Perpetual Challenge for Zero Non-Revenue Water Rate

T. Sayama*

*Bureau of Waterworks, Tokyo Metropolitan Government, 2-1-12 Uchikanda, Chiyoda-Ku, Tokyo,

Keywords: Water leakage rate; Non-revenue water rate; Leakage prevention measures

Abstract: The water leakage rate in Tokyo was 15% in 1982, but currently has been lowered to 3.2%, and has remained at levels below 5% since 2003. This reduced leakage rate is the result of the efforts to implement various measures including improvement of the material qualities of service pipes, where the majority of water leakages occur, in addition to carefully planned water leakage prevention work, such as practical, continuous personnel training so far and the development of inspection equipment. This paper reports water leakage prevention efforts made by the Bureau of Waterworks, Tokyo Metropolitan Government (referred to below as the Tokyo Waterworks).

1 Introduction

Water leakages not only causes the loss of precious water, but can also cause secondary disasters such as road subsidence and flooding of buildings. As it becomes more difficult and takes a longer time to develop new water sources due to reconstruction of the livelihoods of residents and environmental protection of water source basins, it has become an extremely important challenge to reduce water leakage as much as possibly by promoting more effective leakage prevention measures.

Since reaching a record low of 2.0% in 2012, the water leakage rate in Tokyo has hovered around the low rate of just 3.0% **(Figure 1)**. This resulted from tireless efforts to improve leakage prevention measures.

Leakage prevention measures currently implemented by the Tokyo Waterworks are divided into three categories: responsive measures, preventive measures, and technological development **(Figure 2)**.

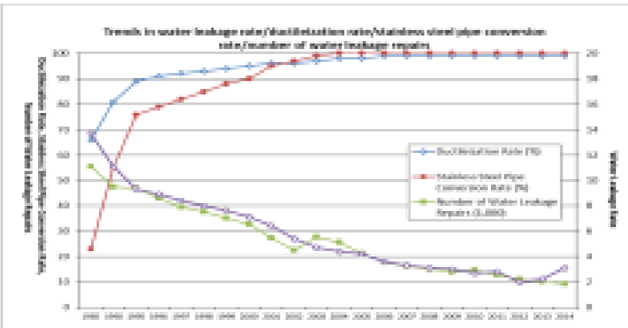


Figure 1 Trends in water leakage rate, ductileization rate, stainless steel conversion rate, leakage repairs

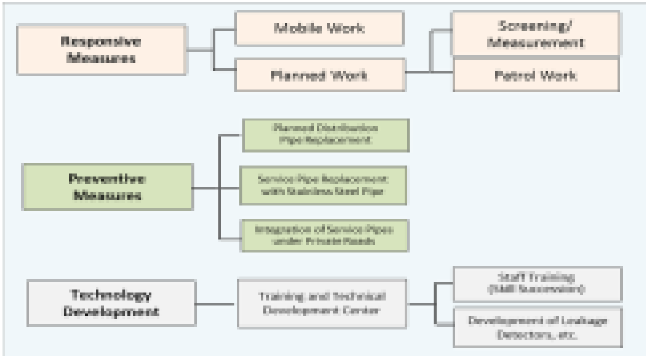


Figure 2 Water leakage prevention measures in Tokyo

2 Responsive Measures

Responsive measures include corrective work to repair water leakage in which water flows up to the surface of the ground, and planned work to detect and repair water leakage underground that is always potentially happening.

(1) Corrective Work (Responses to surface leakage)

Corrective work is conducted in response to surface leakages reported by residents or staff members on patrols, with repairs generally made on the same day. The Tokyo Waterworks was only responsible for repairing service pipe leaks on roads until June 1985 **(Figure 3)**, but from July 1985 until the end of March 1993, this was expanded to included public roads and up to 1 meter onto the property of residential areas. From April 1994, the scope was expanded to include water meters, and eventually to reduce leakages upstream from water meters during repairs, water meters were moved within 1 meter from the boundary of the road whenever possible.

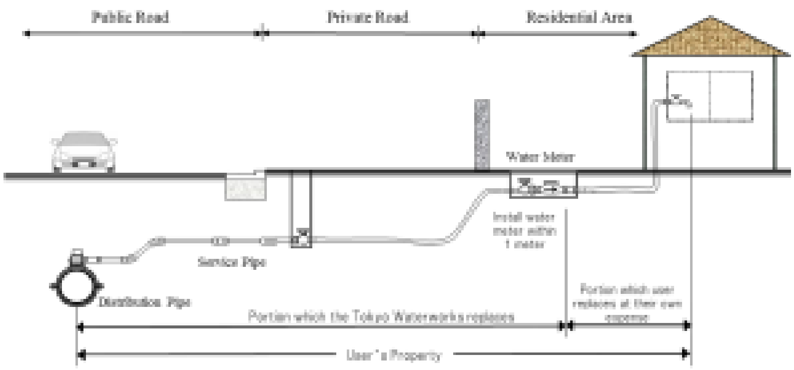


Figure 3 Scope of leakage repairs on service pipes

(2) Planned Work (Response to underground leakage)

Because underground water leakage is not directly visible to our eyes, leaks tend to continue for a long period of time, and account for the majority of water leakage. Detecting and repairing underground water leakage is especially important in leakage prevention measures, and this is called "planned work" by the Tokyo Waterworks. Planned work is categorized into selected leakage volume measurement and routine inspection work. The scope of water leakage repairs in planned work was expanded before corrective work to include water meters in August 1985.

(i) Selected Leakage Volume Measurement (Minimum night flow measurement method)

Selected leakage volume measurement work is conducted by dividing water supply areas in to approximately 4,700 working sections (distribution pipes in each section have a total length of 2.5 km to 3.3 km), which makes for more efficient leakage inspection. This leakage inspection method **(Figure 4)** is intended to inspect potential underground water leakage in each section. It uses a minimum flow rate measurement device to measure the minimum flow rate in that section late at night when people use less water (unoccupied time), and uses that value as the leakage volume **(Figure 5)**. Repairs are made to sections with a high water leakage volume following acoustic leakage inspection of distribution pipe lines with high water leakage volume within the section using a sound detection bar or electric leakage detector **(Figure 6)**, or the correlative leakage detection method using correlation leakage detectors **(Figure 7)**.

Figure 4 Minimum Flow Rate Measurement Device

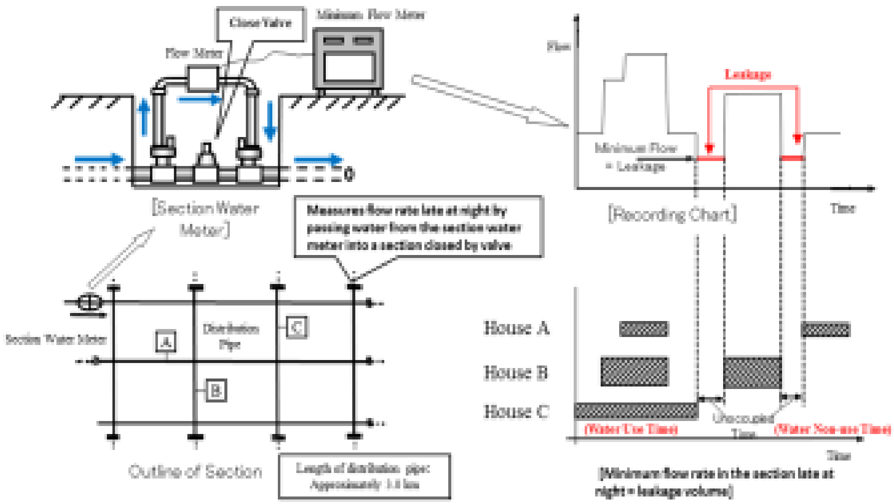
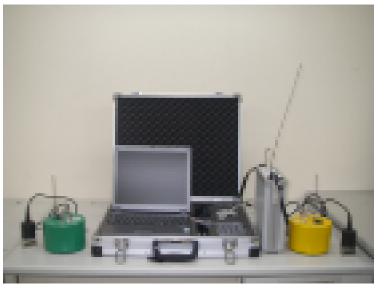


Figure 5 Night Minimum Flow Rate Measurement Method

Figure 6 Acoustic inspection using sound detection bar (day)
and using electronic water leakage detector (night)



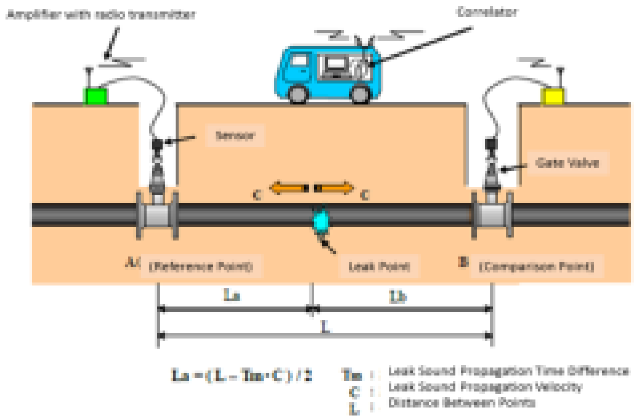


Figure 7 Correlative water leakage detector   Correlative inspection with a correlative water leakage

(ii) Patrol Work (leakage detection with acoustic method)

Patrol work is intended to detect and repair water leakage mainly by inspections using the acoustic leakage sound detection method, without conducting minimum flow measurement work on section believed to have high leakage, by referencing historical night minimum water flow measurement work records and water leakage repair records.

3 Preventive Measures

Leakage is repaired as soon as it is founds, but new leaks occur in different places as time passes. This is referred to as the repetition phenomena of leaks. Preventive measures are an important water leakage prevention measure for predicting and stopping these repetition phenomena in advance. The Tokyo Waterworks implements the following efforts as water leakage preventive measures.

(1) Planned replacement of service pipes (using stainless steel pipes)

Water service pipes account for the greatest part of water leakage repairs, so reducing water service pipe leakage helps to reduce the overall water leakage rate. Since the 1980s, stainless steel pipes **(Figure 8)**, which are stronger and more resistant to corrosion in comparison to other materials, have been used for water service pipes. At first stainless steel pipes were only used for new construction and renovation of water service pipes, but from 1982 when distribution pipes started to be replaced, efforts were also started to replace water service pipes with stainless steel pipes, and over the course of nearly three decades, all water service pipes under public roads were replaced with stainless steel by 2006 **(Figure 1)**.

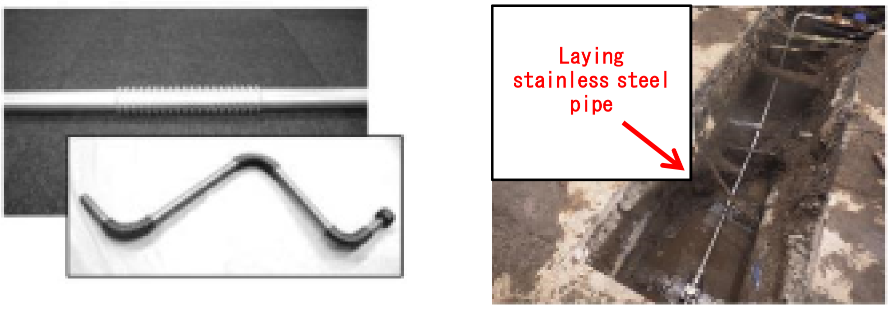


Figure 8 Stainless Steel Pipes (Water Service Pipes)

(2) Planned replacement of distribution pipes (using ductile cast iron pipes and seismic coupling pipes)

Until 1933, normal cast iron pipes were used for distribution pipes in Tokyo, and high grade cast iron pipes were used after that. Since 1960, these were replaced by ductile cast iron pipes, which are superior in terms of strength which are more durable, stronger against shocks, and have stronger seismic resistance. Construction has progressed to replace nearly 27,000 km (equivalent to 2/3 of the diameter of the Earth) total of distribution pipes with ductile cast iron, and this replacement work was nearly complete in 2006, almost 5 decades later **(Figure 1)**. Since 1998, seismic coupling pipes (Figure 9) were used on all distribution pipes, as part of seismic retrofitting efforts.

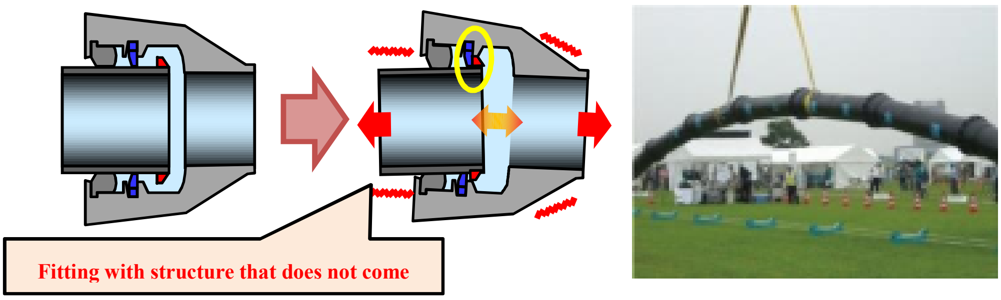


Figure 9 Seismic Coupling Pipe

(3) Integration of water service pipes under private roads

Water service pipes under private roads typically use vinyl pipes that are buried at a shallow depth, In addition, there are many pipes laid, and the pipes laid are very long, so they are easily affected by passing vehicles, resulting in more leaks. As a countermeasure against these leaks, for over 20 years starting in 1994, seismic coupling distribution pipes made with ductile cast iron have been laid under private roads, and service pipes have been organized (Figure 10), which reduces the frequency of leaks by reducing the total length of piping and improving the piping materials. Service pipes that branch under private roads are being replaced with stainless steel pipes as far as the water meter. Furthermore, by installing drain plugs with the same functionality as fire hydrants at the end of distribution pipes **(Figure 11)**, they can also be used for emergency water supply when there is an earthquake **(Figure 12)** or initial firefighting when there is a fire.

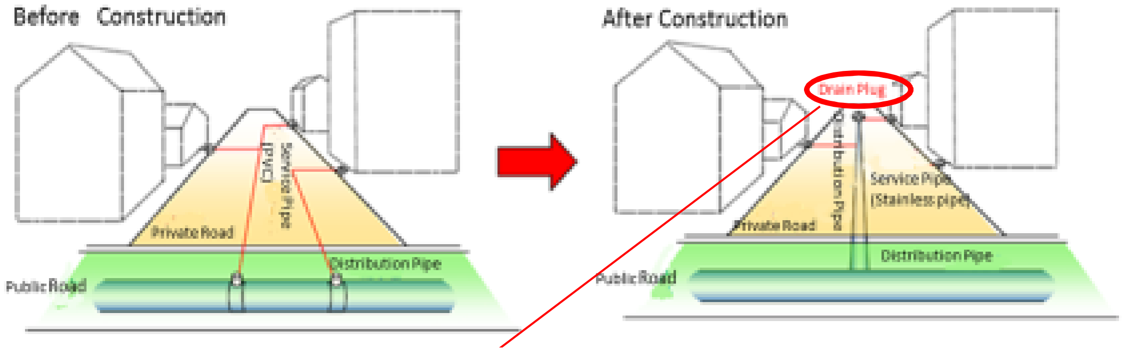


Figure 10 Service pipe retrofitting under private roads

Figure 11 Drain plug

Figure 12 Emergency water supply when there is an earthquake

4 Technical Developments

(1) Training and Technical Development Center

The Office of Leakage Prevention was established by the Tokyo Waterworks in 1974 to work on the research and development of leakage prevention related equipment and technology. Today it is succeeded by the Training and Technical Development Center **(Figure 13)**, which in addition to developing technology for leakage prevention devices, also works on the succession of skills, which includes training to improve the skills of staff **(Figure 14)**.

(i) Staff Training (Skill Succession)

As senior staff members with a wealth of technology retire from their positions, the Tokyo Waterworks has experienced difficulties with skill succession, making training of young staff (skill succession) a pressing task. As a countermeasure against the loss of skills, the Tokyo Waterworks has certified staff members that have a particular abundance of technical skills and experience as “Waterworks Technical Experts”. If there are matters that young staff or transfer staff members do not understand in their normal work, then certified staff members offer guidance and advice based on their knowledge and experience. They also contribute to the training of staff (skill succession) by acting as training instructors, in order to maintain and improve the crisis management and response skills and the ability to perform duties of staff.

Figure 13 Training and Technical Development Center

Figure 14 Training to improve the skills of staff

(ii) Development of leakage detectors

The main technological developments achieved so far, in addition to the leakage detectors introduced earlier, include the following devices.

・Subsurface Radar

When high frequency electromagnetic waves are emitted towards the ground, some waves are reflected back from the earth. This device detects cavities under roads after leakages using the fact that where there are cavities in the ground, differences appear in the strength or travel time of reflected electromagnetic waves compared to other places.

・Main Line Leakage Detector

This device identifies leakage locations by inserting a signal transmission cable with an underwater microphone mounted on the tip through air valves into water pipes, displaying the waveform of leakage sounds picked up by the underwater microphone on a correlative leak detector, and measuring the length of cable that was inserted.

・Non-metallic Pipe Detector

This device is installed on fire hydrants or water meters, where it detects where water pipes are buried by vibrating water inside water pipes with its built-in underwater speaker and sensing the vibrations with a piezoelectric sensor above ground.

・Pipe Fluoroscope

This device transmits radiation through a pipe, and when the radiation passes through the pipe, using the fact that the amount of radiation transmitted through the pipe differs depending on the thickness and density, displays an image of the conditions inside the pipe (rust, etc.) and thickness of the pipe.

・In-pipe Endoscope

This device is used to insert a video signal transmission cable with a camera attached to the end into a pipe from a fire hydrant, where it is moved sequentially to check the conditions inside the pipe with video.

・In-pipe Insertion Type Flow Meter

This device is inserted from a fire hydrant to measure the direction and flow rate inside a pipe.

・Noble Gas Based Leak Detection Technology

This technology identifies leakage points by removing the water from a pipe, inserting helium gas into the pipe, and finding the helium gas that seeps up above ground from the leakage point below ground with a detector above ground. It is capable of small amounts of water leakage or leakage from pipes buried deep underground, which are hard to detect using sound.

These are just some of the diverse devices developed by the Tokyo Waterworks, which continues to engage in new development even now.

5 Conclusions

The Tokyo Waterworks has achieved and maintained a non-revenue water rate, which comes as the result of various efforts including preventive measures taken so far.

The Tokyo Metropolitan Government will ensure the succession of leakage prevention technology cultivated thus far while working unflinchingly to achieve a non-revenue water rate of zero.

References

2017 *Prevention of Leakage in Tokyo*, Bureau of Waterworks, Tokyo Metropolitan Government (Tokyo, Japan)