Leaks, Pipe Breaks, and Preventive Maintenance

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Abstract. A better understanding of leak related effects has implications for pipe rehabilitation, system economics, customer disruption, and environmental sustainability. Reducing leakage be a result of a well-suited preventive maintenance program. The purpose of this study is to inspect approximately 10% of the runouts (branch pipes) between the plumbing fixtures and the risers to estimate the extent of serious corrosion of the runouts that may cause leaks in the future. For collecting the site data for our study, we visited the building and investigated piping through 57 different access openings in 31 randomly selected apartments. These apartments were selected to allow observation of a variety of risers at varying elevations. We observed in about 20% of the runouts inspected, the remaining thickness of the steel pipe was less than 60% in the areas that we could access. The runouts are in danger of developing leaks. Because of the high potential cost of leaks and the possibility of that 20%, or 120 pipes, could leak soon, recommend replacement of all the runouts. System performance can only be reliably characterized through monitoring and analysis of relevant data. Performance monitoring is concerned with measuring system efficiency and to what extent the system is delivering the parameters what it was designed for (i.e., flow, pressure, energy, water quality, etc.).

1. Introduction

“Nothing in the world is more flexible and yielding than water. Yet when it attacks the firm and the strong, none can withstand it, because they have no way to change it. So the flexible overcome the adamant, the yielding overcome the forceful. Everyone knows this, but no one can do it.” [1].

Ignoring the human factor influence, figure 1 shows the way the water flows in nature, continuing to transform from one stage to another.

The social-economic development involved natural resources consumption, and those resources could not have been obtained without effects on the environment; these led to ecosystems degradation. Globally, many cities face water crises, and the estimation is that until 2030 the natural disasters such as flooding, drought, sea level rise may increase. This could have effects as financial losses and urban life influence [3].

The development of cities and human activities (i.e., agriculture and industrial) had an destructive impact on the environment with implication on water quality and consequently on water demand. So, the three factors (population increase, water pollution, and climate change) that affect the drinking water resources, require for both present and future, to act against the water waste. At stake is the quality and...
quantity of water. One of the measures for the water is the water waste reduction both for the water network system and plumbing. There must be found a balance between human activities and its impact on environment.

![Figure 1. The hydrological cycle components][2]

Based on the existing studies on plumbing water loss [4-8], this article is meant to be an investigation of water leak causes and the preventive maintenance of water leakage inside the buildings.

Another issue for the high-rise buildings is that the water leaks are extremely harmful. For instance, the water can go through the building envelope. One of the early signs of the reinforced concrete corrosion and damages is the water leaks which acts like a perfect electrolyte. The corrosion process and depassivation reinforcing steel are possible only in presence of water, oxygen, and corrosive elements, such as chloride and carbon dioxide. [7]. Consequently, the water leaks can make high structural damages for the building elements.

On the other hand, for the high-rise buildings – residential, commercial, etc., the water leaks has a double effect, which means it does not only a problem of the building structure itself, but it is a serious concern for the health and hygiene of the population. The water leaks which can affect the building envelope lead to the mould and epidemic respiratory. For this reason, it is highly recommended to have a preventive maintenance in place.

An import fact is that the water leaks from the plumbing system (i.e. cold and hot water) increased significantly in the last period and this a consequence of both aging plumbing system and excessive water consumption. An important factor is the flow and pressure control of the water system [4].

Therefore, the cost of the system includes not only the financial cost of manufacturing and maintaining the infrastructure, but also such burdens as the health effects of poor water quality, the environmental impact of energy inefficiency and water loss due to leaks, disruptions due to breaks, and a variety of other burdens associated with the system and its operation. [9]
Generally speaking, leakages are supplied by pumping. Real losses in the distribution system are closely related to water pressure. There is a closed relationship between leak prevention and field inspection programs.

On the other hand, field inspection of water system shows a great relationship between water and energy systems. Reducing leakage can be seen as a result of a well-suited preventive maintenance program. Reducing leakage will reduce the frequency of pipe breaks, improve water quality and customers disruption, and lower the operating cost.

Perhaps less obvious, and certainly less well understood, is the connection between leaks and pipe breaks. [9] Pipe breaks are an obvious source of system failure. The ability of leaks to protect against pipe breaks has barely been addressed in the literature; however, [10] have implicitly exploited this attribute by considering the pressure wave attenuation associated with leaks of various sizes.

2. Materials and Methods
For collecting the site data for our study we visited the building and investigated piping through 57 different access openings in 31 randomly selected apartments. These apartments were selected to allow observation of a variety of risers at varying elevations.

Our observations at each access hatch have been recorded with respective apartment numbers and hatch locations. First, a small part of pipe insulation have been cut and removed. Secondly, photographs of the exposed pipe portion have been taken by use of an inspection camera.

After visual observations we measured the nominal diameter and then the wall thickness of the run out and where possible the risers by use of an ultrasonic metal thickness tester. The ultrasonic thickness tester works by bouncing a sound wave through the metal and measuring the time it takes to echo back, similar to a radar. It records only solid metal and will not register any internal corrosion or mineral build up. It is accurate to 0.0254 mm.

After recording our measurements and taking photographs we replaced the cut strip of thermal insulation and taped it with non-permeable metallic duct tape. We repeated this process for every pipe accessible at each of the 57 previously made hatches.

Observations:
- We encountered external corrosion on all pipes we observed. The vapor barrier is almost entirely non-present because of deterioration. The thermal insulation of the pipes is also deteriorated.
- The vapor barrier is a non-permeable membrane normally covered over the layer of thermal insulation on pipes. This non-permeable layer keeps moisture-laden room air away from the insulation material by cutting the contact between ambient air and thermal insulation. Existence of a vapor barrier is very important for efficacy and longevity of thermal insulation. Once the vapor barrier dissolves or decays, the ambient air enters the porous body of the insulation.
- When ambient moist air migrates into the porous absorbent thermal insulation; water vapor starts condensing inside the insulation layer as it reaches near the cold surface of the pipe. Condensate forming within the insulation layer deteriorates insulation quality of the insulating material and causes it to disintegrate. If pipes are left in this condition longer, the steel will corrode. We investigated the samples of previously removed branch piping (Figure 2).
Figure 2. The samples show internal and external corrosion in branch piping.

The back face of riser and branch piping (the face of piping not towards the room but towards the structural wall) is more corroded and present smaller pipe thickness because the inside face was generally coated with the spray brown coat used as a surface on the metal lathe of the walls. This provided some protection for the insulation and vapour barrier.

We tabulated all recorded measurement data and compared the measured pipe thicknesses with Standard Schedule 40 S steel pipe thickness at respective diameters (Table 1).

| Nominal pipe size [mm] | 10S   | 40S   | 30% deficient | 60% deficient |
|------------------------|-------|-------|---------------|---------------|
| 25                     | 2.768 | 3.378 | 2.365         | 1.351         |
| 32                     | 2.768 | 3.556 | 2.489         | 1.422         |
| 40                     | 2.768 | 3.683 | 2.578         | 1.473         |
| 65                     | 3.047 | 5.156 | 3.609         | 2.062         |
| 75                     | 3.047 | 5.486 | 3.840         | 2.194         |

Wall thickness is expressed in "schedules", referred to as pipe schedules.

The table at the end of this report shows all pipe thickness measurements and compares the measured thicknesses with the standard Schedule 40 S steel pipe.

In the Table 2 is presented condition pipes for which it was made study, measurements during inspection and comparative results between branch pipes and risers.
### Table 2. Pipes Study Condition. Branch pipes and riser’s inspection and comparison.

| Apartment No. | Diameter (DN) | Standard 10S pipe thickness | Measured pipe thickness | Diameter | Standard 10S pipe thickness | Measured pipe thickness | Diam. (DN) | Standard 10S pipe thickness | Measured pipe thickness |
|---------------|---------------|-----------------------------|-------------------------|----------|-----------------------------|-------------------------|------------|-----------------------------|-------------------------|
|               | [mm]          | [mm]                        | [mm]                    | [mm]     | [mm]                        | [mm]                    |            | [mm]                        | [mm]                    |
| 1108          | 25            | 3.37                        | 3.45                    | 25       | 3.37                        | 1.82                    | 8          | 1.82                        | 8                      |
|               |               | Nam’                        | Nam’                    |          |                             |                         |            |                             |                         |
| 1109          | 25            | 3.37                        | 3.37                    | 8        | 8                           | 8                       | 25         | 3.37                        | 3.22                    |
| 1116          | 25            | 3.37                        | 1.52                    | 8        | 8                           | 3                       | 25         | 3.37                        | 0.96                    |
| 1114          | 25            | 3.37                        | 0.83                    | 8        | 8                           | 8                       | 25         | 3.37                        | 3.63                    |
|               |               | Nam’                        | Nam’                    |          |                             |                         |            |                             |                         |
| 1005          | 32            | 3.55                        | 3.55                    | 25       | 3.55                        | 3.02                    | 6          | 6                           | 2                      |
| 301           | 40            | 3.68                        | 3.63                    | 3        | 3                           | 3                       | 25         | 3.68                        | -                      |
|               |               | Nam’                        | Nam’                    |          |                             |                         |            |                             |                         |
| 304           | 40            | 3.68                        | 3.65                    | 40       | 3.68                        | 4.21                    | 7          | 7                           | 3                      |
|               |               | Nam’                        | Nam’                    |          |                             |                         |            |                             |                         |
| 307           | 40            | 3.68                        | 3.93                    | 3        | 3                           | 7                       | 30         | 3.68                        | 3.93                    |
|               |               | Nam’                        | Nam’                    |          |                             |                         |            |                             |                         |
| 317           | 40            | 3.68                        | 3.83                    | 5        | 3.68                        | 3.83                    | 30         | 3.68                        | 3.83                    |
|               |               | Nam’                        | Nam’                    |          |                             |                         |            |                             |                         |
| 315           | 40            | 3.68                        | 3.63                    | 2        | 3                           | 2                       | 30         | 3.68                        | 3.63                    |

Note: Measured values may vary from manufactured values due to manufacturing tolerances and measurement errors.
| Apartment No. | Branch piping | Risers |
|---------------|--------------|--------|
|               | Diameter (DN) | Standard 10S pipe thickness | Measured pipe thickness | Diameter | Standard 10S pipe thickness | Measured pipe thickness |
|               | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] |
| 311           | Nam* | 40   | 3.68 | 5.48 | 3   | 6   |
| 314           | 3.37 | 8    | 0.76 | 75   | 40  | 3.68 | 5.23 | 75   | 40  | 3.68 | 5.23 |
| 205           | 2.76 | 8    | 7.46 | 75   | 40  | 3.68 | 3.40 | 75   | 40  | 3.68 | 3.40 |
| 209           | 3.37 | 8    | 5.66 | 75   | 40  | 3.68 | 4.01 | 75   | 40  | 3.68 | 4.01 |
| 2102          | 3.68 | 3    | 6.01 | 75   | 40  | 3.68 | 6.01 | 75   | 40  | 3.68 | 6.01 |
| 2104          | 0.13 | 3    | 0.25 | 75   | 40  | 0.13 | 0.14 | 75   | 40  | 0.13 | 0.14 |
| 2106          | 0.19 | 5    | 0.19 | 75   | 40  | 0.19 | 0.19 | 75   | 40  | 0.19 | 0.19 |
| 2107          | 0.03 | 3    | 0.16 | 75   | 40  | 0.03 | 0.16 | 75   | 40  | 0.03 | 0.16 |
| 2108          | 0.16 | 0    | 0.19 | 75   | 40  | 0.16 | 0.19 | 75   | 40  | 0.16 | 0.19 |
| 2110          | 0.02 | 9    | 0.23 | 75   | 40  | 0.02 | 0.23 | 75   | 40  | 0.02 | 0.23 |
| 2112          | Nam* | 7    | 0.12 | 75   | 40  | Nam* | 0.17 | 75   | 40  | Nam* | 0.17 |

This table represents the measured pipethickness of apartment piping in a building, along with the standard thickness as specified. The data includes the apartment number, branch piping diameter and standard pipe thickness, as well as the measured pipe thickness. The table is structured to compare barrels of various diameters and measurements.
### Results and discussions

We observed in about 20% of the runouts inspected, the remaining thickness of the steel pipe was less than 60% in the areas that we could access (Table 3). The remaining pipe thickness could be less in locations that were inaccessible. The runouts are in danger of developing leaks.

| Apartment No. | Branch piping | Risers |
|---------------|---------------|--------|
|               | Diameter (DN) | Standard 10S pipe thickness | Measured pipe thickness | Diameter (DN) | Standard 10S pipe thickness | Measured pipe thickness |
|               | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] |
| 2114          | -     | 0.12 | -     | 0.10 | 0.03 | -     | 0.22 | Nam* | -     | 0.19 | Nam* |
| 2115          | -     | 0.10 | -     | 0.22 | 0.03 | -     | 0.26 | Nam* | -     | 0.12 | Nam* |
| 2116          | -     | 0.22 | -     | 0.24 | 0.16 | -     | 0.48 | Nam* | -     | 0.24 | Nam* |
| 2117          | -     | 0.24 | -     | 0.19 | 0.14 | -     | 0.42 | Nam* | -     | 0.24 | Nam* |
| 1905          | -     | 0.31 | -     | 0.21 | 0.19 | -     | 0.16 | Nam* | -     | 0.28 | Nam* |
| 1110          | -     | 0.11 | -     | 0.25 | 0.12 | -     | 0.26 | Nam* | -     | 0.17 | Nam* |
| 1103          | -     | 0.19 | -     | 0.26 | 0.11 | -     | 0.26 | Nam* | -     | 0.17 | Nam* |
| 1105          | -     | 0.26 | -     | 0.28 | 0.26 | -     | 0.33 | Nam* | -     | 0.22 | Nam* |
| 1107          | -     | 0.13 | -     | -     | 0.10 | -     | 0.24 | Nam* | -     | 0.24 | Nam* |

Nam* - not accessible for measuring (Some pipes were not accessible because they were behind other building elements or pipes.)
NP* - new pipe Cu 15mm

3. Results and discussions

We observed in about 20% of the runouts inspected, the remaining thickness of the steel pipe was less than 60% in the areas that we could access (Table 3). The remaining pipe thickness could be less in locations that were inaccessible. The runouts are in danger of developing leaks.
Table 3. Pipe thickness measurements

| Summary of pipe thickness measurements | Branch piping | Riser piping |
|---------------------------------------|---------------|--------------|
| Total number of measurements          | 63            | 72           |
| Total number of more than 30% deficient measurements | 12            | 8            |
| Percentage of highly deteriorated pipe portions encountered | 19%           | 11%          |

Because of the high potential cost of leaks and the possibility of that 20%, or 120 pipes, could leak in the near future, we recommend replacement of all of the runouts.

We recommend replacement of all branches with one of the family of cross-linked polyethylene pipes which is known as PEX (or XLPE or PEX-AL-PEX) tubing. Various types of PEX tubing should be investigated and the type suitable to pressure and temperature requirements of this system should be determined before specifying the material and the manufacturer.

PEX tubing is a flexible product that could lessen the plaster damage involved in branch line replacement and make installation faster and easier; it is also non-corroding. Although it will not rust, it will require some insulation to prevent condensation and dripping in the wall cavity. We recommend closed cell flexible elastomeric foam insulation (K-Flex or Armaflex for example). It is very easy to apply and does not require a separate vapour barrier.

There is some concern about the condition of the risers, although we had only a few isolated readings that indicated excessive wear. The replacement of the risers would be a very disruptive project. We see the need to consider replacement of the risers at this time.

For the long-term, since the building could be standing for another 30 or 50 years, we would suggest considering epoxy coating the inside of the risers to ensure their long term viability. Although not at all urgent, we bring this up now because this would be most easily done when the runouts are replaced. If done later, the runouts and valves would have to be removed because they cannot be exposed to the epoxy coating.

In situ epoxy coating of steel pipes is an effective method for controlling corrosion inside the metallic pipes and also for preventing release of soluble metals into water by preventing water from contacting the metal surface. With this method the existing riser pipes are coated with a solid and smooth layer of epoxy. While increasing the service life of the pipes, the technique will also stop pipe deterioration by forming a permanent barrier between the water flow and the metal pipe surface. Even though after the coating effective pipe diameter becomes smaller, since smoothness of the interior surface improves significantly the flow characteristics of the system remain as designed.

Before epoxy coating of risers start all branches shall be cut off and plug nipple(s); all risers shall be epoxy coated. After coating process is completed PEX tubing shall be installed complete with shut-off valves at each riser connection. In the end all branch valves shall be turned on and system will be re-commissioned.

The company who will perform the epoxy coating of the risers should do a cut test of each riser and will inspect the interior of all risers with a camera to find out if mineral build up is going to obstruct the desired coating process.
This technology has been used primarily for lining domestic hot water risers. The companies will prove that it can be used for domestic cold-water risers and for heating and air conditioning pipes (if necessary).

4. Conclusions

System performance can only be reliably characterized through monitoring and analysis of relevant data. Most systems often include some sort of condition monitoring to guide emergency and preventive maintenance programs. While this is an important component of a comprehensive system monitoring program, condition data only gives a limited picture of the total health of the system.

Condition data is useful to maintenance engineers, but system operators are concerned with system performance and would benefit from performance monitoring.

Performance monitoring is concerned with measuring system efficiency and to what extent the system is delivering what it was designed for (i.e., flow, pressure, energy, water quality, etc.).

References

[1] L. Tzu, “Tao te Ching: The Book of the Way”, 600 BC -531 BC, Waking Lion Press, ISBN 978-1-4341-0244-7, 2012.
[2] J. Pokorný, A. Rejšková, Water Cycle Management, Encyclopedia of Ecology, pp. 3729-3737, 2008.
[3] P. Saikiai, G. Beaneii, L. Ellisiii, R. Ginéi, R. Wardi, P. Avelloi, S. Fisherii, J. Leteni, I. Ruiz-Apilánezii, M. Shouleriii, and A. Jiménezi, “City Water Resilience Approach: A five-step methodology to build water resilience at an urban scale”, Second International Conference - Water, Megacities and Global Change 2021, Pre-Conference 7-11 December 2020.
[4] E. Orlov, M. Lavrova, A. Mishueva, “Water losses in internal water supply services of residential buildings”, E3S Web of Conferences, vol. 97, no. 83, p.05015, 2019.
[5] H. Khan., “Water Leaks in Multi Storey Buildings - A Problem Bigger Than Panama Leaks!”, Australasian Concrete Repair Association (ACRA) - Concrete Connection, 2016.
[6] S.S.E. Lam, J.L. Fu, V. Wong, T. HT Chan, “Investigation of Water Seepage in Multi-storey Buildings by Vibration measurements and Moisture Monitoring”, The 24th Australasian Conference on the Mechanics of Structure & Materials, Perth, Australia, 2016.
[7] J.T.Y. Wong, E.C.M. Hui, “Water seepage in multi-storey buildings”, Facilities, vol. 23. Issue 13/14, pp. 595 – 607, 2005.
[8] M.Y.L. Chew, N. De Silva, S.S. Tan, “Maintainability of wet areas of non-residential buildings”, Structural Survey, vol. 22, Issue 1, pp. 39 – 52, 2004.
[9] A. Colombo, B.W. Karney, “Pipe breaks and the role of leaks from an economic perspective”, Water Science and Technology: Water Supply, vol 3, no. 1-2, pp. 163- 169, 2003.
[10] X.J. Wang, M.F. Lambert, A.R. Simpson, J.A. Liggett, J.P. Vítkovský, “Leak detection in pipelines using the damping of fluid transients”, Journal of Hydraulic Engineering, vol. 128, no. 7, pp. 697–711, 2002.