Leakage Prevention Guidebook

2010

Bureau of Waterworks, Tokyo Metropolitan Government
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1 Outline of leakage prevention

1.1 Present situation

The rivers flowing in this area, namely Tone, Ara, Tama and Sagami rivers are the main source of water used in the Tokyo Metropolitan area.

We collect raw water from these rivers, process purification at water plants such as coagulation, sedimentation and filtration, convey into underground water pipes with pressure, then supply as tap water to customers. In the process of supplying tap water, some water leaks from the pipes into the ground. This is the “leakage of water”.

Water leakage in FY2009 decreased to 48 million m³, 3.0% to total distribution of 1.568 billion m³, compared from 7.1% of water leakage rate (120 million m³) in FY 2000, which is ten years ago. (Fig.1, Table-1 and 2)

Most of the leakage is caused by cracked or corroded service pipes and distribution pipes due to aging. The total cases of leakage repair work in FY 2009 recorded around 14,000, and 97% of which were at supply pipes, and the remaining 3% were at distribution pipes. (Table-3 and 4)

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

Surface leakage is handled by mobile work and underground leakage by planned work. The ratio of two types of work is shown in Fig. 2-1.

Basically we conduct repair works of ground leakage within a day of occurrence. Total number of repair cases (mobile work) in FY2009 was 13,046. On the other hand, the underground leakage (planned work) forms a simple majority of total leakage volume because these are kept unnoticed for a long time without public exposure. (Fig.2-2). Therefore, unless we identify and repair leakages systematically, valuable water will continue to leak and large accidents may occur. The number of repair cases (planned work) in FY 2009 was 848.

There always is a danger of water leakage on water pipes from corrosion, affected by heavy traffic loadings, various construction works, not to mention earthquakes and unequal ground subsidence/settling.

Although water leakages are repaired as soon as they are
found, On the other hand, the new leakage increases gradually in accordance with time. This is referred to as the “repetition phenomenon” of leakage. As the solution to this repetition phenomenon may lead to leakage prevention measures, we are trying to understand this phenomenon. (Fig. 3)

Fig.3  Repetition of leakage

1.2  Necessity of leakage prevention

Tokyo metropolitan government currently has a water resource volume of 6,300,000 m³ per day; this volume includes water resources with problems such as difficulty in assuring a sufficient intake, due to river-bed degradation.

In addition, Tone river system which accounts for 80% of the overall water resources of Tokyo can merely assure a low level safety with regard to drought, in that planned dams have not been completed yet, as well as that actual supply capacity deteriorates in comparison to the initial planning, because of rainfall situation of recent years.

In consideration of these circumstances, we are required to work on securing stable water resources by water resources development such as development of dams, as well as to further promote measures for effective use of water and leakage prevention.

On the other hand water distribution pipes installed within municipal Tokyo totals up to 26,000 kilometers as of FY2009, which is worth more than halfway around the world.

Water pipes embedded under ground are constantly subject to a danger of leakage, and when leakage occurs, these pipes pose risks of factors like secondary disasters including poor water flow, sagging road, inundation and so on.

Leakage prevention measures are actively implemented as one of main initiatives of the Bureau, since such measures have effects equivalent to a new water resources development, and that they prevent secondary disasters from occurring.
Fig. 4-1  Scene of water leakage

Fig. 4-2  Corrosion and water leakage of iron pipes
2 Countermeasure of leakage prevention

2.1 System of leakage prevention measures

The leakage control measures that we take in Tokyo are classified as follows.

- Countermeasure of leakage prevention
  - Planned replacement of water pipes and improvement of materials for pipes
  - Replacement of aged distribution pipes and early ductile iron pipes
    - Integration of service pipes under the private road and replacement with sub mains
    - Reinforcement of seismic resistance of large-diameter service pipes
    - Material improvement work of service pipes
  - Early detection and repair work for water leakage
    - Planned work
    - Mobile work
    - Patrol work
    - Leakage volume measurement work
    - Leak investigation and measurement work
  - Secure high technology of water leak prevention
    - Training and Technical Development Center
    - Accreditation of Tokyo waterworks technology experts and super plumbers

Fig.5 System of leakage prevention measures
2.1.1 Planned replacement of water pipes and improvement of materials for pipes

Planned replacement and improvement of the quality of pipe materials are important and effective methods to reduce remaining leakage as well as to forestall leakage and prevent so called “Reversion Phenomena” of water leakage. Followings are the major solutions.

(1) Replacement of aged distribution pipes and early ductile iron pipes

Among distribution pipes, we preferentially replace low-intensity iron pipes without inner linings, aged steel pipes which are built long time ago, early ductile iron pipes mix of straight pipes made of ductile iron and high-quality iron deformed pipes without inner linings, and externally-uncovered and easily-corrosive pipelines which mainly built in the eastern area due to poor subsoil. As part of earthquake disaster measurement, we replace such pipes with earthquake resistant joint pipelines.

(Note) Ductile cast iron pipe has increased material strength by the addition of magnesium to the traditional cast iron pipe and making graphite in the structure spherical.

![Fig.6 Micrograph of cast iron](image)

(Cast iron)  (Ductile cast iron)
(2) Integration of service pipes under the private road and replacement with sub mains

Beneath private roads are congested with many water pipes, causing water leakage due to aging and corrosions. Therefore we are working on to reduce such danger by consolidating pipes with small canals.

In the project that started in FY1994, the work started on the private roads having 3 or more service pipes drawn. Since FY 2007, the scope work has been expanded to private roads which have more than 15 meters, and from FY 2009 further expanded to the ones which have more than 10 meters.

(3) Reinforcement of seismic resistance of large-diameter service pipes

We have focused on reinforcement of earthquake resistance on supply pipes since FY1980 by adopting stainless steel pipes for the ones smaller than 50mm bore diameter. To react on aged deterioration on larger supply pipes that has more than 75mm bore diameter we have been working on earthquake resistant reinforcement since FY2000 in addition to planned (routine) replacement of distribution pipes and leak repair works. From FY2007, we expanded target reinforcement to major supply pipes which yet remain non-earthquake resistant on the routes where replacement of distribution pipes completed before FY2000.

(4) Material improvement work of service pipes

Approximately 97% of total leakage repair works are on supply pipes. (please refer number 4 on page 27) Therefore, prevention of water leakage from supply pipes is the most effective solution to reduce leak rate (please refer number 2 and 3 on page 26). Such pipes were not strong enough and were vulnerable to deterioration, causing water leakage.

In the municipal Tokyo, since FY1980, the supply pipes beneath public roads (from the bifurcation point of distribution pipe to water shutoff valve within 1 meter of residential premises) which used to be made of lead has been replaced by stainless-steel pipes in each case of replacement of small distribution pipes or repair works on pipe leakage.

From FY2000, to prepare for the improvement of lead-containing water quality standard (from 0.05mg/l to 0.01mg/l, effective from April 2003) we formulated the plan to remove lead supply pipes beneath public roads by FY2002, and resolved as planned.

Furthermore, from FY2003 we expanded target quality improvement work to private roads and meters at residential
premises, and managed to remove lead supply pipes of such area by the end of 2006 fiscal year.

Still, there are slight lead pipes remain beneath private roads and residential premises. For them we are re-investigating upon patrol works since FY2007 to dissolve.

Fig.8  Leakage on lead pipes

Fig.9  Material improvement of service pipe

2.1.2  Early detection and repair work for water leakage

Early detection and repair work on water leakage means the initiative that we detect water leaks and provide repair works on early stage for the underground and ground with planned and mobile works.

Distribution pipes are maintained and managed as water facilities by Tokyo Metropolitan Government. On the other hand supply pipes are supposed to be maintained and managed by customers.

In municipal Tokyo, Bureau of Waterworks (Tokyo Metropolitan Government) provides free-of-charge repair works on water leakage to supply pipes up to meters on residential premises unless special cases.

(1)  Planned work

Planned works refer to the planned research works by block compartmented distribution canal pipe networks at a certain extent (please refer number 10 on page 11) within municipal Tokyo. One of them is patrol (routine) work that detects water leakage and provides repair works; another is leakage volume measurement work that is intended to understand leakage trend; the other is leakage investigation and measurement work that aims to check up sluice-gate functions against earthquake and investigate water leakage.
In 23 wards, we have long addressed leakage preventions. We handle leakage investigation works with 6 branches (14 offices) and majority of repair works are subcontracted. In Tama area (excluding some cities and villages) administration of waterworks used to be consigned to respective cities and towns, but sequentially been shifted to direct administration under Tokyo Metropolitan Government. Leak investigation works are currently conducted by administrative bodies (which are the stock companies invested by Tokyo Metropolitan Government at the rate of 25% or more in total capital), and repair works are constructed by subcontractors.

a  Patrol work (Circulating checking)

In the patrol works are individual investigation work that determines leakage with acoustic rod attached to meter on every home, acoustic investigation work that is conducted during the night when there is less traffic to identify point of leakage with electric leakage detector 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 supply pipes into consideration.

In addition to that, we consign administrative bodies to conduct such individual investigation with time integral type leak detector (please refer the page 19) replacing acoustic rod on some blocks since FY2003.

b  Leakage volume measurement work

To estimate total leakage volume within Tokyo municipal and understand the leakage trend, we conduct leakage volume measurement works. To gain an understanding of more accurate leakage volume in urban areas where operate 24 hours a day, we measure minimum flow at night (leak volume) limited to around 400 valves which is the marginal idle volume at night. (Refer to P15 Minimum night flow measurement method) By estimating leakage volume within a certain block, we are able to make total assumption of leakage volume within municipal Tokyo. Together with leakage investigation and measurement work that has been put into practice since FY2010, we will put such works to improve our leakage prevention plan.

For the leakage volume measurement work, we subcontract to external management bodies 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 distribution main to small distribution pipes. To do so it is essential to secure the exhaust valve function at distribution main. And then it is necessary to avoid damaged channel and secure the available water routes as soon as possible and recover the service area.

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. Such data will also be partially facilitated to leakage volume measurement work.
Unable to flow water on routes 1 and 2 due to damages. Ensuring that there is no damage on route 3, flow water to passing water area 2.

Fig. 10 Leakage volume investigation and measurement work

(2) Mobile work

A work for repairing an aboveground leakage found by report of a customer, by patrol of staff or by other means is called mobile work. In the 23 wards, staffs at 6 branch (14 offices) and repair subcontractors at each offices stand-by on a round-the-clock basis to attend to mobile works.

Inside Tama area, Tokyo Waterworks Service Co., Ltd (administrative organization of the Bureau of Waterworks, Tokyo metropolitan government) and repair contractors are at call 24 hours a day so as to undertake mobile works in cities and towns in which the Bureau of Waterworks has a direct control on operation. Inquiries in case of accidents are handled at the Tama Customer Service Center.

On the other hand, as per cities with their office administration being committed to the third parties, staff of each city and repair contractors are ready for mobile works.

2.1.3 Secure high level of leak prevention technologies

With background that we need to “maintain low rate of water leakage” and “mass retirement of veteran workers”, we acknowledge and human resources development are our significant challenges.

(1) Training and Technical Development Center

Training and Technical Development Center launched in 2005 in response to a deterioration of an environment of leakage prevention work supervises research and development directly connected with succession of technology to the
next generation and improvement of staff capability, as well as diversified needs.

Test and verification facilities for solving problems mainly associated with the pipeline are well organized within the pipeline test institution; these facilities are utilized not only for training of staff of Tokyo metropolitan government, but also for trainings for overseas waterworks entities, and so on.

In the meantime, equipments associated with leakage prevention which have been developed and improved by Tokyo metropolitan government are shown in Reference 6.

![Fig.11  Technical training for leakage prevention work](image)

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

In various fields not limited to leakage prevention, many veteran staff with technology backed up with experience approach to the time of retirement, which is a big issue in terms of succession of technology.

Therefore we founded “Tokyo Water Workers Technology Experts Program”, in which veteran workers provide training junior fellows as leaders, and offer instruction courses on leakage prevention technologies at Training and Technical Development Center. Furthermore we enhance inheritance of leak prevention technologies by visualizing implicit 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 construction contractors in order to maintain and succession technology, as well as to enhance the level of the entire plumbing technology and motivation.

2.2 Leakage prevention construction system

Bureau of Waterworks Metropolitan Tokyo Government adopt computerized system for tally records of repair work on leakage (cause and detail of actual repair work) and calculate paid amount for such works. Current systems process the followings.

1) Reception of leakage prevention measures
2) Calculation of construction cost for water leakage repair, material improvements, etc.
3) Summarization of the records of leakage causes and contents of the work done
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; based on maintenance status of pipelines and past history of water leakage, select pipelines necessary to be investigated and conduct leakage investigation (minimum night flow measurement method). Another method is to determine the leakage by the sound and identify the location (acoustic method, correlation method, and method using the time integral type leakage detector.)

3.1 Minimum night flow measurement method

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

First, gate valves surrounding the block to be investigated are closed and the water from other blocks is shut down. Then the water is sent into the block through minimum flow measuring equipment set in the block water meter and the flow rate is measured. The minimum flow rate measured during the vacant period is considered to be the leakage.

For measurement we use high prevision portable minimum flow meter joint-developed by the Bureau and a private company.

![Diagram of minimum night flow measurement method](image)

Fig.11 Theory of minimum night flow measurement method
3.2 Acoustic method

In the acoustic method, the leak sound is detected by an acoustic rod or an electronic leak detector.

The metal tip of the acoustic rod is pressed against the water meter, gate valve or fire hydrant. An inspector then presses an ear against a vibration diaphragm set at the other end of the rod, and listens for transmitted sound of the leakage. The acoustic rod can only tell whether the leakage is present in the neighborhood, and it is difficult to detect the position of leakage.

Using an electronic leakage detector, a pickup to convert the leak sound into an electrical signal is placed on the ground, and the sound transmitted through the ground is amplified and heard through headphones. As the pickup is moved in order, the leak sound is heard most strongly directly above the point of leakage and thus the position of leakage can be detected.
3.3 Correlation method

In the correlation method, the position of leakage is detected by using a correlation type leakage detector (a combination of correlation analyzer, sensor, amplifier, wireless transmitter, etc.).

Firstly we place sensors at two points (where exposed ground surface i.e. gate valve and fire hydrant), then obtain the leakage noise propagation time difference to both sensors with correlation leakage detector. The position of leakage is calculated by the time lag, distance between sensors, and velocity of leaking sound transmitting through the pipe.

Correlation 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 pipelines. It has the excellent characteristic of being largely
unaffected by traffic noise or laying depth of the pipe.

3.4 Time integral type leakage detector

Time integral type leakage detector is the device that identifies the leakage by utilizing the nature that the leakage noise has the continuity. This device measures the noise to be transmitted for a certain period of time (10 seconds up to 3 minutes) by attaching the sensor to the exposure points of supply pipes within individual meter box.

The time integral type leakage detector was jointly developed by the Tokyo Metropolitan Government and private industry. 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.

![Diagram of a transmission-type leakage detector](image)

**Fig. 18** Time integral type leakage detector

### 3.5 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 is used to detect the helium gas leaked from the pipe and seeped through the ground.

This type of method allows to detect very small amount of leakage or leakage in bigger pipes such as main distribution pipes buried deep underground since it is not based on the leak sound as it is necessary with the acoustic leakage sound.
detection method or the correlative leak detection method. The equipment used for the transmission-type leakage
detector method was co-developed by the Tokyo Metropolitan Government and private organizations.

3.6 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.

Metal pipe detector, nonmetal pipe detector and Water hammer Generator are used to detect the pipe location. To
identify whether such water is tap water, we facilitate easy method such as water temperature gauge, residual chlorine
analyzer, pH meter, and conductivity detector, or precise method determining inclusion of trihalomethane.

Fig. 20  Metal pipe locator

Fig. 21  Water hammer Generator
4 Problems and the future of leakage prevention

Phenomena like decreased flow rate and increased risk of drought are observed worldwide due to decreased snow accumulation and instable precipitation pattern which both are likely to result from the recent global warming. Thus the focus is placed on an importance of water resources.

In Tokyo, a main water source, that is, Tone river system assures a lower level safety with regard to drought than other water systems, in consideration of rainfall situation of recent years and many planned but not completed dams.

Still further, the tap water is based on raw water as described above; it is also a resource produced by spending ca. 1% of the electric power consumed within the Tokyo metropolitan area during steps including water treatment and water supply.

Leakage prevention measures aim at an effective use of tap water, and contribute to prevention of global warming from a viewpoint of energy saving and reduction of carbon-dioxide emissions. Additionally they are of paramount importance in that they are a key to avoidance of secondary disasters like sagging road resulting from leakage.

The importance of such leakage prevention measures is now globally recognized. “Promotion of leakage prevention measures and provision of technical information” was designated as an action to be taken by 13 cities including the host city Tokyo, Seoul, Los Angeles and New York at Climate Leadership Group C40 Tokyo Conference on Climate Change in October 2008. As a result of continuous effort to tackle on leakage prevention as one of the key policies in the Bureau of Waterworks, Tokyo Metropolitan Government achieved as low as 3.0% leakage rate as of FY2009. The leakage rate is at a high level, even in comparison worldwide among the cities of same size.

Tokyo Metropolitan Government has positively made international contributions such as acceptance of foreign trainees and sending experts to overseas. In recent years, faced with growing expectations toward Japanese technical contributions such as global water problems, we, the Bureau of Waterworks of the Tokyo metropolitan Government drew up the “Tokyo Waterworks Management Plan 2010”, in which we announced international contributions using our high-level water –work technology and operational know-how on top of past activities. Furthermore we plan to send special research team to overseas to appeal technologies and know-hows of Tokyo Water works globally.

In future, our staff will keep the current low level of leakage by concentration of technology fostered to date, and we will work together on more efficiently and effectively realizing maintenance of the pipeline and the leakage prevention work.
5 参考資料 Annex
Table-1 Distribution volume analysis in FY2009

<table>
<thead>
<tr>
<th></th>
<th>Water Volume (m³/year)</th>
<th>Component Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution total</td>
<td>1,567,900,000</td>
<td>100</td>
</tr>
<tr>
<td>Effective</td>
<td>1,518,141,615</td>
<td>96.8</td>
</tr>
<tr>
<td>Account for</td>
<td>1,499,366,273</td>
<td>95.6</td>
</tr>
<tr>
<td>Charged</td>
<td>1,495,934,247</td>
<td>95.4</td>
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<tr>
<td>Supplied to Tama</td>
<td>3,399,400</td>
<td>0.2</td>
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<tr>
<td>Others</td>
<td>32,625</td>
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<tr>
<td>Unaccount for</td>
<td>18,775,343</td>
<td>1.2</td>
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<tr>
<td>Unmeasured</td>
<td>16,007,306</td>
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<tr>
<td>Waterworks use</td>
<td>1,718,478</td>
<td>0.1</td>
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<tr>
<td>Others</td>
<td>1,049,559</td>
<td>0.1</td>
</tr>
<tr>
<td>Ineffective</td>
<td>49,758,385</td>
<td>3.2</td>
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<tr>
<td>Leakage</td>
<td>47,608,349</td>
<td>3.0</td>
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<tr>
<td>Deduced consumption by settlement</td>
<td>2,150,036</td>
<td>0.2</td>
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</table>
Table-2 Trends in total distribution, leakage volume and rate from FY1999 to FY2009

![Graph showing trends in total distribution, leakage volume, and rate from FY1999 to FY2009.]

<table>
<thead>
<tr>
<th>Year</th>
<th>Distribution vol. $10^6$m$^3$</th>
<th>Leakage vol. $10^6$m$^3$</th>
<th>Leakage rate</th>
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<tbody>
<tr>
<td>11('99)</td>
<td>1,671</td>
<td>127</td>
<td>7.6</td>
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<tr>
<td>12('00)</td>
<td>1,678</td>
<td>120</td>
<td>7.1</td>
</tr>
<tr>
<td>13('01)</td>
<td>1,656</td>
<td>107</td>
<td>6.4</td>
</tr>
<tr>
<td>14('02)</td>
<td>1,639</td>
<td>89</td>
<td>5.4</td>
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<td>15('03)</td>
<td>1,613</td>
<td>75</td>
<td>4.7</td>
</tr>
<tr>
<td>16('04)</td>
<td>1,625</td>
<td>72</td>
<td>4.4</td>
</tr>
<tr>
<td>17('05)</td>
<td>1,616</td>
<td>68</td>
<td>4.2</td>
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<tr>
<td>18('06)</td>
<td>1,606</td>
<td>58</td>
<td>3.6</td>
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<td>19('07)</td>
<td>1,607</td>
<td>54</td>
<td>3.3</td>
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<tr>
<td>20('08)</td>
<td>1,582</td>
<td>50</td>
<td>3.1</td>
</tr>
<tr>
<td>21('09)</td>
<td>1,568</td>
<td>48</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Table-3 Trends in number of each kind of repair works from FY1999 to FY2009

![Graph showing trends in number of each kind of repair works from FY1999 to FY2009.]

<table>
<thead>
<tr>
<th>Year</th>
<th>Planned work cases</th>
<th>Mobile work cases</th>
<th>Total cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>11('99)</td>
<td>6,627</td>
<td>28,476</td>
<td>35,103</td>
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<tr>
<td>12('00)</td>
<td>5,073</td>
<td>27,569</td>
<td>32,642</td>
</tr>
<tr>
<td>13('01)</td>
<td>4,199</td>
<td>23,135</td>
<td>27,334</td>
</tr>
<tr>
<td>14('02)</td>
<td>3,450</td>
<td>18,996</td>
<td>22,446</td>
</tr>
<tr>
<td>15('03)</td>
<td>3,516</td>
<td>24,186</td>
<td>27,702</td>
</tr>
<tr>
<td>16('04)</td>
<td>2,592</td>
<td>22,987</td>
<td>25,579</td>
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<td>17('05)</td>
<td>1,908</td>
<td>19,361</td>
<td>21,269</td>
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<td>18('06)</td>
<td>1,287</td>
<td>16,460</td>
<td>17,747</td>
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<td>19('07)</td>
<td>1,097</td>
<td>15,173</td>
<td>16,270</td>
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<td>20('08)</td>
<td>1,026</td>
<td>14,083</td>
<td>15,109</td>
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<tr>
<td>21('09)</td>
<td>848</td>
<td>13,046</td>
<td>13,894</td>
</tr>
</tbody>
</table>
Table-4 Specifications of leakage cases in FY2009

1 By Uses

- **Mains**
  - Cases: 23 (0.2%)
- **Submains**
  - Cases: 376 (2.7%)
- **Service pipes**
  - Cases: 13,495 (97.1%)

2 By cases

(Mains)

- **Crack**
  - Cases: 2 (8.7%)
- **Corrosion**
  - Cases: 4 (17.4%)
- **Joint**
  - Cases: 41 (28.1%)
- **Others**
  - Cases: 2 (8.7%)
- **Packing of valves**
  - Cases: 9 (39.1%)
- **Packing of hydrants**
  - Cases: 45 (12.0%)

(Submains)

- **Crack**
  - Cases: 31 (8.2%)
- **Corrosion**
  - Cases: 45 (12.0%)
- **Joint**
  - Cases: 41 (10.9%)
- **Others**
  - Cases: 60 (16.0%)
- **Packing of valves**
  - Cases: 154 (41.0%)
- **Packing of hydrants**
  - Cases: 45 (12.0%)

(Service Pipes)

- **Crack**
  - Cases: 1,710 (12.7%)
- **Corrosion**
  - Cases: 3,151 (23.3%)
- **Joint**
  - Cases: 2,130 (15.8%)
- **Others**
  - Cases: 1,327 (9.8%)
- **Packing of meters**
  - Cases: 2,528 (18.7%)
- **Packing of valves etc...**
  - Cases: 2,849 (19.6%)
- **Others**
  - Cases: 1,327 (9.8%)
Number of persons working in the Waterworks is 4,072 (at April 2010). 343 persons of them are engaged in leakage prevention of the 23 wards.
Freezing method

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

Electronic leakage detector

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

Portable minimum flow meter

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

Correlation type leakage detector

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

Underground radar

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

Time integral type leakage detector

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

Non-metal pipe locator

Making use of the transmission noise, this instrument can locate the non-metal pipe.

Transmission-type leakage detector

It is a device to locate the place of water leakage by detecting the helium gas injected into the water pipe and then discharged through the leakage spot to the soil.
Table-7 Trends in percentages of ductile cast iron pipes in distribution, stainless steel pipes in service pipes, leakage repair cases, leakage from FY1999 to FY2009

<table>
<thead>
<tr>
<th></th>
<th>H11 ('99)</th>
<th>H12 ('00)</th>
<th>H13 ('01)</th>
<th>H14 ('02)</th>
<th>H15 ('03)</th>
<th>H16 ('04)</th>
<th>H17 ('05)</th>
<th>H18 ('06)</th>
<th>H19 ('07)</th>
<th>H20 ('08)</th>
<th>H21 ('09)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of ductile cast iron pipes</td>
<td>%</td>
<td>94</td>
<td>95</td>
<td>96</td>
<td>96</td>
<td>97</td>
<td>98</td>
<td>98</td>
<td>99</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>Percentage of stainless steel pipes</td>
<td>%</td>
<td>88</td>
<td>90</td>
<td>95</td>
<td>97</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Leakage repair cases</td>
<td>×1000</td>
<td>35,103</td>
<td>32,642</td>
<td>27,334</td>
<td>22,446</td>
<td>27,702</td>
<td>25,579</td>
<td>21,269</td>
<td>17,747</td>
<td>16,270</td>
<td>15,109</td>
</tr>
<tr>
<td>Leakage rate</td>
<td>%</td>
<td>7.6</td>
<td>7.1</td>
<td>6.4</td>
<td>5.4</td>
<td>4.7</td>
<td>4.4</td>
<td>4.2</td>
<td>3.6</td>
<td>3.3</td>
<td>3.1</td>
</tr>
</tbody>
</table>