should reveal the location of the problem. Pinpointing the problem area as accurately as possible results in less excavation trying to locate the problem. The detailed instructions for conducting and analyzing hydraulic gradient tests are found in PRC.14.1.2.4.