

# Prevention of Leakage in Tokyo

2021



Bureau of Waterworks, Tokyo Metropolitan Government

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# 1 Outline of leakage prevention

## (1) Present situation

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 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”.

In FY1992, the amount of leakage was  $180 \times 10^6 \text{ m}^3$  per year, and the leakage rate was 10.2%. In FY 2020 leakage decreased to  $58 \times 10^6 \text{ m}^3$  and leakage rate accounted for 3.7%. (The annual distribution amount of  $1,541 \times 10^6 \text{ m}^3$  (Fig.1, Reference-1 and 2).

Most leakages occur from 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 2020 recorded around 7,096 and around 97% of which were from service pipes, and the remained around 3% were from distribution pipes (Reference-3).

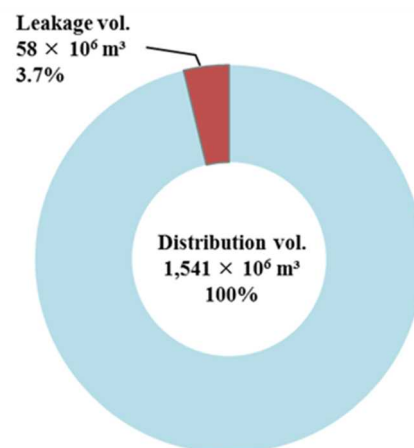
Leakage is classified into two types by its form; “surface leakage” that flows out to surface of the ground and “underground leakage” that leaks out underground without any appearing on the surface.

Basically, leakages occurring above the ground are dealt with mobile work - repair within the day - and those occurring underground are dealt with planned work. The Figure 2 shows the ratio of mobile work and planned work.

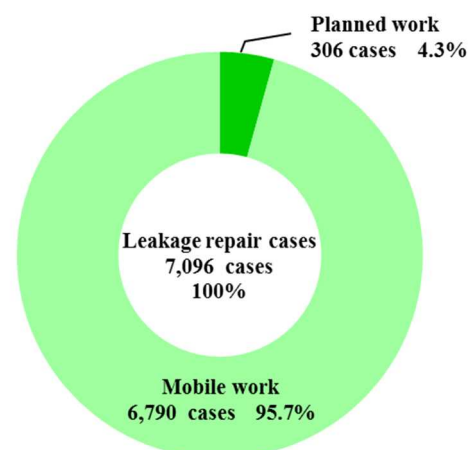
There were 6,790 repairs by mobile work and 306 by planned one in the FY 2020(Reference -4).

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.

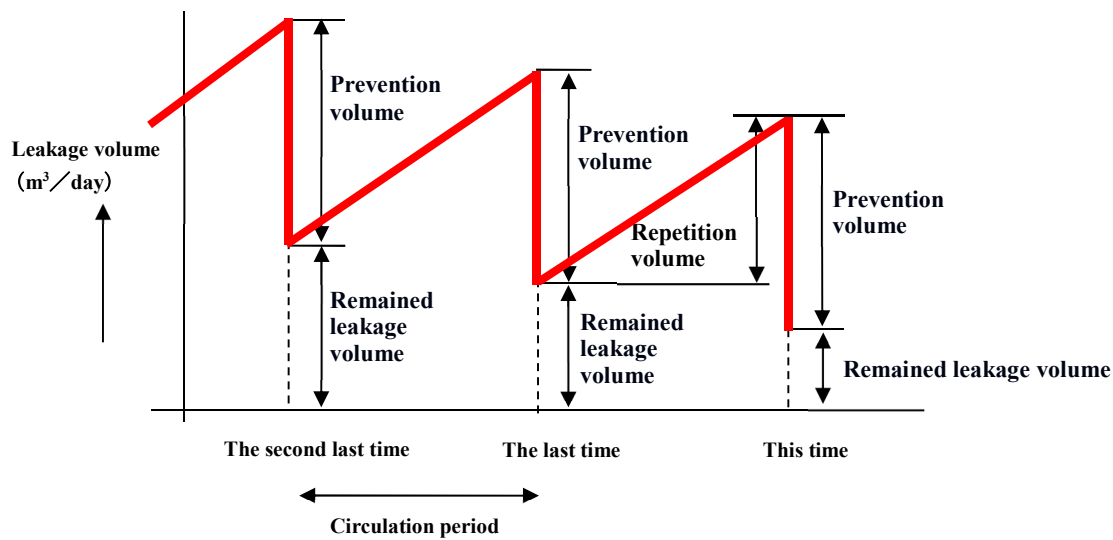
Although leakages are repaired immediately when they are found, the new leakage increases gradually in accordance with time. This is referred to as the “repetition phenomenon” of leakage (Fig. 3). As it is important to develop leakage prevention measures by taking this repetition phenomenon into consideration. We try to collect various data on leakage as much as possible in order to get an understanding of the repetition phenomenon.



**Fig.1 Annual distribution volume and leakage volume in FY 2020**



**Fig.2 Comparison between Mobile Work and Planned work in FY 2020**



**Fig.3 Repetition of leakage**

**(2) Necessity of leakage prevention**

The amount of water resource possession is currently about  $6.8 \times 10^6 \text{ m}^3/\text{day}$ . However, it includes  $0.82 \times 10^6 \text{ m}^3/\text{day}$  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. Therefore, it is necessary to continue promoting effective use of water and leakage prevention measures.

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 about 27,000 kilometers long in FY2020, which is equivalent to two-thirds the length of the earth’s circumference.

Water pipes embedded in underground are constantly subject to a danger of leakage, and when leakage occurs, these pipes lead risks of secondary disasters such as poor water flow, sagging road, and inundation and so on.

Measures against leakage enable us not only prevent from secondary disaster but also saving water that is equivalent to be obtained by developing a new water resource such as dam. Tokyo Waterworks have taken measures against leakage.



**Fig.4-1** Scene of leakage

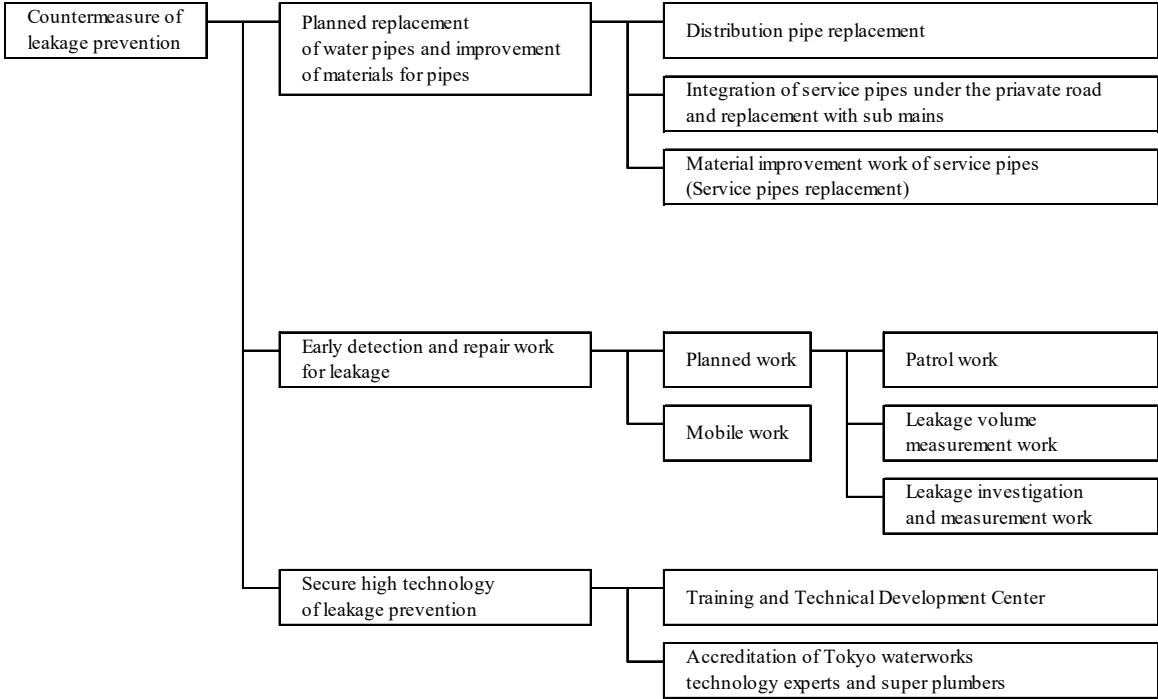


**Fig.4-2** Corrosion leakage of iron pipes

## 2 Leakage prevention measures

### (1) System of leakage prevention measures

The leakage prevention measures that we adopt in Tokyo waterworks are classified as follows.



**Fig.5 System of leakage prevention measures**

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

Planned replacement and improvement of the quality of pipe materials can reduce the remaining leakage amount as well as forestall leakage and prevent “repetition phenomenon” of leakage. Thus, these projects are important and effective to implement leakage prevention measures.

Followings are the major measures.



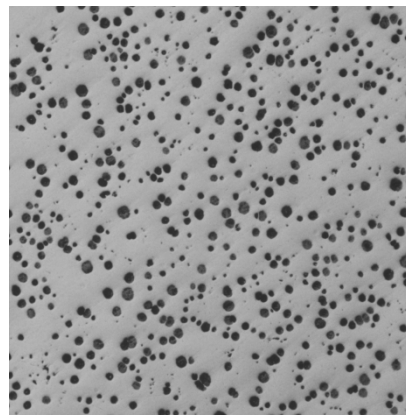
**(A) Distribution pipe replacement**

As part of measures against earthquake, we have been replacing the following distribution pipes with earthquake-resistant-joint pipes.

- a The water supply routes for important facilities such as the capital central agencies, emergency medical institutions, shelters and main stations.
- b Pipes laid in routes that Tokyo Metropolitan Government designed as emergency transport road.
- c Early ductile iron pipes (Pipes used for pipelines consisting of a mixture of straight pipes made of ductile cast iron and special fittings made of high-grade cast iron without inner lining)
- d Pipes without earthquake-resistant joints laid in areas where severe water suspension is anticipated at the time of disaster.

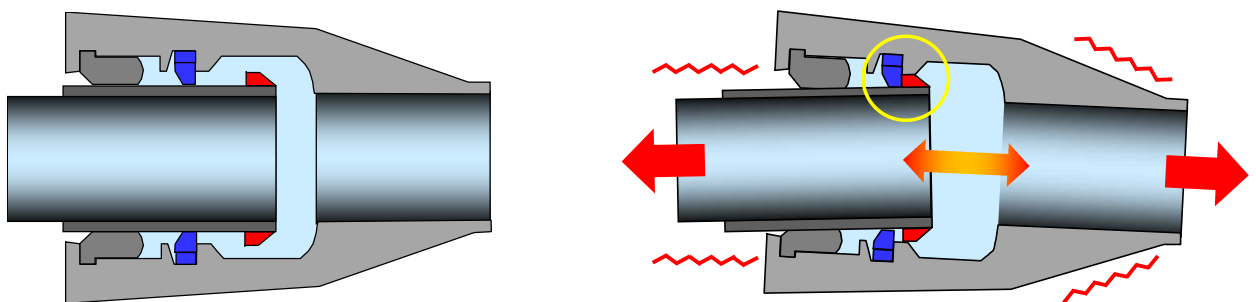


High-grade cast iron



Ductile cast iron

**Fig.6 Micrograph of cast iron**



**Fig.7 Earthquake-resistant joints...**Structure that does not cause joint detachment during the earthquake

**(Left: Normal Condition, Right: Earthquake Condition)**



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

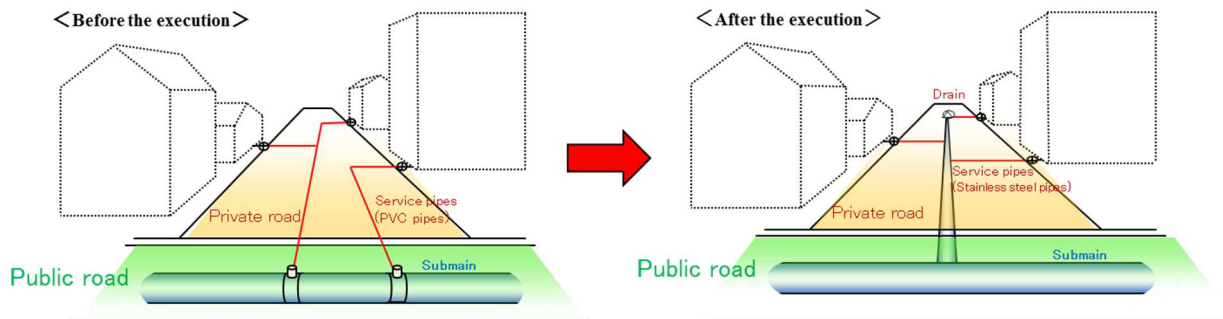
There are many leakages on private roads due to aging and corrosions from service pipes. In this regard, we have been making efforts to prevent leakages and improve earthquake resistance of service pipes under private roads through the consolidation of those service pipes and replacing the existing pipes to stainless-steel ones.

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

Following private roads are the target of this measure.

- 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.8 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 97% 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 submain distribution pipes 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 submain distribution pipes at every opportunity of construction work related to submain distribution pipes
- d Since FY 1985 : execution of replacement work of heavily corroded lead service pipes at the occasions of repairing leakages

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.

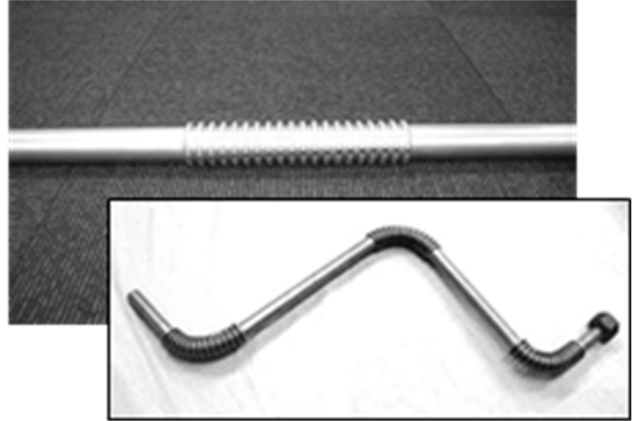
In 1995, we have entirely banned the use of lead pipes to promote use of stainless pipes. In 1998, we adopted corrugated stainless steel pipes that have excellent workability and earthquake resistance. And also we expanded the range of area that can be improved material to water meter, so far it can be used from branching part of service pipes from submain distribution pipe 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.

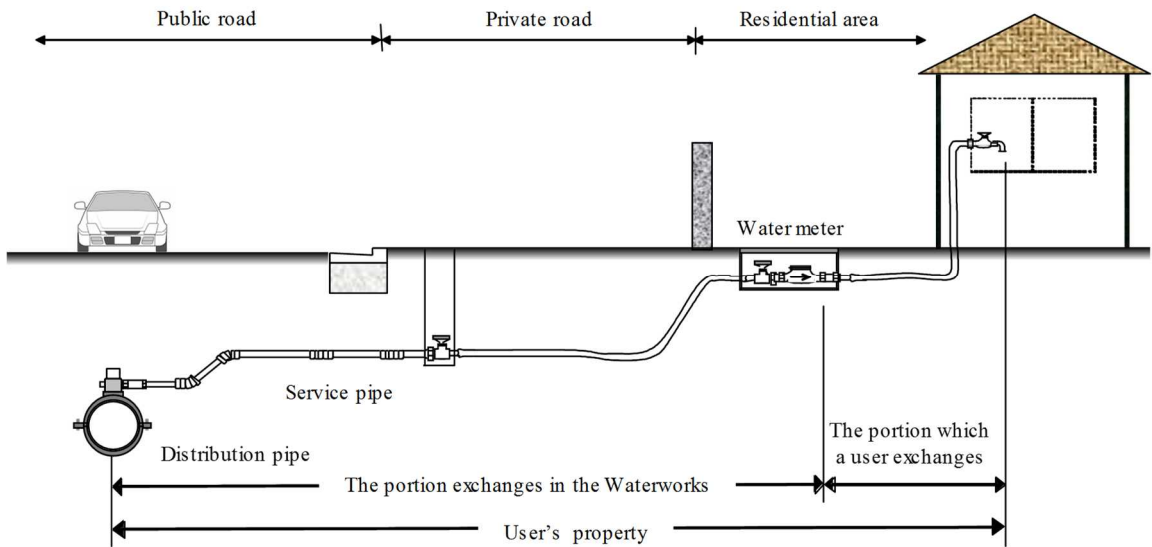
There are still a few lead pipes remaining until now under private roads and within residential land. We have checking and replacing the remaining lead pipes again in the course of the planned activities after 2007.



**Fig.9 Leakage from lead pipes**



**Fig10 Corrugated stainless steel**



**Fig.11 Material improvement of service pipe**

## **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.

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, submain pipes 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. Planned leakage survey is conducted mainly by staff members of Tokyo Waterworks and 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.16) 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.17) from the road surface etc.

To determine the blocks to patrol, we take previous work history, leakage occurrence in the previous year, and residual number of lead service pipes 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.21) replacing leakage sound detection bar on some blocks since FY2003.

## b Leakage volume measurement work

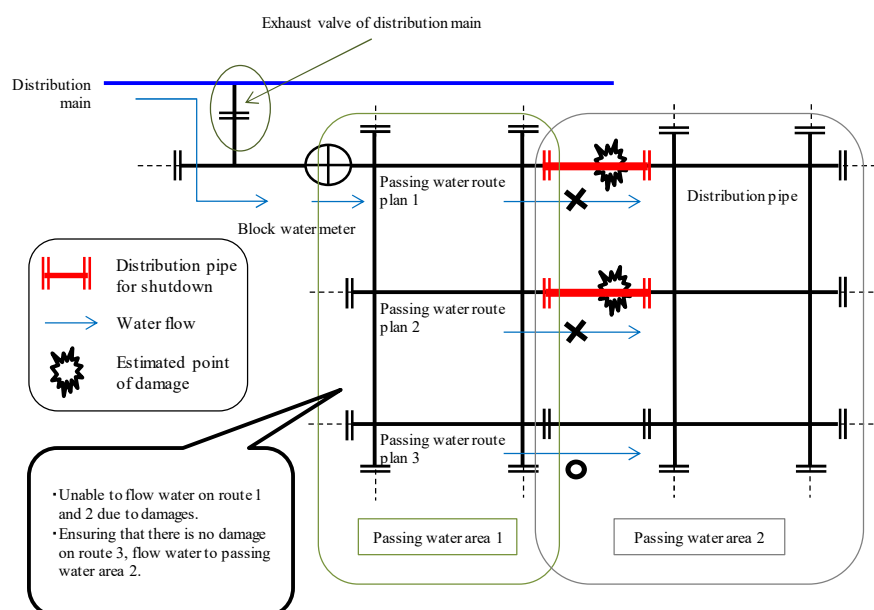
To estimate total leakage volume and understand the leakage trend in Tokyo, we conduct leakage volume measurement works. In order to identify the more accurate amount of leakage in an urban area, we need to measure the leakage volume during the night hours when almost no one uses water. (Refer to 3(1) Minimum night flow measurement method) As a result of the theoretical analysis based on the modeling of the water usage state and the result of the dynamic simulation taking the number of households and pipe network characteristics into consideration, since the number of taps that can be measured is limited to 300 to 400, we measure the minimum flow (leakage amount) at night by narrowing down the scope number of target taps within one block. By estimating leakage volume within a certain block, we are able to make total assumption of leakage volume within Tokyo. Together with leakage investigation and measurement work that has been put into practice since FY 2010, we will put such works to improve our leakage prevention plan.

For the leakage volume measurement work, we consign administrative organizations (Tokyo Water Co., Ltd.) since FY2005 for some blocks.

## c Leakage investigation and measurement work

To minimize water outage during the earthquake disaster and fast react on to recover the facilities, it is important to ensure the water flow from main pipes to submain pipes and it is essential to ensure the function of exhaust valves of main pipes. On that basis, it is necessary to avoid using quake-damaged pipelines (distribution submains) to secure operable water-supply routes as early as possible and then to expand areas to which water can be supplied.

This leakage investigation and measurement work is a practical series of works that conduct functional measurement of water valves required to secure water route after securing the safety of exhaust valve on distribution main, assuming the channel where leakage volume are high as damaged points, then recover/expand the service area sequentially. We conduct investigation on the whole water flow area based on the volume of leakage, and then operate repair works on leakage points one by one when found.



**Fig.12 Leakage investigation and measurement work**

## **(B) Mobile work**

Mobile work is a work for repairing an above-ground leakage found by report of a customer or 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), staff members of 4 management offices (Field management offices of Tokyo Waterworks), Tokyo Water Co., Ltd. and our contractors are on call 24 hours, in which we operate our services, are ready 24 hours to respond to leakage.

## **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) Efforts at Training and Technical 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.13 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) Other measures**

### **A 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.

So that, from the viewpoint of avoiding the risk of leakage and optimizing the water supply environment, if the customer agrees, we remove 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.

## **(3) 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

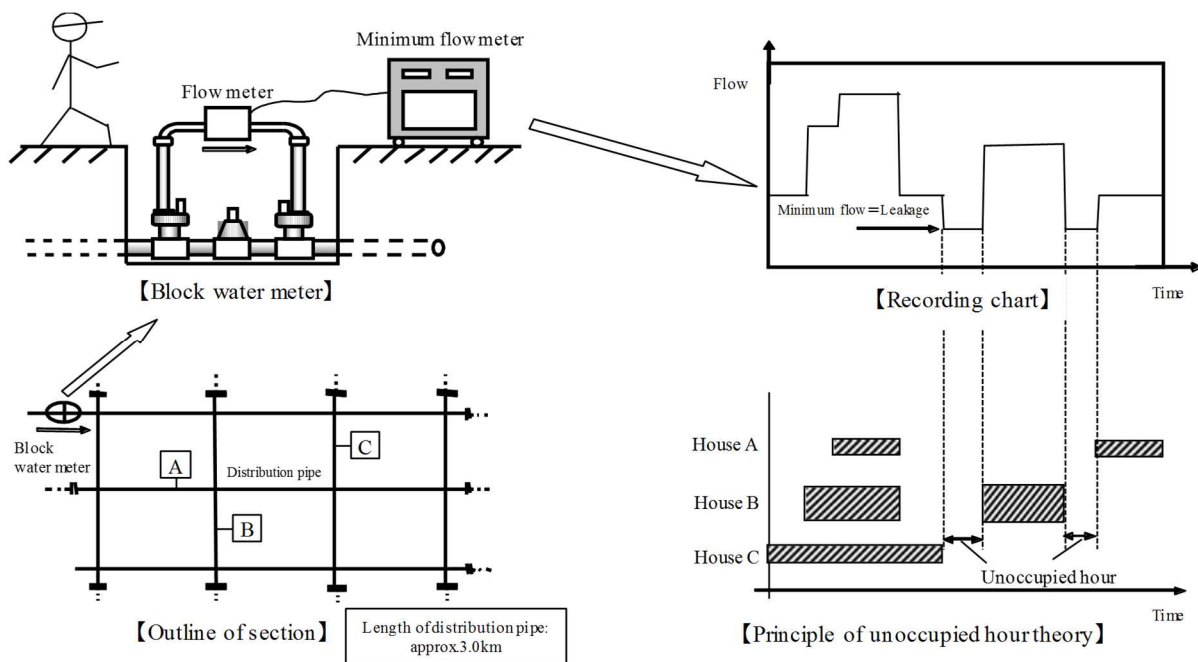
Currently we have mainly two types leakage investigations; “minimum night flow measurement method” is select pipelines necessary to be investigated based on maintenance status of pipelines and past history of leakage, and conduct leakage investigation. Other methods are to determine the leakage by the 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.14 Theory of minimum night flow measurement method**





**Fig.15 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.16 Leakage sound detection bar**



Detector  
(Pickup)

Fig.17 Electronic leakage detector

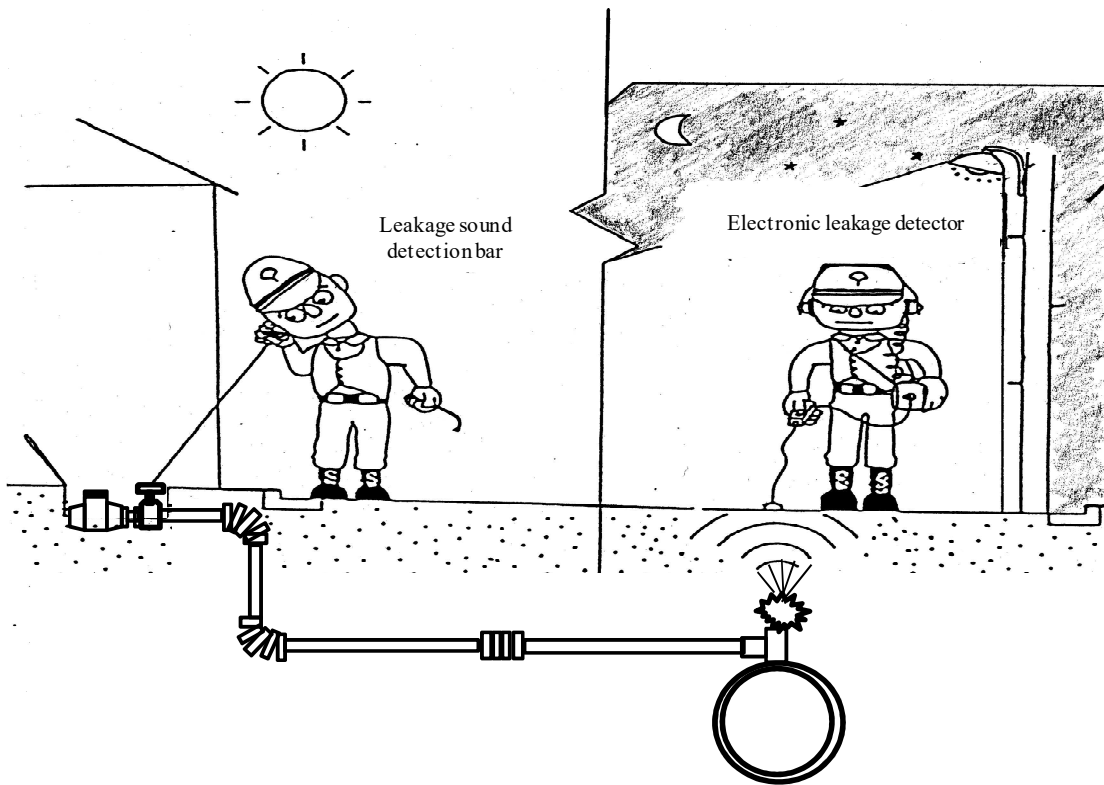


Fig.18 Acoustic leakage sound detection method

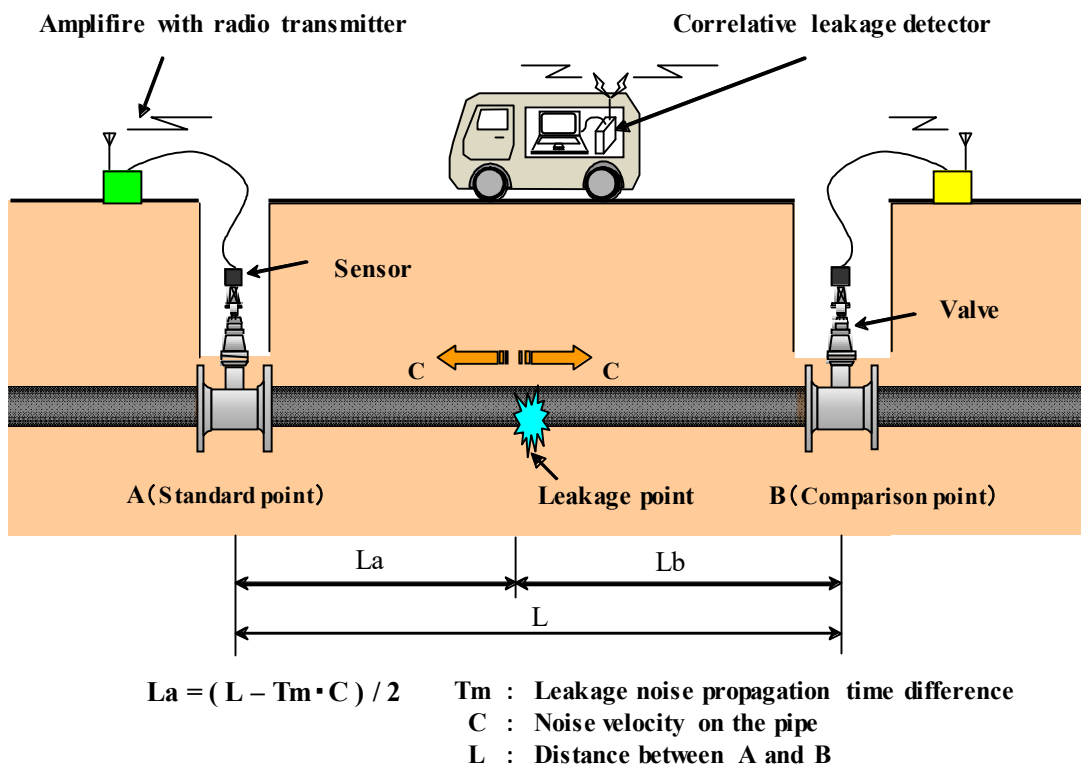
### (3) Correlative leakage detection method

Correlative leakage detection method is searching point of leakage by correlative leakage detection equipment (that include correlative leakage detector, sensor, amplifier, wireless transmitter, etc.).

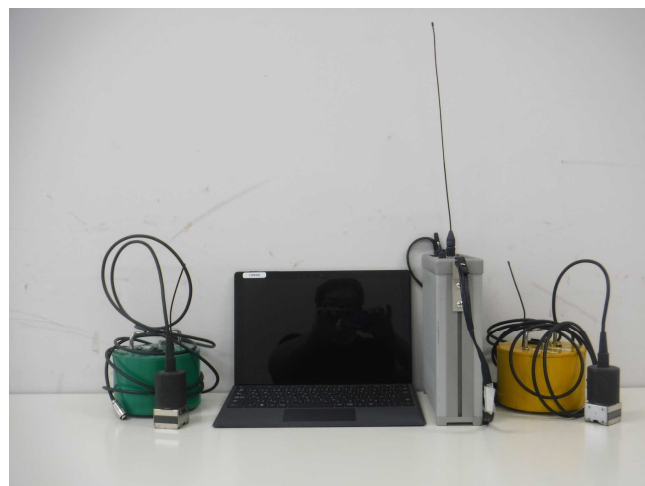
Firstly we place sensors at two points (i.e. gate valve and fire hydrant) span water leakage might be occurred, then obtain the leakage noise propagation time difference from both sensors with correlative leakage detector. The position of leakage is calculated by the time lag, distance between sensors,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

Correlative leakage 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.

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



**Fig.19 Theory of the correlative leakage detection method**



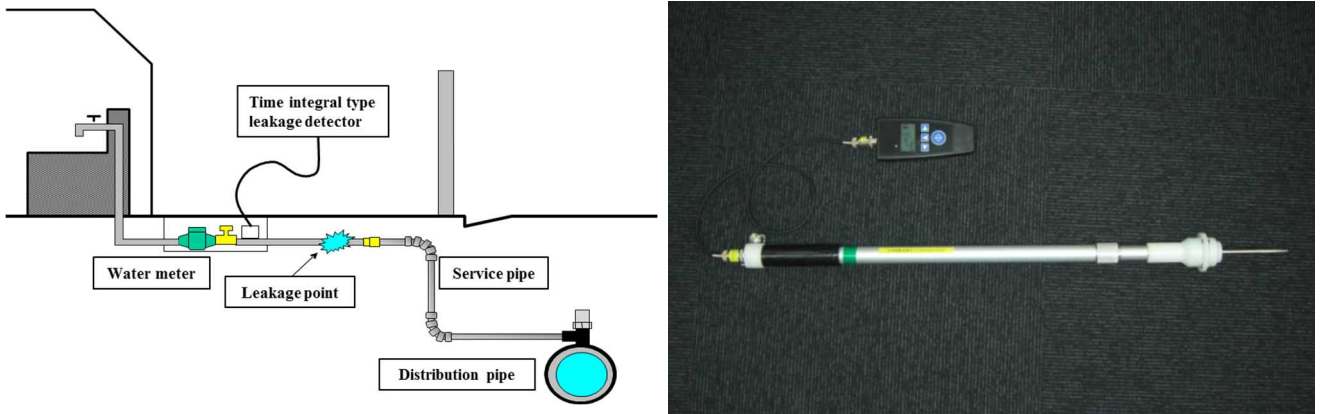
**Fig.20 Correlative leakage detector**

#### (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 usage sound of the waterworks 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.



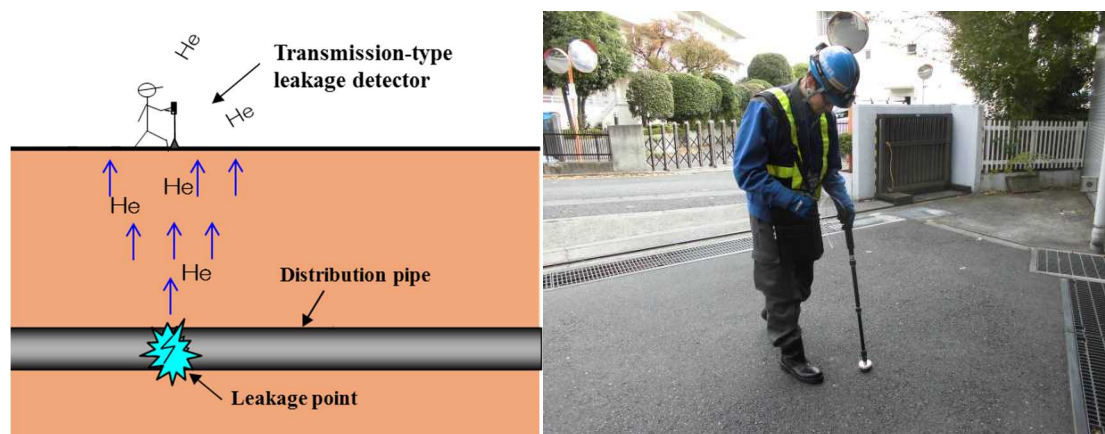
**Fig.21 Time integral type leakage detector**

#### (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.22 Transmission-type leakage detector**



## (6) 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.

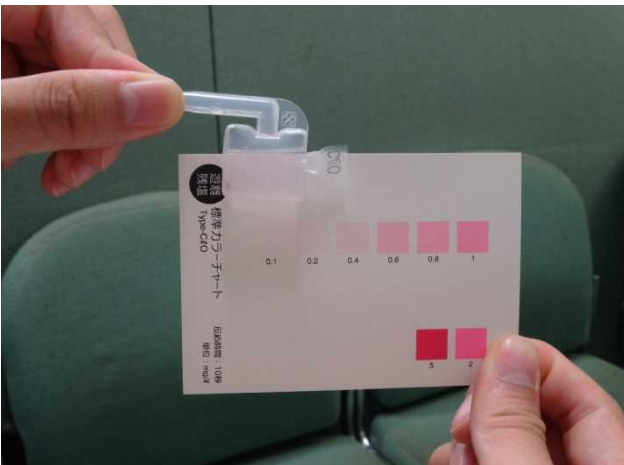
To identify water from tap, we use easy method such as water temperature gauge, residual chlorine analyzer, pH meter, and conductivity detector, or precise method determining inclusion of trihalomethane.



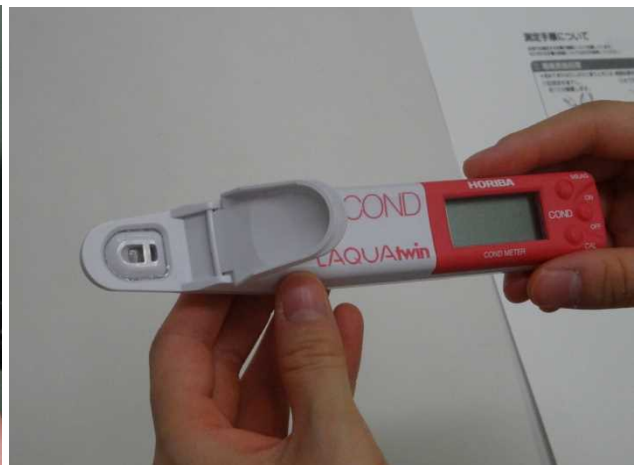
**Fig.23 Metal pipe detector**



**Fig.24 Water hammer Generator**



**Fig.25 Simple Pack (residual chlorine meter)**



**Fig.26 Electric Conductivity Meter**

#### 4 Problems and the future of leakage prevention

Water resources are becoming increasingly precious as there are concerns over streamflow reduction and increased risk of drought due to considerable snowfall reduction, early start of snowmelt season and increase in the number of dry days resulting from climate change and global warming. From the recent rainfall condition, Japan government state that stable water supply volume from dams in such as Tone river system is lower than originally planned. Moreover, there is anxious about severe drought than ever due to progress of global warming.

Leakage prevention measures are of paramount importance because they lead to the effective utilization of valuable water resources and to the avoidance of secondary disasters such as road cave-ins caused by leakage. Furthermore, the measures lead to the reduction of energy used and carbon-dioxide emissions in the process of supplying water - water intake, water purification, water transmission/ distribution -, hence contributing to the prevention of global warming.

As for these measures against leakage, 13 cities (including Tokyo, the host city, Seoul, Los Angeles and New York) agreed to make efforts to promote such measures and provide technical information at the C40 Tokyo Conference on Climate Change held in October 2008. So, the importance of those measures has now been recognized in the world.

In this respect, Tokyo Metropolitan Government's efforts received acclaim at the 2012 International Water Association (IWA) Project Innovation Awards (PIA) in that our leakage prevention measures were significantly conducive to enhance operational efficiency in energy saving as well as efficient use of valuable water resources. Consequently, we received East Asia Awards (July 2012) and Global Honor Awards (September 2012).

Amid growing expectations for Japan's technologies in order to tackle the global water problems, Tokyo Metropolitan Government has made a commitment, under the "Tokyo Waterworks Management Plan 2021" as adopted in March 2021, to cooperation in human resources development and business operations of domestic water suppliers by means of utilizing high-quality water engineering and operational know-how, in addition to our preceding efforts in international cooperation such as acceptance of oversea trainees and oversea dispatch of our staff.

The rate of leakage in Tokyo is 3.7% as of FY 2020, which indicates the outcome of the efforts that have been taken by the Bureau for leakage prevention. This rate in Tokyo stands at an exceptionally high level, even in comparison with those in other cities of the same scale.

We will continue to actively promote its technologies and know-how both at home and abroad, and pass them on to the next generation.

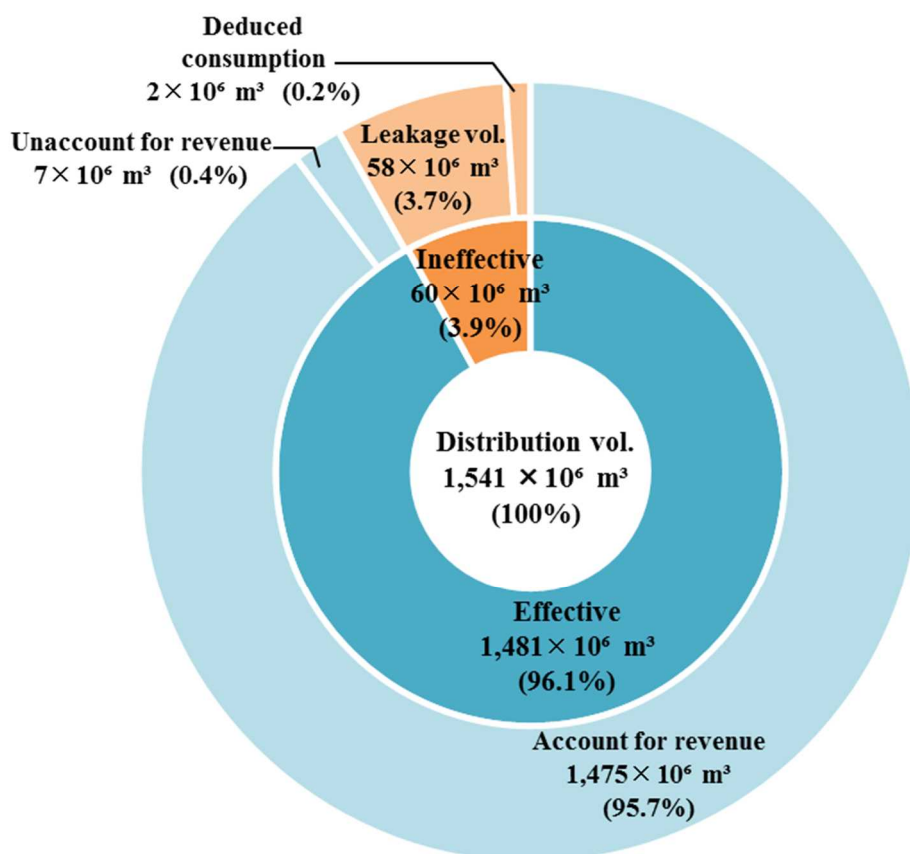
We will also keep the current low-leakage rate by utilizing all of our accumulated technologies.



## 5 Reference



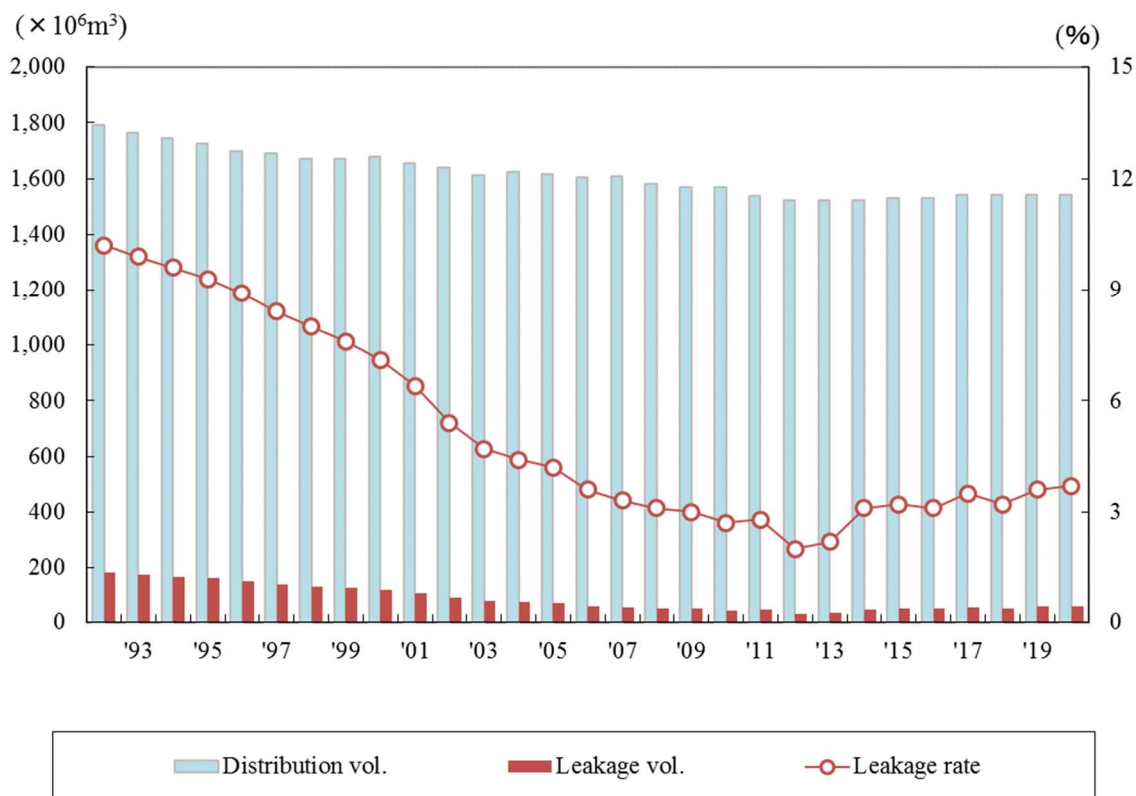
## Reference-1 Distribution volume analysis in FY 2020



	Water Volume (m <sup>3</sup> /year)	Component Rate (%)
Distribution total	1,540,872,300	100.0
Effective	1,481,128,006	96.1
Account for revenue	1,474,614,595	95.7
Charged	1,470,046,994	95.4
Supplied to Tama	4,531,200	0.3
Others	36,401	0.0
Unaccount for revenue	6,513,411	0.4
Unmeasured	2,828,359	0.2
Waterworks use	1,853,967	0.1
Others	1,831,085	0.1
Ineffective	59,744,294	3.9
Leakage	57,591,726	3.7
Deduced consumption by settlement	2,152,568	0.2



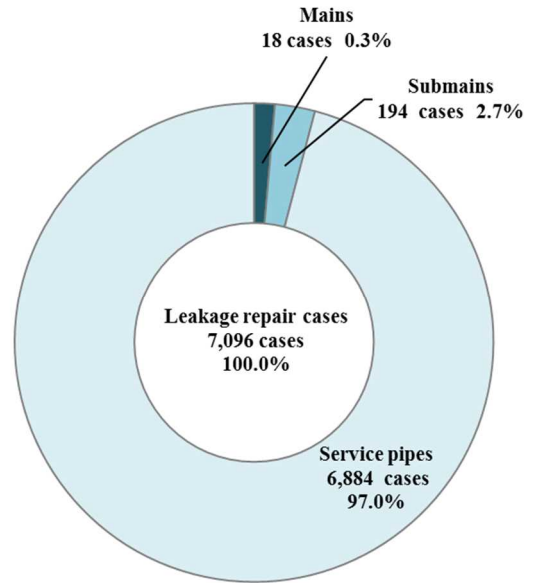
## Reference-2 Trends in total distribution volume, leakage volume and rate from FY 1992 to FY 2020



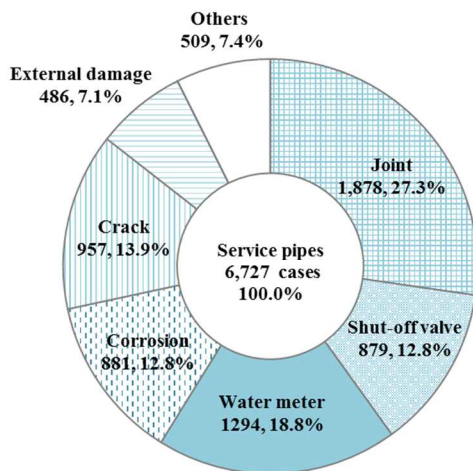
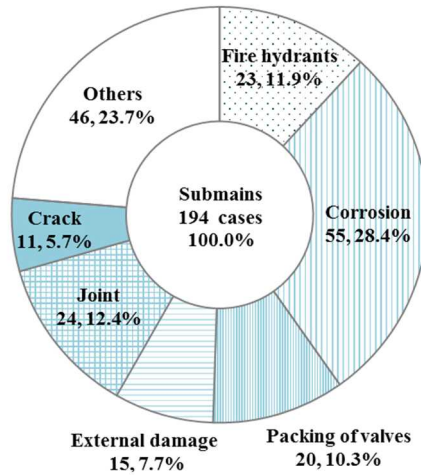
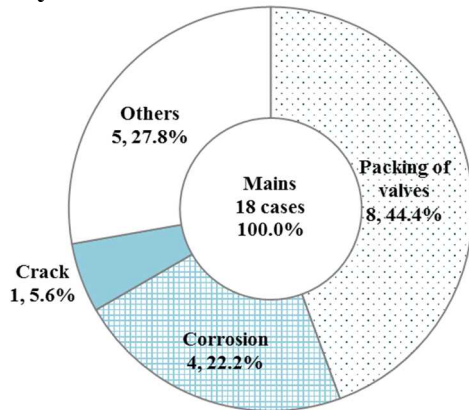
	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04
Distribution vol. $10^6 \text{ m}^3$	1,793	1,763	1,746	1,727	1,697	1,689	1,672	1,671	1,678	1,656	1,639	1,613	1,625
Leakage vol. $10^6 \text{ m}^3$	183	175	168	161	150	141	133	127	120	107	89	75	72
Leakage rate %	10.2	9.9	9.6	9.3	8.9	8.4	8.0	7.6	7.1	6.4	5.4	4.7	4.4
	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17
Distribution vol. $10^6 \text{ m}^3$	1,616	1,606	1,607	1,582	1,568	1,569	1,537	1,523	1,523	1,521	1,530	1,530	1,542
Leakage vol. $10^6 \text{ m}^3$	68	58	54	50	48	42	44	31	33	47	50	48	54
Leakage rate %	4.2	3.6	3.3	3.1	3.0	2.7	2.8	2.0	2.2	3.1	3.2	3.1	3.5
	'18	'19	'20										
Distribution vol. $10^6 \text{ m}^3$	1,541	1,543	1,541										
Leakage vol. $10^6 \text{ m}^3$	50	56	58										
Leakage rate %	3.2	3.6	3.7										

# Reference-3 Specifications of leakage cases in FY 2020

## 1 By Uses

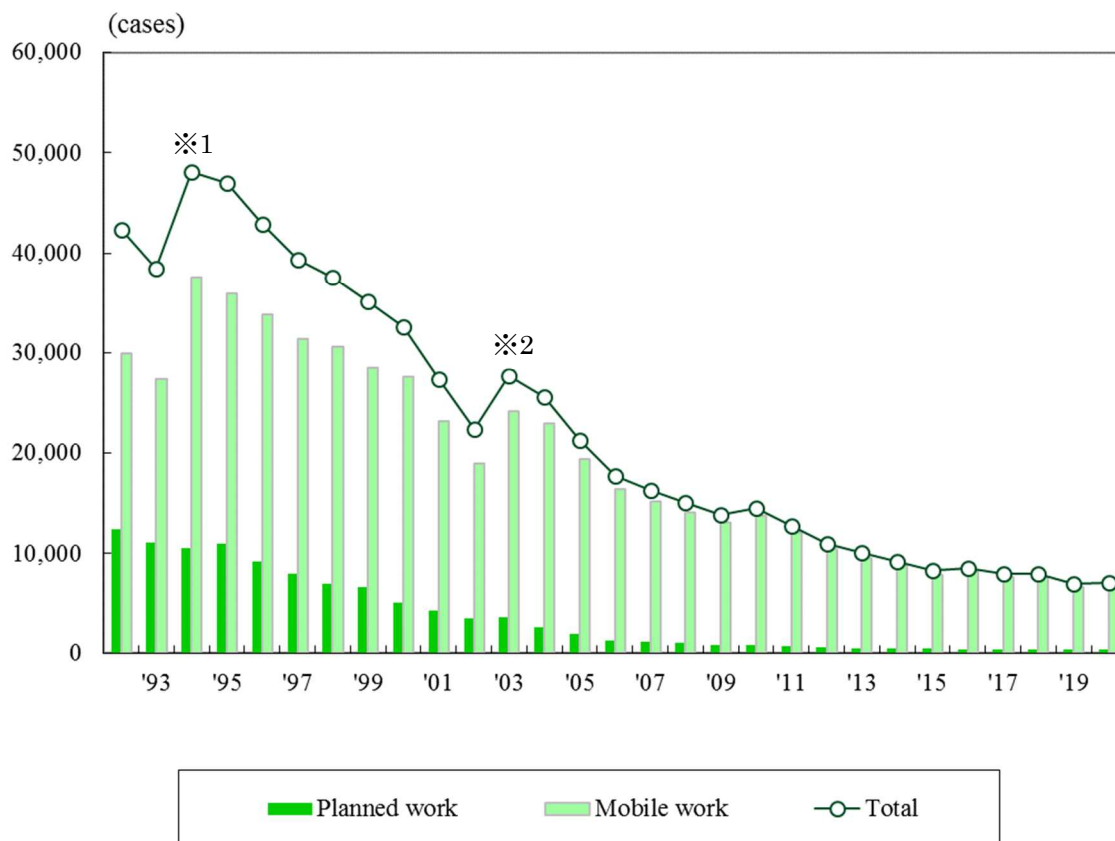


## 2 By Causes



※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 2020

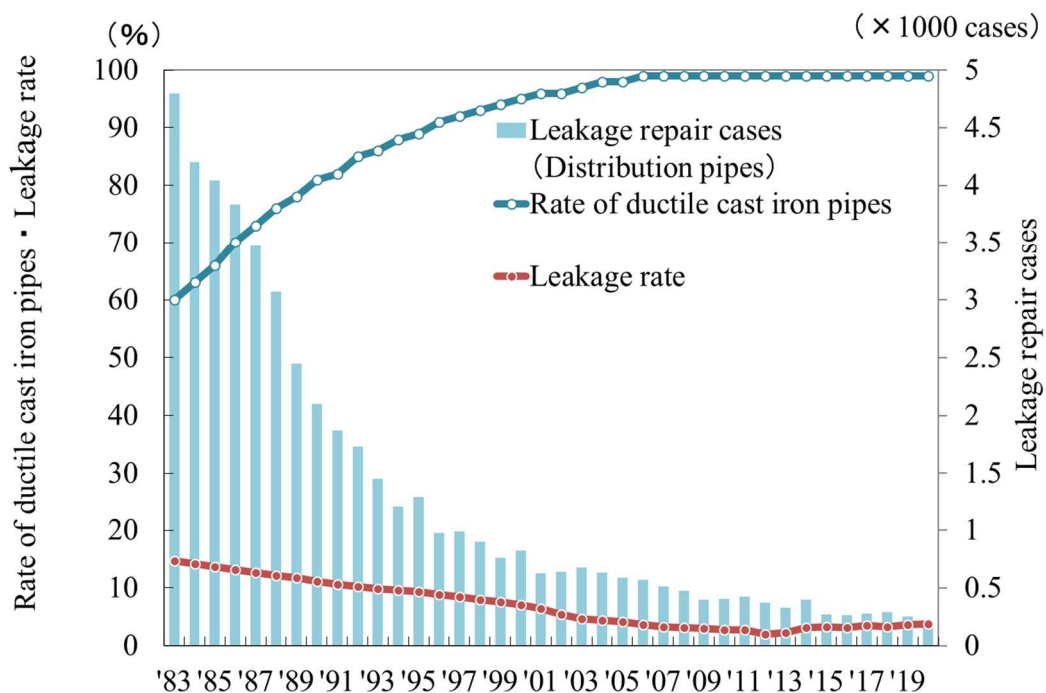


※1 We enlarged the repairing area range from “1m from residential border” to “water meter” in FY1994

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

	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04
Planned work cases	12,383	11,142	10,505	10,979	9,177	8,028	6,964	6,627	5,073	4,199	3,450	3,516	2,592
Mobile work cases	29,960	27,337	37,542	35,965	33,757	31,345	30,575	28,476	27,569	23,135	18,996	24,186	22,987
Total cases	42,343	38,479	48,047	46,944	42,934	39,373	37,539	35,103	32,642	27,334	22,446	27,702	25,579
	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17
Planned work cases	1,908	1,287	1,097	1,026	848	801	684	542	503	454	434	403	357
Mobile work cases	19,361	16,460	15,173	14,083	13,046	13,777	12,090	10,476	9,597	8,752	7,881	8,168	7,620
Total cases	21,269	17,747	16,270	15,109	13,894	14,578	12,774	11,018	10,100	9,206	8,315	8,571	7,977
	'18	'19	'20										
Planned work cases	383	361	306										
Mobile work cases	7,623	6,618	6,790										
Total cases	8,006	6,979	7,096										

**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 2020**

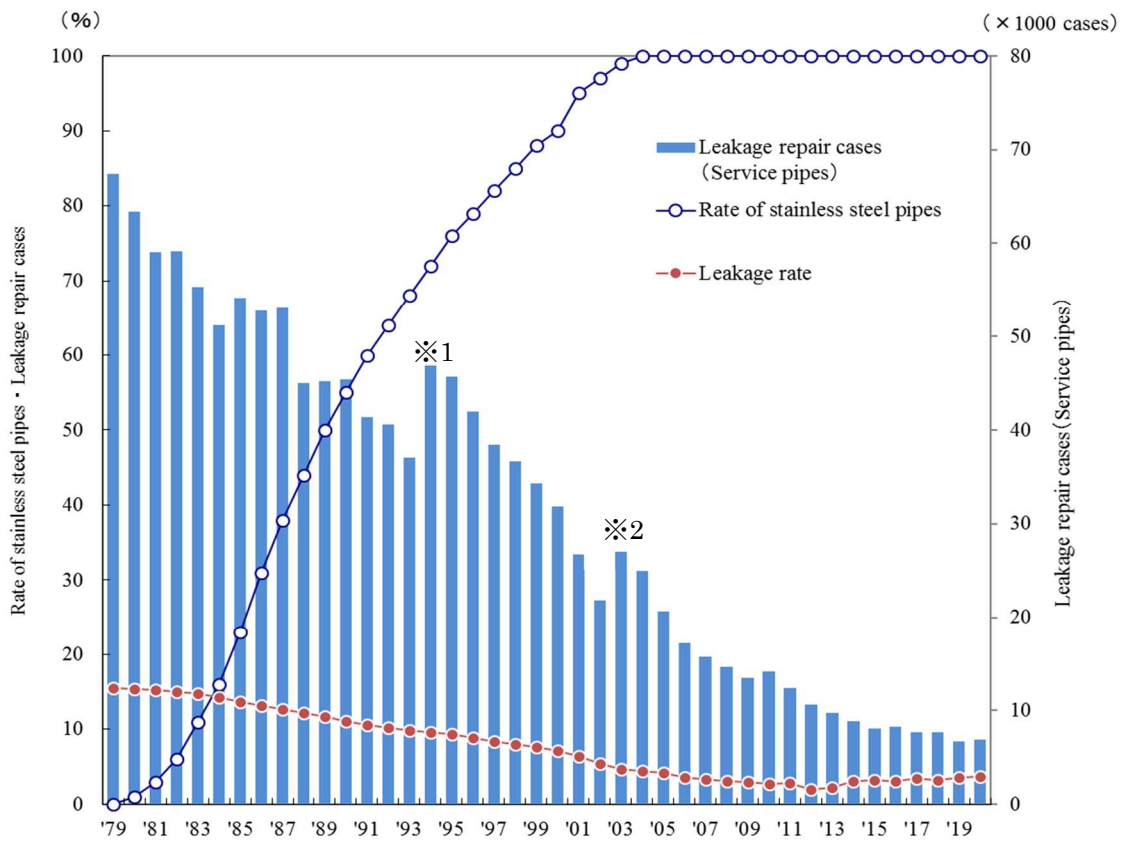


	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	
Rate of ductile cast iron pipes	%	60	63	66	70	73	76	78	81	82	85	86	88
Leakage repair cases (Distribution pipes)		4,800	4,200	4,040	3,834	3,471	3,072	2,447	2,097	1,870	1,730	1,449	1,205
Leakage rate	%	14.7	14.2	13.7	13.2	12.7	12.2	11.7	11.1	10.6	10.2	9.9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

※ 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

## Reference-6 Trends in rate of stainless steel pipes in service pipes, leakage repair cases(service pipes),leakage rate from FY 1979 to FY 2020



※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

	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	
Rate of stainless steel pipes	%	0	1	3	6	11	16	23	31	38	44	50	55	60	64
Leakage repair cases		67,361	63,367	59,041	59,154	55,310	51,206	54,119	52,801	53,022	44,972	45,171	45,382	41,418	40,613
Leakage rate	%	15.5	15.4	15.2	15.0	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	'03	'04	'05	'06	
Rate of stainless steel pipes	%	68	72	76	79	82	85	88	90	95	97	99	100	100	
Leakage repair cases		37,030	46,842	45,656	41,960	38,386	36,641	34,341	31,818	26,707	21,805	27,023	24,944	20,682	17,177
Leakage rate	%	9.9	9.6	9.3	8.9	8.4	8.0	7.6	7.1	6.4	5.4	4.7	4.4	4.2	3.6
	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	
Rate of stainless steel pipes	%	100	100	100	100	100	100	100	100	100	100	100	100	100	
Leakage repair cases		15,759	14,635	13,495	14,175	12,350	10,646	9,774	8,811	8,045	8,307	7,702	7,715	6,727	6,884
Leakage rate	%	3.3	3.1	3.0	2.7	2.8	2.0	2.2	3.1	3.2	3.1	3.5	3.2	3.6	3.7

## **Reference-7 Technology and equipment related to leakage prevention that were co-developed by Tokyo Waterworks and private companies**

### **1 Freezing method**

This method suspends water by freezing up the water inside the pipe with liquid air in repair.

### **2 Electronic leakage detector**

This instrument can pick up the leakage noise electrically on ground surface.

### **3 Portable minimum flow meter**

This flow meter is used at the minimum night flow measurement.

### **4 Correlative leakage detector**

This instrument locates the leakage by processing leakage noise picked up at two points on pipe.

### **5 Underground radar**

This radar radiates electro-magnetic wave to ground so as to search the underground condition.

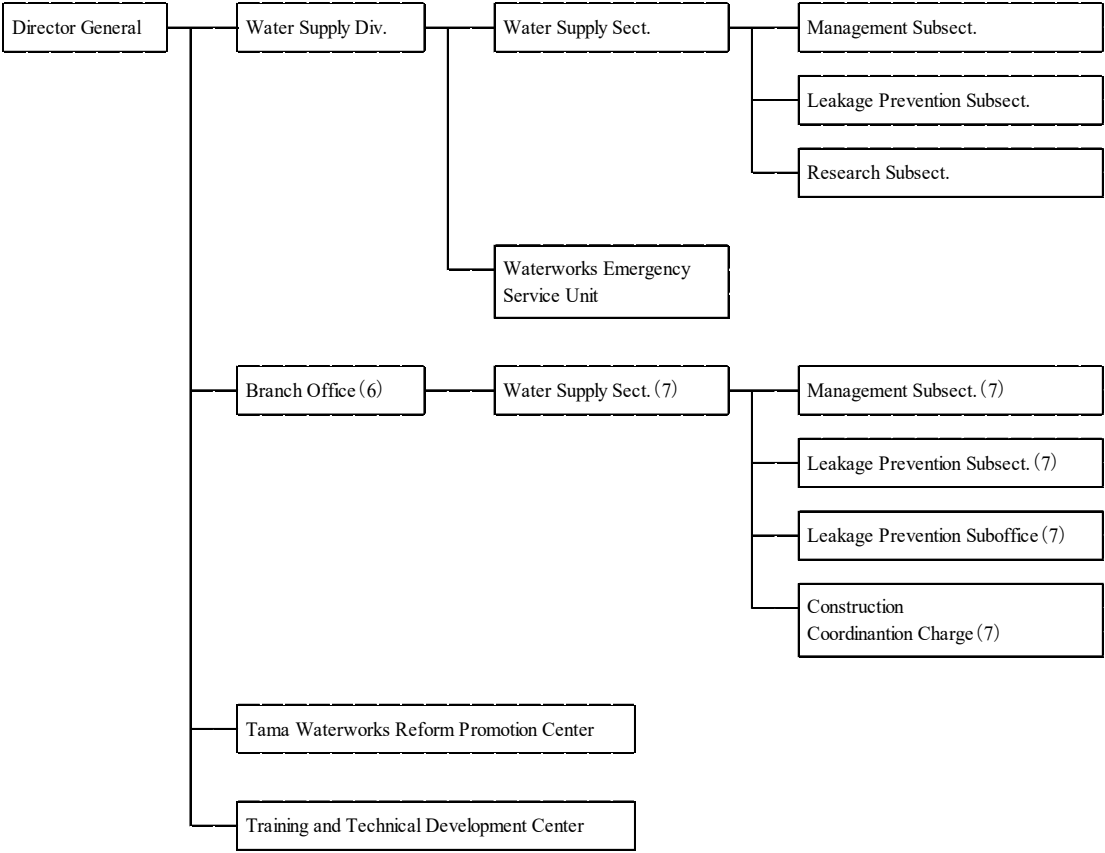
### **6 Time integral type leakage detector**

Making use of the continuity of leakage noise, this instrument is able to check whether leakage exists or not.

### **7 Transmission-type leakage detector**

It is a device to locate the place of leakage by detecting the helium gas injected into the water pipe and then discharged through the leakage spot to the soil.

### Reference-8 Organization of leakage prevention



Number of persons working in the Waterworks is 3,673 (at April 2021).  
 243 persons of them are engaged in leakage prevention of the 23 wards.

## **Reference 9: Glossary of Terms used in "Prevention of Leakage in Tokyo"**

### **Ozonation**

Treatment of decomposing substances causing musty odor and substances trihalomethane by strong oxidizing power of ozone.

### **Biological Activated Carbon Adsorption Treatment**

Treatment of pollutants by combining adsorption action of activated carbon and decomposition action of microorganisms propagated on activated carbon.

### **Advanced Water Treatment**

Treatment aimed at removing odorous substances, trihalomethane precursors, etc. which cannot be adequately removed by ordinary water purification treatment such as rapid filtration method. Treatment using ozonation combined with biological activated carbon adsorption treatment.

### **Remaining Leakage Amount**

Leakage amount that could not be prevented due to underground leakage etc. undiscovered during leakage prevention works.

### **Block**

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

### **Circulation Period**

Operation interval for carrying out planned works in each block.

### **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, etc. Normally, it is installed at an interval of about 500 m to 1,000 m in a main distribution pipe, and an interval of about 150 m to 200 m in a submain distribution pipe.

### **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  $12.5\text{N}/\text{mm}^2$ ). It is 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  $25\text{N}/\text{mm}^2$ ) 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  $45\text{N}/\text{mm}^2$ ). It is used from around 1967.

**Early Ductile Pipe**

A collective term for consisting of a mixture of straight pipes made of ductile cast iron and special fittings made of high-grade cast iron without inner lining.

**Earthquake-resistant joints**

Structure with detachment prevention function in joint part.

