Prevention of Leakage in Tokyo

2025

Bureau of Waterworks, Tokyo Metropolitan Government

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1 Leakage prevention

(1) Abstract

The rivers flowing into the Tokyo Metropolitan area, named Tone, Arakawa, and Tama river systems are the main source of water used in this area.

Raw water collected from these rivers is processed such as sedimentation, filtration and disinfection at water plants, and conveyed by underground water pipes, then supplied to customers as tap water. In addition, water purification plants of Tone and Arakawa river water system are introduced advanced water treatment systems such as ozonation and biological activated carbon adsorption treatment. In this process, some water may leak from the pipes into the ground/out to the ground surface. It is called “leakage”.

The amount of water resource possession is currently about 6.8 $\times 10^6 m^3$/day. However, it includes 0.82 $\times 10^6 m^3$/day problematic water resources. —the water that is temporarily permitted until the development of water resources as a countermeasure to the chronic drought in the 1950s and the water that is agreed upon annually but can be reduced by the situation in the other prefecture—.

Furthermore, in the future, the risk of a severe drought will be increasing because of climate change effect such as decreasing supply capacity of rivers and dams due to extreme decreases in snow accumulation and rainy days.

Under these circumstances, we need to make the best use of its water resources in order to maintain a stable water supply for Tokyo, considering the effects of future climate change in addition to meeting demand.

The distribution pipes consist of the distribution mains and distribution submains that branch out from the mains and directly connect to the service pipes. Water distribution pipes installed in Tokyo totals up to 27,585 kilometers long in FY2024, which is equivalent to two-thirds the length of the earth’s circumference. And, service pipes are installed in each home and business.

Water pipes embedded in underground are constantly subject to a danger of leakage, affected by earthquakes, uneven ground settlement, corrosive soils, traffic loads, and various construction works, and so on.

Leakage leads to not only the loss of precious water resources, but also risks of secondary disasters such as poor water flow, sagging road, and inundation and so on. Tokyo Waterworks have taken leakage prevention measures as a major initiative.

Fig.1 Scene of leakage

Fig.2 Corrosion leakage of iron pipes

(2) Present situation of leakage

In FY1992, the amount of leakage was 180 $\times 10^6$ m^3 per year, and the leakage rate was 10.2%.In FY 2024, the annual distribution amount of 1,528 $\times 10^6$ m^3, and the amount of leakage decreased to 53 $\times 10^6$ $m^3$and leakage rate accounted for 3.5%(Fig.3, Reference-1 and 2). Most leakages occur due to cracks and corrosion caused by aged deterioration of service pipes that are owned by customers and distribution pipes that are owned by waterworks. The total cases of leakage repair works in FY 2024 recorded around 9,117 and around 97% of which were from service pipes, and the remained around 3% were from distribution pipes (Reference-3).

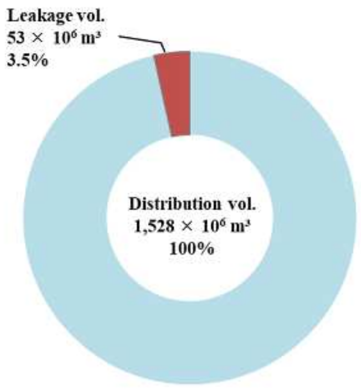


Fig.3 Annual distribution volume and leakage volume in FY2024

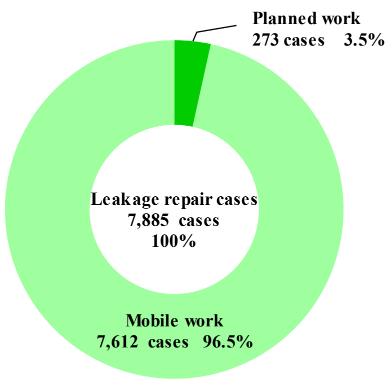


Fig.4 Comparison between Mobile work and Planned work (Cases)

Leakage is classified into two types by its form; "surface leakage" that flows out to surface of the ground and "underground leakage" that leaks out underground without any appearing on the surface. Basically, leakages occurring above the ground are dealt with mobile work - repair within the day - and p those occurring underground are dealt with planned work. The Figure 4 shows the ratio of mobile work and planned work. There were 8,802 repairs by mobile work and 315 by planned one in the FY 2024(Reference -4).

Underground leakage is invisible and thus practically unnoticed; therefore, in many cases water has been leaking for a long time. Therefore, unless we identify and repair leakage systematically, valuable water continue leaking and that lead to terrible accident such as road collapse.

Although leakages are repaired immediately when they are found, the new leakage increases gradually in accordance with time. We call it "Repetition of leakage" (Fig. 5). As it is important to develop leakage prevention measures by taking this repetition phenomenon into consideration.

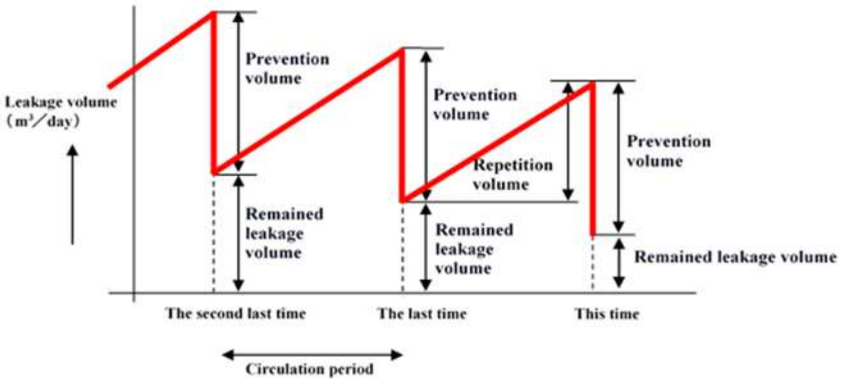


Fig.5 Repetition of leakage

2 Leakage prevention measures

(1) System of leakage prevention measures

Tokyo Waterworks is working on leakage prevention measures based on the pillars of "Planed replacement of water pipes and improvement of materials for pipes", "Early detection and repair work for leakage" and "Secure high technology of leakage prevention".

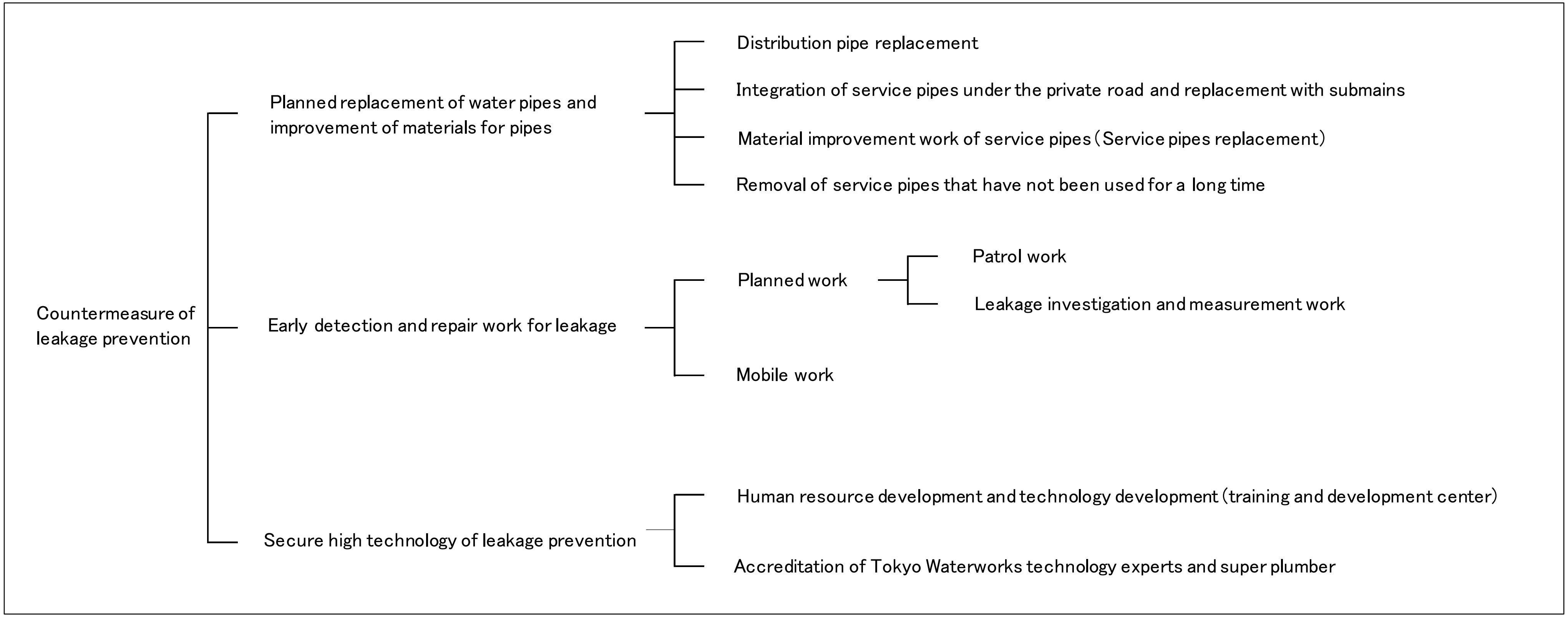


Fig.6 System of leakage prevention measures

A Planned replacement of water pipes and improvement of materials for pipes

(A) Distribution pipe replacement

Distribution pipes extend approximately 27,585 km, and therefore need to be renewed continuously and systematically. For this reason, high-grade cast iron pipes, which are vulnerable to external impacts, have been successively replaced with ductile cast iron pipes, which are tenacious and strong, since the 1960s. However, in areas where construction is difficult, there are pipes that are old and difficult to replace that could leak. In addition, there remain pipes with a high risk of leakage, such as mixed cast iron pipes and steel pipes that are not covered with polyethylene sleeves. With the imminent threat of an earthquake directly under the Tokyo, Tokyo Waterworks has been promoting the installation of earthquake-resistant joints for distribution pipes, including these pipelines, and at the end of FY2024, we increased the rate of earthquake-resistant joints to 52% and completed the installation of earthquake-resistant joints for supply routes to important facilities.

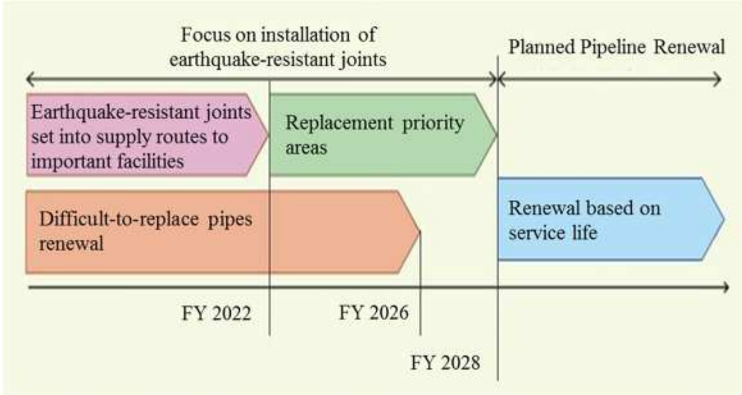


Fig.7 How to proceed with pipeline renewal

To mitigate water outage damage, we are steadily replacing water distribution pipes by eliminating priority areas for replacement and pipes that are difficult to replace. The replacement of water distribution pipes has proceeded as follows.

a	Since FY 1986	Replacement of low-strength cast iron pipes with no inner lining and steel pipes that are difficult to replace because they are older than the year of installation
b	Since FY 2005	Replacement of initial ductile iron pipe with a mixture of straight ductile iron pipe and deformed pipe made of high-grade cast iron
c	Since FY 2007	Pipes in supply routes for important facilities such as the capital central agencies, emergency medical institutions, shelters and main stations
d	Since FY 2013	Pipes without earthquake-resistant joint pipes laid in areas where the water outage rate in the event of an earthquake would exceed 50% (replacement priority areas) according to the Tokyo Metropolitan Government's damage estimates
e	Since FY 2018	Steel pipes without polyethylene sleeves

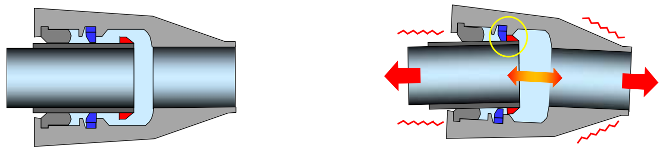


Fig.8 Earthquake-resistant joints…Structure that does not cause joint detachment during the earthquake
(Left: Normal Condition, Right: Earthquake Condition)

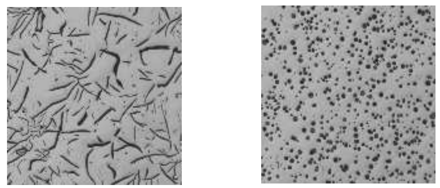


Fig.9 Micrograph of cast iron
(Left: High-grade cast iron, Right: Ductile cast iron)

(B) Integration of service pipes under the private road and replacement with submains

Some private roads have multiple water supply pipes installed over long distances, which is one of the major causes of water leakage and poor water delivery. Thus, since 1994, we has been consolidating service pipes for private roads with three or more water these pipes in order to ensure water pressure and prevent leakage. After that, we have been alleviating the application requirements and promoting the replacement. Many of the leaks that occurred in Tokyo during the 2011 off the Pacific coast of Tohoku Earthquake were caused by PVC pipes in private roads. So, we are installing earthquake-resistant distribution pipes and stainless steel water pipes in all private roads, which are approximately 2,600 km long.

In addition, by installing a drain plug that have same function as a fire hydrant at the end of submains, it can be utilized for emergency water supply at the time of earthquake and for initial fire extinguishing in case of fire.

The requirements for the application of small water distribution pipes in this project have been expanded as follows.

a Since FY 1994 : private roads where more than three service pipes were installed

b Since FY 2007 : private roads where more than three service pipes were installed or the ones which have more than 15 water meters

c Since FY 2008 : private roads where more than three service pipes were installed or the ones which have more than 10 water meters

d Since FY 2012 : private roads which have more than three water meters.

We have been also trying to further improve earthquake resistance of service pipes under private roads by replacing PVC pipes to stainless steel pipes under private roads with two or less water meters with since FY2012.

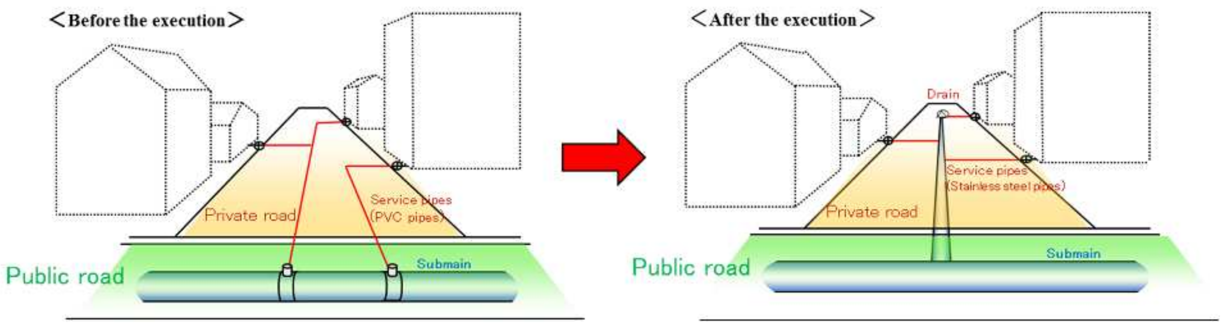


Fig.10 Integration of service pipes under the private road and replacement with submains

(C) Material improvement work of service pipes (Service pipes replacement)

Most of leakages occur in old and corroded service pipes (Reference-3), and they are accounted for about 96% of the total leakage repair cases. Consequently, in order to reduce leakages, it is extremely effective to prevent from them in advance. In Tokyo, we used to use "lead" for service pipes which is easy to construct. However, lead has been a major cause of leakages due to its low intensity and easy to corrosion.

Therefore, since FY 1980 we have abandoned the use of lead pipes for newly installed service pipes on public roads, and adopted stainless steel pipes that have superior strength and corrosion resistance. And since FY 1982, as a project of Tokyo Waterworks aiming for leakage reduction, we have replaced the following service pipes to stainless pipes:

a Since FY 1982 : execution of replacement work of lead service pipes branched from a route of which the aged distribution pipes and frequently leaking distribution pipes were to be replaced with ductile cast iron pipes

b Since FY 1983 : execution of replacement work of lead service pipes branched from submains which have already been ductile cast iron pipes within the areas with much leakage amount selected by planning activities

c Since FY 1984 : execution of replacement work of lead service pipes branched from submains at every opportunity of construction work related to submains

d Since FY 1985 : execution of replacement work of heavily corroded lead service pipes at the occasions of repairing leakages

In the Ministry of the Environment (formerly the Ministry of Health, Labor and Welfare) ordinance on water quality standards, in 1992, the stricter water quality standards for lead were introduced (water quality standard values 0.05mg/ℓ), together with the long-term target for 2002 (water quality standard values 0.01mg/ℓ).Therefore, use of lead service pipes was banned except for repairing leakages in 1992.

In 1995, we have entirely banned the use of lead pipes to promote use of stainless pipes. In 1998, we adopted corrugated stainless steel pipes that have excellent workability and earthquake resistance. And also we expanded the range of area that can be improved material to water meter, so far it can be used from branching part of service pipes from submains to the first stop cock. In addition, when a part of service pipes are lead service pipes, we have replaced them with PVC pipes in addition to replacing them with stainless steel pipes.

In 2000, we formulated an elimination plan of lead service pipes in upstream from water meter and we were almost complete the replacement of lead service pipes under private roads or leading to water meters within residential land by FY 2006.

There are still a few lead pipes remaining until now under private roads and within residential land. We have checking and replacing the remaining lead pipes again in the course of the planned activities after 2007.

Fig.11 Leakage from lead pipes

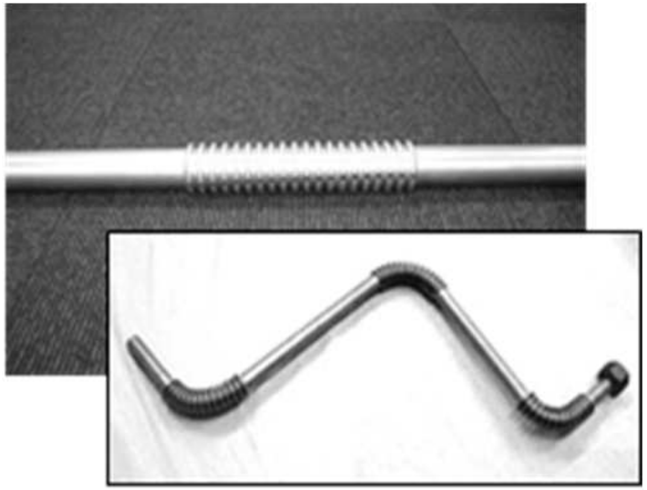


Fig12 Corrugated stainless steel

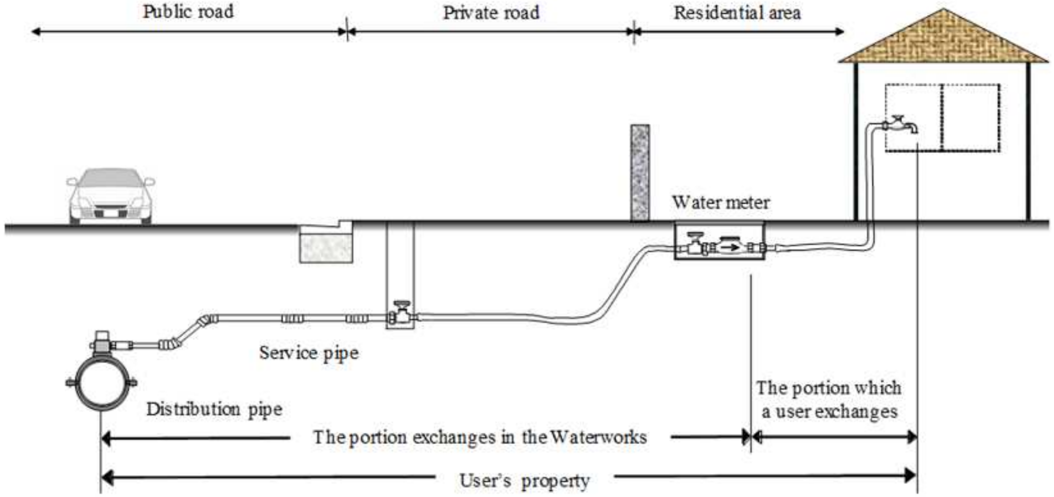


Fig.13 Material improvement of service pipe

(D) Removal of service pipes that have not been used for a long time

More than 90% of the leakages in Tokyo occur in the service pipes that supply water to each household. In particular, poorly managed service pipes laid in vacant houses are left for a long time, leading to delays in finding leakages. If these pipes are not properly managed, they will not only lose valuable water, but also lead to secondary damage such as road subsidence. In addition, if water leakage occurs at the time of a disaster, it is concerned that it may hinder prompt restoration.

In principle, customers are required to remove service pipes that are no longer expected to be used.

However, since 2021, from the viewpoint of avoiding the risk of leakage and optimizing the water supply environment, if the customer agrees, we have removed the service pipes that branch off from distribution pipes that have been made into earthquake-resistant joints and have not been used for more than 5 years.

Fig.14 Service pipe leakage (seep through to the surface)

Fig.15 The service pipe where water meter has been disconnected

Fig.16 Service pipes not expected to be used

B Early detection and repair works of leakage

Water leaks from underground pipes will eventually flow out to the ground. In order to minimize the damage caused by leakage, it is important to detect leakage early and repair it at an early stage. Therefore, Tokyo Waterworks implements planned and mobile operations as leakage prevention works, and is taking measures to prevent leakage day and night.

While water distribution pipes are maintained by Tokyo Waterworks, service pipes are the property of the customer and are therefore maintained by the customer. However, in order to make good use of limited water resources, Tokyo Waterworks repairs leakages in service pipes installed upstream to water meters within residential areas without charge except in special circumstances.

(A) Planned work

In planned work, submains buried in the form of a net are divided into blocks by a certain length, and research is conducted for each block in a planned manner. The research includes patrol work, leakage volume measurement work and leakage investigation and measurement work. In 23 wards, Tokyo Waterworks staff and Tokyo Water Co., Ltd. as the Tokyo Metropolitan Government's policy partner organization work together to conduct leakage surveys in a systematic manner. The majority of repair works of discovered leakage are undertaken by contractors of construction contracts.

Also, leakage survey in Tama area (26 cities/towns) had been conducted by each respective city/town. However, nowadays, these waterworks was integrated under the management of Tokyo Metropolitan Government, patrol survey (circulating checking) and leakage volume measurement work are conducted by Tokyo Water Co., Ltd., one of the administrative organizations, and the majority repair works of discovered leakage are undertaken by contractors of construction contracts.

a Patrol work (Circulating checking)

In the patrol works are individual investigation work that determines leakage with “leakage sound detection bar” (Fig.21) by putting to water meter on every house, acoustic investigation work that is conducted during the night when there is less traffic to identify point of leakage with electronic leakage detector (Fig.22) from the road surface.

To determine the blocks to patrol, we take previous work history and leakage occurrence in the previous year into consideration.

In addition to that, we consign administrative organizations (Tokyo Water Co., Ltd.) to conduct such individual investigation with time integral type leakage detector (Fig.26) replacing leakage sound detection bar on some blocks since FY2003.

b Leakage investigation and measurement work

When an earthquake hits, it is important to accurately assess the condition of the water supply from the mains to the submains in order to reduce the damage from water outages and to restore water supply facilities promptly. If the pipes taken out of the water distribution mains are in good condition, we can ensure water supply routes by avoiding the pipes damaged by the earthquake, and expand water supply areas from those routes.

The work has been implemented since FY 2010 with the purpose of confirming water outage and draining water assuming that we can ensure water supply routes as soon as possible after the earthquake. First, we measure the amount of leakage in each area using the nighttime minimum flow method (minimum flow measurement device). During measurement, in high leakage area, we identify the routes where leaks are occurring, and the flow of water is sequentially stopped on each pipeline, and while monitoring changes in flow rate with a minimum flow measuring device, pipelines that may be leaking are shut off and the water supply area is expanded.

Thus, this work is a practical exercise. Efficient and effective leakage prevention work can be achieved by performing work and leak investigations based on the amount of water leakage measured for each area in this operation.

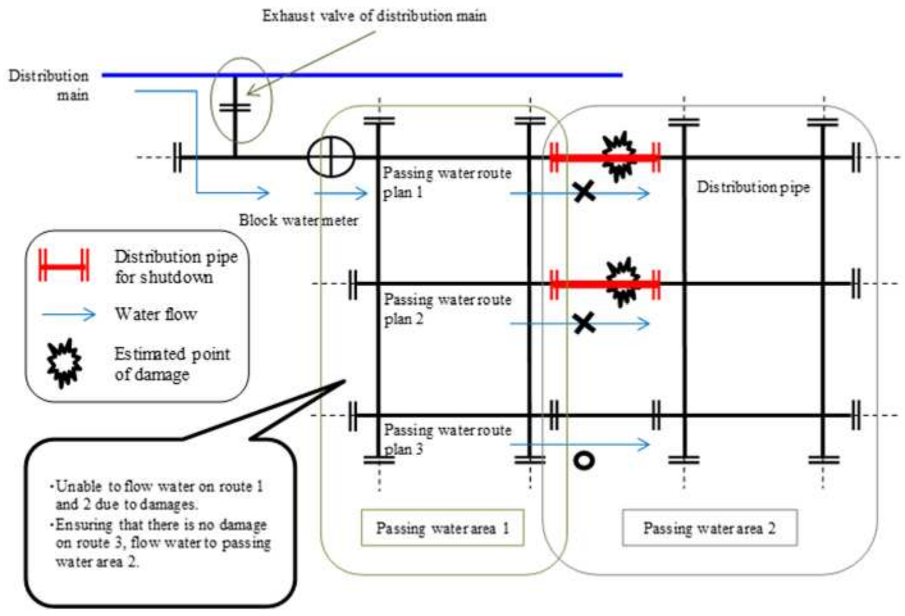


Fig.17 Leakage investigation and measurement work

(B) Mobile work

Mobile work is a work for repairing an above-ground leakage found by report of a customeror by other means. In 23 wards, staff members and contractors are on call 24 hours to respond to leakage at water works branch offices(field management office) (6 branch offices: 7 offices).

In Tama area (26 cities/towns), Employees of the Water Supply Management Office and Water Supply Office (four offices) which are field management offices of the Tokyo Metropolitan Waterworks Bureau, and Tokyo Water Co., Ltd., and our contractors are on standby 24 hours a day to respond to water leaks.

※Among the four site management offices, the operations of the Akiruno Water Supply Office will be entrusted to Tokyo Water Co., Ltd. for the management and operation of multiple facilities starting from the fiscal year 2027.

C Secure high level of leakage prevention technologies

We have 2 big challenges that “maintain low rate leakage” and “mass retirement of experienced workers”. Under these conditions, we have to do technical trainings related to leakage, develop engineering and human resource, for the purpose of efficient and secure leakage prevention measure.

Following efforts are to that purpose.

(A) Human resource development and technology development (training and development center)

The Training and Technical Development Center was established in 2005. Training division and development division work together to ensure the succession of technologies, enhance the capabilities of human resource and to respond appropriately to diverse needs so that we can continue to provide a steady supply of safe and better-tasting water to customers into the future.

There are pipeline facilities for experiments and verification to resolve problems about pipeline. These facilities are similar to actual condition and utilized not only for staff of Tokyo waterworks but neighboring and overseas waterworks companies.

In addition, for the list of items of leakage prevention related equipment that were co-developed by Tokyo Waterworks and private companies, please see Reference -7.

Fig.18 Technical training for leakage prevention work

(B) Accreditation of Tokyo waterworks technology experts and super plumbers

In various fields, many experienced staff that has technic that backed up with experience is faced to retirement. That is a big issue in terms of succession of technology about leakage prevention.

Therefore we founded “Tokyo Water Workers Technology Experts Program”, in which experienced staff provide training for junior fellows as leaders, and offer instruction courses on leakage prevention technologies at Training and Technical Development Center.

Furthermore we enhance inheritance of leakage prevention technologies by visualizing tacit knowledge that has been cultivated/built and uploaded to shared network, enabling browse as-needed basis.

In addition, especially excellent plumbers are accredited as “super plumbers” among the contractors of distribution pipe construction in order to maintain and succession technology, as well as to enhance the level of the entire plumbing technology and motivation.

(2) Leakage prevention construction system

Tokyo Waterworks adopt computerized system for tally records of repair work on leakage (cause and detail work) and calculate expenses of works.

Current systems process the followings.

a　Reception of leakage prevention measures.

b　Calculation of construction cost for leakage repair, material improvements, etc.

c　Summarization of the records of leakage causes and contents of the work.

The data obtained through electronic processing are effectively used for budget-making of the next fiscal year and drawing out long-term plans, selection of planned work blocks, and calculation of leakage volume, etc., contributing largely to the execution of effective preventive measures against leakage.

3 The method of leakage investigation

Currently we have mainly two types leakage investigations; “minimum night flow measurement method” is select pipelines necessary to be investigated based on maintenance status of pipelines and past history of leakage, and conduct leakage investigation. Other methods are to determine the leakage by the sound and identify the point (acoustic leakage sound detection method, correlative leakage detection method, and method using the time integral type leakage detector).

(1) Minimum night flow measurement method

Minimum night flow measurement method is a leakage investigation method that has been developed by taking the note of midnight idle time (water unused time) of water usage in a certain block.

First, close gate valves surrounding the block to be investigated shut the water flow from other blocks. Then the water is sent only through minimum flow measuring equipment set in the block water meter and measure the flow rate. The measured minimum flow rate (The quantity of flow indicated in spite of a situation where nobody is expected to use water) is considered to be the leakage.

This equipment is jointly developed by Tokyo Waterworks and a private company

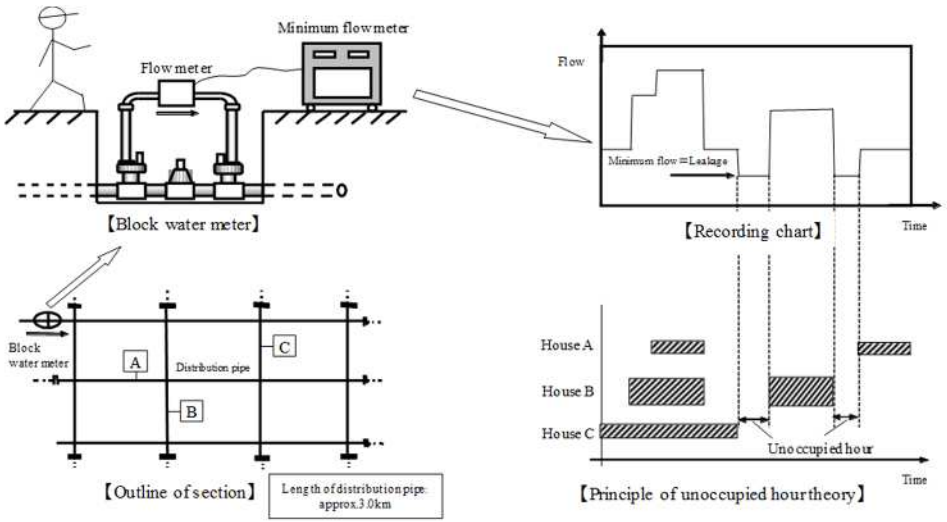


Fig.19 Theory of minimum night flow measurement method

Fig.20 Minimum flow meter

(2) Acoustic leakage sound detection method

Acoustic leakage sound detection method is catching the leakage sound by a leakage sound detection bar or an electronic leakage detector.

The usage of this leakage sound detection bar is putting the tip of the bar to the water meter, gate valve or fire hydrant. After that an inspector presses an ear against a vibration diaphragm set at the other end of the bar, and listens for transmitted sound of the leakage. The leakage sound detection bar can only tell whether the leakage is occurred nearby, and it is difficult to detect the position of leakage.

Electronic leakage detector is an equipment that can convert the leakage sound into an electrical signal by placed the detector (we called “Pick up”) on the ground, and the sound is amplified and heard through headphones. We can search actual leakage point by moving the detector (Pick up) as leakage sound is heard most strongly directly above the point of leakage.

Among the sounds detected by a leakage sound detection bar or an electronic leakage detector, there are sounds quite similar to the leakage sound (pseudo leakage sounds). For this reason, well skilled technique is required to discern leakage sounds.

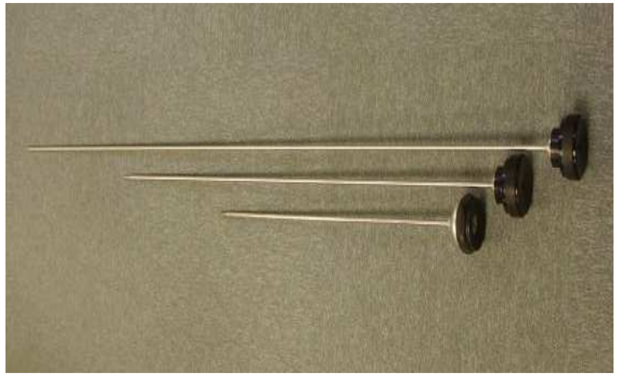


Fig.21 Leakage sound detection bar

Fig.22 Electronic leakage detector

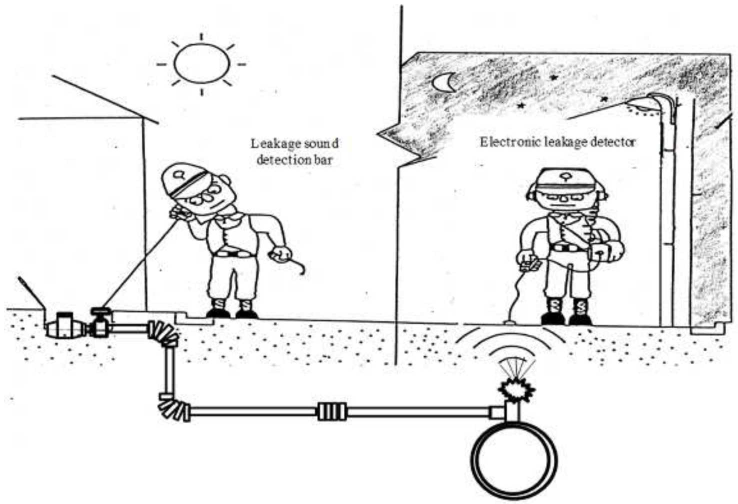


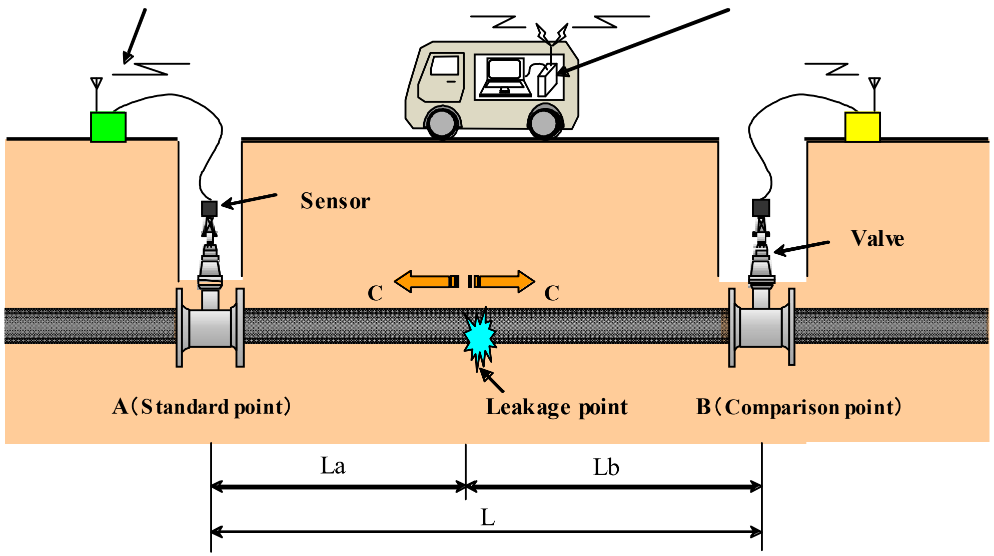
Fig.23 Acoustic leakage sound detection method

(3) Correlative leakage detection method

Correlative leakage detection method is searching point of leakage by correlative leakage detection equipment (that include correlative leakage detector, sensor, amplifier, wireless transmitter, etc.). This detection method has a benefit that enables investigation regardless of noise of cities and depth of pipes buried, because it directly detects the noise of leakage from the pipes.

Firstly we place sensors at two points (i.e. gate valve and fire hydrant) span water leakage might be occurred, then obtain the leakage noise propagation time difference from both sensors with correlative leakage detector. The position of leakage is calculated by the time lag, distance between sensors, and velocity of leaking sound transmitting through the pipe.

The correlative leakage detector equipment was jointly developed by Tokyo Waterworks and private company.



La = (L – Tm・C) / 2　　Tm : Leakage noise propagation time difference
C : Noise velocity on the pipe
L : Distance between A and B

Fig.24 Theory of the correlative leakage detection method

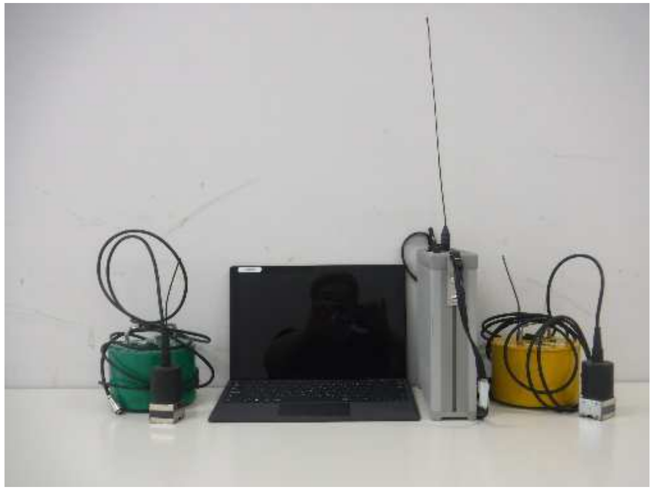


Fig.25 Correlative leakage detector

(4) Time integral type leakage detector

Time integral type leakage detector is the equipment that identifies the leakage by utilizing the feature that the leakage noise has the continuity.

This device measures the noise to be transmitted for a certain period of time (1 second up to 5 seconds) by attaching the sensor to the exposure points of service pipes within individual meter box.

It has excellent characteristics such as being largely unaffected by intermittent sound of water use or traffic noise transmitted through the ground, and not requiring skill to operate.

The time integral type leakage detector was jointly developed by Tokyo Waterworks and private company.

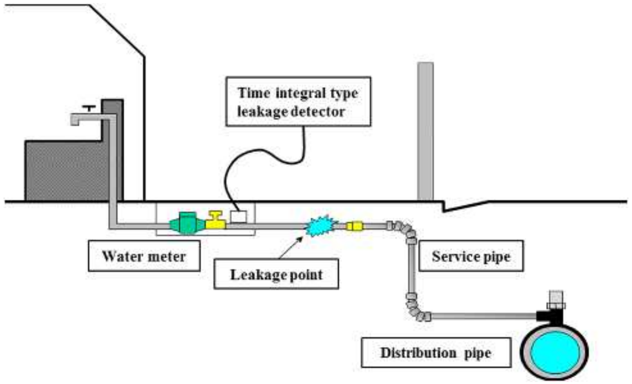


Fig.26 Time integral type leakage detector

(5) Transmission-type leakage detector

The transmission-type leakage detector is the equipment used to detect leakage in a pipe. Chemically inert helium gas mixed with water or air is injected into the pipe and the detector catch the helium gas leaked from the pipe and seeped through the ground.

This type of method can detect very small amount of leakage or leakage in main pipes such as main distribution pipes buried deep underground since it is not based on the leakage sound as it is necessary with the acoustic leakage sound detection method or the correlative leakage detection method.

The equipment used for the transmission-type leakage detector was jointly developed by Tokyo Waterworks and private company.

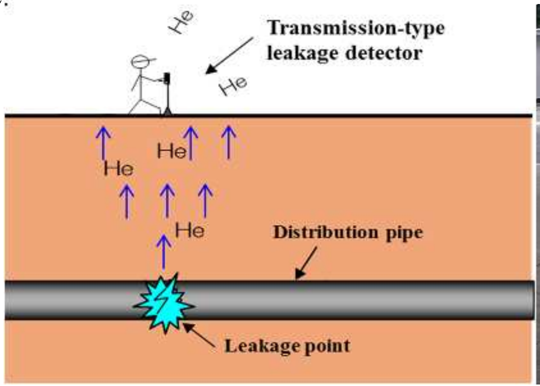


Fig.27 Transmission-type leakage detector

(6) Multipoint correlation type leakage detector

The multipoint correlation type leakage detector is a device that detects leaks by installing loggers at multiple locations in the accessory equipment of water distribution pipes (water control valves, fire hydrants, etc.) and having the loggers detect and analyze the sound of leaks transmitted through the water pipe bodies.

This device can determine the presence or absence of water leakage even in pipelines that are buried in deep locations or under tracks, where it is difficult to use the sound audition method, and can survey a wide area at a time. It also has features such as being less susceptible to ambient noise and not requiring specific skills for the work.

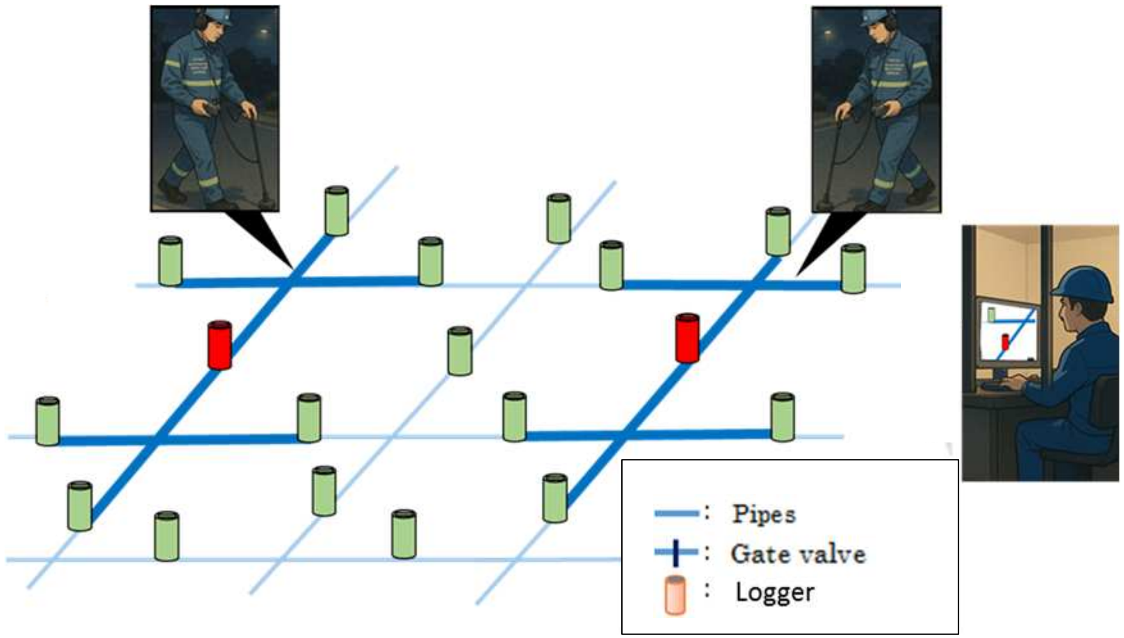


Fig.28 Multipoint correlation type leakage detector

※Images were created using AI generation technology

(7) Other methods

Leakage investigation requires not only the technologies to identify the leakage but also those to detect the position of laid pipes or to test water quality to determine whether leaking water is tap water or not.

Metal pipe detector and Water hammer Generator are used to detect the pipe location.

To identify water from tap, we use easy method such as water temperature gauge, residual chlorine analyzer, pH meter, and conductivity detector, or precise method determining inclusion of trihalomethane.

Fig.29 Metal pipe detector

Fig.30 Water hammer Generator

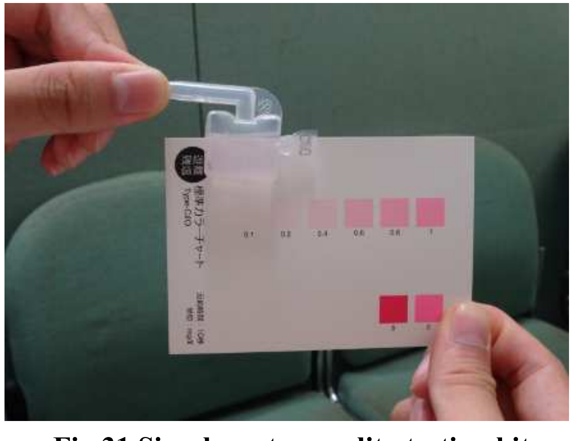
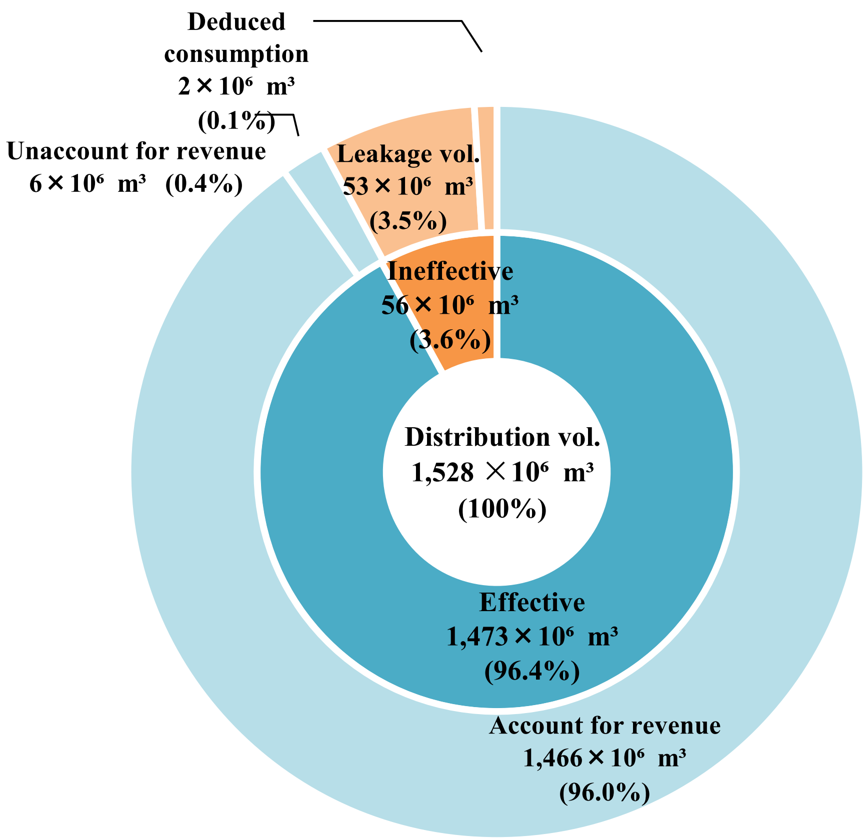


Fig.31 Simple water quality testing kit (residual chlorine meter)

Fig.32 Electric Conductivity Meter

5 References

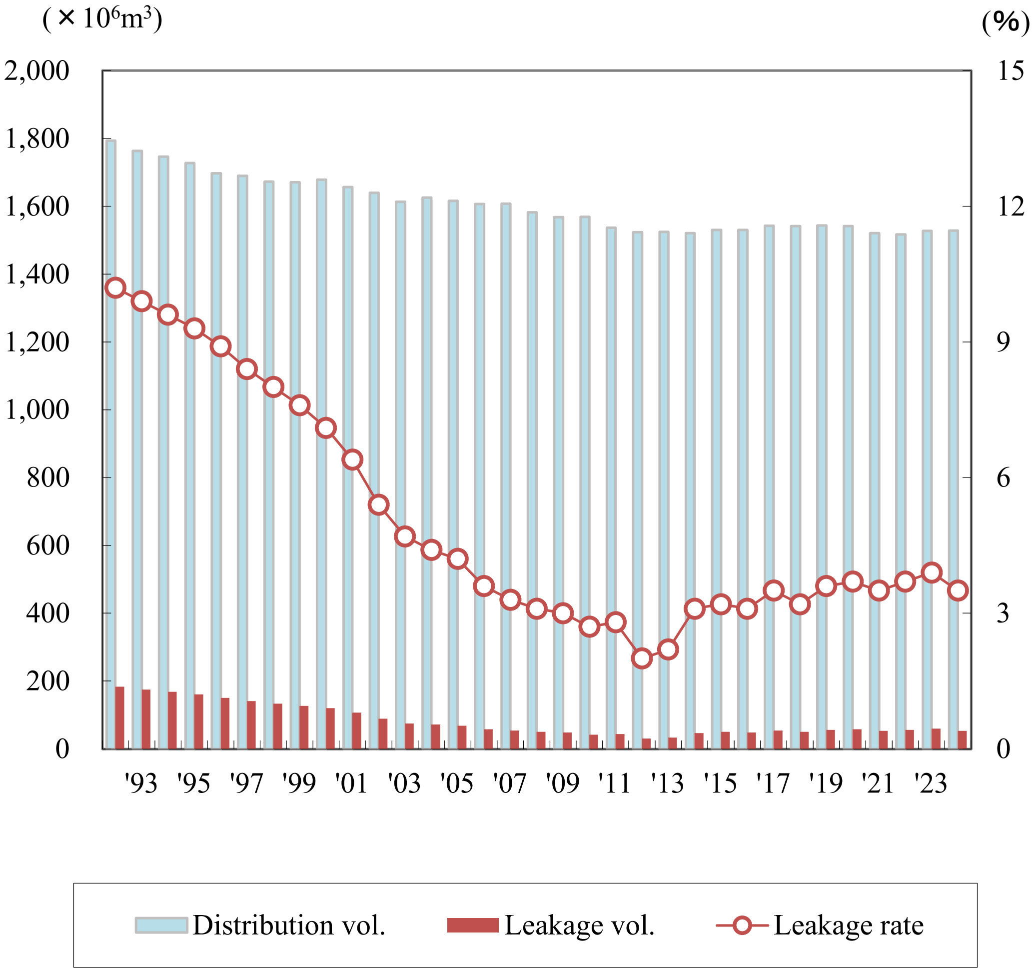
Reference-1 Distribution volume analysis in FY 2024



	Water Volume (m^3/year)	Component Rate (%)
Distribution total	1,528,132,500	100.0
Effective	1,472,529,195	96.4
Account for revenue	1,466,118,287	96.0
Unaccount for revenue	6,410,908	0.4
Ineffective	55,603,305	3.6
Leakage	53,461,099	3.5
Deduced consumption by settlement	2,142,206	0.1

※Totals do not exactly match due to rounding fractional adjustments

Reference-2 Trends in total distribution volume, leakage volume and rate from FY 1992 to FY 2024



		'92	'93	'94	'95	'96	'97	'98	'99	'00	'01
Distribution vol.	10^6m^3	1,793	1,763	1,746	1,727	1,697	1,689	1,672	1,671	1,678	1,656
Leakage vol.	10^6m^3	183	175	168	161	150	141	133	127	120	107
Leakage rate	%	10.2	9.9	9.6	9.3	8.9	8.4	8.0	7.6	7.1	6.4

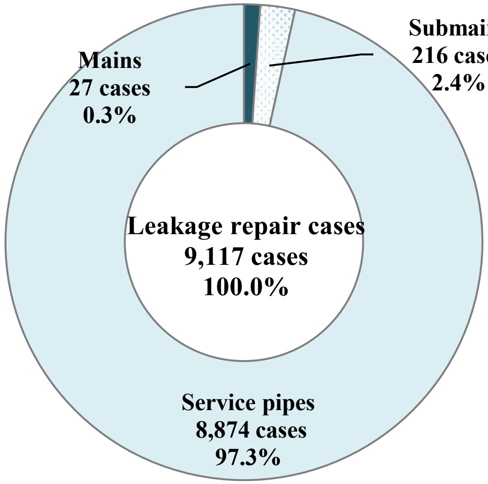
		02	'03	'04	'05	'06	'07	'08	'09	'10	'11
Distribution vol.	10^6m^3	1,639	1,613	1,625	1,616	1,606	1,607	1,582	1,568	1,569	1,537
Leakage vol.	10^6m^3	89	75	72	68	58	54	50	48	42	44
Leakage rate	%	5.4	4.7	4.4	4.2	3.6	3.3	3.1	3.0	2.7	2.8

		'12	'13	'14	'15	'16	'17	'18	'19	'20	'21
Distribution vol.	10^6m^3	1,523	1,523	1,521	1,530	1,530	1,542	1,541	1,543	1,541	1,521
Leakage vol.	10^6m^3	31	33	47	50	48	54	50	56	58	53
Leakage rate	%	2.0	2.2	3.1	3.2	3.1	3.5	3.2	3.6	3.7	3.5

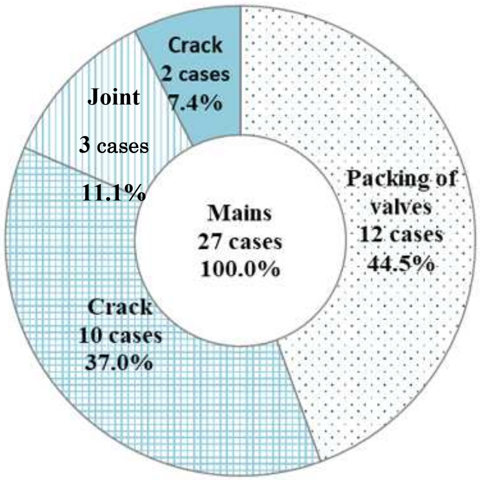
		'22	'23	24
Distribution vol.	10^6m^3	1,517	1,527	1,528
Leakage vol.	10^6m^3	56	60	53
Leakage rate	%	3.7	3.9	3.5

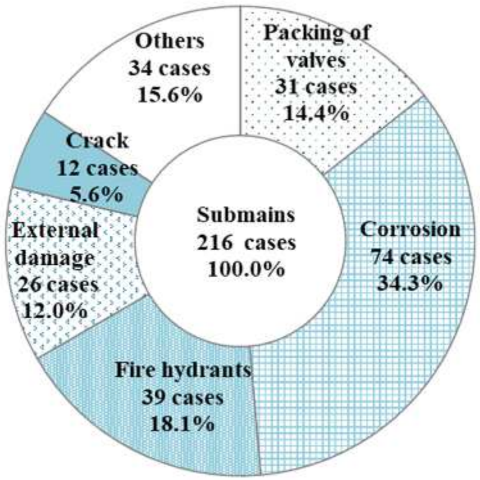
Reference-3 Specifications of leakage cases in FY 2024

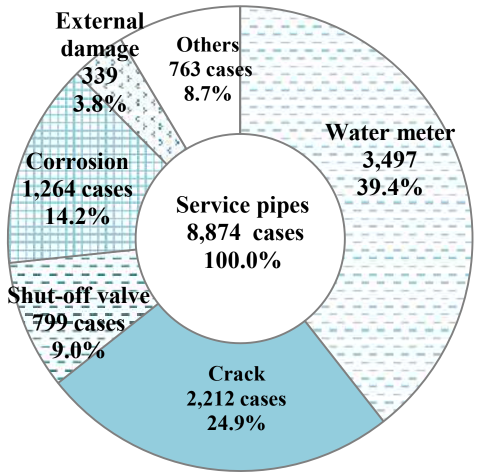
1 By Uses



2 By Causes

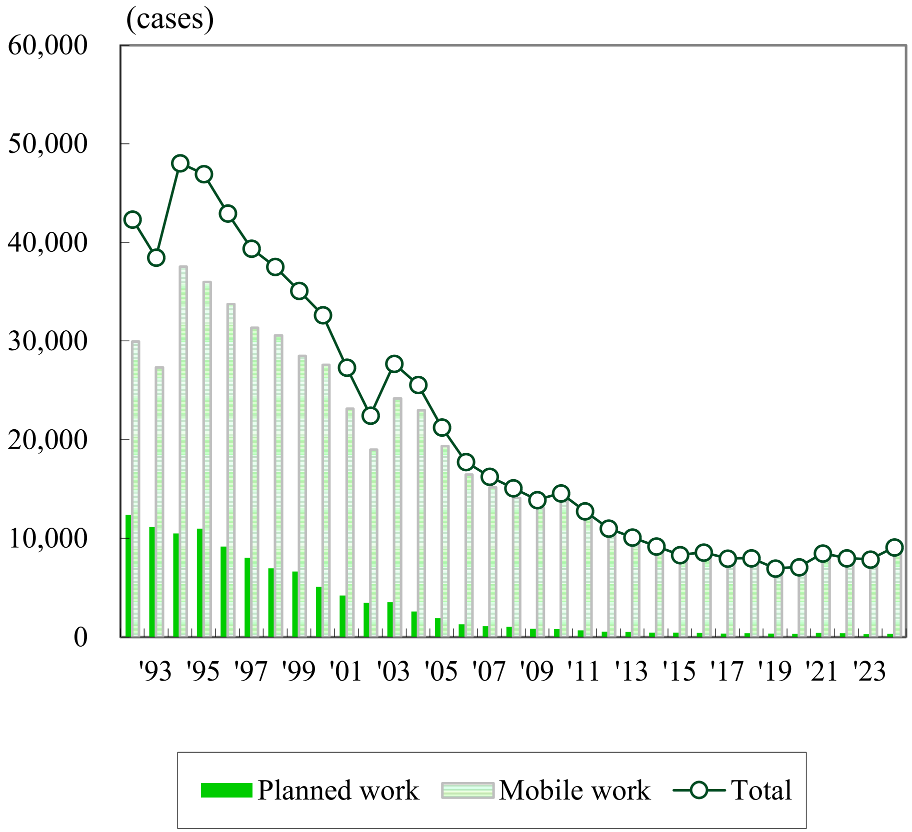






※Leakage from water pipe between branch and meter that service pipes.

Reference-4 Trends in number of each kind of repair works from FY 1992 to FY 2024



		'92	'93	'94	'95	'96	'97	'98	'99	'00	'01
Planned work	cases	12,383	11,142	10,505	10,979	9,177	8,028	6,964	6,627	5,073	4,199
Mobile work	cases	29,960	27,337	37,542	35,965	33,757	31,345	30,575	28,476	27,569	23,135
Total	cases	42,343	38,479	48,047	46,944	42,934	39,373	37,539	35,103	32,642	27,334

		'02	'03	'04	'05	'06	'07	'08	'09	'10	'11
Planned work	cases	3,450	3,516	2,592	1,908	1,287	1,097	1,026	848	801	684
Mobile work	cases	18,996	24,186	22,987	19,361	16,460	15,173	14,083	13,046	13,777	12,090
Total	cases	22,446	27,702	25,579	21,269	17,747	16,270	15,109	13,894	14,578	12,774

		'12	'13	'14	'15	16	'17	'18	'19	'20	'21
Planned work	cases	542	503	454	434	403	357	383	361	306	402
Mobile work	cases	10,476	9,597	8,752	7,881	8,168	7,620	7,623	6,618	6,790	8,097
Total	cases	11,018	10,100	9,206	8,315	8,571	7,977	8,006	6,979	7,096	8,499

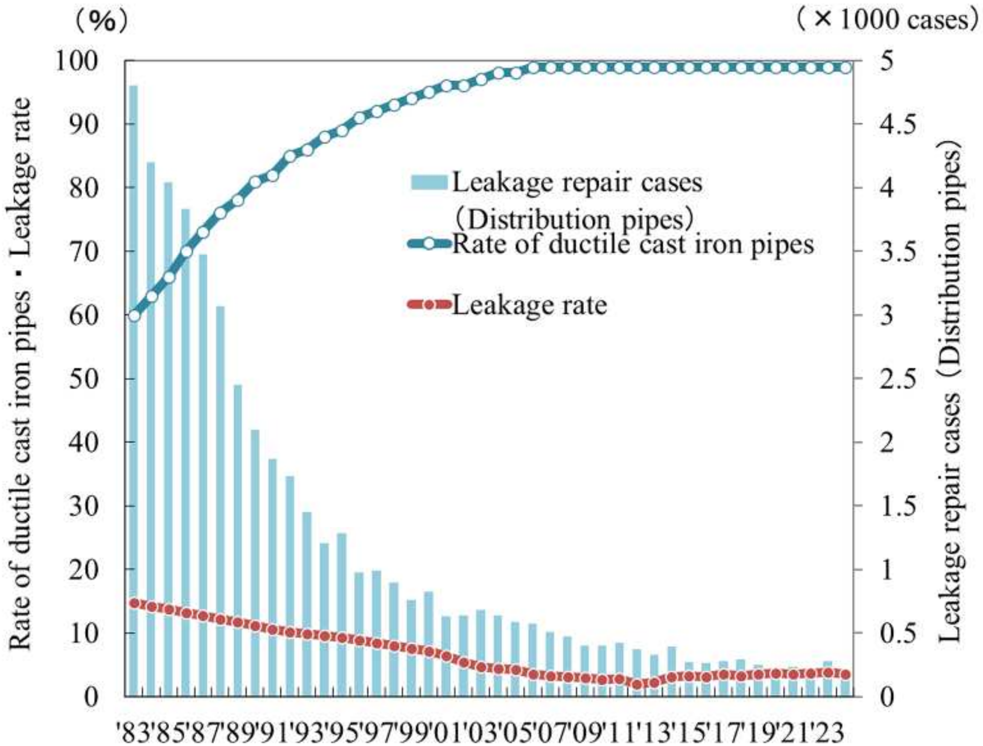
		22	23	24
Planned work	cases	386	273	315
Mobile work	cases	7,628	7,612	8,802
Total	cases	8,014	7,885	9,117

※Since FY2021, the number of water leakage repairs in the Tama area

※1 We enlarged the repairing area range from “1m from residential border” to “water meter” in FY1994

※2 The reason of this rapid change in FY2003 was adding another topic

Reference-5　Trends in rate of ductile cast iron pipes in distribution pipes, leakage repair cases(distribution pipes), leakage rate from FY 1983 to FY 2024



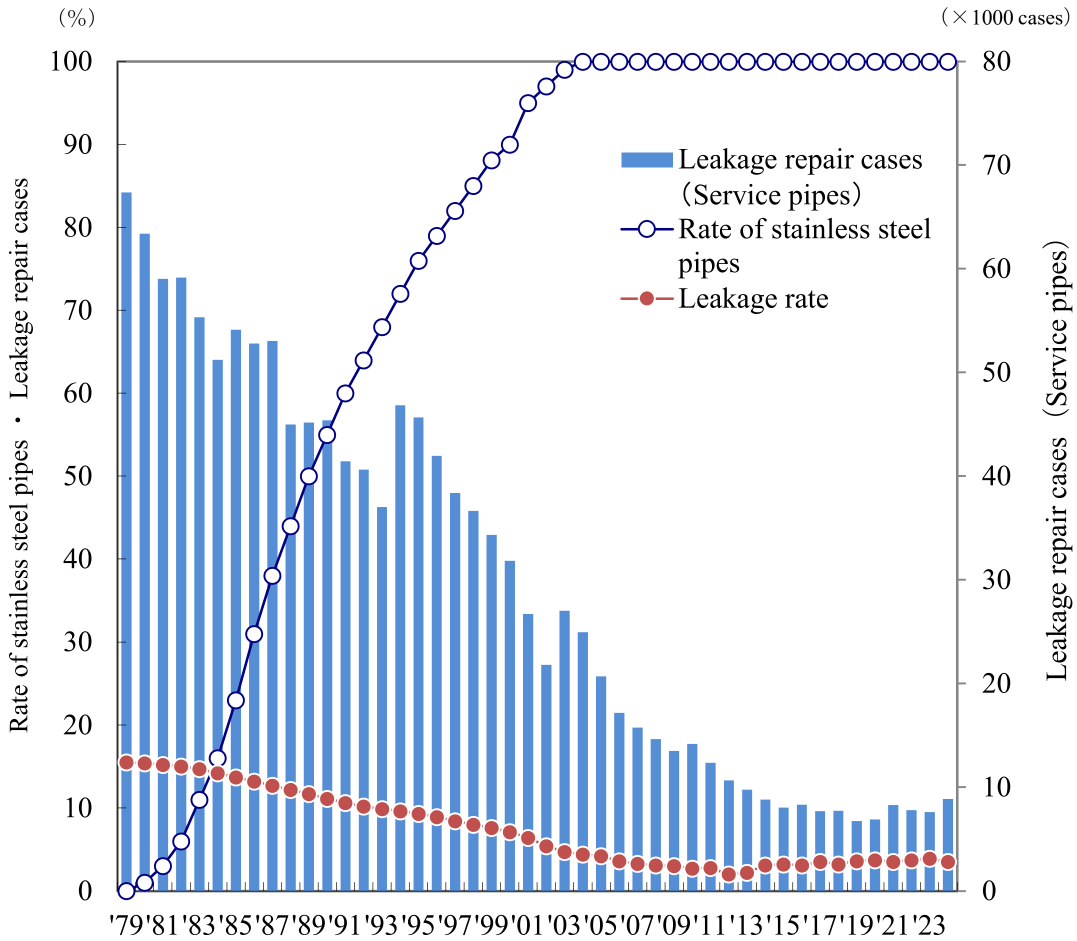
※　Rate of ductile cast iron pipes：

(Until 2019) The proportion of ductile cast iron pipes to the extension of iron pipes in distribution pipes

(From 2020) The proportion of ductile cast iron pipes to the extension of cast iron pipes, including grey and ductile cast iron pipes

		'83	'84	'85	'86	'87	'88	'89	'90	'91	'92
Rate of ductile cast iron pipes	%	60	63	66	70	73	76	78	81	82	85
Leakage repair cases (Distribution pipes)		4,800	4,200	4,040	3,834	3,471	3,072	2,447	2,097	1,870	1,730
Leakage rate	%	14.7	14.2	13.7	13.2	12.7	12.2	11.7	11.1	10.6	10.2
		'93	'94	'95	'96	'97	'98	'99	'00	'01	'02
Rate of ductile cast iron pipes	%	86	88	89	91	92	93	94	95	96	96
Leakage repair cases (Distribution pipes)		1,449	1,205	1,288	974	987	898	762	824	627	641
Leakage rate	%	9.9	9.6	9.3	8.9	8.4	8.0	7.6	7.1	6.4	5.4
		'03	'04	'05	'06	'07	'08	'09	'10	'11	'12
Rate of ductile cast iron pipes	%	97	98	98	99	99	99	99	99	99	99
Leakage repair cases		679	635	587	570	511	474	399	403	424	372
Leakage rate	%	4.7	4.4	4.2	3.6	3.3	3.1	3.0	2.7	2.8	2.0
		'13	'14	'15	'16	'17	'18	'19	'20	'21	'22
Rate of ductile cast iron pipes	%	99	99	99	99	99	99	99	99	99	99
Leakage repair cases		326	395	270	264	275	291	252	212	235	221
Leakage rate	%	2.2	3.1	3.2	3.1	3.5	3.2	3.6	3.7	3.5	3.7
		23	24								
Rate of ductile cast iron pipes	%	99	99								
Leakage repair cases		278	159								
Leakage rate	%	3.9	3.5								

Reference-6 Trends in rate of stainless steel pipes in service pipes, leakage repair cases(service pipes), leakage rate from FY 1979 to FY 2024



		S54 ('79)	S55 ('80)	S56 ('81)	S57 ('82)	S58 ('83)	S59 ('84)	S60 ('85)	S61 ('86)	S62 ('87)	S63 ('88)
給水管 ステンレス化率	%	0	1	3	6	11	16	23	31	38	44
給水管 漏水修理件数	件	67,361	63,367	59,041	59,154	55,310	51,206	54,119	52,801	53,022	44,972
漏水率	%	15.5	15.4	15.2	15.0	14.7	14.2	13.7	13.2	12.7	12.2

		H元 ('89)	H2 ('90)	H3 ('91)	H4 ('92)	H5 ('93)	H6 ('94)	H7 ('95)	H8 ('96)	H9 ('97)	H10 ('98)
給水管 ステンレス化率	%	50	55	60	64	68	72	76	79	82	85
給水管 漏水修理件数	件	45,171	45,382	41,418	40,613	37,030	46,842	45,656	41,960	38,386	36,641
漏水率	%	11.7	11.1	10.6	10.2	9.9	9.6	9.3	8.9	8.4	8.0

		H11 ('99)	H12 ('00)	H13 ('01)	H14 ('02)	H15 ('03)	H16 ('04)	H17 ('05)	H18 ('06)	H19 ('07)	H20 ('08)
給水管 ステンレス化率	%	88	90	95	97	99	100	100	100	100	100
給水管 漏水修理件数	件	34,341	31,818	26,707	21,805	27,023	24,944	20,682	17,177	15,759	14,635
漏水率	%	7.6	7.1	6.4	5.4	4.7	4.4	4.2	3.6	3.3	3.1

		H21 ('09)	H22 ('10)	H23 ('11)	H24 ('12)	H25 ('13)	H26 ('14)	H27 ('15)	H28 ('16)	H29 ('17)	H30 ('18)
給水管 ステンレス化率	%	100	100	100	100	100	100	100	100	100	100
給水管 漏水修理件数	件	13,495	14,175	12,350	10,646	9,774	8,811	8,045	8,307	7,702	7,715
漏水率	%	3.0	2.7	2.8	2.0	2.2	3.1	3.2	3.1	3.5	3.2

		R元 ('19)	R2 ('20)	R3 ('21)	R4 ('22)	R5 ('23)	R6 ('24)
給水管 ステンレス化率	%	100	100	100	100	100	100
給水管 漏水修理件数	件	6,727	6,884	8,264	7,793	7,607	8,874
漏水率	%	3.6	3.7	3.5	3.7	3.9	3.5

※Since FY2021, the number of water leakage repairs in the Tama area has been

Reference 7　Glossary of Terms used in "Prevention of Leakage in Tokyo"

Block

A range in which submain distribution pipes buried in a grid shape is separated by a certain length.

Gate Valve

A valve provided in a pipeline to stop flowing water in the pipe (water outage) and adjustment of water pressure in the pipe (adjustment of flow rate) at a branching part of a distribution pipe or a section crossing a river. It is installed at an interval of about 500 m to 1,000 m in a main, and an interval of about 150 m to 200 m in a submain.

Fire Hydrant

A tap installed in a submain distribution pipe as fire extinguishing water when a fire occurs. It is also used for drainage inside the pipeline.

Mains

Water pipes consisting of the mains that were installed to distribute water from service and booster-pump stations to water supply areas.

Submains

Water pipes that branch off from distribution mains and directly connect to service pipes.

Drain

A tap to drain foreign matters (rust, etc.) inside the pipe after the waterworks construction. It has the same function as fire hydrant.

Block Water Meter

Attached equipment of a submain distribution pipe combined with a single mouth fire hydrant and a gate valve. It is used for minimum night flow measurement during planning work.

Cast Iron Pipe

A cast iron pipe using gray cast iron (tensile strength 12.5N/㎟). It was used until around 1933.

High-grade Cast Iron Pipe

A cast iron pipe with improved tensile strength by improving manufacturing process of gray cast iron. (tensile strength 25N/mm^2) It is used from around 1933.

Ductile Cast Iron Pipe

A cast iron pipe with enhanced material strength by adding magnesium to the conventional cast iron pipe and making the graphite in its structure in a nodular shape (tensile strength 45N /mm^2). It is used from around 1967.

Earthquake-resistant joints

Structure with detachment prevention function in joint part.