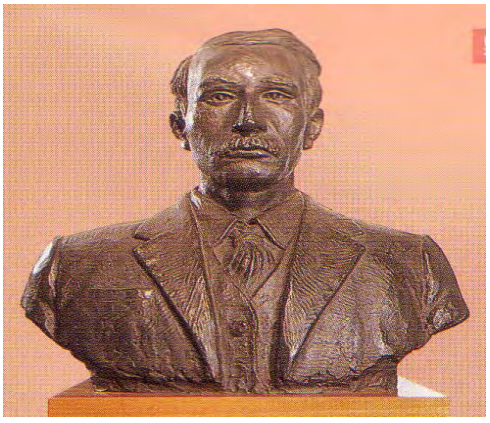
2-3 Yokohama Water Memorial Museum

Ground-1st Floor: Water History in Yokohama

Y01 Appearance of Museum



Y02 Statue of Henry Palmer, Scottish water engineer

Y03 Symbol of water

Y04 Wooden water supply system

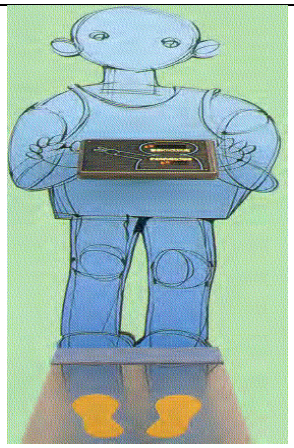
Y05 Kitchen of an ordinal citizen's house when modern water supply system introduced

Y06 Emergency water supply system

Y07 Rainbow tunnel- water planet

Y08 Mini theater

Y09 Water production process

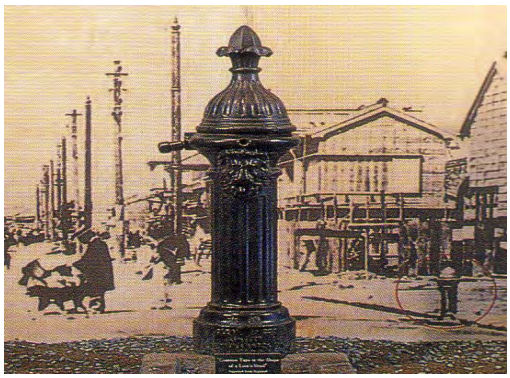


Y10 Human body & water

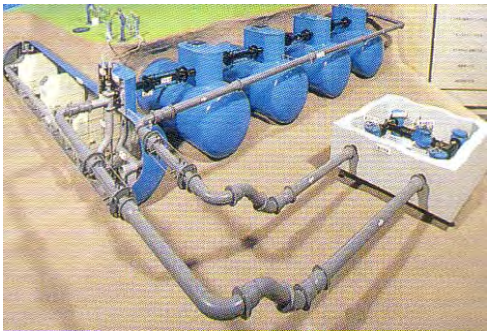
2-4 Water Supply Engineering Museum, Yokohama

Y11 Appearance of Museum

Y12 Tools for construction



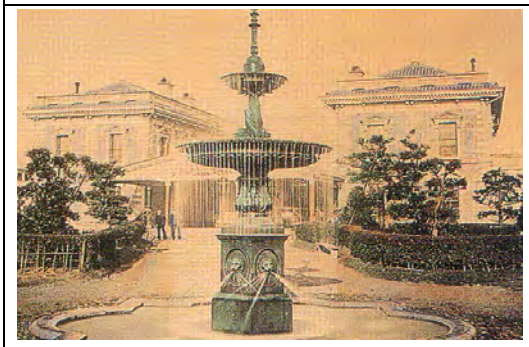
Y13 Dragonhead of public fountain



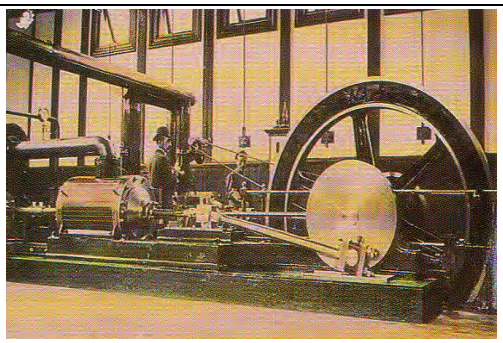
Y14 Circulating underground emergency reservoir

Y15 Water production system

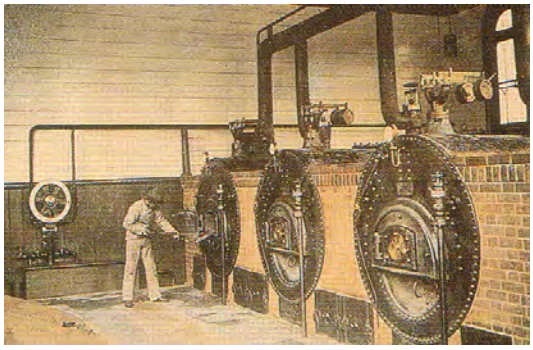
Y16 Water leakage detection tools



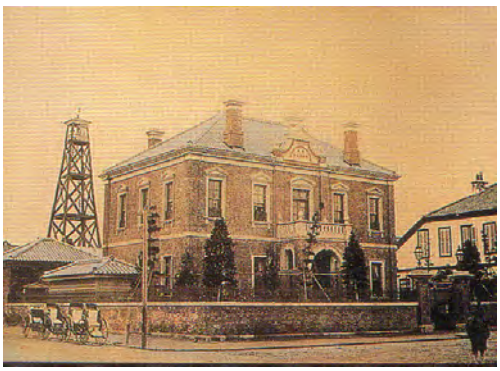
Y17 Public fountain in front of station



Y18 Intake station driven by steam engine



Y19 Steam engine driven by boiler



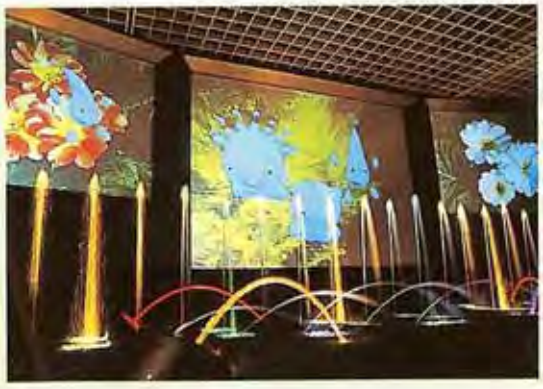
Y20 Water supply office in 1887

2-5 Water Science Museum of Kobe

GF

K01 Appearance of Museum

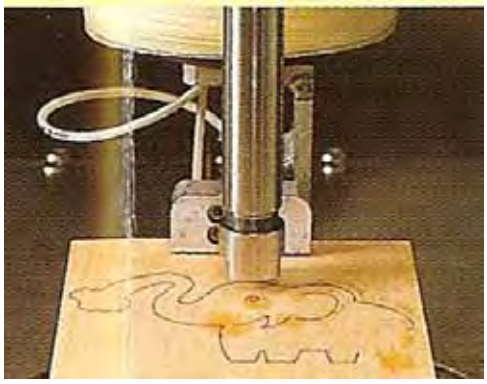
K02 The earth- water planet



K03 Theme theater

K04 Theme theater

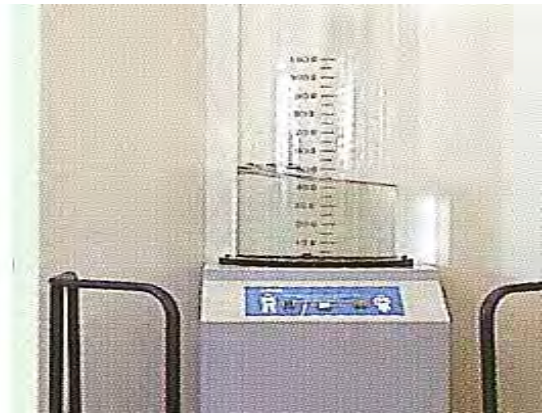
K05 Water science-water circus



K06 Aqua cutter

K07 Floating bubble

K08 Laboratory of water



K09 Human body and water

K10 Around the world

K11 Inside the ordinal family kitchen

APPENDIX-12

The Study Team's Activities for Improvement of NRW Reduction

Several discussions and meetings on NRW were held among the study team and TWWC counterparts for improvement of the activities. Through the discussions the study team introduced the efforts on reduction of NRW to low level by waterworks of Japanese large cities and recommended the methods for further reduction of NRW by TWWC.

The major seminars, workshops and site surveys regarding to NRW reduction are summarized in this Appendix.

Appendix-12.1

THE STUDY

ON

WATER SUPPLY SYSTEM RESISTANT TO EARTHQUAKES

IN

TEHRAN MUNICIPALITY

IN

THE ISLAMIC REPUBLIC OF IRAN

Seminar of Leakage Prevention 1

2005JUL

CONTENT

Factors of leakage

Leakage means water flows from

- damaged pipe
- loose joint
- pipe inside

The factors of leakage can be classified into two types.

Natural factors

- Earthquakes or volcanic activities: Pipes will be damaged totally, especially the joints.
- Ground subsidence: Pipes will be damaged.
- Aging pipes
- Corrosions:
  (1) Micro cell corrosion: Micro cell appears at buried pipe when surroundings, surface conditions and compositions have changed even the change is not so remarkable. Corrosion happens at anodic pipe.
  (2) Macro cell corrosion: Electric potential differences between different metals, concrete and soils make macro cell of anode and cathode happen. Corrosion happens at anodic pipe.

Artificial factors

Traffic load:
Pipes under the roads with heavy traffic are damaged because of constant shocking and overload.

Fault construction:
It is caused because of inexperienced and unskilled staff and inappropriate burying works.

Damages from other constructions:
It is caused because of the increase of construction works and buried objects.

Electric corrosion:
Electric current leaking from trains runs into buried pipes and goes out in the neighborhood of transformer station. Buried pipes are corroded during this process.

External and internal factors of leakage

Water supply facilities consist of tank, intake, raw water transmission, water treatment, purified water transmission, distribution facilities and service pipes at the end. Besides, leakage factors can be classified roughly as following table.

The target of leakage prevention countermeasures is generally regarded as purified water. Therefore, the following factors are relevant from distribution facilities to service facilities.

Table-1　Factors of leakage

<table>
<tr><th>Internal factors</th><th>External factors</th></tr>
<tr><td>Relevant to pipe materials</td><td>Relevant to pipe duct</td></tr>
<tr><td>・Materials and structures of pipes, joints and attachments were not well at beginning.
・Intensity drops down because of corrosion.
・Materials are aging.</td><td rowspan="2">・Traffic load increases.
・ Cavities occur around pipes because of unsolved leakage.
・ Ground movement.
・Pipe breaks when pipe inside is frozen.
・Differences between design and reality.
・Too much external pressure.
・Soil pollution because of factory waste liquid.</td></tr>
<tr><td>Relevant to design and construction skills</td></tr>
<tr><td rowspan="2">・Fault design.
・Fault connections of joints.
・Not buried well.
・In touch with other structures（not protected well）.
・Not anti-corrosion.
・Erosion occurs because of electric potential differences between different metals.</td><td>Relevant to other constructions and disasters</td></tr>
<tr><td>・Damaged by other constructions.*1
・Burying environment changes because of other constructions.
・ground and roads move because of disasters such as earthquakes.</td></tr>
<tr><td>Relevant to pipe inside condition</td><td rowspan="2"></td></tr>
<tr><td>・Pressure, water quality（internal corrosion）.
・Water hammer.
・Temperature changes.</td></tr>
<tr><td colspan="2">Others</td></tr>
<tr><td colspan="2">・Complex factors.</td></tr>
</table>

*1: Other constructions-related leakage repair cases in Tokyo have been decreasing year by year as shown in following table.

Table-2　Other constructions-related leakage repair cases in Tokyo

Year	1982	1983	1984	1985	1986	1987	1988	1989
Natural leakage	12,027	10,000	9,282	8,886	7,980	8,412	5,244	4,504
Leakage from damaged pipes	3,791	4,146	3,739	3,623	4,319	5,032	3,642	3,285
Total	15,818	14,146	13,021	12,509	12,299	13,444	8,886	7,789

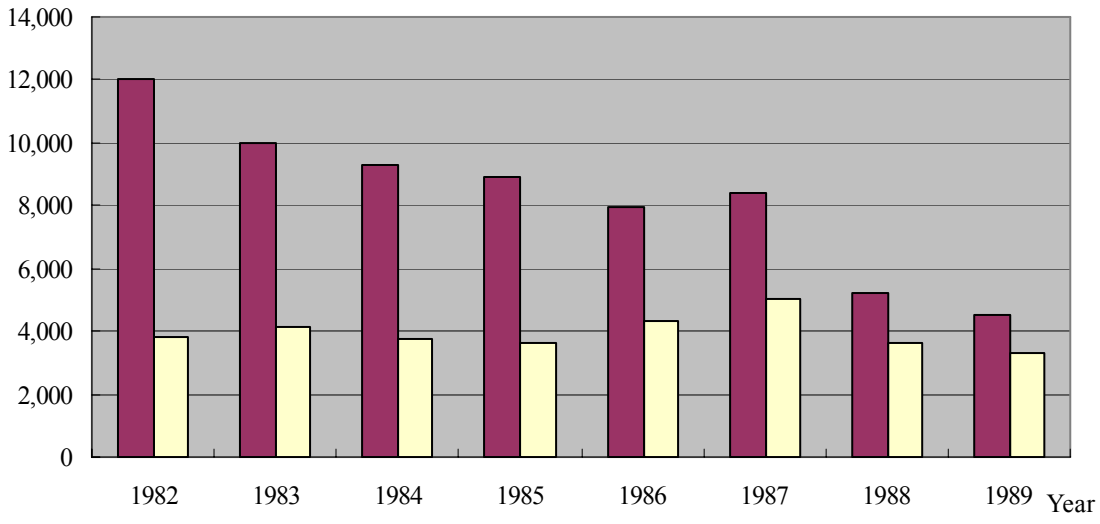


Fig 1

Affects by leakage

Water loss

: Pressure on finance------Because of insufficient water supply, water tariff cannot be charged and finally it results in financial problems.

: Insufficiency of facilities' functions-----Pumps or other equipment are required to cover insufficient water pressure.

: Deficient water supply------Water pressure goes down and it makes water flow become worse.

Secondary disasters

: Road subsidence------dirt and sand underground flow out and hinder traffic.

: Flood, slip accidents------water floods into basements. In winter leakage freezes on roads and causes slip accidents.

: Water pollution in pipes------pressure in pipe becomes negative pressure when stop using water. At the same time dirty water flows into pipe through leak hole and causes water pollution.

Leakage types and locations

There are two types of leakage, which are surface leakage and underground leakage.

- Surface leakage goes out to surface.
- Underground leakage goes down to underground.

Table-3 Comparison of surface leak and underground leak

Item	Surface leak	Underground leak
Location	・Water goes out to surface.	・Water goes down to underground.
Discovery	・Easy to discover. ・Noticed by residents.	・Difficult to discover. ・Planned survey required.
Soil	・Usually happens in loam layer.	・Usually happens in sand layer.
Pavement	・Rarely happens in high class pavement.	・Usually happens in high class pavement.
Leakage volume	・Generally leakage volume is huge.	・Small leakage ・But it increases if no repair. ・A flow channel underground will be made
Sewage	・Usually happens in areas having no sewage systems.	・Usually happens in areas with sewage systems.

Types of pipes and attachments

- Pipes
  There are transmission pipe, distribution pipe and service pipe.

- Accidents happening on pipe body
  Crack, breakage, corrosion, damage and connection-related accidents are included.

- Attachments
  There are gate valve, hydrant, air valve, stop valve and cooperation valve.

Methods for leakage survey

Regarding leakage prevention countermeasures

The meaning of leakage survey is to discover abnormal leak out (leakage) which hides underground and cannot be found from surface. In addition, it aims at supplying water much more smoothly and making water resources, which are purified with high cost, used more effectively.

Leakage survey is carried out because of following reasons.

- To improve effective ratio.
- To decrease ineffective ratio.
- To prevent secondary disasters resulting from leakage.
- To save power cost.
- To respond to deficient water supply.
- To be a kind of water shortage countermeasure.
- To collect every kind of information.
- To improve pipe-related facilities.

System of leakage prevention

In Tokyo, the leakage control measures that have been taken are as following

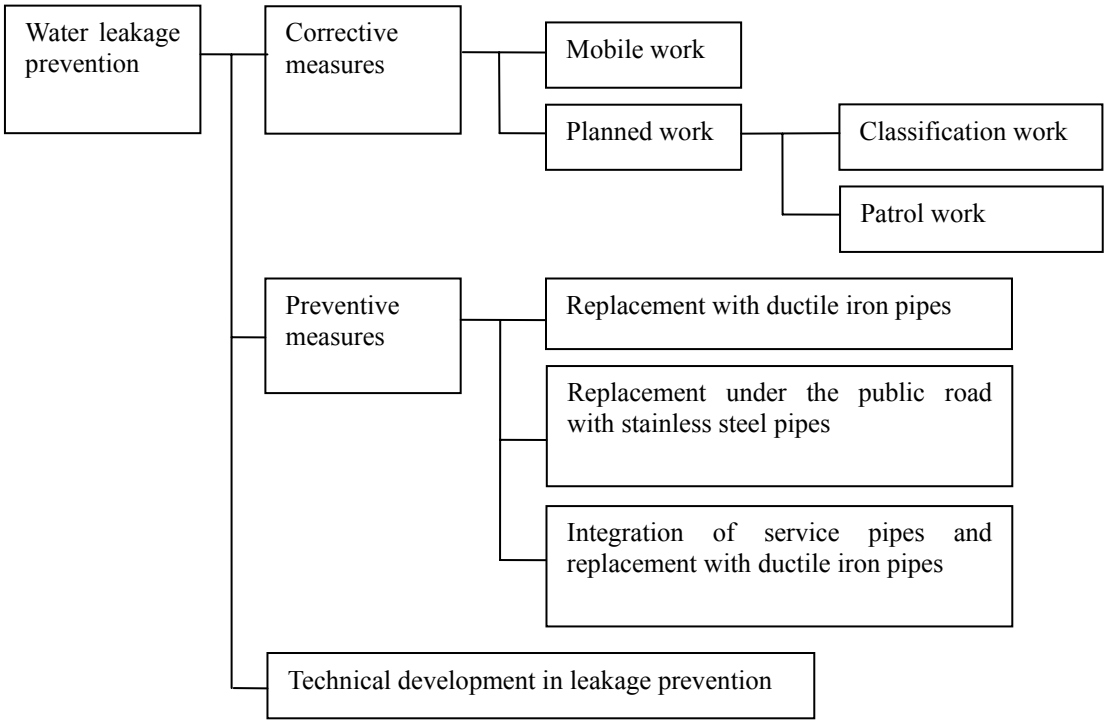


Table-4 Leakage prevention countermeasures

Classification	Item	Countermeasure
Basic strategies	Preparation for leakage prevention	To assure finance and staff for leakage prevention. To prepare documents（pipe drawings and block drawings, etc.）. To set up target areas and install equipment for flow measurement.
	Implementation of surveys	Analysis of distribution and leakage, pressure measurement, analysis of leakage factors and leakage types.
	Research and development of pipe materials	To develop new materials for distribution pipes and service pipes and related joints and attachments.
	Technical development	To research new methods for leakage measurement, buried pipe detection, leakage survey and leakage repair.
Urgent strategies	Mobile work	To repair ground leakage immediately.
	Planning work	To discover and repair underground leakage as soon as possible.
Preventive strategies	Waterworks plan	To draw up plans considering leakage prevention.
	Design and construction of water supply facilities	Earthquake-proof, durability, corrosion resistance, water tightness.
	Replacement of aging pipes	Replacement of distribution pipes and service pipes（including changing materials）
Preventive strategies	Improvement on water supply equipment	Integration of pipes across road.
	Pipe protection	To install meters near the boundary of public area and private area. To use anti-corrosion and leakage preventive attachments. To reinforce elbows.
	Cut off remaining pipes	To cut off remaining pipes completely at branch connections.
	Patrol work	To instruct and supervise other constructions in order to prevent pipes from being damaged.
	Pressure adjustment	To divide distribution systems. To install reduce valves.

Details of mobile work and planning work

Leakage survey includes mobile work and planning work. Mobile work aims at repairing surface leakage immediately. Usually it is carried out while leakage is found and noticed by residents. Sometimes patrol work is also implemented in parallel. This kind of work corresponds to leak conditions in a short time so it is called mobile work. On the contrary, planning work aims at discovering and repairing underground leak. It is the bare bone of leakage prevention.

Planning work includes

- patrol work
- classification work

Working procedures are as following:

Preparation
- Establish structural plan for construction
- Install equipment for flow measurement
- Prepare drawings
- Set up blocks
- Prepare equipment and machines

Preliminary survey
- Analyze distribution
- Analyze leakage volume

Planning
- Draw up annual plans
- Discuss working methods

Implementation
- Site confirmation
- Measure leakage volume
- Leakage detection
- Find out leak point
- Repair leakage
- Verify the effect of leakage prevention

Evaluation
- Discuss the effect of leakage prevention

Preparation

(1) Structural plan for construction

Before carrying out the work, it is necessary to make sure following items.
- required budget
- numbers of target blocks
- working methods
- working period
- numbers of staff

(2) Equipment for flow measurement

The purposes of installation are as following:
- to measure leakage volume
- to set up the goal of survey

The equipment for flow measurement means
- the installation of block meter box

(3) Required drawings

While doing leakage survey, following drawings are required.
- Block drawings
- Piping drawings（construction year, diameter, pipe material, depth, gate valves, hydrants, off set of gate valves.）

(4) Set up blocks

The purposes are described below:
- It is difficult to carry out the work in all area at the same time.
- To improve work efficiency.

According to budget and area scale, blocks are set up by the length of distribution pipe（**km/block）.

(5) Preparation of equipment and machines

Following equipment and machines are required.

- Measurement equipment
- Valve opener
- Sound bar, electronic leak detector
- Light fixture such as generator
- Recording charts
- Telecommunication apparatus

Preliminary survey

(1) What pipe does leakage exist in?

Pipes include

- transmission pipes
- distribution pipes
- service pipes

It is necessary to carry out a survey on current leak conditions in each kind of pipe.

Leakage prevention plan

To implement leakage prevention work as planned, it is necessary to set up the target goal of leakage prevention.

(1)Target goal should be decided in accordance with following factors.

- Block scale
- Sizes of facilities, budget, working period
- Repetition of surface leakage, previous leakage data

(2) Annual plan

Annual plan is drawn up in advance to decide every year's

- target blocks
- budget and working period of each target block

(3) Working methods

Working methods are decided

- in advance
- by studying each block's condition.

While working actually,

- site survey
- survey on current leakage conditions
- leakage detection
- leakage repair
- effect verification
- evaluation

are also included.

(1) Why should site survey be done?

Site survey is carried out to

- confirm survey area
- confirm target block's condition（traffic load, geography, pressure and shopping areas, etc.）
- check functions of valves and hydrants. Locations and functions of stop valves are also checked if necessary.
- decide working period and numbers of staff.
- to draw up action plans.

(2) The actual leakage condition in target block

Measurement of leakage volume before leakage survey is carried out to understand

- how much the leakage volume exists in the block.
- how much the repetitive leakage volume exists in the block.

Measurement of leakage volume is implemented at all pipes in target block. It is contrary to leakage detection, which is kind of point or line survey, it is considered as a plane survey method.

Repetitive leakage means leakage happens after leakage survey and repair. Leakage prevention is regarded as a war against repetitive leakage.

(3) The importance of pressure measurement

- To know the distribution of water pressure in target block.
- To confirm if there is any pipe with abnormal pressure.

(4) Leakage detection

Leakage detection includes point survey and line survey.

What is line survey?

It means to detect leakage through each pipe.

- To detect service pipes in household meter boxes.
- To detect distribution pipes by standing at the top ground of pipes.
- Equipment and machines to use are sound bar, electronic leakage detector, time integral leakage detector, correlator and wave monitor.

What is point survey?

It means to specify the leak point, which is discovered during line survey. Survey is conducted per "point of a pipeline."

Equipment and machines to use are electronic leakage detector, correlator, and boring bar.

What is manhole supplementary survey?

It means to recheck if leakage discovered during point or line survey flows into manholes nearby.

Equipment and machines to use are electronic leakage detector, light fixture, manhole opener, and oxygen concentration measure.

(5) Leakage repair

At distribution pipes, following methods are used.

- Repair band
- Lining repair
- Pipe in pipe
- Others

At service pipes, following methods are used.

・Freezing method
・Stuffing method
・Others

(6) Why should leakage volume be measured after repairing leakage?
Measurement before leakage survey：to understand the actual leakage volume.
Measurement after leakage survey：to understand the effect of leakage prevention.

(7) Evaluation
The effect of leakage survey can be realized by
・counting total leakage volume of each repaired point.
・comparing the results of flow measurements before and after survey.

Patrol work

It includes"leakage survey and leakage repair". However, measurement of leakage volume is sometimes carried out if necessary.
The problem is that it tends to discover large-scale leakages.

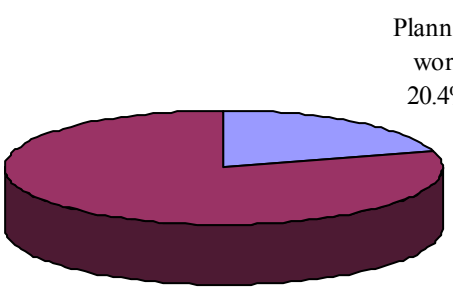
Classification work

It is carried out to measure leakage volume and take advantage of the result of measurement.
According to the measurement, blocks are divided to 3 levels by leakage volumes.
・Small leak block
・Middle leak block
・Large leak block
（The volume for classification is decided by block scales and leak scales.）

By classifying blocks, works can be implemented more reasonably and efficiently.
・In small leak blocks-----mobile work
・In middle leak blocks-----patrol work
・In large leak blocks-----thorough survey on underground leak
-----Route selection for replacement of distribution pipes
-----Effect evaluation（measurement of leakage volume after survey）
Feature：The purpose of work is clear. It enhances working willingness.

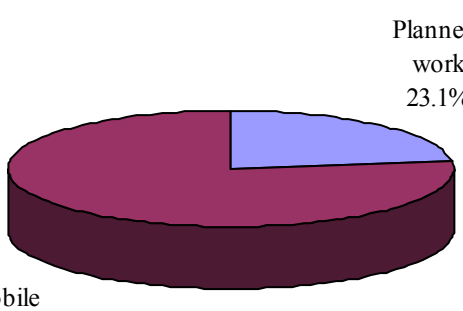
Sample [in Tokyo 1997]
Comparison between Mobile work and Planned work

(Cases)



Fig

(Volume)



Fig

(1) Where

Leak noise means the water sound transmitting from damaged pipe (leak hole) to outside. It is also a dangerous signal to notice us that pipe has been damaged. Following drawing shows how the leak noise happens from the damaged point of the pipe.

a：Comparatively low sound happens in ①pipe inside and ④swirls.

b：Low sound and high sound both happen in ②the edge of damaged point and ③ pipe inside.

c：While water flows out from the edge of damaged point to ⑥ the cavity holes underground, high sound happens because air and water mix.

d：Compared to (c) , the sound level is lower while water flows out from the edge of damaged point to water area in soil.

e：The frequency of leak noise ranges from low level（under 1kHz）to high level（above 1kHz）. It is said that audible sound for human beings is from 0.5kHz～2kHz.

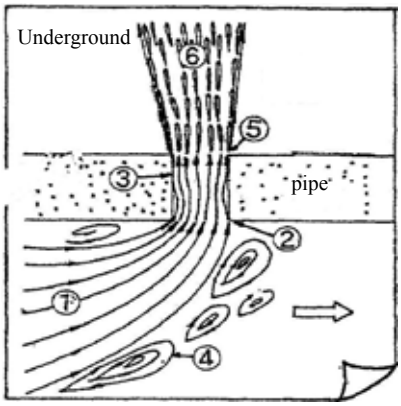


Fig5

(2) What is secondary noise

Secondary noise is generated by stream current from leak hole. It can be classified into two types.

Percussive noise：It happens when water runs through the surroundings of cavity walls which result from leakage.

Striking noise：It happens when water sand and rocks go through pipes or cavity walls.

(3) The same noise does not happen twice.

The reasons are as following:

- damaged shapes are different
- pipe materials are different
- buried conditions are different
- water pressures are different

(4) Dose leak noise change when time goes by?

Leak noise change because the water pressure in the pipe varies according to

- water consumption
- distribution pressure

Therefore, leak noise changes when time goes by.

(5) Are leak shapes and leak velocities difference?

Leak noises are different and complicated because the sizes and shapes of damaged points are not the same.

The frequency of leak noise depends on the velocity at leak point. When the velocity is fast, it

makes high frequency noise happen. On the contrary, when the velocity is slow, it usually makes low frequency noise happen.

To be concrete,

a：High sound happens when leak point is small and water pressure is high.

b：Low sound happens when leak point is large and out flow is huge.

(6) Regarding the change of water pressure

Audibility of leak noise

- When water pressure is low, it becomes low.
- When water pressure is high, it becomes high.
- But when water pressure reaches to an extend, it reaches a saturation point, too.

(7) Is it different according surrounding conditions?

Leak noise varies

by leak volume which is affected by buried depth and surrounding soil pressure.

Regarding the transmission of leak noise

(1) How does leak noise transmit?

A spherical wave is created around the damaged point.

And it is transmitted to a distance of the damaged point by a plane wave.

(2) Where does leak noise transmit to?

The velocity inside the pipe is about 1,400m/sec

The velocity in soil, when it is sandy soil→ about 250m～700m/sec

when it is loam→ about 1,000m～2,000m/sec

(3) Is transmission velocity different by pipe materials and diameters?

Leak noise differs according to pipe materials and diameters.

When the pipe is distribution pipe

In the case of distribution pipe

(compared to the diameter, pipe thickness is thin such as DIP),

$V=\left[(E_V/p)/(1+EV/E\times D/d)\right]^{1/2}$

（The formula of the velocity from which the pressure of a water hammer is transmitted） is used.

When the pipe is service pipe

In the case of service pipe

(compared to the diameter, pipe thickness is thick such as LP, SSP),

$V=\left[(E_V/p)/[1+2Ev(r_2^2+r_1^2)/E(r_2^2-r_1^2)]\right]^{1/2}$ is used.

Table-5 (Reference) Velocity of each pipe material and diameter

Material	Diameter	Velocity of transmission（m/s）
DIP, DP, TYTON	φ 100	1,340
Mechanical joint	φ 100	1,330
Socket	φ 100	1,320
SSP	φ 20	1,300
SP	φ 100	1,290
LP	φ 13	1,130
AC	φ 100	1,110
PVC	φ 13	640

(4) Does the velocity of transmission change at duplex pipes?

Velocity changes at joint point with diffrent pipe material or diameter.

The reasons are as following:

a：Pipe material・diameter changes

b：Elastic coefficient changes

（Note）Elastic coefficient: While the same elasticity is pressed, asymmetry occurs in proportion. The propotionality factor in this relational expression is called elastic coefficient. The value in non-metal pipe is larger than metal pipe.

(5) Comparison of metal pipe and non-metal pipe

Non-metal pipe

Compared to metal pipe, the velocity of transmission is slower and the distance is shorter. The reason exists in elastic coefficent.

Table-6 (Reference) Inclination of the distance of leak transmission

Item	Long distance	Short distance
Diameter	Small diameter	Large diameter
Material	Metal	Non-metal
Year	New pipe	Old pipe
Joint	welding・metal materials	Robber
Leak noise	Low	High

(6) How does the velocity change when there is scale sticking to pipe inside?

The velocity of transmission changes

① according to the conditons of scale.

② the velocity slows down when the amount of scale is large.

(7) Does leak noise change at different places and distances?

① At leak point（damaged point）

Noises with different frequency such as high, normal, low frequencies occure at leak point.

② Far from the damaged point

At a far distance, noises with high frequency decrease and finally only low sound remains.

When leak noise travels far away,

a：noise with high frequency decreases sharply and finally disappears.

b：On the contrary, low frequency can last longer and transmit far.

Generally, if the noise is low, the leak point is considered being far away from the current location.

（Reference）Specific transmission distance of leak noise

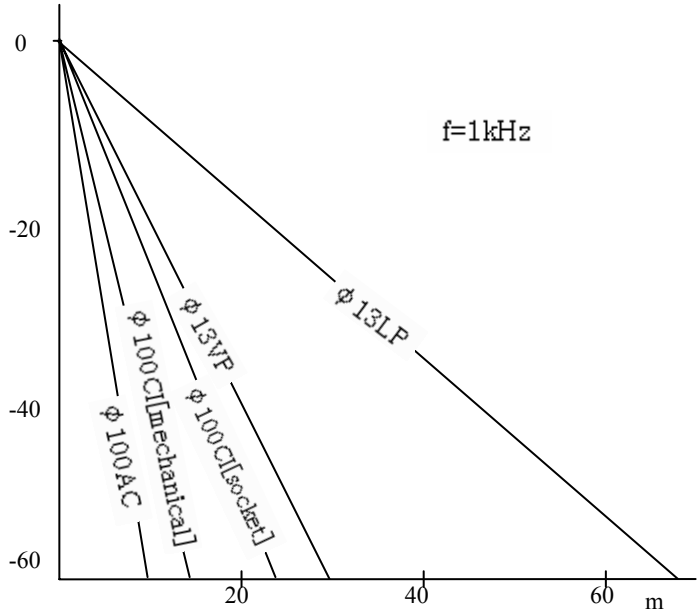


Fig6 Velocity of transmission

The inclination of the transmission distance of leak noise is as following（experimental value by different pipe materials when frequency band is 1kHz）

Service pipe（LP） ＞ PVC ＞ Distribution pipe（DIP＞AC）

While carrying out leakage survey, please remember the principle.

Noise similar to leak noise

Suspected noise：It is similar to leak noise and disturb leakage survey.

<u>Is there any method to distinguish suspected noises?</u>

(1) Noises from water flow in pipes

① Why does it happen?

a：When gate valves are limited.

b：When the velocity in pipe is very fast（such as cross pipe, T pipe, frequency band is about 0.2～3kHz）.

② How to distinguish it?

a：Check if the noises disappear when open and close valves.

(2) Noises happen when using water

① Why does it happen?

a：When cooking, doing laundry, flushing toilets or others（the same as leak noises, frequency band is about 0.5～3kHz）.

② How to distinguish it?

a：Check if meter is running.
b：Check the noises from meter's rotation and how long it continues.

(3) Noises from sewage systems

① Why does it happen?

a：When water is discharged to sewage pipes（frequency band is about 0.2～2kHz）.

② How to distinguish it?

a：The acousticity is different from leak noise.
b：Check if it continues.

(4) Noises from cars and trains

① Why does it happen?

a：When cars and trains pass through（frequency band is around 1～2kHz）.

② How to distinguish it?

a：Check if there is car or train passing around.
b：Check if noises continue and the audibility（variation in short time）.

(5) Noises from wind

① Why does it happen?

a：When wind blows though the metal part of sound bar for leakage survey or the cable of electronic leak detector（frequancy band is about 0.5～0.8kHz）.

② How to distinguish it?

a：Shut off wind by your body to check the influence from wind.
b：Make 5cm of the cable of electronic leak detector a loop and press it by your finger. Check if noises disappear（It is easy to tell it apart because the noise is a special sound）

（Note）When the wind speed is above 4m～5m, leak detection cannot be carried out because wind sound is too strong.

(6) Noises from electricity

① Why does it happen?

a：From electricity and cables.
b：From inverters and street lights（frequency band is about 0.05～0.5kHz）.

② How to distinguish it?

a：Check sound of alternating electrical current
b：Check if there is any electric equipment around.

(7) Noises from motors

① Why does it happen?

a：From vending machines
b：From air conditioners in buildings
c：From ventilators
d：From purification mixers
（frequency band is about 0.5～0.8kHz）

② How to distinguish it?

a：The noise is a continuous machinery sound and very different from leak noise.
b：Stop the machine and check if there is any sound left.

(8) Noises from buildings

① Why does it happen?

a : When noises in air（wind, air conditioners, motors, cars, trains）hit buildings, it makes new noises（frequency band is about 0.3～1kHz）.

② How to distinguish it?

a : Compare sounds from 2 or 3 buildings around and find out the acousticity different from leak noise.

Acoustic method

Acoustic mehtod for leakage survey is usde to detect the sound of lekage occuring in damaged pipe from

a：pipes in meter boxes or attachments
b：ground
c：others
It is also used to
d：confirm if there is any leakage in pipes
e：assume the leaking condition
f：make sure the leak point

“Leakage detection”is not a difficult skill. However, it is easy to find out leakage which is noisy but it is difficult to discover leakage with weak sound or in noisy places.

The big differences between a new comer and an experienced staff are the accuracy of detection, speed, operating efficiency of machines and correct judgment of every condition. However, the differences have been shrinking by the development of leakage detection equipment these years.

Table-7
(Reference) 7 items for the classification of leakage sounds and conditions for experienced staff

Item	High level sound (Above 1kHz)	Normal sound (0.5～1kHz)	Low level sound (Under 0.5kHz)
Leak hole	Small	Big	Very big
Leak shape	Complicated	Considrably simple	Simple
Leak flow	Very fast	Slow	Very slow
Pipe diameter	Small	Middle	Large
Pipe material	SP, SSP	DIP	AC, PVC, PE
Distance	Close	Normal	Far
Water pressure	High	Low	Very low

Leakage survey

Regarding the measurement of leakage volume

(1) Why is it necessary to measure leakage volume?

Measuring water volume before detection makes us understand the following matters of each block.

① Current condition
② Priority of implementing leakage survey
③ Methods to use
④ Target goal
⑤ Working period
⑥ Condition of repetitive leakage

And measuring leakage volume after detection makes us understand

① Remaining leakage
② Effect of leakage survey

(2) On the other hand, assumption of leakage without detection is carried out by using

① existing data and information
② distribution analysis
③ unaccounted-for-water

From effective water
Leakage volume is assumed by block distribution and statistical data of accounted-for-water.

From the variation of water level in distribution reservoirs
Leakage volume is assumed by the variation survey data such as the change of water level in distribution reservoirs.

From the measured data of main pipes
Leakage volume is assumed by the measured data (pressure, flow) of main pipes.

(3) Measurement of leakage volume
According to the measured distribution data,

① leakage volume is assumed as the lowest flow happening in midnight.
② However, the disadvantage is that the minimum flow includes water consumption, which affects the accuracy of leakage assumption.

Block leakage measurement while using water（Indirect method）

① Leakage volume is assumed as the minimum flow while using water.
② The advantage and disadvantage are
  a : compared to the direct method, the accuracy is lower because water consumption is included.
  b : compared to the direct method, it could be carried out by shorter work period and lower expenses and labor.

Leakage measurement under no water consumption（Direct method）

① Leakage volume is assumed after stop all water used in the block（close water valves）.

② The advantage and disadvantage are

a：it is the most accurate among all leakage mesurment methods.

b：Mostly it is carried out at night and it costs more money（labor cost, function survey on gate valves and water valves） and time.

Advanced leakage measurement（during the time without water consumption）

① Leakage volume is measured

a：while water is used.

b：The minimum flow (regarded as leakage volume) is measured（5 seconds to 1 minute） at midnight（2～3 hours）when no water is used.

② Features

a：Device（Elecmagnetic or ultra sonic flow meter）

should be equipped with automatic recorder which is available to measure flow and pressure by second.

b：Values are automatically measured. Therefore, it is easy to obtain highly accurate leakage rate.

Fundamental distribution analysis

Distribution analysis is used to understand how water is consumed and what details inside. It is very important basic information for analyzing the effect of previous works when planning leakage prevention projects.

Table-8 Distribution analysis

DISTRIBUTION	Total flow at the start point of distribution pipe ***Distribution total***			
	EFFCTIVE	Water which can be charged or used in waterworks bureaus ***Effective***		
		ACCOUNTED	Water which can be charged and used effectively ***Accounted for water***	
			Charged	1：Basic criteria for collecting water tariff 2：nonmetered tap and its water consumption
			Supplied	Water supplied to other waterworks bureaus.
			Others	Free of charge but covered by other accounting items as maintenance fee such as water used in parks, public toilets, fire fighting and fire fighting training programs.
		UNACCOUNTED	Water which can not be charged but used effectively ***Unaccounted for water***	
			Unmeasured	Water used effectively but not measured because of meter's insensitivity.
			Waterworks use	For washiing distribution pipes and service pipes while construction is under way or for drainage while carrying out leakage survey works. Moreover, water used in waterworks bureau inside especially distribution facilaties-related is also included.
			Others	Water for parks or fire fightings.
	INEFFCTIVE	Water which is used ineffectively ***Ineffective***		
		Leakage		Leakage from distribution pipes and service pipes（till meter）.
		Free of charge		Water for releasing trubid water or repair is regarded as the target of this item. It is not charged while collecting water tariff.
		Others		Ineffective water from distribution facilities damaged by other constructions or unknown water loss.

Data collection and filing work

Filing and analysis of survey results

It is very important to write reports to record detected leakages.

Information which should be recorded in the “leakage survey report” is as following:

① Date of survey
② Leakage location
③ Distribution pipe or service pipe
④ Public area or private area
⑤ Pipe material
⑥ Pipe diameter
⑦ Leak point
⑧ Leak volume
⑨ Leak condition

Pipe numbers are required in order to compile information, data and accident history of pipes.

“Report of repair results”

It is effective for gathering correct information（pipe materials, diameter, joint types, depth, occupied space）of leak related facilities and information.

Leakage results from various reasons. Generally, it is classified as the following table.

Table-9 Leakage conditions and reasons

Conditions	Reasons
Broken	Overload, shaking, defect burying
Hole	Corrosion, electric erosion
Crack	Water hammer, defect materials
Removal	Fault connections, overload, shaking
Others	Other constructions, fault constructions

Regarding the reasons for leakage

It is very rare that leakage is caused by only one simple reason. Usually leakage is caused by multiple and complicated reasons.

To analyze it

Compilations and counting of each item on leakage survey reports and repair reports such as pipe routes, work sites (areas), distribution system unit should be carried out, furthermore, numbers of leakage cases and prevented volume (detected leakage volume) should be indicated by the unit of km or km/Y. It makes comparison easier.

Reference: Water Supply in Tokyo

Promotion of Leakage Prevention Measures

We make it a rule to carry out repair work on the same day when the surface leakage is found under the 24-hour work system. The actual number of repairs was 24,186 cases during FY 2003. As for underground leakage, the potential leakage quantity is estimated by using the minimum night flow measurement method, and then leaks are detected by using electronic leak detectors, correlation type leak detectors, etc. During FY 2003, sub-mains totaling 3,689 km in length were investigated by the above methods. We have been engaged in preventive leakage control measures such as replacement of pipes and improvement of pipe materials, i.e., from cast iron to ductile cast iron for distribution pipes and from lead to stainless steel for service pipes laid under public roads.

In addition, the following measures have been adopted one after another. Since 1994 any leaks occurred on service pipes up to the meter inside the premises have been repaired and more than three lines of service pipes under a private road have been replaced by integrating them into one line of submains at the Waterworks Bureau's expense. Since 1998 existing lead pipes laid down from the branch of sub-mains to the meter have been replaced with stainless pipe financed by our budget.

We will continue to implement these measures to achieve the goal of a leakage rate of 4% in the future.

Corrosion

Regarding the types of corrosion

Definition of corrosion

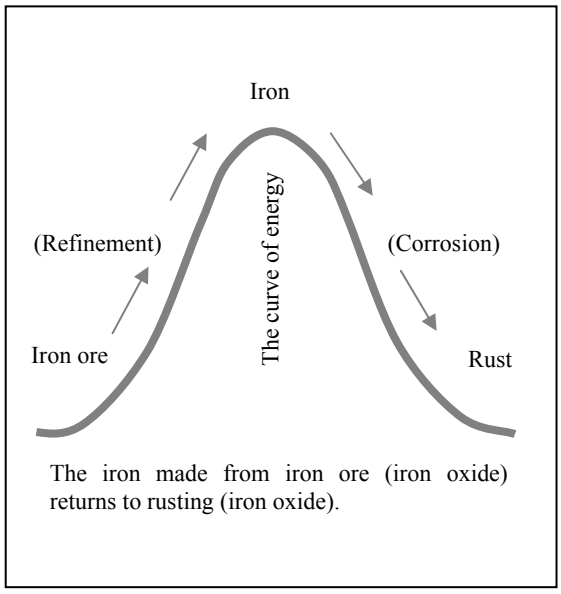


Fig 3

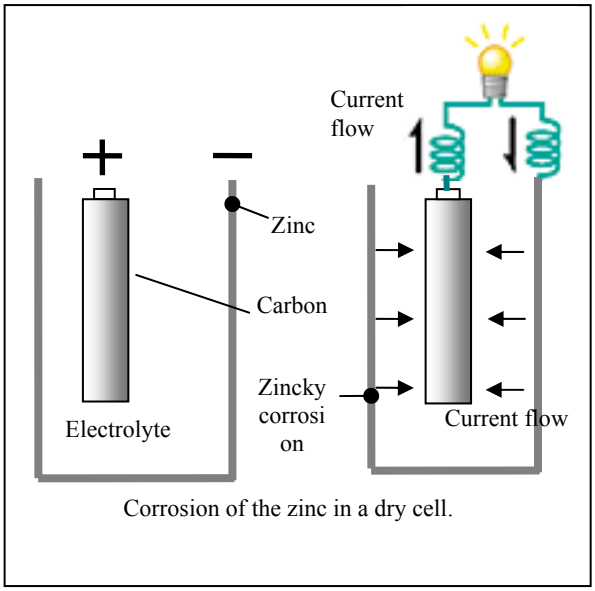


Fig 2

Corrosion means a phenomenon, which occurs when metal is corroded chemically by environmental reaction.

Thermodynamically speaking, except of some precious metal, most of metal such as iron and steel are unstable and have a feature returning to a stable rusty condition, which is like mineral ore.
To make metal corrosion happen, the existence of liquid water or high temperature is necessary. Corrosion occurring by electrochemical reaction with water is called wet corrosion. On the contrary, the one without water but with high temperature is called dry corrosion.

Classification of corrosion

・Metal corrosion could be classified to wet corrosion and dry corrosion, not limited to iron and steel.

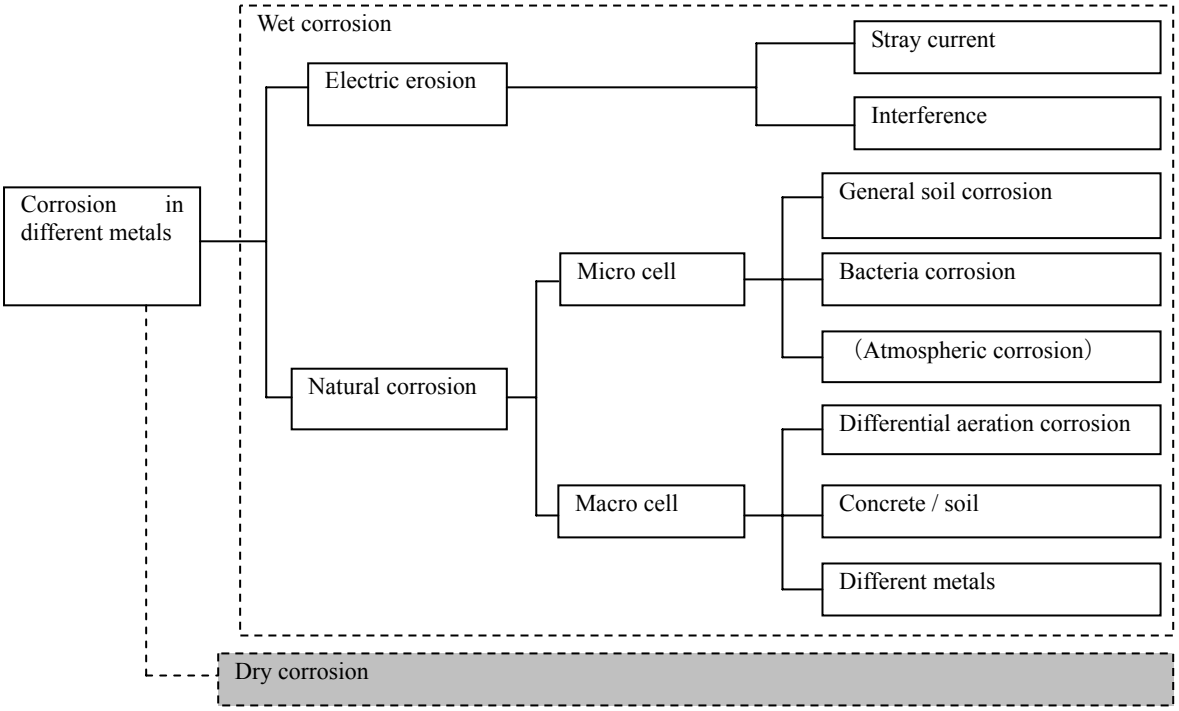


Fig 4

Corrosion occurring in pipes (iron and steel) buried in soil or water is wet corrosion, which means the corrosion occurs with the existence of water.

Wet corrosion is classified into electric erosion and natural corrosion. The former comes from stray current and the latter comes from soil and water. Moreover, natural corrosion includes micro cell corrosion on the surface of steel (generally called complete corrosion), corrosion from different metal's contact（galvanic corrosion）, bacteria corrosion, differential aeration corrosion and macro corrosion , which is caused from a potential difference from reinforcing bars in concrete.

Complete corrosion（Uniform corrosion）

When the surface of metal and the corrosive environment（water, soil and air） are the same, the corroded conditions will be the same. This phenomenon is called complete corrosion or uniform corrosion. When complete corrosion occurs in iron, no matter it is in air, water or soil, the movement is very slow, only 0.1mm/year at most. Therefore, facilities or structures will not be badly damaged. However, in reality, it is rare to see this kind of corrosion. Especially in soil or water, most of corrosion is like macro cell, partial corrosion, etc.

Partial corrosion

Because the differences of metal surfaces or environments, corrosion sometimes occurs intensively in one specific place. This phenomenon is called partial corrosion. Especially it tends to happen in very small place and make metal corroded with holes. The causes of partial corrosion mainly include galvanic cell, which occurs when different metals put together, concrete macro cell and macro cell, which is caused by differential aeration.

Electric erosion

When AC such as stray current leaking from electric railroads goes through buried structures such as pipes, it makes corrosion at start and end points. This phenomenon is called electric erosion（in a narrow sense）. Sometimes the leak of current penetrates in a short time. Additionally, galvanic cell corrosion, which was mentioned above, is sometimes regarded as one of erosion, too（in a broad sense）.

Others

Recently it has been known that special kinds of bacteria in acid soil, soil, ground water and rivers cause corrosion or make corrosion grow quickly. Particularly the corrosion caused by iron bacteria and chloric sulfate bacteria are mostly emphasized.

The reaction of corrosion

● Chemical reaction of wet corrosion

The metal corrosion in normal temperature range means the electrochemical reaction occurring under the existence of liquid water and oxygen (acid substances). The typical one is the corrosion reaction of iron (Fe) as following.

● In acid environment（Under pH4）

Reaction formula	＋electrode　$2H^+ + 2e^- \rightarrow H_2$
Reaction formula	－electrode　$Fe \rightarrow Fe^2 + 2e^-$
Total	$Fe + 2H^+ \rightarrow Fe^{2+} + H_2$

● In neutral environment（pH5～10）

Reaction formula	＋electrode　$1/2\ O^2 + H_2O + 2e\text{-} \rightarrow 2OH^-$
Reaction formula	－electrode　$Fe \rightarrow Fe^{2+} + 2e^-$
Total	$Fe + 1/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2OH^-$

Corrosion rarely occurs if pH is beyond 10. This is because alkaline reaction happens and makes an inactive membrane on the surface of iron.

Appendix-12.2

THE STUDY

ON

WATER SUPPLY SYSTEM RESISTANT TO EARTHQUAKES

IN

TEHRAN MUNICIPALITY

IN

THE ISLAMIC REPUBLIC OF IRAN

Seminar of Leakage Prevention 2

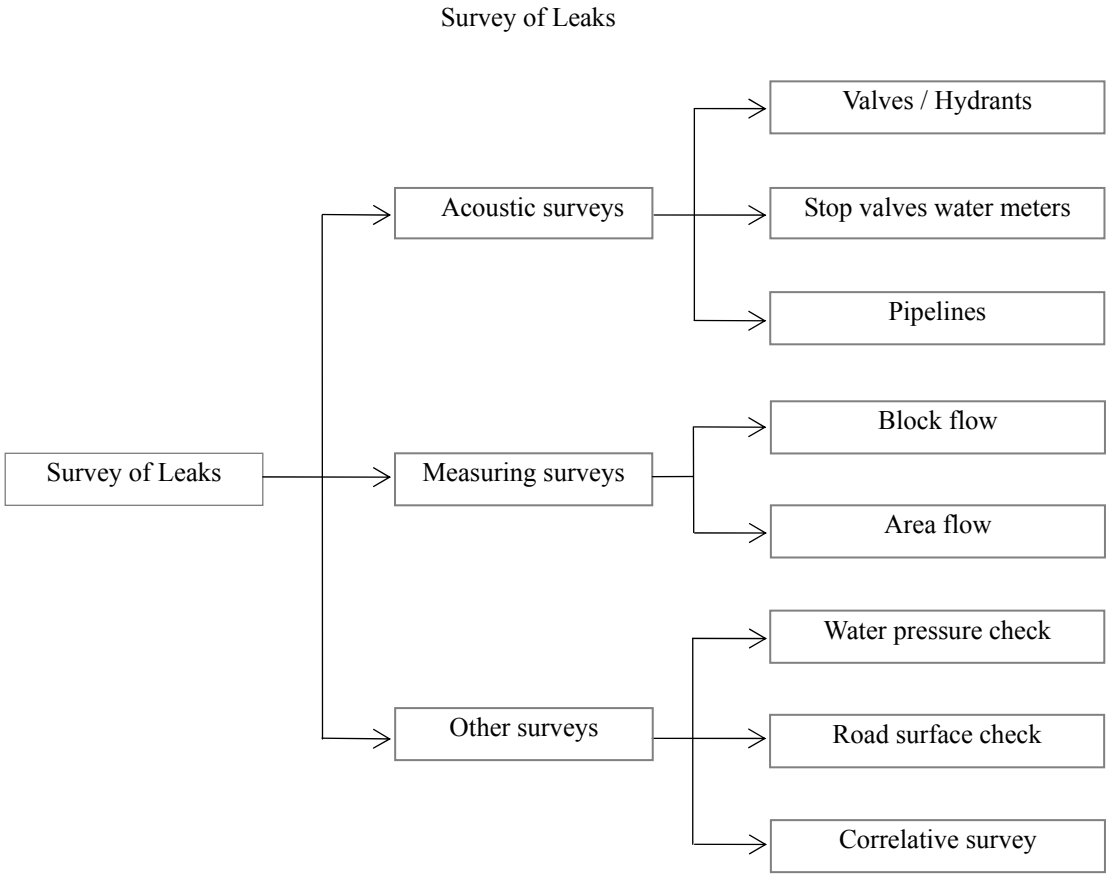
2005AUG

CONTENTS

Leakage detection equipments

Survey of Leaks

Survey methods can be divided into three types.
1) Acoustic surveys (locating leaks by detecting leakage sounds)
2) Measuring surveys (detecting leaks by measuring flows)
3) Others



In general in field leakage survey correlator (and geophones if necessary) is used.

Every district has the same equipment in general.

Each District equipment list [QUANTITY]

Item	District1	District2	District3	District4	District5	District6	total
Leak Noise Logger	1	1	1	1	1	1	6
Globe Geophone	2	2	2	2	2	2	12
Leakage Detector	1	1	1	1	1	1	6
Correlator	2	2	2	2	2	2	12
Metal Detector	5	1	4	4	6	4	24
Pipe Locator	2		1	1			4
Water Pressure logger	3		2				5

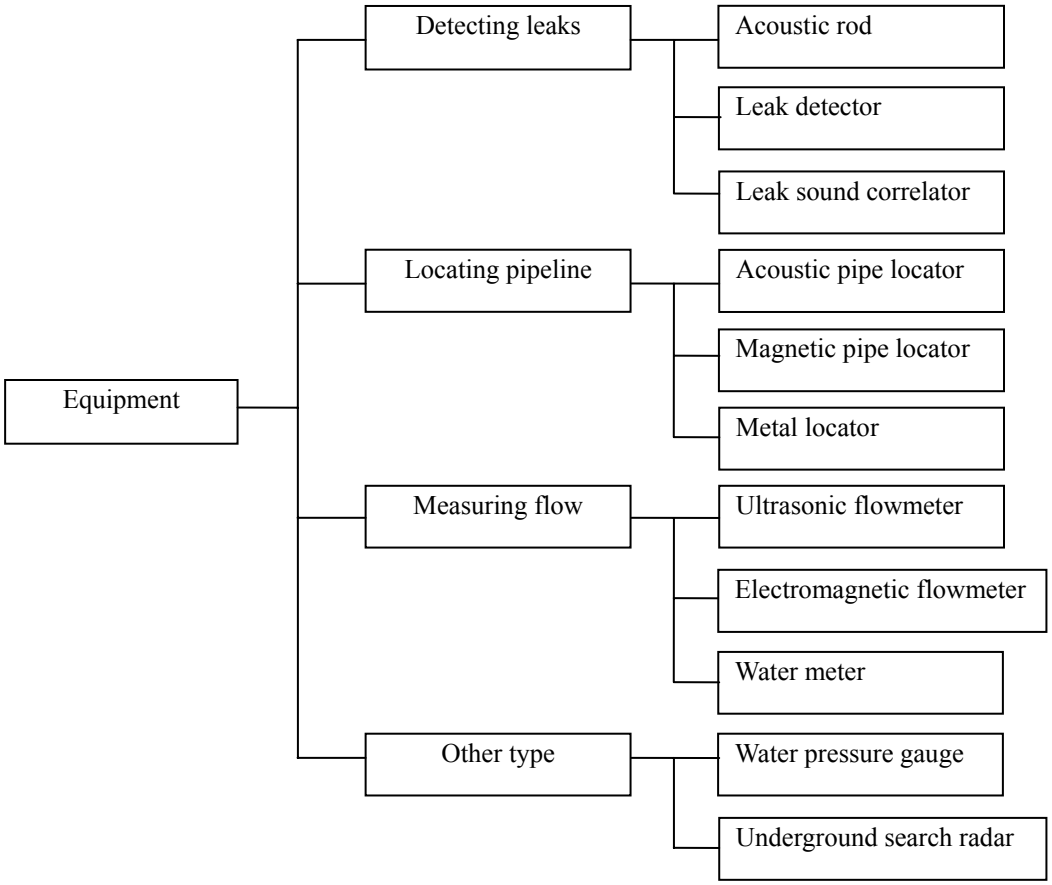
Tehran equipments are the same as those in Japan.

Acoustic method: In Japan it has become a necessary part of detection as well and still they use them. They use acoustic rod as a very important equipment in their detection.

In big cities instead the aforementioned equipments they use the time integral type leakage detector. (At present Tokyo water works and Toshiba are cooperating to develop this equipment).

In the following table the leakage equipments in Japan are listed.

Equipment for the Leakage Survey



Standard construction method	Application construction method	Special construction method
Acoustic Rod	Ultrasonic Flow meter	Subsurface Detector
Leak detector	Electromagnetic Flow meter	Regarding the Tracing Method
Metal locator	Time integral type leakage detector	Water Leak Detector Using Electromagnetic Waves
Hammer drill & Electric generator	Water pressure logger	Acoustic pipe locator
	Correlator	
	Leak noise logger	

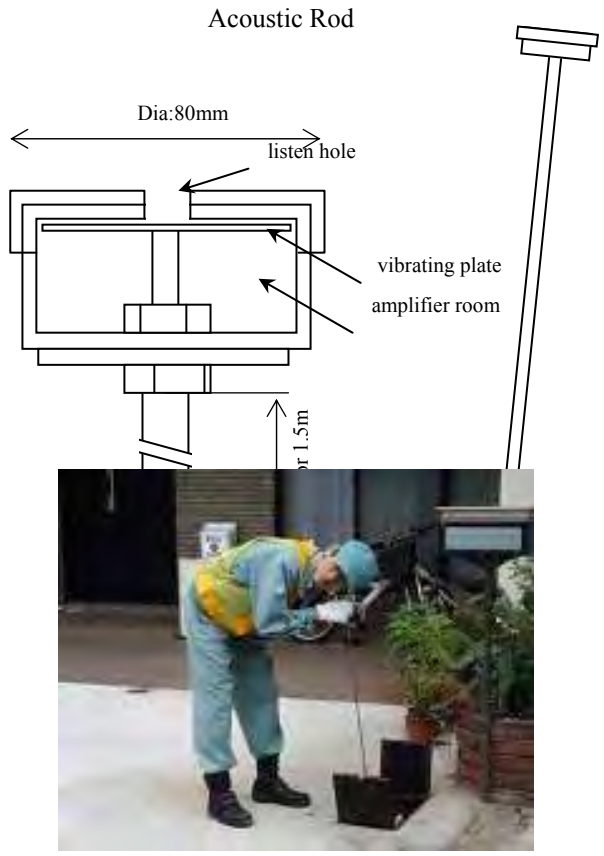
Equipment for Detecting Leaks

A. Acoustic Rod

The acoustic rod is a metal bar (7mm in diameter and 1.5m in length) equipped with a vibrating plate which catches leak sound by direct contact with valves, hydrants and pipes.

The acoustic rod is used only to determine the existence of leaks.

A leak detector is then used to detect the location.

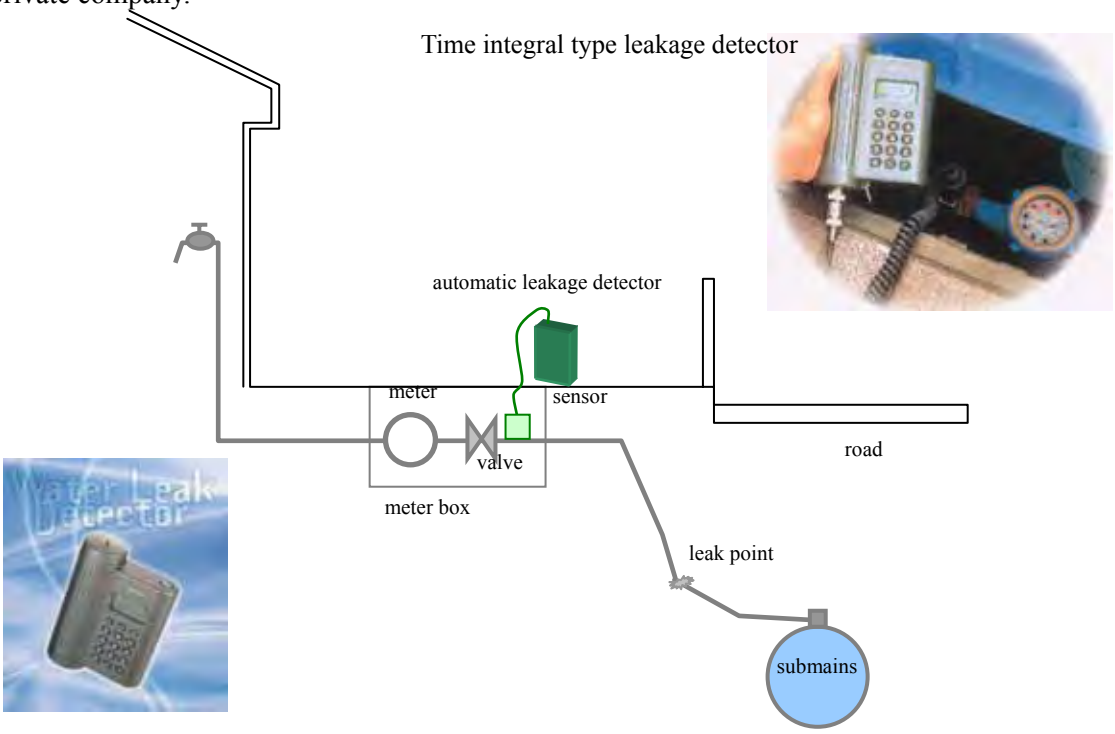


B. Time integral type leakage detector

This instrument makes use of the continuity of the leakage noise, and it can check whether the leakage exists on the pipe or not.

The usage of this instrument is as follows, to begin with, the operator sets the sensor on the exposed service pipe in customers' meter, secondly the instrument measures the propagation noise through the pipe for a time, accordingly, and automatic leakage inspector loses no time judging whether leakage exists or not. Effective length is about 20m from the sensor.

The measure of this instrument is not influenced by the noise of water use or traffic, is in need of no proficiency in this work. This instrument was developed by joint development with private company.



- As water meter survey is being done, simultaneous measurement is possible.
- Every two months each water meter should be checked.
  Because at the time of meter reading, the equipment is used for leakage detection, the speed of the process is lowered.
- Even if the occurrence is low, the existence of water leakage from the water meter to the connection should be checked six times a year.
- Data should be collected, analyzed, calculated regularly because it judges the existence or nonexistence of the leakage automatically and record them to avoid artificial mistakes.

(Leak detector staff is prone to misjudgment.)

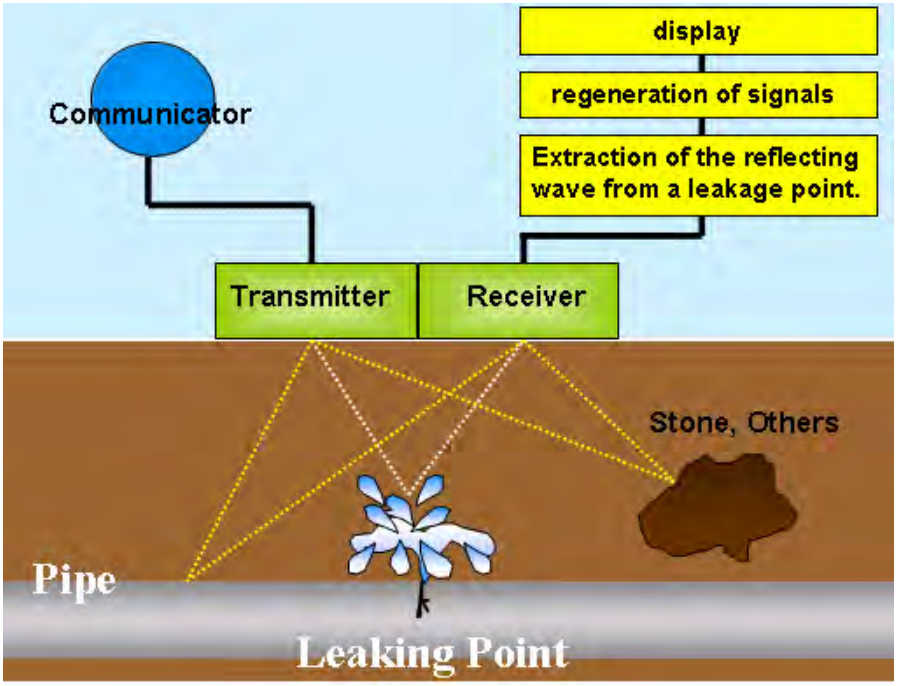
C. Water Leak Detector Using Electromagnetic Waves

This leak detector can identify a spot of water leakage by detecting fluctuations of reflected electromagnetic waves in accordance with the movement of leaking water and analyzing it.

Characteristics

- Underground water flow due to leakage is measured directly.
- Regardless of material, diameter survey could be done.
- Detection could be done day and night.
- Pinpoint search is possible.

D.



Regarding the Tracing Method

The tracing method is a new method developed for detecting any kinds of leakage. In the past, acoustic method using leaking sounds to find out leak points was mainly adopted. However, it has limitations and should be carried out under many preconditions as follows:

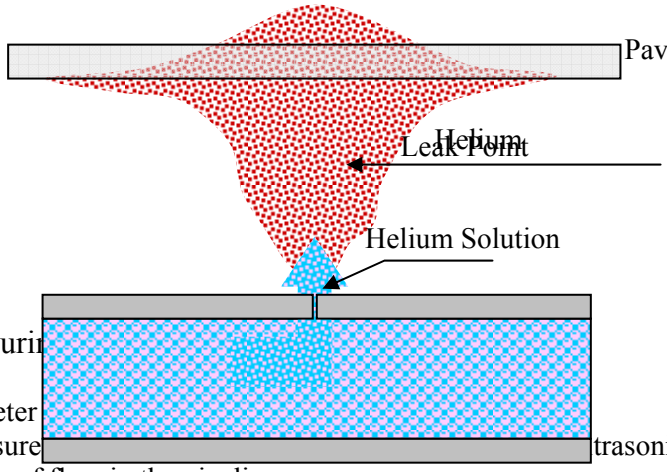
- Excellent skills of identifying different sounds
- Water pressure above 0.1Mp
- Difficulty to find out leakage without sounds
- Easily affected by peoples' activities, other noises and the c consumption

From above, it is easy to know that traditional acoustic method is not an effective way to carry out leakage detection. On the contrary, the new tracing method, which uses the solution or gas mixed with Helium to detect leakage, could be carried out in any places no matter the pipe's condition is existing pipe, new pipe, no water or under supply. Leak points could be found by detecting the penetration of Helium gas. Therefore, it is able to conduct detection works more effectively by adopting this method which could ignore strict conditions.

Principle

To begin with, Helium should be dissolved into water, than injected into water supply pipelines. Afterwards, Helium in the solution which spouts out from leak points will flee out by atmospheric pressure and diffuse to the ground (it is like that while opening the tab of a carbonated drink or beer, carbonic acid flees out while contacting atmosphere and becomes

bubbles).
Leak points could be found by detecting the concentration of helium.



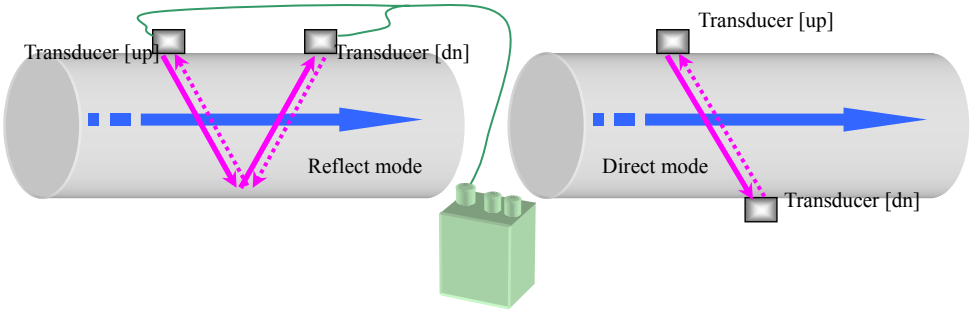
Equipment for Measuri

A. Ultrasonic Flow meter

This instrument measure trasonic waves as they vary relative to the rate of flow in the pipeline.

It is basically a sensor which transmits and receives radio waves and can be installed on the existing pipeline without interrupting the pipes.

Ultrasonic Flowmeter



B. Electromagnetic Flow meter

This instrument measures pipeline flow from the electric force generated by moving conductors such as water in a magnetic field.

It is degree of accuracy is high; however the flow meter must be installed in the pipeline.

Electromagnetic Flowmeter

C. Water Meter

Water meters are commonly used on service pipelines and may be used to measure the leakage

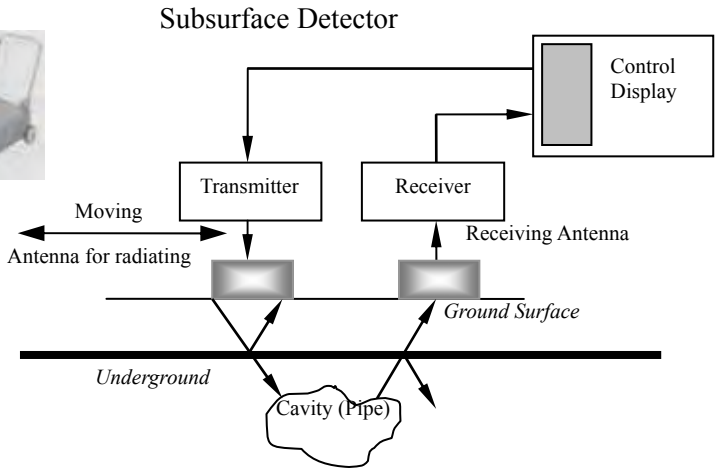
flow.

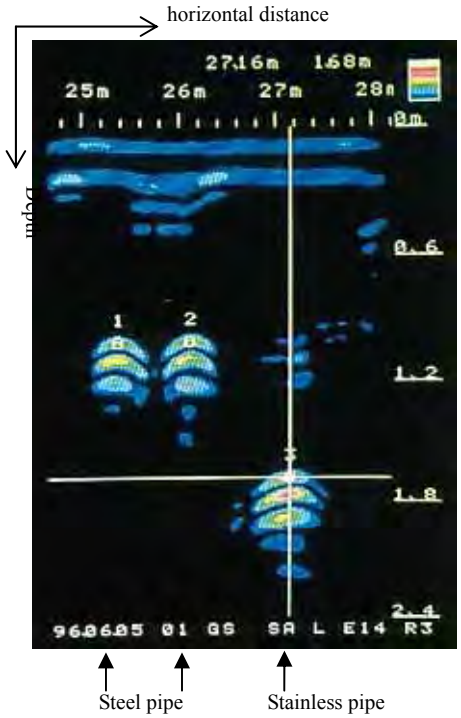
Other Types of Equipment

A. Subsurface Detector

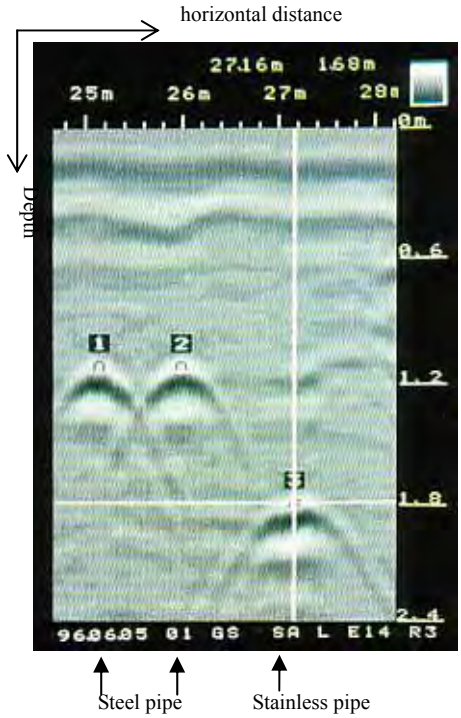
This device emits radio waves which propagate underground from an above ground antenna and picks up the reflected waves on the radar screen monitoring the underground conditions.

The radio waves are bounced back by buried pipes, cables, voids, difference in soil textures, etc., and their different induction rates are shown as images.





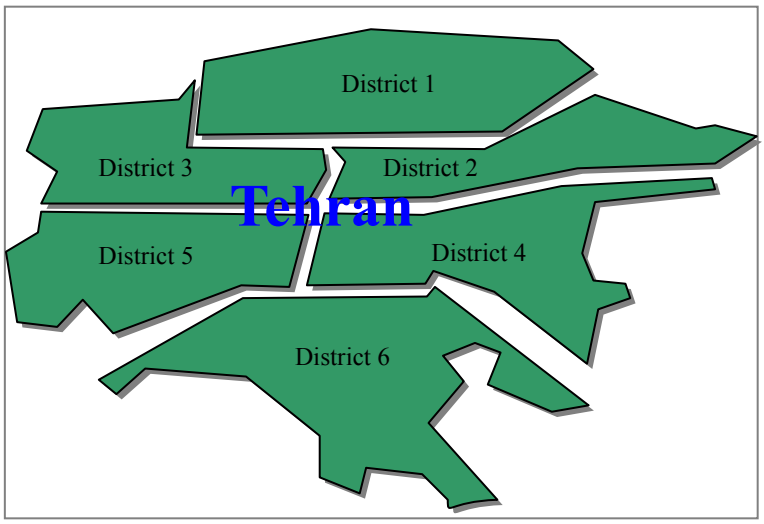
Example output [B mode color]



Example output [B mode mono]

Report of leakage

Tehran water supply system is divided into 6 districts, each of which according to their area and location plus the relevant emergency post comprises 2 to 4 Emergency Posts.



District 1	Zarghandeh	Niavaran	Shahrakeh gharb	Total	
a:	4,140	3,731	4,072	11,943	
b:	47,136	34,642	23,501	105,279	
District 2	Majideh	Narmak	Estakhar	Total	
a:	1,289	2,155	3,575	7,019	
b:	42,875	35,070	82,884	160,829	
District 3	Amir abad	Shahreh ziba		Total	
a:	2,291	4,203		6,494	
b:	37,000	55,000		92,000	
District 4	Afsarieh	Soleimanieh	Parkeh shahr	Total	
a:	4,389	1,690	1,912	7,991	
b:	54,000	62,000	64,000	180,000	
District 5	Monyrieh	Azarii	Yaftababd	Total	
a:	874	2,359	2,258	5,491	
b:	30,000	67,000	60,000	157,000	
District 6	Alaein	Moshyrieh	Naziabad	Khaniabad	Total
a:	2,978	1,156	1,780	1,491	7,405
b:	48,000	57,000	39,000	40,000	184,000

a: Area (km^2) b: Number of connections

(FY2004)

In addition they are divided into two groups- the group which is responsive to the problems informed by people and the group which is actively doing surveys on water leakage.

The emergency post after getting informed by people's reports or leakage detecting teams or having leakages noticed through construction work drillings or other relevant organizations or information center 122 or group of inspectors of main valves went to the area and repaired them immediately with a daily average of 442 cases.

Population (Thousands person)	8,194
Area (km^2)	46,343
Number of connections	879,108
Length of distribution (km)	9,200
Total number of Accidents (/D)[*1]	442

[*1](Branches ,Network ,valves .fittings,…)

Quantity of repairs per day	442	(221)
Quantity of repairs / month	13,260	(6,630)
Quantity of repairs / year	161,330	(80,665)

Table (2): A simple estimation of the information regarding the water meter and its accessories- 40 to 60 per cent is being repaired by private companies.

Also very simply by estimating this quantity per year, the figure161,330 is obtained. Half of these leakages were leakages in the water meter. Most of the water leakages around the water meter (under direct management of the emergency post) were assigned to private employers. These employers provided the simple instruments, while patrolling on motor bikes in order to avoid the traffic problems in getting to the area.

Out of the information received about ten per cent was not relevant to water leakage, and if a case were related to water leakage it was not the responsibility of TWWC to take care.

On the other hand the area in which water leakage patrol has been performed according to FY2004 is 3,202km with a total of 1,453 leakage cases in all the districts.

Report of leakage in Tehran

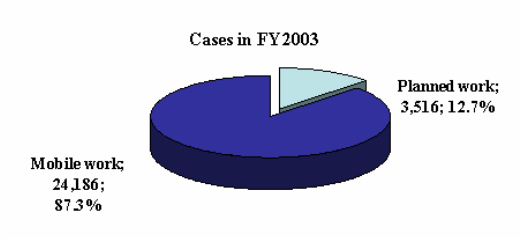
FY2004	Length Leakage Detection (km)	The Number of Leak in Connection	The Number of Leak in Network
District 1	292.0	20	35
District 2	812.0	240	256
District 3	501.0	73	75
District 4	579.2	188	117
District 5	323.1	55	89
District 6	695.8	166	139
Total	3,202.1	742	711
		1,453	

By comparing the growth rate in the reported districts the number of the reported districts by people is high.

FY2004	km	Cases	Cases/km	%
Emergency	9,200.0	159,877	17.378	99.11
Leak detection	3,202.1	1,453	0.454	0.89

In the city of Tokyo in Japan the leakages reported by people approximates 90%.

FY2003	Cases	%
Mobile work (Emergency)	24,186	87.31
Planned work (Leak detection)	3,516	12.69



Estimation of the rate of water leakage

The issue that how much is the rate of water leakage in leakage survey has been calculated in one of the districts by a hypothetical method by calculating the rate of water leakage which amounts to 450 liter/hour.

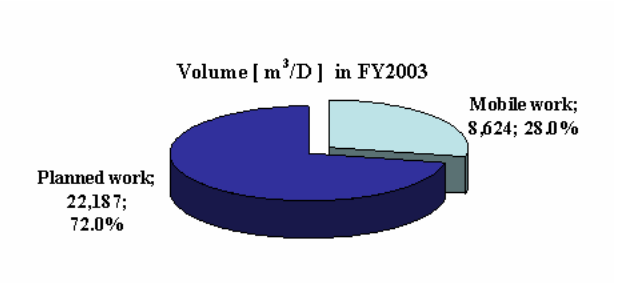
	km	Cases	Cases/km
Leak detection	3,202.1	1,453	0.454

1,453×450 liter/hour　653,850 liter/ hour＝653.85m^3/H

	m^3
Per hour	653.85
Per day	15,692.40
1 month	470,772.00
1 year	5,727,726.00

In addition in the example of Tokyo it is calculated as FY2003, 924.458 m^3/H

	m^3
Per hour	924.458
Per day	22,187
1 month	665,610
1 year	8,098,255



Prevention of water loss and relevant cost saving

In Tokyo	Amount/D	Cost saving/D	Cost saving/M	Cost saving/Y
Mobile work	8,624	15,843	475,290	5,782,695
Planned work	22,187	40,761	1,222,830	14,877,765
Total	30,811	56,604	1,698,120	20,660,460
Leakage Volume=4.7%				
Leakage Volume	205,890	377,852	11,335,560	137,915,980

Total expense: JP¥206.48-/m^3 costs table provided based on US$

Every year 20,660,460 US$ is saved by prevention of water loss. Yet about 138 million US$ is lost. Mobile work by the emergency post is being done in less than 24 hours in water leakage repairing.

In Tehran	Amount/D	Cost saving/D	Cost saving/M	Cost saving/Y
Emergency				
Leakage detection	653.85	499,541.4	14,986,242	182,332,611
Total				
Leakage Volume=8.0%				
Leakage Volume	213,090	162,800,760	4,884,022,800	59,422,277,400

Total expense: RIALS 764-/m^3

Target setting of leakage prevention and its effects

Tehran -FY2004 – total distribution volume in Tehran municipality is as below:

Annual production distributed	972,222,881 m^3/Y	100.00%
Revenued rate	704,985,506 m^3/Y	72.51%
UFW	267,237,375 m^3/Y	27.49%

Note: Total length of distribution network equals about 9,200 km.

If we can reduce the 27.49 per cent of water loss to 26.49 per cent we should be able to save 9,722,228.81 m^3.

In short, you need to find the equivalent leakage volume as above through leakage survey to reduce one percent of UFW annually.

Total length of leakage survey conducted in Tehran municipality (DISTRICTS 1-6) in FY2004

FY2004	Total length surveyed(km)	Cases	Cases/km	Saved water (m^3/Y) (based on calculations)
Leak detection	3,202.1	1,453	0.454	5,727,726.00

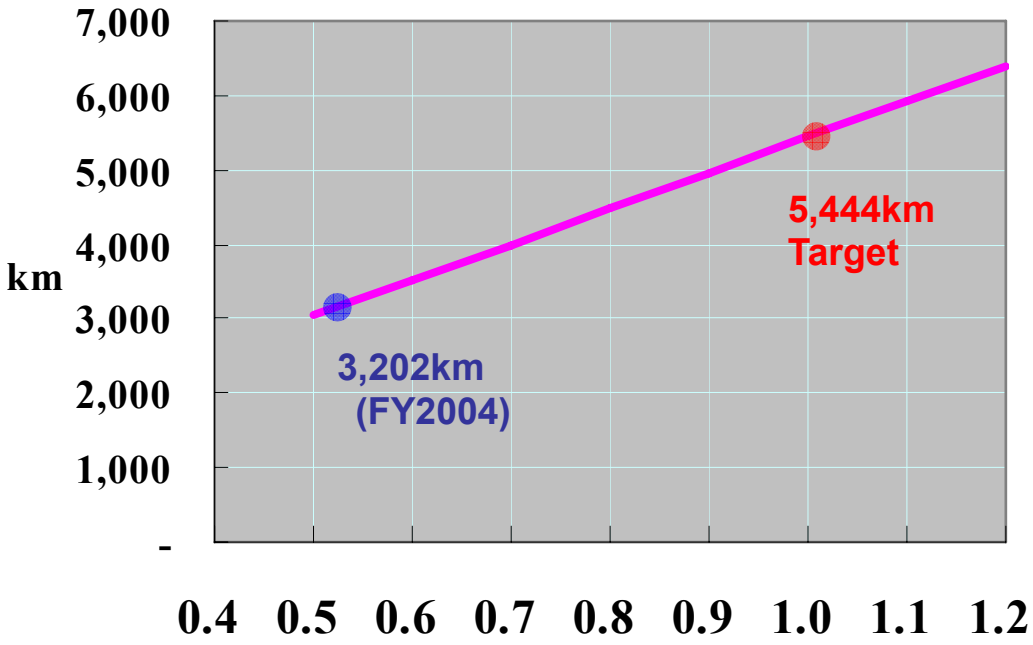
In order to reduce one per cent of water loss you have to save 9,722,228.81 m^3/Y but the amount we managed to save was actually 5,727,726.00 m^3/Y

m^3/Y	m^3/D
5,727,726.00	653.856≒654
9,722,228.81	1,109.843≒1,110

Regarding this formula 1,110/654=1.697≒1.7

3,202.1km×1.7=5,443.57km≒5,444km

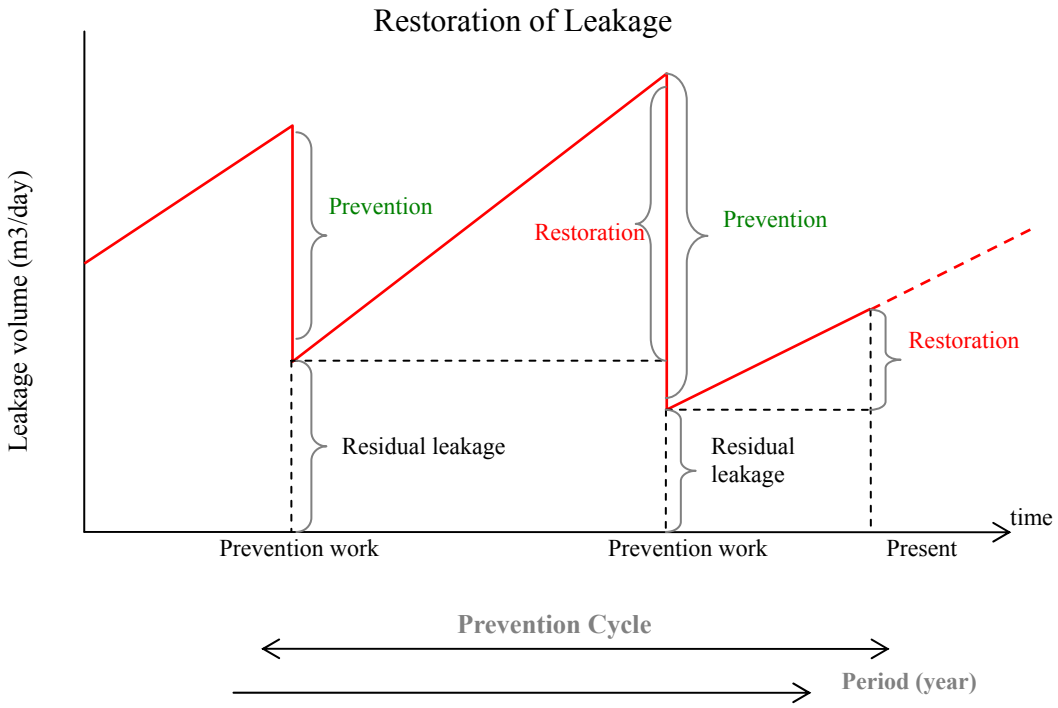
If we do not survey 5,444km per year we are not able to achieve the rate of 1%. Therefore to achieve this goal at least 60% of the total pipes should be surveyed per year.



All these calculations are hypothetical and it is far from our reach because at the rate that we investigate the pipes and precede it is possible that the area that we had finished with, might suffer new leakages.

Recurrence of leaks

Flow paths of leaks remain underground and accumulate with time and the repair and reappearance of underground leaks is known as the recurrence of leaks.
It is thus important to carry out leak prevention based on long range plans, as only continuous efforts to control leaks are effective.



In order to prevent leakage as much as possible it is important to clarify the repetition phenomenon. Therefore we must pay full effort to monitor this phenomenon.

Leakage volume

As a measure for estimating the rate of water leakage, there is a method of measuring the rate of actual real water leakage and the calculation method. If we manage to estimate the rate of water leakage, the ground water leakage volume could be calculated and its characteristics could be known which is important in water leakage survey.

(1) Estimation based on measurement

a. The observation method

The observation method is a kind of visual estimation on spot which compares the set of pictures and the maps which show the water leakage conditions according to drainage testing and rate of water leakage.

b. The direct measurement method

The direct measurement method, just before the ground drilling and repair, could be done by using instruments for covering and the tube. The part which has a leakage is surrounded and the leakage is gathered in one place and measured by measuring instruments. For measuring the rate of leakage there are also simple means.

c. Method of measurement by removing

This method is being done by removing the defected part and taking it to lab and checking the rate of water leakage through it as in the abovementioned (a) and (b). In order to know the accurate volume of leakage, the water pressure should be maintained the same as the actual condition. However this method could not be applied to where the leakage hole is relatively big.

(2) Method of water leakage estimation based on measurement

a. Calculating the area of the water leakage hole according to water pressure
The rate of water leakage could be calculated by the following in addition to the area of the water leakage and water pressure.

$Q=C \cdot a \cdot P^n$

Q: Rate of water leakage (m^3)
P: Water pressure inside the pipe (kgf/cm^2)
a : The area of leakage hole (cm^2)
n : Index (0.5 as well as 1.15)
Regarding index n there are two different ways of thinking
$n=0.5$ Cases where the water leakage holes are assumed to be orifices
$n=1.15$ (Testing the cases where there is an assumption that through fitment connection and crack there is water permeation to the surrounding)

b: Estimation based on the size of the leakage hole

Size of the leakage hole is calculated (by shape and form is estimated), the rate of leakage based on the area of the hole and by using the real measurements table is calculated.

(3) Others

If a sustained standard for the rate of water loss (rate of leakage) in a constructional accident could be achieved the calculations will be done accordingly. Considering the amount of water loss in the accident, the water needed for washing in drainage and the rusty water should be added which are abundant.

(4) Important notice in calculation of leakage volume

It is recommended to use average water pressure to estimate leakage volume.

Analysis and deduction of the survey results

(1) Results deduction

Regarding the detected leakages, making reports and filing is necessary. During the repair time for obtaining the correct relevant leakage information the facilities data is necessary (in addition to the material, diameter, joint type, depth and location wise physical relationship with other facilities.

(2) Analysis of the water leakage conditions and causes.

These are caused due to different issues which are responsible for water leakage but the causes are mainly classified according to these factors: breakage, hole, cracks, dislocation, aging, washer packing , etc.

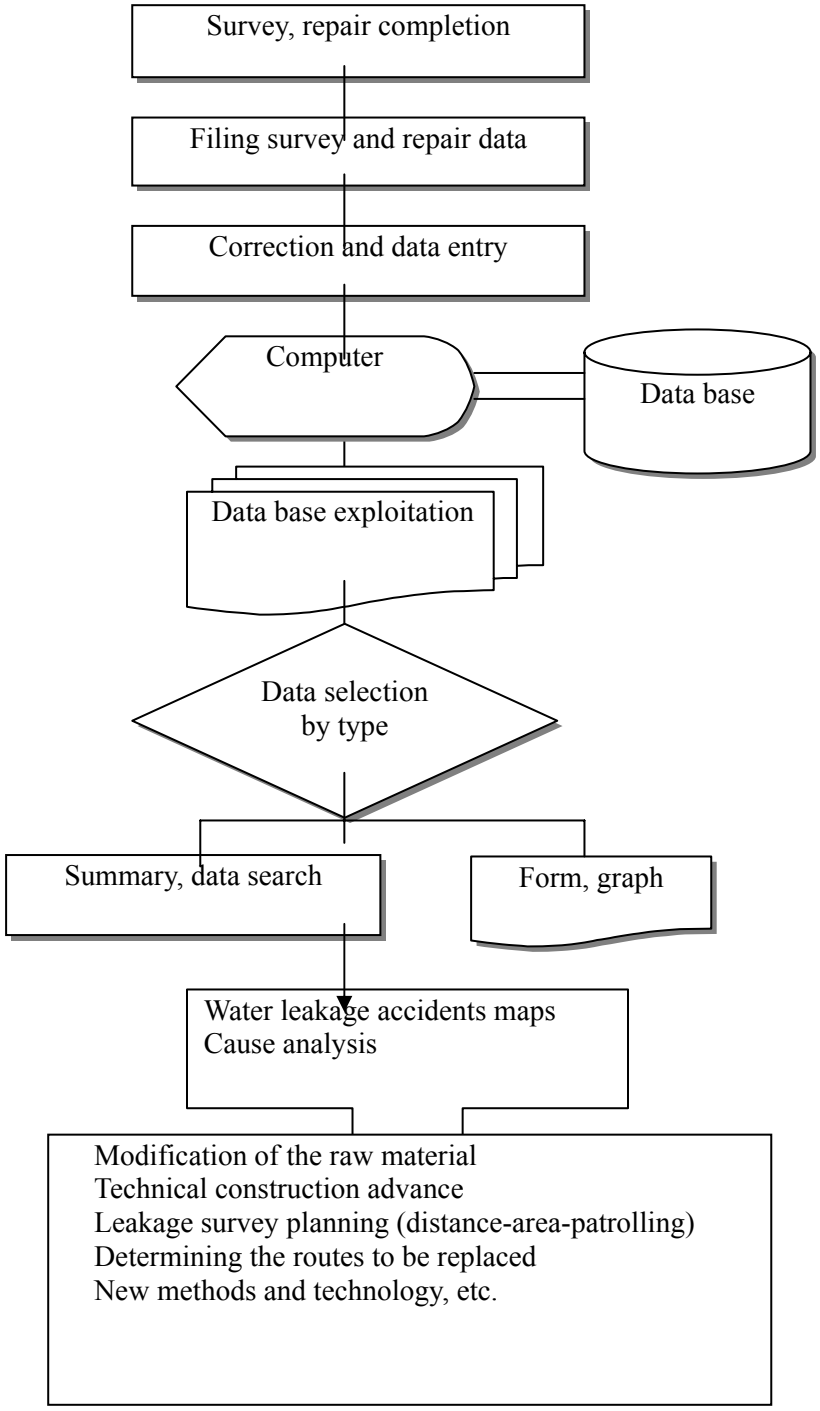
Conditions	Reasons
Broken	Overload, shaking, defect burying
Hole	Corrosion, electric erosion
Crack	Water hammer, defect materials
Removal	Fault connections, overload, shaking
Others	Other constructions, fault constructions

But the accidents did not occur as a result of only one reason but are due to a combination of the reasons.

(3) Filing of water leakage information

The information obtained from the water leakage survey and repair work should be considered effectively from now on in making and correcting the survey implementation plan. By the aid of this information, the mentioned leakage causes could be applied to all the pipes of line, block and area.

At present TWWC from each District has collected the repair quantity and leakage quantity data online. It is very efficient in filing and collection of the data. By considering the causes and condition of water leakage in detail it is possible to exploit more efficiently.


Survey, repair completion
Filing survey and repair data
Correction and data entry
Computer
Data base
Data base exploitation
Data selection
by type
Summary, data search
Form, graph
Water leakage accidents maps
Cause analysis
Modification of the raw material
Technical construction advance
Leakage survey planning (distance-area-patrolling)
Determining the routes to be replaced
New methods and technology, etc.

Appendix-12.3

Workshop on NRW on 17th January 2006

The workshop was held on 17th January 2006 among the study team, counterparts of TWWC and chief / staffs of Divisions for Management of Consumption and NRW affair and O/M district offices.

TWWC counterpart presented the situation of TWWC and then the study team presented the understanding of problems and recommendation on improvement methods for further discussion. After presentation, discussion was made among the attendants to find the problems / obstacles and methods for improvement of NRW reduction activities.

This appendix shows the following

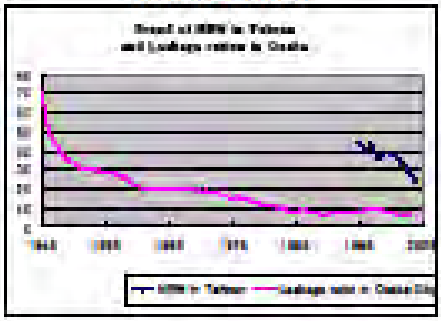
(1) Presentation by the study team for discussion
(2) Ideas for reduction of NRW and other comments and opinions form participants

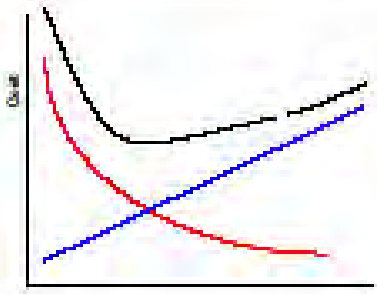
(1) Presentation by the study team for discussion

Discussion
for Further Reduction of
Non Revenue Water
(NRW)

January 17, 2006
JICA Study Team: S.Kobayashi

Trend of NRW



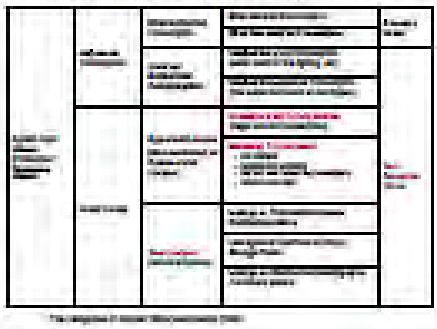


1. Common Understanding/usage of Terminology

Proposed Terminology

(1- Billed water / System Input Volume*) x100%
* System Input Volume :
Production or
Clear water transmission &
Distribution Volume

Terminology for NRW and its Components



2. The Major Approach for Reduction of NRW

- Measurement/estimate of Unbilled Authorized Consumption (and minimize it)
- Replacement of Consumer Meters
- Reduction of Leakage

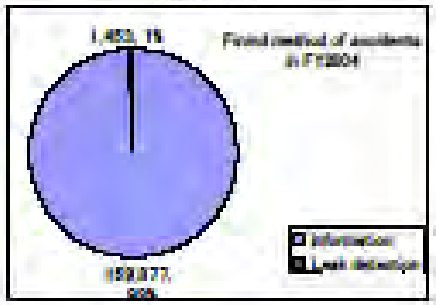
2.1 Major Approach for Reduction of Leakage

- Control of Water Pressure
- Replacement of old pipes, frequent leak pipes and other troublesome pipes
- Replacement of house connections
- Measurement /Monitoring of Leakage
- Finding of Visible Leakage
- Leak Detection (Invisible Leakage)
- Leak Repair (Proper repair and quick attendance)

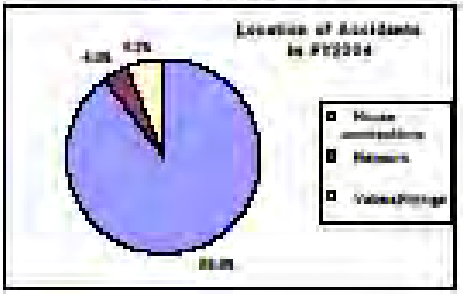
3. Major Findings on Current Situation / Problems

- Insufficient meter to measure NRW
- Unbilled Authorized Consumption, such as pipe flushing, park supply and military usage, is unknown
- Difficult Control of water pressure (Mainly by PRV but not by zoning)
- Lots of Accidents are found every day (442 /day in FY 2004)
- Reporting, transfering and compiling of information are insufficient (not digitalized)

Majority are from information from customers



Lots of leakage (cases) from house connections



4. Recommendation for Improvement of Activities

1) Installation, measurement and monitoring of bulk flow meters and consumer meters at unbilled authorized consumption

2) Analysis of factors / cause of NRW

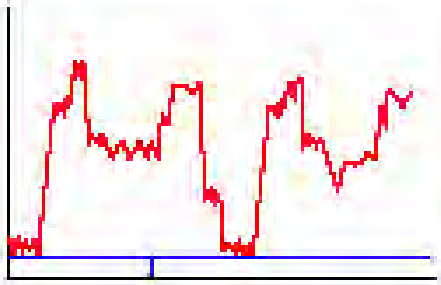
- For finding problems to be settled
- Unbilled Authorized Consumption, Illegal Connection, Meter Error, Leakage at transfer/distribution mains, leakage / overflow from storage tanks, leakage from service connections

3) Zoning, Monitoring

(1) Pressure control – Monitoring of pressure and operation of limited number of PRV (Operation of daytime and nighttime if required)

(2) Installation of bulk flow meters at inlet of each zone and monitoring of flow (minimum night flow)

(3) Limitation of damage and quick recovery during earthquake



4) Reporting, transferring, compiling and utilization of information on leakage

(Data base for leakage accidents and repair information)

4) Data Reporting / compiling /Utilization

(1) Introduction of uniform data base system (Head office)

(2) Preparation of leakage maps (District office)

(3) Updating of distribution pipe network drawings whenever noticed (District office)

(4) Other data to be collated /assumed such as leak volume (District office)

(5) Data compiling (at least every 3 months) (Head office)

(6) Utilization of Data

Especially for Selection of Priority

- route/area for leakage survey
- pipe replacement and pressure control.

and for Selection of

- appropriate pipe materials
- preventative countermeasures

Summary of Recommendation

FOR DISCUSSION

1 Measurement of Unbilled Authorized Consumption

2) Analysis of NRW component

3) Zoning / Monitoring

4 Data compiling and utilization

5) Improvement of Repair Skills

6) PR for information encouragement

7) Improvement of MOTIVATION

(2) Ideas for reduction of NRW and other comments and opinions form participants

After presentation by the study team and discussion for the improvement of NRW reduction activities, each participant states ideas for improvement of the activities and comments on the problems / obstacles for reduction of NRW, which are summarized as follows:

Mr. Abdolreza AMIRI (District 5 expert):

1- Perhaps it would have been better if the study team had given us the questions on improvement of NRW reduction, at least one or two days beforehand.
2- What is the water input of a district? How can we determine this? (We cannot determine the water into each district.)
3- The engineering office does not have enough authority to exercise the technical ideas. (Insufficient right for budget allocation and usage)
4- Directors of districts do not have the authorities to create motivation in the relief personnel.
5- The NRW experts are not exactly determined- their position in the chart is not determined so their duty description is not clear either.
6- Leakage detecting teams are not very well equipped and staffed. There are shortages.
7- It is not a good idea to employ contractors. Personnel in TWWC works much better than them.

Mr. DEHQAN (District 5):

1- As the study team pointed out, it is indeed necessary to create motivation in the personnel who are involved in leakage detection.
2- Leak detection and repair teams should be better equipped with new /modern tools and equipment.

Mr. MOHAMMAD-ZAADEH (District 6):

1- As we are experiencing privatization, it is highly essential to choose contractors and individuals who are honest good workers. With regard to the material we adopt for renovation, we must choose very discreetly and carefully.

Mr. BARAATI (District 6 Deputy):

1- From the viewpoint of technical and implementation capability, we have no problem. In my district what the study team is suggesting that we should do will take only a year to achieve. On the whole I think it will take around a year or two in all districts to execute the ideas of the study team. We ourselves requested for 16 flow meters to the network in our district (district-6) in 1996 but this demand has not been fulfilled yet. In other words what the study team wants us to do is not technically complicated or difficult to achieve but needs financial resources and equipment facilities.

Mr. TABRIZI (District 5 Deputy):

1- Concerned with polyethylene pipes there is the problem of leakage detection by using the equipments we have.
(Upon the comments and questions regarding to the problem, the study team introduced the situation and leak detection methods in Japan.)

Mr. HAAMEDI (Consumption Management):

- We have been using and maintaining the existing facilities for fourteen years. The problem we face is that we buy our goods from various companies. The materials they are made of are not consistent. They tend to change due to the time of purchase as well as the company. We are not coordinated with ministry of housing. In a future period they might allow construction and use of some material right next to the one which was installed in a previous period of time and which is not congruent and adaptable with the new one. (Old material and new materials are used in the same place even if they do not match properly.)
- From the viewpoint of execution we do not have quality control. From the aspect of pipes, fittings and components there is no observation made to convey the data to the utilization department and make them usable for a longer period of time. (Problems found in material are not considered for the next procurement.)

Supervision of construction works is also very poor.

Mr. NO-PARAST (Consumption Management):

- Leakage types and its details have been prepared and statistical data are available. Nevertheless no good use has been made of it. I believe we have to operate in an executable manner to achieve the objective of isolation of the zones. It would be very expensive if we start from the component and conclude about the whole. I think it is better to act vice versa. By determining the rate of water loss and leakage in various zones and determining the zone with the highest leakage rate, we should first isolate that zone from the others. It would be more practical and cost-effective to isolate such a zone and further provide it with meters, pressure gauge and other equipments.

Mr. MALAKOOTI (District 1 Deputy):

- In water distribution network, we have no standards for pipe material which is being used. All different kinds of pipes of various diameters are being used.
- To make it more complicated, the equipments we use for leak detection are out of date and out of calibration and rendered the measuring inaccurate.
- Meter readers (contractors) do not report the leakages they notice. Therefore no measures will be taken afterwards such as the attendance of leak repair teams.
- Water should not be distributed from the pumping transmission line because that causes fluctuations due to turning on and off and subsequently the increase of tolerance which damages the system.
- Water pressures in Japan in much lower than Tehran and Japanese methods cannot be applied to Tehran directly.

Mr. FALAAHAT-DOOST (District 1):

1- How the causes of leakage / accidents could be determined and reduced in each district? (The study team presented the ideas and emphasized the importance of discussion among the staffs.)
2- Accuracy of consumer meters should be checked, especially those of large diameters.

Mr. JAAJARM: (Consumption & NRW Management)

- From the very beginning point of production all along pumping system and transmission lines, our consumers are connected to the system, which is a problem and needs to be reviewed.
- Out of the two major problems of "Pressure Management" and "High Consumption", which one is better to deal with first? Both are challenging. (Together with NRW reduction, water conservation shall be considered for effective use of limited water.)
- Connection material of fittings and pipes material are important.

Mr. SHAKOOR (District 4):

- Permanent installation of noise loggers on the system (online) will be useful for finding leakage.

Mr. ZANDI (District 4):

- In distribution network due to some problems some junctions are not shown or registered on any map. How they could be possibly identified and isolated? (The study team showed some methods and requested for further discussion.)
- In our district we have already installed a PVR controller in "*Park-eh-Shahr"* which has been a very successful experience and has helped us reduce water accidents by 90%.
- Reducing the limits of water stoppage area and installation of backline would be desirable (reducing and isolating the area of zones). Furthermore replacement of valves would be much better than repairing them.
- Experience of accident relief, accident density causes should be surveyed but what needs more attention is the proper utilization of these data. If statistics are prepared, the causes could be determined more effectively and the management could be done more efficiently.
- Emphasis should be placed on isolation of pressure zones.

Mr. PAARSI (District 3):

—

Mr. SAAMAANIYAN (District 2):

1- I am interested to know how much in fact the study team knows about our water system and how different is it from that in Japan? (The study team explained briefly and requested for further discussion after the workshop)

Mr. OMIDI (District 3):

- What I would request for is to focus more on the problems and have more discussions.

- Prioritization is an important issue which needs more attention.

Mr. Younesloo (Consumption and NRW Management, Counterpart of the Study Team):

Problems in distribution Network and Connections regarding NRW

- Age of pipes and valves and other network components, The fact that most of the valves are either buried or out of order, Shortage of updated distribution maps, Lack of proper pressure zonation of distribution, Management and operation problems, Paying no attention to the cause of repeated accidents, Network variety from the aspect of design and material used, Age and inaccuracy of the meters, breakdown and no proper installation of the meters, Meter readers' mistakes, Low quality material used in the connections

Strategies for NRW Water

- Observance of design, operation and execution standards- Observance of technical standards in installation of consumers' connections- Enhancement of the level of operators' technical knowledge- Paying attention to consumers' opinion and different procedures of approaching them and applying cost-effective water use propaganda- Due attention and analysis and finding the cause of repeated accidents, Use of C meters of high accuracy- Modifying reading methods of meters- Renovation of network and connections, Quick and in time response during pipe breakage and accident

- Using appropriate strategy- Training of meter installers- Proper installation of meters- In time repair of meters- Periodical replacement of meters- Use of standard material in the connections- Observance of design and pressure control standards, Renovation network of old pipes- Installation of meters in the inlet and outlet sources and measurement of the rate of treated water, water of wells and reservoirs- Registering water consumption and wastage

Appendix-12.4

Workshop on NRW on 30th May 2006

The workshop was held on 30th May 2006 among the study team, counterparts of TWWC and chief / staffs of Divisions for Management of Consumption and NRW affair and O/M district offices.

Main discussions are summarized below:

(1) Setting a committee of deputies of districts and NRW
Mr. Ghassemi agreed the importance of discussion on NRW reduction and recommended meetings of once a month or every 15 days. Setting a committee of deputies of districts and other officials related to NRW reduction was discussed.

(2) Comparison of NRW reduction trend in Tehran and Osaka
It was discussed that graph of NRW reduction in Tehran shows a great achievement of reducing from 70 to 30 in a relatively short period of 10 years with great efforts of TWWC. Nevertheless it will become more difficult to make progress in further reduction of NRW with the same efforts.
After the discussion, TWWC requested and JICA Study Team agreed to introduce Osaka's effort on reduction of NRW in each stage.

(3) Calculation of Water Balance
Upon the questions of the attendants, JICA Study team replied that the most important things for the next stage will be setting priority of water loss reduction activities. (The priority includes priority actions and priority areas.) The study team explained that water balance shall be measured / calculated for deciding the priority activities after clear definition of terminology of water loss components.

(4) TWWC staff's ideas:

- We are at the beginning of way and would like to use the Japanese experiences in this regard.

- Instruments, equipment and methodology of leakage detection is appreciated by the JICA team and we are familiar with all subjects mentioned in the previous workshop and this one. But there are some problems related to leakage detection as follows:
  1) Shortage of leakage detection experts; each district has only one group for leakage detection which need to be supported.
  2) Leakage detection instruments should be sent to other countries for repairing and that is a time consuming process.
  3) Operation is a main part of TWWC system but head offices don't give enough attention to this part.
  4) Getting information of revenue & customers affairs is so hard; for instance information is insufficient about change of flow meter type.
  5) Incorrect management, coordination and programming.
  6) Lack of motivation of personnel.
  7) Low quality material such as flow meters that lead to errors in leakage detection.
  8) Low quality of repairing.
  9) Shortage of budget.

  - Usage of new instruments of leakage detection would be much more effective in exact leakage detection.

  - Giving more authority to staff who are in charge of NRW.

- Mr. Ghassemi addressing TWWC staff: “Tehran has been designed in a totally different fashion. I/We transmit water drop by drop from each different zone to another to meet the demands of each area. With respect to such idiosyncratic situation as of Tehran, hydraulic zonation might be somewhat impossible, nevertheless focus your attention on whatsoever measures should be taken according to their experience.

- We know most of the recommended activities by the JICA Study. The important thing is how to execute. This matter shall be discussed.

(5) Questions and Answers

During the discussion, TWWC and the JICA study team asked questions and responded each othres. The major questions and responses are summarized below.

1) Questions from TWWC to the Study Team

Q What shall be a practical 5 years strategy considering the strong and weak points of TWWC ?

A. Meters will be installed in the telemetry improvement project and pilot area study is under way to know the water balance in certain areas. Taking into account the these results, water balance shall be calculated /estimated, and then priority activities shall be decided. By the time, the JICA study team proposed TWWC to consider the execution of the some of the recommended methods, which TWWC can start now.

Q Introduction of Zoning (hydraulic isolation) will take time. What activities will be required for water pressure control?

A. Hydraulic isolation will require great efforts such as appropriate planning, reinforcement of distribution pipes and installation of valves. It will take time but hydraulic isolation will be the most effective methods for Tehran.

Before hydraulic isolation, TWWC’s current efforts such as installation of pressure breaking valves and auto valves are considered to be in the right way.

Q What figure is the appropriate target of NRW in Japan ?

A. The target was set below 10% and some of the cities achieved around 5%. The target depends on the characteristics of the cities. In many cities the target figures are amended to upper side considering high cost for maintaining the low NRW ratio.

2) Questions from JICA Study Team to TWWC

Q NRW has been reduced drastically by the efforts of TWWC. What does TWWC think are the most effective activities?

A Improvement of billing by replacement of old customer meters contributed to reduction of NRW.

The other effective measures are improvement of quick attendance to leaks, replacement of pipes, replacement of defective valves, pressure control.

Appendix-12.5

Site Visit of the Study Team

1 Visit of the District Offices

The study team and TWWC counterparts visited each and every emergency post under O/M district offices to inquire general information. Afterwards, the study team and TWWC counterparts followed staff of the post to repair sites and leakage survey sites. In addition, the study team and TWWC counterparts also went to see parts and equipment for leak repair and confirmed the management conditions of machineries.

2 Repair work

We accompanied with the staff to see how the repair work was done and confirmed following items.

- Safe facilities, protection conditions
- Excavation work
- Repair work（including water suspension）
- Restoration work（burying）

(Fig 1 Excavation)

(Fig 2 Repair)

(Fig 3 Burying)

3 Leakage survey

We accompanied with the staff to see how the leakage survey was carried out and confirmed following items.

- Preparation of equipment for survey
- Installation of sensors
- Leakage detection, specification of location

(Fig 4 Leakage detection)

(Fig 5 Acoustic work)

(Fig6 Leakage detection)

4 Conditions of Materials Management

We checked the followings.

・Storing conditions

・Go out slips

(Fig 7 Equipment warehouse) (Fig 8 Equipment warehouse) (Fig 9 Construction materials warehouse)

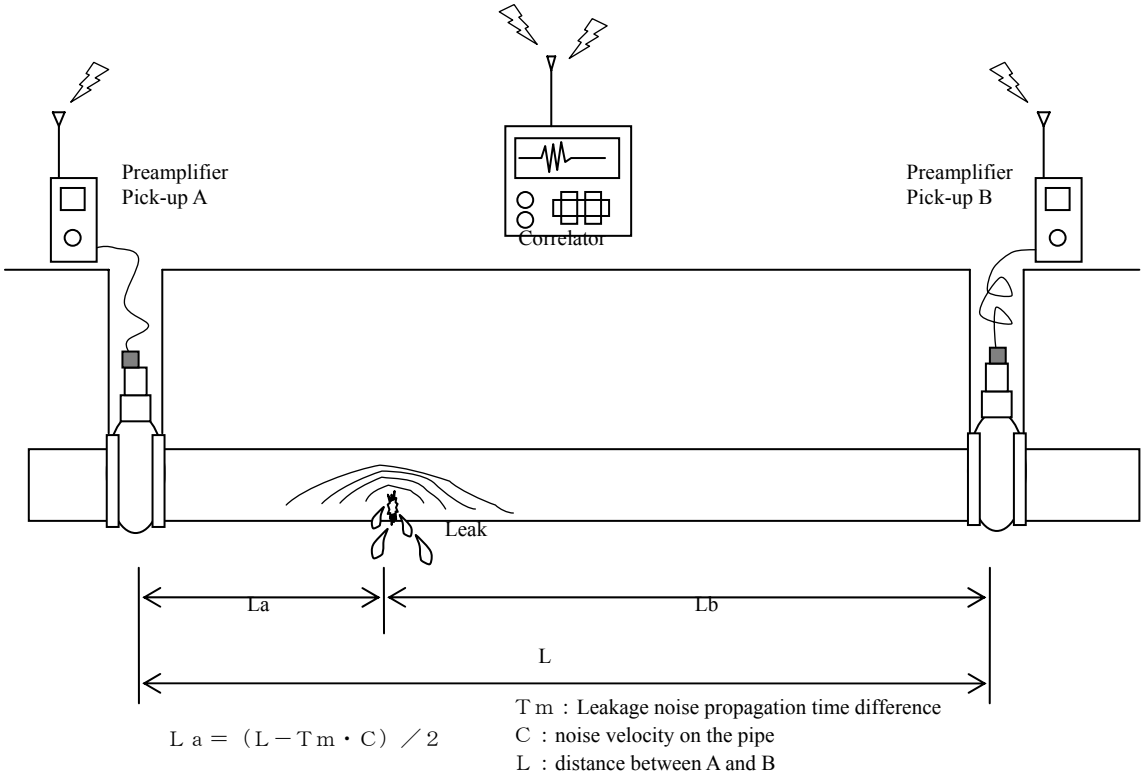
5 Leakage survey and the equipment

The leakage team is trying very hard detect leakage by using leakage correlators. It seems that the staffs are already good at using the introduced machineries. According to the JICA preliminary survey report, leak noise logger (logger type leakage detector: Palmalog) has been already introduced. In fact, it was surveyed that *(a) in the above table was introduced 6 years ago, *(b) was introduced 5 years ago. And *(c) was introduced 2 years ago.

Generally, correlators (and geophones if necessary) are used during leakage survey in the field. The leakage survey by using correlators are briefed below.
This device identifies the location of leakage by receiving leaking sounds generated at two valves with a microphone. It measures the difference in transmission time between the two valves and processes the information by a computer. This device is used effectively under the conditions such as pipes are laid deeply or under a (railroad) track, the use of sound detectors is unreliable, noises of busy streets make the sound detection difficult, etc.

Even though, some problems remain such as the reliability is affected by the accuracy of pre-feed information and the inherent decrease of computation accuracy due to the larger-size and longer-distance of pipelines. The survey does not need a water supply cut. It can be used on pipes, which are still supplying water.

Fig 10 Correlator method



6 Conclusion of Site Visits

Generally speaking, equipment and materials for leakage survey are already provided and repair works are well maintained, and the management has also been done well. Besides, staff are good at operating these equipment and machines.

If replacement of service pipes could be carried out along with the replacement of distribution pipes, it will make preventive countermeasures more effectively. It is considered that speeding up the circulation of leakage survey and widening target survey areas in short period of time for the discovery of underground leak are necessary.