Appendix 3) Training materials of KEWI Revised Practical Training Course on NRW Reduction

3) -1 Text Book for Revised NRW Practical Training Course

Internal Information

TEXTBOOK

FOR

JOINT TRAINING

(DRAFT)

"INTRODUCTION TO NON-REVENUE WATER REDUCTION"

R-2

August, 2018

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs

(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)

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***Original Edition, First Edition and Second Edition* August, 2018**

Table of Contents

Introduction to Non-Revenue Water Reduction 2018 Aug.

1. Objectives (Out-put)

① Understand the concept of Non-Revenue Water Reduction.
② Understand the components of Non-Revenue water
③ Understand Vicious circle.
④ Understand the benefits of NRW management.

2. Introduction

One of the major issues affecting Urban Water and Sanitation Providers (WSPs) in Kenya is the considerable difference between the amount of water put into the distribution system and the amount of water billed to consumers commonly referred to as "non-revenue water" (NRW). In general, many of the Kenyan towns have 40–65 percent Non-revenue water. This seriously affects the financial viability of water utilities through lost revenues and increased operational costs. By implementing measures to reduce Non revenue water means additional revenue to the WSP and additional water being available consumers without further investment.

3. Key words definition

NRW Management	Monitoring the water supplied and taking corrective action to reduce water that is not supplied to authorized consumers.
Non-Revenue Water	The difference between System input volume and Billed authorized consumption
Vicious circle	-

4. What is Revenue Water?

Non-Revenue water is defined as the amount of water input into the distribution system and is not translated to revenue.

◆ **NOTE:**
NRW = SYSTEM INPUT VOLUME – BILLED AUTHORISED CONSUMPTION

Non-Revenue water ratio is the percentage of the amount of water not billed against the amount of water input into the distribution system.

$$\text{NRW (\%)} = \frac{\text{System input volume} - \text{billed authorized consumption}}{\text{System input volume}} \times 100$$

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5. Components of Non-Revenue water

The components of Non-Revenue water are:

- Unbilled authorized consumption
- Apparent losses (commercial losses)

- Real losses (physical losses)

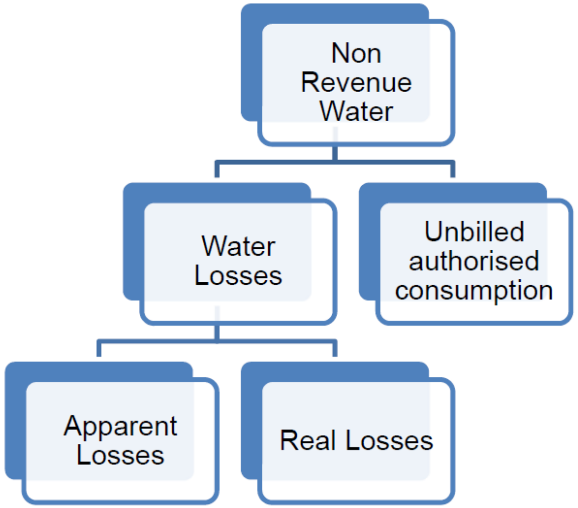

Figure 1: Components of Non-Revenue Water

6. Challenges

Many Water Service Providers are struggling to ensure that customers receive a reasonable water supply to sustain health and life. However, they encounter the following challenges:

- Dilapidated infrastructure with high leakage levels
- Poor operations and maintenance policy, including ineffective record-
- keeping systems
- Poor governance
- Limited skills in non-revenue water management and technology
- Financial constraints, including ineffective and inefficient revenue
- collection
- Weak enabling environment and performance incentives
- Political, cultural, and social influences
- A higher incidence of commercial water losses, particularly illegal connections.

These factors all influence the scope for managing losses and demand. At the same time, continued NRW limits the financial resources available to tackle these challenges facing water utilities.

7. Impacts of Non-Revenue Water

7-1. Vicious circle

The *'Vicious Circle'* of NRW illustrates the key reasons for poor company performance, which results in water losses. The losses divert precious water from reaching customers and increase operating costs. They also result in larger investments than necessary to augment network capacity. A utility has high NRW which means it has lower revenues, which means it does not have funding to fix the problems that cause NRW. **(Refer to Figure 2)**

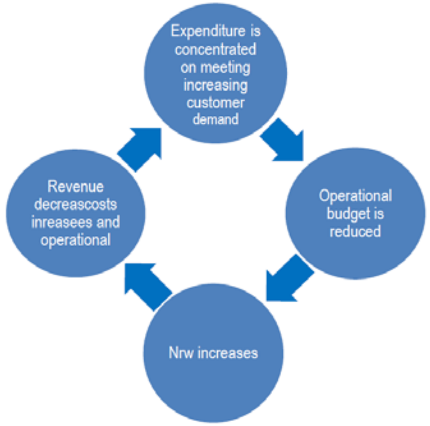

Figure 2: Vicious circle for Non-Revenure wate

7-2. Challenge into Virtuous Circle

The challenge for water utility managers is to transform the Vicious Circle into the *'Virtuous Circle'*. In effect, reducing NRW releases new sources of both water and finances. Reducing losses results in a greater amount of water available for consumption and postpones the need for investing in new sources. It also lowers operating costs. Similarly, reducing commercial losses generates more revenues**. (Refer to Figure 3)**

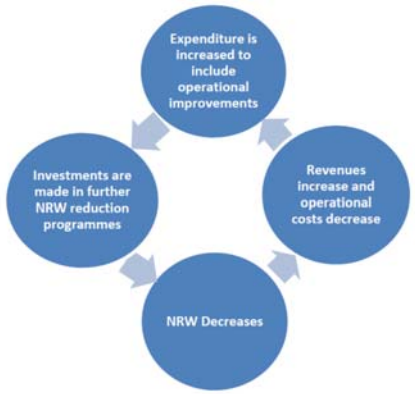

Figure 3: Challenge into Virtuous Circle

(1) There are various challenges that contribute to this vicious cycle, including:

- Denial: The water utility denies the effects of NRW, with reasons like, *«we meet the norm or standard NRW figures, so there is no problem»*
- Illegal consumption: Utilities claim that it's mostly illegal connections that result in unknown consumption.
- Network Age: aging water network and associated systems need total replacement and this can be expensive.
- Political interference: Politicians don't allow disconnection for non-payment.

... New installations easier: Network Capacity/expansion is politically more important than rehabilitation – it is easier to serve new areas than it is to carry out repairs.
... Skills competence: A utility does not have the right kind of staff.
... Intermittent versus sustained supply: Intermittent or rationed supply keeps water losses low at the expense of customer service.

(2) Reducing high NRW has many added benefits:
... More water being available for consumption that can be sold
... Delaying the need for capital investments
... Lower operating costs
... Reducing commercial losses will generate more revenue.

(3) Reasons for the failure in reducing NRW include:
... Little understanding of the nature of water losses by the people tasked with this Responsibility
... Little or no appreciation of the impact of water losses
... Poor project design
... Grossly under-estimated costs of water loss reduction resulting in this task being Abandoned
... 'Lip service' to obtain funding – 'NRW reduction' used as a politically correct term that is included in project proposals when sourcing for funding.

NRW reduction is:
- **Not just an isolated technical problem**
- **Tied to overall asset management and operation**
- **Not a once-off activity, but one requiring long term commitment**

#
8. Benefits of NRW-Management
NRW Management consists of knowing what is happening with the water supplied and taking corrective action to reduce water that is not supplied to authorized consumers.

NRW Management offers the following benefits to water utilities:
... Reduces energy and treatment chemical costs
... Reduces water treatment and pumping costs
... Defers capital expenditures
... Reduces damage to infrastructure
... Improves systems hydraulics and utility efficiency
... Reduces unauthorized usage
... Reduces potential claims due to water damage
... Improves public awareness of water's value
... Improves environmental protection as water resources become scarcer.

9. Addressing NRW
Water utilities should use a diagnostic approach, followed by the implementation of solutions that are practicable and achievable to reduce NRW.

(1) The first step is to learn about the network and operating practices. Typical questions during this process include:
... How much water is being lost?

... Where are losses occurring?
... Why are losses occurring?
... What strategies can be introduced to reduce losses and improve performance?
... How can we maintain the strategy and sustain the achievements gained?

(2) NRW management is not a one-off activity, but one requiring a long-term commitment and involvement of all water utility departments. There is need for utility managers to have access to information on the entire network, which would enable them to fully understand the nature of NRW and its impact on utility operations, its financial health, and customer satisfaction. Successful NRW reduction is not about solving an isolated technical problem, but is instead tied to:

... Asset management
... Operation and maintenance of the infrastructure
... Customer support
... Financial allocation to support NRW strategy or efforts
... Management support
... Capacity know how – network and non-revenue water
... Commercial operations

Figure 4: Elements to reduce NRW

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Internal Information

TEXTBOOK
FOR
JOINT TRAINING
(DRAFT)

"TYPICAL WATER SUPPLY FACILITIES"
R-1

August, 2018

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
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Table of Contents

1. Objectives (Out-put)

① Understand objectives of water supply
② Understand components of Typical Water supply facility
③ Understand concept of Water service equipment
④ Understand functions of the distribution System
⑤ Understand life of the Water Supply facility
⑥ Understand typical miss connection of service line in housing area

2. Introduction

Water Supply facilities topic will be describing the components in the water supply from the source of the water up to when it reaches the consumer. This will include the water source, Intakes, Raw water mains, Treatment works, Storage reservoirs, Distribution networks and individual connections

3. Key words definition

Waterworks facilities	Water abstraction (intake) facilities, water treatment facilities, water storage facilities, and water distribution facilities
Distribution facility	Water supply facility after the water treatment plant and it consists of distribution pipes, distribution reservoirs, pumping facilities and the consumer connection facilities.
life of the Water Supply facility	The expected lifespan of a water supply facility as described in the asset register.

4. Objectives of water supply

The following maintenance plan is indispensable. A good water supply system should aim to achieve the following objectives:

(1) To provide clean and safe Water Supply. This objective can be achieved by:

・ Improvement of water quality of water treatment facilities,
・ Reinforcement of water quality in water supply facilities (replacement of lead pipes / prevention of pollution from leakage section / washing cleaning of pipe network etc.)
・ Hygienic management of the reservoir
・ Expansion of direct water supply,

(2) To provide a stable and reliable water supply. The water supply facility should be able to

meet the water demand of the consumers on demand. This can be achieved by:

- Securing a stable water source,
- Promotion of leakage prevention measures,
- Using rainwater,
- Expansion of water purification facilities,
- Depleting of water supply facilities / bypass water line /networking,
- Expansion of distribution facilities
- Water pressure management, etc.

5. System Description

Waterworks facilities include water intakes, water storage reservoirs, raw water transmission pipelines, water treatment facilities, distribution facilities and consumer service assembly which are managed by the Water Service Provider.

It is important to strive to maintain the operation and maintenance of water facilities as "safe, secure and stable water supply" from customers.(Refer to **Figure 1-1**)**Components of water supply facilities**

6. Components of water supply facilities

System

Waterworks facilities consists of water abstraction (intake) facilities, water treatment facilities, water storage facilities, and water distribution facilities which are managed by the Water Service Provider. Other facilities beyond the consumer water meter are managed by the customer.

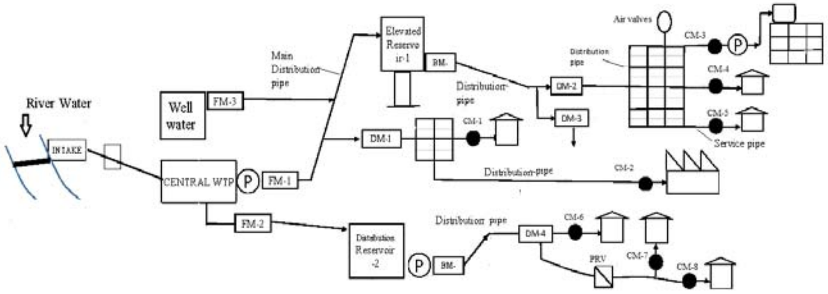


Figure 1: Typical Block Diagram of water supply facility Scheme

Components

(1) Abstraction facilities (Intakes)

The intake facility reliably abstracts raw water of good quality according to demand from a water source. At the intake facility, raw water from the source (river or lake) is withdrawn and transmitted to the water treatment facility by gravity or by pumping.

(2) Raw water transmission main.

Raw water transmission main transfers raw water the intake facility to the water treatment facility. Water may flow by gravity or by pumping.

(3) Water treatment plant

A water treatment plant is intended to convert raw water to potable standards. In this regard the facility should produce clean and safe water that meets WHO standards for drinking water. Conventional water treatment processes include sedimentation (plain or chemically aided sedimentation), filtration (rapid or slow sand filtration), stabilization and disinfection. Treated water is transmitted to the distribution facility by gravity or by pumping.

(4) Distribution facility

A water distribution system is intended to distribute from the treatment plant to the intended consumers. The objective of the water supply system is to maintain the water quality and at the intended pressure with minimum water loss. The facilities consists of water supply pipelines, storage reservoirs, pipeline appurtenances, flow meters and monitoring equipment.

(5) Consumer Service Connection.

The Water Service Provider is responsible for the installation of water supply pipelines up to the consumer water meter, measures against water leakage, installation of meters / boxes, maintenance of the meters. The consumer service connection is the *'last mile connectivity'* to the authorized consumers and is expected to meet the consumer demand by supplying the required amount of safe, stable and adequate quantities of water. (It consists of a water stop box, a supplementary stop cock, a water meter, a check valve. (**Refer to Figure 2**)

NOTE:

The responsibility of the WSP is to install and maintain the water distribution system up to the water meter including taking appropriate measures against water leakage, installation of meters, meter boxes and meter maintenance.

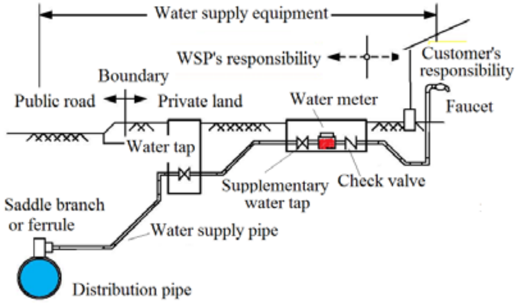


Figure 2: Concept of Water service equipment

(6) Cross-connection

Cross-onnection means that a water supply pipe and another water supply pipe (for Example, water from a rainwater tank, a water tank, well water, etc.) are directly Inter-connected. Due to this cross connection, contamination and reversing of the water meter may occur. To prevent cross-connection, install valves/Check valves and/or use separate system piping (**Refer to Figure 3**).

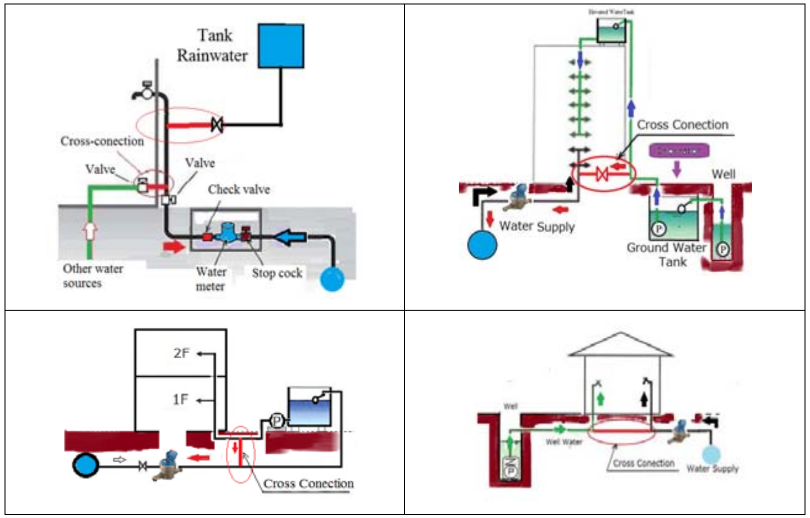


Figure 3: Cross-connection

7. What is Role of a water distribution facility?

The water distribution facility is a general term for the water supply facility after the water treatment plant and it consists of distribution pipes, distribution reservoirs, pumping facilities and the consumer connection facilities.

The objectives of the water distribution facilities are shown below.

① Supply steady water quantities at the proper pressure to meet the consumer demand.
② Maintain the water quality. There should be no deterioration in water quality in the distribution system through external pollution.
③ Monitor the flow rate.
④ Detect water leakage early from flow rate / pressure fluctuations in the pipelines.
⑤ Minimize the impact on the water supply area when the facility fails.
⑥ Monitor the water supply volume and water demand volume

8. Life of the Water Supply facility?

Deterioration of the Water Supply facility ~~is~~ starts as soon as it is built.

The rate of this deterioration depends on the period of use of the facility, design strength / construction accuracy, material quality, equipment performance, and operation and maintenance situation. In general, if maintenance is appropriately implemented for a long period of time, this life will be longer (**Refer to Table 1)**.

"A measure of aging" is judged from the number of years of use of the facility described in the asset management register, that is, "useful life".

Table 1 Example of concept of service life

Items	Actual life(years)	Japanese(Legal standard)	Other country
Civil structure	50～100 years	Water purification plant 60 years	40 years
water pipeline	25～100 years	Distribution pipe 40 years	40 years
Water supply pipe	25～50 years	Building accessory equipment 15 years	
Valves	10～40 years	Pipeline 30 years (recommended)	
Water meters	10～20 years	Water meters 8 years(Measurement Act)	7-8 years
Flowmeters	—	Flow meters 15～20 years (recommended)	10 years
Machinery equipment	10～30 years	Pumps 15 years	

9. Review exercise

10-1 Cross-Connection

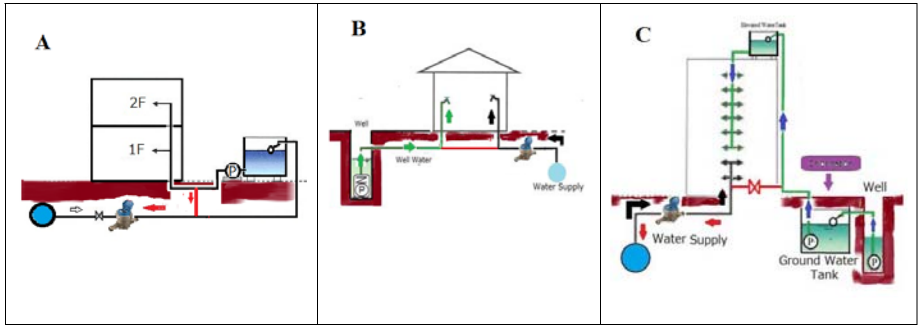
Questions

(1) Which piping is cross-connection?

(2) What kind of problem will occur?

(Amount of water volume used, water pollution, others) ?

(3) What is the countermeasure method of WSP?



Comments:

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Internal Information

TEXTBOOK
FOR
JOINT TRAINING
(DRAFT)

"HOW TO CONDUCT WATER BALANCE"
R-1

August, 2018

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
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Table of Contents

1. Objectives (Out-put)

① Understand objective of water balance
② Understand components of the Water Balance
③ Understand Water Balance Terms.
④ Understand how to calculate NRW ratio

2. Introduction

"Water survey" is said to be *"business management"* in the water supply business, and its water distribution analysis is a basic investigation item for measures to prevent non-revenue water.
The purpose of the water distribution analysis is to investigate / analyze how the water distribution volume was delivered from the distribution reservoir to the water supply area (DMA) by the distribution main pipe and how it was used. (**Refer to Figure 1**)

For leakage reduction, a plan should be formulated including the update plan from the cause analysis of the amount of ineffective water (rate) shown in this analysis table.
The responsibility of the water business operator is to keep the results of the non-revenue water rate shown in the water distribution analysis table always at "low" level

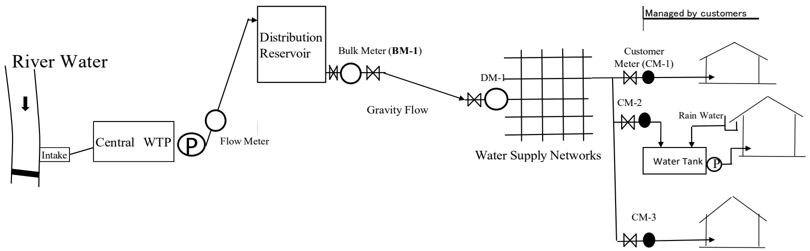

Figure 1: Typical Block Diagram of water supply facility Scheme

3. Key words definition

Non- Revenue Water	The difference between System input volume and Billed authorized consumption
System Input Volume	Annual volume put into the part of the water supply that relates to water balance calculation
DMA	District Metered Area

4. What is water balance analysis?

Distribution analysis is the "tracking survey of water distribution" in order to find out where water is used and where the amount of non-revenue water is generated in the "Water Displacement Survey Table".

As a result, the amount of non-revenue / effective water can be known.

The distribution analysis table is shown below. **(Refer to Table 1)**

Table 1 Water Balance analysis (IWA STD)

Q1: System Input Volume (m^3/Y)	D1: Authorized Consumption (m^3/Y)	V1: Billed Authorized Consumption (m^3/Y)	① Billed Metered Consumption (including water exported) (m^3/Y)	Q2: Revenue Water(m^3/Y)
			② Billed Nan-metered Consumption(m^3/Y)	
		V2: Unbilled Authorized Consumption(m^3/Y)	③ Unbilled Metered Consumption(m^3/Y)	Q3: Nan-Revenue Water(m^3/Y)
			④ Unbilled Non-metered Consumption(m^3/Y)	
	D2: Water Losses(m^3/Y)	V3: Apparent Losses(m^3/Y)	⑤ Unauthorized Consumption(m^3/Y)	
			⑥ Metering Inaccuracies(m^3/Y)	
		V4: Real Losses (m^3/Y)	⑦ Leakage on Transmission and /or Distribution Mains(m^3/Y)	
			⑧ Leakage and Overflows at utility's Storage Tanks(m^3/Y)	
			⑨ Leakage on Service Connections up to Customers 'Meters(m^3/Y)	

Source：IWA: International Water Association Standard

Box 9.1 International Water Association Water Balance

The following are definitions of principal components of IWA water balance.

- ***System Input Volume*** *is the annual volume put into the part of a water supply system that relates to water balance calculation.*
- ***Authorized Consumption*** *is the annual volume of metered and/or non-metered water taken by registered customers, water suppliers, and others who are implicitly or explicitly authorized to do so for residential, commercial, and industrial purposes. It includes water that is exported.*
- ***Water Losses*** *can be identified by calculating the difference between system input volume and authorized consumption. They consist of apparent losses and real losses.*
- ***Apparent Losses*** *result from unauthorized consumption and all types of inaccuracies associated with metering.*
- ***Real Losses*** *result from losses at mains, service reservoirs, and service connections (up to the point of customer metering). The annual volume lost through all types of leaks, bursts, and overflows depends on their individual frequencies, flow rates, and duration.*
- ***Non-Revenue Water*** *is the difference between system input volume and billed authorized consumption, and it consists of the following:*
  - *Unbilled Authorized Consumption (usually a minor component of water balance),*
  - *Apparent Losses, and*
  - *Real Losses.*

5. What is an index on water balance analysis?

For the management index, (a) the non-revenue water rate, (b) the **Revenue Water**, etc. are calculated from the water distribution analysis table.

■ For example,**(Refer to Table 1)**

a) Total **System Input Volume** is the total flow rate measurement **(BM 1**) at the outlet of the distribution reservoir

b) The amount of Revenue water is an aggregated value of the meter reading amount of （**C.M. from 1 to 3**）

■ The relationship between the **Revenue Water rate** and the non-revenue water, the Non-revenue Water Rate is "high" and the Revenue Water Rate is "low".

■ Each indicator is calculated in the following way.

a) Calculation formula of water quantity(m^3)

Q1=Q2+Q3

Q3=Q1-Q2

Q2=Q1-Q3

b）Formula for calculating percentage (%)

Q3(%)＝(Q3÷Q1)×100

Q2(%) =(Q2÷Q1)×100

Q3(%)＝(Q3÷Q1)×100

6. Points to note in Water Balance Analysis

Points to note concerning investigation of water distribution are as follows:

(1) Preliminary preparation items

Before measuring the water distribution volume, it is necessary to consider the following items.

① Is the measurement accuracy, operation, and use conditions of the flowmeter appropriate?

② Is the measurement point / appropriate?

③ Is the flow rate calculation method appropriate?

(2) Procedure for measuring and recording flow rate

① System Input Volume

Record the total water distribution on the discharge side of the water treatment reservoir/ distribution reservoir of the water treatment plant.

② Water volume of each distribution (DMA) block
Record the amount of water that flows into and distributes to all water distribution blocks / compartments.

③ Billed Authorized Consumption
Record and sum up the amount of water used by each meter installed in the water supply pipe.

◆ NOTE:
That the following is an example of a simple method of calculating the flow rate when "Flow meter is not maintained" or "cannot be used due to" Other causes of failure ".

① Calculate the water distribution from the water distribution of the water purification plant and the record of the water level change of the distribution pond.

② Calculate from the rated water quantity of the distribution pump, the number of units operated and the operation time.

③ Calculate from the electric power consumption of the distribution pump.

(3) Revenue Water volume
(Calculate amount of water received from meter's meter reading water volume)
① Whether the amount of water in the fixed rate tariff is appropriate?
② What is the insensitive amount of water (measurement error) of the meter?
③ Is the amount of water per one stopper of the fixed rate tariff appropriate?
④ Is there a mistake in the presence of illegal connections, or the amount of water used for free tariff?

(4) Un received water quantity
① The amount of non-revenue water shall be the amount of water obtained by subtracting the amount of total collected water from the total water distribution.

7. What is the insensitive water volume of the water meter?

It is the amount of water that cannot be measured with a meter due to a small flow rate (called initial water flow) that cannot be measured by a water meter and measurement accuracy of the meter (called instrumental error). **(Refer to Table 2, Figure 2)**

Table 2: Expected value of meter insensitive water rate (Example)

Descripción	Water rate of Meter insensitive (%)
Paraguay	12.0
Japan (JWWA Q 100 standard)	2.0
Past experiencia (Figure 3-2)	2.0〜3.0
Measurement range of instruments (Test tolerance 2% to 5%)	5.0
Do not consider	0.0

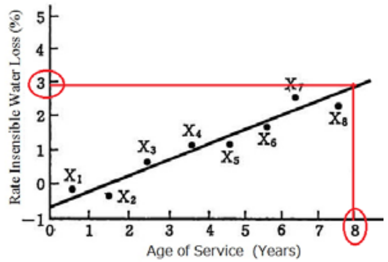

Figure 2: Year of use of meter and insensitive water rate (%)

-END-

Internal Information

TEXTBOOK

FOR

JOINT TRAINING

(DRAFT)

"HOW TO MANAGE WATER DISTRIBUTION NETWORK"

R-1

August, 2018

Implemented by

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***Original Edition, First Edition* August, 2018**

Table of Contents

1． Objectives (out-put)

① Understand the role of the distribution pipe network.
② Understand water distribution management.
③ Understand the structure of the pipeline that constitutes the water supply facility.
④ Understand the layout of water distribution network
⑤ Understand the role and managing of water distribution network
⑥ Understand the challenges of managing water distribution network in Kenya

2. Introduction

The distribution pipe network has the function of transporting, distributing, and supplying purified water, and it is necessary that the water supply is stably supplied at an appropriate water pressure at all times, and in order to be able to maintain the supply of water at emergency.
Also, since most of the water distribution pipes are laid under the ground like a stitch in the water supply area, it is necessary to construct a piping network in which operation and maintaining is easy and water quality in the pipe can be sufficiently conserved

3. Key words definition

The scope of the pipeline to be discussed in this water distribution pipe network management shall be the pipe network of water supply pipe and water distribution pipe.

Key words	Descriptions
Raw water Pipe (channel)	Pipeline for sending raw water to the water purification plant
Main water distribution pipe （Transmission pipe）	A pipeline that sends water treated as drinking water at the water treatment plant to the distribution hubs.
Water distribution pipe	A pipe network that diverges from the main water distribution pipe and distributes to all customers.
Water service pipe	A pipe that supplies water to each customer from a water distribution pipe
Gravity flow method	Method of distributing water naturally by utilizing height difference from the hill (high).
Pumping method	Method of distributing water with a pump
Combined method	A water distribution system combining gravity system and pumping system.
Blocking / Zoning	Divide all water distribution areas appropriately so that pipeline maintenance and management can be easily performed. (Zoning: A relatively large area) (Blocking: Area where zoning was further divided)
Hydraulic control	Maintaining stable pipe net water pressure "and" Monitoring abnormal water pressure "

Water hammer	Abnormal pressure rise phenomenon caused by sudden change in water flow (It may causes breakage of the pipe network)
Mapping	Pipeline details drawings
GIS	Information on Geographic Information and water distribution network is digitized and shared.(Geographic Information Systems)

4. General information

4-1 What is the facility function (role) of the water distribution network?

The role of the water distribution network is to provide water supply service that enables the following basic elements to be fairly safe and secure to all beneficiaries.

① Water volume (Provide adequate amount of water)
② Hydraulic pressure (maintenance of steady pipe water pressure)
③ Water quality (Provide safe water quality conforming to water quality standards)

4-2 What is the meaning of management of water distribution network?

Main items to be implemented mainly for maintaining the function of the water distribution network are shown below.

① Facility management that can cope with an increase in water demand
② Maintenance and management of the flexibility of pipeline that can provide stable (safe and secure) water supply service even in leakage / water cutoff
③ Longevity maintenance of the service life of the distribution

Table 1: Example of Concept of service life

Items	Actual life(years)	Japanese (Legal standard)	Kenya	Other country
Civil structures	50～100 years	Water Treatment plant 60 years		40 years
Water pipelines	25～100 years	Distribution pipe 40 years		40 years
Water supply pipe	25～50 years	Building accessory equipment 15 years		
Valves	10～40 years	Pipeline 30 years (recommended)		
Water meters	10～20 years	Water meters 8 years(Measurement Act)		7-8 years
Flowmeters	—	Flow meters 15～20 years (recommended)		10 years
Machinery equipment	10～30 years	Pumps 15 years		

4-3 General distribution system

The water distribution system from the water purification plant to each water distribution zone has a natural flow method and a pump pressurization method.

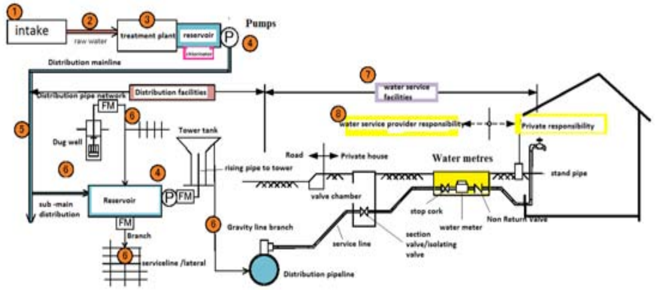


Figure-1: Flow of Constituent Facilities of Water Supply Facilities

4-4 Status of laying pipeline

The pipeline is largely classified as follows.

Pipeline	Raw water pipe
	Transmission pipe
	Distribution pipe
	Water service pipe

Most of these pipelines are buried alongside roads, but due to circumstances during laying it may be buried in places other than roads (forests, upland fields, etc.).

These pipelines are subject to the influence of ground subsidence, corrosion, traffic loading, construction, etc. in addition to deterioration of the pipeline materials constantly exposed to the risk of leakage.

Also, in places where pipelines are laid where there other structures, maintenance is difficult.

4-5 Points to keep in mind when planning for future placement of water distribution facilities

1) Effective utilization of topography data in distribution facilities

(a) Ideally, the distribution facility utilizes the potential energy of water and considers energy conservation.

(b) The shorter the distribution distance, the smaller the diameter of the water distribution pipe.

(c) After seeing the future of water demand, it shall be a distribution facility adapted to the topography.

2) Appropriate placement of water distribution pipe
3) Operation of rational and economical facilities
4) Facilities that are economical and easy to maintain and operate
5) Improvement of bypass function of piping in main water distribution pipes and in water Distribution pipes

5. Challenges in Kenya

5-1 Limit of piping network system function

1) Main issues

(1) Occurrence of unfair balance of water distribution (decrease in water supply service)

In the current water distribution system, as a result of an urgently expanded piping network, "proper water balance" collapsed, water supply volume was insufficient, uneven water pressure distribution occurred, and it became a factor of lowering the water supply level"

As a result, the trust relationship between WSP and customers is obstructed.

2) Main cause

① Unplanned expansion work

(a) The required diameter of the water distribution pipe cannot correspond to the Supply volume

② Insufficient number of valves to adjust the water distribution volume

③ There is no freedom of water distribution by the bypass pipe

④ Materials for judging the update time are not yet developed

(a) Delay in maintenance of pipeline map (Mapping or GIS)

(b) Asset ledger of water supply facilities is not maintained

⑤ Insufficient piping materials used

(a) Since the piping network is maintained with available materials, durability is deteriorated and the function is deteriorating.

⑥ Improper construction supervision

(a) Settling of covering caused by defective burial construction occurred

(b) After completion of construction, water pressure test, washing, removal of contaminants, disinfection work on pipeline is unconfirmed

⑦ Insufficient maintenance of function monitoring system of pipe network

· It relies on leakage information from public.

⑧ insufficient investigation of underground leakage

(a) Planned leakage investigation has not been implemented yet.

⑨ Insufficient cleaning of pipe network

(a) Since the washing of the piping network is insufficient, internal corrosion and water quality deterioration caused by precipitates in the pipeline occurred

5-2 Items that should be focused on improving maintenance function of piping network

1) Improve blocking and zoning of distribution areas,
2) Improve monitoring system in water distribution network (Flow, pressure and quality)
3) Improve water pressure management
4) Improve water distribution regularly
5) Improve water hammer reduction
6) Improve Pipe line drawing arrangement (by mapping)
7) Function evaluation of pipeline / Implementation of physical evaluation
(Degree of aging / water leak condition / survey of hydraulic condition / investigation of laid condition / water quality deterioration investigation)
8) Implementation of water leakage survey by leak detectors,
9) Implementation of the operations and maintenance of distributing reservoirs
10) Confirmation of functions of valves
11) Implementation of rehabilitation and renewal of distribution pipes
12) Upgrading of ledger (pipe ledger, valve ledger, asset ledger, leakage accident ledger)
13) Upgrading store stock yard management of materials / equipment
14) Offer maintenance records of underground buried pipe

5-3 Points to remember to upgrade occurrence of the unfair balance of water distribution

5-3-1 Improve blocking and zoning of distribution areas,

1) Purpose

(a) Appropriate distribution and balance of distribution pressure

(b) Improvement of water management

(c) Reduction of function of pipe network due to construction, damage

Here, the concept of zoning management is understood.

2) Examples of sectioned scale and items to be monitored

Table 2: Monitoring items for distribution category

Classification (Zoning/Block)	Scale sectioned	Monitoring items	Expected effects
Large	Based on trunk transmission line network centered on water supply by water treatment plant and water source	Distributed volume and water pressure measurements	a) It is possible to effectively reduce non-revenue water in zonal blocks. (b) It is possible to balance supply and distribution pressure and supply

Middle	Based on distribution reservoir level	Measurement of water distribution, residual leakage, water pressure in each area	/ water distribution. (Equalization of water distribution) (c) Water quality can be monitored. (d) Leakage monitoring is enhanced.
Small	Further divide the middle block (total extension 5 to 10 km, number of meters of 100 to 700)	Early detection of water leakage accident by pressure gauges	(e) It is possible to prevent expansion of damaged areas at the time of accident occurrence

3) Items to be confirmed in preliminary survey

(a) Understand existing water distribution facility conditions

Arrangement in ledger form: Layout, capacity, structure and special problem to be noted such as aging, difficulties in upgrading and so on

(b) Understanding the conditions of water demand

Understand the current population density and predict the population from urban planning.

(c) Grasp the hydraulic condition

Approximately estimate the required supply water volume and water pressure to each area in consideration of the application area, urban topography, etc. in urban planning.

4) Points to keep in mind when planning Zoning / Blocking

When considering proper blocking / zone allocation, it is also important to improve the following points to keep in mind.

a) Main points

① Integration of piping network and distribution reservoirs.
② Securing flexibility in maintenance management.
③ Strengthened water distribution control policy.
④ Reinforcement of water pressure management policy.
⑤ Reinforcement of water quality management policy.
⑥ Improvement of operation effect of facilities.
⑦ Reinforcement of monitoring system. (Flow control, leakage accident, water pressure management)

b) The way of thinking of division of Zoning / Blocking

As for the determination of the boundary line of zoning, the following "optimal combination" is discussed.

① Based on the distribution reservoir.
② Based on difference of elevation area.
③ Based on the area where the rate of non-revenue water is high.
④ Based on the integrated plan of a water supply reservoir and a pipeline.
⑤ Based according to water source.
⑥ Based on the improvement area in the area where water supply service is low.
⑦ Based on the city water supply usage by urban development.
⑧ Based on a direct connection water supply area.
⑨ Others

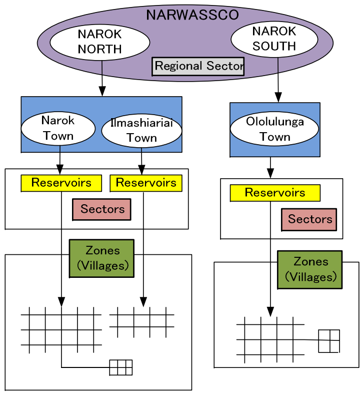


Figure 2: Classified Water Supply Areas by Sectored（NARWASSCO）

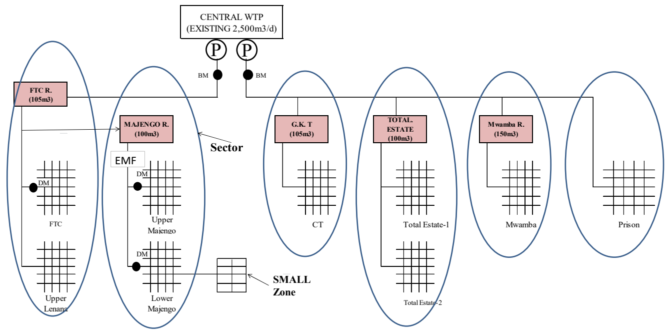


Figure 3 : Typical Concept of the Pipe network by Sectored Classified（NARWASSCO）

5-3-2 Improve monitoring system in water distribution network.

1) Purpose

It is duty that WSP should maintain the water distribution system with which a customer can always be satisfied of the service(Safety, relief, and reliance)is working, therefore, it is necessary to build the monitoring system (flow, water pressure, water quality) of 24 hours.

Especially the monitor of a leakage-of-water accident is understood in WSP headquarters and/or Measure unit in an instant, is that repair work is carried out quickly and can contribute to water supply service keeping and Physical losses reduction.

Here, the monitoring system in water distribution pipeline is understood.

2) Main monitoring items are as flows;

① Flow rate

The amount of water of every point is measured by installed bulk Meters by stream, and the following items are needed improvable.

(a) Correct water supply analysis is achieved.

(b) Measurement of the daily minimum flow will grasp leakage amount.

(c) Correct water supply analysis is achieved.

② Water pressure

A momentary pressure variation installed in pipeline is monitored with a mechanical pressure gauges or a pressure sensors.

As a result, the following items are improved.

(a)A leakage-of-water accident is discovered early.

(b) The time zone which the deficiency of water pressure created is grasped.

(c) The improvement of a pressure insufficiency block becomes easy.

③ Water quality

Common degradation in doxes of water quality are shown as Residual chlorine, turbidity, color and pH

The safety of a water pipe network is confirmed at value of Residual chlorine, concentration by block.

2) The momentary pressure variation by change of hydraulic balance occurs by a following cause.

(a) Change of water consumption.

(b) Variation in water supply pressure (Water level of a reservoir and the Pumping situation)

(c) Change of water temperature.

(d) In the long run, it is the fall of the flow velocity factor of a pipeline. (C-value)

3) Surveillance system of amount of water and water pressure (24-hour monitor)

(a) Water pressure management of a pipeline will be carried out with two or more pressure gauges installed in the pipeline.

(b) Water pressure data is sent to a water supply center with an automatic distant place supervising system, and the stable water pressure of a pipework network is monitored.

(c) If especially leakage of water is detected, cause survey and repair work are carried out immediately.

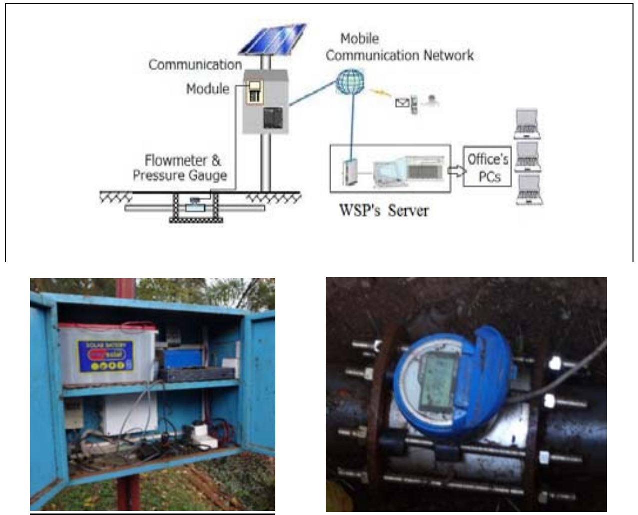


Figure 4: Example of the appliance of an automatic pressure monitor (EMBU)

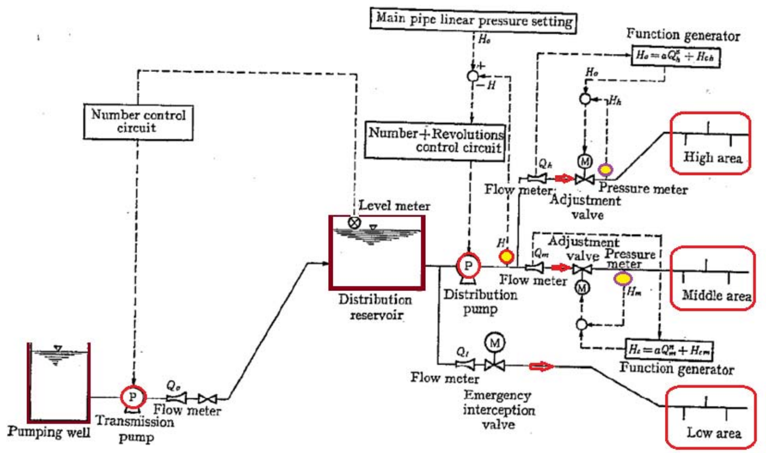


Figure 5: Typical Instrumentaion system in Distrubution Facilities

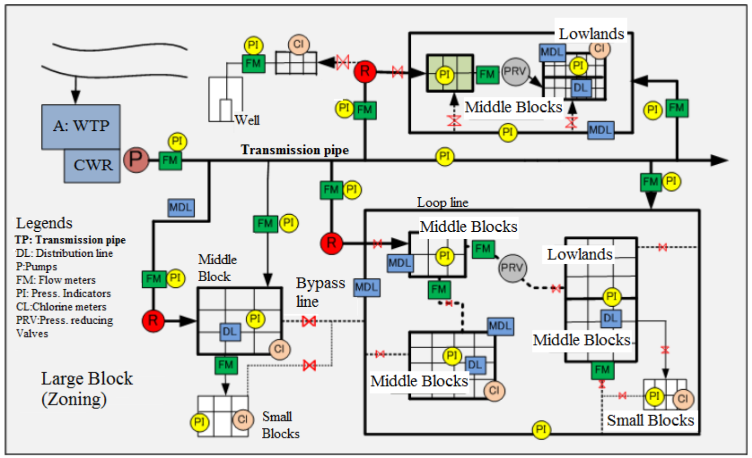


Figure 6: Typical monitoring system (By Flow meter, water pressure gauges and chlorine sensor)

5-3-3Improve water pressure management

1) Purpose

Water pressure management with the optimal water pipe network is stable keeping of water pressure and monitor of anomalous water pressure.

Especially the water supply with high water pressure becomes the leakage of water from piping with low resistance to pressure, and a cause of a damage.

On the other hand, lack of the amounts of water supply produces the water supply with low water pressure.

Moreover, from the damage section of piping, contaminated water flows backwards to a water pipe, and there is a possibility that water quality may deteriorate and the health damage caused by drinking water may occur.

Here, the management method of water pressure is understood.

2) Measuring method of water pressure

Water pressure management must be made a top priority in WSP located in area with a large difference of elevation.

(1) How to select water-pressure gauge installation points

① Points at the near branch from the main water pipe to each zone

② Points at the pipe end of a piping network

③ Height points (the minimum water pressure occurs)

④ Points at the front and after of reducing valve (verification of reliability)

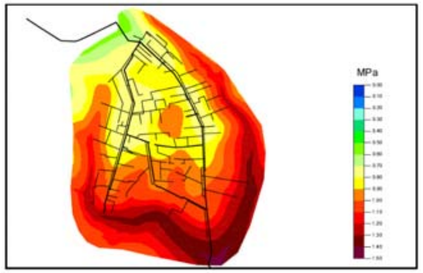
⑤ Points which a water hammer tends to generate

⑥ Point in 2 to 4 km distance (for leakage-of-water information)



(2) Distribution Map of Water Pressure

Plot distribution map of water pressure based on the results of measurement of water pressure



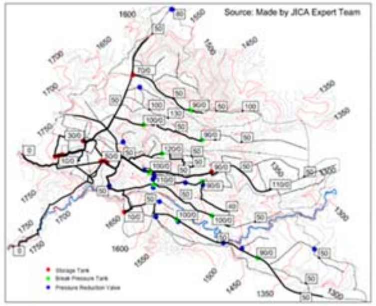


Figure 7: Example of Presser Map

3) What is the pressure loss in a piping network?

The pressure loss of a piping network is the frictional resistance of the pipeline which occurs when supplying water, and a pipeline loss increases, so that the length of a pipeline is long.

In consideration of the surface roughness of the inside of a pipeline, Hazen Williams's formal is especially used for calculation of the friction loss head of water (Pressure loss) of a piping network.

4) Hazen-Williams formula

The Hazen-Williams equation is more readily used for network analysis.

It gives acceptable results provided the coefficient is carefully determined. The formula is:

$$V = CR^{0.63}\, S^{0.54}\ x\ 0.001^{-0.04}$$

In which V is the velocity of flow in feet per second, C is a coefficient depended on the interior conditions of the pipe (sometimes called the coefficient of roughness), *R* is the hydraulic radius or the area of the pipe divided by the wetted perimeter in feet, and S is the slope (H / L) of the hydraulic gradient or head loss, in a meter per 1,000 m of pipe.

Note: Application

- Hazen-Williams formula: more than φ100
- Weston formula: φ75 or less paths

5) The relation of general pressure and flow

The conditions of a review: Both A service pipe calibre and inflow flow are set constant.

(1) Because the water pressure of an end will fall if the frictional resistance of a pipeline increases, the flow of end water supply decreases.

(2) If water consumption increases, pipeline frictional resistance will increase and the water pressure of an end service pipe will fall.

(3) Therefore, in order to maintain the flow of an end service pipe uniformly, it is necessary to make water pressure high by the friction loss of a pipeline, and to supply water in advance.

(4) Water pressure "it is high" The Q-H performance curve of a pump will become, if a flow decreases.

(5) Therefore, water pressure will become high if the amount of the water used at night decreases.

(6) If the water pressure of a pipeline is high, the amount of leakage of water will increase.

(7) Because the pipeline lacking in intensity becomes damage and a cause of leakage of water, there is the necessity of carrying out water pressure control with a valves.

6) Water pressure reduction

(a) "Valve travel" of a water supply valve at night is a few.

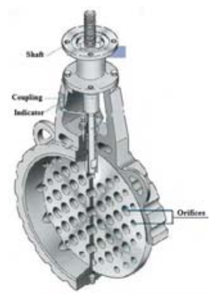
(b) Modify connection of a water pipe route and a bypass pipe.

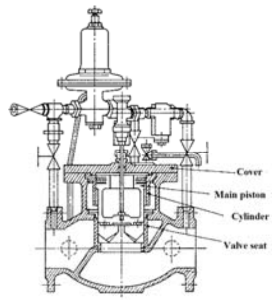
(c) Install Orifice Valves controlled by Micro-computer

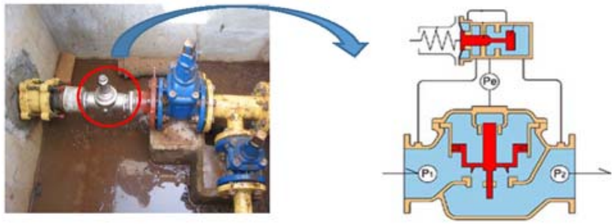
(d) Install Auto valves

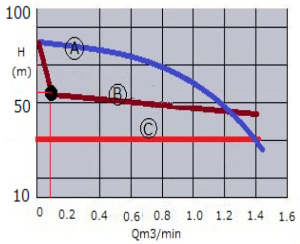
(e) Install Reducing valves

(f) Use Electric rotational-frequency motor -pump.





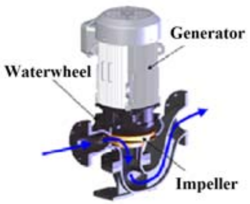




Q-H Performance curve

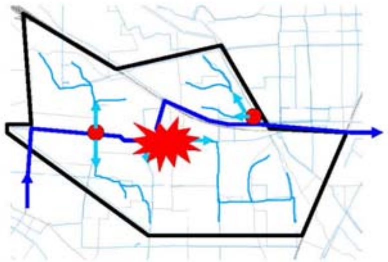
Install a reducing valve in the pump discharge side.

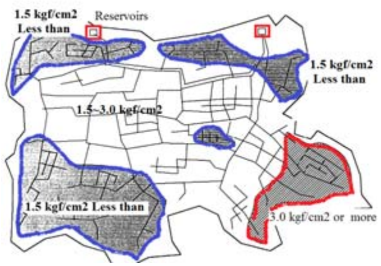
Remarks: Ⓐ:Typical Pumps, Ⓑ:Reducing valve installed, ⒸRotational-frequency Pumps



9kW
Difference:35m、 Flow:2.8m^3/min
Small scale hydroelectric power pumps

3kW
Deference:30m、
Flow1.0 m^3/min





Example of a leakage generating point's map **Example of a water pressure distribution map**

Figure 8: Example of Leakage points and Pressure Distribution Maps

5-3-4 Improve Water hammer reduction

1) Purpose

Water hammer is generated by sudden stop of a pump and rapid closed a valve, it may damage a water pipe network.

Here, Water Hammer Reduction method is understood.

2) Feature of the pressure wave of water hammer

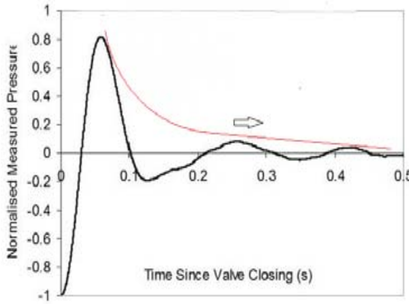
The wavelength of a water hammer is a sine wave, and high pressure and negative pressure occur repeatedly and decrease it gently.

(1)Water hammer due to sudden pressure rise

(2) Water hammer by water column separation

(a) High pressure occurs, when water and water collide rapidly.

(b) Low negative pressure occurs, when water and water separate rapidly.



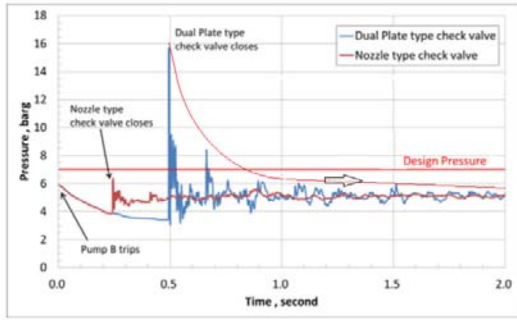


Figure 9: Example of Wavelengths of Water Hammer Reduction Maps

3) Where is the piping network which Water hammer tends to generate?

If it generates within a piping network, because the rise of water pressure diffuses Water hammer pressure, it does not become a not much big problem.

However, in the pipeline of the following conditions, a possibility that a water hammer will be generated is high.

① In the case of a metallic piping

② The total extended distance is long at a single pipeline.

③ The equipment installed which generates change of pressure, such as a pumps and a valves.

④ Total pump head on the delivery side is large.

◆ **NOTE;**

Most Main distributing pipe lines may be required for the review of the measure against Water hammer.

4) Problems by the pressure fluctuation by a water hammer

① The pumps in a pipeline, piping, a valve, a joint, a piping support, are damaged by rise pressure.

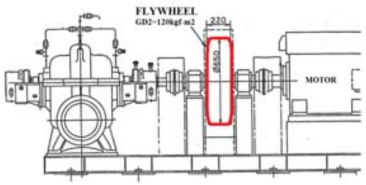
② A pipeline is destroyed by the drop in pressure by pressure deformation of a pipeline and the secondary pressure increase by water column separation.

5) Measure against water hammer

General measures are measures with most realistic keeping water from changing "rapidly."

(1) Flywheel

In order to prevent the sudden stop of a pump at the time of pump pressure feed, it is the method of preparing weight in the axis of rotation of a pump, and stopping a pump gently using the inertial force.



(2) Conventional surge tanks and One-way surge tank

It is the method of installing the tank which has the free water surface in the high place which the negative pressure in a pipe tends to generate, and missing water pressure by up-and-down motion of the water surface.

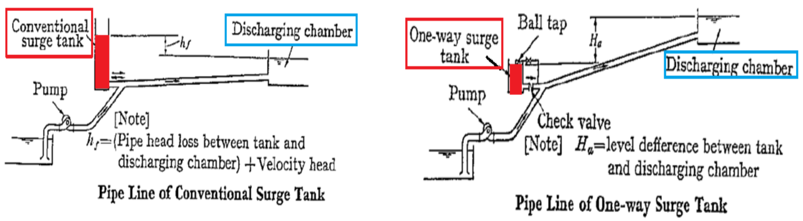
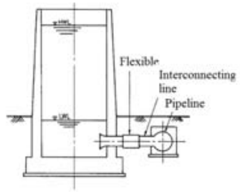
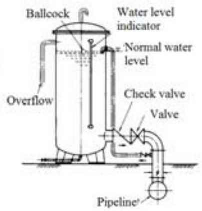
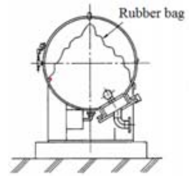


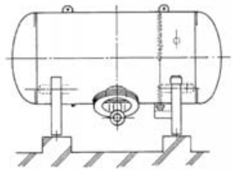
Figure 10: Example of Conventional Surge Tanks and One-way Surge Tank Systems

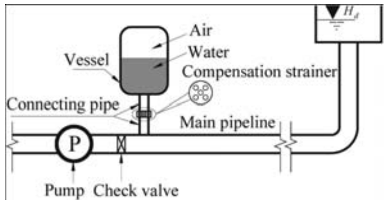




It is the method of controlling a negative pressure by supply of water or Rubber bag.







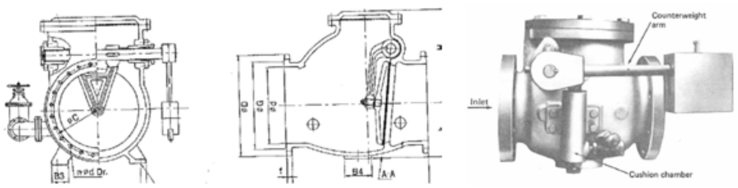
(4) Air release valves

An air valve is the method for a small size pipe of always installing in a pipeline's height and release pressure by suction of air.

Maintenance management is frequently required because a function is maintained.

(5) Slow Shut Type Check Valves

This type of a Check valve to be installed at pipe line after Pump's discharge side shuts a door slowly by effect of Counter-weight & by-pass Valve assembled.



5-3-5 Improve water distribution adjustment

1) Purpose

As for water supply fair to two or more water pipes, according to a valve operation plan, opening and closing of a valve are managed for the skillful valve Operator from a water supply reservoir.

As for the result of valve operation, the data of a flow instrument is recorded.

Here, the distribution method of water supply is understood.

2) Information required for preparation of the delivery allocation

(1) Preparation of a water supply valve operation plan

This plan predicts the amount of allocation for every zone block from the weather and a season, draws up a plan per season, and is reexamined periodically.

An allocation plan on the day is determined on the previous day, and is directed to a valve operator.

- Information required for the review of a plan is shown below.

(a) Quantity of water intake

(b) Amount of water-purification

(c) All the amount of water to be supplied

(d) Required amount of water of each zone and/or block

(e) Peculiarity of a distribution area

(f) Peculiarity of a distribution area

(g) Suspension-of-water-supply time

(2) Operation method of allocation amount of water

Water is supplied by plurality by operation of an allocation valve.

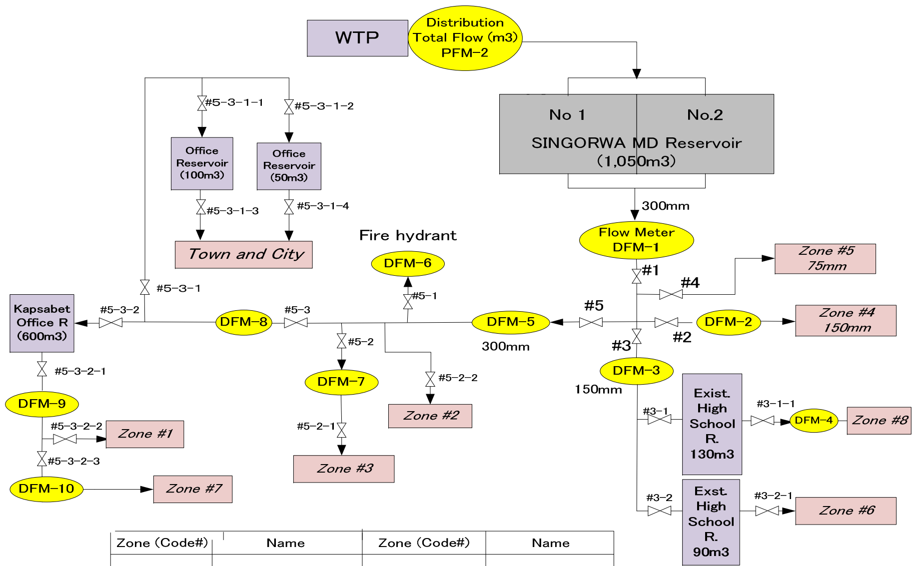
The point to be checked of valve operation is shown below.

(a) Grasp of the water level of a water supply reservoir

(b) Amount of water supply is measured with a flow instrument.

(c) Achievement record is created

(3) Example of OJT Training in Kapsabet Nandi WSC: KANAWASCO 2011



Zone (Code#)	Name	Zone (Code#)	Name
Zone #1 (1000)	Showground	Zone #5 (5000)	Kamartugui
Zone #2 (2000)	Prison	Zone #6 (6000)	Kapngetuny (No. H.C:)
Zone #3 (3000)	Town Center (No. H. C.:)	Zone #7 (7000)	Kamobo
Zone #4 (4000)	Chebarar (No. H.C.:)	Zone #8 (8000)	Kabutie (No. of H.C.:)
NOTE: Total House Connection: about 300			

(1) Peak Flow:8:00am/18:00 pm

(2) Flow Survey: DFM-1/DFM-2/DFM-3/DFM-5

(3) Time consumption Survey: Zone#8(DFM-4)/#1(DFM-9)/#7 (DFM-10)

Figure 10: Example of Water supply flowsheet

Table 3: Example of Schedule of Valve Operation

Valve #	Zone / Reservoir	Size	Valve Opening Indication	Position	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
-	WTP		100%	Outlet Open													**Open**											
				Outlet Close				Closed																	Closed			
				-																								
#1	Singorwa Reservoir	300mm	10-20%	Outlet Open													**Open**											
				Outlet Close				Closed																	Closed			
				From WTP																								
#2	Zone #4	150mm	50%	Inlet Open													**Open**											
				From Sin R																								
#3	-	150mm	50%	Inlet Open													**Open**											
				From Sin R																								
#3-1	High School R 130m3	150mm	100%	Inlet Open													**Open**											
				From Sin R																								
#3-1-1	**Zone #8**	150-100 mm	10-20%	Outlet Open																								
				Close				Closed									Closed								Closed			
				From HSR																								
#3-2	High School R 90m3	150mm	0%	Inlet Open													Closed											
				From Sin R																								
#3-2-1 (Route-1)	**Zone #6**	100mm	10-20%	Outlet Open																								
				Close				Closed									Closed								Closed			
				From HSR																								
#3-2-2 (Route-2)	**Zone #6**	100mm	10-20%	Outlet Open																								
				Close				Closed									Closed								Closed			
				From HSR																								

WTP Operation	Size		M3/d	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Operation (Dry :Oct.~Mar)	300mm		500							6:30													19:00				
			1,000																								
			2,000																								
			3,000																								

WTP Operation	Size		M3/d	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Operation (Wet :Apr~Sep)	300mm		500								7:00:00~8:00									16:00~17:00							
			1,000																								
			2,000																								
			3,000																								

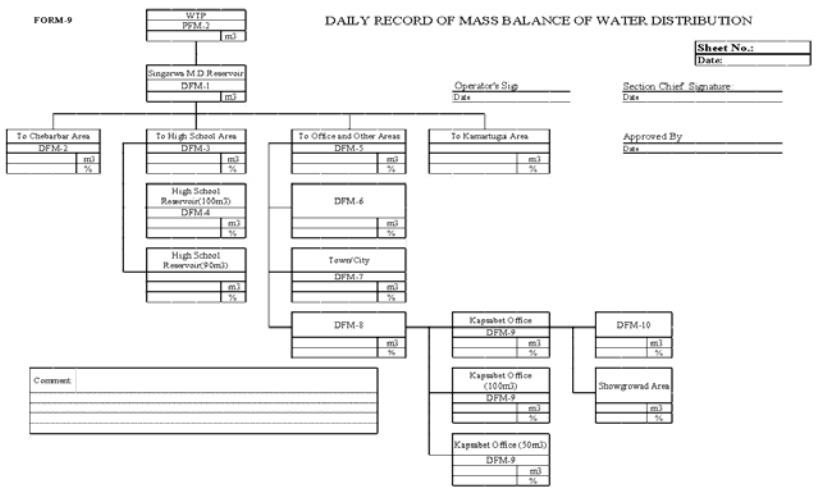


Figure 11: Example of Daily Record of Mass Balance of Water Allocation

5-3-6 Improve Pipe line drawing arrangement (by Mapping / GIS)

(1) Purpose

The concept of the unified management technique of pipeline information in which is utilized the Mapping and GIS are understood.

(2) Utilization of IT technology

(a) Features of IT system

The feature of this system is that digitized letters, numbers and image information are incorporated into Geographic information, and necessary information is unified and reproduced on the computer, and as output data, analysis results of the position and location of the piping network, the pressure distribution etc.

It is a unification system of maintenance and management work that can express on the PC screen.

(b) Classification of IT system

① Mapping system (only pipe network data can be outputted)

It is aimed at inputting relatively basic information only and outputting limited data.

Mapping of the pipeline network is absolutely necessary for WSPs to implement efficient NRW reduction measures.

In case of WSP without any map of its pipeline network, the first step is to prepare a hand drawn map by carrying out a site survey of the supply area. It is recommended that this hand drawn sketches to be converted to digital files (CAD, etc.)

The first step to the preparation of the pipeline network map is to conduct a survey of the supply area on foot.

A hand-drawn map must be sketched at the time of the foot survey.

All sketched maps must be organized to produce a sketch of the pipeline network of the supply area.

More information such as location of valves and information on water meters, can be added onto this map.
The hand-drawn maps should eventually be converted to digital files using CAD and/or GIS.

② GIS (Various data can be outputted)
By inputting more information into the mapping information, it is aimed at outputting various kinds of data.
GIS has been introduced as a platform for the management of water service system, especially for its characteristic capacity for comprehensive management of maps and databases. GIS is used in areas such as data analysis methods, customer registers, revenue collection, etc.

(3) Basic information required (varies depending on the system to be utilized)

① Map information
- Geographic map
- Boundary (zone, block etc.)

② Transmission / distribution network
- Water treatment facility location map
- Route map of pipeline
- Distribution facility location map
- Information on leakage accident occurrence, others

③ Water Service
- Route map of service line
- Information on meter management
- Information on toll collection
- Information on illegal connection
- Information on leakage accident, others

④ Information on facility maintenance management
⑤ Information on water leakage survey
⑥ Information on the business register
⑦ Information on urban planning, others

(4) Strengthening the confidentiality of personal information
Since digital information necessary for utilizing IT technology includes personal information and internal confidential information, it should be strictly managed.

(5) Items to be considered in advance of system introduction
It is necessary to select the IT system in advance by examining the introduction purpose and introduction effect.
The items to be examined are shown below.

(a) Purpose of introduction
① Effect of cost reduction
② Improvement in service
③ Effect on advanced strategy planning
④ Cost effectiveness

(b) Confirming the achievement priority of the introduction effect
① Group 1:
Improve water supply service activation of organization and Improve reliability of water supply
② Group 2:
Lack of water pressure, decrease in water cut-off time, Open business information
③ Group 3:
Accelerate response to complaints, anyone may allow to use analysis tool,
④ Group 4:
Providing information such as leakage at home

(c) Example of checking the priority item of output data
① Display:
Topographic map, Location map of water supply facility, Pipe route, assumption of natural disaster damage map Update plan of pipeline

② Search result (output of charts & drawings, etc.):
Distribution map of aged pipe, map of zoning (by boundary) piping network, Hydrostatic pressure distribution, Customer meter information, Information on leakage occurrence point, Distribution analysis table, location map of the discarded remaining pipe, others

③ Calculation result (management):
Numerical value of water pressure distribution, management index, flow direction, Timing of pipeline updated, approximate information on repair cost, leakage in Block, cost of improvement, others

> - Utilization of IT technology is effective as a means of water supply assets and pipeline operation management.
> - When choosing the introduction of the system, it is necessary to consider the cost effectiveness from a long-term perspective.
> - Input of accurate basic data is indispensable.
> - It is essential to constantly update the data to the latest information.

(6) Introductory effect of a Mapping System

The mapping system is a simple IT system to facilitate the maintenance operation work that inputs digital information of water supply facility maintenance information, pipeline rout, location of valves, and meter location of each household in a topographic map and/or aerial photograph, and displays necessary data output on a PC screen and print out.

As a result, WSP can respond instantaneously to customer consultation to improve citizen service and help improve WSP management efficiency

> ◆ **Example of effects**
>
> ☆ **At the time of leakage, it is possible to quickly respond because the location of the valves and the water failure-houses can be specified easily.**
>
> ☆ **When building a house, you can see where a water pipe is located with one button on a PC.**

(7) Introductory effect of a GIS（Geographic Information Systems）

GIS can input more digital information to Geographic information than mapping system and displays necessary data output on a PC screen and print out.

As a result, pipeline information (for example, pipeline, meter reading, ledger work), management indicators, and calculation data are outputted in a timely manner, so that management can speed up management decisions to improve management soundness and strengthen water supply service

(8) Examples for GIS data output

① Predicting the effect of an update plan

② Mark out risk of leakage

③ Proposal for proper water distribution and countermeasure in case of emergency by valve operation and

④ Piping network management by hydraulic calculation software

⑤ Calculation of update priority order

(9) Example of data input work procedure (GIS case)

The basics of data input work is to input a lot of related digital data as map data to base information.

The following is a flow of construction of a simplified GIS-piping network maintenance management system.

Procedure of work			Work contents
#1	Input basic data (Geographic Information map) to PC		-Utilize aerial photograph data, satellite image data, etc., taken with the Geographic data as it is. -It is necessary to periodically update to the latest data in order to correct the change of Geographic data（For example: Q-GIS, Quick-Bird ,Ikonos and Google）
#2	Input database (attribute information) to PC		-Distribution facility information, existing pipe network diagram, completion drawing, maintenance record, customer ledger, meter management information, calculation software, billing information etc. -After digitizing the database, input it to each file.
#3	Combining basic data and database in PC		-Precisely overlay coordinate values of satellite imagedata with digitized drawings. -Check the coordinate values of the current piping route, valves etc., by actual measurement or simple GPS.
#4	Editing digitized information and confirming output		-The database is updated on a regular basis. -Confirm the accuracy of data output by PC screen display and/or printing.
#5	Completion of database creation of GIS		-Output of edit data -Example: drawing, simulation analysis, operation index, invoice, others

Figure 12: Example of Work schedule of GIS

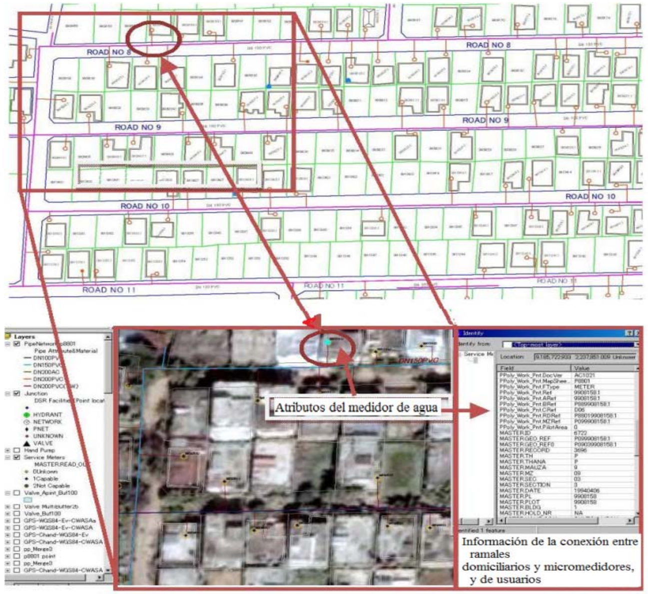


Figure 13: Example Route of piping network by GIS

—END—

5－5 Distribution reservoirs

5－6 Pipe material

5－7 Air Valve

Internal Information

TEXTBOOK
FOR
JOINT TRAINING
(DRAFT)

"PHYSICAL WATER LOSSES MANAGEMNENT"
R-1

February, 2019

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)
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***Original Edition, First Edition* February, 2019**

Table of Contents

1. Objective (out-put)

① Understand how reduction of physical losses
② Understand the components of physical losses
③ Understand the sources of physical losses
④ Understand the causes of physical losses
⑤ Understand the factors that influence leakage occurrence
⑥ Understand the layout of water facilities
⑦ Understand the importance of leak records
⑧ Understand pipe laying procedures
⑨ Understand on how to detect water leakages

2. Introduction

Water losses occur in all distribution networks, even new ones. Physical Water Losses sometimes called 'real losses' or 'leakage' includes the total volume of water losses minus commercial losses.

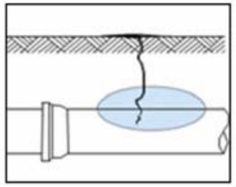
3. Key words definition

Key word	Definition
Water losses	Water that does not generate revenue
Apparent losses	Commercial losses
Physical losses (Real Losses)	Loss of water through leakages from pipelines
Visible leaks	Leaks that can be seen on the surface
Non-visible leaks	Leaks that cannot be seen on the ground
DMA	District meter area

4. Component of Physical (Real) Losses

The main cause of Real Loss is leakage from pipelines**. (Refer to Figure 4-1, Table 4-1)**
Many water pipelines are buried, and water leaks will not be visible since they occur below the ground, so they will continue to flow out unless repaired.
For this reason, they cause secondary disasters such as road collapse due to leakage, flooding in houses and buildings.
Leakage is classified as Surface leakage and underground leakage below. (**Refer to Table-1)**

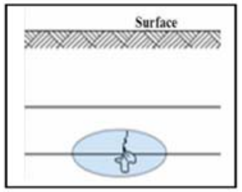
① Visible leakage (Surface leakage)
(a) Surface leaks are few because they are easy to find and repair.
(b) Surface leakage occurs in area with high water pressure.



② Non-visible leakage(Underground leakage)

(a) Subsurface leakage, infiltrates underground so "discovery is difficult". In addition, leakage continues over a long period of time, so the number of water leak points increase and leakage volume also increases year after year.

(b) Underground leakage occurs in area with low water pressure.



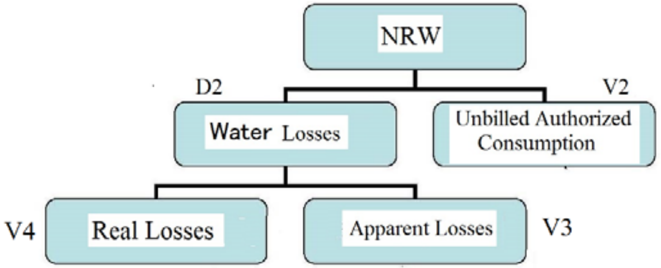



Figure-1 Component of non-revenue water

Table-1 Component of Physical losses

NRW Cause	Countermeasures	Examples of countermeasures
Physical losses (D2)	Real Losses (V4)	a) Detection of water leaking points/ Repair in water distribution pipe / water supply pipe network b) Overflow prevention of distributing reservoir, others

PHYSICAL WATER LOSSES MANAGEMNENT 2019 February

Table-2 Comparison of Surface leakage and underground leakage

Items	Surface leakage	Underground leakage
Large and small leakage	Those with large water leakage tend to go to the surface	Less leakage volume tends to cause underground leakage.
Geological relationship	Clay-based, loamy, etc. are easy to go to the surface.	Sandy, sandy gravel etc. tend to cause underground leakage
Paving, sewerage etc. '	Regions of unpopulated pavement are more likely to leak water to the surface	It is prone to underground leakage.
Influence on leakage rate	The number of water leaks is large, but because it is discovered early, the leakage duration per case is short	Although the number of findings is small, there is a tendency for water leakage for a long time, leakage tends to grow, and the leakage volume varies from a trace amount to a medium level.
Types of damage	It causes direct damage such as collapse of the road, sediment discharge, traffic disturbance, house flooding, suction of wastewater and so on	It causes economically damaging indirectly such as loss of water quantity, decline of revenue water, water pressure decrease, suction of wastewater, wear of facilities and so on.

5. Some Sources of Physical Water Losses

- ◆Leakages in valves
- ◆Leakage on the pumping main
- ◆Overflows at the collection and treatment tank
- ◆Back flow of pumped water that has remained in the transmission main
- ◆Bursts on distribution mains
- ◆Leakages on service lines
- ◆Leakages on transmission and distribution pipes
- ◆Faulty ball valve
- ◆Leakages at the joints







6. Some Causes of Physical Water Loses

- ◆Malfunction of the ball valves
- ◆Heavy traffic
- ◆Poor quality of pipes
- ◆Lack of technical support
- ◆Pipe diameter small compared to the pump capacity hence causing burst
- ◆Leakage at customer point
- ◆Back washing of filters








7. Factors that influence leakage occurrence

(1) Causes of leaks

Main causes of water leakage from distribution facilities are shown below

Table-3 Factors of leakage occurrence

Internal causes	External causes
1） Due to tube / material ① Materials and structures of pipes, fittings and accessories are incomplete from the time of construction ② Strength deterioration due to corrosion ③ Aging of materials	**5) Due to the buried environment** ① Increase traffic load ② Movement of the ground ③ Rupture due to high water pressure inside the pipe ④ Difference between design and actual condition ⑤ Excessive external stress ⑥ Soil contamination by industrial waste liquid etc.
2) Due to design / construction technology ① Incorrect design ② Joining problem such as joint part ③ Inappropriate backfilling ④ Contact with other structures (insufficient protection) ⑤ Corrosion method is inadequate ⑥ Potential corrosion by dissimilar metals	**5) Other work or cause attributable to disaster** ① External damage caused by corporate construction ② Changes in buried environment caused by other construction works ③ Changes in the ground and road caused by disasters such as earthquakes
3） Due to internal factors ① Water pressure, water quality, water temperature (internal corrosion) ② Water hammer	**6) Other** ① Several causes overlap

Source: Yokosuka city water and sewerage authority

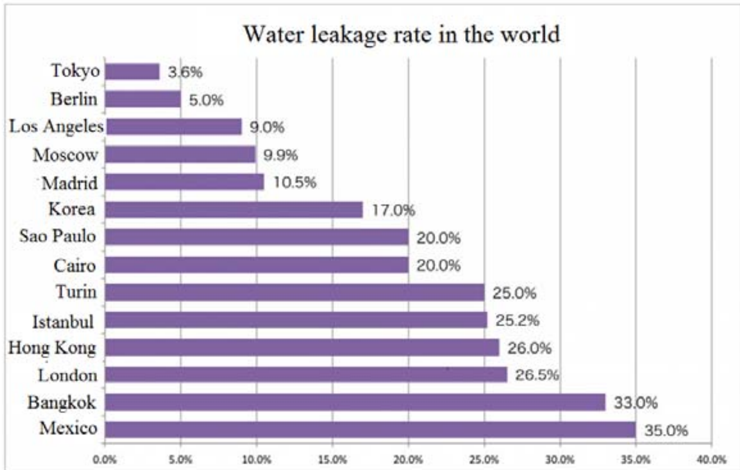
8. Installation status of water distribution facilities

The installation condition of the current distribution facility is shown below.

Table-4 Example of Installation statuses of water distribution facilities

Description		Japan	Kenya（Typical WSP）
History	Completion of water supply facilities	A British engineer completed in Yokohama City in 1886	
	Initiation of water leakage survey	Water leakage occurred in 1890 due to immature construction technology	
Establishment of guidelines		Goals of MHW (Revenue	Strategic Plan 2013-2015

		Water rate 90% in Sep. 1976	(NRW30%)
Example for Yokosuka city water supply and sewerage office	Inauguration of water leakage prevention staff	Since Oct. 1965 (completion of WTP in 1908	
	Creating a target achievement plan	Revenue Water rate 90% in 1988	
	Current situation (%)	84% in 1978	
	Study of individual Listening stick	Since 1977	
	Study of Meter Insensitivity	Investigated in 1980 (13～100mm) 2.2 %	
	Amount of water supply	24 hr. water supply	Temporal water supply
	Quality of water	Satisfying (Meet STD)	Satisfied (but not meet STD)
Facility maintenance situation	Mapping and/or GIS	Developed	Almost un-developed
	Remote monitor system	Developed	Under developed
	Pressure reducing valves	100 % Installed	Partially installed
	Customer meters	100 % Installed	Partially installed
	Bulk meters	100 % Installed	Partially installed
	Control valves	100 % Installed	Partially installed



Source: JW "Water Security Study Group" Final Report July 2008

Figure-2 Non-revenue rate in each country

9. Record of the number of water leaks

As a method to realize the actual condition of water leakage, below is a table showing the number of water leaks repaired.

Table-5 Example of Record of number of water leak repaired

Cause	Material of pipe	Distributing pipe (Cause of leakage)				Water supply pipe (Cause of leakage)			
		2013	2014	2015	2016	2013	2014	2015	2016
Aged pipe	Cast iron pipe (mm)								
	Vinyl pipe(mm)								
	Galvanized steel pipe(mm)								
	Steel pipe(mm)								
	Lead pipe(mm)								
	Total								
Corrosion	Fittings								
	Bolts								
	Snap taps								
	Vinyl pipe fittings								
	Total								
Joining problem	Vinyl pipe fittings								
	DCI pipe								
	Sockets								
	Lead pipe								
	Other								
	Total								
Gland packings	Gate valves								
	Air valves								
	Snap taps								
	Water shutoff valves								
	Total								
Dynamic load pressure/ vibration/ Corrosive soil Other	Ductile cast iron pipe								
	Steel pipe								
	Vinyl pipe								
	Asbestos pipe								
	Total								

Left piping abandoned	Disposal piping								
	Total								
Water pressure	Crack of Pipe								
	Detachable								
	Total								
G. Total									

10. Status of laying pipeline

Pipelines are generally buried, below the ground level and usually along the road networks but sometimes they are buried in places other than road side (forests, upland fields, etc.) due to prevailing circumstances during laying. These pipelines are subject to the influence of soil erosion, subsidence of ground, corrosion, traffic loading, construction, etc.

In addition to deterioration of the material of the pipe itself due to aging, and are constantly exposed to the risk of water leakage.

Table-6 Breakdown of pipeline

Pipeline	Raw water pipe
	Transmission pipe
	Distribution pipe
	Water service pipe

11. How to detect water leakage

(1) Leakage detection / notification method ;

There are three ways to know leakage from pipeline.

- ◆ Report leaked water on the ground by residents and passing by
- ◆ Reporting by public works such as electricity, telephone, sewage
- ◆ Proactive water-leakage investigation by water utilities / notification by line patrol

(2) Visual detection of signs of underground water leakage

①The ground is wet even though it is no rain.

②Road surface / Building is collapses / cracked.

③Strange smell Presence of objectionable odor and dirt in tap water.

④ The meter is running even though it is not using water (leakage at home)

⑤ The garden is always wet (in-house leakage)

(3) Detection by public construction

① Water came out after excavation

② Water is falling down the river from the vicinity of the bridge

③ Water is present in manholes

④ Clean water flows in the sewer pipe

⑤ Water springs from the cliff

⑥ Spring water comes out from the bottom of the river

(4) Detection by regular survey by WSP staff

① Survey result of Water balance to be implemented periodically;

Survey and analyze the actual condition of Water balance by DMA on a regular basis (every week / month / year) and grasp the amount of non-revenue water

② Survey result of regularly investigate remaining water leakage / restoration water volume.

(a) What is selected measurement survey?

In this method, after conducting the preliminary water leakage survey, the leakage section / pipe / leak point in the DMA is specified.

(b) What is a patrol measurement?

In this method, without conducting the water leakage survey in advance, the water leakage survey of DMA is determined from the circulation years and leakage accident information, and the leakage section / pipe / leakage point is specified.

③ Confirmation of abnormal usage amount at the time of meter reading (suspected leakage in residential area);

(a) Compare the previous and current meter reading values at the worksite / office and check the cause of the abnormal value

④ Monitoring results of water pressure / flow rate variation in a water distribution pipe system

(a) On-site automatic monitoring device monitors abnormal values of water pressure / water distribution. (**Refer to Figure -3**)

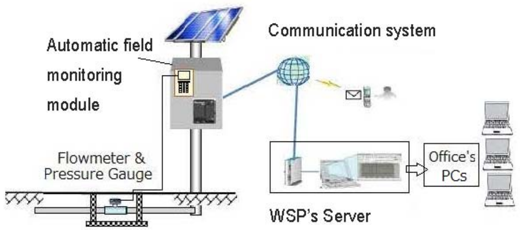


Figure -3 Conceptual diagram of monitoring system

⑤ Concentration survey result of frequent occurrence points of leakage accident

(a) From the record of water leakage accident, predict the number of repairs, the leakage scale cause pipe type, occurrence place, deterioration situation of pipeline in cloth pipe area.

NOTE: More detail is shown in **THE TEXTBOOK of DISTRIBUTION PIPELINE**, **(5-3-2 Improve monitoring system in water distribution network).**

-END-

Internal Information

TEXT BOOK
FOR
JOINT TRAINING
(DRAFT)

"BASIC CONCEPT OF LEAKAGE PREVENTION WORK"
R-2

August, 2018

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
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Table of Contents

1. Objectives (out-put)

① Understand what is Leak prevention work

② Understand Main basic countermeasure work against leakage

③ Understand Concept of Leakage Recurrence

④ Understand Concept of compositional unit of total water leakage

⑤ Understand Concept of Record sheet of leakage survey

2. Introduction

Water leaks can be either surface or underground. When water leaks to the surface, it can be repaired quickly. On the other hand, if it does not appear on the surface, it will continue to leak for a long time.

Most leakage losses by volume over the course of the year occur on customer service connection piping – not water mains

Policies that place the burden on customers to repair leaks on their service connections are often inefficient

New policies/programs to address service line leakage are needed to economically reduce this leakage

3. Key words definition

Surface Leakage	Visible Leakage
Underground Leakage	Non-Visible Leakage
Leakage Recurrence	Amount of leakage which increased with time from remaining leakage
Remaining leakage	Amount of the minimum leakage amount, immediately after the measure against leakage
Total water leakage	Restored amount + Remaining leakage =Preventable leakage by technology + unable to prevent leakage + Ture water leakage= Allowable water leakage +
Allowable leakage	Quantity which admits the amount of leakage of water
Electrolytic corrosion	Is an accelerated corrosion when a metal is in contact with another in presence of electric current
Peatlands	Accumulation of partially decayed vegetation or organic matter unique to natural areas

4. Objectives of Basic concept of leakage prevention work

To understand the need;-

(1) To Increase efficiency in O&M of our water schemes

(2) To Increase knowledge of our networks (via Mapping and /or GIS systems, computer modelling) and consumption patterns (via metering)

(3) For Value for money by deferring capital expenditure on new water supply schemes through improved supply and reduced consumption

(4) For Environmental protection by deferring new water sources

(5) To Improve supply service to our consumers

(6) For PR of the need for water conservation.

5. Leak prevention works

5-1. Guidelines for leak prevention

In formulating the water leak prevention plan, it is necessary to consider economic efficiency considering the water demand plan of each city, the actual condition of water resources, facility size, etc.

If ~~it~~ water leaks to the surface it can be repaired quickly. On the other hand, if it does not appear on the surface, it will continue to leak for a long time.

Leakage countermeasures work is divided into three categories. **(Refer to Table 1)**

Table 1: Water leak prevention measures

Classification	Items	Policies
① Implementation of Collection / analysis of basic information	・Preparation for water leakage prevention work	・Securing financial resources and organization ・Preparation of documents (piping diagram, DMA drawing) ・Setting of DMA, maintenance of measuring equipment
	・Investigation of actual situation	・Analysis of water distribution and leakage volume and water pressure measurement ・Analysis of leakage cause and preservation of data of record
	・Research and improvement of piping materials, and development	・Maintenance of tube materials of pipes and water pipes, recording of joint materials ・Function check of accessory equipment
② Implementation of Survey of leakage volume	・Mobility work	・Immediate repair of ground leakage
	・Panning work	・Early detection and repair of underground leakage
③ Implementation of Preventive measures	・Plan for water supply project	・Preparation of a plan formulating leakage prevention
	・Design and construction of water supply facility	・Examination of earthquake resistance, durability, corrosion resistance, water tightness
	・Replacement of aged pipe (replacement of leaky water pipe)	・Replacement of water distribution pipe and water supply pipe (including change of pipe type)
	・Improvement of the structure of water supply equipment	・Consolidation of road transverse pipes ・Install customer meter near public and private sector boundary
	・Protection of collapse of pipeline	・Corrosion prevention, leakage prevention and reinforcement of bent pipe section
	・Treatment of remaining pipe (owner unknown pipe)	・Improvement of construction inspection of pipe branch points ・Strengthen management of water supply equipment
	・Patrol of pipeline	・Guidance and supervision at other company construction sites
	・Adjust water pressure	・Installation of a distribution line for each distribution system and installation of a pressure reducing valve

·Source: Yokosuka City Waterworks and sewerage bureau

6. Outline of leak prevention work

6-1. Implementation of Collection / analysis of basic information

The **main basic countermeasure work** is collection of information necessary for action against leakage and analysis of the result.

(1) Creating pipeline drawings

(a) Creating pipeline

(b) Mapping - Creating a GIS diagram

(2) Implementation of water distribution analysis, others

(a) DMA conversion

(b) Installation of bulk meter and customer meter

(c) Analysis of leak occurrence records, others

6-2. Implementation of Survey of leak volume

Investigation of leaks (surface and underground) from buried pipeline, and survey of water leakage and implementation of early repair work.

(1) Method of leakage survey work

- Mobility investigation work

(a) Repair ground leakage discovered by notification from the citizen and patrolling.

(b) Correspond in principle on the same day repair.

- Planning survey work

The method for investigating water leakage can be divided into two.

(a) Selection measurement work

(Determine leakage abundance in the survey area beforehand and conduct detailed leakage survey)

(b) Cyclic measurement work

(Do not measure the leakage abundance of the survey section beforehand and conduct the leakage investigation directly in order)

(2) Study on leakage survey

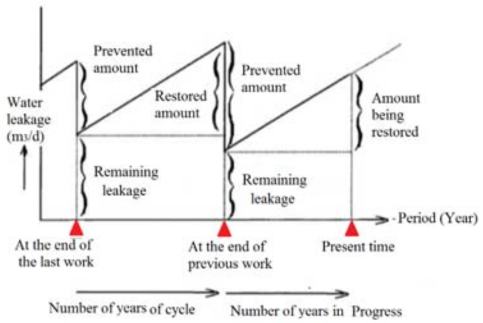
The leakage survey methods and frequency are discussed below.

① **Survey of restored water volume**

Regardless of once repairing water leakage, new leakage occurs as time passes (called restoration of leakage), so regularly investigate this restoration leakage. (**Refer to Figure 1**)

∴Control index of recovery volume (m ^{3} / day·/ km / year)

"Overall investigation period" and "priority of repair / update plan" are judged comprehensively from the increase situation of restoration amount of each DMA.



Source: (Water leakage survey for practitioners: From planning to implementation 1995, JPRC

Figure 1 Concept of Leakage Recurrence

② **Selection of an investigation area**

(a) When doing leakage-of-water prevention work, it is necessary to select the area which should be investigated first in the order of priority.

(b) In selection of an investigation area, you have to take into consideration the number of ~~the~~ past leaks repaired in the area, the age of the pipeline, the depth of the water table, the status of preparation of a sewer, etc.

The selection of an investigation area must take into consideration the number of leaks in the past.

◆The history of leak occurrence according to area

◆Composition of a pipeline

◆Environment etc.

③ **Evaluation of effectiveness and economy**

The economics of leakage prevention needs to be evaluated from the following.

◆ Frequency of investigation

◆ Amount of work involved ~~to conduct~~ in conducting the survey

In considering the evaluation, the conditions of water demand, the difficulty of developing water resources, the content of effective rate, etc. should also be taken into consideration, and considering various obstacles caused by water leakage, the leakage prevention work cost is calculated from an economic point of view. It can be said that even if it becomes higher than the value, it is unavoidable.

(a) Estimation of circulation frequency (e.g. 2 to 5 years / times)

The relationship between the frequency of investigation (circulation years) and expenses is as follows.

● generally, as the number of years of the circulation survey becomes longer, the investigation working distance (km) per year becomes shorter and the expenses decrease, but the leakage volume may increase.

● conversely, when the circulation period of the survey becomes shorter, expenses increase, but leakage volume decreases.

● the evaluation is a condition that the sum of leakage prevention work cost (Xn) and leakage loss cost (Qn) becomes the minimum value.

∴ Xn= A x L/n ……… (Formula-1)

$A=A^1+A^2$……… (Formula-2)

$A^2=n \times a$……… (Formula-3)

Herein;

Xn: Amount of money that can be prevented from leakage during n-year circulations (Ksh / year)

A: Water leakage prevention cost per pipe line 1km (Ksh / km)

A1: Out of A, regardless of water leakage cost (Ksh / km)

A2: Out of A, expenses required for repairing water leakage points (Ksh / km)

A: Cost of repairing leak points when circulating all work in one year.(Ksh / km)

N: Year of circulation (year):

n: Total distance of water distribution pipe line subjects to leakage prevention work (km)

(b) Allowable leakage volume

Actually reducing the water leakage amount to zero requires a heavy cost and labour (work volume / expenses increase) and it is uneconomical.

Therefore, in order to avoid this inefficiency, it is necessary to determine the numerical value of the allowable water leakage considering the current status of NRW% achievement and the budget. (Refer to **Figure 2)**

◆ What is remaining leakage?

The remaining leakage amount is the "minimum leakage amount" immediately after countermeasures against leakage.

However, since this amount of restoration is added with the lapse of time, the total amount of water leakage increases.

Therefore,

∴ Total leakage amount = Restored amount + Remaining leakage= ①+②+③

Restored amount (A) = Preventable leakage amount

Allowable leakage= ②+③=Remaining leakage

◆ What is preventable leakage?

It is the amount of water leakage that can be prevented by survey technology.

◆ What is the allowable leakage?

The permissible amount of water leakage should be prevented to "zero leakage" as much as possible, but it is regarded as leakage which cannot be prevented by many causes. (Including, cost effectiveness, limit of exploration technology, target permissible water leak rate, etc.)

◆ What is true water leakage?

The amount of water leakage (about 2 to 4%) which can not be prevented by any leakage prevention measure. (Eg, it is difficult to detect water leakage due to evaporation, a slight leakage at pipeline joints, soil adsorption, etc.)

◆ Setting allowable water leakage

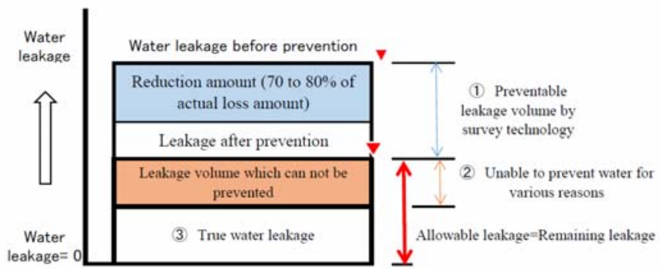
The set value of the allowable water leakage is influenced by the target value of leakage reduction. In other words, if you do, lowering the allowable leakage volume will improve the leakage rate early, but the leakage improvement cost will be higher.

Examples of set target values;

★ 30 m^3 / day / km or less

★ About 80% of ineffective water quantity

★ 0.5 ~ 1.2 m^3 / hr. / Km



Source: Yokosuka city waterworks & sewerage bureau

Figure 2 Concept of total water leakage

(c) Other

- Economic effect =〔Prevented amount × Water supply cost〕- Total Expenses required for prevention
- Leakage prevention unit price = Total expenses ÷Prevented amount

6-3. Implementation of Preventive measures

Based on the results of leakage survey, repair and update facilities, reduce leakage rate. The main outlines of the study are as follows.

① Create a plan

- Draw up an effective facility improvement plans
- Up grading of equipment in piping network of water supply equipment
- Strengthening O/M organization and monitoring system of distribution network

② Implementation of repair / renewal of distribution facilities

- Repair of water supply equipment and measures
- Replacing the installation of the water supply pipe ... From the branch point to the meter, partial repair leaves the factor of recurrence.
- Removal of public water stop cock
- Disposal of remaining pipes
- Optimization of burial depth
- Consideration of used piping type
- Construction management of backfill soil
- Collection of pipeline information

③ Structural improvement of water supply equipment

- Integration of multilayer pipes
- Elimination of road crossing pipe
- Examination of material used、Pipe caliber used
- Review of meter installation, etc.

7. Case study of leak occurrence (surface leakage)

An example of a typical site of water leakage is shown below. (**Refer to Table 2**)
Incidentally, the number of small water leakage from the water supply pipe is large, and when left for a long time the leakage volume increases.

Table 2: Cases of occurrence of ground leakage

① Leakage point of water distribution valves	② Leakage point of water supply pipe	
	Small leakage	Large leakage
Water control valves / valves	Stopcocks / water taps	Branch part from the water distribution pipe
- Fire hydrants, Air valves, Pressure reducing valve - Water pipe	Meter installation locations Joint to water supply pipes / Joint parts	Insufficient material strength of the water supply pipe, poor construction part
		

8. Capture the actual condition of leakage and keep records

8-1. Capture the actual condition

In order to prevent water leakage, it is necessary to first analyze the results of leaks occurred in the past, to analyze the actual condition of leakage and causes, and to better understand the leakage phenomenon.

8-2. Utilization of records

The record of leakage survey is important for future planning of piping network update plan and piping network management by GIS, so it is important to capture and keep records

8-2-1. Example of recording form

(1) Water leakage occurrence record by facility

We organize the number of water leaks and the amount of water leakage every place where leakage occurred (by district, by leakage survey block by block, address, survey execution time, facility part, caliber, etc.).
(**Refer to Table 3**)
The amount of water leakage is an estimation from leak points, leakage noise, wet condition in the ground, etc. at the times of checking leakage.

Table 3: Record table of leakage occurrence by facility (for each month / year)

Distribution main pipe			Water supply equipment		
Name of facility	Number of water leaks	Water leakage (m3)	Name of facility	Number of water leaks	Water leakage (m3)
1. Top of Pipe			1. Top of Pipe		
2. Fittings			2. Fittings		
3. G. packing of valve			3. Water faucets		
4. Fire hydrants			4. Stop valves (union)		
5. Gate valves			5. Water faucets (union)		
6. Air valves			6. Stop valve (G. packing)		
7. Drain			7. stop cock		
8. Other			8. Meter (Union)		
Distribution branch			9 Parts (elbow)		
1. Top of Pipe			10. Parts (cheese)		
2. Fittings			11. Parts		
3. G. packing of valve			12.Water Meter		
4. Fire hydrants			13. Parts (Saddle		
5. Gate valves			14. Parts (socket)		
6. Air valves			15. Ball taps		
7. Drain			16. Other		
8. Other					

(2) Record of leakage survey

There is a record of the repair situation as a method to know the actual condition of water leakage. (**Refer to Table 4**)

Table 4: Record Table of Leakage Repair

Cause	Material of pipe	Distributing pipe				Water supply pipe			
		Number of water	leaks Leakage (m ^{3})	Cost	Photo	Number of water	leaks Leakage (m ^{3})	Cost	Photo
Aged pipe	Cast iron pipe (mm)								
	Vinyl pipe(mm)								
	Galvanized steel pipe(mm)								
	Steel pipe(mm)								
	Lead pipe(mm)								
	Total								
Corrosion	Fittings								
	Bolts								
	Snap taps								
	Vinyl pipe fittings								
	Total								
Joining problem	Vinyl pipe fittings								
	Ductile cast iron pipe								
	Sockets								
	Lead pipe								
	Other								
	Total								
Gland packing~~s~~	Gate valves								
	Air valves								
	Snap taps								
	Water shutoff valves								
	Total								
Dynamic load pressure/ vibration/ Corrosive soil Other	Ductile cast iron pipe								
	Steel pipe								
	Vinyl pipe								
	Asbestos pipe								
	Total								

Left piping abandoned	Disposal piping								
	Total								
Water pressure	Crack of Pipe								
	Detachable								
	Total								
Installation environment	Corrosive soil (pH)								
	Groundwater quality								
	High groundwater level								
	Total								
G. Total									

Table 5: Record Table of Investigation of laying condition

Investigation of laying condition	Distributing pipe				Water supply pipe			
	Number of water	leaks Leakage (m^3)	Cost	Photo	Number of water	leaks Leakage (m^3)	Cost	Photo
Distribution of corrosive buried environment								
Painting condition of buried pipeline								
Corrosion situation of pipeline								
Distribution of water leakage accident								

8-3. Preparation of management indicators by leakage area

For data effective for leakage prevention work, it is desirable to set / record-management indicators and to be reflected in the project management plan. Examples of management indicators are shown below.

(a) Leakage per 1 km of distribution branch (m^3 / day / km) by region or by section

(b) Number of water leakage repairs (cases / km)

(c) Other indicators

8-4. Investigation of occurrence of rust corrosion on the outer surface of the metal pipe and corrosion of the inner surface

(a) Inner surface

This item is a survey on the actual situation of "water supply service degradation due to pipe hydraulic conditions". (**Refer to Table 6**)

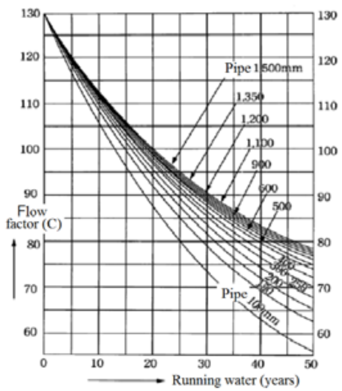
Rust bumps etc. occur on the inner surface of the pipe of the aged pipe, and the friction resistance of the pipe line increases or decreases, and there is a situation where it is impossible to supply sufficient water pressure and water supply amount.

In addition, examples of changes in aging number and flow rate coefficient of the cast iron pipe are shown below. (**Refer to Figure 4**)

Table 6: Survey items on occurrence of inner surface (corrosion bumps)

No.	Survey item	Contents
1	No lining pipe (inner surface)	Location/diameter/ caliber/ Number of years passed
2	Non-corrosive protective pipe (inner surface)	Location/diameter/ caliber/ Number of years passed
3	Investigation of flow velocity (m / s)	Distributing pipe/ Water supply pipe
4	Survey of flow rate (m^3 / d)	Distributing pipe/ Water supply pipe/ Water taps
5	Survey of water pressure (kg/cm^2)	Distributing pipe/ Water supply pipe/ Water taps
6	Frequency of maintenance	Drain frequency/Drain pipe diameter / internal repair
7	Survey of water quality (unusual taste/red water/ Residual chlorine/others)	Distributing pipe/ Water supply pipe/ Water taps

Source; Japan Water works Association H17, Guidelines for updating water supply facilities



Source：Japan Water works Association H17, Guidelines for updating water supply facilities

Figure 4: Corrosion of the inner surface

(b) Outer surface (laying conditions)

This item is a survey on the actual condition of "deterioration of pipeline due to pipeline installation conditions". (**Refer to Table 8**)

Table 8: Survey items on occurrence of Outer surface

No.	Survey item	Contents
1	Distribution of corrosive buried environment	Place/cause of corrosive environment
2	Painting condition of buried pipeline	Material/caliber/number of years passed, total length (km)
3	Corrosion situation of pipeline	Corrosion condition of pipeline/ rust condition of bolt/pipe thickness
4	Distribution of water leakage accident	Location/caliber/corrosion status of leak pipe/leakage area/ water pressure

Source; Japan Water works Association H17, Guidelines for updating water supply facilities

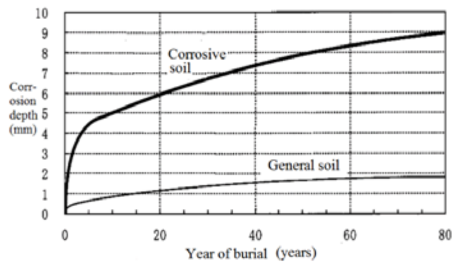
(c) Cause of metal buried pipe corrosion

When a metal pipe which is not properly protected performing against outer surface corrosion protection is laid under corrosive soil conditions, corrosion proceeds quickly and the strength of the pipe is remarkably lowered, which causes water leakage.

The laying conditions under which corrosion easily occurs are shown below.

(**Refer to Figure 5**)

・Where electrolytic corrosion occurs
・The pipeline is dirty (mud may cause pipes to corrode)
・Place where liquid acidic factory waste penetrates underground
・Places where corrosion progresses under the ground water table
・Places containing salt in the groundwater
・Acid soil (pH 4 or less),
・Even in the alkaline range of pH 8.5 or higher, (so-called natural alkaline soil) may be susceptible to corrosion
・Peatlands and waste landfill areas



Source: Guidelines for updating water supply facilities 2005,JWWA

Figure 5: Corrosion degree of ductile iron pipe

Electrolytic Corrosion of mild steel pipe

-END-

Internal Information

TEXT BOOK
FOR
JOINT TRAINING
(DRAFT)

"WATER LEAKAGE SURVEY METHODS"

R-2

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Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
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③ Understand type of noise
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⑥ Understand general purpose of flowrate survey of MNF
⑦ Understand measuring method of the amount of leakage
⑧ Understand concept of relationship between leakage and pressure

2 Introduction

2-1. What is leakage?

Leakage occurs when the water your system produces leaves the system before it reaches your customers. In the rule, the term “leakage” includes:

- Physical or “real losses” such as water lost from main breaks and tank overflows.
- Inaccurate meters, accounting errors and theft. Many people call these losses, “apparent losses.”
- All unauthorized uses and any water you cannot account for.

The rule does not classify any water that enters the distribution system as “unaccounted for.” Although many people use that term, there is no standard definition for it. The rule considers all water “accounted for,” either as authorized consumption or as distribution system leakage.

2-2. Why reduce leakage?

Reducing leaks has many benefits for water systems and customers including greater reliability through an efficient water system, reduced costs for pumping, treating, and transporting water, and preserving water supplies for future use.

3. Key words definition

Leakage	Water finding way out of the pipe, going to waste
Isolation valves	Valves used to cut-off flow to section of the network
DMA	District metered area
Total Leakage Volume	Restored leakage + Allowable leakage
Restored leakage Volume (Remaining Leakage)	Total leakage + Allowable leakage
Pseudo leakage sound	Noise or simulated noise similar to leaky sound

4. Procedure of the NRW reduction measures

4-1 Outline

The foundation of the plan is to discover leakage of "water distribution network" at an early stage.
Meanwhile, it is important to implement repair work as soon as possible and to prevent water leakage beforehand.

Improvement measures of many waterworks facilities are planned to replace the old water distribution pipes and water supply pipes that leakage frequently occurs with new pipe, and by replacing the failure meter and improving the meter dissemination rate, it is possible to reduce the non-revenue water. It is expected to increase the effect of countermeasures.

(1) Examination method of a leakage

The leakage survey is carried out by combining the following measuring methods, in advance, by selecting the route requiring the leakage investigation based on the maintenance status of the pipeline within the DMA, the number of leaks occurred in the past, and so on.

① Method of identifying water leakage location by leakage sound (listening stick, correlation method, time integral type leakage detector, etc.)
② Method of measuring leakage volume (Night minimum flow rate measurement method, others)
③ Other

(2) Concept of leakage

Measurement of "leakage" in general means the measurement of the total water leakage.
"Recovery water leakage amount" is obtained from the following calculation formula.
The definition of total water leakage is shown below.

∴**Total leakage volume** = (Restored leakage) + (Allowable leakage)
∴**Restored leakage volume** (Remaining leakage)
= (Total leakage) – (Acceptable leakage)

(3) Main effective basic policy of leakage preventive measures

Leakage survey is the collection of basic information indispensable for formulation of NRW reduction plan.
Activities to prevent water leakage means to continually investigate changes in the piping facility situation and to permanently take measures against water leakage at the facility.

The main activities are shown below.

① Detection of leak points early
② Measuring water leakage
③ Improvement of old pipeline quickly and systematically
④ Simplification of multiple small pipes, others

(4) Precondition of leakage examination

① Up grading of piping network diagram

The prerequisite for conducting leakage survey systematically is preparatory work, and it is essential to improve the pipeline network drawing of all water supply districts.

Also, if the piping network diagram of all water supply districts is undeveloped (under construction), DMA is decided for each water distribution system, and it is created sequentially.

② Installation of isolation valves for DMA

In order to accurately ascertain the water leakage, it is essential to install a valve to limit the amount of water to be distributed to the surveyed DMA and the amount of water used.

③ Installation of measuring instrument (bulk meter)

It is necessary to install bulk / meter to measure total anhydrous amount in DMA main line water pipe.

④ Installation of customer meter

In order to analyze water distribution, it is necessary to install customer meters

⑤ Install water level in the water reservoir

In order to analyze the water distribution from the measurement of the water distribution and the summation of the customer meter, a water level measuring device of the distribution pond is necessary.

4-2 Outline of an investigation procedure

Procedure for planned leakage prevention investigation is as follows. (**Refer to Figure 1)**

(1) Observation survey (preliminary survey)

<u>Purpose</u>

It is a work to investigate leakage point of " distributing pipe / water supply pipe" from survey of each door to door in the water supply district in advance.

<u>Outline of work</u>

① Survey of door to door is a process of bringing with Listening stick (Fig. 15) / time

integral type leakage detector into contact with all customer meters and full stop cocks in the survey district and checking the leakage of "distribution pipe / water supply pipe".

② In the night-time when the traffic low, identify the location of leakage on the road surface with the digital leak detector.

③ Selection of the DMA, consideration of past leakage occurrence situation and the aging pipes.

④ In places suspected of leakage from survey work, specify the position with paint.

(2) Leakage measurement work (full-scale survey)

<u>Purpose</u>

The leakage measurement work is a work to grasp the amount of the NRW of the small piping in stages from the trunk water distribution pipe in the DMA and to specify the water leakage location with reference to the results of the previous survey.

<u>Outline of work</u>

① Measurement is carried out in order to accurately grasp the amount of leakage of each DMA. (For example, conduct with Night minimum flow rate measurement)

② The number of faucets to be investigated is limited to 300 plugs to 400 plugs or less.

③ Prediction of water leakage in all water supply districts is estimated from leakage amount of each DMA.

④ Survey of leakage volume of each DMA will be used for consideration with priorities of effective detailed investigation.

(3) Confirmation of water leakage location

<u>Purpose</u>

This leakage confirmation work is a work at the final stage of the water leakage investigation to determine the water leakage point at the position of the abnormal sound found by sound detection.

<u>Outline of work</u>

① Investigate the position of the detected abnormal sound again and judge the presence or absence of leakage.

② If it is confirmed as a water leakage point, further work out the central point.

③ To determine the position of the water leakage sound hole, drill a hole in the road surface, insert a sound hearing bar, and check the leakage

(4) Improvement of old pipe

<u>Purpose</u>

In order to provide water services trusted by citizens, improvement of leakage pipe / deteriorating pipe is important for securing reliable water supply system on a continuous basis.

It is important to prioritize this countermeasures priority, according to priority on damaged pipelines with high risk of water leakage, as soon as possible.

Concept of Improvement

Depending on the current situation of leakage / aging, the following methods are considered as improvement methods.

① Renewal
② Rehabilitation
③ Partial repair
④ Change of pipe route

(5) Points to be aware of when selecting piping improvement method

① Confirmation of the cause of the functionally damaged pipeline (pipe type, years of use, frequent occurrence of accidents, etc.)
② Confirmation of the scale of leakage pipeline
③ Confirmation of the work environment at the site (difficult to improve)
④ Securing construction costs, others

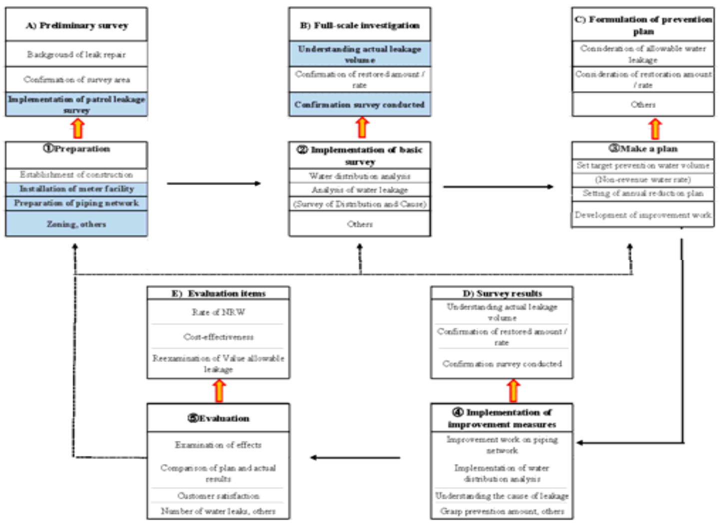


Figure 1: Outline of procedure for examining non-revenue water reduction

4-3 Approach of leakage investigation

(1) Approach to narrow down a water-leakage area

A survey method for narrowing the leakage location in stages from a wide water supply district will be shown below. (**Refer to Figure 2 &Table-1 to 2**)

(A)"Surface detection"; (by Circuit investigation "preliminary survey")

This is a survey that specifies the leakage volume generated in DMA as "rough".

(B) "Line detection": (leakage measurement work: full-scale survey)

This is a survey to identify the location of the leak pipe route in the DMA rail.

(C) "Point detection"; (Confirmation work on leakage points)

It is a survey to confirm the leakage location of the specified leakage pipe

Table 1: Concept of water leakage survey

Classification	Items to investigate	Equipment used
(A) Surface detection	Calculation on medium blocks (leakage volume / NRW rate	Flow meter at distribution pond (Electromagnetic flowmeter, etc.)
	Calculation on small blocks (leakage rate / NRW rate)	Portable flowmeter (Ultrasonic)
(B) Line detection	Survey of acoustic noise of stop-cock /Valve (identification of leakage location)	Water leak detector
	Leak pressure level detector (Identification of leak location)	Correlation noise leak detector
(C) Point detection	Correlation survey (confirmation of leakage point)	
	Survey of water leakage sound on pipeline (Confirmation of water leakage point)	
	Acoustic survey of stop-cock (confirmation of water leakage point)	

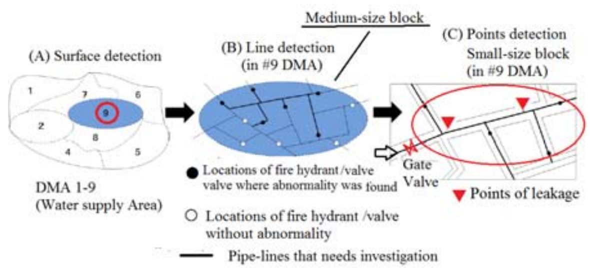


Figure 2: Concept of how to identify leak location

Table 2: Example of results by observation survey (Preliminary Survey)

Year	Survey method	Distance of survey conducted (㎞)		Number of discoveries(Cases)				Total
		Distance of acoustic detection	Distance of flow investigation	In public road	Before the meter	In the meter box	After meter	
1994	Surface leakage			438	631	163	1,159	2,391
	Discovered by survey	543	12.84	140	261	357	24	782
	Total	543	12.84	578	892	520	1,183	3,173
1995	Surface leakage			396	740	102	1,142	2,380
	Discovered by survey	639	15.13	202	381	218	27	828
	Total	639	15.13	598	1,121	320	1,169	3,208

Source：Yokosuka City waterworks and sewerage bureau, Water leakage prevention

5. Specificity of leakage sound

5-1. Generation of leak noise

Detection of water leak sound will be judged from direct sound listening or amplified vibration sound or vibration wavelength.

It is said that the main sources of leak noise or vibration sound are as follows.

① Fricative sound when water spouts from the leak hole to the outside of the pipe
② Impact sound that the jetted water collides with the surroundings
③ Frictional sound or turbulent sound flowing in the pipe
④ Synthesized sound / vibration waveform

5-2. Characteristic

① Leakage sound depends on the state of its generation point (depth of leakage point, direction of leakage point, leak hole, damage shape, water pressure, tube material, valve opening, water pressure, surrounding pipeline state, etc.) It is different.(Refer **to Table 3 to 4 and Figure 3 to 4)**

② "Level" of leakage sound is influenced by pipe type, flow speed in pipe, leak hole-diameter, etc. There is a limit in leak detection ability depending on the type of detector.

③ Leakage sound varies depending on the propagation path (soil, concrete, pipe material etc.) and propagation distance.

④ The leakage sound attenuates as it propagates from the generation point. In particular, non-metallic tubes such as VP pipes tend to have more remarkable attenuation in the high frequency range than metals such as cast iron pipes.

⑤ Changes in water leakage sound due to water leak hole, water pressure, etc、tend to

increase leak noise usually when the water pressure is high.

⑥ Water leakage noise in a low water pressure network (about 0.05 MPa: water column 5 m or less) is "low", so leakage detection may be difficult.

5-3. Pseudo leakage sound

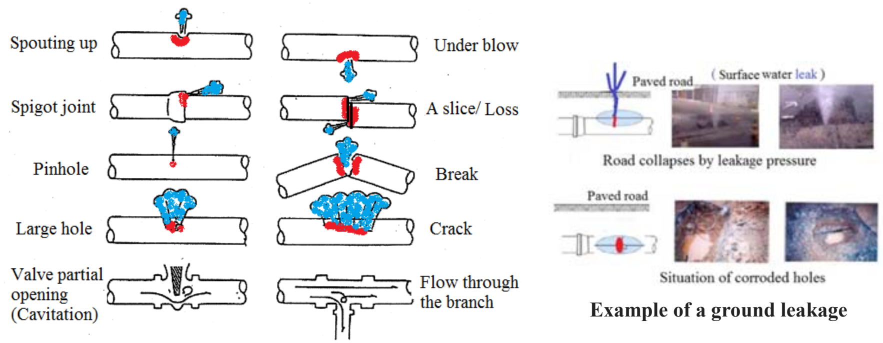
Noise or simulated noise (pseudo leakage sound) similar to leaky sound is often a problem in detection of hearing performed at midnight.

Also, there is a case that the pseudo leakage sound is distressed by correlation leakage survey.

In order to improve the accuracy of leakage survey, it is necessary to grasp the characteristics of the simulated sound beforehand.

(1) Cause of pseudo noise

① Running water sound in the water pipe
② User tone of water supply
③ Circuit sound such as power cable
④ Vibration noise of power transformer
⑤ Motor vibration sound of vending machine / air conditioning equipment
⑥ Sewage flowing water sound
⑦ Water drop sound falling into the manholes
⑧ Vehicle vibration noise, wind noise
⑨ Noise of work
⑩ Urban noise, others



Source：Yokosuka City WWSB, Water leakage prevention

Figure 3: Configuration of leakage

Table 3: Example of Relationship between high and low of leak noise

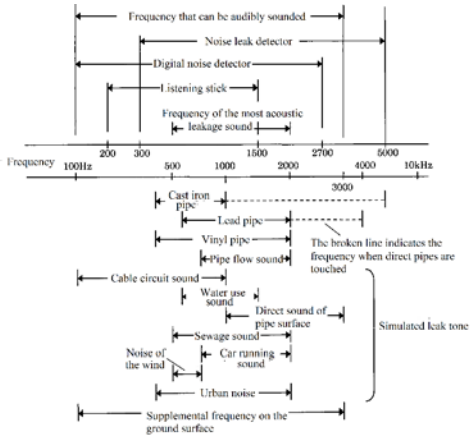
Classifications	When high tone	When the middle tone	When it is low tone
Frequency band	More than 1KHz	Under 0.5～1KH	Less than 0.5KHz
Size of leak hole	Small.	Large	Very large
Shape of water leak hole	Complexity	Simplicity	Simplicity
Flow in leak hole	Very fast	Slow	Very slow
Pipe diameter	Small dia.	Medium dia.	Large dia.
Material of pipe	Steel pipe/Stainless steel pipe	Cast iron pipe/Asbestos cement pipe Vinyl pipe /Polyethylene pipe	
Distance	Near	Far	Very far
Water pressure	High	Low	Very low

Source：Yokosuka City WWSB, Water leakage prevention

Table 4: Example of leak noise sound and survey conditions

Conditions		Impact on investigation, etc.	Note
Depth of burial	Shallow	Good	Attention to echo etc.
	Depth	Bad	The deeper the depth the more the leakage sound attenuates.
Density of soil	Rough	Bad	The damping of leaky sound is bigger and dense.
	Dense	Good	-
Pipe material	Soft	Caution	Soft pipes such as vinyl pipes and polyethylene pipes attenuate the leakage noise during propagation, so care is taken because the range to be captured is narrow
	Hard	Small impact	
Pipe diameter	Small	No effect	-
	large	Effected	Pipe vibration is less likely to occur as the larger diameter.
Amount of leakage	A little	Difficulty	Minor leakage water leakage sound is small and difficult to grasp.
	Much	Easy	Pay attention to the water pool near the leak hole.
Water pressure	Low	Bad	Usually 1.5 kef / cm 2 or more.
	High	Good	Generally, leakage noise is higher as high water pressure.

Source：JWRC



Source：JWRC

Figure 4: Range of hearing of leakage detection, and frequency of leakage

6. How to apply leakage detectors

6.1 Detection methods of point of leakage and leakage volume

The investigation methods for checking the presence or absence of water leak include the method of identifying the water leakage position (e.g., sound listening, correlation method, time integral formula) and measurement of water leakage (e.g., nighttime minimum flow rate).

(1) Procedure for water leakage survey

To confirm the presence or absence of leakage, carry out in the following procedure.

① Formulation of survey plan

a) Preliminary survey

⬇

b) Full investigation

⬇

c) Confirmation survey

② Formulation of survey methods on leakage point and volume

Confirmation of water leakage point and leakage volume is carried out with the following equipment

a) Specific investigation of water leakage location (e.g., a listening stick, correlation method, time integral equation)

⬇

b) Measurement of water leakage (e.g., minimum nighttime flow rate by flowmeter).

⬇

c) Confirmation of leakage point (e.g., boring equipment)

③ Evaluation criteria for frequency rank of acoustic noise detection survey and leakage volume survey

◆ Frequency rank of implementation of acoustic noise detection survey

As for the evaluation of the leakage survey frequency in the water supply district, it is important to formulate the ranking of the survey frequency in advance by referring to the number of water leaks so far An example of the plan is shown below. **(Refer to Table 5)**

Table 5: Example of Planning Frequency of acoustic noise detection survey

Place name	Number of survey sections	The period required for the whole city cycle	Distance of sound listening(km)	Remarks
D-1 Area	76	One year round	371	Leakage accidents occur frequently
D-2 Area	63	One round in 2 years	344	Over the service life
D-3 Area	43	One round in 3 years	321	Update construction is over
Total	**182**	**-**	**1,037km**	**-**

◆ **NOTE:**

Leakage volume survey results and additional survey plan

It is important to prepare a work plan for additional investigation that is accompanied by the result of leakage measurement (e.g., nighttime minimum flow rate value).

An example of the plan is shown below. (**Refer to Table 6**)

Table 6: Example of leakage survey results and additional survey policies

Rank	Night minimum flow rate value	Contents of additional survey
A	20 L/Min./㎞ or less	-Do not conduct additional investigation work -If leakage occurs, respond with emergency work.
B	26~60 L/Min. /㎞	-Continue survey focusing on sound listening work and leak noise correlator -Repair leak points - If leakage occurs, respond with emergency work
C	60 L/Min. /km or more ~	-Perform thorough leak detection work - Particularly, to replace drain pipes and water supply pipes with many leaks

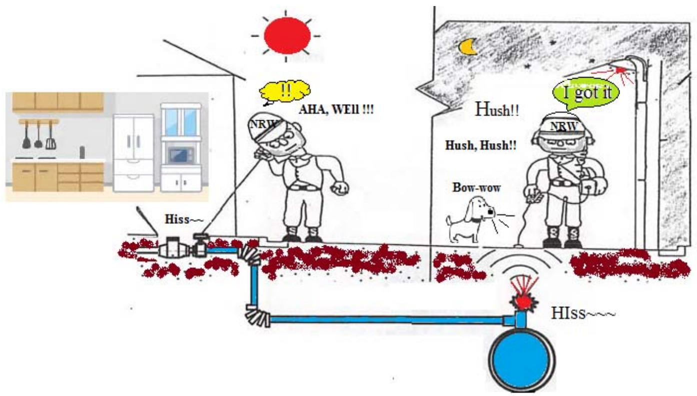
6-2. Arrangement of time zone of work by acoustic noise detection method

In the acoustic noise survey, from the point of view of prevention of deterioration in accuracy of detection by Pseudo leakage sound, prevention of security / troubles of residents, prevention of traffic accidents, basically the survey is conducted at the following time zones. (**Refer to Table 7& Figure 5**)

Table 7 Working time arrangements

No.	Places to be surveyed	Equipment to be used	Working time	Remarks
(a)	Door to door survey（C. Meters others）	listening stick others	8：30am～ 17：00pm	Daytime
(b)	Stop valves, air valves, others			Daytime
(c)	Survey of road surface (survey of buried pipe)	Digital noise leak detector, others	22:00pm～ 5：00am	Late-night

Basically;（In urban area）
① At Daytime ….Door to door survey
② At Late night…..Road surface survey



Source: Edited Tokyo Metropolitan Government Bureau of Waterworks Tokyo's Leakage Control H27

Figure 5 Working Time for water leakage survey by acoustic noise detectors

7. Preliminary survey method with Acoustic leak detectors

(Standard survey method for specific investigation of leakage location)

7-1. planning for preliminary survey

(a) Purpose

The preliminary survey is carried out to grasp the current state of water leakage in order to formulate a full-scale research plan.

(b) Survey method

It is carried out with the most basic leakage survey method called "standard survey method" centered on tone survey In addition, many leakage investigations are applied by combining this survey method.

7-2. Flow diagram of standard survey method

The flow diagram is shown below. (**Refer to Figure 6**)

	Flow diagram	Activities
(1)	Creation of work plan	A setup of investigation plan (preparation of a plan for site investigation, an understanding of a piping-drawing, functional verification of a measuring equipment/valve, information disclosure of a activity to residents, others)
	↓	
(2)	Implementation of preliminary site survey	Collation of a piping-drawing and an on-site conditions
	↓	
(3)	Implementation of survey on door-to-door by acoustic noise detection	Implementation of acoustic noise investigation in a customer meter and a water stop valve
	↓	
(4)	Implementation of survey on road-surface by acoustic noise detection	Implementation of the leakage detection activity on a buried line
	↓	
(5)	Implementation of verification survey	The verification activity of presence of a leakage, a leakage location, and implementation of boring survey
	↓	
(6)	Preparation of a report	Arrangement of survey data, and implementation of analytical work

Figure 6: Procedure of leak detection with Acoustic leak detectors

7-3. Outline of work

(1) Creation of work plan

The work plan is composed of preparation of plans necessary for investigation, process control and selection of workers and so on.

<u>Main work contents</u>

(a) Creating a work plan (**Refer to Figure 7**)

- Understanding the contents of the survey

-·Confirmation of the drawing in the survey area (**Refer to Figure 8**)

-·Establishment of survey formation team

-Create a process chart

-Function check of used equipment

-Others

(b) To hold a preliminary meeting with workers.

(c) Consider how to compile daily work results.

(2) Items to be checked in advance

(a)Check documents to be submitted.

(b) Information disclosure to inhabitants and announcement

(c) Correction of incomplete drawing

(d) Confirmation of work contents

(e) Confirmation of the form of the report. (**Refer to Table 8**)

Name of waterworks office（Name＋Sign）; Date and time;

Name of the investigation area;

Scope of work (Investigation time zone) Door-to door survey （160 km : 16,000 Customer meters）::::8:30AM to17:00 Duration of the survey;

Stop valves / stop-cocks Caustic noise survey (150 km);;;;;8:30AM to17.00 Name of the researcher;

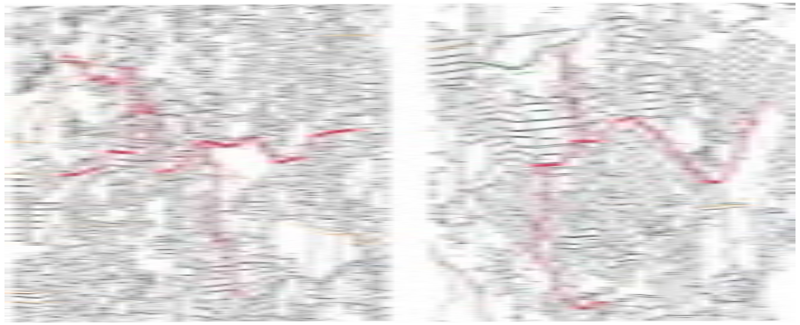
Road surface survey (160 km);;;;22 PM to 5AM

No.	Activities	June				July				August				September			
（1）	Work plan																
（2）	Preliminary site survey																
（3）	Survey on door-to-door survey																
（4）	Survey on road-surface																
（5）	Verification work																
（6）	Preparation of report																

Supervisor （Name +Sign);

F

igure 7: Examples of the survey schedule table



Source：Yokosuka City WWSB

Figure 8: Examples of the survey area and pipe line

Table 8: Example of Report Summary
(Number of water leaks by type and prevention amount))

Classification	Number of cases	%	Estimated water leakage (m3/hr.)	%	Remarks
On the water distribution pipe	20	7.0%	4.6	14.1%	
Air valve	30	10.6%	1.8	5.5%	
Diaphragm	50	17.6%	15	46.0%	
On the water supply pipe	22	7.7%	5.13	15.7%	
Stopcock	70	24.6%	2.64	8.1%	
Meter	62	21.8%	0.53	1.6%	
Inside the house	30	10.6%	2.94	9.0%	
Total	284	100.0%	32.64	100.0%	

7-4. Implementation of preliminary site survey

In-situ preview survey is to conduct survey on-site in the survey target DMA in advance, to understand the accuracy of the piping drawing, the situation of the water distribution facility, the road surface condition, and as a result so that proper and accurate this survey can be carried out .**(Refer to Figure 9**)

(1) Main work

① Confirmation of buried piping route
② Check the location where valves are installed,
③ Confirmation of the source of trouble vibration given to sound listening test of stop valve
④ Survey of position unknown valves and piping routes, confirmation of these places in the office
⑤ Confirm embedment status of electricity, gas, communication facilities etc.

(2) Equipment to be used

① Listening stick
② Digital noise leak noise detectors, others

Source JPRC #20

Figure 9 Example of piping network diagram in survey target DMA

7-5. Implementation of survey on door-to-door by acoustic noise detection

The door-to-door listening survey is a process in which all water supply devices (including customer meters / stopcocks) and piping (including exposed parts such as gate valves, fire hydrants and water pipe bridges) in the DMA where are subjected to water leakage detection and visual confirmation .

The survey shall be daytime work taking into consideration such as entering the site on an individual basis.

(1) Main work

① Acoustic surveillance with a plug valve
This survey is to check the presence or absence of leakage with a listening stick to the spindles part of the gate valve installed in the water distribution pipe, a fire hydrant valve, an opening / closing stopper, an air valve.
② Acoustic surveillance with a meter / a stop-cock
This survey is to check the presence or absence of leakage with a listening stick to a stop-cock, a customer meter.
If it is recognized as a leaky sound, close the stopcock for a short time and check again for leaky sound
③ When checking abnormal sounds, check marks are given on the drawing and survey points.
It is subject to the road surface tone survey conducted at a later date.
④ Leakage sound confirmed with a meter or a stopcock is different in the magnitude of sound that can be heard depending on leakage condition / place / water pressure. Care must be taken in identifying leak points. (Refer to **Figure 10**)
⑤ If you need to enter the residential area, always wear an identity card and armband so that you do not have trouble with the residents. We also request advance inquiries and cooperation to the residents in advance

(2) Equipment to be used

① Listening stick / digital listening stick.
② Time integrated type leak detector
③ Road surface digital noise leak detector, others

Figure 10 Application of Listening stick

7-6. Implementation of survey on road surface by acoustic noise detection

This survey is a walking survey on roads where buried pipes are laid by Road surface digital noise leak detection sensors at intervals of 0.5 to 1.0 m, and explores leakage sites.

The survey is carried out during the time period (nighttime) which is not affected by dummy sounds such as noise and water used, but it is susceptible to weather conditions such as wind and rain and traffic vehicles.

The leakage sound also differs at the leakage point (**Refer to Figure 11**)

(1) Main work

① If you have confirmed abnormal sounds, put a check mark on the road (white stain) and drawing, and make a detailed confirmation investigation.

②As an auxiliary work, listen to a water stop valve, a water control valve, a fire hydrant with a listening stick

(2) Equipment to be used

① Road surface digital noise leak detector

②Listening stick / digital listening stick, others

③ Tool

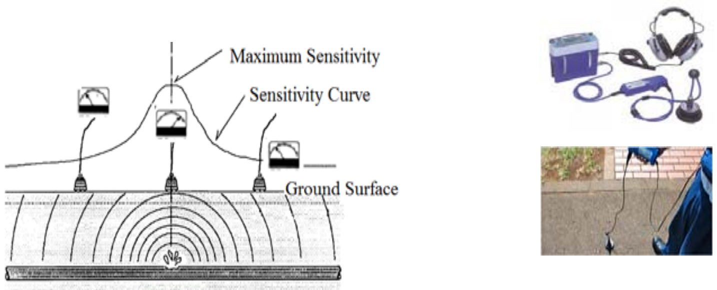


Figure 11: Overview of Road surface digital noise leak detector

7-7. Implementation of verification survey

Confirmation survey is the work at the final stage of the leakage investigation to further

examine the location of the abnormal sounds found from the previous survey, to determine whether there is water leakage and the water leakage point. (**Refer to Figure 12)**

If water leakage is suspected in the water supply pipe, it is also necessary to check whether there is a leakage point before or after the stop-cock while opening and closing the stop-cock

(1) Main work

① In the drilling operation, to identify the leakage position under a hard road surface, open 2 to 4 holes with a diameter of about 15 to 20 mm. Using the several openings, drill holes to near the buried pipe predicted by the boring bar. (Be careful not to damage the buried pipe) (**Refer to Figure 12)**

② To determine the final water leakage position, move the listening stick bar to 3 to 4 holes, confirm the water / sand condition adhering to the bar, the wet condition of the soil and the sound of weak noise, and then determine the water leakage position. (**Refer to Figure 13 to 14**)

③ The determined leakage position is marked on the road surface with paint, recorded and reported to the responsible person.

④ If ground exploration is difficult, a Correlation survey or Leak zone tester will be carried out (**Refer to Figure 15**)

⑤ It may be confirmed by residual chlorine reaction as a survey of the spill where leakage flows out.

⑥ As an auxiliary work, explore the location of buried pipes and buried faucets with metal detectors

⑦ The survey worker needs to pay sufficient attention so as not to damage other buried pipes and other business facilities (e.g. Electricity, gas, communication facilities).

⑧ Mainly work on the roads will be more frequent, so be sure to implement safety measures thoroughly.

(2) Equipment to be used

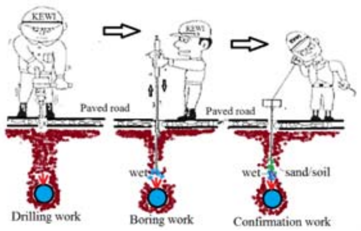
① Bowling equipment (electric drill, hammer drill, boring bar),

② Listening stick / digital listening stick, others

③ Road surface digital noise leak detector

④Leak noise correlator, Metallic pipe locator/Metal locator

⑤ Reagent of Residual chlorine (DPD)、tool、Survey vehicles, others



Source: JICA-Nagoya City Edit NRW Textbook

Figure 12: Procedure for investigation to confirm the leakage point

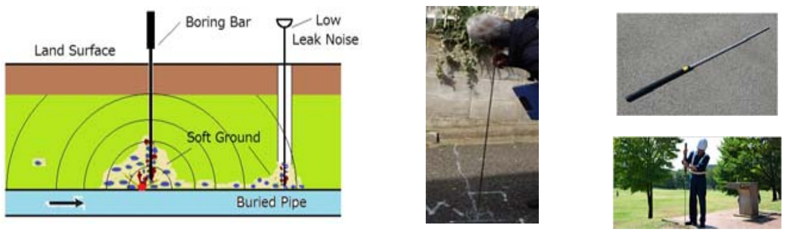


Figure 13: Outline of Checking Leak Location

Source:Yokosuka cityWWSB Working on Paved roadway

Figure 14: Confirmation of leakage at the opening

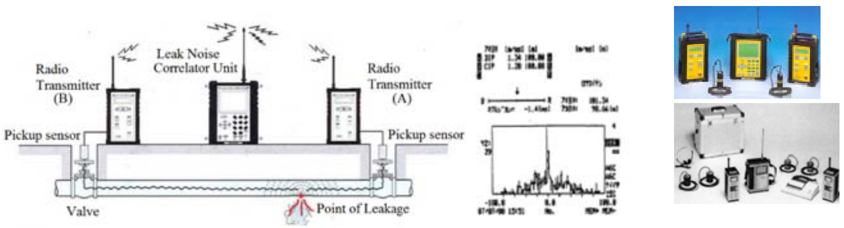


Figure 15: Overview of leak noise correlator

7-8. Arrangement of results of an investigation

This activity is performing results of an investigation for arrangement, an analysis, a consideration, etc.

Items to create such as documents are as follows.

(1) Main work

① Drawing showing water leakage point

② Daily reports and weekly reports

③ Photo collection

④ A tabulation of a leakage occurrence spot, a data reduction, a taxonomy

⑤ The table of contents of a report is as follows.

・Introduction /Summary of survey/Content of survey/Result of investigation / Discussion / Postscript

(2) Collection and analysis of an information by investigation obtained

Data obtained by the survey activities (e.g. Leakage cause, number of leaks per pipe type, leakage restoration situation, are collected and analyzed to help prevent water leakage.

8. Implementation of Main survey work

8-1. Procedure of leak detection by flow rate

(1) Measurement category

The method of estimating the amount of water leakage from the flow measurement is largely divided into two categories: Prolonged 24 hour sequence measuring method and Midnight measuring method.

∴Assume**
Minimum Flow Rate (MFR) is the leakage amount

◆ **Caution！！！**

①Since the flow rate survey that predicts the minimum flow rate as the leakage amount includes some authorized consumption and various water losses, the data is used as a rough water leakage amount only.

②The DMA suspected to be leaked will further investigate in step tests further to identify the pipeline that is leaking

③In the case where measurement is carried out by fully closing the water faucet, when the cooperation of the residents is not obtained, the reliability of the measured value is lost

(2) Application

This investigation method is suitable for studying medium to large leakage volume.
The main measurement methods are shown below.

(3) Ensure the reliability of data on water leakage

Ensure the reliability of data on water leakage

Water leakage obtained by measurement is merely water pressure at the time of measurement. For estimating the actual leakage volume, it is important to calculate the average leakage volume from the average water pressure (converted water pressure) in the measuring area.

Therefore, by announcing the data on the amount of water leakage together with "leakage volume converted into converted water pressure" and "leakage volume at the time of measurement", data reproducibility and "data reliability" as statistical data are secured

① Water pressure conversion formula

(a) Condition (For example)

- 40 m^3 / d @ 1.3 kef / cm^2 ……. (At the time of measurement)

- Converted to 2.0 kef / cm^2….. (Average water pressure in DMA)

(b) Water pressure conversion formula

$$Q = \left(\frac{P}{P_0}\right)^{\eta} \times Q_0 = \left(\frac{2.0}{1.3}\right)^{1.15} \times 40 = 65.6 \quad m^3/d$$

Here;

Q: Converted water leakage= m^3/d

Qo:Water leakage when measured =(eg.40 m^3/d)

η: Index=1.15、or 0.5 : pipe crack, leakage from the joint of valves / plug joints is assumed to be leakage=(e.g. 1.15)

Po: Measuring water pressure=(eg.1.3 kg/cm^2)

P: to be converted water pressure=(eg.2.0 kg/cm^2)

◆ **NOTE**
Water leakage will be influenced by water pressure.

8-2. Measuring method of flowrate

The example of a measuring method is shown below.

(1) Prolonged 24 hour sequence measuring method
- (a) Distribution pipe flow
- (b) DNA

(2) Midnight measuring method
- (a) Not stopping service
- (b) Night minimum flow measurement
- (c) Step test

(3) Estimated amount from water used

8-2-1. Prolonged 24 hour sequence measuring method

This measurement method is based on estimating the amount of water flowing into DMA for 24 hours in a row for a certain period of time and assuming the amount of water leakage from the minimum amount of water.

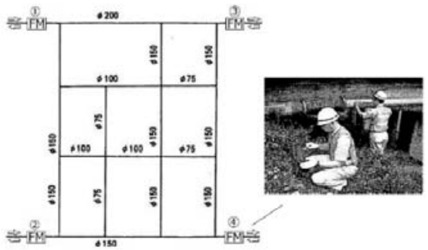
The outline of the investigation method is shown below.

(1) Install flow meter in distribution pipe flow

In this method, a flow meter, a pressure gauge, etc. are directly installed in the piping flowing into the target investigation block and measured for "water distribution (flow rate)" for 24 hours continuously for a long time, and roughly estimate the water leakage amount. (**Refer to Figure 16)**

Select the place where the flowmeter and pressure can be installed in places where long-term measurement is possible (e.g., in the water pipe bridge or the measuring device pit).

It is desirable to select a type of flowmeter to be used (e.g., ultrasonic flowmeter), which can perform measurement under the condition of "actual water pressure" without loss head.



Source: JPRC 1995 #20

Figure 16 Flow measurement in Distribution pipeline

(2) Install flow meter in inlet pipe to isolated DMA

In this method, with the distribution pipe length of 2 to 3 kilometers as a guide, all of the partition valves, stoppers, water faucets, etc. other than the compartment inlet valves are "closed" and in the absence of the amount of water used in this DNA, which is measured as "short time", and assuming the water leakage amount. **(Refer to Figure 17)**

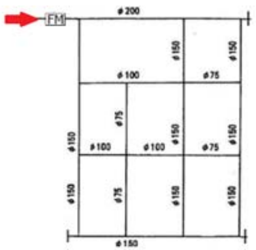


Figure 17: Flow measurement in isolated DMA

8-2-2. Midnight measuring method

In this method is based on the flow rate (leakage amount) flowing into the DMA **in the midnight time zone** in which the usage amount by customers is generally small in the normal water supply state is measured with the flow meter.

This flowmeter is installed in the only main water pipe flowing into the DMA and is "completely isolated from the adjacent section" and assumes the water leakage amount from the minimum water amount in a state that it is not affected by the adjacent pipeline

(1) Not stopping service

In this method, the water distribution is kept "in a state where water supply is not

stopped" for a certain period, and the minimum flow rate value is assumed as leakage. It is necessary to investigate the actual condition of flow rate (FR) use characteristics (factory / commercial district, public facilities, domestic lifestyle such as water for pool / water tank, whether there is a water service used 24 hours, etc.) beforehand.

(2) Night minimum flow measurement

In this method, "Minimum water volume is assumed to be leakage" in "longevity not restricting water supply" to "time zone at midnight when the most used water volume decreases in a day".**(Refer to Figure 18)**

Survey area is as compact as possible, simplified as much as possible.

When the minimum flow rate at night is small, measure with a small flow meter installed in the bypass.

Assume; MFR = Leakage amount

Bypass line& Flow meter

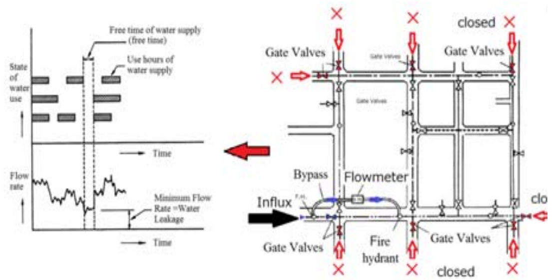


Figure 18: Example of water use "free time" and variation in the minimum nighttime

(3) Step test

In this method, the inside of the DMA is subdivided, for example, by piping branch lines, the smallest nighttime flow rate of the small section is measured in order, and the leakage amount is assumed from the total of the leakage sections.

In addition, it is possible to specify the section with the smallest flow rate.

Total MFR = MFR at small section (a) + small section (b)+ …….

8-2-3. Estimated amount from water used

In this method, leakage is calculated from the difference between the amount of water distributed for a certain period of time and the revenue water amount and assumed.

This leakage contains the meter's insensitive water amount, causing a considerable error.

Assume:

Leakage amount＝ Input volume – Revenue water＝NRW

Exercises:-1

① When is the minimum water volume (m^3/hrs.) generated ?

② Which minimum flow rate should be estimated as leakage amount?

Source: NYAHUWASCO 2018 Aug.

Exercises-2

① Describe how to proceed with additional survey, measuring the minimum flow rate at night at main distribution pipe line, dia.200mm~500 mm.

.

Rank	Night minimum flow rate value	Contents of additional survey required
A	$12m^3$/d/㎞ or less	
B	$12m^3$/d/㎞~$24m^3$/d/㎞ or less	
C	$24m^3$/d/km ~$50m^3$/d/km or less	
D	$50m^3$/d/ ㎞ more	

Exercises-3

① We measured the nighttime minimum flow rate in each small district, but from which area should we implement leakage countermeasures?

② What is the NRW rate of each section?

◆ Hint : NRW (%) =(45 ÷ 75) × 100 ＝ 60 %

③ What is the total leakage amount in this surveyed residential zone ?

④ How to deal with it?

Partition number	Input water (m3/d)	Loss amount (m^3/d)	**NRW (%)**	Piping distance (m)	No. of faucets (pcs)	Expected leakage amount (m^3/m/ d)
No.1	75	45	**60**	2,500	125	0.018
No.2	60	18		2,000	100	0.009
No.3	45	22.5		1,500	75	0.015
No4	54	43		1,800	90	0.024
No.5	60	21		2,000	100	0.011
No.6	105	63		3,500	175	0.018
Total	399	212.7	**Ave.**	13,300	665	

9. Method to collect leak volume at site by volume and /or weight.

9-1. Measurement category

As a method of grasping the amount of water leakage, it is divided into two categories by measurement such as actual flow rate and by visual observation.

Leak water measurement measures the total water leakage directly while measuring the time before repairing the part

9-2 Application

This method is suitable for small leak measurement and large leak measurement.

9-3. Measurement method

Examples of measurement methods are shown below.

① Direct measurement (with bucket etc.)

② Comparison of distribution flow rate (before repair and after repair)

③ Reproduction survey reusing removal pipe、

④ Visual

9.4. Outline of direct measurement method

The main methods for investigating water leakage are shown below.

(1) Direct measurement method.(Refer to Figure 19)

① Overview

In this method, water leakage is collected in a bucket / measuring cup or the like while measuring time at a leakage site, and the leakage amount is ascertained from the volume / weight measurement.

② Tools

In the case of small leakage, measurement cup, bucket, excavation tool、 Stopwatch, Scales.

Figure 19：Tools for instrumentation

(2) Calculation formula

$$\boxed{\textbf{Formula: } Q = Q_1 \times T \times \eta}$$

Here

Q: Total water leakage (m^3)

Q_1: Actual water leakage (m3 / hrs.)

T: Time required from the start of leakage to repair (hrs.)

η: Experience value of loss (permeation amount, outflow amount etc.) due to piping burying environment

(3) Reference (Refer to Figure 20)

① Relationship between weight of water and volume (volume)

$$\boxed{\textbf{Formula : } W = R \times V}$$

Here

W = Weight (g)

R = Density g / cm ^{3} = Specific gravity (water = 1)

V = Volume (Capacity) L, cc, mL

Table 20: Conversion table (Water Specific gravity = 1)

Volume		Weight		Note
L (liter)	mL(mill-liter)	g (gram)	mg(milligram)	
1.0	1,000	1,000	1,000,000	
0.5	500	500	500,000	
0.1	100	100	100,000	
0.01	10	10	10,000	

Exercises-4

(a) We measured the weight of water leakage, but what is the equation for calculating the leakage volume? **(Refer to Figure 21 & Table-9)**

Formula for calculation of water leakage:

V = W ÷ R

V = Volume (Capacity) L, cc, mL

W = Weight (g)

R = Density g / cm ^{3} = Specific gravity (water = 1)

(b) What is the unit indicating weight?

(c) What is the unit indicating the quantity?

(d) Calculate leakage amount by measured weight

Figure 21: Different bottles weigh

Table 9: Answer sheet

Container		Weight		Volume	
Type	Empty container (g)	g (gram)	mg (milligram)	L (liter)	mL (mill-liter)
Measure cup	31.0	131			
		42			
Bottle	15.0	130			
		99			

9-5. Comparison method of distribution flow rate (before repair and after repair)

(1) Overview

It is suitable for measuring medium to large leakage accident and is a method of measuring leakage volume from the difference between the water distribution flow rate before repair and the water distribution flow rate after repair.

(2) Tools

Flowmeter (External ultrasonic flowmeter, others)

(3) Calculation formula

Formula: $Q=(Q_1-Q_2) \times T \times \eta$

Here

Q: Total water leakage (m ^{3})

Q_1: Actual water volume after repair (m ^{3})

Q_2 Actual water volume before repair (m ^{3})

T: Time required from the start of leakage to repair (hrs.)

η: Experience value of loss (permeation amount, outflow amount etc.) due to piping burying environment

9-6. Reproduction survey reusing the removal pipe

(1) Overview

This method is a method of reproducing the leakage amount by using a removal pipe cut by repair. In the reproduction test, leakage can be measured relatively accurately by making it equal to the local water pressure, but when the large diameter and the leak hole is large, the reproduction facility and the measurement facility become large.

(2) Tools

Water leakage reproduction equipment and flow measurement equipment

9-7. Visual method

(1) Overview

In this method, the amount of water leakage is estimated by "comparing" the water leakage at the site with the "flow state photograph or chart" created by the water discharge experiment.

An example of a chart showing the water leak condition is shown below. (**Refer to Table 10 & & Figure 22 to 23)**

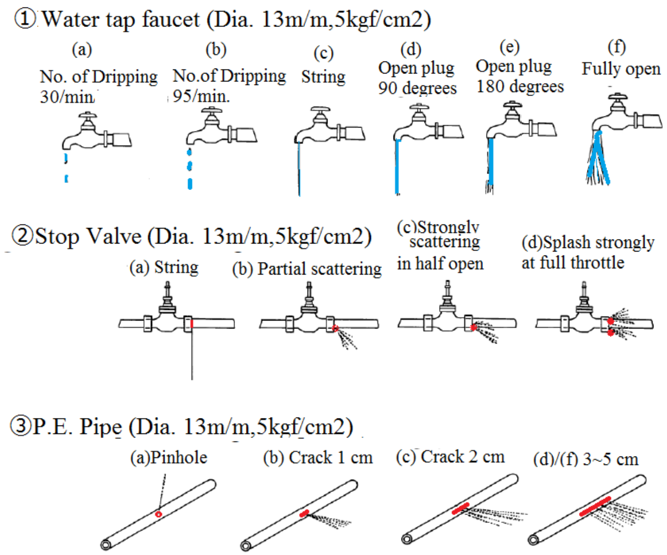
(2) Example of leakage volume experiment value (Dia.13 m/m pipe)

<u>Conditions</u>

- Water pressure: @ 3.5 kef / cm ^{2}is converted to 5 kef / cm ^{2}

Table 10: Table of leakage flow rate (at 5kgf/cm²)

Items		W. Leakage	(a)	(b)	(c)	(d)	(e)	(f)
①	Faucet	m^3/d	0.011	0.036	0.09	309	39.6	56.8
②	Stop valve	m^3/d	0.045	2.3	3.0	7.2	-	-
③	P.E. pipe	m^3/d	0.03~0.05	2.7	15.4	28.4	43.8	68.8



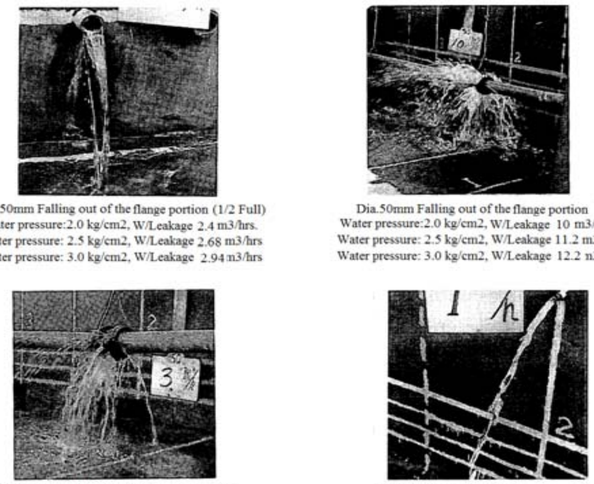
Source: JPRC 1995 #20

Figure 22: Example of Grasp water leakage (dia. 13 mm water service pipe)

(3) Example of leakage volume experiment value (Dia.13-50 m/m pipe)

<u>Condition</u>

-Water pressure: @ 2.0kef / cm ^{2}



Dia.50mm Falling out of the flange portion (1/2 Full)
Water pressure:2.0 kg/cm2, W/Leakage 2.4 m3/hrs.
Water pressure: 2.5 kg/cm2, W/Leakage 2.68 m3/hrs
Water pressure: 3.0 kg/cm2, W/Leakage 2.94 m3/hrs

Dia.50mm Falling out of the flange portion
Water pressure:2.0 kg/cm2, W/Leakage 10 m3/hrs.
Water pressure: 2.5 kg/cm2, W/Leakage 11.2 m3/hrs
Water pressure: 3.0 kg/cm2, W/Leakage 12.2 n3/hrs

Dia.50mm Falling out of the flange portion
Water pressure:2.0 kg/cm2, W/Leakage 3.0 m3/hrs.
Water pressure: 2.5 kg/cm2, W/Leakage 3.35 m3/hrs
Water pressure: 3.0 kg/cm2, W/Leakage 3.97 m3/hrs

Dia.13mm Falling out of the flange portion
Water pressure:2.0 kg/cm2, W/Leakage 1.0 m3/hrs.
Water pressure: 2.5 kg/cm2, W/Leakage 1.12 m3/hrs
Water pressure: 3.0 kg/cm2, W/Leakage 1.32 m3/hrs

Source: JPRC 1995 #20

Figure 23: Example of Leakage amount of understanding

10. Prediction method of leakage by calculation from pore size and/or water-pressure

10-1. Overview

In this method, damaged parts are converted into areas based on the breakage situation of piping, and leakage is calculated.

10-2. Calculation formula

$$\boxed{\text{Formula: } Q = C \times a \times P^n}$$

Here

Q: Water leakage (m^3)

P: Pipe water pressure (kef/cm^2)

C: Coefficient according to the shape etc. of leak hole

a: Area of leak hole (cm^2)

n: Index (0.5 or 1.15 assumed)

However;

The index (n) is assumed by reference to experimental values.

(a) Assuming that the index η = 0.5, the leak hole is an orifice.

(b) Assuming that the index η= 1.15, the leak crack in the pipe, a gap in the joint part of valves and plugs.

10-3. Relationship between Water leakage and Hydraulic pressure

assuming the size of the water leak hole, calculate the water leakage from the calculation.

(1) Overview

In this method, when it is difficult to measure the leakage of the high water pressure distribution pipe, water leakage amount (range from 1.0 cm to 0.01 cm) is converted to surface area (cm 2) and water leakage amount is predicted from the "quick catch table". (**Refer to Table 11**)

(2) For example

① Leakage hole diameter: 1.12 cm (radius = 0.564 cm)

② Leakage area: 3.14 × radius ^{2} = 3.14 × (0.564) ^{2} = 1.0 cm ^{2}

③ Hydraulic pressure: assumed to be 3.0 kef / cm $^{2.}$

(3) Prediction method of water leakage

For the calculation method, select the "pore area 1.0 cm ^{2} and water pressure 3.0 kef / cm ^{2}" of "Quick Reference Tables".

∴Leakage volume is estimated to be about

76.0 m ^{3} / d = 3.16 m ^{3} / min = 52.8 L / min

Table 11: Quick looking table (leakage and water pressure)

Dia (cm²)		Water Pressure (kgf/cm²)			
		3.0	4.0	5.0	6.0
1.00	Water leakage (m³/d)	76	88	98	107
0.60	Water leakage (m³/d)	54	63	70	76
0.50	Water leakage (m³/d)	52	60	67	73
0.40	Water leakage (m³/d)	50	57	64	70
0.30	Water leakage (m³/d)	33	38	43	47
0.20	Water leakage (m³/d)	27	31	35	38
0.10	Water leakage (m³/d)	17	20	22	24
0.08	Water leakage (m³/d)	15.5	18	20	22
0.06	Water leakage (m³/d)	11.6	13.4	15	16.4
0.04	Water leakage (m³/d)	7.7	8.9	10	11
0.02	Water leakage (m³/d)	3.9	4.5	5	5.5
0.01	Water leakage (m³/d)	1.3	1.6	1.8	2

Source: JPRC 1995 #20

Table 14: Pressure unit conversion Table

	ata (kg/cm²)	mm water (4℃)	bar	Mpa	Kpa	PSI(lb/in)
ata (kg/cm²)	1	10,000.03	0.981	0.0981	98.07	14.22
mm water (4℃)	9.99×10^{-5}	1	9.81×10^{-5}	9.81×10^{-6}	9.81×10^{-3}	1.422×10^{-3}
bar	1.02	101197.44	1	0.1	100	14.5
Mpa	10.2	101,974.42	10	1	1,000	14.5
Kpa	0.01	101.97	0.01	0.001	1	0.145
PSI(lb/in)	0.07	703, 09	0.0689	6、893 x 10^{-3}	6,863	1

Exercises:-5 Practice for finding water leakage

(1) Overview

In this method, when it is difficult to measure the leakage of the high water pressure distribution pipe, water leakage amount (range from 1.0 cm to 0.01 cm) is converted to surface area (cm ^{2}) and water leakage amount is predicted from the "quick catch table". (**Refer to Table 15**)

(2) Conditions

① Leakage hole diameter: 1.12 cm (radius = 0.564 cm)

② Leakage area: 3.14 × radius ^{2} = 3.14 × (0.564) ^{2} = 1.0 cm ^{2}

③ Hydraulic pressure: assumed to be 3.0 kef / cm $^{2.}$

(3) Calculation

Select the "pore area 1.0 cm ^{2} and water pressure 3.0 kef / cm ^{2}" of "Quick Reference Tables".

∴Leakage volume is estimated to be about

76.0 m ^{3} / d = 3.16 m ^{3} / min = 52.8 L / min

Table 15 Quick looking table (leakage and water pressure)

Dia. (cm²)		Water Pressure (kgf/cm²)			
		3.0	4.0	5.0	6.0
1.00	Water leakage (m³/d)	**76.0**	88.0	98.0	107.0
0.60	Water leakage (m³/d)	54.0	63.0	70.0	76.0
0.50	Water leakage (m³/d)	52.0	60.0	67.0	73.0
0.40	Water leakage (m³/d)	50.0	57.0	64.0	70.0
0.30	Water leakage (m³/d)	33.0	38.0	43.0	47.0
0.20	Water leakage (m³/d)	27.0	31.0	35.0	38.0
0.10	Water leakage (m³/d)	17.0	20.0	22.0	24.0
0.08	Water leakage (m³/d)	15.5	18.0	20.0	22.0
0.06	Water leakage (m³/d)	11.6	13.4	15.0	16.4
0.04	Water leakage (m³/d)	7.7	8.9	10.0	11.0
0.02	Water leakage (m³/d)	3.9	4.5	5.0	5.5
0.01	Water leakage (m³/d)	1.3	1.6	1.8	2.0

Source: JPRC 1995 #20

—END-

Internal Information

TEXTBOOK

FOR

JOINT TRAINING

(DRAFT)

"USE OF NON-REVENUE WATER INVESTIGATION EQUIPMENT"

R-2

February, 2019

Implemented by
KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)

Mr. Maina / Mr. Walela #8

Assisted by JICA KENYA

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TABLE OF CONTENTS

1. Objective

① Understand concept of Pipelines locating/ tracing equipment
② Understand concept of Leak detecting equipment
③ Understand concept of Water flow measurement equipment
④ Understand concept of Water pressure measuring equipment

2. Introduction

To manage Non-Revenue Water one needs to understand the components and then lay strategies on how to manage them. From the understanding that there are two main components to deal with, mainly Physical and Commercial losses. Non-Revenue water investigating equipment are used to deal with physical losses, accuracy of meters and pressure management. This chapter will deal with equipment used for pipe location, flow measurement and leak detections

3. Key Words Definition

Metallic Iron pipe locators	It is a detector that investigates the location of buried metal objects.
Non-metallic pipe locator	It is a detector which investigates the location of a burial nonmetallic thing.
Acoustic rods	It is a device to investigate the location of buried leak sound by human hearing.
Electronic acoustic rods	It is a device that amplifies leakage sound from the water supply pipe and investigates it.
Water Leak Detectors	It is an electronic detector that investigates the location of water leakage sound from the road surface with an amplification device.
Leak noise correlators	It is an electronic detector that specifies a leakage point of the water distribution pipe network.
Electromagnetic flow meters	It is a flow meter that calculates the flow rate from the electromotive force generated when water crosses.
Ultrasonic flow meters	When an ultrasonic wave is transmitted from a sensor installed at an angle to both ends of the pipe, the flow rate is calculated from the delay of the propagation arrival time between the two points depending on the flow velocity.

4. Pipelines Locating/ Tracing Equipment

4.1 Metallic Iron pipe locators

(1) Principle of operation and application (See Fig.-1)

(a) They compose of Transmitter & Receiver

Traces any continuous metal, such as; iron, steel & copper water lines, gas lines, tracer wire by plastic pipe, telephone/TV cables, copper &aluminium wire, conduit, and Power lines whether energized or not.

Figure-1 Metal Pipe Locators

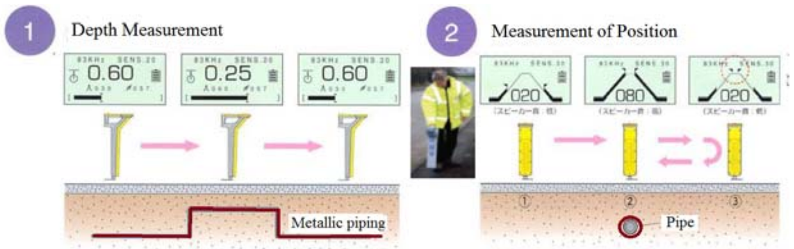


Figure-2 Metal Pipe detection signal example

(b) Operation Principal

As a transmitter emits electromagnetic waves, a magnetic field is generated. If a metal pipe or a cable is laid within the magnetic field, induced current (signal current) is produced and flows through the underground metal pipe or cable according to the principle of electromagnetic induction. Then, a receiver picks up the magnetic field generated by the subsurface metal pipe or cable. The location and depth of the subsurface pipe or cable is located by the angle of the magnetic force concentrically generated by the metal pipe and the strength of the magnetic field.

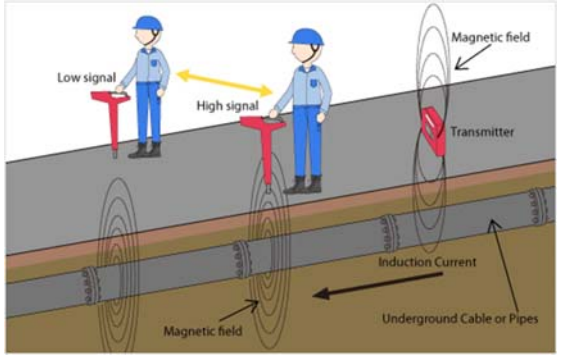


Figure-3 Inductive Mode

Passive Radio Mode, which does not require the Transmitter. This feature detects the Induced magnetic field present on underground utilities.

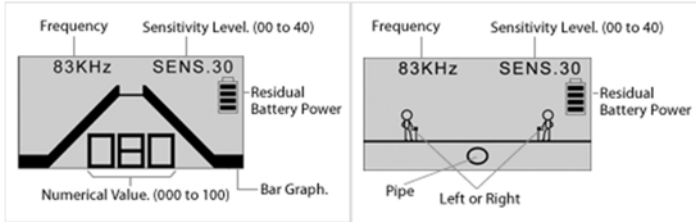


Figure-4 Maximum mode

(c) Minimum mode

Optional External Coil available for locating Utility-line that has an insulated coating and for Power-line and Telephone-line that cannot be connected directly in the direct mode.

- **Detection Accuracy**

① **In case of the induction method**

- The magnetic field generated by the underground metallic pipe is picked up by a receiver.
- The angle of the magnetic force continuously generated by the underground metallic pipe and the strength of the magnetic field are measured to determine the location and depth of the pipe.

② **In case of the direct method**

The transmitter is directly connected to an underground metallic pipe to supply a signal current to the pipe, it and the receiver is used to locate the current on the pipe.

4.2 Non-metallic pipe locators

(1) Principle of operation and application

Low frequency sound waves are generated by the sonic vibrator, which are transmitted through the water in the non-metal pipe, then received by the pickup sensor of the sound wave detector placed on the ground surface.

Figure-5 Plastic Pipe Locators

The transponder locates all clean water pipes including PVC, Plastic, AC without tracer wires by creating water pulses on the pipes.

The Radio detection transponder locate PVC, plastic pipe locator valve that connects to the water supply pipes and creates 5 psi pulses higher than the pipe pressure. Then locate PVC pipe by listening with the RD547,

Figure-6 Application example of Vibration-wave water method

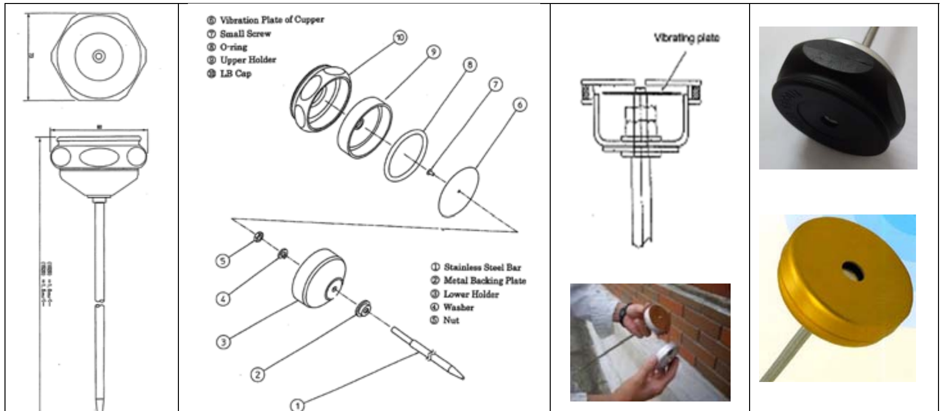
Electronically controlled water valve opens and closes creating water pulses in the pipe causing noise in the pipe. Water Pulse Generator sends water pulses along the pipe which then can be located using leak detectors.

5. Leak Detecting Equipment

5.1. Acoustic rods

(1) Principle of operation and application

Sounds of leakage can be heard by directly touching the end of the rod to valves, hydrants and pipes



Part of Listening Stick

Figure-7 Application example of Acoustic rods method

5.2. Electronic acoustic rods

(1) Principle of operation and application

By directly touching a water supply facility element, the sound of leakage (vibration) is numerically shown on the indicator.

It takes a combination of excellent service and quality water Leak Detection equipment to detect a hidden leak. With State-of-the-art equipment and water leak detection services Combined, we have saved billions of Litres of water leaking away

Figure-8 **Application example of Electronic acoustic rods method**

5.3. Water Leak Detectors

(1) Principle of operation and application

… Leak detector catches the leak noise electrically. The principle is that a vibration pick-up is placed on the ground detects the vibration sound of leakage transmitted underground.

… This vibration energy is converted to electrical energy and is amplified for meter indication or detection by a headphone.

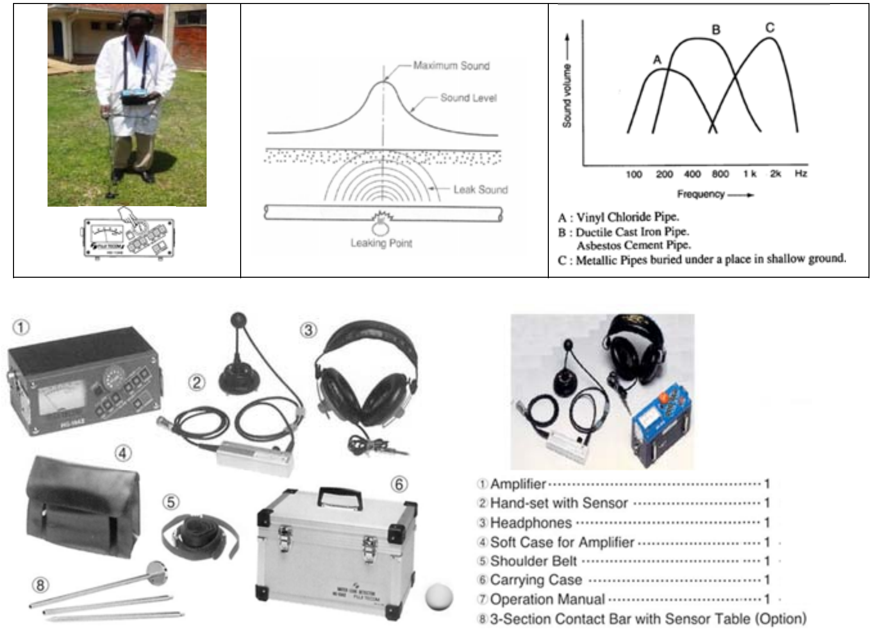


Figure-9 **Application example of Water Leak Detectors method**

5.4 Leak noise correlators

(1) Principle of operation and application

…The leak noise correlator is a device used to locate the point of leakage at underground water pipes.

…Pickup sensors are placed at two measuring points on the pipeline through which the sound of leakage transmitted.

…The distance to the point of leakage from each pickup sensor is determined by calculating the difference in the time it takes for the sound to reach each pickup sensor.

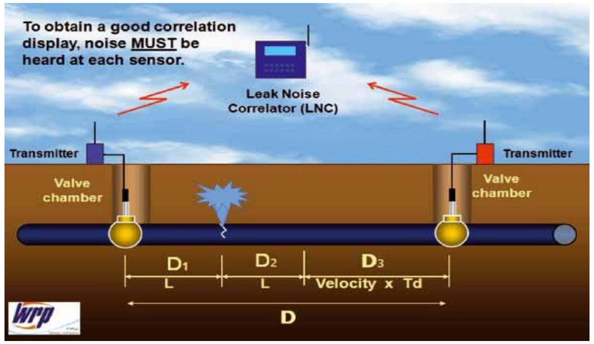


Figure-10 Application example of Leak noise correlator method

5.5 Sonic type pipeline detectors

This detector utilizes the property that "sound waves have a high propagation rate in water" and is used on "nonmetallic pipes" such as asbestos cement pipes rigid polyvinyl chloride pipes~~,~~ polyethylene pipes etc. which do not conduct current, or "electrically insulated Metal tube of a joint type "in which it is located. (**Refer to Figure 11**)

Sound waves propagate "signal sound waves" matching the resonance frequency of the pipeline from fire hydrants and partition valves on the pipeline to the water in the pipeline with a vibrator and propagate it far.

This "vibration of water" propagates on the ground ~~road~~ surface as it travels through the ground as a vibration of the pipe, so that the signal sound wave is detected on the ground surface.

However, when the pipe is buried deep into the ground, judgment may be difficult.
In addition, we will consider preventing pipe damage of aging pipes by vibration.

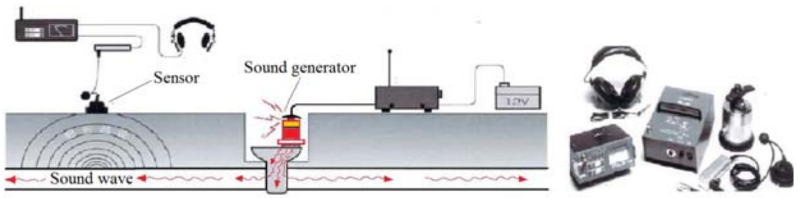


Figure 11 Sonic type pipeline detection system

5.6 Impact wave

In this method, a shock is given to the water of the pipe from the valves, and the shock wave is traced on the ground to identify the pipeline of the buried pipe.

1) Classification of exploration method

a) Striking sound injector method

b) Pressurized water method

c) Vibration-wave water method

2) Striking sound injector method

The striking sound injector method is a piston-like striking sound injector provided at the tip of a small-diameter water supply pipe, generates shock waves in water in the water supply pipe, and detects vibration transmitted from the buried pipe with a sensor on the ground surface. (**Refer to Figure 12**)

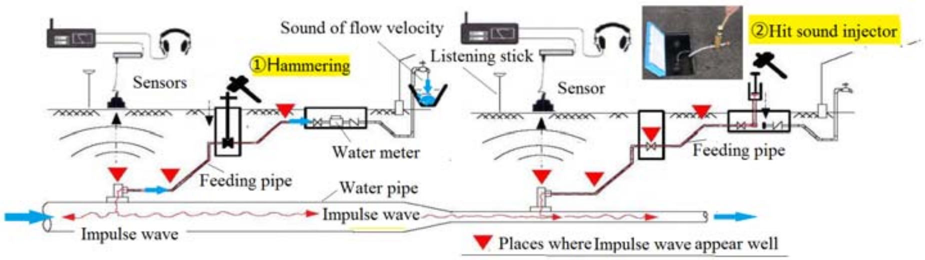


Figure 12 Overview of Striking sound injector method

5.7 Underground radars

This underground exploration radar moves a radar device on a dolly.
While moving, the electromagnetic wave of the pulse periodically radiates to the

underground, the weakly reflected wave that hits the object buried under the ground is received (caught) by the receiving antenna, the ground interruption face image is displayed, It is used to specify the burial depth (maximum about 1.5 m) and position of metal pipe / nonmetal pipe. **(Refer to Figure-13)**

Chirp optical pulses

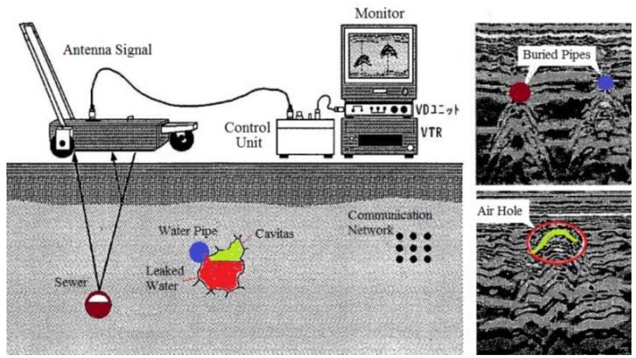


Figure-13 Outline of underground radar

6. Flow Rate Measurement Equipment (Bulk Meters)

6.1 Characteristics of Bulk flowmeters

The flowmeter is a device that accurately measures the flow rate.
The measured value becomes the basic data of the water balance analysis, and it is used for the calculation of Non-revenue water rate, **Revenue** water rate, and the water leakage amount.

The typical flow rate is shown below.

1) Flow velocity Type (For example):
Electromagnetic flowmeter, Ultrasonic flowmeter, Woltman turbine Meter, others.

2) Volumetric Type Flowmeters (For example):
Gear pump, Rotary valve pump, Piston pump, others.

6.2. Electromagnetic flow meter

(1) Principle of operation and application

The electromagnetic flow meter is capable of measuring the flow volume of a fluid by applying a magnetic field to the fluid from the outside. As the conductive fluid flows through the magnetic field, an electromotive force is generated perpendicularly to both the flowing direction of the conductive fluid and the direction of magnetic field.

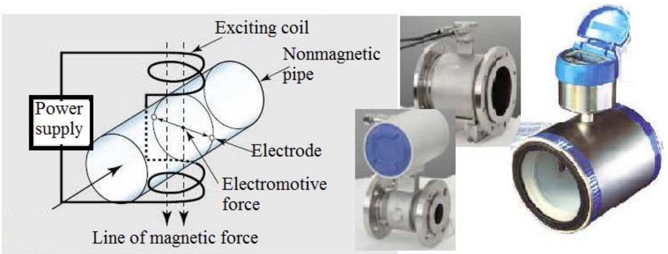


Figure-14 **Application example of Electromagnetic flow meters method**

(2) Points to keep in mind

① The piping is always filled with fluid and water that does not contain a large amount of bubbles (2% or more as a guideline).

② The diameter is selected within the optimal flow range with average flow velocity of 2 to 4 m / s.

③ When the average flow velocity is less than 1 m / sec, the electromotive force is small and the problem of accuracy tends to occur.

④ The pressure loss is the same as the pipe of the same length and is "small".

⑤ If the flow rate decreases if the diameter is the same as the pipe diameter, use a reduction pipe (reducer).

⑥ Because turbulence and drift occurring at the fitting part of the pipe cause measurement errors, rectify and equalize.

(3) *Installation and operation*

① Installation of an electromagnetic flow meter.(have higher accuracy than the mechanical meters)

② Connect the EMFM to a pulse maker (to change volume passed from m3 to pulses)

③ The pulse maker is connected to a web enabled to data logger

④ The data logger is connected to a router which transmits the information gathered to a communication base through internet.

⑤ The communication base sends the information to an office router at step 6

⑥ The data is passed to the office server.

⑦ Real time data as per settings easily available 24 hr internet enabled phones or a desktop PC. (In case of no flows, abnormal flows, bursts, peak flows the user can easily get alerts for action)

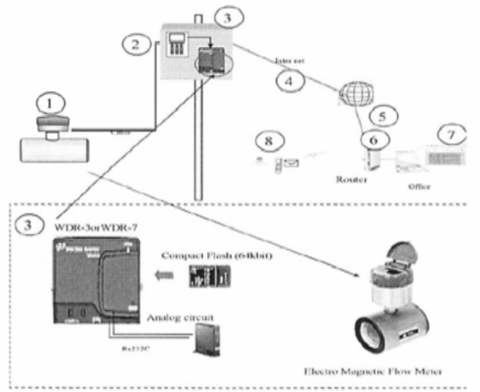


Figure-15 **Application example of Installation and operation method**

6.2 Ultrasonic flow meters

(1) Principle of operation and application

The ultrasonic flow meter operates based on the difference in time required for ultrasonic waves to be transmitted through a fluid. It consists of two transducers mounted on the outer wall of a pipe and measures the flow rate from the transmission velocity of ultrasonic waves generated and received by itself through the fluid

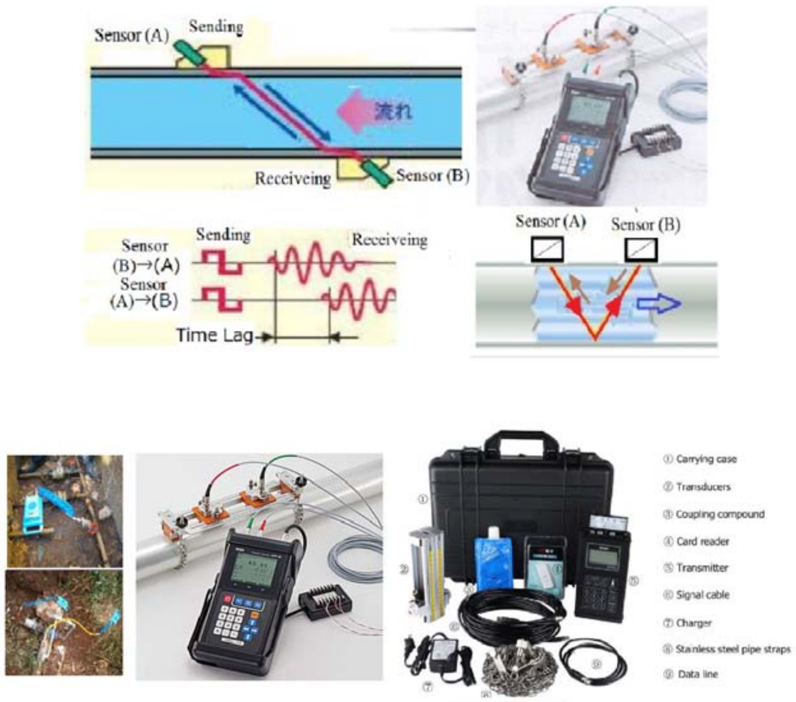


Figure-16 Application example of Installation and operation method

(2) Points to note

Attention should be paid to considerations that affect the measurement accuracy of the ultrasonic flowmeter.

① A channel that is always filled with fluid and does not contain a large amount of bubbles (2% or more as a guideline).

② The aperture should be selected within the optimum flow range with an average flow velocity of 2 to 4 m / s.

③ There is a flow speed and pipe diameter inside the pipe, and as the flow rate is slow (flow rate is small), the error becomes more likely to occur as the pipe diameter becomes smaller.

④ If there are scales (deposits such as rust) on the inner surface of the pipe, volume of earth and sand, etc. the tube cross section changes and affects measurement accuracy,

⑤ Especially when there is extreme scale adhesion or peeling of lining material, measurement becomes difficult.

⑥ Measurement error will occur if the outer surface of the pipe is rough with a cast iron pipe.

⑦ PVDF pipe (Poly Vinylidene fluoride fluoride resin) wall thickness of 9 mm or less, PP tube (polypropylene tube) with wall thickness of 15 mm or less.

⑧ SGPW pipe [Galvanized steel pipe for water supply (commonly called white gas pipe) and lining pipe may have errors.

⑨ Sensor installation Linear part (upstream: 10D to 50D) · Downstream: 10D) is necessary, please confirm details with the manufacturer.

(3) Procedure of installation and inputs

① Pipe parameters entered must be accurate; otherwise the flow meter will not work properly.

② During the installation, apply enough coupling compound to bond the transducer onto the pipe wall. While checking the signal strength and Q value, move the transducer slowly around the mounting site until the strongest signal and maximum Q value are obtained. The larger the pipe diameter, the more the transducer may have to be moved.

③ Check to be sure the mounting spacing is as calculated and the transducer is mounted at the pipe's centreline on the same diameter. Note that you can adjust the spacing slightly as described above to fine tune the device.

④ Pay special attention to those pipes that formed by steel rolls (pipe with seams), since such pipe is always irregular. If the signal strength is always displayed as 0.00, that means there is no signal detected. Thus, it is necessary to check that the parameters (including all the pipe parameters) have been entered accurately.

Check to be sure the transducer mounting method has been selected properly, the pipe is not worn-out, and the liner is not too thick. Make sure there is there is indeed fluid in the pipe or the transducer is not very close to a valve or elbow, and/or there are not too many air bubbles in the fluid, etc. Once you have ruled out all these possible reasons, if there is still no signal detected, the measurement site has to be changed.

(4) Steps for accurate Flow measuring

① Assembling the equipment.

Assemble the equipment as per the instruction manual provided for different models of flow meters.

② Data entry

Accurately Input the following data following the operational manual.

Flow Totalizer Display	Pipe Outer Perimeter	Liner Material
Flow Rate/Net Totalizer	Pipe Outer Diameter	Liner Sound Velocity
Flow Rate/Velocity	Pipe Wall Thickness	Liner Thickness
Flow Rate/POS Totalizer	Pipe Inner Diameter	Fluid Type
Flow Rate/NEG Totalizer	Pipe Material	Fluid Sound Velocity
Date Time/Flow Rate	Pipe Sound Velocity	Fluid Viscosity
		Transducer type

After the data entry the machine computes the transducer distance. Use this distance to mount the transducers

(5) Transducer Mounting Methods

Four transducer mounting methods are available. They are respectively: V method, Z method and N method. The V method is primarily used on small diameter pipes (DN100-300mm, 4"-12"). The Z method is used in applications where the V method cannot work due to poor signal or no signal detected. In addition, the Z method generally works better on larger diameter pipes (over DN300mm, 12") or cast iron pipes. The N method is an uncommonly used method. It is used on smaller diameter pipes (below DN5Omm, 2").

① V Method

The V method is considered as the standard method. It usually gives a more accurate reading and is used on pipe diameters ranging from 50mm to 400mm (2"-16") approximately. Also, it is convenient to use, but still requires proper installation of the transducer, contact on the pipe at the pipe's centreline and equal spacing on either side of the centreline

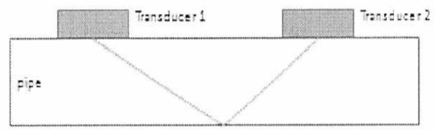


Figure-17 Application example of Installation V-method

② Z Method

The signal transmitted in a Z method installation has less attenuation than a signal transmitted with the V method. This is because the Z method utilizes a directly transmitted (rather than reflected) signal which transverses the liquid only once. the Z method is able to measure on pipe diameters ranging from 25mm to 1200mm (1"-48") approximately.

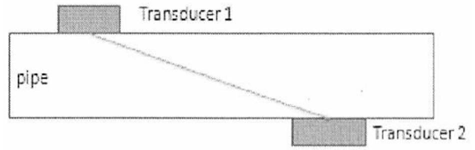


Figure-18 Application example of Installation Z-method

③ W-Method (not commonly used)

With the W method. the sound waves traverse the fluid twice and bounce three times off the pipe walls. It is suitable for small pipe diameter measurement.
The measurement accuracy can be improved by extending the transit distance with the W method (uncommonly used).

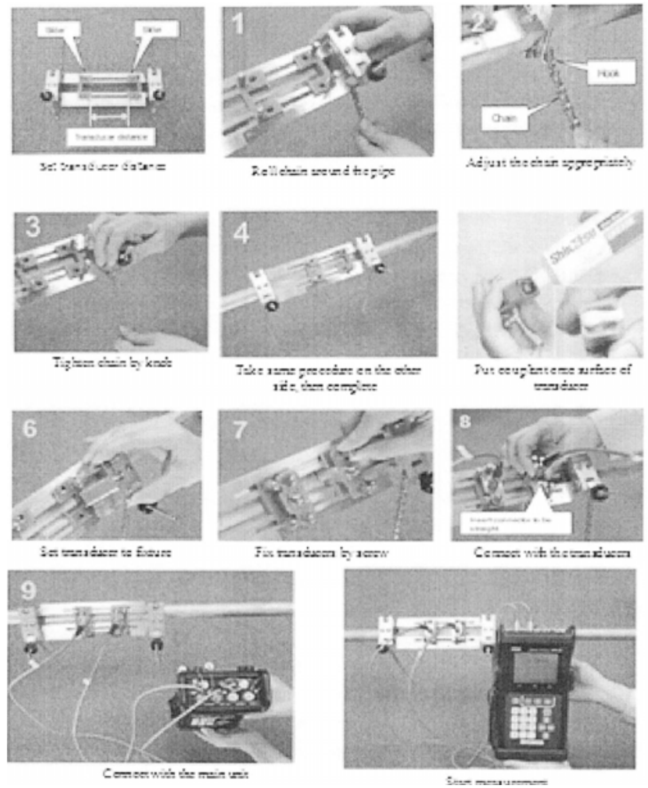


Figure-19 Example of Installation procedure

(6) Check for Signal Strength

Signal strength indicates a detected strength of the signal both from upstream and downstream directions.

The relevant signal strength is indicated by numbers from 00.0-99.9. 00.0 represents no signal detected while 99.9 represent maximum signal strength. Normally, the stronger the signal strength detected, the better the measurement.

Adjust the transducer spacing to the best position and check to ensure that enough sonic coupling compound is applied during installation in order to obtain the maximum signal strength.

This is essentially fine tuning the calculated spacing shown in menu 25 (transducer spacing). It may be slightly different. System normal operation requires signal strength over 60.0, which is detected from both upstream and downstream directions.

If the signal strength detected is too low, the transducer installation position and the transducer mounting spacing should be re-adjusted and the pipe should be re-inspected. If necessary, change the mounting to the Z method (Z has the highest signal strength).

(7) Check for Signal Quality (Q value)

Q value is short for Signal Quality. It indicates the level of the signal detected. Q value is indicated by numbers from 00-99. 00 represents the minimum signal detected while 99 represent the maximum. The transducer position may be adjusted and enough coupling used to get the signal quality detected as strong as possible.

(8) Data Transfer

Logged data and site conditions can be stored into internal memory.

Figure-20 Example of Data transfer procedure

(9) Mounting condition

① When selecting a measurement site, it is important to select an area where the fluid flow profile is fully developed to guarantee a highly accurate measurement.

Use the following guidelines to select a proper installation site:

② Choose a section of pipe that is always full of liquid, such as a vertical pipe with flow in the upward and turbulent points.

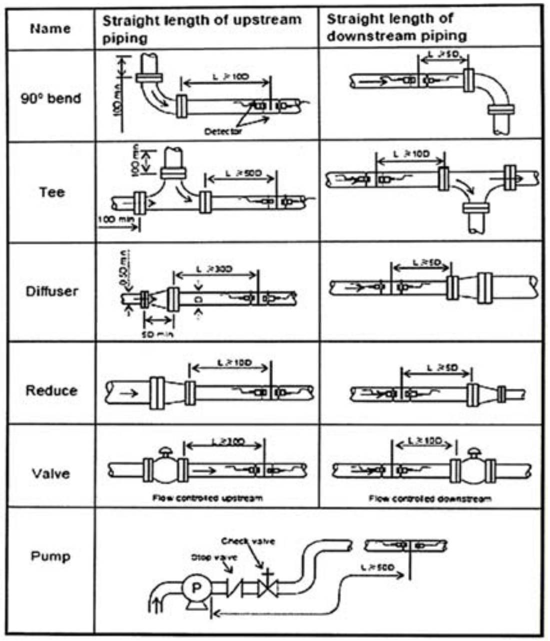


Figure-21 Example of Installation method

6.3. Portable insert type flow meter

Used to measure flow rates, fluid velocity, flowing direction, and water pressure by inserting it to a pipeline. A connection has to be done on the pipeline

Figure-22 Example of Portable insert type flow meters

7. Bulk Flow Meters

7-1 Woltman Turbine Meters

7-1-1 Principle of operation and application

The axial flow type flowmeter is installed with a turbine wheel / blade wheel in the pipe flow, rotates at a speed substantially proportional to the flow rate, and integrates the flow rate from this rotation number.

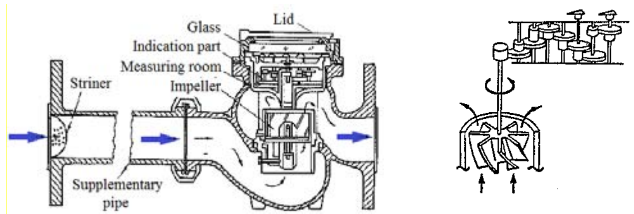


Figure-23 Example of Vertical Woltman Meters

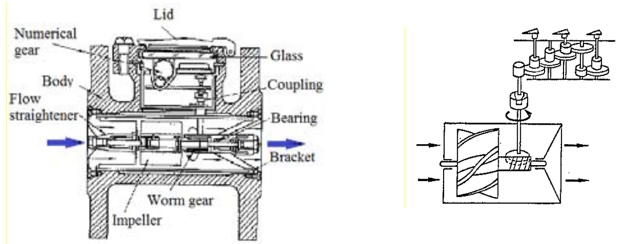


Figure-24 Example of Horizontal Woltman Meters

Figure 25 Example of Trbine Meters (Bermad Co.,LTD)

7-1-2 Bermad's Meter Installed DFM (ES-Waternet Co., LTD.)

(1) Outline

This model Woltman Turbine Meter is installed DFM next to the acuminate meter.
The number of rotations of this turbine blade has accumulated volume of water displayed by upside Register.
By connecting two wires from Register to DFM, the digital display of both accumulate volume of water and the instantaneous volume of water is carried out.

(2) Features

① Dry type register (Water meter): Hermetically sealed and adjustable to any position (360°) for easy reading

② Magnetic transmission keeps the register completely separate from water, only the impeller and transmission shaft contact water

③ Digital flow meter (DFM) was designed for flow rate display while connected to the Woltman Turbine Meter register pulse output device.

④ Volume and flow rate units, decimal point, volume per pulse and output specifications are factory set.

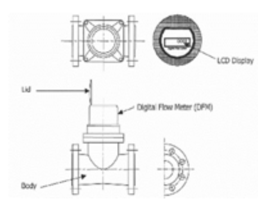
⑤ Meets or exceeds all relevant metrological standards including ISO 4064 class B, EEC

Figure 26 Example of EMBU's Trbine Meters

7-1-3 What is DFM?

(1) General

The Digital Flow Meter (DFM) is designed for Flow display while connected to a Flow Meter generated the pulse output by magnet force

Specifications; (1) Display: Digital cumulated number / Instantaneous flow (2) Unit range: Total volume (m^3 or Liter) Flow rate (m^3/hr or L/hr or L/sec) (3) Digital Flow Meter (DFM) has a built-in TADIRAN lithium battery；TADIRAN lithium－3.6V、TL-5903/P、 ISRAL		

(2) Reassembling the DFM

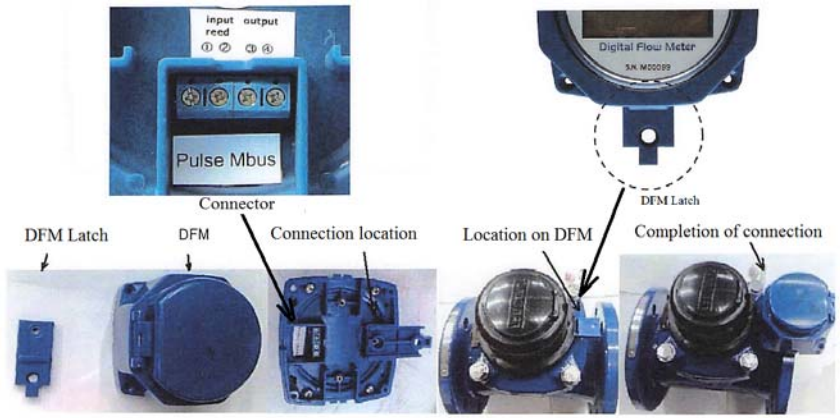
① Connect the reed switch two-wire cable to the terminal at the DFM bottom to the "reed" location number 1&2 according to the sticker.

② In case terminal sealing is required, fill the terminal chamber using sealing material such as Silicon.

③ Push the DFM down and turn it clockwise.

④ Retighten the sealing screw and seal the register if required.

NOTE: Make sure the DFM operates properly before sealing



Example of Fixing New DFM for Small size meters

Figure 27 Example of Details of DFM's Connections

(3) Replacing The Lithium Battery

This battery is not changeable so periodical DFM replacement is required.

◆Warning
(Replacing the lithium battery is dangerous, be sure to do it at a special factory)

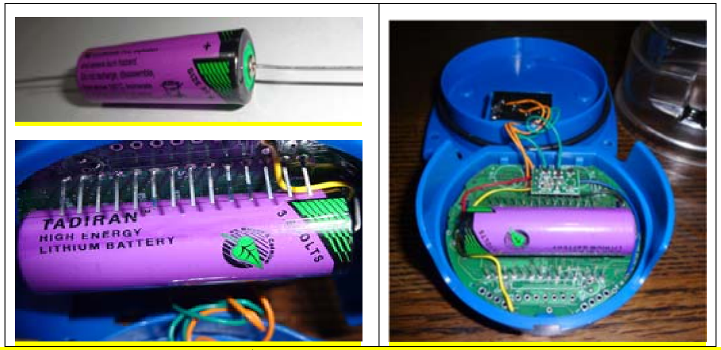


Figure-28 Wiring board of DFM（Warning ：Replacing the lithium battery is dangerous)

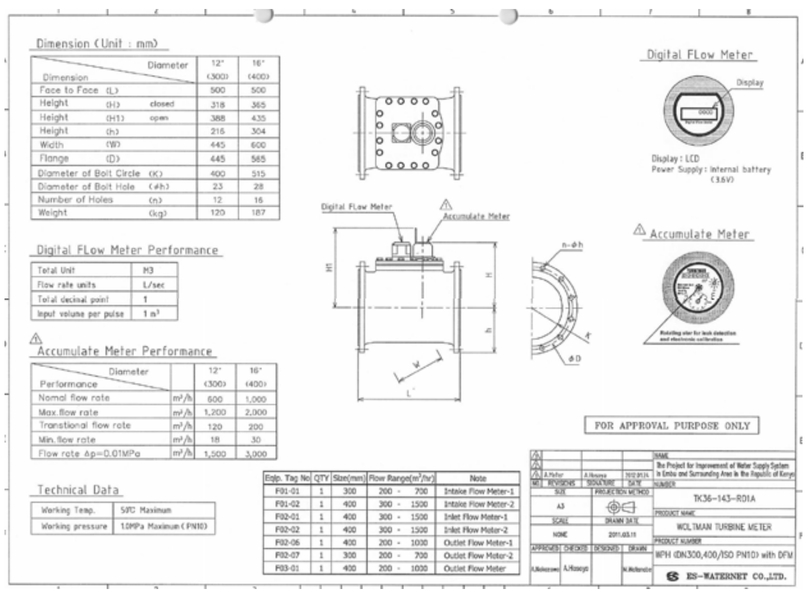


Figure-29 Speciation of Woltman Water meter Installed DFM

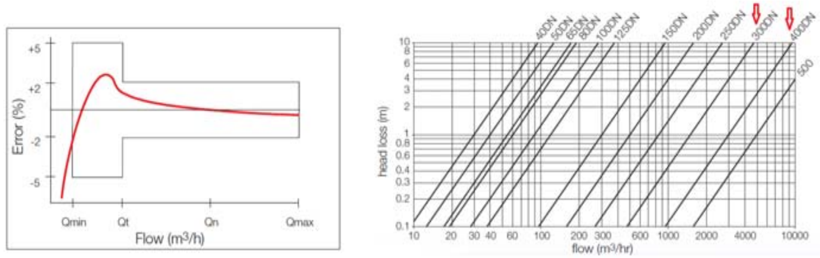


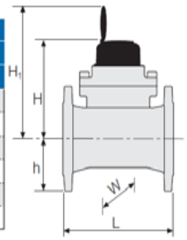
Figure-30 Accuracy Curve

Table-1 Example of Specification of Woltman Water Meter

in	1½"	2"	2½"	3"	4"	5"	6"	8"	10"	12"	16"	20"
DN	40	50	65	80	100	125	150	200	250	300	400	500
Qn - Nominal flow rate (ISO 4064) (m^3/h)	10	15	25	40	60	100	150	250	400	600	1,000	1,500
Qp - Max. Permanent flow (m^3/h)	20	30	30	60	100	160	180	300	600	1,000	1,500	3,000
Qmax - Max. flow rate (ISO 4064) (m^3/h)	20	30	50	80	120	200	300	500	800	1,200	2,000	3,000
Max. flow peak duty (m^3/h)	30	50	80	120	200	250	300	500	800	1,500	2,500	4,000
Qt - Transmition flow rate (±2%) (m^3/h)	3	3	5	8	12	20	30	50	80	120	200	300
Qmin - Min. flow rate (±5%) (ISO 4064) (m^3/h)	0.7	0.45 0.7	0.75	1.2	1.8	3	4.5	7.5	12	18	30	40
Flow rate Δp = 0.1 bar (m^3/h)	30	40	55	60	90	120	300	500	850	1,500	3,000	5,000
Max. reading m^3	1,000,000						10,000,000		100,000,000			
Min. reading (liter)	1						10		100			

Table-2 Example of Dimensions and weights of Woltman Water Meter

in	1½"	2"		2½"	3"	4"	5"	6"	8"	10"	12"	16"	20"
DN	40	50	50	65	80	100	125	150	200	250	300	400	500
Size		ISO	ANSI/BSTD										
L - Length (mm)	260	200	310	200	225	250	250	300	350	450	500	500	500
H - Height (mm)	268	275	270	285	295	304	318	366	393	512	534	669	765
H1 - Height (mm)	338	345	340	355	365	374	388	436	463	582	604	739	835
h - Height (mm)	68	75	70	85	95	104	118	135	162	194	216	304	355
W - Width (mm)	160	170	160	190	200	230	250	285	340	395	445	600	700
Weight (kg)	13	12	15	14	16	19	20	39	52	105	120	187	256



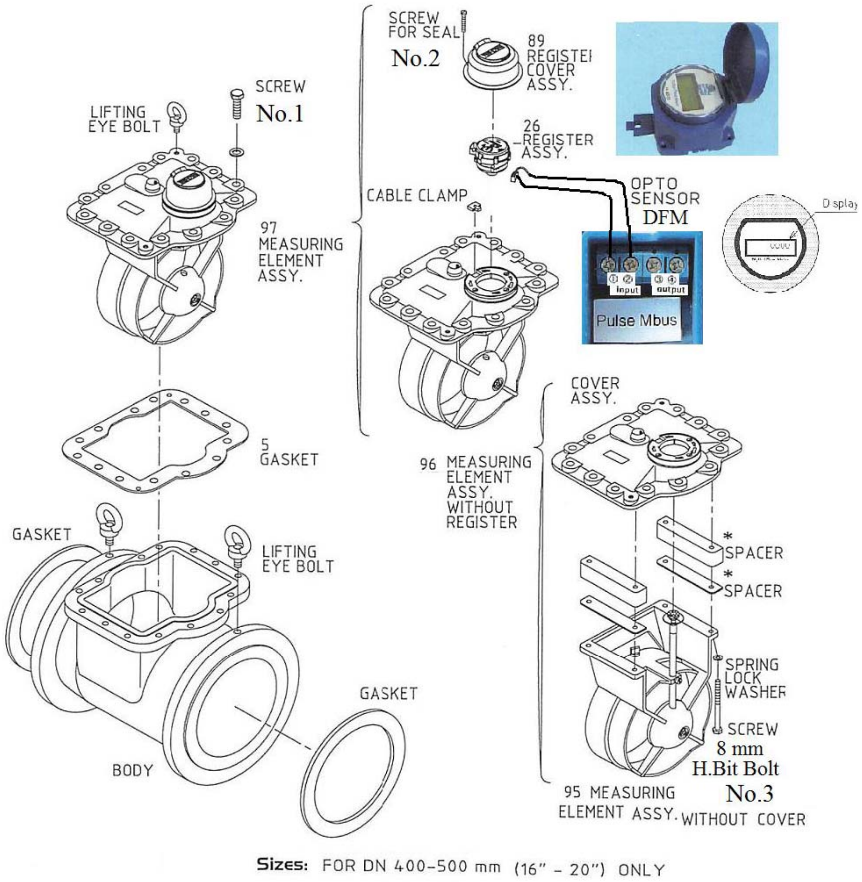


Figure-31 Structure Drawing of Meter

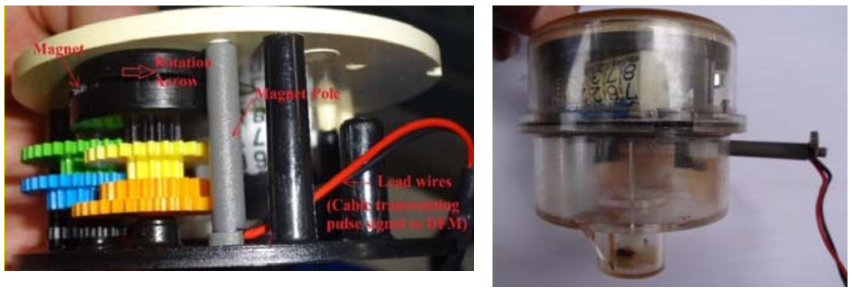


Figure-32 Image diagram of pulse generation mechanism (Resister/Accumulate meter)

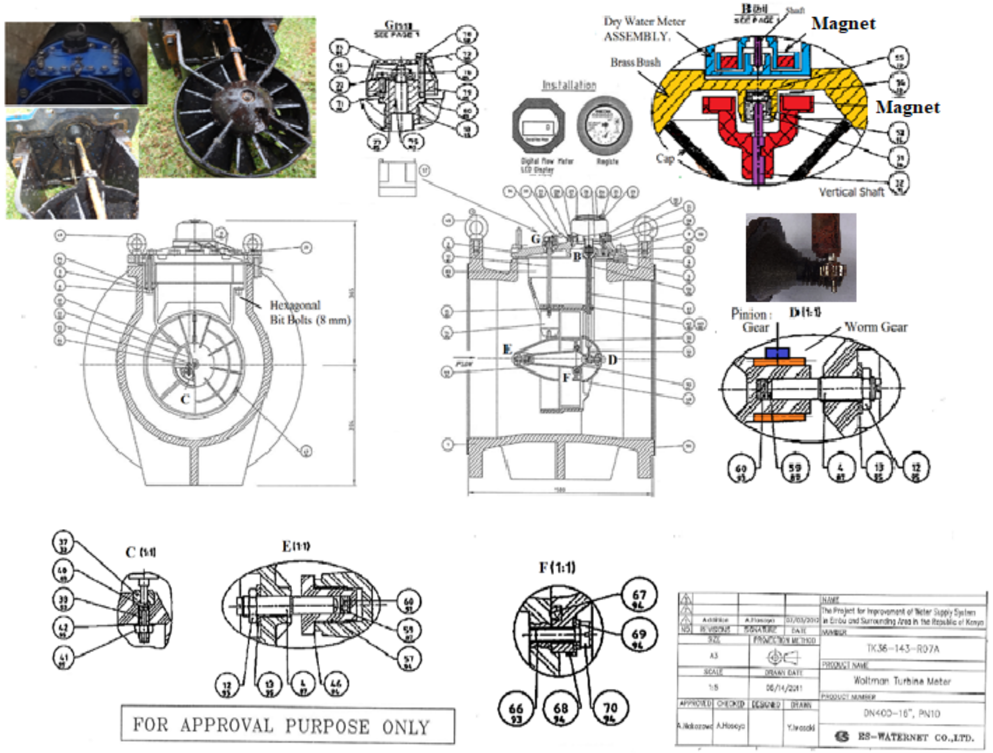


Figure -33 Detail Example of Structure of Flowmeter

7-1-4 Installation (See Fig. 33)

① Allow enough room around the Meter for any maintenance/disassembly work in future.

② In order to prevent falling, remove oil and grease completely around the place where the Meter is installed.

③ thoroughly flush the pipeline to remove debris, etc. prior to installing. Failure to do this may result in the meter malfunction.

④ Isolation valves should be installed at upstream and downstream sides of the Meter to allow for future maintenance.

⑤ Installation of a strainer or a filter is recommended at upstream side of the Meter to eliminate debris that could damage or stop operation of the measuring elements.

⑥ Install the Meter for the proper direction in accordance with the flow direction arrow mark on the valve body.

⑦ After installation, carefully inspect/correct any damaged accessories, piping, tubing, or fittings.

⑧ Make sure that the Meter works normally with test watering before use.

⑨ Ensure that the Meter is full of water during measuring.

⑩ Proper installation helps maximize the accuracy and lifespan of the Woltman Turbine Meter. All turbine meters are sensitive to turbulent conditions caused by diameter changes, pumps, tees, valves etc. Therefore, install the meter far from these disturbances and according to the following specifications;

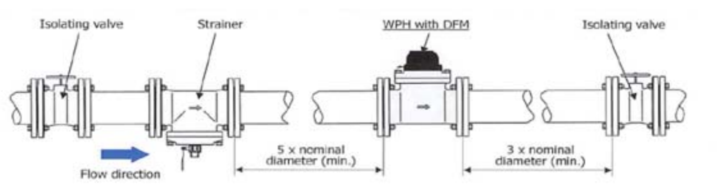


Figure-34 Recommended Installation Diagram

7-1-5 Maintenance

A periodic inspection schedule should be established to determine how the flow, the foreign materials and etc. are affecting the Meter.
The maintenance items and recommended frequency are shown below.

◆**NOTE:**
(1) The performance of the flowmeter needs to be confirmed every year at KESB.
Warning
(Replacing the lithium battery is dangerous, be sure to do it at a special factory)

Table-3 Maintenance items and frequency of the water meter recommended by the manufacturer

ITEM	FREQUENCY
Disassemble	Once/ 6-month
Sealing: leakage or not	Once/ year
Flow rate (compare with pumps etc.)	Once/ year
Corrosion: existence or not	Once/ year
Digital Flow Meter (DFM) : Replace *	Once/3---5 years

Table-4 Typical Trouble shooting

PHENOMENON	CAUSE	MEASURE
Flow rate does not meet the actual flow rate.	The flow direction is wrong.	Change the Meter direction as specified.
	The straight lines for both upstream and downstream is not enough.	Confirm the length of straight lines.
	Flow rate is out of specification.	Confirm the flow rate range of the Meter and actual flow rate.
	Impeller does not rotate smoothly.	Clean or replace the measuring element assy.
DFM display disappears	DFM battery is out of charge.	Replace DFM.
Abnormal sound / vibration	Screw is loosened.	Retighten screws on the cover.
	Pipeline is abnormal.	Install or check air valve. Check the pipeline.

8. Pressure Measuring Equipment

8.1 Bourdon-tube pressure gauge

(1) Principle of operation and application

Pressure is applied on the lower induction part. Curved Bourdon tube expands. End of tube widens and the rod and rod pin lever push up on the bottom of the indicator to displace it around the center.

The Bourdon tube pressure gauge (Bourdon gauge) transmits (links) the operation in which the coiled part (Bourdon tube) "stretches or returns" according to pressure to the display needle directly with the internal gear, and the pressure is displayed.

Points to remember

(a)When measuring the water pressure of a fluid containing chlorine gas, a diaphragm pressure gauge is preferable.

(b) Diaphragm type is a type in which a membrane of a thin plate is placed between the measuring fluid and the indicator and the degree of bulging or recessing of the diaphragm by pressure is displayed as pressure.

(c) When the water pressure fluctuation is high, use a vibration resistant pressure gauge.

Bourdon Tube Type Diaphragm Type High-pressure Type

Figure 35 Type of mechanical pressure gauge

8.2 Self-recording water pressure gauge

(1) Principle of operation and application

This measuring instrument is a device that measures the hydraulic pressure of a fire hydrant by connecting to a hydraulic fitting of a fire hydrant with a dedicated connecting fitting (coupling) with a water pressure sensor. **(Refer to Figure 36)**

The recorder is a "pen" attached to an arm interlocking with expansion and contraction of a Bourdon tube, and it has both fixed and portable. Recording paper is preferred to be a recorder that can record for over 24 hours with built-in clock.

Used to record water pressure in the pipeline and record by plotting on a paper provided.

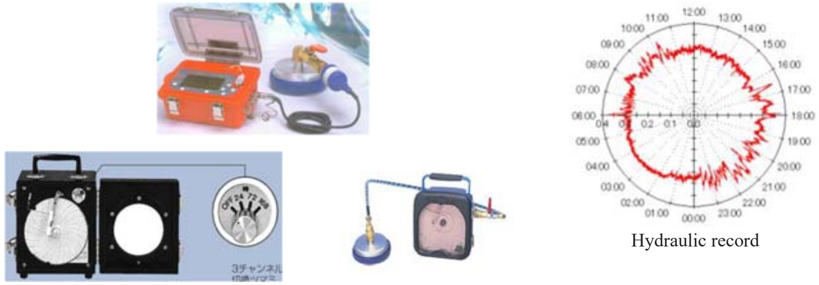


Figure 36 Example of Self-recording water pressure gauges

8.3. Water pressure data logger

(1) Principle of operation and application

The water pressure loggers make it easy to verify low water pressure complaints, locate water pressure spikes, and even provide water distribution system modelling data. The water pressure logger' large memory buffer will store over a huge amount of water pressure readings with user defined intervals from 1 per second to more than 1 per year.

You can easily capture momentary pressure spikes and dips with the water pressure logger's fast, 10 water pressure samples per second sampling mode. (Note: fast recording will reduce battery life.)

NOTE:
Used to record water pressure changes over an extended period

Pressure loggers have programmable start and stop alarm times makes it possible to synchronize multiple water pressure data loggers to start at the same time, delay starting until a present time, or limit the number of recordings during a day.

Pressure data loggers can record water pressure data just about anywhere you need it as most of them are harsh weather resistant.

Figure 37 Example of Water pressure data loggers

(2) Application

It is used in the monitoring and reporting of pressure levels for the following Potable Water Applications:

① District Metering Areas (DMA) and General pressure Logging

② Demand Managements Assessments

③ Customer Metering Diagnostics

④ Pressure mapping

(3) Procedure

① Software installation

Water Pressure Data Loggers are equipped with a standard USB data port and includes user friendly Windows software, which allows for easy setup, calibration, upload, and water pressure data transfer to a spreadsheet program on your laptop or desktop PC.

They includes a USB cable for communication between the water pressure logger and your computer.

NOTE:
Different loggers use different software the user should use the guidelines given to install software

② Data input (set up)

This involves configuring the logger using the installed software to facilitate data collection in the field. This includes Channels to be used, transducer data, logging intervals, start time, pressure units etc. Finally upload the logger.

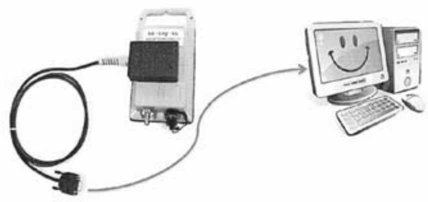


Figure 38 Example of Software installation

③ Data collection

The logger is water resistant but it is advisable to install it in chamber or box.
Use the pressure flex tubes connect the logger to the tapping point as described below.
Logging will start automatically as per set time.

(a) Connect the data logger to a computer using the infra-red cable and follow steps provided.

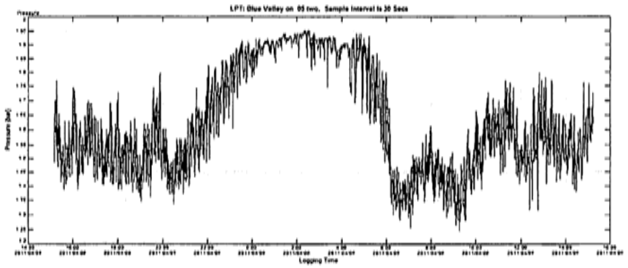


Figure-39 Example of Pressure graphs

(4) Maintenance

Check the batteries frequently and calibrate the equipment as per recommended logging hour's expiry.

(5) Other related equipment

① Under-pressure Pipe tapping machine
② Portable Meter tester
③ Portable Pressure tester
④ Pipe Thickness meter
⑤ Pressure Reducing/ Control valve
⑥ GPS
⑦ Residual chlorine meter
⑧ Conductivity meter

-END-

Internal Information

TEXTBOOK
FOR
JOINT TRAINING
（DRAFT）

"COMMERCIAL LOSSES MANAGEMENT"
R-1
August, 2018

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs

(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)

Mr. KIHARA KIBUCHI #9

Assisted by JICA KENYA

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Table of Contents

1. Objectives

① Understand concept of how to control commercial losses

② Understand concept of various methods to minimize commercial water losses

③ Discussion about pictures

2. Introduction

The general objectives of this manual are: -

(1) To promote an apparent loss (AL) reduction approach based on the reduction of four main AL components: -
- (a) Meter Under-Registration,
- (b) Illegal Consumption,
- (c) Meter Reading Errors and
- (d) Water Accounting Errors.

(2) To enable participants, identify and reduce commercial water losses in their utilities,

(3) To define the various types of apparent losses that can be classified within the four AL components,

(4) To give special emphasis on water under-registration and other metering issues,

(5) To review current methods and techniques to reduce the various components of apparent loss to a minimum achievable level.

(6) To give recommendations to establish a cost effective programme to reduce AL to economically, environmentally and socially acceptable level, and

(7) To give recommendations on how to get sustainable results on AL management.

3. Key words definition

3-1. Abbreviations, Acronyms & Definition of Terms

IWA	International Water Association (IWA)
NRW	Non-Revenue Water (NRW)
UAC	Unbilled Authorized Consumption (UAC) and Real Losses (RL)
RL	Real Losses (RL).
UAC	Unbilled authorized consumption (UAC).
WL	Water Losses (WL)
DMAs	District Metered Area

3-2 The International Water Balance

The Figure below shows the International Water Balance

<table>
<tr><td rowspan="9">System Input Volume (corrected for known errors)</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Commercial (Apparent) Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies and Data Handling Errors</td></tr>
<tr><td rowspan="3">Physical (Real) Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to Point of Customer Use</td></tr>
</table>

Figure 1: Recommended Water Balance with focus on Apparent Losses

3-3 Water Balance Definitions

In the following, all terms used in the Figure above are listed in hierarchical order – as one would read the water balance form from left to right. Some of the terms are self-explanatory but are still listed and briefly explained in order to having a complete list available.

(1) System Input Volume

The volume of treated water input to that part of the water supply system to which the water balance calculation relates.

(2) Authorized Consumption

The volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so by the water supplier, for residential, commercial and industrial purposes. It also includes water exported across operational boundaries.

Authorized consumption may include items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These may be billed or unbilled, metered or unmetered.

(3) Water Losses

The difference between System Input and Authorized Consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as transmission or distribution schemes, or individual zones. Water Losses consist of Physical (Real) Losses and Commercial (Apparent) Losses.

(4) Billed Authorized Consumption

Those components of Authorized Consumption which are billed and produce revenue (also known as Revenue Water). Equal to Billed Metered Consumption plus Billed Unmetered Consumption.

(5) Unbilled Authorized Consumption

Those components of Authorized Consumption which are legitimate but not billed and therefore do not produce revenue. Equal to Unbilled Metered Consumption plus Unbilled Unmetered Consumption.

(6) Commercial (Apparent) Losses

Includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading and billing), plus unauthorized consumption (theft or illegal use).

Note: Over-registration of customer meters, leads to under-estimation of Physical (Real) Losses.

Under-registration of customer meters, leads to over-estimation of Physical (Real) Losses.

(7) Physical (Real) Losses

Physical water losses from the pressurized system and the utility's storage tanks, up to the point of customer use. In metered systems this is the customer meter, in unmetered situations this is the first point of use (tap) within the property.

The annual volume lost through all types of leaks, breaks and overflows depends on frequencies, flow rates, and average duration of individual leaks, breaks and overflows.

Note: Although leakage, after the point of customer use, are excluded from the assessment of Physical Losses, this does not necessarily mean that they are not significant or worthy of attention for demand management purpose.

(8) Billed Metered Consumption

All metered consumption which is also billed. This includes all groups of customers such as domestic, commercial, industrial or institutional and also includes water transferred across operational boundaries (water exported) which is metered and billed.

(9) Billed Unmetered Consumption

All billed consumption which is calculated based on estimates or norms but is not metered. This might be a very small component in fully metered systems (for example billing based on estimates for the period a customer meter is out of order) but can be the key consumption component in systems without universal metering. This component might also include water transferred across operational boundaries (water exported) which is unmetered but billed.

(10) Unbilled Metered Consumption

Metered Consumption which is for any reason unbilled. This might for example include metered consumption by the utility itself or water provided to institutions free of charge, including water transferred across operational boundaries (water exported) which is metered but unbilled.

(11) Unbilled Unmetered Consumption

Any kind of Authorized Consumption which is neither billed nor metered. This component typically includes items such as fire fighting, flushing of mains and sewers, street cleaning, frost protection, etc. In a well run utility it is a small component which is very often substantially overestimated. Theoretically this might also include water transferred across operational boundaries (water exported) which is unmetered and unbilled – although this is an unlikely case.

(12) Unauthorized Consumption

Any unauthorized use of water. This may include illegal water withdrawal from hydrants (for example for construction purposes), illegal connections, bypasses to consumption meters or meter tampering.

(13) Customer Metering Inaccuracies and Data Handling Errors

Commercial (Apparent) Water Losses caused by customer meter inaccuracies and data handling errors in the meter reading and billing system.

(14) Leakage on Transmission and/or Distribution Mains

Water lost from leaks and breaks on transmission and distribution pipelines. These might either be small leaks which are still unreported (e.g. leaking joints) or large breaks which were reported and repaired but did leak for a certain period before that.

(15) Leakage and Overflows at Utility's Storage Tanks

Water lost from leaking storage tank structures or overflows of such tanks caused by e.g. operational or technical problems.

(16) Leakage on Service Connections up to point of Customer Metering

Water lost from leaks and breaks of service connections from (and including) the tapping point until the point of customer use. In metered systems this is the customer meter, in unmetered situations this is the first point of use (tap) within the property. Leakage on service connections might be reported breaks but will predominately be small leaks which do not surface and which run for long periods (often years).

(17) Revenue Water

Those components of Authorized Consumption which are billed and produce revenue (also known as Billed Authorized Consumption). Equal to Billed Metered Consumption plus Billed Unmetered Consumption.

(18) Non-Revenue Water

Those components of System Input which are not billed and do not produce revenue. Equal to Unbilled Authorized Consumption plus Physical (Real) and Commercial (Apparent) Water Losses.

4. Water Balance and Apparent Losses

4-1 Introduction

The need for water loss management or water loss reduction should be the aim of every water utility since it leads to improved economic, ecological efficiency and better service for customers. Before developing a water loss reduction strategy, decision-makers should be aware of the need to provide financial and personnel resources to reduce water losses. From the perspective of a water utility, the following objectives justify increased expenditure on water loss management:

4-2 Objectives of Water Loss Management

(1) Operating cost efficiency:

A well-maintained water distribution system will require fewer repairs, lower production costs and prevent compensation payments.

(2) Capital cost efficiency:

A lack of maintenance and intermittent operation increase wear and tear on pipes, valves and meters. Improved supply will extend the service life of the system components and lead to lower fixed costs for the water utility in the long run.

(3) Improved metering and billing:

Fewer leaks and an improved supply situation may also have positive effects on apparent water losses because air inside the distribution system can cause metering errors.

(4) Reduced health risks:

Sewage and other pollutants can infiltrate the pipe system through leaks and trigger water-borne diseases in low-pressure systems or in the case of intermittent operation.

(5) Reduced ecological stress:

Finally, the development of a water loss reduction strategy makes sense from an ecological point of view. In the case of scarce or over-exploited water resources, water losses should be reduced to decrease the stress on these resources.

(6) Increased security of supply:

A well-maintained system with fewer leaks and bursts will increase the supply guarantee.

(7) Less infrastructural damages:

Leakage might create voids below ground which can lead roads and buildings to collapse.

(8) Reduced loads on sewers:

Infiltration of water lost to sewers places an additional load on sewer pipes and wastewater treatment plants.

(9) Improved consumer satisfaction:

In addition to poor water quality, inadequate quantity and health risks, leakages also decrease the pressure at customers’ appliances. Enhancing the supply service will improve customer satisfaction and willingness to pay.

(10) Publicity and willingness to pay:

Fewer bursts, increased security of supply and hygienic conditions will enhance the public’s perception of the water utility. This may also positively affect the consumers’ willingness to pay.

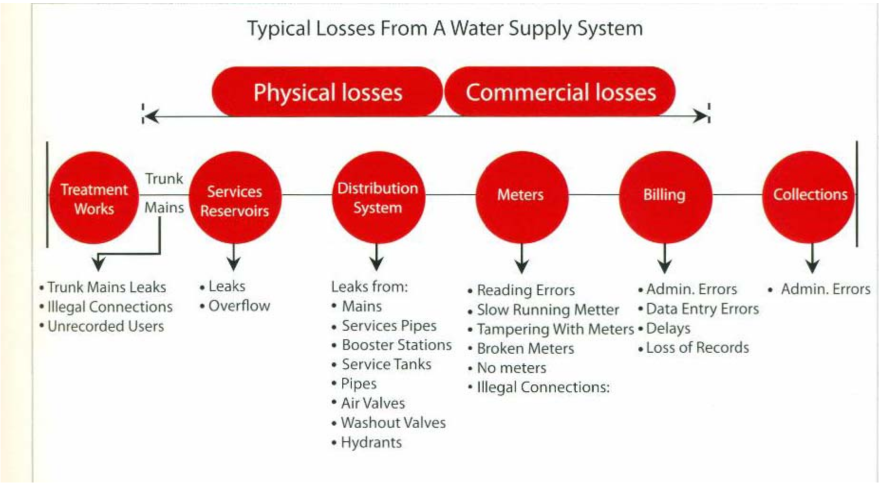


Figure 2: Typical Losses from a Water Supply System

4-3 Reasons for using the Water Balance format in Figure 1

The differences in the four Apparent Losses components in Figure 1 allow for unmetered customers, and a breakdown of customer metering inaccuracies into the loss due to the water meters themselves and the management of the water meters (such as poor installation or poor meter reading practices). They can be summarized as: -

- **Unauthorized consumption** refers to unregistered service connections and various types of fraud on the registered service connections (including public equipment).

- **Customer Metering Errors** refers to the errors generated by the water meters themselves but not by the management of the water meters
- **Errors in Estimates of unmetered consumption** refers to the errors generated by the estimates of unmetered consumption. This point is very important in the case of systems that are not metered or not fully metered.
- **Errors throughout the Data Acquisition Process** refers to the errors that may be generated at the various stage of the data acquisition process such as data capture, data transmittal, data processing, data manipulation, etc.

4-4 Commercially-Oriented Water Balance

The IWA water balance in Figure 1 is "technically-oriented" as it is based on the continuity of water flow (i.e. mass balance), but not "commercially-oriented" (i.e. taking into account the value or cost of the water). For instance, one point that is not taken into account is that the volume of water that is billed and not paid by the customers could be considered as a component of non-revenue water.
This definition may lead to an alternative definition of NRW. NRW would consist of the four components: **Real Losses, Apparent Losses, Unbilled Authorized Consumption and Unpaid Bills.**

4-5 Focusing on Unbilled Authorized Consumption (UAC)

Unbilled authorized consumption (UAC) is an NRW component but not a water loss component. However, it is not recommended to calculate the water balance without a good understanding and evaluation of the unbilled authorized consumption. UAC may be classified into two categories:

- Water used for servicing or field operation: any Water Utility has to use water for its own operational needs.

- Water provided free of charge: The Water Utility may provide water free of charge to various consumers or categories of customers: some administrative or religious premises, its own employees, etc. Such practice may be based either on habits and customs or on legal provisions. Whatever the causes, it needs to be listed and quantified.

Consumption free of charge is a concept that may be quite different according to the country, its law, its tradition or its culture. However, it is also important to list and quantify it in order to design the water balance.

Table 1: Examples of Unbilled Authorized Consumption (UAC)

Unbilled Authorized Consumption				Selected Examples
1		2	3	4
Servicing (Or Field Operation)		Tank Cleaning	Unmetered	Regular Cleaning of Service Reservoirs
		Pipe Cleaning	Unmetered	Flushing of Pipes to Improve Water Quality in Distribution 'Dead Ends'
		Discharge	Unmetered	
		Hydrant Tests	Unmetered	Flow and Pressure Test at Hydrants
		Water Treatment Devices	Metered/ Unmetered	Backwashing of Filters
		Others	Metered/ Unmetered	Fire Fighting
Consumption free of Charge		Utility Staff	Metered/ Unmetered	Municipal/Water Authority Housing
		Admin. Customers	Metered/ Unmetered	Government Buildings
		Others	Metered/ Unmetered	

4.6. Focusing on Apparent Losses (AL)

Apparent losses are classified according to the following categories: **unauthorized consumption, customer metering errors, errors in estimates of unmetered consumption,** and **errors linked to the data acquisition process**. Table 2 lists and describes different causes that may impact the level of apparent loss in each category
It is important to note that some components of apparent losses can be either positive or negative. For instance, a water meter may over register in some specific conditions; similarly, unmetered authorized consumption may be over-estimated or under-estimated. This list clearly shows that measurement is the core issue in terms of apparent losses. Defective measurement generates apparent losses: -

(1) Meter error relates to water meter precision and uncertainty
(2) Poor estimate of unmetered consumption relates to the lack of water meter on the service connections
(3) Unauthorized consumption is generally not metered
(4) Data handling errors are due to measurement errors at the various stage of the data acquisition process: data capture, data collection; data transmittance, data processing and manipulation.

Therefore, the topic of the reliability of the measurement is essential for the establishment of water balances.

Table 2: Apparent Losses (AL): Components and Causes

Apparent Losses			
1	2	3	Description
Unauthorized consumption	Registered customers	Meter by-pass	Unauthorized parallel, unmetered flow of water alongside the meter.
		Additional Unregistered connections	Case of double connection: one is registered, the other is not
		Disconnected customers illegally/unauthorized reconnected	Very frequent source of apparent loss in case of poor customer management: specially when disconnected connection are never checked
		Non-active customers illegally/unauthorized reconnected	As above
	Unregistered customers	Unregistered (illegal) connection	Also called illegal (or clandestine) connection
		Unregistered consumption in low income areas	
	Network equipment	Water theft from hydrants or other equipment	
Customer Metering Errors	Meter errors	Intrinsic errors	Error of indication of a water meter determined under reference conditions (ISO 4064: 2005)
		Aging	Change in the performance characteristics of the meter, due to the historic operational conditions of the meter.
		Inappropriate meter installation	Installation of a meter outside the limits of the reference conditions of the meter's pattern approval and/or the installation requirements stipulated by the manufacturer
		Inappropriate sizing	Incorrect matching of meter's specified flow range with the range of water demands associated with the particular user
		Impact of customer's in-house installation	Effect of the downstream-connected installation on the error of the metered volume passed through the meter. (E.g. storage tank etc.).
	Meter* management	Meter out of operation	Stopped meters
		Errors in meter reading	Error in reading of the meter display: incorrect reading of the value on the meter display.
		Invented meter reading	Intentionally incorrect reading of the value on the meter display.
Errors in estimates of unmetered consumption	Unmetered service connections	Misestimate of current unmetered connections	
	Meters out of operation	Misestimate in the case of meter out of operation	
Errors linked to Data Acquisition Process (data handling errors)	Data Capture	Measurement errors*	Related to the selection, sizing and calibration of meters
	Data Collection and Transmittance	Reading and signal path errors	Errors associated with the conversion of the data at various points along the pathway it is required to travel. Water meter lag
	Data Processing	Statistical errors	Errors associated with the lack of data validation processes
	Data Manipulation	Understanding errors	Misinterpretation of the data and its true meaning
	Application errors	Application errors	Incorrect application of the data and not using statistically representative samples.

(*) these errors may be also registered as errors linked to data acquisition system or handling errors

5. Reducing Apparent (Commercial) Losses

The elements of Apparent (commercial) losses are: -

(1) Customer meter inaccuracies

(2) Unauthorized consumption; illegal connections, theft and fraud

(3) Customer data base (accounting) errors

(4) Data collection (meter reading) and data transfer errors.

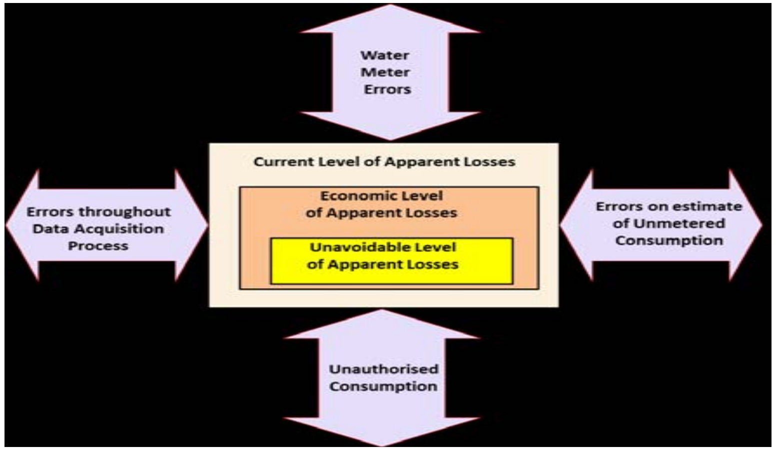


Figure 3: Cause of Losses

6. Controlling Apparent / Non-physical / Commercial Losses

6-1 Customer Metering Policy, Dealing with Inaccuracies

Customer Metering is generally a "Win/Win "Situation… since it: -

(1) Encourages sensible of water use

(2) Is essential for reducing water consumption through demand management

(3) Fairness: customers pay for true consumption

(4) Generates vital information for use by Wsps.

…. But not necessarily so in Every Situation –Questions are: -

(5) Cost effectiveness if tariffs are very low?

(6) Cost of maintenance and replacement?

(7) Can we afford to buy, maintain and read meters for all customers?

(8) Corrupt meter readers?

(9) Multi-story buildings: where to meter and whom to bill?

….. But don't give up Control: Some General Principles

(10) Introduce metering in stages, meter large customers first

(11) Don't rely on "normed" or "assumed" per capita consumption for billing purposes

(12) Sample customer groups –one month, one week -to get a better idea on consumption and establish realistic figures for billing

(13) Meter districts, apartment blocks, and poor settlements (as a whole)

(14) The Many Causes of Meter Inaccuracies

- Wrong installation layout
- Poor materials, improper installation
- Poor water quality, intermittent supply
- Unsuitable size, meter flow profile
- Inappropriate class and type of meter
- Spinning or jetting
- Roof Tanks
- Lack of proper maintenance/replacement.
- Reduction of Commercial Losses
- Focusing on reducing commercial losses can reduce NRW ratio to as low as about 30%,

7. Meter Errors

- Inspect of Customer Water Meter its operation, registration, location, etc.

- Install customer water meters to all customers (Gradually move towards 100% installation).

- Replace all aged and non-functioning meters with new ones

7-1 How to address Customer Meter Inaccuracy

Inaccurate meters tend to under-register water consumption—leading to reduced sales and reduced revenue. Rarely do meters over-register consumption. Utilities should focus initially on large customers, such as industrial or commercial users, since they consume a larger volume of water and often pay a higher tariff. Using data from accurate meters to bill customers, rather than charging them based on an assumed per capita basis, ensures that customers are charged according to their actual consumption and encourages them to preserve water. The following are common problems with customer meter accuracies and solutions for utilities.

(1) Installing Meters Properly

Meters should be installed properly according to the manufacturer's specifications. For example, some meters require a specific straight length of pipe upstream and downstream of the meter. Therefore, a standard meter stand should be designed and constructed onsite. Utilities should purchase the meters on the customers' behalf, so that only standard, high quality meters are used.

Meters should also be installed where meter readers can easily read them, and where it is easy to identify each property's meter. In addition, the management and staff responsible for meter installations should be trained on proper handling of meters.

(2) Monitoring Water Quality

Poor water quality—resulting from poor raw water, inadequate treatment processes, or dirt infiltration due to pipe shutdowns—may cause sediments to form in the pipes. These sediments can also build up on the internal parts of meters, especially mechanical meters. The buildup in sediment affects the meter's accuracy by increasing friction losses, which causes the meter to run more slowly and thus under-register consumption. Utilities must regularly monitor water quality and clean mechanical meters to minimize sediment levels and promote accurate meter measurements.

(3) Meter servicing this is essential, especially in areas of poor water quality. The accuracy of mechanical meters changes over time as the mechanical bearings wear down, causing friction to increase and thus the meters to under-register. These changes will occur over a number of years,

depending on the quality of the meter. Testing a range of meter brands and ages with a calibrated meter test bench will determine which meters should be replaced.

(4) Monitoring Intermittent Water Supply

Where water supply is intermittent, i.e. the customer receives water only a few hours a day. Customer meters will register a certain volume of air when the water supply is first turned on. In addition, the sudden large increase in pressure can damage the meter's components. Intermittent supply should be avoided for a number of reasons, including the negative impact on customer meter accuracy.

(5) Sizing Meters Properly

Customer meters work within a defined flow range, with the maximum and minimum flows specified by each manufacturer. Large meters will not register low flows when the flow rate is lower than the specified minimum. Therefore, utilities should conduct customer surveys to understand the nature of each customer's water demand and their likely consumption. This information helps to determine the proper meter size for households and businesses. For customers with a high demand, checking the flow pattern and the newly installed meter verifies whether the correct meter size is used.

Problems with low flows can occur when a storage tank, with the water flow controlled by a ball or float valve, is installed on the customer's premises. These valves operate by slowly closing as the water level in the tank rises, which has the effect of reducing the flow through the meter, often below the minimum flow specification. This problem is compounded even further if the size of the storage tank is large in comparison to the customer's consumption because the ball or float valve will never fully open and the flow through the meter will be continually low.

(6) Maintaining and Replacing Meters Properly

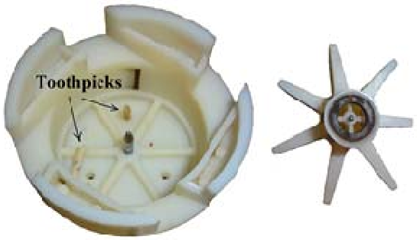
All meters should be installed above ground and located where they can be audited easily, including by the meter readers during their regular rounds. The utility should replace the meters systematically, beginning with the oldest meters and those in the worst condition. Poor maintenance will not only encourage inaccuracy but may shorten the life span of the meter. A scheduled maintenance and replacement programme should be in place to manage this problem.

Meter servicing is crucial in areas of poor water quality. The accuracy of mechanical meters changes over time as the mechanical bearings wear down, causing friction to increase and thus the meters to under-register. These changes will occur over a number of years, depending on the quality of meter. The water utility should regularly test a sample of its customer meters, including a range of meter brands and ages, using a calibrated meter test bench. This testing will determine the optimum age at which customer meters should be replaced.

(7) Addressing Meter Tampering

Although water tariffs in Kenya are relatively low, customers still tamper with their meters to lower the measured volume. Customers may insert pins or other objects into the meter to disturb its moving parts or affect the readings of metal meters by attaching a strong magnet to it. Most reputable meter manufacturers now produce meters that are extremely tamper resistant, with non-metallic parts, strong clear plastic windows, and impenetrable casings. Although these meters may cost a bit more, reduced tampering helps to reduce commercial water losses.

For properties with older meters that are not as tamper-resistant, utility managers should conduct customer surveys to assess expected water usage according to the number of household occupants or the nature of businesses in commercial areas. A comparison of expected and actual water use will highlight cases of likely meter tampering.



7-2 How to Minimize Meter Under- Registration.

The service provider can take the following measures to prevent or minimize meter under- registration: -

① Choose meters that are known for quality and durability

② Choose the right size meter for the customer flow: meters that are too large may not register all of the flow

③ Install meters according to manufacturer's specifications in convenient locations

④ Regularly monitor water quality and clean mechanical meters to promote accurate meter measurements

⑤ Avoid intermittent supply

⑥ Replace meters systematically, beginning with the oldest meters and those in the worst condition.

The initial focus should be on large customers, such as industrial or commercial users who will likely prove beneficial since they consume a larger volume of water and often pay a higher tariff.

(1) Unauthorized Consumption

Unauthorized consumption includes illegal connections, meter bypassing, illegal use of hydrants, and poor billing collection systems. The following paragraphs describe common problems and possible solutions.

(2) How to find and Reduce Illegal Connections

Illegal connections involve the physical installation of a connection to water distribution pipelines without the knowledge and approval of the water utility. Illegal connections can occur during the installation of a new supply connection, or sometimes the customer's supply is cut off after non-payment and the customer cannot afford, or does not want to pay, to be reconnected.

During customer awareness programmes, customers should be encouraged to report illegal connections, and regulations should be in place to penalize the water thieves. Meter readers should also report cases of direct connections without accompanying meters that they see during their rounds.

(3) How to Tackle Meter Bypassing

Some customers try to reduce their water bills by using a meter bypass, which is an additional pipe installed around the meter. This bypass pipe is often buried and very difficult to detect. This type of unauthorized consumption is usually committed by industrial and commercial premises, where only a small volume of the consumption goes through the meter and the rest through the bypass pipe. Because large customers tend to steal large volumes of water, the discrepancy will show up when the utility conducts a flow balance analysis. The utility should then undertake customer surveys and leakage step tests to determine where the missing flow occurs.

(4) Preventing Illegal Use of Fire Hydrants

Although the only legal use of fire hydrants is for firefighting, some use them illegally to fill tankers (normally at night) or to provide water supply to construction sites. The utility staff can detect these flows, often high volume over a short period of time, through appropriate flow measurements at DMA meters. Such high flows are not only incidences of water theft, but also a detriment to the pipe network and water quality, which affects the service to the customer.

Through customer awareness programs, the utility staff should encourage customers to report cases of illegal uses of fire hydrants. In addition, the utility manager needs to cooperate with relevant local agencies or departments to identify owners of tankers suspected of drawing water illegally and without proper permission. Developing and enforcing regulations to penalize water thieves together with local agencies will also deter unauthorized consumption.

7-3 How to Reduce Water Theft

People steal water when they make an illegal connection to the network or tamper with the meter. The techniques one can use in order to reduce water theft include: -

① Use tamper resistant meters (see Meter Reading Errors) or install seals that indicate tampering has occurred.

② Remove meter by-passes. A bypass pipe is often buried and very difficult to detect. This type of unauthorized consumption is usually committed by industrial and commercial premises, where only a small volume of the consumption goes through the meter and the rest through the bypass pipe. The discrepancy will show up when the utility conducts a flow balance analysis.

③ Find and reduce illegal connections. They can occur during the installation of a new supply connection, or sometimes the customer's supply is cut off after non-payment he or she cannot afford, or does not want to pay, to be reconnected.

④ Prevent illegal use of fire hydrants. Some use them illegally to fill tankers (normally at night) or to provide water supply to construction sites. Encourage customers to report cases of illegal uses of fire hydrants.

7-4 How to Avoiding Corrupt Meter Readers

Corrupt meter readers can significantly impact a utility's monthly billed consumption. For instance, the same meter reader who walks the same route for an extended period of time, thus becoming familiar with the customers and their monthly billed consumption, may collude with those customers to record lower meter readings in exchange for a monetary incentive. To reduce this risk, the utility manager needs to rotate meter readers to different routes on a regular basis.

8. Actively Checking the Customer Billing System

Sometimes connections are made legally, but the billing department is not notified of the new connection; therefore, the customer is never billed. These unregistered customers can be detected during the regular meter reading cycle when diligent meter readers find meters that are not in their reading book. However, this process may not identify all of the errors in the billing system.

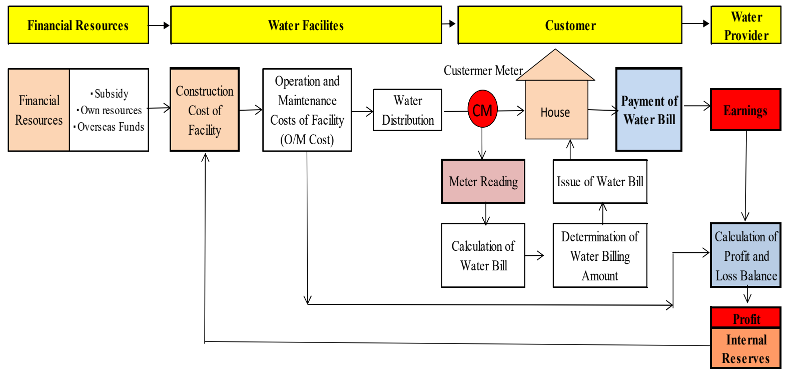


Figure 4: Shows the steps in the billing process

Conducting a complete customer survey within each DMA, whereby utility representatives visit every property in the DMA—whether or not they are recorded in the billing system—is the best method of comprehensively identifying billing system errors. The survey should include the following information: property address, name of owner, and meter make and number etc. The representative should also conduct a meter test to ensure that the accurate flow is recorded.

For metered areas, utilities should focus on large users by encouraging good customer relationships through frequent visits. Checking large customers' accounts monthly will help detect anomalies, which may be due to water theft. In areas of suspected high commercial losses, temporary DMAs can be established to analyses flows through standard monitoring activities, such as step testing and flow balancing, to pinpoint problematic areas.

8-1 Meter Reading Errors

Errors can be easily introduced through negligence, aging meters, or even corruption during the process of reading the meters and billing customers. Incompetent or inexperienced meter readers may read the meter incorrectly or make simple errors, such as placing a decimal in the wrong place. Dirty dials, faulty meters, and jammed meters can also contribute to meter reading errors.

The meter readers should immediately report any observed problems, and the maintenance team should take action to remedy the problem immediately. If remedial action is too slow, meter readers may become demoralized and less inclined to report problems.

Because meter readers are the utility's frontline in liaising with customers, their activities have an immediate impact on cash flow. Utility managers should therefore invest in training and motivating their meter readers to record and report information effectively and efficiently. The manager should also establish systems and procedures to prevent meter reading errors by improving its meter reading and billing processes through greater supervision of meter readers, implementation of rotating reading routes, and frequent spot checks.

The success of meter reading, billing and collecting revenues depends on accuracy, check & balances and diligence. The goal is:

① to ensure that all people who use water are connected and in the utility's information system,
② that usage is metered accurately,
③ that the meter readings result in accurate bills to customers and
④ That the billed amounts are collected on a timely basis.

At any step in this process, inaccuracies or errors will result in NRW.

8-2 How to Improve Accuracy and Eliminate Errors:

a. Conduct customer surveys to make sure that every user is a registered customer and that the utility's records are accurate as to address, name of owner, customer number and meter information.
b. Analyze flows in areas of suspected high commercial losses, in order to pinpoint problem areas.
c. Compare the usage metered to the usage billed for each billing cycle.
d. Ensure that all amounts that are billed are collected.

e. Arrange the functions (metering, billing and collection) so that one person is not responsible for all of them.

NOTE:
A **robust billing database** is one of the key elements of minimizing accounting errors. State- of-the-art billing software has built-in analysis functions that can identify potential data handling errors, zero readings, and report them for verification

(1) Reading Meters

Meter readers are responsible for reading meters and sending the data to the billing officer, who manages a customer's account and issues bills. They are also responsible for reporting on the status of the meters. The following diagram sows the procedure followed in meter reading: -

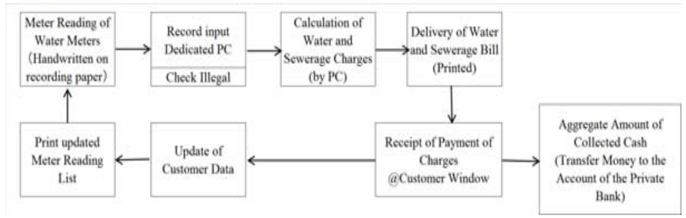


Figure 5: Procedure of How to Issue Billing

(2) Right to enter property

A provider has the right to enter a customer's property to read the meter without prior notice or consent. However, some customers are frequently absent, keep fierce dogs, lock their gates making the service provider use estimates for billing purposes.

(3) Estimated and actual reads

The water distributor for the area is responsible for reading the meter and sending the meter data to the retailer. If the meter reader is not able to access the meter (e.g. due to a locked gate, or a dog in the yard), the distributor will provide the retailer with an 'estimated' read, usually based on the customer's past usage.

(4) Self reads

After a customer receives an account based on an estimated reading, a retailer may agree to accept a customer's reading of their own meter. This will be considered an estimated read. Tis may cause problems on accuracy of readings.

9. Examples of common water rate complaints

Complaints about water charges are excessive charges for water consumption.

The cause may be a final evaluation error of the amount of water used, a malfunction of the customer water meters, and/or water leak occurring in the residential area.

The following describes the leaked / unidentified water generated in the residential area.

The amount of water measured by the customer mater are;

(1) Household water actually used

(2) Household leaked water

(3) Unknown consumption (theft losses)

Among them, leaked water and unknown water generated at home are the amount of useless water generated continuously, and each household pays for water charges.

9.1 Common cause of occurrences in residential area

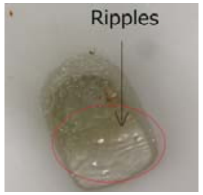
Below are some typical examples of causes.

(1) Continuously water supply to the flush tank of the toilet

Before flushing, check if there is a water ripple in the toilet, if a ripple occurs, repair the float valve failure.

(2) Malfunction of faucet valves in the house and yard

If the water drops still flow after closing the faucet valve, repair the damaged packing / damaged / cap loosed.



(3) Forgetting to close the faucet valve

(4) Water leakage and unknown consumption (theft losses)

If all the faucets in the home are "closed" and the water meter pilot is still rotating, it is suspected that leaked or unknown water will occur.

(a) Occurrence phenomenon of damaged water supply pipe

-The soil in the garden is always moist.

-The plants are partially growing.

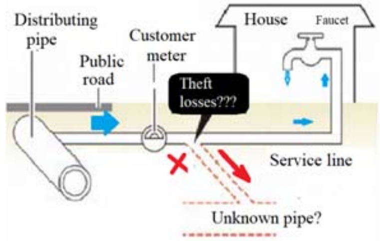
-There is a puddle.

-The floor / base of the building is constantly damp.

(b) Occurrence of unknown consumption (theft losses)

If the pilot continues to rotate even if there is no water leakage, unknown water may have been generated.

- Ask the Waterworks Bureau for investigation.



Source: Mainichi Newspaper 2019−05-25 Japan

Figure 6: Image flowing into unknown water pipe line

10. Data Handling and Accounting Errors

The typical method of data handling and billing requires a meter reader to visit each property and read

the customer meter. The data is then recorded by hand on a form, taken back to the office, given to the billing department, and typed into the billing system. A bill is then printed and mailed to the customer. In this scenario, a variety of errors may occur at the different stages: the meter reader writes down incorrect data; the billing department transfers incorrect data into the billing system; or the bill is sent to the wrong address.

A robust billing database is one of the key elements of minimizing these errors and should be the initial purchase of any water utility striving to improve its revenues. The latest billing software has built-in analysis functions that can identify potential data handling errors and report them for verification. In addition, billing software will report monthly estimate readings and zero reads, both of which may indicate a problem with the customer's meter. Site visits will help identify meters needing replacement.

Training of meter readers promotes diligence, good customer meter maintenance, and decreased meter reading errors. If financially viable, utilities should consider electronic meter-reading devices, which reduce data handling errors to a minimum since all data transfers to the billing system are done electronically.

11. Key Messages

1. Commercial losses occur mostly through faulty or tampered meters and through errors committed during meter reading or processing in the billing system.
2. Meters are essential tools for measuring water consumption and should be as accurate as possible.
3. Coordination from the public and relevant local authorities is required to overcome illegal uses of water.
4. Training meter readers, staff, and crews is a continuous process to ensure competent customer service.
5. Investing in high quality meters and a robust billing system can result in higher returns.

12. Learned lessons

What are your comments from the pictures below?

(1) Residents secure water for daily life 	① Stealing water? ② Illegality or legality? ③ Effective use of water ④ What is the method of investigating whether or not it is stolen? ⑤ Countermeasure? ⑥ Other comments?
(2) Booster pumps in service line 	① illegal connection? ② If you suspect illegal connections, what kind of investigation is necessary? ③ Countermeasure? ④ What is the impact of illegal connections? ⑤ Other comments?

-END-

Internal Information

TEXTBOOK

FOR

JOINT TRAINING

(DRAFT)

"HOW TO IMPROVE BILLING IN WATER UTILITIES"

R-1

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KENYA WATER INSTITUTE AND LEAD WSPs

(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)

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Assisted by JICA KENYA

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1. Objectives (out-put)

① Understand objectives of billing system

② Understand importance of revenue collection

③ Understand how to avoid wrong meter reading

2. Introduction

Effective billing and collection systems are a critical components for ensuring the viability of a service provider. Improving these has an immediate impact on the revenue streams of a service provider that can, in turn, help in improving services.

However, while effective billing and collection practices depend on many internal factors like customer databases, the extent of metered and unmetered service provision, tariff and billing structures, delivery of bills, and facilities for customer payments, the institutional arrangements under which service providers operate and provide services determine whether such practices will remain sustainable in the long term.

Efficient billing and collection practices can set incentives for the provider to effectively charge and collect water bills.

An effective billing and collection system encourages commercial and operational efficiencies which aids in the expansion and delivery of improved, reliable, and sustainable services.

3. Key Words Definition

Billing may refer to: The process of sending an invoice (a bill) to customers for goods or services.

It’s the process of sending people bills asking them to pay money owed:

The total amount of the cost of goods or services billed to customer, usually covering purchases mad e or services rendered within a specified period of time.

Billing	The process of sending an invoice (a bill) to customers for goods or services. It’s the process of sending people bills asking them to pay money owed: The total amount of the cost of goods or services billed to customer, usually covering purcha ses made or services rendered within a specified period of time.
Revenue	The income generated from sale of goods or services, or any other use of capital or assets, associated with the main operations of an organization before any costs or expenses are deducted. Revenue is shown usually as the top item in an income (profit and loss) statement from which all charges, costs, and expenses are subtracted to arrive at net income.

4. Objective of Billing System

The aims to a billing system create or develop a system that is capable and reliable in the whole transaction flow such as tracking, retrieving and storing data in an appropriate way. In particular it aims to:

1. Provide a database that will store information.
2. To identify the actions that may be taken with respect to billing and collection of water charges for services provided to customers.
3. Develop a system that will lessen process delay in terms of releasing receipts and customer bill.
4. Provide summary reports of daily and monthly sales including revenue reports.
5. To prescribe billing and accounting procedures for the utility commercial activities
6. Design system that could accommodate billing transactions from customers.
7. Provide security of two levels of users

5. Why is Effective Billing and Collection Necessary?

The basic aim of the performance improvement in utilities is to help water utilities and service providers understand and adopt mechanisms that promote cost recovery, sustainable revenue strategies, achieve financial viability and sustainable improved services.

5.1 About the Billing Process

The typical billing process includes accumulating costs, creating and printing invoices, and recording journal entries for income and receivables. When you perform the billing process using the Contract Billing system, you can:-

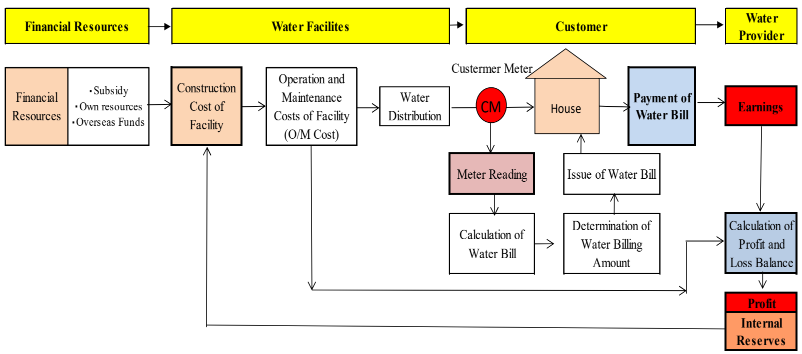


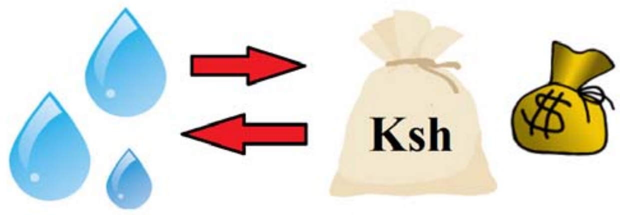
Figure 1: Billing Process

NOTE:

Why is collection of water REVENUE necessity?

The water service work is managed with the money which the customer paid.

WATER is MONEY TREES !



- Accumulate billable costs from multiple systems, such as Accounts Payable, Equipment/Plant Management, and Payroll, without re-entering the cost information into the billing system
- Calculate markup amounts and taxes based on a hierarchy of multiple user defined rules
- Revise work-file transactions for T&M costs, including components
- Calculate the billing amounts at the time you create invoices
- Facilitate immediate billing upon entering the costs into the system
- Print invoices to customer specifications
- Automatically create and record the journal entries for the Accounts Receivable and General
- Accounting systems that result from billing
- The billing process consists of the following tasks:
- Accumulating costs
- Reviewing the work-file
- Revising the work-file
- Working with the work-file history
- Generating invoices automatically
- Working with invoices
- Creating invoices manually
- Printing invoices
- Working with A/R and G/L entries
- Working with final invoices

6. Billing and Revenue Strategies

A strategy involves using all the forces of a company to execute approved plans as efficiently and as effectively as possible. It's a plan of action intended to accomplish a specific goal.

Water Companies must improve their billing and collection practices if they are to become financially viable, sustainable and deliver quality and standard services. Each will need to focus on specific steps for it to achieve service and revenue improvements. They should adopt the principles and components that govern an efficient billing and revenue collection system. Some of these are:

1. Customer databases,
2. Levels of metered and un-metered service provision,
3. Billing structures and cycles,
4. Practices and delivery,
5. Staff capacity and involvement,
6. Efficiency in billing and collection, and facilities for customer payments.

6.1 Strategies that Determine Effective Billing and Revenue Collection

(1) Monthly Billing System Based on a Volumetric Structure
(2) Computerized System of Billing
(3) 100 Percent Customer Metering, 100 Percent Billing and 100 Percent revenue collection
(4) Prepaid Meters and Automatic Meter Reading
(5) Outsourcing the Billing and Collection Function
(6) Incentives for Meter Readers
(7) Regular and On-Time Payments
(8) Resolving Customer Grievances
(9) Delinquent / erroneous Accounts
(10) Managing Debt

6.2 Monthly Billing System Based on a Volumetric Structure

An effective billing system must have a billing cycle that bills customers on a monthly basis. In so doing, companies must give adequate details to ensure appropriate and structured monthly billing.

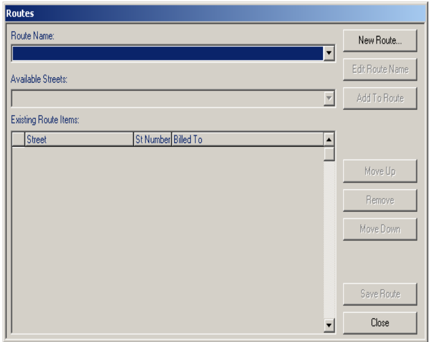
The billing system should be based on a volumetric structure. This ensures that customers are billed for the water that they have consumed. Volumetric charges are based on:

(1) A uniform volumetric charge;
(2) A rising block tariff where the unit charge is specified over a range of water use for a specific customers and then increases as water consumption increases; and
(3) An increasing linear tariff where the unit charge increases linearly as water usage increases.

All volumetric charging are based on meter readings. This requires that customers have metered connections. Therefore companies must make sure that the meters work properly and are read on a periodic basis. Billing practices are based on different pricing mechanisms:

(1) Flat rate charging,
(2) Volumetric charging or flat and volumetric-based charging.
(3) Water service providers can have different billing cycles (bi-monthly, monthly, quarterly or yearly).

6-3 Computerized System of Billing



A computerized system of billing and an updated and complete customer database is a must for a water company seeking to maintain high billing efficiency. This is done by ensuring that customer databases are updated and computerized, through vigorous accounting and recordkeeping. A computerized system customer database allows:-

(1) Generation of reliable data that can inform the decision-making process of the water company,
(2) The utility to track customer records by its respective management unit (that is, by zone, ward, district, etc.).

(3) Monitor and track exceptions in billing records.

(4) Tracking billing exceptions allows for a thorough investigation for the reasons behind the exception leading to redressal of the situation.

6-4. 100 Percent Customer Metering and 100 Percent Billing

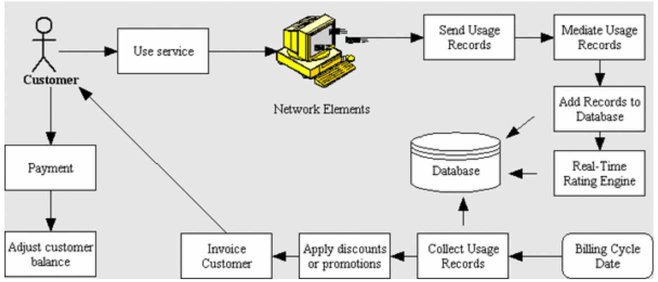


Figure 2: Billing Network System

Volumetric charging is effective if all connections are metered and all meters are in good working condition and working properly. This means the billed invoices are based on metered consumption. An effective metering practice depends on:

(1) Customers who cannot cheat the system by tampering or damaging the meters,

(2) Repairs and replacement policy of the utility,

(3) Timely identification of faulty meters and

(4) Installation of meters even in poor and low-income settlements etc.

6-4-1 Service provider's needs to check on:

(1) The accuracy of meters on a systematic basis so that there are no problems.

(2) The bill whether the meter is in working condition or its defective.

6-4-2 The service provider must:

(1) Authorize a single point from where customers can purchase their meters

(2) Provide the meters themselves, so that a standardized meter is authorized by the service provider

(3) Have a meter checking, maintenance, and repair policy in place so that any faults as identified by meter readers at the time of meter reading can be reported and addressed.

(4) A responsible staff who could single out problem cases, especially those of incorrect consumption units recorded (data entered could indicate unrealistic consumption units such as negative units or excessive figures).

(5) Set in place appropriate incentives such that meter readers actually read the meter and do not cheat the system by reporting average consumption figures at the time of meter reading.

7. Introduction of advanced technologies

7-1 Prepaid Meters

The basic idea behind the use of prepaid meters is to facilitate those who may be denied access to water because they cannot pay upfront. It gives the concerned persons the flexibility to avail of water services even if they have not made an upfront connection payment for a fixed water connection.

◆ NOTE:
For more information, refer to "How to manage customer meters"

7-2 Automatic Meter Reading

Automatic meter reading is a technology that allows for automatic collection of data from the water meter and transfers it to a central database for billing.

For Nairobi Water, handheld data loggers enable meter readers to record readings easily.

They are preloaded with set information, based on which the water meter data needs to be collected. Data loggers generate alerts for incorrect entries or anomalies. For example, in case meter readers enter erroneous data or if they do not read the meter but continues to generate readings. The data loggers give meter readers two options for generating bills:

(1) Spot billing, where they could generate bills on the spot and hand them over to the customers once the meter readings are entered in the data loggers.

(2) Batch billing, where meter readers can collect the required data and, at the end of the day download the data in their office computers. In the office, master database gets updated and bills are generated according to the billing cycle.

Innovations of using data loggers could prevent malpractices / corruption and, help confirm with the customers all bill details on the spot.

8. Outsourcing the Billing and Collection Function

Some water companies are using improved billing technologies by outsourcing the entire billing and collection process to companies with proven expertise in such fields as illustrated by Nairobi Water partnering with Safari Com, Equity bank, Post office etc. Benefits of outsourcing are:

(1) The experts provide a fully managed service starting from bill generation and payment collection, to credit and debt management,

(2) The experts use improved technology, systems, and processes to realize improvements in billing and collection,

(3) Collections from customers are also monitored regularly by tracking revenue indicators like gain in net cash generation, new-billed revenue, costs to undertake billing and collection etc.

(4) The time saved and a reduced need for in-house systems and staff for billing practices.

(5) Outsourcing billing and collection is cost-effective since the system of competitive tendering gives the job to the most efficient and specialized providers.

(6) It also leads to better cost control since the provider knows the exact price of the outsourced services and such services can be monitored more strictly.

9. Incentives for Meter Readers

Water companies need to encourage efficiency in billing practices. This can be achieved by developing a system that gives incentives to meter readers.

If there is a perceived risk of meter readers engaging in malpractices, such as colluding with customers and forging consumption details in the areas that they are operating, they could be rotated from time to time to avoid such risks.

Some companies give incentives to their staff by linking improvements and efficiency in billing directly to staff remunerations. The meter reader pay is based on the number of bills delivered in the month. Many water companies set monthly **targets and then reward the best performer.**

10. Regular and On-Time Payments

Incentives for customers: Billing and revenue collection efficiencies are hindered by illegal connections and deliberate non-payment's by customers. Water Companies should encourage customers to connect to the network by setting up plans for regularization of connections through an incentive on the connection fee.

Continuous default, non-payment and cases of illegal connections, using sanctions, such as water connection cut-offs, should be exercised.

(1) Credible disconnection policies - some water companies have used credible disconnection policies and have been able to exercise this sanction more often for defaulting and illegal customers. Water utilities could send a notification for payment and, if not adhered to, resort to then cutting off the water connection.

Incentive for customers – water companies could develop incentive schemes for customers who have huge arrears in their bills. Discounts, instalment facilities for payment etc., could be designed such that customers are encouraged to settle their bills once and for all and start afresh.

(2) Disincentives - utilities could also use disincentives for late and irregular payments through disconnection of water, or imposition of heavy fines etc, that deter customers from such habits.

(3) Customer conveniences to pay: Water utilities must encourage customers to pay on time for services by simplifying the payment process. They should **set up payment agreements for customers to pay at banks, post offices or convenience stores, or put up their own conveniences** for easy bill payments such as customer care centres, collection centres, online payment facilities etc.

When setting up centres for collection of water bills, companies should ensure that these centres are convenient for the customers. The location of the centres should be planned to serve the entire service area. They should be located at prominent places that are convenient to access by customers.

For the poor - water companies should give options like instalment payments to ensure poor people are encouraged to take individual connections and keep paying for them for continued service delivery.

11. Delinquent / Erroneous Accounts

Many water companies have to deal with an overdue or unpaid account at some point or another. The following steps can help your WSP improve its receivables.

(a) Don't grant credit

(b) Require deposits

Utilities can ask for advance payments. Water providers may ask for 30 to 50% up front, depending on the client, with remaining payments due later.

(1) Offer credit terms

Credit terms outline how you expect to get paid, and what interest or penalties you charge for late payment. State these clearly on your contracts and invoices.

(2) Get a signed agreement

Never extend credit without getting something in writing. Review payment deadlines with clients and express that you expect to be paid on time. Point out the terms for late payment.

(3) Check credit

Collect the information you'll need to run a credit check on a "new customer form." For customers, this data includes name, address, phone numbers, I.D and bank account numbers, tax pin number, at least two credit references.

(4) create a billing / overdue notification system

◆ NOTE:
You should know how much is owed to you and when it is due. For this, your system should alert you on overdue accounts. Most accounting software programs do this automatically.

12. Managing Debt

For Water Company, it's reasonable to have a manageable level of debt. Growth and expansion often demands considerable capital which may require you to seek a bank loan. For this, you may need the following guidelines.

(1) Explore your reasons for borrowing / seeking a loan include:

(2) Working capital - when you're looking to increase your utility's work force or boost your stock.

(3) Expanding into new areas or markets.

- END-

Internal Information

TEXTBOOK
FOR
JOINT TRAINING
(DRAFT)

"How to Manage Customer Meters"
R-1

August, 2018

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)
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1. Objectives (out-put)

① Understand how to management items of the water meters.
② Understand maintenance of the water meters.
③ Understand the role of water meter
④ Understand the concept of meter installation
⑤ Understand the caliber of selecting a water meter
⑥ Understand the maintenance status of water meters in Kenya
⑦ Understand on how you read meters

2. Introduction

In this textbook, the following items are briefly introduced.

① Basic items of customer meters
  -Type, structure, performance, installation method, maintenance items and troubleshoot
② Trend of revision of international standard of water meters
③ Introduction for measures to reduce errors in meter reading
  - Remote-reading meters, smart meter, etc.
④ Introduction of overseas meter protection methods
⑤ Introduction of meter error manufactured under old standard (ISO 1993)
⑥ Way of thinking of selection of the meter caliber, etc.

At the end of the book, as a summary of learning, discussion themes of "reading meter and why necessity of hydraulic test of meter" are posted.

3. Key words definition

Radial vane water meters	Vane rotation by velocity and flow rate is integrated by the rotation speed
Volumetric water meters	Measurement cell rotation by velocity and flow rate is integrated by the rotation speed
Pilot	Rotation indicator when the meter is working.
Flow restrictor	Iinstalled on the outlet of the water meter, and prevents backflow from the residential piping
Check valves	As a prevention of backflow of piping, it is installed in pipeline.
Remote-reading meters	It is an electronic device installed at the top of the meter, and the indicated amount can be read from a remote place.
Cross-connection	Water service piping has connected directly with other piping.

KEBS	Kenya Bureau of Standards

4. What is maintenance management of the water meter?

(1) Currently, the water meter once installed has not been implemented maintenance (function inspection chief / evaluation) systematically.
(2) Failure to maintain and manage the water meter makes it difficult to predict the measurement error, so it is difficult to formulate an improvement plan systematically for the water meter.
(3) Maintenance and management of the water meter is to maintain the management standards, ensure measuring accuracy, and ensure functions in order to "maintain a stable water meter's role for a long time".

◆ **NOTE:**
①Maintenance management point of the water meter is to always maintain accurate mode of metering accuracy.
② The Measurement error from water meters cannot visualize the loss, unlike leakage outflow from the water reservoirs.

(4) Items to maintain and manage the water meters are shown below.
(a) Management of metering accuracy
(b) Management of installation status
(c) Development of management standards
① Standards of meter accuracy control (new & in-use meters, repaired meters.
② Criteria for model selection
③ Evaluation of purchased manufacturing company
④ Meter installation standard
⑤ Meter replacement standard
⑥ Ownership of the meters
⑦ Strengthen penal regulations, others

5. Role as a water meter

(1) A water meter is a meter for accurately recording the amount of water used in a tap
(2) The exact amount of water used is measured at the time of meter reading and charged to the customer as a water fee

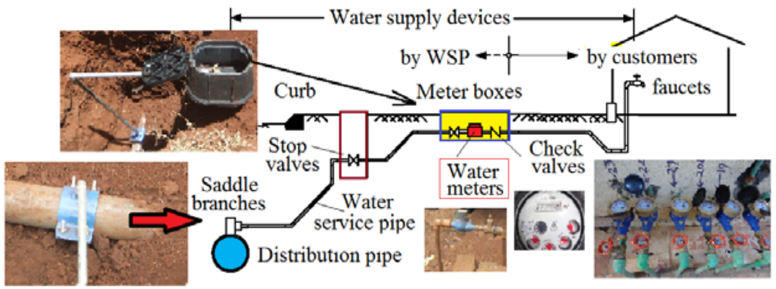


Figure 1: Location of Water meter Installed

> ◆ NOTE:
> ① Performance quality of general purpose water meters is stipulated by international standards, but **makers with insufficient quality control are on the market.**
> ② Low-quality products are inexpensive, but the amount of **Unmeasured water increases in a short period of time, resulting in an increase in commercial loss year by year.**

5-1 General requirements as a water meter

The water meter has an important role of grasping the basic data for managing the proper amount of water, such as calculation of water meter fee, revenue water rate, non-revenue water rate.

The general conditions that the water meter should have in order to fulfill this role are shown below.

(1) Points to remember

(1-1) Performance aspects

① The metering accuracy (verification tolerance) is good.

② Good sensitivity.

③ The measuring range is wide.

④ Low pressure loss / Large capacity can be passed.

⑤ have durability.

(1-2) Easy to structure and easy to repair.

(1-3) Maintenance aspects

① Easy to read the meter reading amount.

② Ease of repair / installation

③ The failure frequency is less .

(1-4) Low price is desirable

5-2 Classification of water meters

(1) General customer water meters

① Inferential water meters

② Volumatic water meters

> ◆ NOTE:
> **The meters that are widely used in general customers are "Radial vane type", which are divided into 2 types, "single-jet type and multiple-jet type".**

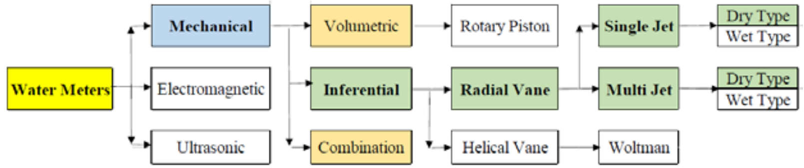


Figure 2: Classification of Water Meters

5-3 Types of water meters

5-3-1. Radial Vane Water meters (Inferential)

This vane is a flow velocity type, the vane rotates according to the speed of the flowing water, and the water flow rate is measured using the fact that the rotation speed of the vane is proportional to the flowing speed of water.

The outline of each function is shown below.

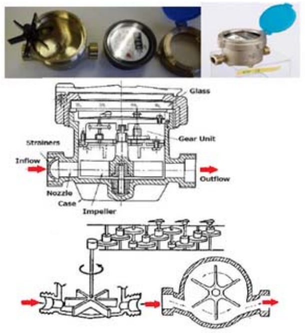
(1) Classification by structure

(a) Single-Jet meters

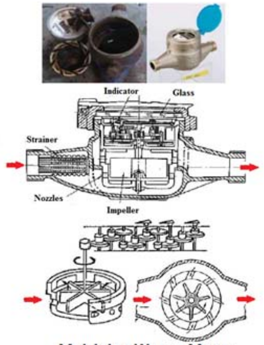
The single-jet water meters are a structure in which the water flow flowing into the meter case directly contacts the impeller.

(b) Multi-Jet meters

The multi-jet water meter has a different measurement chamber in the meter case, and the water flow is a structure that gives an impingement flow to the impeller from a plurality of nozzles.



Sigle-jet Water Meter



Multi-jet Water Meter

(c) General characteristics of Single-jet and Multiple-jet (Mechanical type)

Table 1: Example of General Characteristics of Radial Vane

Characteristic	Single-jet	Multi-jet
Easy to structure and easy to repair	simple	Slightly complicated by the inner case
Rotation of blades	Wear of the nozzle affects the rotation of the impeller	A smooth flow of blades can be obtained with a uniform flow rate
Pressure loss	Almost the same（Max 0.1 Mpa=1.0kgf/cm2）	
Less failure	Few	A plurality of nozzle portions are blocked
Metering accuracy	Almost the same	
Diameter (R = 100)	13mm (Qn=2.5 m3/hr)	20~40 mm (Qn=4~10 m3/hr)

(2) Classification by indicators

Radial vane water meters can be roughly classified into dry type and wet type depending on the structure of indication mechanism part.

(a) Dry type

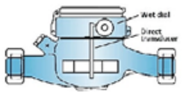
In the indication mechanism part, the rotation of the vane completely isolated from the running water (tap water) is transmitted to the upper indicator by the magnetic coupling.

(b) Wet type

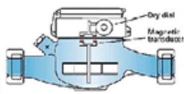
The entire indicator mechanism is in running water (tap water).

Or the indicating mechanism part is immersed in liquid.

(a) Wet Type



(b) Wet Type



(c) Dry Type

◆ **NOTE:**

Dry type is used a lot because it is difficult to cause meter reading failure by glass smoked with water vapor.

(c) Characteristics of Dry and Wet (Mechanical type)

Table 2: Example of General Characteristics of Dry and Wet

Characteristic	Dry	Wet (a) Type
Easy to reading meter	Inside of the glass is not cloudy	Inside of the glass may be cloudy with water vapor
Good performance	Equal	
Less Failure・breakdown	Even if the glass breaks, it does not leak from the meter.	If the glass breaks, it leaks from the meter.

(3) Classification by a display type

The mode of a display of reading meter is shown below.

(a) Circular reading-indicator type (Analog)

The indicator turns over the circular graduation to indicate the indicated amount. The method of reading the amount of water has a clockwise / counterclockwise model, but it is an analog type that records each of the rotated pointers.

(b) Direct reading-indicator type (Digital)

The numeral car rotates to indicate the indicated amount of water, and the numerical value is recorded as it is.

(c) Combination type

Digital display and analog display are displayed on the same meter.

Circular reading-indicator type (Analog)

Direct reading-indicator type (Digital)

Combination type (Digital and Analog)

◆ **NOTE:**

"Analog display" can easily be inspected by the display part subject to charge for water billing.

(4) Classification of Pilot-indicators

(a) The pilot-indicator is a monitoring gauge indicating whether or not the meter is sensing (counting) the water supply amount.

(b) Even if all the water faucets in the residential area are "closed", there is a high possibility of leakage in the residential area when the rotation pilot indicator is moving.

(c) Even if all of the faucets in the residential area are "closed" (the Pilot-indicator is not moving), if water is being supplied to the residential area, there is a high possibility of illegal connection by bypass.
(However, it is necessary to confirm whether or not there are multiple meters in the residential area)

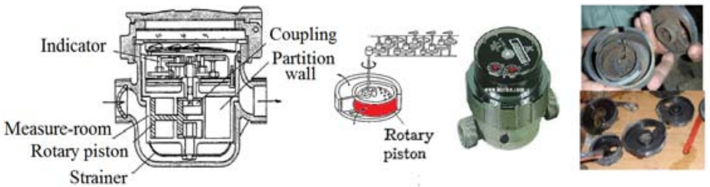
Example of Pilot-Indicators

◆ **NOTE:**
(a) The Pilot- indicator should be "large" as much as possible.
(b) "Structure and color" that can clearly confirm the motion will be selected.

5-3-2. Volumatic Water meters (Mechanical)

(1) Rotary Piston

There is a rotary piston in the meter case, rotate the volumetric rotor at the flow velocity, and transfer the rotation number to the indicating section to accumulate the water amount.



Rotary Piston Meter

5-3-3. Prepaid Water meters

In the prepaid method, a customer buys a card (eg, magnetic card, pin type, code # type) in advance and inserts it into the prepaid water meter at home, so that the tap water can be used by the purchase fee.
When the card is inserted, the "solenoid valve opens", when the specified amount of charge is reached, the solenoid valve is closed system.

(a) Features

① It is possible to omit meter reading work and issuance of invoice, which can save expenses.
② Users' consciousness of water conservation is increased.
③ Magnetic cards (pins), meters are remodeled and may be illegally used.
④ Social consent is required. (E.g. measures against weak people)

Example Application of Prepaid Water meters

5-3-4. Remote-reading meters

Equipped with a transmitter attached to the water quantity indicator of a conventional water meter and capable of sending wired or wirelessly the amount of water used.
Equipment is installed in which a transmitter is attached to the water quantity instruction part of a conventional water meter and the amount of water used can be transmitted by wired or wireless.

Usage of this remote-reading meters can be automatically read (Handy terminal: SD card) at a place away from the meter's indicated amount.

As a result, it is possible to reduce errors in meter reading and improve the efficiency of meter reading operation.

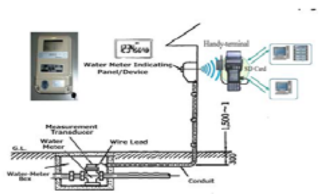
(a) Features

① Automatic meter reading by radio communication is possible

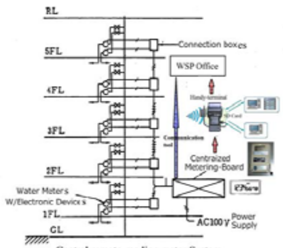
② Improvement of meter reading accuracy

③ Improvement of water service in the distribution block

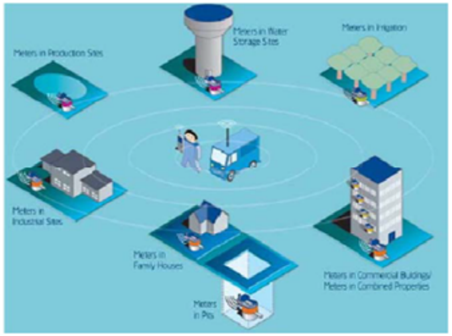
④ Early detection of leakage from the vicinity of the meter, others



Remote -reading meter System



Central remote-reading meter System



Example Application of Remote-reading meters

5-3-5. Smart water meter (e.g. iPERL ™)

A smart meter is a water meter that can be automatically inspected for high measurement accuracy applied by electromagnetic flow measurement technology (equivalent to R - 800). The recorded flow rate is connected via a 280 MHz wireless network, and data such as velocity rate and water flow rate is transmitted to the receiving base.

(1) Features

① Removal of work by meter reader

② Improvement of meter reading accuracy of used flow rate

③ Improvement of operation efficiency of water distribution service

④ Improve customer service by improving leakage countermeasure efficiency

⑤ Reduction of non-revenue water amount, etc.

(2) Future tasks

① It is necessary to acquire the frequency band for communication

② The service life of the battery is about 15 years

③ Health harm caused by California State has been complained (headache, tinnitus

④ Illegal operation is performed due to illegal operation of radio waves.

⑤ Past records:

- In Kenya, a demonstration test level (eg, MABOKO WSP, Nairobi WSP, others)
- In overseas, it has been in use since 2010.

MAVOK WSP NAIROBI WSP

5-4 Improvement of Water meter Standards

5-4-1. International standards

Examples of international・national standards and guidelines for water meters are shown below.

(a) OIML R 49-1/2/3 (International Organization of Legal Metrology) R 49-1:2006, R49-2:2006

(b) ISO 4064-1,3,4（International Organization for Standardization）,4064-1：2005

(c) EU (European Union：)

(d) CEN (European Standards Coordinating Committee)

(e) JIS B 8570-1/2 (Japanese Industrial Standard)JISB 8570-1:2005/2009

(f) AWWA（American Water Works Association）C708-96-1. Others

5-4-2. Latest standard

(a) Formulation of ISO and OIML joint standard (ISO 4064 / OIML R 49-1)

(b) Harmonization of EN 14154 and ISO 4064 / OIML R 49

(c) Harmonization with BS EN ISO 4064-2: 2004 (ISO 4064-2: 2014)

(NOTE: In 2014, BS EN ISO revised the joint standard based on ISO 4064-1 / 2/3/4/5)

5-4-3 Outline of ISO 4064-2005 standards (NEW Standards)

The international meter quality standard (ISO 4064-1993: old standard) was improved in 2005 (ISO 4064-2005: new standard) because the amount of dead water reduction is greatly affected by the performance of the meters.

(1) What is advancement?

Conventional meter accuracy evaluation (ISO - 1993) was classified by Class A to E (Class A is low performance, Class E is high performance), but in the new standard (ISO - 2005), from Class display It is revised to "R value = Q 3 / Q 1 ratio" indication, and as R value increases, it is classified as high performance.

(2) Upgraded accuracy ranges

As a result, with the new standard, the instrumental range of ± 5% is narrowed, while the instrumental range of ± 2% is widened, and the meter performance is improved.

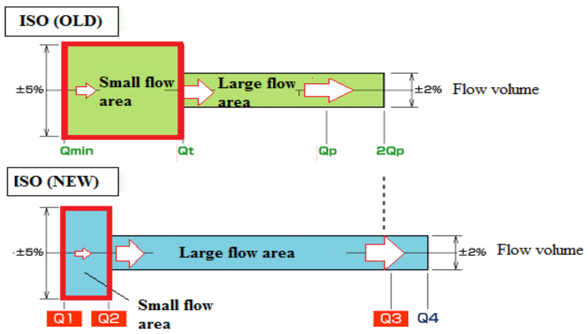


Figure 3: Comparing accuracy range changed

	ISO 4064-1993 (Old Standard)	JIS B 857-2013/ISO 4064-2005 (New)
Type	Multi jet-Dry-Radial vane	Single jet-Dry-Radial vane
Class	C	R-100= (Qn / Qmin)

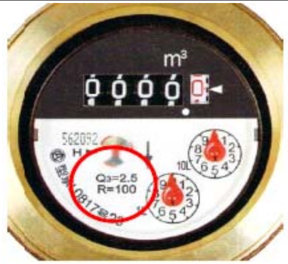
DN (mm)	15	**13**
Qn (m3/hr)	1.5	**2.5**
Display		

Figure 4: Examples of performance comparison between the new standard and the old standard

◆ **NOTE:**
Even if the meter of the new standard (example of R = 100) has a small bore diameter of 13 mm, the use flow rate of Qn (m3 / hr) having a larger capacity than the old standard product (ISO-C) can be obtained

(3) How to calculate New R-value Water meters

The procedure of selection is shown below.

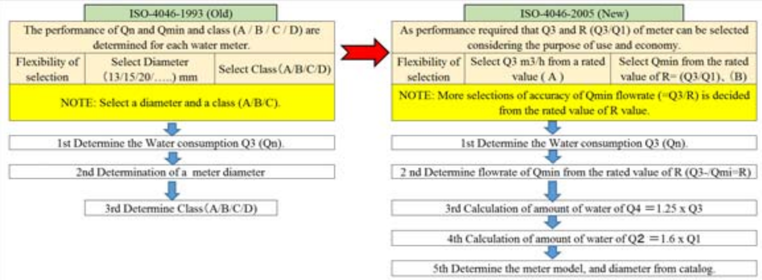
Step-1: WSP determines flowrate Q3 (Qn) from estimated water consumption.

Step-2: WSP needs to decide expected minimum ERROR in Q1 (Qmin) ranges.

Step-3: Calculate R-value to be installed the water meters

Step-4: Find the proper Meter model to be purchased meeting R-value-water meter specifications such as the Q3 (Qn) and Q1 (Qmin) is chosen by the manufacturer in an authorized list.

◆ NOTE:
With this new standards, the manufacturers have more possibilities technical information to select the performance of their meters like accuracy curve and head loss curve.



Selection factors

A) ISO-4046-2005	Value of Q3 (in m3/hr.)							
Q3 (m3/hr.)	1	1.6	**2.5**	4	6.3	10	16	More

B) ISO-4046-2005	Values of Ratio (R value) between the Q3 and Q min flowrate							
R= Q3 / Q1	10	12.5	16	20	25	31.5	40	50
	63	80	**100**	200	125	160	**200**	250
	315	400	500	630	800	—	—	—

Calculate Q4	=	**1.25**	x	**Q3**
Calculate Q2	=	**1.6**	x	**Q1**

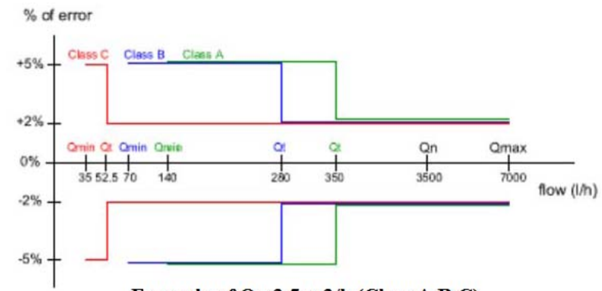
Table 5: Difference in the selection way by the old standard and a new standard

Table 3: Adoption trend of new standards in oversea

Country name	**Japan**	**England**	**France**	**Germany**	
Model of meter	Single/Multi-Jet	Rotary-Piston	Single-Jet	Single-Jet	Multi-Jet
R –value (Q3/Q1)	80/100/125	80/100/160 /200/250/315/400	100/125/ 160/200	80/100/12 5	100/125/1 60

5-4-4. Outline of ISO 4064-1993 standards (OLD Standards)

Old water meters manufactured to be conformed ISO 4064 Edition 1993 until 2003-2004. In this standard, a meter is defined by its nominal flow, Call Qn, and accuracy classes, A, B, C and D.



Example of Qn 3.5 m3/h (Class A,B,C)

Classes (ISO4064-1993)	Meter of Qn	
	< 15m3/h Small meters	> or= 15 m3/h Large meters
Class A	-	-
Value of Q max	2.0 Qn	2.0 Qn
Value of Qt	0.10 Qn	0.30 Qn
Value of Qmin	0.10 Qn	0.08 Qn
Class B	-	-
Value of Q max	2.0 Qn	2.0 Qn
Value of Qt	0.08 Qn	0.20 Qn
Value of Qmin	0.02 Qn	0.03 Qn
Class C	-	-
Value of Q max	2.0 Qn	2.0 Qn
Value of Qt	0.015 Qn	0.015 Qn
Value of Qmin	0.010 Qn	0.006 Qn

Qn (m3/h)	DN (mm)
1.5	15
2.5	20
3.5	25
5-6	30-32
10	40
15	50

Values of Nominal Diameter(DN mmm)

Source: KWLOG

Figure 6: Typical ISO 4064-1993 Performance Ranges and Value of classes

◆ **NOTE:**

Since the meter to be tested is the ISO-A, B, C class, the water meter test bench is subjected to instrumental error check according to the ISO 1993 standard.

5-4-5. Kenya Standards (KEBS)

(a)The standard for water meters in Kenya is a joint standard of British standard, EN and ISO which KEBS recommends. (ISO 4064-1-2-3-4-5 2014/OIML R-49: 2013: standards are the basis)

(b) The test methods conform to ISO 4064-1: 2014 / OIML R 49-1: 2013.

5-5 Introduction example of protection method of water meters

5-5-1. Kenya

5-5-2. Philippine

5-5-3. Paraguay

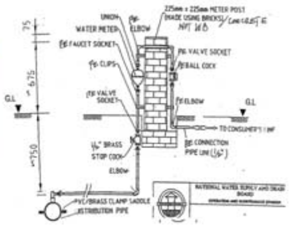
5-5-4. Nepal（Local）

5-5-5. Sri Lanka









5-5-6. Others


Pakistan(Local)



Japan

5-6. Handling of the measure against a complaint of a water meters

◆ **NOTE:**
(1) Failure of the meter often occurs by combining several obstacles.
(2) The general countermeasure is to remove the causes, repair and replace the water meter.

5-6-1. Mechanical water metes

The causes and measures of typical failure are shown below.

Table 5: Typical Troubleshooting

Case examples	Causes	Measures
1) Meter does not move	Foreign matters (sand, rust, dirt, piping material) bite into the rotating part	- Always wash after piping - Install strainers
2) Much month-long water consumption.	Parts are worn out / damaged by an excessive flow.	- Change into a large meter model - Install a flow control valve
3) Meter does not move after the impact sound rom piping.	Breakage of the parts by a water hammer	- Open a valve gently
4) Indication part is damaged	Intentional breakage an /or fall on passage	-Take the protective measures of meter = Implement a meter error check
5) Motion of meter is slow	Foreign matters (sand, rust, dirt, piping material) bite into the rotating part	- Always wash after piping - Install strainers
	Defect of the installation angle of meter	-install the display part of meter in level piping upward
	Illegal remodeling of meter	- Strengthen control of illegal remodeling
	Attached scal	- Attach drain before meter - Clean regularly
	Much rotation friction at the time of use of a too little flow	- Change into the model suitable for the use real condition
	Wear the shaft of rotation by use of an excessive flow	- Change into a large meter model - Install a flow control valve
6) Move of meter is fast.	In the flashbulb of the toilet, water is flowing by trouble	- Early detection of a leak - Check whether the water inside a toilet bowl is waving - Replacement of gaskets
7) Rotation is reversed	Installation of meter is an opposite direction	- Install in piping in compliance with the arrow of meter
	Occurrence of cross-connection flow	- Install check valves/ flow restrictors - Install the valves and /or check valves against cross – connection flow
8) Water is leaking	Damage by a water hammer	- Open a valve gently
	Deformation / degradation / falling of a gasket	- Use the gasket and /or seal tape of the good quality of the material - Install a gasket by bolting and wrap appropriately
9) Glass of the meter is unclear/ cloud up	Meter reading is impracticable at deposits, such as the mud	- Remove a deposit

	Glass part has become cloudy with water drops due to damage	- Clean the inner side of glass - Replace glass
	Glass was clouded by the scratches	- Apply oil/water to the surface of the glass damaged
10) Meter is damaged	Damage due to dropping	- Especially cautious of handling at the time of transport / installation.
	Corrosion damage	- Change to plastic - Remove factors of corrosion.
11) Meter is stolen	Lost meters・Valves	- Change to plastic - Enhance management responsibilities to customers

5-6-2. Occurrence of the complaint "reliability of a water meter" from a citizen with poor work of the service pipe in a house

The cause of a civic complaint is due to poor water service-line work (Cross-connection) implemented by a general contractor in the private housing site, and that cause, WSP requires great cost for the measure against a complaint.

(a) What is cross connections?

It is shown that water service piping has connected directly with other piping.

When a service pipe and pipes other than water service are connected directly, other head water (an example, a well, tanks-for-holding-rainwater water) may flow backwards to distributing pipe according to trouble and poor operation of check valves and stop valves, etc.

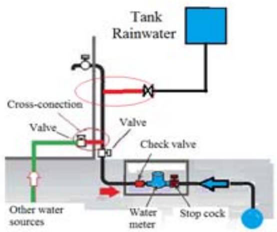


Figure 7: Concept of Cross-connection

(b) The occurring example of trouble

The fault by cross-connection piping is shown below.

① A water meter carries out inversion rotation and a mistake occurs in billing.

② Top water may be supplied to the well/pool in housing site, and a large amount of water rates occur.

③ Incorrect connection with piping of storm water use

④ Incorrect connection with distribution pipe for an agricultural-chemicals

⑤ Danger of the water pollution of the tap water by other heads

(c) Preventive measure

① Don't connect a water pipe and other head pipes.

② Change the class of pipe materials.

③ Color water for miscellaneous use.

5-7 Mounting arrangement of meter

5-7-1. Installation angle

◆ NOTE: Inferential water meter's installation level is a horizontal (allowable angle of less than 5 degrees).

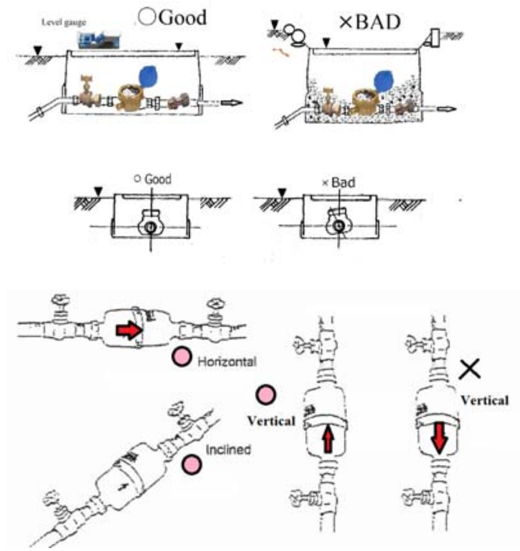


Figure 8: Installation angle

5-7-2. Installation of associated fittings (ISO-4062-2)

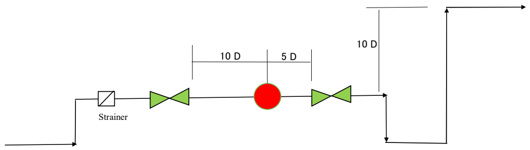


Figure 9: Installation space needed

5-7-3. Installation of meter

(a) Harmonizing meter installation with "the arrow of the direction of a flow →" currently displayed on the meter side part.

(b) Prohibition of underwater meter installation work

Replacement of old water meter in 8th year New meter (13mm R-100)

(c) The proper packing for meter, strainers and seal tape for connection are used.

(d) Use of Flow restrictors

To prevent the water meter operation in reverse direction and possible contamination by Back-flow from resident area. The pressure loss of this reverse flow restrictor is between 0.02 bar and 1.0 bar depending on the flow velocity.

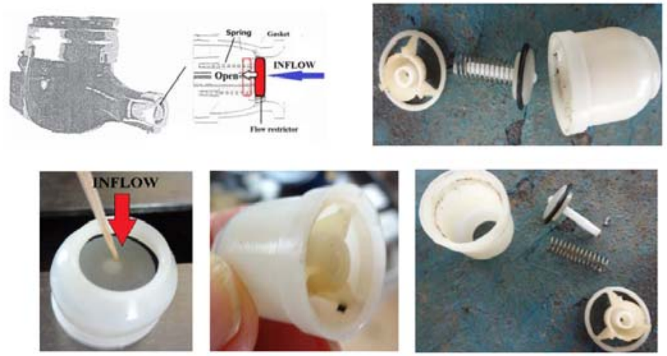


Figure 10: Flow restrictors

5-8 Procedure of the beginning of using of meters

5-8-1. Removal of the air in meter

After fixing meter, when you start "Open and passing water", fully eliminate the air in meter by opening a valve gradually.

<u>Below, the reason is shown.</u>

* If a valve (a stop cock and ball valve) is opened rapidly, water hammering action and / or high velocity may cause inaccurate measurement and/or damage inside mechanism of meter.
* When air remains in a service pipe, meter may measure inaccurately by unusual rotation with accuracy

5-8-2. Verification of direction of rotation of pilot after passing water

(a) Confirm that the meter pilot is rotating normally.

(b) Confirm that whether the Pilot is rotating in the direction of a flow shown in meter.

(c) By confirming pilot rotation, the accuracy of meter installation procedure, such as a meter's reverse attachment by mistake and possibility of mixing foreign substance, can be confirmed at an early stage.

(d) After installing the meter, it is possible to discover the water leak by closing the water faucet in all the residential land by checking the movement of Pilot.

5-8-3. Confirmation of water leakage

・ Confirm that there is no water leakage from the joint branch part, meter with "feel and Visual inspections".

・ Since leakage of water may occur under the influence of a pressure increase at night, confirm "the existence of a leak" from the joint in a meter box periodically.

5-8-4. Verification of water quality

After installing the meter, check the water quality (turbidity, color, presence or absence of sediment) of the faucet inside the residential area

5-9 Transportation of meters

When transporting the meter, handle the meter carefully so as not to cause troubles such as damage to the meter attachment screw thread, glass breakage, pointer needle removal, etc.

6. Concept of meter installation standards

The example of installation of the meter of a home, a residence, and a compound building by one meter per structure is shown below.

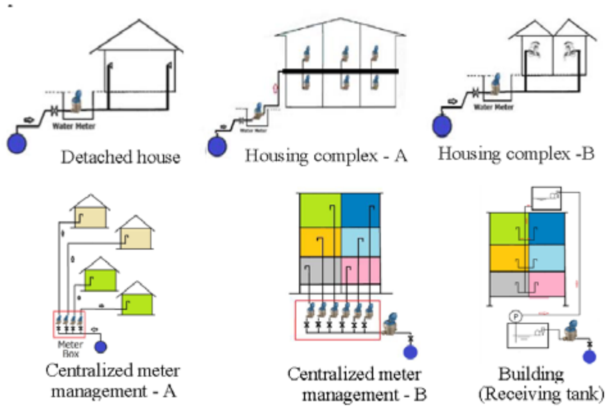


Figure 11: Typical house connections

7. How to determine the caliber of a water meter

The caliber of the water meter may be examined in the following way.

① Keep the same diameter as existing water supply pipe.

(Check the family composition of the applicant)

② It is decided from the "planned amount of water used" by surveying the actual condition of the amount of water used.

・The planned amount of water used is obtained from the survey of distribution of fluctuation in usage flow rate such as simultaneous use water amount, fluctuation of used water amount per day.

・When determining the meter Diameter from the calculating the planned amount of water used (l / min) by number of forces , person and living condition, and select the caliber / model of the meter by referring to the model data of the meter etc.

③ It is decided from "proper usage flow rate range".

The “proper usage flow rate range” is a standard flow rate that can be used with the performance of the meter stabilized for a long period of time.

◆ NOTE:

(a) The planned amount of water used is a basis for determining the diameter of the water supply pipe.

(b) Choose the type / caliber of the water meter that best suits the Qmin, Qn, Qmax range from the flow rate reference table and/or catalog for each type of water meter, taking into consideration the planned amount of water used / the amount of water used per day etc.

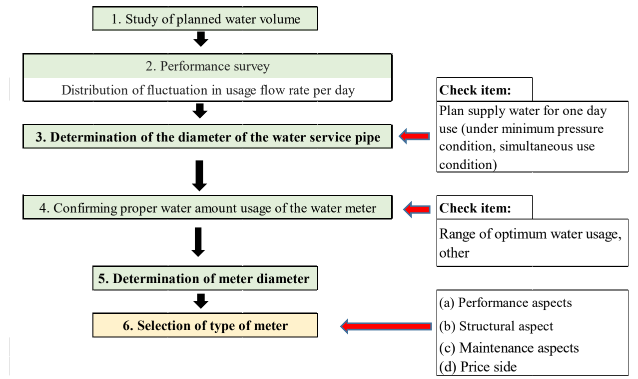


Figure 12: Selection Procedure of Water Meter Model

Table 6: Examples of standard water usage of water service pipe

Dia.（mm)	13	20	25
Standard amount of water used(l/min)	17	40	65

Source: Hamamatu city

Table 7: Example of Delivery classified by use and corresponding faucet size

Classification	Use amount (l/min)	Diameter (mm)
Sink	12～ 40	13～20
Draining floor	12～ 40	13～20
Washbowl	8～ 15	10～13
Bath (Japanese style)	20～ 40	13～20
Bath (Western style)	30～ 60	20～25
Shower	8～ 15	10～13
Urinal (Washing tank)	12～ 20	10～13
Urinal (Flush valve)	15～ 30	13

Source: JWWA 1978

Table 8: Example of Standard consumption by service faucet

Diameter o faucet (mm)	10	13	20	25
Standard consumption (l/min)	10	17	40	65

Source: JWWA 1978

Table 9: Number of faucet and consumption ratio

Number of faucet	1	2	3	4	5	6	7	8	9	10	15	20	30
Consumption ratio	1	1.4	1.7	2.0	2.2	2.4	2.6	2.8	2.9	3.0	3.5	4.0	5.0

Source: JWWA 1978

Table 10: Example of Number of faucet considered from simultaneous use rate

Number of faucet (pieces)	Number of faucet considered from simultaneous use rate (pieces)
1	1
2～ 4	2
5～10	3
11～15	4
16～20	5
21～30	6

Source: JWWA 1978

Table 11: Example of Flow rate standard by type of water meter (R = 100)

Water meter Dia (mm)	Qn (m3/h)	Proper usage flow rate range (m3/h)	Allowable flow rate for temporary use (m3/h)		Usage per day (m3/d)			Monthly usage (m3/M)	
			Less than 1 hour / day	In the case of instantaneous use	Total daily usage time is 5 hours	Total daily usage time is 10 hours	24 hours a day use		
13	2.5	0.1-1	1.5	1.5-2.5	4.5	7.0	12.0	100	Radial vane water meters
20	4.0	0.2-1.6	2.5	3-4	7.0	12.0	20.0	170	
25	6.3	0.23-2.5	4.0	4-6.3	11.0	18.0	30.0	260	
30	10.0	0.4-4	6.0	6-10	18.0	30.0	50.0	420	
40	16.0	0.5-4	6.0	7.5-10	18.0	30.0	50.0	420	

Source: JWWA 2010

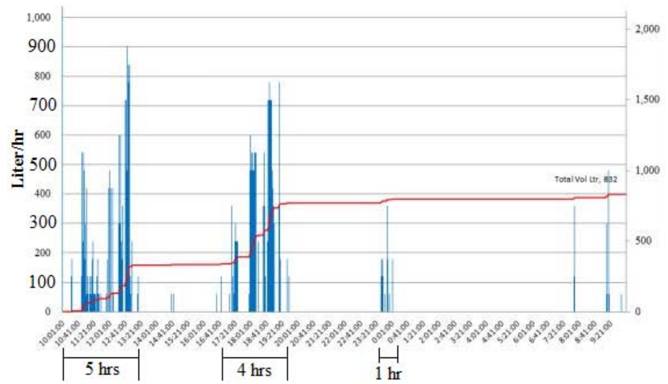


Figure 13: Example of Distribution of fluctuation in usage flow rate per day

8. Management status of water meters in Kenya

8-1 Type of Troubles occurred

(1) Troubles

① Increase in mechanical wear due to elapsed years

② Small floating objects are caught in gears, rotational friction resistance increase

③ Occurrence of malfunction due to precipitation of soluble substance

④ Damage of upper glass plate and measurement canter

⑤ Repair meter using reusable parts with poor precision

⑥ "Installation angle" of water meter is inappropriate

⑦ Mistake in installation direction of water meter

⑨ Selection of bad water meter and etc.

8-2 Meter condition

(1) Model

Radial vane type water meters (ISO Class B / C) have recently been spreading from the Rotary piston type, but future transition to the R standard is also being studied.




(2) Accuracy management of water meters

In Kenya domestically, the metering error standard manufactured by ISO-1993 (Class B/C) is not unified. But some WSPs set up the original inspecting standard.

(3) Maintenance of the meters

The meter fault information is from the meter reader / customer, and the number of cases is small. (Most of the water meters haven’t been managed for a long period)

8-3 Proposal for strengthening maintenance system

Maintenance items of the water meter to be implemented urgently are listed below

(1) Implementation of functional investigation of total water meters in use

① Operation status of meters

② Damage status

③ Easiness of meter reading

④ Dirtiness situation of meter

(2) Formulation and implementation of replacement plan for defective water meters

(3) Appointment of performance manager of water meter and implementation of action plan

① To find out abnormality at an early stage, check the amount of water used from monthly meter readings.

② Investigate regularly with a test meter etc. Whether instrumental error of the water meter is within use tolerance.

③ It is necessity to understand the actual condition of the amount of water used in a typical household from the day to day

④ To systematically replace the meter, manage the certification valid period.

⑤ Maintain the meter management ledger on a regular basis

(4) Strengthening oversight of installation work (before and after)

① Check the mounting angle of the meters.

② Check for leakage from around the meter.

③ Removal of earth and sand around the meter (included meter boxes)

④ Check whether the certification stamp / indicator etc. is properly attached.

(5) Preparation of management criteria

① Creation of planned amount of water usage table

② Creation of selection standards for “flow rate standards by type of water meters”

③ Development of an action plan for updating and exchanging meters

④ Update meter installation standard

⑤ Development of meter inspection standard

⑥ Updating installation guidelines for meters

8-4 Procedure for selecting proper water meter size, model and diameter of water service pipe

(1) Current status

The method of selecting the meter diameter that many WSPs implement is as follows.

① Meter diameter is selected according to the size of existing water service pipe.

② The quantity of water used is confirmed from the family composition of the applicant.

(2) Implementation of information gathering to provide meters with stable performance for long periods to customers

① Implementation of field survey of water usage

(Choose a customer with a typical family composition, collect basic data for a long period with "electronic test meter / master meter" and use it as the basic data for calculation of planned water volume)

② and then, Creation of planned amount of water usage table

Example of simple standard Table

Table 12: Example of Planned water amount to be service

#	Classifications	No. of house	Amount of Water to be supplied	Remarks
1	Residential	1	1.0	-
2	Residential	1	0.5	single room
3	Mass housing	1～3	Q=1.0 x N x 100%	N = Number of resident
		4-10	Q=1.0 x N x 90%	
		11-20	Q=1.0 x N x 80%	
		21-29	Q=1.0 x N x 70%	

Yokosuka WSB

③ Buildup of the diameter calculation way of a service pipe and a water meter

④ Creation of flow rate standard by type of water meters

⑤ Collective analysis and arrangement of the catalog and engineering data of meter

◆ **NOTE:**

With the spread of meters of R standards, the precision of metering error in the small flow rate range improves over the ISO-B / C class, so knowledge that the choice of caliber and model of highly reliable water meters for long periods can be proposed to customers,

9. Exercises

9-1 Meter reading

Questions

(1) How to read the water meter

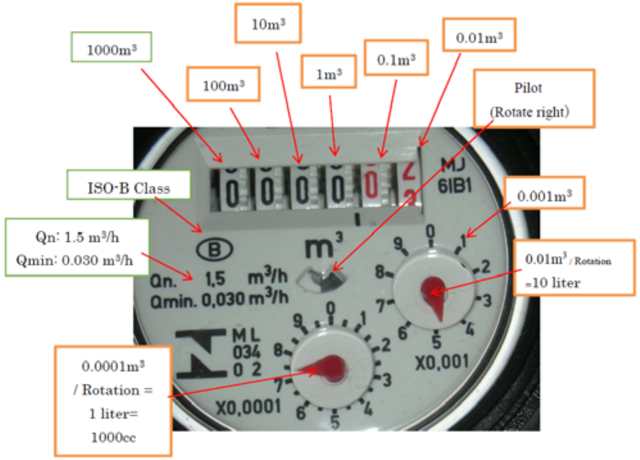


Figure 14: Example of Water meter display

(2) What is the displayed water volume?

Comments:

(3) How many years do you use?

(Condition: 10 m³/M is used)

Comments:

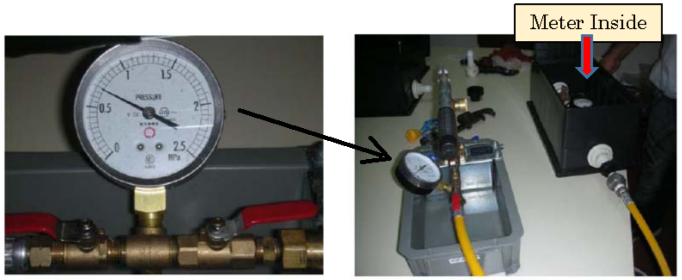
Figure 14: Example of Water meter display

9-2 Meter Pressure test

<u>Questions</u>

(2) Why, you need a water pressure test of the meter?

For Example:
Loaded water pressure: 7kgf/cm^2 (for 60 sec.)
Acceptance condition: No Leakage of water & NO deformation by visual examination



Meter Leak Test Equipment **Loaded Water Pressure (7kgf/cm^2)**

Figure 15: Water meter Pressure test

Comments:

—END—

Internal Information

TEXTBOOK

FOR

JOINT TRAINING

（DRAFT）

“HOW TO USE WATER METER TEST BENCH”

R-1

August, 2018

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SANITATION COMPANY ANDMERU WATER AND SEWERAGE SERVICES)
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1. Objectives

① Understand the test standard

② Understand purpose of water meter accuracy test

③ Understand outline of ISO 4064-1993 test methodology

④ Understand water meter test bench method by volume-capacity method

⑤ Understand concept of the test method (ISO 4064-1993)

⑥ Understand how to record on the data sheet

⑦ Understand how to analyse test result

2. Introduction

(a) Since the meter to be inspected is manufactured under the old ISO standards, the method of inspecting instrumental differences is in conformity with ISO 1993 standards.

(b) A Water meter test bench is used to test water meters in Qn, Qt, Qn and Qmax flow rates and be able to determine accuracy errors

3. Key words definition

KEBS	Kenya Bureau Of Standards
JWWA	Japan Water Works Association
ISO	International Standards Organization
Q	Flow Rate
Qmin	Minimum Flow rate
Qn	Nominal Flow Rate
Qt	Transitional Flow Rate
Qmax	Maximum Flow Rate

4. Why is water meter test bench necessary?

4.1 Purpose of the survey

In order to grasp the commercial loss caused by the water meter, the water meter test bench is operated to be invested the meter error, and the influence is evaluated.

① Prediction of meter insensitive water amount

(See Water Balance Analysis Table: Item-⑥in Water balance analysis table of Metering Inaccuracies below)

② Impact on toll collection

③ Non-revenue reduction effect by exchanging new meter

④ Others

Table 1: Water Balance Analysis Table (IWA STD)

Q1: System Input Volume (m³/Y)	D1: Authorized Consumption (m³/Y)	V1: Billed Authorized Consumption (m³/Y)	① Billed Metered Consumption (including water exported) (m³/Y)	Q2: Revenue Water(m³/Y)
			②Billed Nan-metered Consumption(m³/Y)	
		V2: Unbilled Authorized Consumption(m³/Y)	③Unbilled Metered Consumption(m³/Y)	Q3: Nan-Revenue Water(m³/Y)
			④Unbilled Non-metered Consumption(m³/Y)	
	D2: Water Losses (m³/Y)	V3:Apparent Losses(m³/Y)	⑤Unauthorized Consumption(m³/Y)	
			⑥Metering Inaccuracies(m³/Y)	
		V4: Real Losses (m³/Y)	⑦ Leakage on Transmission and /or Distribution Mains(m³/Y)	
			⑧ Leakage and Overflows at utility's Storage Tanks(m³/Y)	
			⑨Leakage on Service Connections up to Customers 'Meters(m³/Y)	

Source：IWA: International Water Association Standard

4.2. How to determine meter insensitive water rate (For example)

When it is difficult to grasp the amount of insensitive water of the current water meter, estimate it by the following method.

① "2 to 3%" is adopted from the accuracy check result of the meter.
② Experience value in the past
③ In the JWWA Q 100 standard, "2%" is proposed.
④ The instrumental error of the meter is set to "5%". (Due to verification tolerance2% to 5%)
⑤ Quotation of numerical values of other water enterprises.
⑥ Do not consider

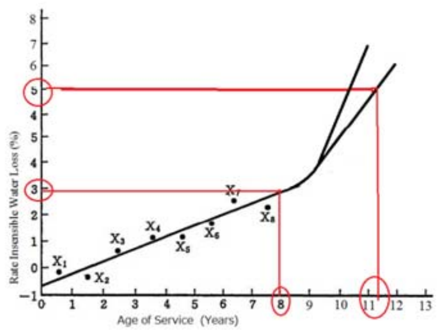


Figure 1: Year of use of meter and insensitive water rate (%)

◆ **NOTE:**

Confirmation of water meter error is important (reduction of insensitive water of the water meter)

(1) Measures to reduce commercial losses caused by insensitive water specific to a water meter are important issues
(2) If you do not maintain and manage the water meter, the accuracy of measurement decreases along with the age of use.
(3) Resulting in an increase in the amount of insensitive water.

4.3. Cause of occurrence of commercial losses (Refer to Figure 2)

① Insensitive water of the water meter
② Illegal connection / Water theft / stealing
③ Meter reading/accounting error
④ Other (for example Occurrence of arrears payment)

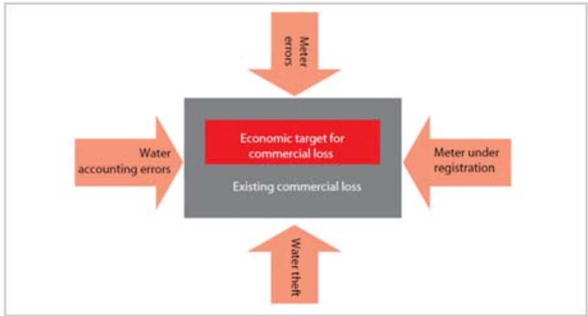


Figure 2: Conceptual diagram of commercial loss (by IWA)

5. Standards of water meter accuracy test

5.1. Kenya Standards (KEBS)

(1) The standard for water meters in Kenya is a joint standard of British standard, EN and ISO which KEBS recommends. (ISO 4064-1-2-3-4-5 2014/OIML R-49: 2013: standards are the basis)
(2) The test methods conform to ISO 4064-1: 2014 / OIML R 49-1: 2013.

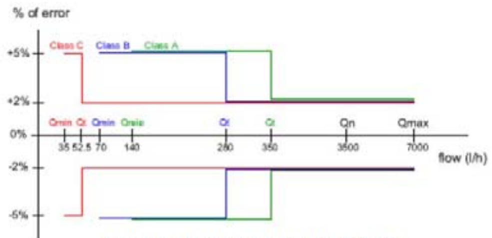
5.2. Main improvement of ISO Standards

(1) The international meter quality standard (ISO 4064-1993: old standard) improved in 2005 (ISO 4064-2005: new standard) because the amount of dead water reduction is greatly affected by the performance of the meters.

(2) Conventional meter accuracy evaluation (ISO - 1993) was classified by Class A to E (Class A is low performance, Class E is high performance), but in the new standard (ISO - 2005), from Class display It is revised to "R value = Q 3 / Q 1 ratio" indication, and as R value increases, it is classified as high performance.

5.3. Outline of ISO 4064-1993 standards (OLD Standards)

Old water meters manufactured to be conformed ISO 4064 Edition 1993 until 2003-2004. In this standard, a meter is defined by its nominal flow, Call Qn, and accuracy classes, A, B, C and D. **(Refer to Figure 3)**



Example of Qn 3.5 m3/h (Class A,B,C)

Figure 3: Example of Error Range of ISO 1993 Standard

Table 6: Adoption trend of new standards in each country

Country name	Japan	England	France	Germany	
Model of meter	Single/Multi-Jet	Rotary-Piston	Single-Jet	Single-Jet	Multi-Jet
R –value (Q3/Q1)	80/100/125	80/100/160 /200/250/315/400	100/125/ 160/200	80/100/12 5	100/125/1 60

◆ **NOTE:**

(a) Since the meter to be tested is the ISO-A, B, C class, the water meter test bench is subjected to instrumental error check according to the ISO 1993 standard.

(b) Refer to the topic "How to manage a Customer Meter" page XXXXX

6. Various types of meter test methods in field

6.1. Survey methods

The method for investigating the change in the meter difference with the number of years past is shown below.

① Master-meter method

② Measurement method of actual flow rate (with container)

③ **Water meter test bench method (Test procedure equivalent to ISO 1993 standard)**

④ Electronic test meter method

⑤ Dedicated water flow device (at the meter factory)

6.2. Outline of survey method

(1) Master-meter method

In this method, "existing water meter" and "master meter: tested meter" are connected in series at the site, the difference between the flow rate values of both is calculated, and the instrumental error is measured.

<u>(a) Points to remember</u>

① Make sure to calibrate the measurement precision for the master meter.

<u>(b) Features</u>

① Equipment difference is calculated at a flow rate close to actual usage.

② Continuous investigation is possible without disturbing residents (without stopping water supply).

<u>(c) Equipment to be used</u>

① Meter already certified · 1 set

② Protective Box 1 set

③ Installation / Removal work 1 set

(2) Measurement method of actual flow rate (container method)

In this method, the amount of water of the existing faucet is stored in a container, and the amount of water of the existing meter and the actual volume (amount of water of the container) are compared on the spot.

(a) Points to remember

① When converting the weight of water into a volume, it is necessary to consider water temperature difference "specific gravity difference".

(b) Features

① Equipment difference can be calculated with a flow rate close to actual usage.

② Measurement is possible in a short time without disturbing residents (without stopping water supply).

(c) Equipment to be used

① Water receiving container (Ex. bucket) · · 1 piece

② Weight scale 1 piece

③ Water temperature gauge 1 piece

(3) WATER METER TEST BENCH METHOD

The test method can be roughly divided into three kinds by the standard machine. (Refer to **Table-3)**

Table-3 Types by Standard Equipment

	Methods	Standard Equipment
1	Volume	Water tank/ container, and etc.
2	Weighing	Weight/ water tank/ density meter
3	Comparison with flow rate	Master meter and etc.

(1) Volume method

This method measures the capacity of a standard water tank. (Refer to Figure 4)

The test water is sent to the inspection meter, and "instrument difference" is measured from the difference between "measured value of the test meter" and "actual flow volume of the tank".

(a) Points to remember

① Always calibrate measurement precision with a flow meter.

② Check that the pressure gauge on the outflow side always has a back pressure of 0.05 KPa or more.

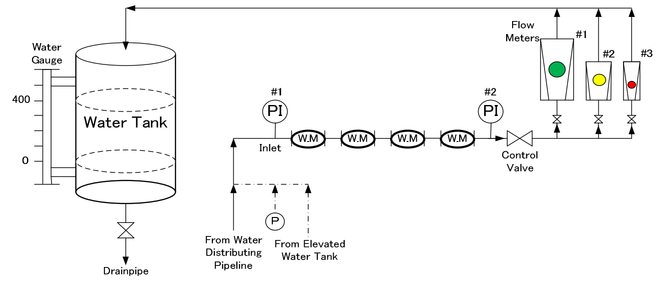


Figure 4: Principle of the Water Meter Test Apparatus Method (Volume method)

(b) Equipment to be used

①Water meter test bench,

②Water tank (small: 100 to 500 liters, large size: 1 m^3 or more) · · 1 set

③Flow meter (3 to 4 types L/h): 5 to 100, 100 to 1000, 1,000 to 100,000) · 1 set

④Pressure gauge 2sets

(2) Weighing method

This method is based on the weight of the water tank as standard equipment. **(Refer to Figure-5**)

The test water is sent to the inspection meter and "measured value of the test meter" and "measured amount of water passed through the platform scale" are calculated, and "instrumental difference" is calculated from the difference.

Note that water temperature correction is important when converting from weight to water amount.

(a) Points to remember

①Be sure to calibrate measurement precision for weighing scale and water temperature gauge.

②Check that the pressure gauge on the outflow side always has a back pressure of 0.05 KPa or more.

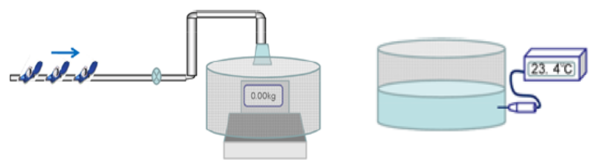


Figure 5: Principle of the Water Meter Test Method (Weighing method)

③ The density g/cm³ (specific gravity) of water depends on water temperature. Measurement of water temperature is indispensable when converting the amount of water from the weight of water.

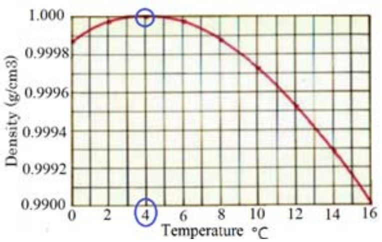


Figure 6:Density of water (g/cm3)

Table 4: Water Density Chart

Water density (g/cm³)

Temp.(°C)	After the decimal point									
	0	1	2	3	4	5	6	7	8	9
0	0.999841	0.999847	0.999854	0.999860	0.999866	0.999872	0.999878	0.999884	0.999889	0.999895
1	0.999900	0.999905	0.999909	0.999914	0.999918	0.999923	0.999927	0.999930	0.999934	0.999938
2	0.999941	0.999944	0.999947	0.999950	0.999953	0.999955	0.999958	0.999960	0.999962	0.999964
3	0.999965	0.999967	0.999968	0.999969	0.999970	0.999971	0.999972	0.999972	0.999973	0.999973
4	0.999973	0.999973	0.999973	0.999972	0.999972	0.999972	0.999970	0.999969	0.999968	0.999966
5	0.999965	0.999963	0.999961	0.999959	0.999957	0.999955	0.999952	0.999950	0.999947	0.999944
6	0.999941	0.999938	0.999935	0.999931	0.999927	0.999924	0.999920	0.999916	0.999911	0.999907
7	0.999902	0.999898	0.999893	0.999888	0.999883	0.999877	0.999872	0.999866	0.999861	0.999855
8	0.999849	0.999843	0.999837	0.999830	0.999824	0.999817	0.999810	0.999803	0.999796	0.999789
9	0.999781	0.999774	0.999766	0.999758	0.999751	0.999742	0.999734	0.999726	0.999717	0.999709
10	0.999700	0.999691	0.999682	0.999673	0.999664	0.999654	0.999645	0.999635	0.999625	0.999615
11	0.999605	0.999595	0.999585	0.999574	0.999564	0.999553	0.999542	0.999531	0.999520	0.999509
12	0.999498	0.999486	0.999475	0.999463	0.999451	0.999439	0.999427	0.999415	0.999402	0.999390
13	0.999377	0.999364	0.999352	0.999339	0.999326	0.999312	0.999299	0.999285	0.999272	0.999258
14	0.999244	0.999230	0.999216	0.999202	0.999188	0.999173	0.999159	0.999144	0.999129	0.999114
15	0.999099	0.999084	0.999069	0.999054	0.999038	0.999023	0.999007	0.998991	0.998975	0.998959
16	0.998943	0.998926	0.998910	0.998893	0.998877	0.998860	0.998843	0.998826	0.998809	0.998792
17	0.998774	0.998757	0.998739	0.998722	0.998704	0.998686	0.998668	0.998650	0.998632	0.998613
18	0.998595	0.998576	0.998558	0.998539	0.998520	0.998501	0.998482	0.998463	0.998444	0.998424
19	0.998405	0.998385	0.998365	0.998345	0.998325	0.998305	0.998285	0.998265	0.998244	0.998224
20	0.998203	0.998183	0.998162	0.998141	0.998120	0.998099	0.998078	0.998056	0.998035	0.998013
21	0.997992	0.997970	0.997948	0.997926	0.997904	0.997882	0.997860	0.997837	0.997815	0.997792
22	0.997770	0.997747	0.997724	0.997701	0.997678	0.997655	0.997632	0.997608	0.997585	0.997561
23	0.997538	0.997514	0.997490	0.997466	0.997442	0.997418	0.997394	0.997369	0.997345	0.997320
24	0.997296	0.997271	0.997246	0.997221	0.997196	0.997171	0.997146	0.997120	0.997095	0.997069
25	0.997044	0.997018	0.996992	0.996967	0.996941	0.996914	0.996888	0.996862	0.996836	0.996809
26	0.996783	0.996756	0.996729	0.996703	0.996676	0.996649	0.996621	0.996594	0.996567	0.996540
27	0.996512	0.996485	0.996457	0.996429	0.996401	0.996373	0.996345	0.996317	0.996289	0.996261
28	0.996232	0.996204	0.996175	0.996147	0.996118	0.996089	0.996060	0.996031	0.996002	0.995973
29	0.995944	0.995914	0.995885	0.995855	0.995826	0.995796	0.995766	0.995736	0.995706	0.995676
30	0.995646	0.995616	0.995586	0.995555	0.995525	0.995494	0.995464	0.995433	0.995402	0.995371

(4) Electronic test meter method

In this method, "electronic meter (certified meter)" is connected in series to the existing meter and the "equipment difference" is measured from the difference between "existing meter value" and "actual flow value of electronic meter" at the site is there. (**Refer to Figure 7**)

(a) Points to remember

①The electronic meter (tangential impeller) must always calibrate the measurement accuracy.

② Measurement of flow rate other than set flow rate increases measurement error.

③ Do not bring strong magnets closer to the electronic meter during measurement.

(b) Features

① The equipment difference is investigated at the usage flow rate.

② Measurement is possible in a short time without disturbing residents (without stopping water supply).

(c) Equipment to be used

① Portable electronic meter1 set

② Hose · Connecting device 1 set

(d) Measurement range

① Maximum flow rate 1.0 m^3 / h, intermediate flow rate 0.2 m^3 / h, minimum flow rate 0.1 m^3 /hr,

② Measurement accuracy ± 2.0%

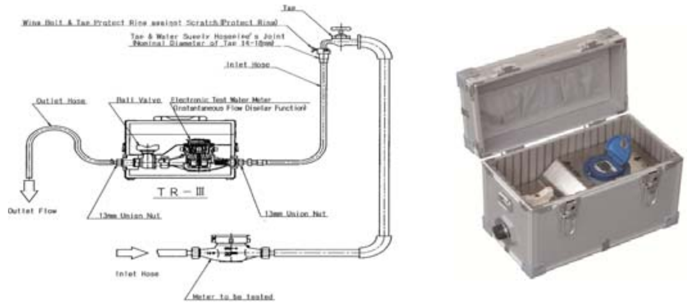


Figure-7 Installation drawing of Portable electronic Test meter

7. Implementation of the meter accuracy test by water meter test bench

7.1. Component of the Test bench

① Water Meter Test Bench 1 set **(see Figure 8)**

② Recording paper 1 set

③ stopwatch 1 set

④ Water meter to be inspected 6 to 10 pieces

⑤ Tool, others 1 set

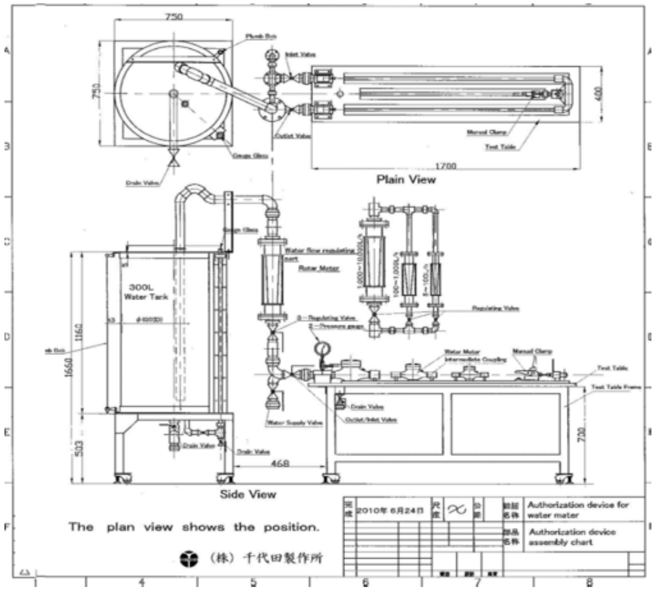


Figure 8: Water Meter Test Bench to be used (EMBU Delivered model)

7.2. Confirmation of water meter specification to be inspected (ISO-Class)

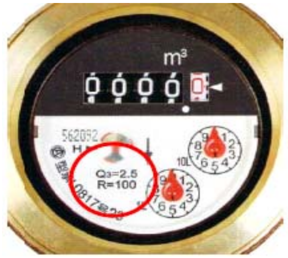
	ISO 4064-1993 (Old Standard)	JIS B 857-2013/ISO 4064-2005 (New)
Type	Multi jet-Dry-Radial vane	Single jet-Dry-Radial vane
Class	C	R-100= (Qn / Qmin)
DN (mm)	15	13
Qn (m3/hr)	1.5	2.5
Display		

Table 5: Coefficients of small caliber meters（ISO4064-1993、Qn=1.5m³/h less)

Classes (ISO4064-1993)	Meter of Qn < 15m3/h Small meters
Class A	-
Value of Q max	2.0 Qn
Value of Qt	0.10 Qn
Value of Qmin	0.10 Qn
Class B	-
Value of Q max	2.0 Qn
Value of Qt	0.08 Qn
Value of Qmin	0.02 Qn
Class C	-
Value of Q max	2.0 Qn
Value of Qt	0.015 Qn
Value of Qmin	0.010 Qn

Qn (m3/h)	DN (mm)
1.5	15
2.5	20

Values of Nominal Diameter(DN mmm)

Source: KWLOG

7.3. Conditions of performance test

<u>Conditions</u>

① Temperature of water used: 20 ± 5 ℃

② Water Quality:

・The test water shall be tap water or equivalent water quality.

・Do not include objects (e.g. air bubbles, floating objects, etc.) that will adversely affect the meter operation.

③ Water pressure: A positive pressure of at least 0.03 Mpa at the meter outlet can be secured steadily.

④ Ambient temperature range: 15 ℃ to 35 ℃

⑤ Range of peripheral relative humidity: 25 ° C to 75 ° C

⑥ Range of surrounding atmospheric pressure: 86 kPa to 75 kPa

⑦ Scope of measurement (R value): Selection from the table (see Table 9.8)

⑧ The pressure loss of the water meter shall be within the operating conditions and shall not exceed 0.063 MPa (6.3 m = 0.63 kg · cm 2) at rated maximum water flow.

7.4. Meter test range of flow rate

Accuracy measurement of the meter is tested at three flow rate points.

① Rated minimum flow rate Q1 = Qmin = 30 L / h

② Transitional flow rate Q 2 = Qt = 120 l / h

③ Nominal flow rate Q3 = Qn = 1,500 L / h

④ Limiting flow rate Q 4 = Qmax = 3,000 L/h

ISO-4046-1993

Class-B	Qmin.	Q2	Q3	Q max
Facters	0.02	0.08	1,500	2.0
Formulas	Qmin ∗ Q3	Q2 ∗ Q3	Q3	2 ∗ Q3
Test Flowrate (l/hr)	**30**	**120**	**1,500**	**3,000**

7.5. Example of Error specification of test flow rate (ISO-4064-2005)

At minimum 3 points calibration point, the test should be conducted in the following flow rate adjustment range. **(Refer to Figure 9)**

· ① First point = between Q1 and Q1 × 1.1

· ② Second point = between Q2 and Q2 × 1.1

· ③ Third point = between (Q 3 × 0.9) and Q 3

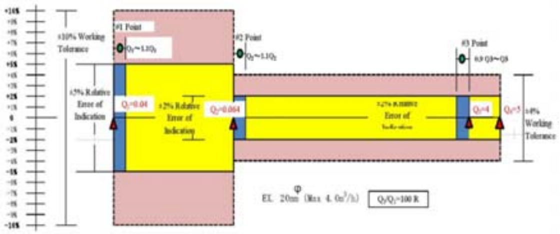


Figure 9: Concept of Detail Error Range of Test Flow

8. How to evaluate the test result

8.1. Calculation method of equipment error ratio

Meter error indicates the ratio between the amount indicated by the meter and the actual amount of water.

$$\text{Relative Error of Indication (\%)} = \frac{I - Q}{Q} \times 100$$

I= Meter's Indication Q= Actual Volume

8.2. Meter test performance curve

(1) Acceptance criteria for tolerance

The allowable range for judging acceptance or rejection of product inspection is shown below. **(Refer to Table 7 and Figure 10)**

① It must be less than the test tolerance of each flow rate.

② If only one flow rate exceeds the test tolerance, the test must be repeated three times, two times within the test tolerance, and the arithmetic mean of the three measurement results shall be within the test tolerance

Table 7: Example of Allowable Tolerance

JIS B 8570-2			
Test tolerance			Flow area
Rated minimum flow rate	Q1 and above	±5%	Small flow rate range
Transitional flow rate	Below Q2		
Nominal flow rate	Q3 and above	±2% (Water temperature : less than 30 degrees)	High flow rate range
Limiting flow rate (max.)	Below Q4		

8.3. Data sheet

Table 8: Example of Measurement Data Sheet (Class-B)

Data Sheet of Water Meter Test Bench at EMBU 2018-March @ EWASCO

P1 inlet pressure = 0.4 bars							P2 outlet pressure = 0.05 bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Total accumulated water Vol. (m3)	Appearance Situation	Flow Rate: Qn (1500 l/h) Total flow vol = 200 lts (Water Tank volume Flowed)					Comments ±4 % (in use)	Comments
								START	END	DIFRENCE		Fluctuation of Error %		
	Volume used ; 200 lts=0.2 m3					0.2 R1 max (m3)		R1max (m3)	R2 max (m3)	R2 max - R1 max (m3)	%			
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

P1 inlet pressure - 0.4 bars							P2 outlet pressure = bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	Appearance Situation	Flow Rate: Qt (120 l/h) Total flow vol= 50 lts (Water Tank volume Flowed)					Comments ± 10% (in use)	Comments
								START	END	DIFRENCE		Fluctuation of Error %		
	Volume used: 50 lts= 0.05 m3					0.05 R2 tf (m3)		R2 tf	R3 tf	R3 tf - R2tf	%			
1														
2														

8.4. Performance curve

(1) Confirmation of Instrument Difference on Estimated Test Flow Curve

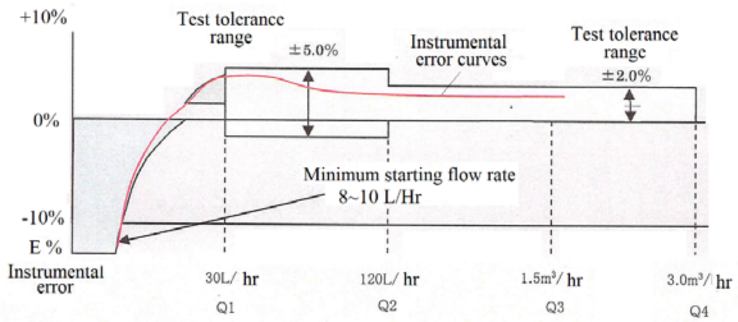


Figure 10: Example of Performance Curve (Class B)

(2) Items to be evaluated

(A) Flow rate of Qn

(B) Flow rate of Qt

(C) Flow rate of Qmin

(D) Examples of comments on;

① Prediction of meter insensitive water amount (distribution analysis table)

② Impact on toll collection

③ Non-revenue reduction effect by exchanging new meter and

④ Others

(a) Calculation of loss volume (loss amount) due to insensitive water amount

(b) Accumulation of expense necessary for exchange meter

(E) Overall evaluation

① Examination of cost effectiveness

② Examination of the timing of meter replacement

③ Confirmation method of investment effect

④ Future improvement plan

9. Analysis of output from water meter test bench training

9.1 Result of OJT Training

Table 9: Example of result of OJT's Water meter Test Bench (Class-B)

Result of Joint OJT at EMBU 2017-June-22 @ EWASCO

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
							Flow Rate: Qn (1500 l/h) Total flow vol = 200 lts						
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	START	END	DIFRENCE		Error	Comments ±4 % (in use)	Comments
Volume used ; 200 lts=0.2 m3						0.2	R1 (m3)	R2 (m3)	R2-R1	%	100%		
1	Old	AC175298	PSM		15	3576.782	3576.782	3576.974	0.192	96%	-4%	Pass	
2	Customer	13081721	psm		15	2355.6125	2355.6125	2355.8089	0.1964	98%	-2%	Pass	
3	New	15-05855	MJET	Kiambu WSP	15	0.4081	0.4081	0.6058	0.1977	99%	-1%	Pass	±2 % (New)
4	Customer	7090712	psm		15	163.3051	163.3051	163.5014	0.1963	98%	-2%	Pass	
5	New	15-05853	MJET	Kiambu WSP	15	0.3868	0.3868	0.5848	0.198	99%	-1%	Pass	±2 % (New)
6	Above 1000	H570060	SJET		15	2779.702	2779.702	2779.891	0.189	94%	-6%	Reject	
7	Above 500	05-1059537	SJET		15	686.1175	686.1175	686.1175	0	0%	-100%	Reject	
8	In Service	8024018	psm		15	0.7072	0.7072	0.9016	0.1944	97%	-3%	Pass	

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
							Flow Rate: Qt (120 l/h) Total flow vol= 50 lts						
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	START	END	DIFRENCE		Error	Comments ±10% (in use)	Comments
Volume used: 50 lts= 0.05 m3						0.05	R2	R3	R3-R2	%	100%		
1	Old	AC175298	PSM		15	3576.974	3576.974	3576.975	0.001	2%	-98%	Reject	
2	Customer	13081721	psm		15	2355.8089	2355.8089	2355.8585	0.0496	99%	-1%	Pass	
3	New	15-05855	MJET	Kiambu WSP	15	0.6058	0.6058	0.6562	0.0504	101%	1%	Pass	±5 % (New)
4	Customer	7090712	psm		15	163.5014	163.5014	163.5525	0.0511	102%	2%	Pass	
5	New	15-05853	MJET	Kiambu WSP	15	0.5848	0.5848	0.6355	0.0507	101%	1%	Pass	±5 % (New)
6	Above 1000	H570060	SJET		15	2779.891	2779.891	2779.938	0.047	94%	-6%	Pass	
7	Above 500	05-1059537	SJET		15	686.1175	686.1175	686.11	-0.0075	??	??	Reject	
8	In Service	8024018	psm		15	0.9016	0.9016	0.9524	0.0508	102%	2%	Pass	

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
							Flow Rate: Qmin (30 l/h) Total flow vol = 20 lts						
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	START	END	DIFRENCE		Error	Comments ±10% (in use)	Comments
Volume used: 20 lts						0.02	R3	R4	R4-R3	%	100%		
1	Old	AC175298	PSM		15	3576.975	3576.975	3576.974	-0.001	??	??	Reject	
2	Customer	13081721	psm		15	2355.8585	2355.8585	2355.8585	0	0%	-100%	Reject	
3	New	15-05855	MJET	Kiambu WSP	15	0.6562	0.6562	0.6756	0.0194	97%	-3%	Pass	±5% (New)
4	Customer	7090712	psm		15	163.5525	163.5525	163.5716	0.0191	95%	-5%	Pass	
5	New	15-05853	MJET	Kiambu WSP	15	0.6355	0.6355	0.6541	0.0186	93%	-7%	Pass	±5% (New)
6	Above 1000	H570060	SJET		15	2779.938	2779.938	2779.958	0.02	100%	0%	Pass	
7	Above 500	05-1059537	SJET		15	686.11	686.11	686.11	0	0%	-100%	Reject	
8	In Service	8024018	psm		15	0.9524	0.9524	0.9718	0.0194	97%	-3%	Pass	

9.2. What is your comment? （Refer to Table 9）

(1) Is the instrumental errors standard of the water meter of WSP fixed?

(2) About the meaning of plus / minus indicated by error rate。

(a) Is the error rate that WSP loses plus/minus?

(b) Is the error rate that the customer loses plus / minus?

(3) About rejected meter of ISO standard.

(a) Which trial flow rate has many rejected goods in using meters?

(b) Which trial flow rate has many rejected goods in NEW meters?

(4) Can you calculate the prediction of commercial loss from the measurement error of the meter?

(5) What is corrective strategy about the claim of the unfair water rates by measurement error of meter?

-END-

Internal Information

TEXTBOOK
FOR
JOINT TRAINING
（DRAFT）

"HOW TO IDENTIFY LEAK BY WATER QUALITY TEST"

R-2

August, 2018

Implemented by
KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)

Ms. B. Maundu #13

Assisted by JICA KENYA

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Email: info@kewi.or.ke, Web: www.kewi.or.ke

Original Edition, First Edition and Second Edition August, 2018

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How to Identify Leak by Water Quality Test 2018 Aug.

1. Objectives (Out-put)

① Understand impart knowledge and skills to trainees on how to carry out water quality test as a tool for leak detection and water theft in visitation

② Understand determination of residual chlorine by colorimetric method collect representative samples,

③ Understand interpret laboratory test results.

④Understand determination of soil pH

⑤ Understand concept of danger prevention equipment

2. Introduction

Water is the primary need in human life. Therefore there is need to distribute water to the consumers with a sufficient quality, quantity, and pressure, which needs a good piping system. However, in its distribution process, sometimes there is some water lost problem caused by the pipe leakage and illegal connection which can be detected by monitoring using basic parameters like pH, free residual chlorine and Conductivity.

3. Key words definition

Water quality	Measurement of suitability of water for desired use
Water analysis	Physical/ Chemical/ Biological examination of water against standards
Sampling	Process of collecting a sample portion from large body for analysis
Sample	A small portion taken from parent material
Represented sample	A small portion that resemble the parent material
Water quality standards	Set standards beyond which water is contaminated
Water quality parameter	Contaminants used in water quality monitoring

4. Method of Water Quality Analysis and Equipment

4-1 Determination of water quality as a tool for leak/water theft investigation.

(1) General

① Residual chlorine measurement is done to determine the presence of residual chlorine in water leakage and to determine the source of water leak.

② "Water" containing residual chlorine may be ~~is~~ treated water or industrial waste water determination of leakage source should be confirmed in combination with other water quality analysis methods. It is also important to comprehensively grasp information on the environment and buried pipe at the site.

③ The residual chlorine concentration at the consumer point ~~of the faucet~~ is about 0.1 to 0.2 mg / liter of free residual chlorine.

④ It is desirable to carry out "multiple times" water quality test to improve the accuracy of judgment

⑤ Examples of water sources containing chlorine are shown below.

(a) drinking water
(b) Spillage of disinfectant for water supply and pool
(c) Drainage of pool water (standard value: about 0.4 mg / liter)
(d) Process drainage of sterilization, Deodorization, washing water, etc. in the food industry, etc.

4-2 Determination of residual chlorine by colorimetric method

(1) Application

(a) Normally there is residual chlorine in tap water.

(b) In the colorimetric method, a reagent is added to the test water, and the leak source is judged from the reaction color.
(c) Generally, the DPD method is used. (**Refer to figure 1**)

(2) Reagent to be used
(1),Diethyl Para Phenylene diamine(DPD method)
(a) Reacted color
·●Peach → peach red discoloration
●When there is an interfering substance, it fades instantly and it may change to other color.
(b) Substances that interfere with the reaction
Interfering substances include the following. (Bromine, iodine, chlorine dioxide, ozone, manganese, chromium, aluminum, iron, copper, nitrite nitrogen, alkalinity · acidity)

(2) Reaction colour by the Orthototidine method (OT method)
Note: The use of OT method is currently banned in some countries due to suspected carcinogenic health concerns.
(a) Reactive colour
· Light yellow → change to yellowish brown

DPD reagent used OT reagent used

Figure 1: Colorimetric reaction with residual chlorine

Powder / solid DPD reagents Residual chlorine analyzer Spectrophotometric residual chlorine analyzer

Figure 2: Example of residual chlorine measurement method

4-3 Measurement of water temperature

(1) Application
① Water leakage survey
Water temperature of tap water is different from groundwater, sewage and the like, and it can be determined from water temperature measurement in some cases. In general, the water temperature of the groundwater changes "not much change throughout the year" but the others change.

② Water pressure change
The water temperature gauge is used to check the change of the pressure in the pipe due to the change of the water temperature.

(2) Model
A common water temperature gauge uses a red liquid thermometer made of glass.
① Mercury thermometer · · · High precision and wide operating temperature range.

② Red liquid thermometer · · The accuracy is slightly inferior, but it is easy to see.

(3) Features
① The difference between the expansion coefficient of alcohol and mercury used for water temperature measurement for water supply can be neglected.

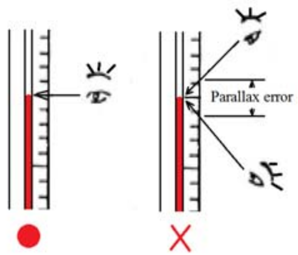
② When the water temperature gauge breaks, alcohol (coloring kerosene to red) thermometer is safer.

(4) Classification by shape etc.
① Bar thermometer:
The scale is carved directly on the surface of the glass tube, it is hard to read, but it is strong.

② Double tube thermometer:
Since the scale is engraved on the glass plate behind the capillary tube, it can be read accurately.

(5) Handling Considerations
① Out of liquid
Since the temperature sensitive liquid of the glass thermometer may be cut in the middle of the temperature-sensitive liquid column due to vibration, shock, abnormal partial heating or the like, space may be generated. Before using it, be sure to check that there is no liquid break about.

② Parallax · · ·
When reading the reading of the glass thermometer, read your eyes vertically to the temperature-sensitive liquid column and within the same horizontal plane as the liquid column top. (**Refer to Figure 3**)



Rod like red liquid thermometer

How to read the water temperature gauge

Figure 3: Measurement of water temperature gauge

4-4 Measurement of Conductivity

(1) Application

Conductivity measurement the instrument measures the amount of soluble substances in water (indicator showing how much substance is dissolved in liquid). (**Refer to Figure 4**)

Figure 4: Example of portable electric conduction measuring instrument

(2) Relationship between electrical conductivity and water temperature

(a) It is usual to display the electric conductivity at 25 ° C because the electrical conductivity increases as the water temperature rises (about 2% increase at 1 ℃ rise).

(b) The electrical conductivity of tap water whose source is surface water as raw is about 100 to 300 µS / cm, but it varies with weather, season, and water quality, so the exact numerical value will be confirmed by water quality analysis. (**Refer to Table 5**)

(c) The unit is in the relationship of conductivity = µS / cm = 1 / (Ω · cm).

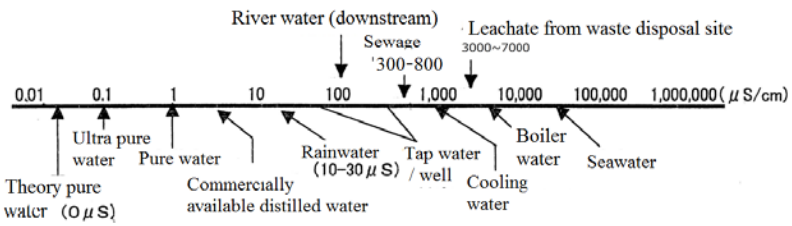


Fig. 5: Approximate electric conductivity (@25 ° C)

4-5 Measurement of pH value

(1) What is pH measurement?

It represents the degree (strength) of acidity / alkalinity of the aqueous solution, and it is to measure the numerical value from 0 to 14. (Refer to Table 1)

Table 1 pH classification

pH	Nature of the liquid
0～3.0	Acidic
3.0～6.0	Mild acidity
6.0～8.0	Neutral

8.0～11.0	Weakly alkaline
11.0～14	Alkaline

(2) Application

(a) Measure the degree of pH of test water. (Used as a judgment index of leak source)

(b) Investigate corrosion environment degree of piping from soil pH of buried pipe.

(3) Measurement method

(a) Abbreviation for pH meter (pH: potential Hydrogen, power of Hydrogen)

● The pH of the tap water (5.8 to 8.6) is close to the pH of natural water, and it is decided that the value around neutral is desirable from the viewpoint of preventing corrosion etc. of the water supply facility. **(Refer to Figure 6 and 7)**

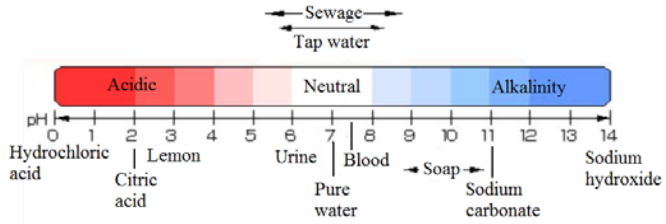


Figure 6: Comparison of pH values

Figure 7: Example of pH measurement instrument

(b) Litmus paper

● Application

Litmus paper is a paper impregnated with litmus solution and is used to easily distinguish acidity / alkalinity of liquid. (**Refer to Table 1**)

● Type

There are a roll type, a book type (there are two kinds of blue and red) and a bottle type in Test paper. **(Refer to Figure 8)**

● Measuring method

① Gently put the litmus paper into the liquid and raise it within 1 second.

② Shake the test paper gently to remove any excessive liquid

③ Compare the wetted part with liquid to the standard discoloration table within 5 seconds and read the pH.

④Reactive color (for book type)

● In the case of acidity

Blue test paper → turn red. (PH = 6 to 0)
In case of neutral · · · not discoloring (pH = 8 ~ 6)

● In case of alkaline
Red test paper turns to blue (pH = 8 to 14)

Roll Type

Book Type

Figure 8 Types of litmus paper

5 . Soil pH

(1) Purpose

Soil pH affects external corrosion of buried pipe.
When implementing water leakage repair, it is necessary to measure soil pH in the vicinity of burial, to utilize it to analyze the cause of water leakage and preserve analysis records.

Incidentally, corrosion of the buried pipe complicates overlapping of various values in addition to the pH value, and corrosion occurs / progresses, but measurement of soil pH value is important. (**Refer to 4, (4) - (c)**)

·

● Corrosion rate increases when pH is 4 or lower
● PH value of acid rain (5.6 or less)
● Tap water (5.8 to 8.6)

(2) Measurement procedure (simple soil pH measurement method)

(a) Overview

After washing the dried sampling soil with tap water, measure the pH with Supernatant water with litmus paper.

(b) What to prepare

① Soil (dried in air): 20 g
② Beaker (50 ml or 100 ml)
③ Measuring cylinder (container)
④ Weight scale and Glass rod
⑤ Pure water (or tap water *)
⑥ pH test paper (pH 4 to 7 can be measured)

Figure 9: Analytical balance and test paper

(c) Experiment method

Step-1; Weigh the soil dried in air (20 g) into a beaker

Step-2; Add 50 ml of tap water and stir with a glass rod for about 3 minutes.
(Or put in a lidded container and shake vigorously for 1 minute)

Step-3; Leave it for about 2 to 5 minutes until the supernatant becomes transparent.

Step-4; Apply pH test paper (litmus paper) cut to 1 to 2 cm to the supernatant, and measure the pH against the color sample. **(Refer to Table 2**)

◆ **NOTE:**
As time passes, colour changes color, so quickly collates with colour sample

(d) Fill in the recording form, and utilize / keep it. (**Refer to Table 4 Installation Environment)**

Table 2 Relationship between soil pH value and iron corrosion degree

pH value	Degree of corrosion
4.5 or less Acidic	Extremely corrosive
4.5 ~ 6.5 Weakly acidic	Corrosive
6.5 to 8.5 Neutral or weakly alkaline	Non corrosive
More than 8.5 alkaline	—

Source: Electric erosion and soil erosion handbook (1966)

6 . Equipment to prevent danger

(1) Application

(a) Danger prevention equipment

It is equipment to ensure the safety of the working environment so as not to cause occupational injury accidents when conducting leakage survey

(b) Securing traffic safety during work

When conducting water leakage survey and repair work, implement traffic accident countermeasures

(2) Type of safety / security equipment

a) Toxic gas detector

The toxic gas detector is a device for always conducting an inspection before the leakage prevention work is started in order to prevent workers' accidents of staff at dangerous places.

Analysis of hazardous gases is carried out with dedicated measuring instruments, but we will ask surveys by specialized agencies as much as possible.

(a) Example of detection device (Refer to Figure 12-9)

① Explosion by flammable gas: methane gas (CH 4),
② Asphyxia caused by oxygen-deficient air: Oxygen concentration meter
③ Gas intoxication due to harmful gas: hydrogen sulphide, carbon monoxide

Figure 10 Example of Multi Gas Detector

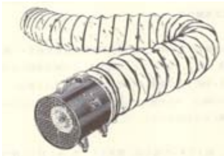
(3) Security equipment ~~Tools~~

Safety equipment is a tool to prevent accidents caused by occupational accidents, and equipment such as ventilator, air respirator, oxygen concentration meter, shall be prepared as necessary. **(Refer to Figure 11)**

Oxygen/Air respirator

Gas mask

Oxygen concentration meter



Mechanical ventilator

Figure 11 Example of Safety equipment ~~tools~~

- END-

Internal Information

TEXTBOOK

FOR

JOINT TRAINING

（DRAFT）

"PLANNING AND IMPLEMENTING A NRW REDUCTION STRATEGY"

R-1

August, 2018

Implemented by
KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)
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Original Edition, First Edition August, 2018

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1. Objectives (Out-put)

① Understand objective of planning and implementing NRW reduction Strategy
② Understand steps in developing and implementing NRW reduction plan.
③ Understand concept of self-assessment plan
④ Understand concept of action schedule
⑤ Understand WASREB tools for NRW reduction plan by WSPs

2. Introduction

The key to developing a strategy for management of non-revenue water (NRW) is to gain a better understanding of the reasons for NRW, and the factors which influence its components. Then techniques and procedures can be developed and tailored to the specific characteristics of the network and local influencing factors, to tackle each of the components in order of priority. This diagnostic approach, followed by the practical implementation of solutions which are practicable and achievable, can be applied to any water company to develop a strategy for NRW management.

The first step in planning and implementing a NRW reduction strategy is to ask some questions about the network characteristics and the operating practices, and then use the available tools and mechanisms to suggest appropriate solutions for formulating the strategy. Typical questions are:

- **How much** water is being lost?
- **Where** is it being lost from?
- **Why** is it being lost?
- **What** strategies can be introduced to **reduce** losses and **improve** performance?
- **How** can we **maintain** the strategy and **sustain** the achievements gained?

(1) The first two questions: **"how much"**? and **"where from"**? can be addressed by conducting and analyzing the water balance.

(2) The components of NRW, and the priority areas of the network for investigation, can be determined by conducting a **water balance**.

(3) The planning and implementation of the NRW strategy addresses the remaining three questions – "**why** is water lost?", "**how** can we control losses?", and "**what** policies can be put in place to sustain the improvements?"

(4) Tasks and tools for development the NRW reduction strategy is shown in **Table 1**.

Table 1: Tasks and tools for developing a NRW reduction strategy

QUESTION	TASK
1. How much water is being lost? ... Measure components	**Water balance** ... Improve estimation/measurement techniques ... Meter calibration policy ... Meter checks ... Identify improvements to recording procedures
2. Where is it being lost from? ... Quantify leakage ... Quantify apparent losses	**Network audit** ... Leakage studies (reservoirs, transmission mains, distribution network) ... Operational/customer investigations
3. Why is it being lost? ... Conduct network and operational audit	**Review of network operating practices** Investigate: historical reasons ... poor practices ... quality management procedures ... poor materials/infrastructure ... local/political influences ... cultural/social/financial factors
4. How to improve performance? ... Design a strategy and action plans	**Up grading and strategy development** ... Update records systems ... Introduce zoning ... Introduce leakage monitoring ... Address causes of apparent losses ... Initiate leak detection/repair policy – design short-medium-long-term action plans
5. How to maintain the strategy?	**Policy change, training and O&M** ◆ Training: o Improve awareness o Increase motivation o Transfer skills o Introduce best practice/technology ◆ Operation and maintenance: o Community involvement o Water conservation and demand management Programs. o Action plan recommendations o O&M procedures

Planning and Implementing NRW Reduction Strategy 2018 Aug.

3. Key words definition

Strategy	A plan of action designed to achieve a long-term or overall aim.
Target	The process of identifying something that you want to accomplish and establishing measurable goals and timeframes.
Prioritization	To arrange (items to be attended to) in order of their relative importance
Monitoring	Observe and check the progress or quality of (something) over a period of time; keep under systematic review.
Sustainability	The ability to be maintained at a certain rate or level.

4. Planning and Implementing a NRW reduction Strategy

Water is a fundamental resource for human and economic development. Many water Utilities in Kenya, are not able to account for large portions of water they deliver.
In some cases, the NRW is above 50%. This is a major cause of concern in terms of inefficient use of the scarce water resources.

It also affects a Utility ability to earn revenue to support its financial sustainability and thereby offer efficient services. A utility which has high NRW means it has lower revenue which implies it does not have funding to fix the problem that causes NRW and NRW increases.

In order to address the situation of high NRW and achieve the required efficiency, a water utility need to operate in an environment in which NRW declines, revenues increase, the utility has funding to invest in system improvement and network expansion resulting to further decline in NRW.

◆ **Developing and implementing a successful NRW reduction plan entail the following steps.**

Step 1: Gain support for a Non-Revenue Water Reduction Project.
NRW programmes require resources and time which are scarce. Therefore the first step should be to outline an NRW programme.

The programme should show the anticipated benefits in order to gain support of utility leadership and customers.

Step 2: Establish an NRW management team.
The team performs the analysis and develops a strategy, recommends intervention and oversee simple mentation.
The team must include members from all the utility departments that are Administration, Technical (production, distribution) and incorporate (customer service, communication etc).

This is crucial in order to promote ownership and build consensus by the utility senior management.

Step 3: Calculate the water balance.
The water balance will show the magnitude of the losses and the areas where NRW is present. This will enable making decisions in the use of the limited utility resources in areas of high return in revenue and cost cutting.

Step 4: Set NRW reduction targets.

The utility should set realistic targets for NRW reduction taking into consideration the utility's goals, policies and resources and any targets established by the National water policy and the regulator.

The National Water Services Strategy (NWSS-2007-2015) for NRW is 42% by 2015 while the benchmark by WASREB is 20% in 2030.

Step 5: Identify NRW reduction projects.

Undertaking Pilot Project to demonstrate the effectiveness of NRW reduction is a useful way to start because it will generate lessons and it will show the value of NRW reduction strategy.

Pilot Project cover small areas that are still large enough to test the NRW reduction strategy.

The type of pilot projects can vary from improved metering to better customer accounting to full-scale repair and rehabilitation of the network and customer service connections.

Step 6: Prioritize NRW projects.

Most utilities face scarce resources in staffing, equipment or funding.

The potential projects will have different levels of payback, impacts on service, timing etc. Prioritizing is the way to select the projects that will have the greatest overall benefit and to decide on the timing of when projects are accomplished.

Some projects may reduce NRW significantly but will have a high cost. Others may have a lower cost and lower reduction but can be accomplished more readily because resources are available. Gains from doing these projects may generate additional revenues, which can then be used to accomplish the more expensive projects.

Step 7: Planning and Approvals

In order to gain resources, the NRW team will need a budget that is approved by the utility leadership.

Therefore when developing a NRW plan, remember that reducing NRW is not a short- term process. Some activities may span years rather than months.

A time frame between four and seven years is reasonable. Anything less is ambitious and any more will not be as cost effective. In preparing the budget, the team must identify costs that may include:

(1) Staffing for both direct NRW Works (e.g. Leakage technicians) and indirect support (e.g. Procurement staff)

(2) Equipment installed permanently (e.g. OMA meters) and those used on a day to day basis (e.g. Leakage detection equipment)

(3) Vehicle and equipment to maximize the productivity of staff.

Step 8: Implementation and Monitoring.

As the Project takes place, it is a good idea to monitor both the costs and benefits and compare them to budgets and NRW targets.

This will demonstrate the benefits of NRW reduction and build support for the strategy. It will also allow the team to take action to improve performance as needed.

Step 9: Sustain the gains of an NRW reduction projects.

NRW management is a continuous process. Even after the initial gains are made, NRW must continue to be managed.

This requires vigilance and attention to make sure that leaks are eliminated when they occur, that all customers are legally connected and billed and all water uses are tracked.

5. Contents and Layout of NRW Reduction Plan

There are many activities that constitute NRW reduction measures.

The purpose of a NRW Reduction Plans to determine the most suitable measures for adoption and use the available budget effectively. A NRW Reduction Plan must include the following components:

5-1. Introduction

This covers the WSP's background; rationale for the Reduction Plan, assumption in developing the plan methodology of developing the plan, and organization of the plan.

As geographical and social conditions are unique to each WSP, any existing problems related to these conditions must be identified. Hence the overall management, financial status and funds availability are all important factors in the planning for NRW reduction.

5-2. Analysis of the Current Status

It is important to first understand the current situation that is causing high NRW in the WSPs. Therefore the analysis of the current status should be based on a self-assessment carried out by the WSPs using the SELF ASSESSMENT MATRIX.

As a first step it is important to understand to what happens to water when it enters the network. Therefore NRW ratio must be calculated by using volume of distributed water (system input volume) and billed authorized consumption volume.

In cases where the volume of distributed water and/or volume of consumption cannot be correctly established, then the priority should be placed on the installation of flow meters and/or water meters.

5-3. Setting Targets (Target NRW ratio and target area)

A companywide target for NRW reduction, taking into account the utilities other goals or policies that will either complement or conflict with NRW reduction should first be established.

This target should be guided by the National water services strategy and the sector benchmark as issued by the Regulator. Often, many utilities chose the NRW target arbitrarily, without any real consideration of cost implications or whether it is achievable.

Identifying the economic level of NRW is essential to setting the initial NRW target, and it requires a comparison of the cost of water being lost versus the cost of undertaking NRW reduction activities.

For utilities with more than 35 % NRW ratio, commercial loss reduction and visible leakage reduction measures must be given priority.

For those utilities with NRW ratio of between 35% and 25%, invisible leak detection and repair are necessary. At 25% to 15%, it is necessary to replace aging pipes.

Significant amount of funds will be required to replace all aging pipes and therefore, it is necessary to prioritize areas and also activities.

Generally, leakage occurrence record must be plotted onto a map, which will show areas with high occurrences of leakages.

Areas with high water pressures and also large pressure variations should be given priority. Further if there are any asbestos cement pipes, replacement of those must be prioritized.

5-4. Implementation plan of NRW reduction

It presents the implementation matrix, which covers for each of the strategies, proposed actions, Bill of Quantities and Cost Estimates, Implementation Schedule, expected outputs and output indicators.

5-5. Monitoring and Evaluation

This is essential for the success of the NRW management programme.

It allows managers to track progress against plans, budgets and expected results in the form of performance indicators.

It also allows managers to take action when performance is lagging behind expectations or exceeding budgets. To achieve the desired results from this plan, Monitoring through regular observation and recording of activities taking place is important.

6. Prioritization Implementation Plan of NRW Reduction

Once the utility-wide NRW target is set, utility managers should calculate the proposed volume of water saved by comparing the NRW baseline with the target level.

The various components, as detailed in the implementation plan for NRW reduction **Table 1** are then prioritized according to how the required total reduction can be most cost-effectively achieved.

That is, some components may comprise a significant volume, but would not be targeted because of the high cost to achieve reductions in that component. On the other hand, focusing on another component may cost less while reducing the same volume.

Therefore, the scope of implementation will depend on the financial capability of each and be guided by the action plan in **Table 2**.

In general, if a physical loss is detected and repaired hen the savings will be in terms of a reduction in variable operational costs.

When a commercial loss is detected and resolved, then the saving will be an immediate revenue increase and this is based on the water sales tariff.

The water sales tariffs higher than the variable production cost for all profitable water utilities. Therefore, a smaller volume of commercial loss may have a higher financial value, so if increasing financial resources is the objective, then commercial losses should be prioritized.

Similarly, where a water utility has a shortage of treated water, and some customers receive less than a 24-hour supply or the supply coverage is less than 100%, then reduction in physical losses would effectively create additional water supply.

◆ **NOTE:**
Hence if increasing water supply is the objective, then prioritizing physical losses could enable customers to receive water 24 hours a day, or new customers to be connected to the supply system.

Table 2: Example of Implementation plan of NRW reduction

Issue	Activity	Description	Concept and Quantified Aim
Fundamental measures: Water balance, Flow, pressure monitoring	Water balance	Establish water balance	- This should be the first step in NRW reduction plan in order to establish the necessary components
	System input metering	Install production meter	- To determine actual levels of authorized consumption and water losses in the water supply. - It is imperative that master meters must be installed at the exit of water treatment plants and bulk meters at the at the entrance of each zone.
	Consumer metering	Install customer meters	- Installation of consumer meters at every consumer point to measure actual consumption and therefore assist in the determination of NRW
	Pressure monitoring	Pressure gauge installation	- Determine current water pressure
	Water pressure maps	Water pressure map	- Water pressure must be prepared from the results of the pressure gauges
	Maps/GIS	Pipeline map	- Pipe network maps and drawings are absolutely necessary for WSPs to implement efficient and effective NRW reduction measures in the absence of drawings the WSP should start by constructing drawings of distribution mains and appurtenances. Information should include: type, age length, valves, size.
		Digitize mapping data	- Comprehensive map of the pipeline by CAD
	Leak repair records	Check and repair leaks Report and repair leaks promptly Check and report meter tampering	- Necessary to provide repair records including: diameter material, location, date of repair.
	Provision of Basic equipment		- Procurement of NRW reduction equipment. To carry out leakage control work. - Minimum requirements: listening stick, electronic leak detector, pipe locator Metallic and non-metallic)
	DMA		- Establishment of DMAs require a lot of resources. It is therefore recommended to start by establishing a pilot DMA and to conduct training on NRW reduction measures to relevant staff.
Reduce commercial losses	Customer metering	Inspection of customer meters	- Inspection of stuck meters, non-active and aged meters
		Ensure 100% meter connection	- Improve customer meter ration
	Replacement of aged	Replacement of non-active	- Investigate all suspected customer meter

	Customer meters.	and/or aged meters	tampering - Repair or replace faulty customer meters
	Customer meter class	Procure meters that meet set standards	- Replace meters not meeting required specifications
	Customer database	Customer data base and billing	- Update and maintain database with specific times of update - Procure suitable software to manage database
	Customer meter reading	Bill all customers on monthly basis	- Develop schedule on meter reading cycle
		Reduce errors in meter reading	- printing of meter reading books - Capturing all meter readings - Bill adjustments - Process the bills
	Illegal connections, meter tampering, bypass.	Inspect illegal and dormant accounts	- Identify illegal accounts - Disconnect/legalize accounts Management to be more vigilant in dealing with corruption cases like meter interference, illegal connections etc.
		Form inspection team, take legal action on illegal cases, random monthly inspection by Senior management	
Reduce physical losses	Active leak control	Leak detection	- Conduct continuous leak detection on non-visible leaks
		Leak repair	- In principal, detected leaks must be repaired immediately
		Replacement of service pipes	- When frequent leaks occur in pipelines, replacement is preferable other than repair.
		Replacement of distribution pipes	- Effect plan for distribution pipe replacement by providing adequate financial resources
	Reduction of leak repair time in distribution system	Record time taken to repair leaks. Analyze data to determine average time taken.	- Reduce reaction time of pipe repair to 6 hrs. irrespective of size.
	Water pressure management	Use pressure reducing valves (PRV)	- Water pressure of about 1MPs must be maintained as much as possible throughout the distribution system.
Capacity building	Training on NRW management	Train relevant staff on NRW management	- To improve technical skills and capacity.
		Field visits	
		OJT	
Public awareness	Awareness of stakeholders on NRW management	NRW public campaign	Create stakeholder awareness for proper water use and disseminate benefits of NRW management

7. WASREB tools for NRW Reduction Plan by WSPs

7-1. Self-Assessment Matrix by WSPS

WSPs are required to prepare their own Non Revenue Reduction Plans based on the information and practical guidelines as enumerated by WASREB standards for NRW reduction.

WSPs should take into consideration the characteristics and conditions of its service area to ensure that procedures and measures established in the Reduction plan prepared in this manner will be custom made and therefore best suited to reduce Non Revenue water effectively.

At the start of NRW activities, WSPs are required to conduct **self-assessment** in accordance with the matrix shown below:

Table 3: Example for Self-assessment format

	Level / Issues	1 Basic	2	3	4	5 High
1	Water Balance, Flow and Pressure Monitoring, Mapping					
1.1	Water Balance	We have not established a water balance table	We have tried to establish a water balance table but gave up since we don't know the split in physical and commercial losses	We have established a water balance table following our own format	We have established an annual water balance table in accordance with the international format	We have established an annual water balance table in accordance with the international format and also use 95% confidence limits to indicate accuracy levels.
1.2	System Input Metering	Most of our system input is not metered	Not all, but less than 50% of our system input is metered	Our system input is metered but we are not sure about the accuracy of the meter readings	Our system input is metered with mechanical and/ or magnetic flow meters that are rarely calibrated	Our system input is metered with magnetic flow meters that are regularly calibrated
1.3	Pressure Monitoring	We do not have any pressure recorders installed	We have a few pressure recorders installed at pumping stations and treatment plants	We have a few pressure recorders installed at pumping stations and treatment plants and sporadically measure pressure in the distribution network with pressure gauges	We have a few pressure recorders installed at pumping station and treatment plants and sporadically measure pressure in the distribution network with pressure loggers	We have permanently installed pressure loggers and continuously monitor pressure in the distribution network
1.4	Maps/GIS	We do not have maps at all	We have maps, but they are not updated	We have started to update our maps	Our maps are updated but do not include GIS	We use GIS based on updated maps

	Level / Issues	1 Basic	2	3	4	5 High
2	**Leak Repair Records**					
2.1	Leak Repair Records	We have no records of leak repairs	The only way to know the number of leaks repaired is to look into the customer complaints book	We keep basic leak repair records that only tell us whether the leak was on a main pipe or a service connection	We keep detailed records that indicate location, pipe diameter, material and type of leak as well date of detection and date and duration of repair	We keep detailed records that indicate location, pipe diameter, material and type of leak, date of detection, date and duration of repair and have linked this to our GIS
3	**Performance Indicators**					
3.1	Performance Indicators	The only PI used is % NRW	We have tried to calculate water loss performance indicators	We regularly calculate physical losses performance indicators	We regularly calculate physical and commercial losses performance indicators	We regularly calculate physical and commercial losses performance indicators and publish them in our annual report
4	**Active leakage control**					
4.1	Active leakage control	We only repair visible leaks.	We have leak detection equipment but we do not use it.	We carry out leak detection occasionally if there is a specific problem in an area.	We have started to do regular leak surveys.	We cover the network by leakage survey at least once a year.
4.2	District Meter Areas (DMAs)	We have no DMAs and have no plans to establish DMAs	We have started to establish the first DMAs	The first DMAs are established and we have already obtained the first results	We have several DMAs and sporadically check and analyze inflow data	We have several DMAs and monitor flow and pressure on a regular basis
4.3	Leak Repair - Distribution Pipes (Repair Time)	We have no records and therefore don't know how fast our leaks are repaired	Our average repair time is more than 7 days per leak	Our average repair time is between 7 and 3 days per leak	Our average repair time is between 3 and 1.5 days per leak	Our average repair time is less than 1.5 days per leak
4.4	Leak Repair - House Connections	We have no records and therefore don't know how fast our leaks are repaired	Our average repair time is more than 14 days per leak	Our average repair time is between 14 and 7 days per leak	Our average repair time is between 7 and 2 days per leak	Our average repair time is less than 2 days per leak
5	**Customer Metering**					
5.1	Customer Metering	We have no customer metering	Only large customers are metered	We have started with universal customer meters but at present not all customers are metered	Nearly all our customers are metered, except public fountains, stand pies and connections of similar nature.	100% of our customers are metered
5.2	Customer Meter Replacement and Age	We do not have reliable information on the age of our customer meters	Many of our customer meters are older than 10 years, we have not yet introduced meter replacement policy	We only change or replace meters if they stop functioning	We have a meter replacement policy but have not been able to replace all meters so some of our customer meters are still older than 10 years	We strictly follow our customer meter replacement policy and replace ALL meters which are 5 - 7 years old

	Level / Issues	1 Basic	2	3	4	5 High
5.6	Illegal Connections, meter tampering, bypasses	We have not made any assessment and have no program to deal with water theft	We occasionally detect illegal connections	We occasionally detect illegal connections and other forms of fraud	We have a thorough illegal connection detection program	We have a thorough illegal connection detection program and also identify bypasses

Planning and Implementing NRW Reduction Strategy 2018 Aug.

8. Analysis and Self-assessment and Action schedule

8-1 By WSPs

Based on the self-assessment matrix submitted by WSPs, WSBs analyses the priority activities to be implemented the WSP. **(Refer to Table 4)**

8-2 By WSB

Also, WSPs Self-assessment should be evaluates by WSB (County Government) for budgetary request to the Central Government. (**Refer to Table 5**)

8-3 Action schedule by WSP/WSB

(Refer to Table-6)

Table 4: Example of Analysis and Self-assessment

Issues and questions	Focal Point	Activities by WSB
1. Water Balance, Flow and Pressure Monitoring, Mapping		
1.1 Water Balance	Accurate volume of NRW must be determined. In order to determine this, accurate volume of distributed water (system input) and accurate volume of water consumption are required.	In cases where minimum requirement of flow meters are not installed, installation of the flow meters must be prioritized
1.2 System Input Metering	Determine that flow meters are giving accurate readings.	In cases where minimum required flow meters installed are not accurate, inaccurate flow meters must be identified and replaced at the earliest opportunity.
1.3 Pressure Monitoring	Determine current water pressures. Water pressure of around 1 MPa must be maintained as much as possible throughout the distribution system.	Water pressure map must be prepared using water pressure gauge. Pressure Reducing Valves – PRV must be installed or rearrangement of distributed pipe lines will be necessary.
1.4 Maps/GIS	Accurate pipe drawings must be prepared.	In case there are no pipe network drawings, WSP must prepare them. WSB provides training for Mapping.
2. Leak Repair Records		
2.1 Leak Repair Records	Records of repair work must be maintained. Results must be recorded and reflected on the existing pipe drawings.	WSB provides training for improvement of information system.
3. Performance Indicators Refer to Chapter 3		
4. Active leakage control		
4.1 Active leakage control 4.2 District Meter Area (DMA) 4.3 Leak Repair Distribution Pipes (Repair Time) 4.4 Leak Repair – House connections	WSB must seek to support the implementation of efficient and effective leakage control measures for all WSP.	WSB must provide the following. - Orientation in the organization necessary for NRW reduction measures. - Procurement of necessary equipment - Training for use of equipment - Budget provision for implementation of NRW reduction activities based on priority of each WSP.
5. Customer Metering		
5.1 Customer Metering	Complete understanding on volume of customer consumption and customer meters.	Awareness creation on the need for 100% installation of customer water meters. Budget provision for installing customer water meters.

5.2 Replacement of non-active and/or aged customer meter	Determine the water meters that need to be replaced. Oldest meters and those in worst conditions should be prioritized.	Training must be conducted for specified meter qualification test (Meter Test). Budget must be prepared for replacement of customer water meters.
5.3 Customer Meter Class	Determine the type of meters installed. The most suitable type of meters for the site condition must be selected.	Training must be conducted for knowledge on water meter types and meter mechanisms.
5.4 Customer Database	Customer information must be rationalized for a more comprehensive management of NRW reduction.	Information Management System such as the GIS should be introduced. Training must be conducted for GIS.
5.5 Customer Meter Reading	Customer meter reading errors must be detected and eliminated.	Training must be conducted for accurate meter reading. Electronic meter reading devices and computerized billing system must be introduced.
5.6 Illegal Connections, meter tampering, bypasses	Detect illegal connections as much as possible. The best way to eliminate illegal connections is to replace all service pipes.	Penalties must be implemented as stipulated by law, and water theft must be punished. Illegal connections must all be legalized.

Table 5: Example of Format for NRW reduction Plan for WSB base on Self- assessment by WSPS

	Issues / questions	Current Status	Desired Status / Target	Short Term Measure	Resources Required	By Whom	By When
1	Water Balance, Flow and Pressure Monitoring, Mapping						
1.1	Water Balance						
1.2	System Input Metering						
1.3	Pressure Monitoring						
1.4	Maps/GIS						
2	Leak Repair Records						
2.1	Leak Repair Records						
3	Performance Indicators						
3.1	Performance Indicators						
4	Active leakage control						
4.1	Active leakage control						
4.2	District Meter Areas (DMAs)						
4.3	Leak Repair - Distribution Pipes (Repair Time)						
4.4	Leak Repair - House Connections						
5	Customer Metering						
5.1	Customer Metering						
5.2	Customer Meter Replacement and Age						
5.3	Customer Meter Class						
5.4	Customer Database						
5.5	Customer Meter Reading						
5.6	Illegal Connections, meter tampering, bypasses						

Table 6: Example of Action schedule (For WSP/WSB)

ACTION SHEDULE BASED ON FORM-7, BY WSP
(Name of XXX WSP)

Form-7
Date :As of XXXX-XX-XX

	Descriptions	Desired Status /Target	2018			2019												2020												2021	2022	2023	2024
			Apr	May	Jun	Jul	Au	Sep	Oct	No	De	Jan	Feb	Ma	Apr	Ma	Jun	Jul	Au	Sep	Oct	No	De	Jan	Feb	Ma	Apr	Ma	Jun				
A	Establishment of the organization for NRW Reduction																																
B	Establishment of the Department for Data and Information Management																																
C	Non-Revenue Water Reduction Rate (%)	From xx (%)																															
		To xx (%)																															
D	Budget	Phase-1																															
		Phase-2																															
		Phase-3																															
		Phase-4																															
1	Water Balance, Flow and Pressure Monitoring, Mapping																																
1.1	Water Balance																																
1.2	System Input Metering																																
1.3	Pressure Monitoring																																
1.4	Maps/GIS																																
2	Leak Repair Records																																
2.1	Leak Repair Records																																
3	Performance Indicators																																
3.1	Performance Indicators																																
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5.2	Customer Meter Replacement and Age																																
5.3	Customer Meter Class																																
5.4	Customer Database																																
5.5	Customer Meter Reading																																
5.6	Illegal Connections, meter tampering, bypasses																																

-END-

Internal Information

TEXTBOOK
FOR
JOINT TRAINING

"FIELD ON-JOB TRAINING"
(Field Technician)
(R-3)

February, 2019

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)
W. Moseti #15

Assisted by JICA KENYA

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Original Edition, First Edition, Second Edition and Third Edition
February, 2019

Table of contents

1. Outline of training DMA

(1) Area: about 83,000 m2

(2) Number of Customer meters: 150 pieces

(3) Extended pipe-line: Diameter 63~100 mm (PVC)

Diameter 20 mm (PVC)

Diameter 32~50 mm (HDPRE)

(4 Total length:2,500 m

(5) MAP of DMA

In the DMA diagram, position information such as a gate valve for isolating the DMA, route of pipeline, diameter, material, flowmeters, air valves, drain valves, water meters, etc. are described. **(Refer to Figure 1)**

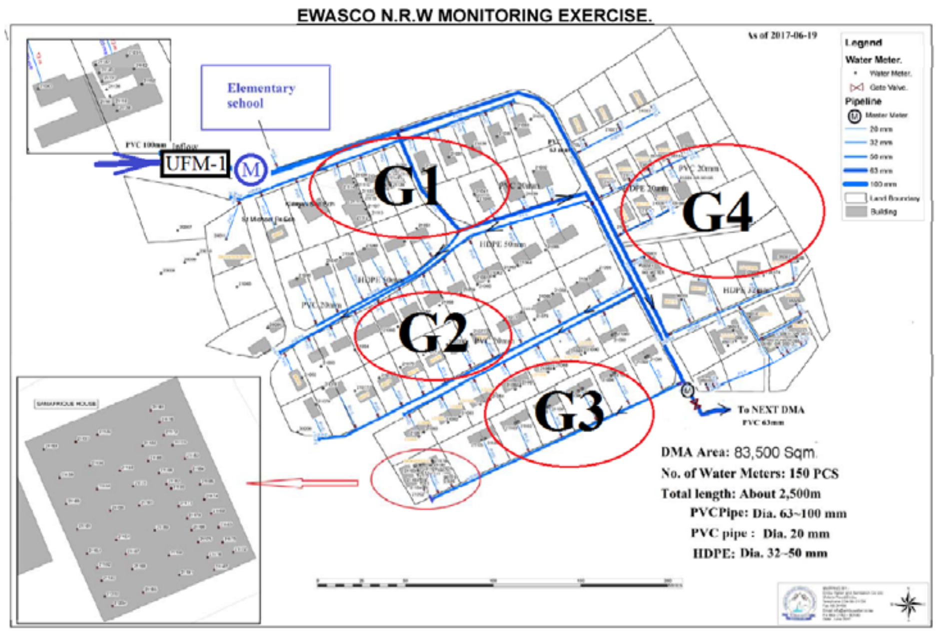


Figure 1 Example of DMA for Training at MTETU in EMBU (Option-1)

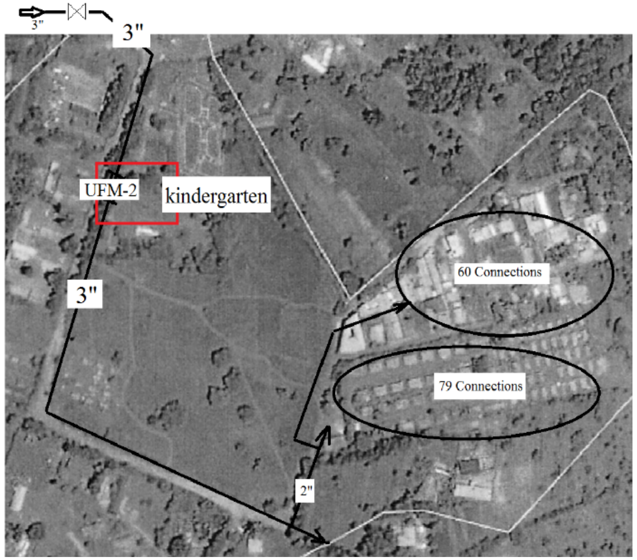


Figure 1-2 Location of Flow measurement by UFM-2 in Mugoko Area in EMBU (Option-2)

2. Causes of pipe damage

The causes of the leakage which occurred on a buried pipeline are shown below.

Table -1 Causes of pipe damage

Quality of pipe material	① Shortage of strength (pipe, joint, valve and etc.) ② Lack of corrosion-resistant ③ Rapid progress of physical aging
Technic of pipe laying	④ Poor pipe jointing ⑤ Poor backfilling ⑥ Touch with the other pipe and the other facilities
Condition of water	⑦ Unsuitable water pressure ⑧ Water hammering ⑨ Corrosion by water quality ⑩ Rapid change of water temperature ⑪ Neglect of leakage
Environment of pipe laying	⑫ Increase of traffic accidents ⑬ Movement of soil around pipe (freezing, upheaval, and etc.) ⑭ Corrodent soil for backfill ⑮ Change of temperature
Other utilities' construction work and disasters	⑯ Damage as the result of construction works ⑰ Damage of the road by earthquake

Source：JICA-Nagoya NRW training

3. Introduction hearing ability of Human beings

The ability to detect leaky sounds is influenced by many experiences of leakage sound survey and human hearing.

Here, we introduce the basic knowledge about sound and the inspection method of individual hearing ability.

3.1 Mechanism for recognizes sound

The mechanism in which a brain catches sound captures a sound wave (sound) by an ear and a bone, and a brain recognizes it as a sound by transmitting to an external ear ⇒ middle ear ⇒ eardrum (vibrate sound) ⇒ brain cell. （**Refer to Figure-1**）

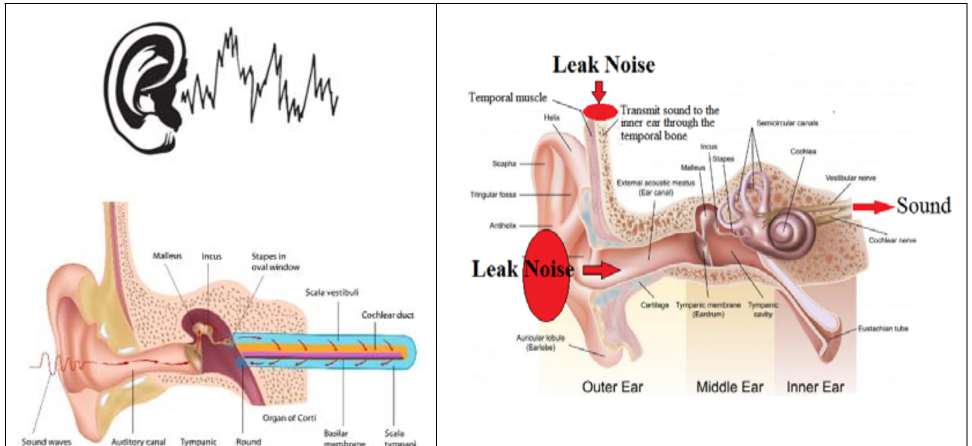


Figure-1 Anatomy of the Ear

Source：Internet data edited

3-2. Feature of a sound waves

Vibration which occurred from the sound source acts as a pressing-out wave (sound wave) further, acts as a sine wave, and transmits the next air.

The example of a wavelength by an oscillating source is shown below.

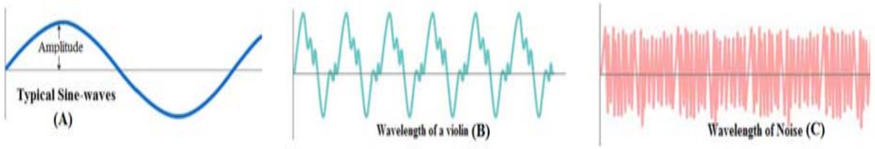


Figure- 2 Example of the wavelength according to a difference oscillating sounds

(1) Sound character

The following two character (dB and Hz) can hear phonic character as a sound put together intricately.

(a) Sound "volume" (dB)

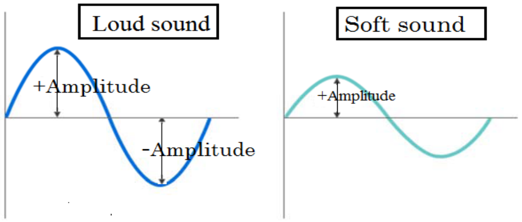


Figure-3 Typical pattern of Volume (dB)

(b) Sound "pitch" (Hz)

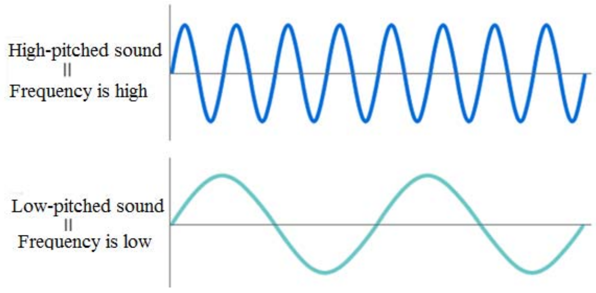
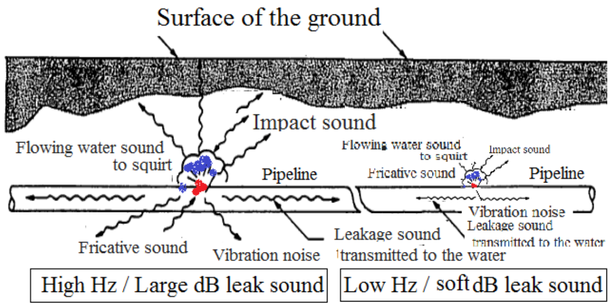


Figure-4 Typical pattern of Pitch (Hz)

3-3. Nature of occurring leakage-of-water sound

Types of water leakage sounds generated at the water leakage point are shown below. **(Refer to Figure-5)**

① Fricative sound when water spurts out of the pipe from the water leak hole
② Impact sound that the jetted water collides with the surroundings
③ Flowing water sound to squirt
④ Vibration noise of pipes generated by running water flowing out
⑤ Fricative sound generated by running water flowing out
⑥ Leakage sound transmitted to the water
⑦ The above synthesized sound



Figuer-5 Types of leakage sounds generated

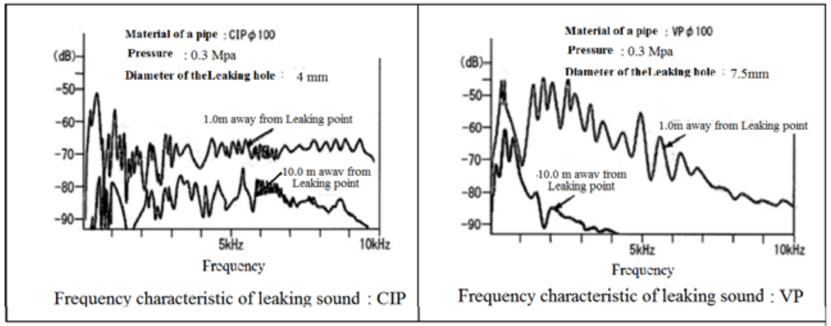


Figure- 6 Example of a waveform of leakage (1)

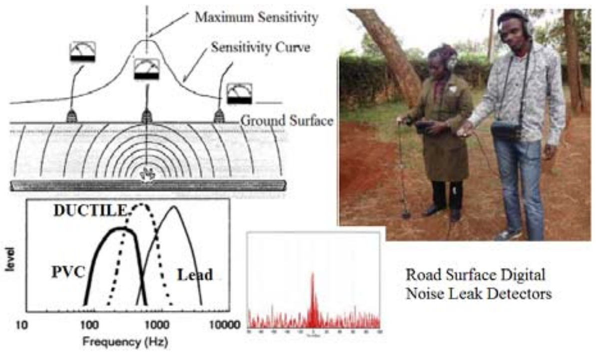


Figure- 7 Example of a waveform of leakage (2)

3-4. Man's listening Capability

The accuracy of leakage investigation is dependent on man's listening capability.

The leakage-of-water investigation person needs to understand self- listening capability to select proper survey equipment to be used.

3-5. How to test

(1) Location of consultation

Inspect in the special hospital of otolaryngology.

(2) Method

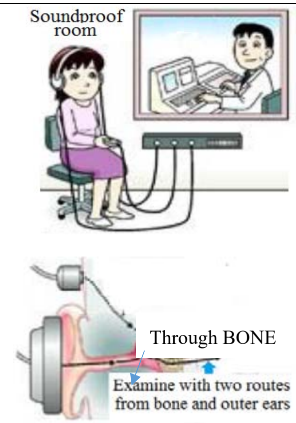
Generally hearing test is inspected by **Pure-tone audiometry**

(3) Procedure of a test **(Refer to Figure-8)**

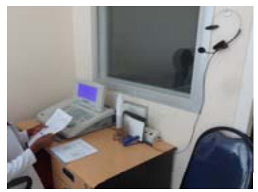
(a) Inspect the combination sound of Hz and dB to produce from an eardrum.

(b) Inspect the strength of occurring Hz from the bone of an ear.

(c) The relation between Hz and dB which was able to be caught is shown in a graph.



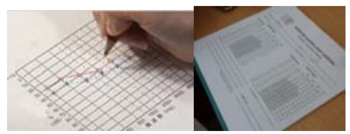
Source：Internet data edited,Yomiuri online 2018-03



Oscillo meter (Audiometer)

Hz; 125,250,500, 1000,2000,4000 and 8000

dB: 0 to 110



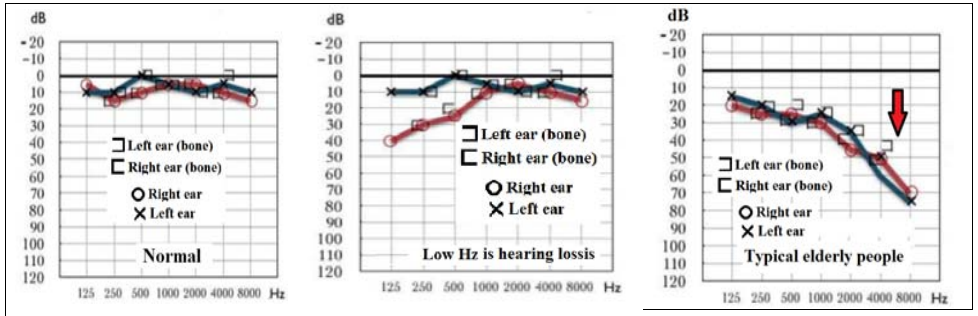
Preparation of Oscillogram record

Figure-8 Procedure of Simple hearing test approach by Pure-tone audiometry

3-6 Test result

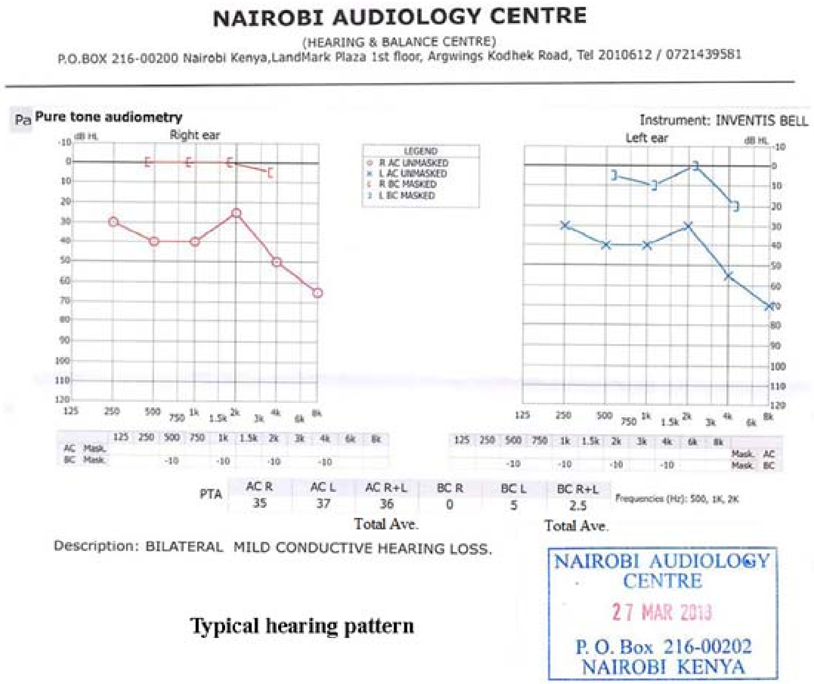
(1) Typical Patterns

The example of a test result is shown below.



Source：Internet data edited,Yomiuri online 2018-03-18

(2) Test report form Nairobi Hospital



Typical hearing pattern

3.7 Listening capacity

Listening comprehension capability tendency by age **(Refer to Figure-9)**

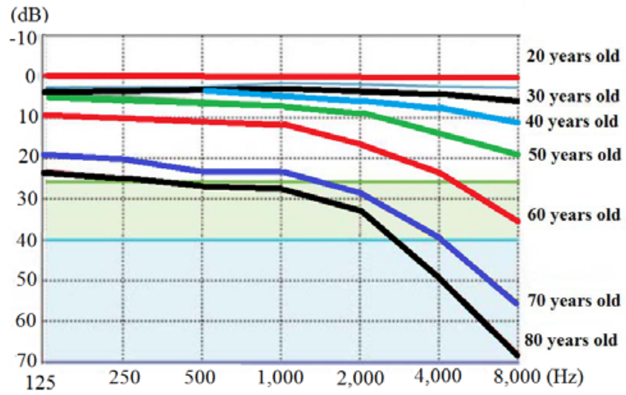


Figure-9. Typical hearing loss Vs age relationship of Japanese

3-8 Etiology of hearing loss

Mainly Hearing loss can be classified as conductive, sensorineural, or both (mixed loss).

The most common causes are as follows:

（1） External ear (conductive loss)

For example, caused by cerumen, a foreign body, otitis externa, or, rarely, tumor.

Cerumen (earwax) accumulation is the most common cause of treatable conductive hearing loss, especially in the elderly.

(2) Middle ear (conductive loss)

(3) Inner ear (sensory loss)

(3-1) Noise exposure

N**oise** can cause sudden or gradual sensorineural hearing loss.

In acoustic trauma, hearing loss results from exposure to a single.

For example, a nearby gunshot or explosion and or chronic exposure to noise more than 85 decibels (dB—sound level)

(3-2) Presbycusis (Aging)

Age-related hearing loss is termed presbycusis.

Presbycusis is due to a combination of sensory cell (hair cell) and neuronal loss.

More than 55 years old in men, more than 65 years old in women will be progressive, bilateral loss

3-9 Gridline of Level for Healing Capability

The equipment to be used for leakage-of-water survey, needs to be selected according to an investigator's listening capability. (**Refer to Table-1**)

Table-1 Evaluation of the Healing capability level

Levels of hearing loss	Evaluated dB level (Average)	Descriptions	Ability of sound hearing
Good sensitivity	3～7	Even small leak noise/ flow running sound can be detected. (Experience required)	Optimal
Normal	8～20	Leak noise/flow running sound can be detect (Experience required)	Suitable
Mild hearing loss	25～39	Even small leak noise/flow running sound can be detected.	Amplified detectors required
Moderate hearing loss	40 or more	Difficult to detect leak noise/ flow running sound	Inappropriate

4. How to detect water leakage

4.1 Leakage exploration technology

① Acoustic noise detector (detection of sounds generated from leak points)

② Inject gas with no adverse effects to water quality in~~to~~ the water pipe

Currently, acoustic detection technology is the most common method used in leak detection.

4.2 Leakage detection by leakage sound

1) Features of leak noise

Leakage sound that jets out of the pipe from the water leak hole generates continuous vibration sound.

However, this vibration sound changes under the following conditions.

①Characteristics of the leak point (e.g. leak hole, pipe material, water pressure, surrounding condition etc.)

②Propagation path (e.g. earth, concrete, pipe material, etc.)

③Propagation distance from the leak point

①Leakage sound depends on generation condition.
②The propagation of the vibration sound is gradually attenuated from the generation point.

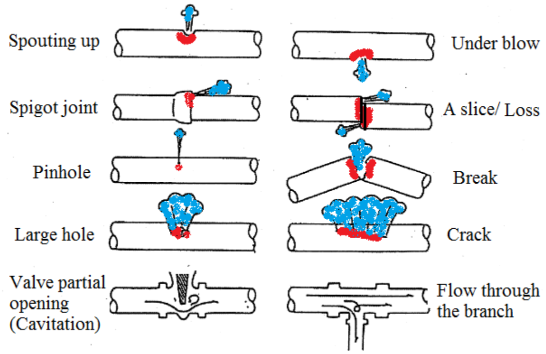
2) Decay rate

In general, vinyl chloride pipe (VP) has higher attenuation with distance than cast iron pipe (CIP) and lead pipe (LP). (**Refer to Tables-2~3 and Figure 2**)

Table-2 Example of decrement of pipe classification (At 10m point)

Pipe Kind	Quality of material	Sound of leakage	Decay rate
Distributing water pipe	CIP φ100 mm dia	Low frequency	About 1/10
		High frequency	About 1/6
	VP φ75 mm dia	Low frequency	About 1/8 at 2m off point
		High frequency	About 1/28
Service line	LP φ13 mm dia	Low frequency	Hardly decrease
		High frequency	About 1/3
	VP φ13 mm dia	Low frequency	About 1/2
		High frequency	About 1/44

Source：Yokosuka City, NRW training



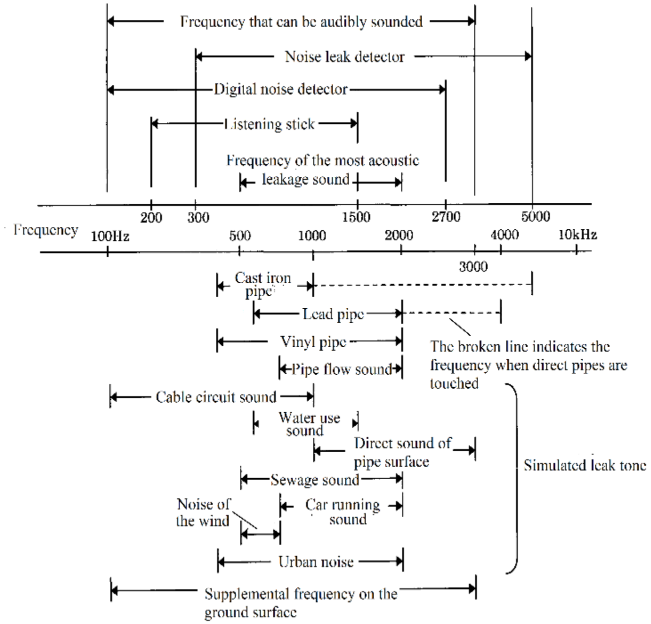


Figure 2 Changes in leak noise

Table-3 Example of Typical leak noise sound

Conditions		Impact on investigation.	Note
Depth of burial	Shallow	Good	Attention to echo etc.
	Depth	Bad	The deeper the depth the more the leakage sound attenuates.
Density of soil	Rough	Bad	The damping of leaky sound is bigger and dense.
	Dense	Good	-
Pipe material	Soft	Caution	Soft pipes such as vinyl pipes and polyethylene pipes attenuate the leakage noise during propagation, so care is taken because the range to be captured is narrow
	Hard	Small impact	
Pipe diameter	Small	No effect	-
	large	Effected	Pipe vibration is less likely to occur as the larger diameter.
Amount of leakage	A little	Difficulty	Minor leakage water leakage sound is small and difficult to grasp.
	Much	Easy	Pay attention to the water pool near the leak hole.
Water pressure	Low	Bad	Usually 1.5 kef / cm 2 or more.
	High	Good	Generally, leakage noise is higher as high-water pressure.

Source：JWRC

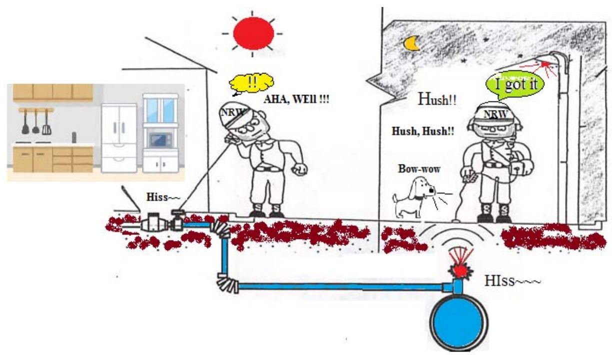
3) False sound

Since the road surface digital noise leak detector is susceptible to the influence of the simulated sound, it is necessary to confirm the location of the dummy sound in advance.

4) Working time

Since DMA area for survey had comparatively little traffic flow, the acoustic noise detection Survey ~~is~~ was conducted at daytime**. (Refer to Figure 3)**

Basically;（In urban area）
① At Daytime ….Door to door survey
② At Late night…..Road surface survey



Source: Edited, Training Handout (2017-May) at Bureau of Waterworks, Tokyo Metropolitan Government

Figure 3 Working Time for water leakage survey by acoustic noise detectors

5. Concept of how to identify leak location

The process of water leakage detection is basically based on narrowing down the order of surface, line and point. (**Refer to Figure -4**)

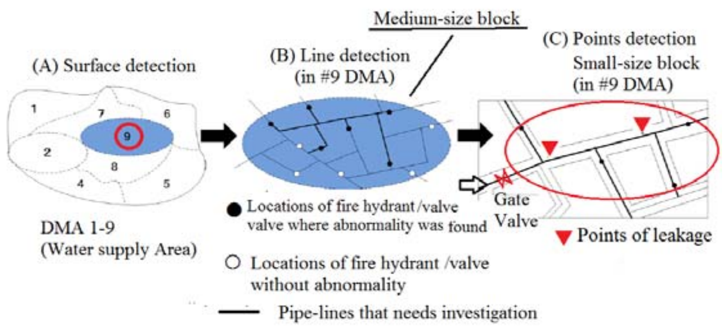


Figure 4 Concept of how to identify leak location

6.Content of leakage investigation work（Procedure of a standard survey）

5-1 Procedure for leakage survey

The flow of leakage investigation work is as follows:

Basic work procedure in leak detection survey

Step-1 : **Formulation of work plan** (Confirmation of work content, confirmation of work method, confirmation of notes, **Preparation of working process & Map)** **(Refer to Figure 1/5~6 Table 4)**

⬇

Step-2: Conducting preliminary inspections on site with **detail route map of pipe laying** (confirmation of consistency between drawing and site, confirmation of work method, confirmation of machine used)

⬇

Step-3: Implementation of Door to door survey (Discovery of water leakage sound from Faucet valves/ shutoff valve/ distribution pipes with listening sticks, mainly daytime work because of work in the residential area,)

⬇

Step-4: Implementation of road surface detection (Discovery of water leakage sound of distribution pipes at night with digital leak detector / listening sticks, etc.)

⬇

Step-5: Confirmation of leakage point survey (Check with/by boring equipment / excavation / listening sticks / digital leak detectors / buried pipe detectors/ leak

FIELD ON-JOB TRAINING"（Field Technician）(R-3) February, 2019

noise correlators, DPD reagent etc. to make sure whether the location of leakage, etc.)

⬇

Step-6: Preparation of a report (Arrangement of survey data, analyze survey results) **(Refer to Forms -1 to 3)**

Table-4 Example of Working schedule

Name of waterworks office（Name＋Sign）; Date and time;

Name of the investigation area;

Scope of work (Investigation time zone): Door-to door survey （160 km : 16,000 Customer meters）::::8:30AM to17:00 / Stop valves / stop-cocks Caustic noise survey (150 km);;;;;8:30AM to17.00 / Road surface survey (160 km);;;;22 PM to 5AM

Duration of the survey;

Name of the researcher;

No.	Activities	June				July				August				September			
(1)	Work plan																
(2)	Preliminary site survey																
(3)	Survey on door-to-door survey																
(4)	Survey on road-surface																
(5)	Verification work																
(6)	Preparation of report																

Supervisor （Name +Sign);

Figure -5 Example of piping rout map in survey area

Figure-6 Sample of detailed rout map of pipe laying

7. Equipment required for leak investigation

7-1 listening sticks

(1) Objectives

a) In this practice, use a sound hearing bar, bring the vibration sensing rod into contact with a faucet and a meter, and experience the presence or absence of water leakage sound.

b) In order to distinguish leakage sounds, it is necessary that the participant concentrates and focus on the point of investigation.

c) Mark the position where suspicion of leakage is suspected on the map and on the ground.

d) Have the consultation on the findings. (**Form-1 to 3**)

(2) Points of concern

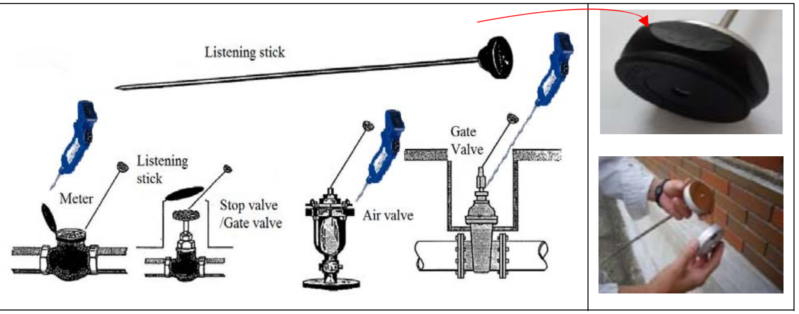
a) If necessary, close the consumer tap and check whether leak noise is generated before and after the meter.

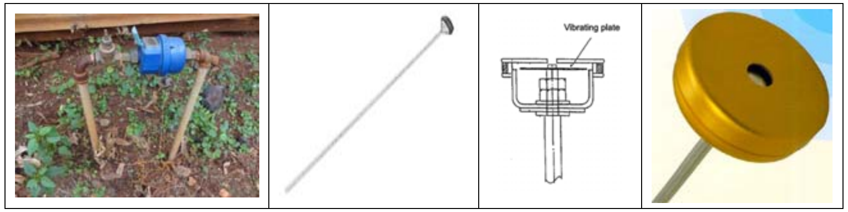
b) Mark the position suspected leakage.

(3) Equipment used

a) A Listening stick、(**Refer to Figure-7**)

b) A Digital noise leak detector





Fifure-7 Configuration of Listening stick

7-2 Road surface digital noise leak detector

(1) Objectives

a) In this practice, as a result of a **Listening stick** survey, the leakage position is searched by a road surface digital noise detector and/or a **Listening stick** on a pipeline where leakage is suspected.

b) Mark the position where suspicion of leakage is suspected on the map and the ground.

c) Confirm the leakage location by excavating.

d) Have the consultation on the findings. (**Form-1 to 3**)

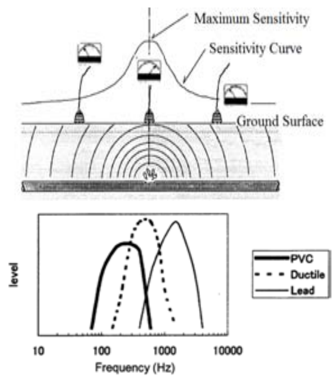
(2) Points of concern

a) Since this investigation is influenced by dummy sounds, it is necessary to check the occurrence of noise beforehand.

b) Recording of data (**Form-1 to 3**)

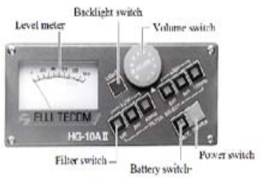
(3) Equipment used

a) A Road surface digital noise leak detector (**Refer to Figure-8**)



The following four (4) Filter Band Widths are recommended as the basic selection on site.

Pipes \ Hz	100	200	400	600	800	1200
Distribution Pipe of Cast Iron Pipe.		◎			◎	
Distribution Pipe of Vinyl Pipe.	◎			◎		
Service Pipe of Vinyl Pipe.		◎			◎	
Service Pipe of Galvanized Pipe.			◎			◎



Nine(9)ways of Filter Combination are selectable as follows. Those Filtering Ranges enable the Operator to distinguish the leak sound from other noise.

LOW 100	LOW 200	LOW 400Hz	HIGH 600	HIGH 800	HIGH 1200Hz	Filter Combination
▣			▣			100Hz ~ 600Hz
▣				▣		100Hz ~ 800Hz
▣					▣	100Hz ~1200Hz
	▣		▣			200Hz ~ 600Hz
	▣			▣		200Hz ~ 800Hz
	▣				▣	400Hz ~1200Hz
		▣	▣			400Hz ~ 600Hz
		▣		▣		400Hz ~ 800Hz
		▣			▣	400Hz ~1200Hz

e

Figure-8 Overview of Road surface digital noise leak detector

7-3 Leak noise correlator

(1) Objectives

a) In this method, the equipment specifies the leak position where leakage is suspected in the buried (metal pipe / nonmetal pipe) pipe.

b) Mark the position where suspicion of leakage is suspected on the map and the ground.

c) Have the consultation on the findings.

(2) Points of concern

a) Secure the sensor installed at two points on the piping fixed.

b) Water leakage position is specified from the waveform displayed on the monitor of the main unit.

c) The location of water leak is ~~final~~ finally checked by boring or excavation.

(3) Equipment used

a) Leak noise correlator **(Refer to Figure-9)**

b) Tool for attaching sensor

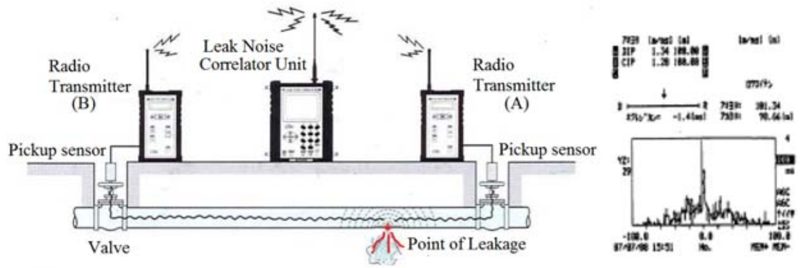


Figure-9 Overview of Leak noise correlator

7-4 Verification Work

(1) Objectives

(a) Understand how to check where leakage is suspected by leakage exploration by Excavation. **(Refer to Figure-10)**

(b) Introduction of Boring work method **(Refer to Figure-11)**

(2) Points of concern (by Boring work)

a) Boring work needs to be investigated carefully so as not to damage the buried pipe.

b) The water leakage position is determined by drilling a number of holes with a boring tool and judging from the strength of the leak sound while moving the Listening sticks to the number of holes.

c) Moreover, it is possible to specify the water leakage position from the situation of water and soil / attaching to the boring bar and/ or a Listening stick.

d) Boring bar is a tool that punctures hard surface.

(3) Equipment used (by Boring work:**Refer to Figure-11**)

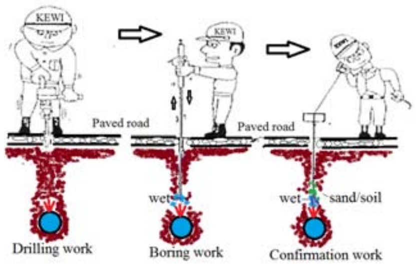
a) An Electric drill (used for drilling pavement surface)

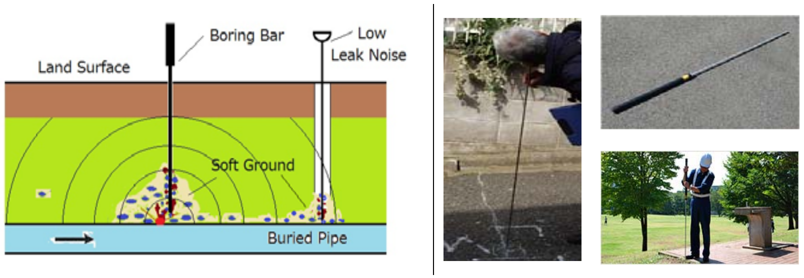
b) A Boring bar

c) A Listening stick

d) A Road surface digital noise leak detector

Figure-11 Overview of Verification work by Excavation





Source:Yokosuka cityWWSB　　Working on Paved roadway

Figure-11 Overview of Verification work by Boring work

8. Equipment required of survey for Buried pipe detection

8-1 Electromagnetic induction detectors (For metallic pipes)

(1) Objectives

a) The objective of this practice is to understand the operation method of the equipment to specify the position of the buried pipe (Metal pipe)

b) Have the consultation on the findings.

(2) Points of concern

a) Detection is difficult if the burial depth is deep.

b) Since it also reacts with piping which is not currently used (buried disposal), it is necessary to follow up to the connecting part of piping currently in use.

(3) Equipment used

a) Direct metallic pipe detector (**Refer to Figure-12**)

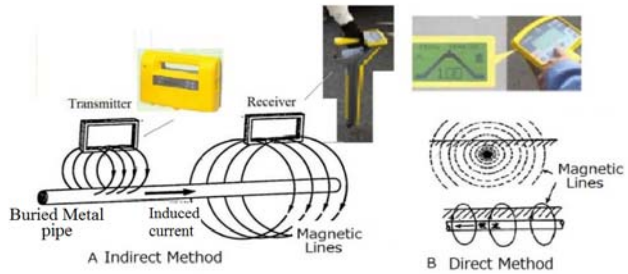


Figure-12 Overview of Electromagnetic detectors

8-2 Vibration-wave water instrument

(1) Objectives

a) This practice is to understand the operation method of the equipment to specify the position of the buried pipe (Metal and Non-metal pipe)

b) Have the consultation on the findings.

(2) Points of concern

a) Since pulsation is generated and the vibration sound is investigated by listening to the sound on the ground, there is a possibility of damaging the broken tube with a shock wave.

b) Although it is applied to the investigation of a relatively small diameter and a short distance, if the burial depth is deep, the search becomes difficult

(3) Equipment used

a) Vibration-wave water instrument (**Refer to Figure-13**)

b) Listening stick

c) Road surface digital noise leak detector

Figure-13 Overview of Vibration-wave water detector

9. Measurement of leakage volume

9-1 Measurement of minimum night flow a night minimum flow

(1) Objectives

a) This practice will make you understand the concept of estimating the amount of water used during the night time when water demand is lowest in the isolated DMA and is assumed to be the water leakage amount.

b) Identify the night-time minimum flow rate from the collected data.

c) Have the consultation on the findings.

(2) Points of concern

a) Measure the amount of water flowing into the partitioned DMA. (**Refer to Figures 14-15**).

b) Leakage, legitimate consumption and theft are included in the measured minimum flow rate.

c) In order to investigate the actual leakage volume, further investigation is necessary according to the items of the water distribution analysis table.

d) Customer cooperation is indispensable for accurate water leakage survey.

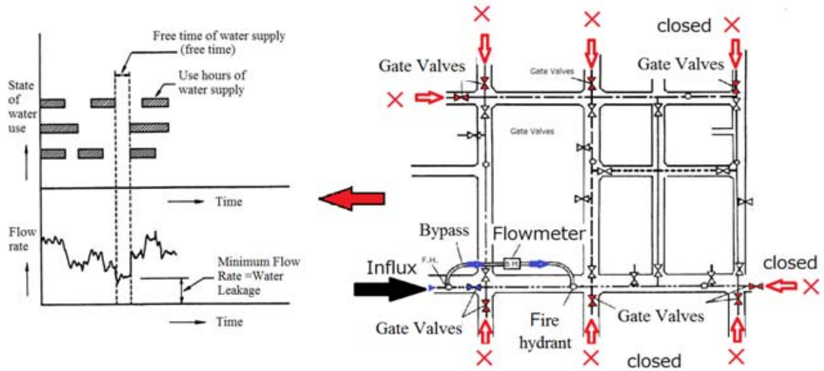


Figure-14 Flow measurement in isolated DMA

(**3**) Procedure for flow measurement survey (for example)

a) Confirm that the amount of water flowing into the survey target DMA is from one location.

b) Install a clamp type ultrasonic flowmeter on the inflow pipe.

c) Manage the gate valve of the outflow pipe into the adjacent DMA.

d) Investigate with the water faucet in the "open" state.

e) Data timer setting: every 5 minutes

f) Survey time

- AM 9: 00: Preparation for measurement
- AM 10:00 ....Start flowmeter survey (Read BFM).

  ↓ Keep opening gate vale at outflow pipe send to adjacent DMA (Automatic recording of data)
- PM 11: 00 ~ AM 05; 00: "**Close**" the gate valve at outflow pipe.

  ↓ (Start measurement of nighttime minimum flow rate)

- AM 05: 30 - AM 06: 00: End of measurement and Set the gate valve to "**Open**". & Set another UFM on the outflow pipe. (To ripen long water supply stop)

↓

- AM 05: 00 to AM 10: 00; Measurement of daily minimum flow rate
- AM 10; 00: …. End of survey

↓

- PM 16: 00: Output by graphing

h) Example output of nighttime minimum water graph (**Refer to Figure-13**)

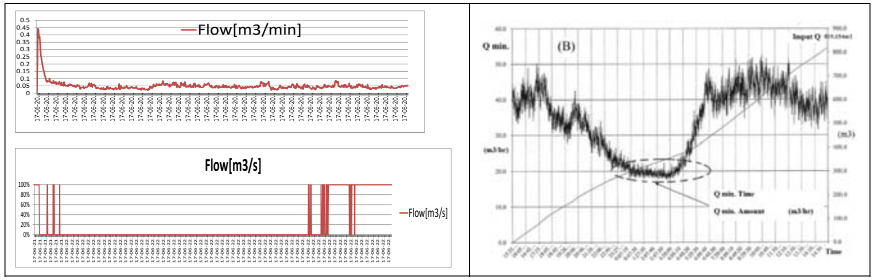


Figure-15 Example of nighttime minimum flow rate

（4）Equipment used

(a) Ultrasonic flow meter **(Refer to Figure-16)**

(b) Tool

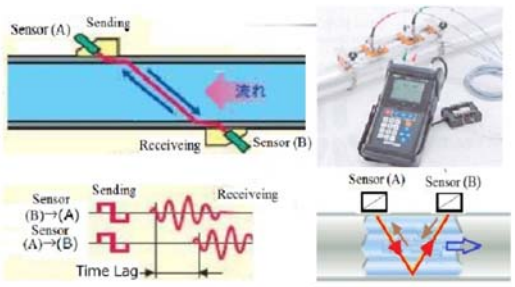


Figure-16 Overview of Ultrasonic flow meter

9-2 Measurement of Water pressure gauge

(1) Objectives

a) The objective of this exercise is to monitor the 24-hour pressure variations in order to understand the characteristics of the nighttime minimum flow rate.

b) It is also possible to grasp the relationship between the minimum flow rate at night and pressure fluctuation.

c) Have the consultation on the findings. (**Form 4**)

(2) Points of concern

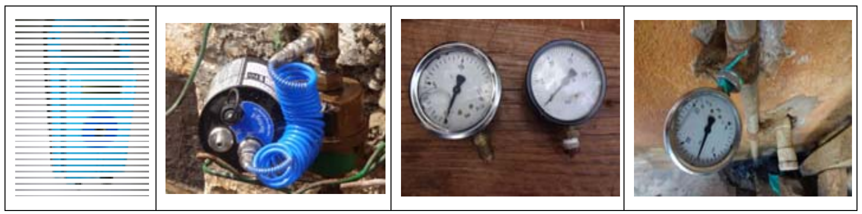
a) Record the water pressure on the recording paper at intervals of 5 minutes. (For reading)

b) Recording of data (**Form 4**)

(3) Equipment used

a) Digital pressure data logger

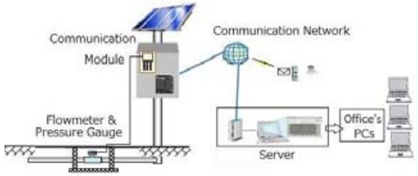
b) Mechanical pressure gauge



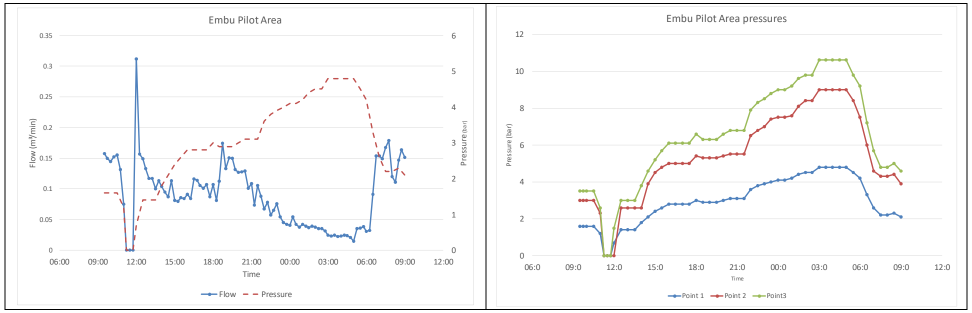
(4) Monitoring system

The water pressure of the pipeline is monitored by a plurality of water pressure gauges installed in the pipeline.

The water pressure data is displayed on the monitoring panel of the waterworks bureau by the automatic remote monitoring system for 24 hours and monitors whether or not the proper water pressure is maintained.



Conceptual diagram of monitoring system



Examples of fluctuations in water pressure and flow rate

9-3 Portable electronic test meter

(1) Objectives

a) The objective of this training is to determine the measurement error of the installed customer meter by connecting the electronic meter testers and the consumer meter in series and comparing the volumes recorded through each meter.

b) Check the measurement error (numerical value) of the existing meter.

c) Have the consultation on the findings. (**Form-5-6**)

(2) Points to remember

a) The electronic meter (tangential impeller) must always be calibrated to record accurate measurements.

b) Measurement of flow rate other than set flow rate increases measurement error.

c) Do not bring strong magnets close to the electronic meter during measurements.

(3) Measurement range

a) Maximum flow rate 1.0 m^3 / hr., intermediate flow rate 0.2 m^3 / hr., minimum flow rate 0.1 m^3 /hr.,

b) Measurement accuracy ± 2.0% for intermediate and high flows and ±5% on the lower flow rate.

(4) Equipment to be used

a) Portable electronic meter …1 set **(Refer to Figure-17)**

b) Hose · Connecting device · · · ·1 set

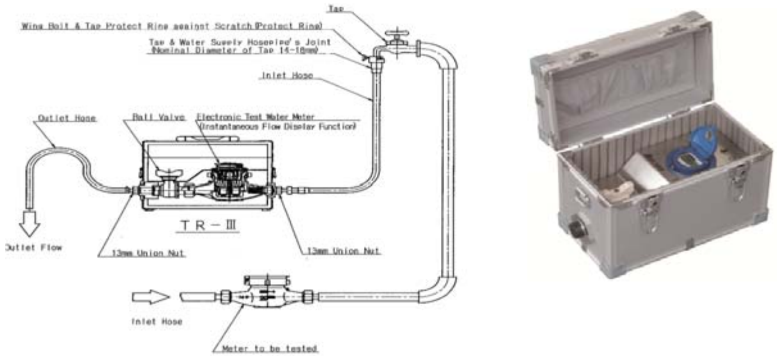


Figure 17 Installation drawing of electronic meter

10. Survey of Customer meter reading &meter condition

(1) Objectives

a) The objective of this survey is investigating the measurement accuracy of the customer meter.

b) Have the consultation on the findings. (**Form-6**)

(2) Procedure of survey

a) 5 EMBU staff will guide 5 groups of trainees (5-6 people / group) on site.

b) The number of customer meters surveyed by each team is about 20 to 40 for each Group.

c) Each group will use the Listening Stick placed on the water meter / stopcock and Listens to the characteristic leak sound.

11. Water meter bench test

(1) Objectives

a) The objective of this training is to accurately determine water measurement error caused by deterioration of customer's water meter and insufficient maintenance.

b) Observe the demonstration of the water meter test method and recognize the malfunction of the meter and recording data (**Form-8**)

c) Have the consultation on the findings.

(2) Measurement procedure (demonstration by EMBU staff)

a) "Instrument difference" of the customer's water meter is compared with "measured value" passed through the test water meter and the passed water volume with "capacity of the standard tank".

b) Select 8 to 10 customer meters to be inspected (aged), meters with different usage conditions.

c) Meter difference is evaluated by 3-point flow performance test. (Qmin. = 30 liters, QT = 120liters Qn = 1.5 m 3 ... For Class B)

d) Note: Conversion formula from old standard Class-B to new standard (R)

- **For example: ISO B Class**

  R=ISO B=Q3/Q1=1.5/0.03 =50

  *** ISO-B（old STD）= R50(New STD)**

The standard of a Japanese customer meter is R100.

（The larger the R value, the lower the measurement error of the water meter.）

e) How to find **Qn** numbers? (**Refer to Figure-18**)

item	ISO 4064-1993
Manufacturer.	LAO(Brazil)
Model,	M6011B
	Multi-jet-Dry-Tangential flow impeller
quality standard,	Classe-B
caliber（mm）	–
Qn(m^3/h)	1.5
Qmin(m^3/h)	0.030
Display version	

Figure-18 Example of Old ISO-STD (Class-B)

f) Example of Computation method of each flow rate in a measurement point (**Refer to Figure-19**)

- **For example: ISO B Class (Qn = 1.5m³/hr.) (Refer to Table-5)**

  ① Minimum flow rate(Q min.)= (Q1) =1.5 x **0.02**=30 liters/hr.

  ② Transitional flow rate (Q t) = (Q2)= 1.5 x **0.08**=120 liter/hr.

  ③ Nominal flow rate (Q n = (Q3)= 1.5 m3/hr.

  ④ Maximum flow rate(Q max) = (Q4) = 1.5 x **2.0**=3.0 m3/hr.

Table-5 Typical calculation table of test water volume

ISO4064-1993 Class	Qmin＝Q1	Q t=Q2	Q n ＝Q3	Qmax＝Q4
A	Qn x 0.04	Qn x 0.10	-	Qn x 2.0
B	Qn x 0.02	Qn x 0.080	-	Qn x 2.0
C	Qn x 0.01	Qn x 0.015	-	Qn x 2.0

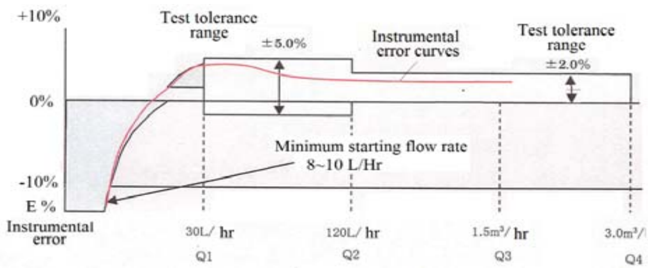


Figure-19 Typical Instrumental error curve at 3- flow rate (Class B)

- Determination of allowable error of test water quantity **(Refer to Table-6-7)**

Table- 6 Typical Allowable tolerance (For New meter)

Test tolerance （New Meters）			Flow area
①Rated minimum flow rate	Q1 and above	**±5 %**	Low flow rate range
②Transitional flow rate	Below Q2		
③Nominal flow rate	Q3 and above	**±2 %** (Water temperature: less than 30 degrees)	High flow rate range
④Maximum flow rate	Below Q4		

Table-7 Typical Working tolerance（Using customer meters）

Test tolerance （In use Meters）			Flow area
①Rated minimum flow rate	Q1 and above	**±10 %**	Low flow rate range
②Transitional flow rate	Below Q2		
③Nominal flow rate	Q3 and above	**±4 %** (Water temperature: less than 30 degrees)	High flow rate range
④Maximum flow rate	Below Q4		

What is your allowable tolerance of customer meters?

(1) NEW meters

at Q 1 = Q min

at Q 2 = Q t

at Q3 = Q n

(2) Meters in use

at Q 1 = Q min

at Q 2 = Q t

at Q3 = Q n

(3) Repaired meters

at Q 1 = Q min

at Q 2 = Q t

at Q3 = Q n

(3) Points of concern

① Always calibrate measurement precision with a flow meter.

② Check that the pressure gauge on the outflow side always has a back pressure of 0.05 KPa (0.51 kgf/cm^2 =0.00005 bar) or more.(1kpa=0.01 bar)

③Water temperature :less than 30 degrees

(4) Equipment used **(Refer to Figures 20-21)**

①Water meter test bench,

②Water tank (small: 100 to 500 liters, large size: 1 m^3 or more) · · 1 set

③Flow meter (3 to 4 types L/h): 5 to 100, 100 to 1000, 1,000 to 100,000) · 1 set

④Pressure gauge · · · · · · · · · · · · 2sets

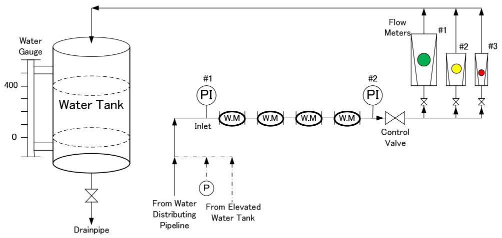
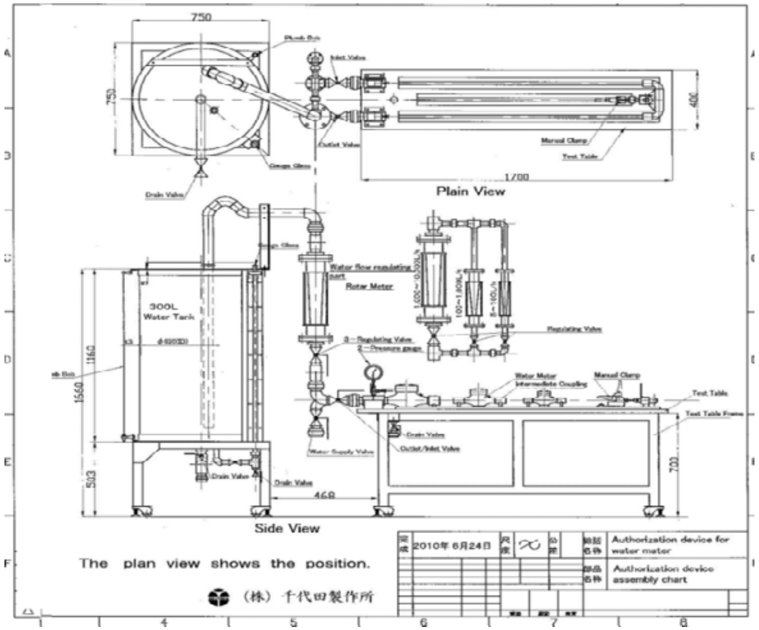


Figure-20 Principle of the water meter test apparatus method (volume method)



Fugue-21 Plan of EMBU’s water meter test bench

(5) How to use data

(1) Quality control of new meter

(2) Confirming the current condition of equipment difference of water use meter used

(3) Confirmation of occurrence status of instrumental error of repair meter

(4) Confirmation of Consistency of Assumed Value of Meter error of Water Balance Analysis Table

(5) Estimation of replacement timing of meter

12. Water Quality Equipment

(1) Objectives

a) To determine the water quality of tap water and leak flow.

b) Have the consultation on the findings. (**Form-9**)

12-1 Determination of residual chlorine by colorimetric method

（1） Object of achievement

The objective is to conduct color discrimination analysis technique with chlorine agent, from water leakage or tap household use water supply (illegal connection), to customers in the field.

(2) Reactive color

(a) Normally there is residual chlorine in tap water.

(b) In the colorimetric method, a reagent is added to the test water, and the leak source is judged from the reaction color.

(c) Generally, the DPD method is used. (**Refer to figures 22-23**)

(3) Reacted color

(a) Diethyl Para Phenylene diamine (DPD) method)

●Peach →change to peach red discoloration

(b) Orthotolidine (OT) method

●Light yellow → change to yellowish brown

NOTE: Note: The use of OT method is currently banned in some countries due to suspected carcinogenic health concerns.

DPD reagent used

OT reagent used

Figure-22 Colorimetric reaction with residual chlorine

(3) Appliance used

Powder / solid DPD reagents

Residual chlorine analyzer

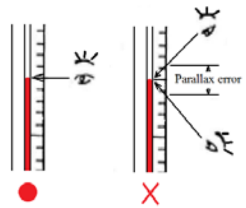
Spectrophotometric residual chlorine analyzer

Figure-23 Measurement equipment

12-2 Water temperature gauge

（1） Objectives

a) In this training, skills to measure the temperature of leakage/tap water is learned. **(Refer to Figure-24)**



How to read the water temperature gauge

Rod-like red liquid thermometer

Figure-24 Measurement of Water temperature

12-3 Conductivity meter

(1) Objectives

In this training, skills to measure the conductivity of leakage will be learned.

(Refer to Figure-25)

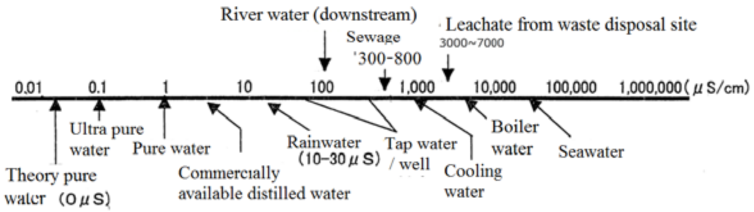


Figure-25 Measurement of Water Conductivity

12-4 pH measuring instruments

(1) PH meters

（1） Objectives

In this training, skills to measure pH from a leak will be learned.

(Refer to Figure 26-27)

Table 8 pH classification

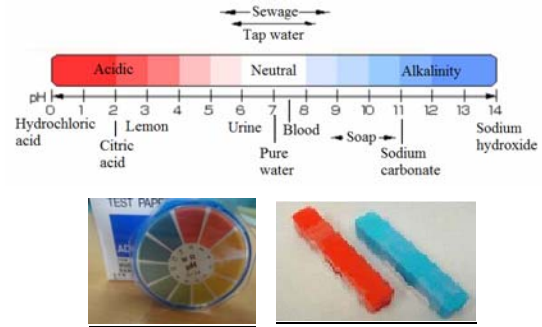
pH	Nature of the liquid
0～3.0	Acidic
3.0～6.0	Mild acidity
6.0～8.0	Neutral
8.0～11.0	Weakly alkaline
11.0～14	Alkaline

Figure-26 pH meters

(2) Litmus papers

（a） Objectives

In this training, skills to measure pH with litmus paper are learned.



Roll Type　　Book Type

Figure-27 Measurement of Water pH

13. Measurement of Flowing Water from a Water tap

（1） Objectives

a) In this training, measure the amount of water flowing from the faucet so that the amount of water loss at the leak point can be easily and quickly determined on site.

b) Have the consultation on the findings. (**Form-10**)

（2） Survey procedure

a) Capture the amount of water from the tap against a given time and save it in a container.

b) Measure the water in the container with a measuring cup or weight and convert it to the amount of water.

c) Measure the pressure at the outlet of the water supply tap.

d) Record the survey results.

e) Photograph the flow of water.

（3） Relationship between weight of water and volume (volume)

$$\boxed{\textbf{Formula : } W = R \times V}$$

Here

W = Weight (g)

R = Density g / cm ^{3} = Specific gravity (water = 1)

V = Volume (Capacity) L, cc, mL

Table-9 Conversion table (Water Specific gravity = 1)

Volume		Weight		Note
L (liter)	mL(mill-liter)	g (gram)	mg(milligram)	
1.0	1,000	1,000	1,000,000	
0.5	500	500	500,000	
0.1	100	100	100,000	
0.01	10	10	10,000	

(4) Equipment used (In the case of small leakage) **(Refer to Figure- 28)**

a) Measurement cup,

b) Bucket,

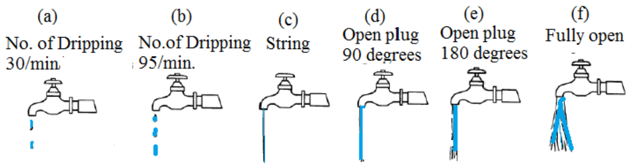
c) Weight scale

d) Stopwatch, & water pressure gauge

Figure- 28 Equipment for instrumentation

(5) Example

① Water faucet (Dia. 13m/m,5kgf/cm2)



Source: JPRC 1995 #20

	Items	W. Leakage	(a)	(b)	(c)	(d)	(e)	(f)
①	Faucet	m^3/d	0.011	0.036	0.09	309	39.6	56.8

Figure-27 Understanding water leakage (flowing from water faucet)

14. Formats

13-1 (Form-1) Leak survey

(1) CUSTOMER METER: Registration number___________________________

(2) Location____

(3) Type of Meter____

(4) Operation period____________________________________

(5) Tested by ____

(6) Date_______________________________

Sheet No, ___________________

Example and data format

Classification		No. of cases	%	Estimated W. leakage (m^3/hr.)	%	Remarks
1/2"-1" on the distribution pipe	For Ex.	20.0	7.3%	4.6	9.6%	
	Format					
Air vale	For Ex.	30.0	11.0%	2.5	5.2%	
	Format					
11/2"- 2" on the distribution pipe	For Ex.	30.0	11.0%	15.0	31.3%	
	Format					
Stope cock	For Ex.	70.0	25.6%	5.2	10.8%	
	Format					
Gate valve	For Ex.	15.0	5.5%	3.2	6.7%	
	Format					
Other valves	For Ex.	5.0	1.8%	4.2	8.8%	
	Format					
B. Meter	For Ex.	6.0	2.2%	5.8	12.1%	
	Format					
C. Meter	For Ex.	62.0	22.7%	0.7	1.4%	
	Format					
Inside the house	For Ex.	30.0	11.0%	3.1	6.5%	
	Format					
Other	For Ex.	5.0	1.8%	3.7	7.7%	
	Format					
Total	For Ex.	273.0	100.0%	48.0	100.0%	
	Format					

What is your comment?

14-2 (Form-2） Leak survey

LEAKAGE REPORT

KENYA WATER INSTITUTE				
LEAKAGE REPORT				
DATE:		ROAD:		
BLOCKMAP No.:		REPORT No:		
Method of finding:	LEAKAGE ON:	Location	DN	Material
	Service Connection			
	Main Pipe			
	Pipe Saddle or Ferrule			
	Pipe Fitting			
Estimated loss: (m3 /hr.)	Valve			
	Hydrant			
	Air Valve			
	Bulk Meter			
	Pump			
COMMENTS:				
SKETCH of LOCATION:				
Report issued	Report approved		Work Instruction to	Work done

What is your comment?

FIELD ON-JOB TRAINING”（Field Technician）(R-3) February, 2019

14-3 (Form-3） Format of Leak Survey Reporting

(1) CUSTOMER METER: Registration number___________________________

(2) Location____

(3) Type of Meter____

(4) Operation period___________________________________

(5) Tested by ____

(6) Date______________________________

Sheet No, ___________________

Result sheet

Year	Survey method	Distance of survey conducted (㎞)		Number of discoveries (Cases)				Total
		Distance of acoustic detection	Distance of flow investigation	In public road	Before the meter	In the meter box	After meter	
2017 June (DMA-1)	Surface leakage			438	631	163	1,159	2,391
	Discovered by survey (underground)	543	12.84	140	261	357	24	782
	Total	543	12.84	578	892	520	1,183	3,173
2017 June (DMA-1)	Surface leakage			396	740	102	1,142	2,380
	Discovered by survey (underground)	639	15.13	202	381	218	27	828
	Total	639	15.13	598	1,121	320	1,169	3,208

What is your comment?

14-4 (Form-4) Format of Pressure test Reporting

Time	Pressure (bar)	Accumulated total Flow (m3)	Note	Time	Pressure (bar)	Accumulated total Flow (m3)	Note
AM 10:30				**23:00**			
11;00				**23:30**			
11:30				**24:00**			
12:00				**0;30**			
12:30				**1:00**			
13:00				**1:30**			
13:30				**2:00**			
14:00				**2:30**			
14:30				**3:00**			
15:00				**3:30**			
15:30				**4:00**			
16:00				**4:30**			
16:30				**5:00**			
17:00				**5:30**			
17;30				**6:00**			
18;00				**6:30**			
18:30				**7:00**			
19:00				**7:30**			
19:30				**8:00**			
20:00				**8:30**			
20:30				**9:00**			
21:00				**9:30**			
21:30				**10:00**			
22:00				**10:30**			
22:30				**AM11:00**			

What is your comment?

14-5 (Form-5) Format of Checking of operation of Customer meters

(1) Name of data collector______________________________

(2) Date of survey____________________

No.	Name of customer	Area	R/Number	Type of Meter	Dia. (mm)	Manufacture	Rotation of Pilot Indicator			Meter Condition		Presence of Leakage				Installation status of the meter		Note
							Freely	Sticking	Stack	Normal	Damaged	Drying	Damping	Drip-drip	Running	Underground	Abouve G.level	
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
21																		
22																		
23																		
24																		
25																		

What is your comment?

14-6 (Form-6) Accuracy survey of Customer meter with Master Meter

Date_________________ & Name of staff__________________________ Investigation period___________________________________

#	Meter R/N	Type of Meter	Time		A: Record Customer meter (liters)			B: Read Master Meter (liters)			Difference (liters)	Error (%)	Comment
			Start	End	Start	End	Total	Start	End	Total	B-A=C	C/A*100	
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

What is your comment?

14-7 (Form-7）Water meter test bench

14-7-1 Format

Result of Joint OJT at EMBU 2018-March @ EWASCO

P1 inlet pressure = 0.4 bars							P2 outlet pressure = 0.05 bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Total accumulated water Vol. (m3)	Appearance Situation	Flow Rate: Qn (1500 l/h)					Comments ±4 % (in use)	Comments
								Total flow vol = 200 lts (Water Tank volume Flowed)						
								START	END	DIFRENCE		Fluctuation of Error %		
	Volume used ; 200 lts=0.2 m3					0.2								
						R1 max (m3)		R1max (m3)	R2 max (m3)	R2 max - R1 max (m3)	%			
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

P1 inlet pressure - 0.4 bars							P2 outlet pressure = bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	Appearance Situation	Flow Rate: Qt (120 l/h)					Comments ±10% (in use)	Comments
								Total flow vol= 50 lts (Water Tank volume Flowed)						
								START	END	DIFRENCE		Fluctuation of Error %		
	Volume used: 50 lts= 0.05 m3					0.05								
						R2 tf (m3)		R2 tf	R3 tf	R3 tf - R2tf	%			
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

P1 inlet pressure - 0.4 bars							P2 outlet pressure = bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	Appearance Situation	Flow Rate: Qmin (30 l/h)					Comments ±10% (in use)	Comments
								Total flow vol = 20 lts (Water Tank volume Flowed)						
								START	END	DIFRENCE		Fluctuation of Error %		
	Volume used: 20 lts=0.02 m3					0.02								
						R3 min (m3)		R3 min	R4 min	R4min-R3min	%			
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

What is your comment? (Refer to Table 7-2)

(1) Is the instrumental errors standard of the water meter of WSP fixed?

(2) About the meaning of plus / minus indicated by error rate。

(a) Is the error rate that **WSP loses** plus/minus?

(b) Is the error rate that th**e customer loses** plus / minus?

(3) About rejected meter of ISO standard.

(a) Which trial flow rate has many rejected goods **in using meters**?

(b) Which trial flow rate has many rejected goods **in NEW meter**s?

(4) Can you calculate the prediction of **commercial loss** from the measurement error of the meter?

(5) What is corrective strategy about the claim of the **unfair water rates** by measurement error of meter?

14.7-2 Sample of data analysis

Sample of Water Meter Testing at EWASCO's Test Bench 2017/6/15

S4#Lqohw#Suhvvxuh@#317#edu							S5#Rxwohw#Suhvvxuh@#318#edu						ISO STD	EMBU STD
Qr	Fodwlifdwlrq	Phwhu#qr	Prgho2 WG	\hdu#i pdqxidfwxuh	Fdoleu +pp,	Wrwdo dffxpxodwhg zdwhu#p6,	Dsshdudqfh vlwxdwlrq	Iorz#Tq#4833#o2k, Wrwdo#iorz#yro@#53#ow#Zdwhu#Wdqn#yroph,					Comments (4% or less)	Comments (5% or less)
Yroxph#xvhg#53#ow@3135#p6						3E U4#p6,		WDUW U4#p6,	HQG U5#p6,	GLIIHUHQFH U5-U4@p6,	(	Ioxfwxdwlrq b#hur#(		
4	rog	K8:3<9:	nw2FE		5:	5::<3<		5::<3<	5::<634	3544	438(	8(	Pass	Pass
5	vwxfn	534338376:	sp2FE		5:	7<17<74		7<17<74	7<17<74	3	3(	0433(	NO	NO
6	vhyhlq	437863:	sp2FE		5:	3179:7		3179:7	31998	314<;	<<(	04(	Pass	Pass
7	fxwrph	4933685:	bq2FE		5:	45:1578		45:1578	45:1779;	31535	<9(	07(	Pass	Pass
8	fxwrph	483:75<5	bq2FE		5:	93;1474		93;1474	93;1:45E	314<;4	<<(	04(	Pass	Pass
9	ryh#433	37046<75;	nw2FE		5:	47961E		47961E	47961:8;	3148:;	:<(	054(	NO	NO
:	ryh#33	53433839<:	sp2FE		5:	<96136		<96136	<9713<4<	314;;<	<7(	09(	NO	NO
;	qhz	DF077:;86	sp2FE		5:	3143E		3143E	31636	314<;	<<(	04(	Pass	Pass

S4#Lqohw#Suhvvxuh@#317#edu							P2 Outlet Pressure= bars						ISO STD	EMBU STD
Qr	Fodwlifdwlr q	Phwhu#qr	Prgho2 wsh	\hdu#i pdqxidfwxuh	Fdoleu +pp,	Wrwd dffxpxodwhg zdwhu#p6,	Dsshdudqfh vlwxdwlrq	Iorz#Tw#453#o2k, Wrwdo#iorz#yro@83#ow#Zdwhu#Wdqn					Comments (4% or less)	Comments (5% or less)
Yroxph#xvhg#83#ow@3138#p6,						313E U5p6,		WDUW U5#p6,	HQG U6#p6,	GLIIHUHQFH U6-U5@p6,	(	Ioxfwxdwlrq b#hur#(		
4	rog	K8:3<9:	nw2FE		5:	5::<634		5::<634	5::<6E	313<	<;(	05(	Pass	Pass
5	vwxfn	534338376:	sp2FE		5:	7<17<74		7<17<74	7<17<74	3	3(	0433(	No	No
6	vhyhlq	437863:	sp2FE		5:	31998		31998	31:4:4	31384:	436(	6(	Pass	Pass
7	fxwrph	4933685:	bq2FE		5:	45:1779;		45:1779;	45:17<:	3138E	435(	5(	Pass	Pass
8	fxwrph	483:75<5	bq2FE		5:	93;1:45E		93;1:45E	93;1:8<7	3137:5	<7(	09(	No	No
9	ryh#433	37046<75;	nw2FE		5:	47961:8:;		47961:8;	47961;3:	3137;;	<;(	05(	Pass	Pass
:	ryh#33	53433839<:	sp2FE		5:	<9713<4<		<9713<4<	<97146<9	3137::	<8(	08(	No	Pass
;	qhz	DF077:;86	sp2FE		5:	31636		31636	3168E	3137<	<;(	05(	Pass	Pass

S4#Lqohw#Suhvvxuh@#317#edu							P2 Outlet Pressure= bars						ISO STD	EMBU STD
Qr	Fodwlifdwlr q	Phwhu#qr	Prgho2 wsh	\hdu#i pdqxidfwxuh	Fdoleu +pp,	Wrwd dffxpxodwhg zdwhu#p6,	Dsshdudqfh vlwxdwlrq	Iorz#Tp lq#63#o2k, Wrwdo#iorz#yro#54					Comments (10% or less)	Not decided yet
#Yroxph#xvhg#54#ow@#3154#p6,#"1#53#ow,						31354 U6p6,		WDUW U6#p6,	HQG U7#p6,	GLIIHUHQFH U7-U6@p6,	(	Ioxfwxdwlrq b#hur#(		
4	rog	K8:3<9:	nw2FE		5:	5::<6E		5::<6E	5::<6:4	31354	433(	3(	Pass	Pass
5	vwxfn	534338376:	sp2FE		5:	7<17<74		7<17<74	7<17<74	3	3(	0433(	No	Pass
6	vhyhlq	437863:	sp2FE		5:	31:4:4		31:4:4	31:6;4	31354	433(	3(	Pass	Pass
7	fxwrph	4933685:	bq2FE		5:	45:17<:		45:17<:	45:1849E	3134<5	<4(	0<(	No	Pass
8	fxwrph	483:75<5	bq2FE		5:	93;1:8<7		93;1:8<7	93;1:8<7	3	3(	0433(	No	Pass
9	ryh#433	37046<75;	nw2FE		5:	47961;39E		47961;3:	47961;5E	3134;4	;9(	047(	No	Pass
:	ryh#33	53433839<:	sp2FE		5:	<97146<9		<97146<9	<97148;7	3134;;	<3(	043(	No	Pass
;	qhz	DF077:;86	sp2FE		5:	3168E		3168E	3169<	3134:	;4(	04<(	No	Pass

14-8 (Form-8) Water quality test

(1) CUSTOMER METER: Registration number___________________________

(2) Location____

(3) Type of Meter____

(4) Operation period____________________________________

(5) Tested by ____

(6) Date_________________________________

Sheet No, ___________________

No. of sample	Location	Colorimetric reaction by DPD	Numerical value of Conductivity	Numerical value of pH	Note

What is your comment?

14-9 ((Form-9) Measurement of flowing water form water Tap

S/No.		1	2	3	4	5	6	7
Illustration								
Status of running water		No. of Dripping (10/min)	No. of Dripping (30/min)	No. of Dripping (90/min)	String	Open faucet 90 degrees	Open faucet 180 degrees	Fully Open
Feed-water pressure (bar)								
Dia of faucet (mm)		15	15	15	15	15	15	15
Measurement of Weighing of water volume (g)								
No. of Sampling	Trial-#1							
	Trial-#2							
	Trial-#3							
	Ave.							
Conversion calculation to water quantity (liter)								
Prediction of commercial loss amount (m 3)	24 hrs							
	30 days *24Hrs							
	365 days *24 Hrs							

What is your comment?

14-10 (Form-10) Measurement of flowing water

(1) Custer meter (Registry number) ____________________________

(2) Diameter of meter; _________ mm

(3) Pressure__________________ (Kg/cm^2)

(4) Name of test staff____

(5) Date_____________________

No.	Measured amount of water (liters)		Weight (g)	Volume of flowing water (liters)			Flow Velocity (liters/ min)	Photo
				60 min	1 day	365 days		
1	5	1st trial						
		2nd trial						
2	10	1st trial						
		2nd trial						
3	20	1st trial						
		2nd trial						
4	30	1st trial						
		2nd trial						
5	40	1st trial						
		2nd trial						
6	50	1st trial						
		2nd trial						
7	70	1st trial						
		2nd trial						
8	100	1st trial						
		2nd trial						
9	200	1st trial						
		2nd trial						

What is your comment?

15. References

15-1 Site Visit to EWASCO’s MUKANGU Water Treatment Plant (WTP

15-1-1 Outline of Water treatment plant

a) Construction period: 2010 to 2012 (New WTP),

b) Design Capacity: 12,100m^3/day (New WTP) & 11,000 m^3/day (Existing WTP),

c) Financial resources: A grant from the Japanese Government (New WTP),

d) System : Conventional (Flocculent settling ＋ Rapid sand filter+ Sludge lagoon),

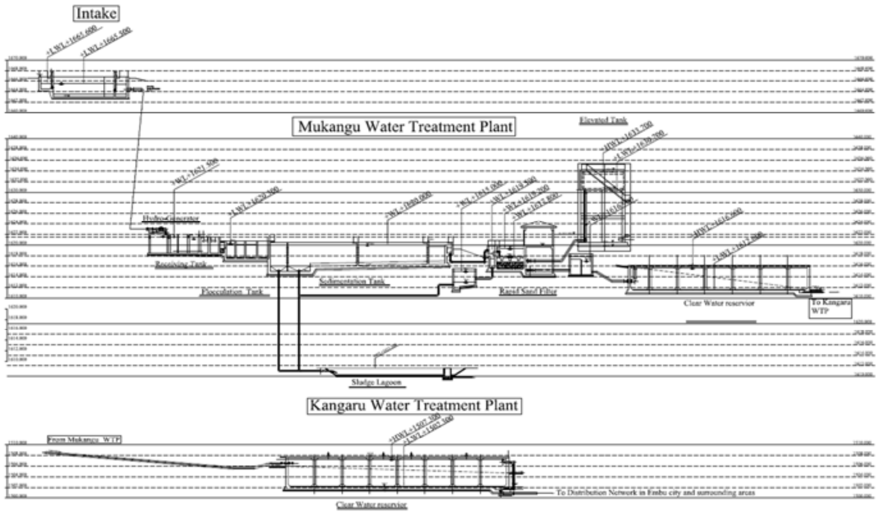
e) Main facilities constructed (Constructed New Water utilities)

- Improvement of intake dam
- Construction of water purification plant (12,100m^3/day)
- Installation of water conduit (Ø 500 mm x 5.9 km, Ductile cast iron tube)
- Main water pipeline (Ø 315 mm diameter x 5.2 km UPVC)
- Water distribution pipeline (Ø 250mm~400 x 10.8 km Ductile cast iron/ UPVC)
- Construction of distribution pond 6000 m^3 (kangaroo) + 3000 m^3 (Mukangu)
- Supplied equipment
  - Water meter test bench (1)
  - Water Quality Test Equipment
    (Ph meter, Residual chlorine concentration meter, Jar tester, Workbench, Electronic balance, Spectrophotometer, Refrigerator, Pure-water equipment, Desiccator, Bacteria Incubator, Colony canter and others
  - 3-ton truck (1)

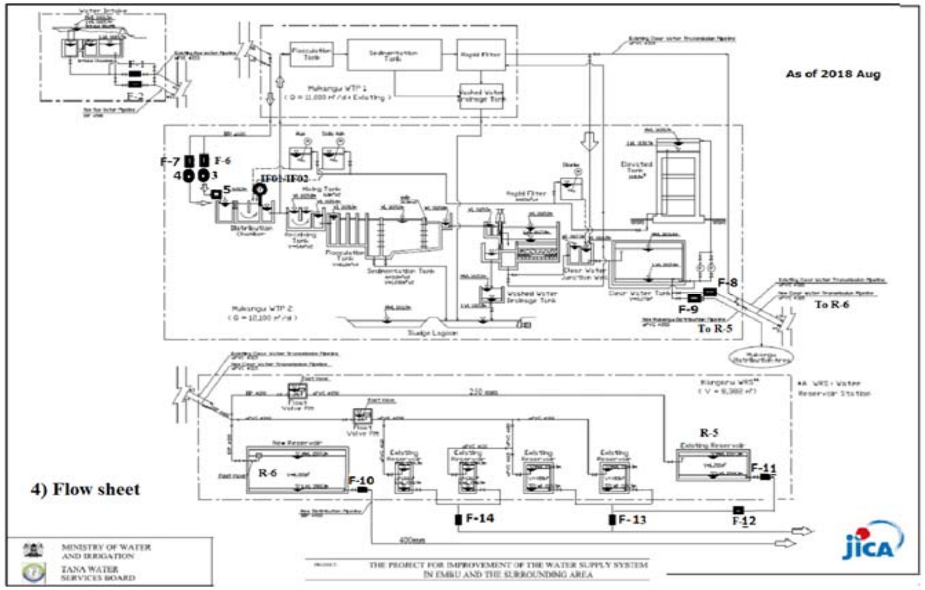
15-1-2 Photos



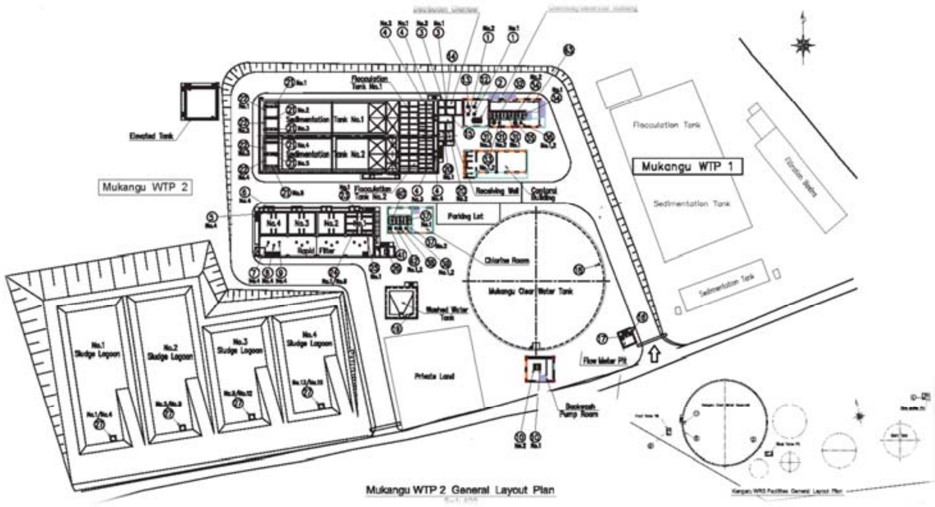
15-1-3 Hydraulic Profile (Gravity Flow)



Hydraulic Profile



15-1-5 General Layout Plan

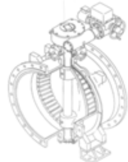


15-1-6 Monitoring Facilities

6-1) Intake

F01-01 (F1)	Intake Flow Meter-1 (Connect to Existing Pipe line)	Mechanical turbine	
F01-02 (F2)	Intake Flow Meter-2 (Connect to New Pipe line)	Mechanical turbine	

6-2) WTP

M02-01-01/02 (3)/(4)	Inlet Flow Control Valves (Toothed Butterfly)	Ø400mm		
M02-02 (5)	Hydro Power Generator (Double suction volute type)	0.266m^3/sec x 30m x 50kw		
F02-01/02 (6)/(7)	Inlet Flow Meters (Mechanical turbine)	Ø400mm		
E02-IF01 E02-IF02	Distribution Chamber Inlet Flow Meter Ultrasonic weir type)	0-600 m^3/h		
F02-06 (F8)	Clear Water Reservoir Outlet Flow Meter (Mechanical turbine)	Ø400 mm, 200～1000m^3/h		
F02-067 (F9)		Ø300 mm, 200～700m^3/h		

6-3) Distribution reservoirs (At Kangru)

R-6 (F10)	6,200m^3 Clear Water Reservoir Outlet Flow Meter (Mechanical turbine)	Ø400 mm, 1Unit	
R-5 (F-11)	1,200m^3 Clear Water Reservoir Outlet Flow Meter (Mechanical turbine)	Ø 200 mm	
R-5 (F-12)	1,200m3 Clear Water Reservoir Outlet Flow Meter (Mechanical turbine)	Ø 200 mm	
R-3 / -4 / R-5 (F13)	2-450m^3 Clear Water Reservoir Outlet Flow Meter (Mechanical turbine)	Ø 200 mm	
R-1 / R-2 (F14)	2-136m^3 Clear Water Reservoir Outlet Flow Meter (Mechanical turbine)	Ø 100 mm	

15.2 Conversion Tables

15-2-1 Pressure

	ata (kg/cm^2)	mm water (4℃)	bar	Mpa	Kpa	PSI(lb/in)
ata (kg/cm^2)	1	10,000.03	0.981	0.0981	98.07	14.22
mm water (4℃)	9.99 x 10^{-5}	1	9.81x10^{-5}	9.81 x 10^{-6}	9.81 x 10^{-3}	1.422x10^{-3}
bar	1.02	101197.44	1	0.1	100	14.5
Mpa	10.2	101,974.42	10	1	1,000	14.5
Kpa	0.01	101.97	0.01	0.001	1	0.145
PSI(lb/in)	0.07	703，09	0.0689	6、893 x 10^{-3}	6,863	1

15-2-2 Volume Vs Weight (Water Specific gravity = 1)

Volume		Weight		Note(500mg)
L (liter)	mL(mill-liter)	g (gram)	mg(milligram)	
1.0	1,000	1,000	1,000,000	
0.5	500	500	500,000	
0.1	100	100	100,000	
0.01	10	10	10,000	

15-2-3 Water density

Water density (g/cm^3)

Temp.(℃)	After the decimal point									
	0	1	2	3	4	5	6	7	8	9
0	0. 999841	0. 999847	0. 999854	0. 999860	0. 999866	0. 999872	0. 999878	0. 999884	0. 999889	0. 999895
1	0. 999900	0. 999905	0. 999909	0. 999914	0. 999918	0. 999923	0. 999927	0. 999930	0. 999934	0. 999938
2	0. 999941	0. 999944	0. 999947	0. 999950	0. 999953	0. 999955	0. 999958	0. 999960	0. 999962	0. 999964
3	0. 999965	0. 999967	0. 999968	0. 999969	0. 999970	0. 999971	0. 999972	0. 999972	0. 999973	0. 999973
4	0. 999973	0. 999973	0. 999973	0. 999972	0. 999972	0. 999972	0. 999970	0. 999969	0. 999968	0. 999966
5	0. 999965	0. 999963	0. 999961	0. 999959	0. 999957	0. 999955	0. 999952	0. 999950	0. 999947	0. 999944
6	0. 999941	0. 999938	0. 999935	0. 999931	0. 999927	0. 999924	0. 999920	0. 999916	0. 999911	0. 999907
7	0. 999902	0. 999898	0. 999893	0. 999888	0. 999883	0. 999877	0. 999872	0. 999866	0. 999861	0. 999855
8	0. 999849	0. 999843	0. 999837	0. 999830	0. 999824	0. 999817	0. 999810	0. 999803	0. 999796	0. 999789
9	0. 999781	0. 999774	0. 999766	0. 999758	0. 999751	0. 999742	0. 999734	0. 999726	0. 999717	0. 999709
10	0. 999700	0. 999691	0. 999682	0. 999673	0. 999664	0. 999654	0. 999645	0. 999635	0. 999625	0. 999615
11	0. 999605	0. 999595	0. 999585	0. 999574	0. 999564	0. 999553	0. 999542	0. 999531	0. 999520	0. 999509
12	0. 999498	0. 999486	0. 999475	0. 999463	0. 999451	0. 999439	0. 999427	0. 999415	0. 999402	0. 999390
13	0. 999377	0. 999364	0. 999352	0. 999339	0. 999326	0. 999312	0. 999299	0. 999285	0. 999272	0. 999258
14	0. 999244	0. 999230	0. 999216	0. 999202	0. 999188	0. 999173	0. 999159	0. 999144	0. 999129	0. 999114
15	0. 999099	0. 999084	0. 999069	0. 999054	0. 999038	0. 999023	0. 999007	0. 998991	0. 998975	0. 998959
16	0. 998943	0. 998926	0. 998910	0. 998893	0. 998877	0. 998860	0. 998843	0. 998826	0. 998809	0. 998792
17	0. 998774	0. 998757	0. 998739	0. 998722	0. 998704	0. 998686	0. 998668	0. 998650	0. 998632	0. 998613
18	0. 998595	0. 998576	0. 998558	0. 998539	0. 998520	0. 998501	0. 998482	0. 998463	0. 998444	0. 998424
19	0. 998405	0. 998385	0. 998365	0. 998345	0. 998325	0. 998305	0. 998285	0. 998265	0. 998244	0. 998224
20	0. 998203	0. 998183	0. 998162	0. 998141	0. 998120	0. 998099	0. 998078	0. 998056	0. 998035	0. 998013
21	0. 997992	0. 997970	0. 997948	0. 997926	0. 997904	0. 997882	0. 997860	0. 997837	0. 997815	0. 997792
22	0. 997770	0. 997747	0. 997724	0. 997701	0. 997678	0. 997655	0. 997632	0. 997608	0. 997585	0. 997561
23	0. 997538	0. 997514	0. 997490	0. 997466	0. 997442	0. 997418	0. 997394	0. 997369	0. 997345	0. 997320
24	0. 997296	0. 997271	0. 997246	0. 997221	0. 997196	0. 997171	0. 997146	0. 997120	0. 997095	0. 997069
25	0. 997044	0. 997018	0. 996992	0. 996967	0. 996941	0. 996914	0. 996888	0. 996862	0. 996836	0. 996809
26	0. 996783	0. 996756	0. 996729	0. 996703	0. 996676	0. 996649	0. 996621	0. 996594	0. 996567	0. 996540
27	0. 996512	0. 996485	0. 996457	0. 996429	0. 996401	0. 996373	0. 996345	0. 996317	0. 996289	0. 996261
28	0. 996232	0. 996204	0. 996175	0. 996147	0. 996118	0. 996089	0. 996060	0. 996031	0. 996002	0. 995973
29	0. 995944	0. 995914	0. 995885	0. 995855	0. 995826	0. 995796	0. 995766	0. 995736	0. 995706	0. 995676
30	0. 995646	0. 995616	0. 995586	0. 995555	0. 995525	0. 995494	0. 995464	0. 995433	0. 995402	0. 995371

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Internal Information

TEXTBOOK
FOR
JOINT TRAINING
（DRAFT）

"INTRODUCTION TO NRW IN DISTRIBUTION RESERVOIRS"

February, 2019

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)
Mr. Karisa ＃16

Assisted by JICA KENYA

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Original Edition February, 2019

Table of Contents

1. Objectives (Out-put)

① Understand the General Distribution systems
② Understand the typical Inflow and Outflow patterns
③ Understand the type of Non-Revenue Water caused from distribution reservoir
④ Understand the concept of how to investigate Non-Revenue Water in distribution reservoir
⑤ Understand the Roles of flowmeters and water gauges.
⑥ Understand the concept of how to investigate the change in the Inflow volume hourly
⑦ Understand the concept of how to investigate the change in the water level hourly

2. Introduction

The non-revenue water (Physical - Real Losses) generated in the water reservoir is mainly caused by (a) degradation of the function of the distribution reservoirs, (b) loss of purified water, (c) water pollution caused by invasion of contaminated wastewater from the outside, become.

In order to reduce NRW, it is important to detect / predict water leakage / deterioration early from records of daily inspection and maintenance work (abnormality, deterioration, damage, leakage etc.) and records of water supply management monitoring.

2.1 The Investigation Method of Water Leakage is shown below.

① Study of structure of distribution reservoirs;
(a) Inspection of visual and deterioration,
(b) Watertight survey of the distribution reservoirs,
② Study of evaluation of measuring equipment functions and piping installation status,
③ Implementation of evaluation for monitoring function of water distribution / water level management (Introduction of Case study - 1 to 3)
④ Confirmation of current design specifications (Exercises)

2.2 The Places where Non-revenue Water Mainly Occurs are shown below.

① Main body of structure
② Near the penetration pipe of the wall
③ Outflow Piping
④ Others (measuring instrument for water distribution management)

In this lecture, "outline of basic knowledge" about "the procedure of water supply functional survey" and the "verification way of the main design criteria" required for evaluation of the monitoring function of water supply control is explained below.

Introduction to NRW in distribution reservoirs February, 2019

3. Key Words Definitions

Service/Distribution reservoirs	It is a reservoir for temporarily storing purified water in order to properly distribute water according to demand in the water supply area.
Water distribution management	It is to accurately predict the hourly fluctuation of demand from well-balanced water volume & water level management and to carry out safety, rational and efficient operation management
Effective capacity of distribution reservoir	It is the capacity between HWL and LW.L of the distribution reservoirs. (Usually 6 to 12 hours of maximum daily consumption)
Planned maximum daily consumption	It is the maximum amount of water supply per day. （Service population × Max. supply per day per head ×Safety factor）
planned maximum hourly consumption	It is the maximum water consumption during the year's hourly consumption.（It is 1.5 to 2.0 times the average daily consumption）
Hourly-variation graph of daily water distribution	Predict water distribution change per hour by comparing the balance of "Inflowing" and "Outflowing “in a bar chart.
Hourly-variation curve graph of daily water level.	To predict water distribution change per hour, the "difference (water level)" between the Inflowing amount and the Outflowing is represented by a curve graph. (Predicts the risk time zone of Overflow and Air mixed water supply)

4. What is the Function of the Distribution Reservoirs？

The function of the water supply reservoir provides stable water supply service even in the increasing water supply demand time during the daytime.

In particular, it has the ability to store the amount of consumption required during the daytime during the night when the water consumption is low.
Also, there is no loss of purified water, the structure of the reservoir is not polluted by sewage or groundwater invasion and normal maintenance is required.

5. What is Water Distribution Management?

Distribution management is to maintain the balance of the day's balance according to changes in demand. The simple management method is to measure "the difference in water level" between Inflow (A) and Outflow (B) over a period of 24 hours every hour.
In other words, proper water distribution management, timely the "simulation graph" is created / analyzed from the measurement data of the current water level change, so that the water level of the water distribution reservoir will not become zero and not Outflowing while predicting the demand trend by hourly. As a result, it is possible to reduce non-revenue water by Overflow etc.

NOTE- 1 What is the fluctuation range of the target water level?
(a) Set less than full water at night, (b) Set slightly higher during daytime.

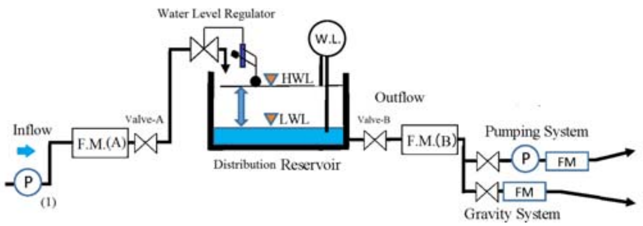


Figure-1 Concept of flowmeter and water level measurement in water distribution management

6. Outline of Distribution Facilities

6.1 Types of Distribution Methods

There are two types of water distribution system, gravity type and pump pressure type.（Refer to **Figure-2**）

6.2 Patterns of Inflowing and Outflowing

In general, the water distributed from the water purification plant is constantly Inflowing into the distribution reservoirs, but the Outflowing as consumption from the distribution reservoir fluctuates irregularly in the state of use of consumption in the water supply area.

6.2.1 Patterns of Inflowing

(a) Purified water is usually distributed to a water distribution pond at a constant quantity for 24 hours.

(b) A certain WSP operates the water purification plant only during the daytime and does not operate the Outflowing valve at night, so the Outflowing stops or the Outflowing decreases / becomes zero.

6.2.2 Patterns of Outflowing

Demand for annual water supply volume fluctuates with time due to the following factors.

(a) Change in scale / area of water distribution system
(b) Change in application of water supply area
(c) Changes in water distribution by weekday / holiday
(d) Change in temperature / season / relationship between weather and water distribution
(e) Status of change of replacement / expansion work of piping

◆**NOTE-2: Consumption Patterns（KENYA STD）**

(Details : Refer to the Practice Manual for Water Supply Services in Kenya Dec. 2005l)

① **Rural Areas**

(a) It should be assumed that all water is drawn between **7 a.m. and 7 p.m.**

(b) Exceed 1,000, it be should assumed that the draw-0ff is constant through the **12 –hour** consumption period.

(c) Large institutions, industry etc., may have their own balancing reservoirs、which may reduce the peak demand

② **Principal towns and Urban Centres**

(a) It should be assumed that all water is drawn within the within the **whole day i.e. 24** hours.

(b) No additional peak factors should be applied to water consumption rates

(c) It should be assumed that most houses have individual roof tanks which will reduce the peak factors considerably.

③ **Loss amount due to NRW**

The water consumption figures include about **20%** allowance for water losses through leakage and wastage.

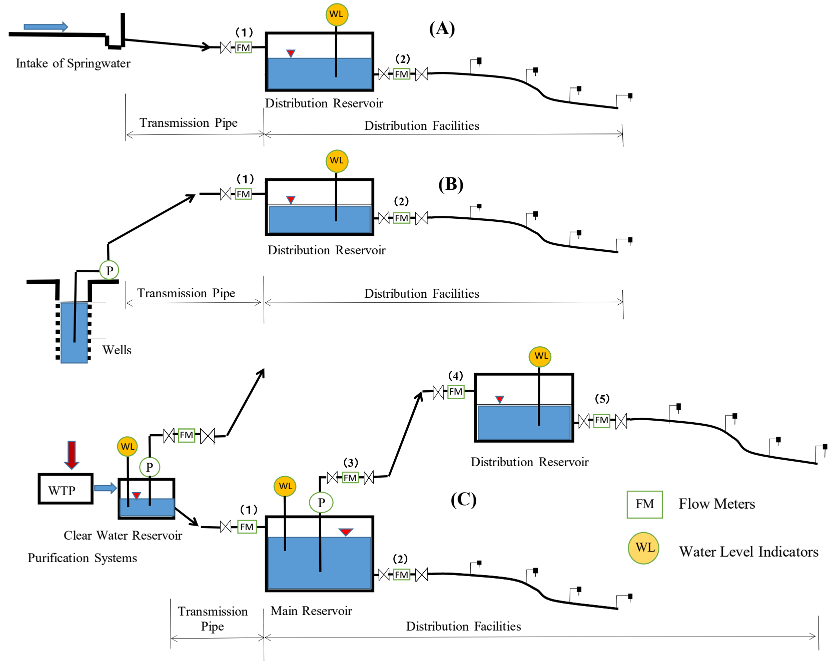


Figure-2 Example of water distribution methods

6.3 Types of Distribution Reservoirs

There are ground type, semi-underground type, and underground type in large-capacity distribution reservoirs. (**Refer to Fifure-3**)

In addition, the elevated tank is used as a small scale distribution tank.

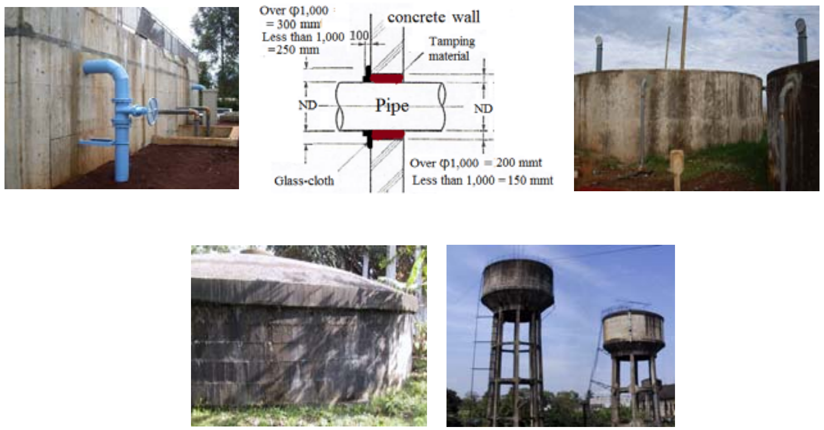


Figure-3 Example of a concrete-type distribution reservoirs

6.4 Introduction of the Concept of Design Criteria

6.4.1 Necessity for a Review

The formulas of design criteria for evaluating the current water distribution function due to changes in the distribution environment are shown below.

(a) Changes in water demand

(b) Generation of non-revenue water

(c) Appropriate effective capacity (increase of fire extinguishing water quantity)

6.4.2 Calculation Formulas of Design Criteria

◆ **Calculation of planned water distribution**

(1) Formulas :

① Design daily maximum supply per head : q (l/capita/d)……………….(1)

(Refer to actual values or Item **10.2.)**

(a) Assumptions;

This amount of water supply (water supply volume) is the demand amount (m^3 / d) assuming that all customers in the planned distribution area use water

concurrently during that time zone.

(b) Application :

This formula serves as the basis for calculating the basic water volume for the planned maximum daily consumption.

② Planned maximum daily consumption: Qd (m^3/d) ……………….(2)

$= q \times P \times (1+Lf)$

(a) Assumptions;

・q (l/head/d)= daily maximum supply per head

・P (head) = Design population served

・Lf = Loss amount due to non-revenue water **(Refer to Note-2-③)**

(b) Application :

This formula serves as the basis for calculating the basic water volume for waterworks' scale determination

③ Planned maximum hourly consumption Qh max (m^3/h) ……………….(3)

$= Q / 24(h)$

(a) Application :

This formula serves as the basis for calculating the basic water volume for determining the equipment specifications

④ Planned daily average consumption: Qd av (m^3/d) ……………….(4)

= **Qd av** × (70~80%)

(a) Application :

This formula serves as a basis for calculating the basic water volume of the water supply finance plan, including the calculation of chemicals / electricity consumption / maintenance and maintenance cost / water fee etc.

⑤ Planned maximum hourly consumption in normal condition : Qn h max (m^3/h) ……………….(5)

=Qn h max × K

(a) Assumptions;

・K-value: Maximum hourly-variation factor

=(Qh max (m^3/h) ÷ Average hourly consumption (Q h av: m^3/h)

=1.3 (large city) ~2.0 (small city/ special case)

(b) Application：

This formula serves as the basis for calculating the basic water volume of the water distribution facility plan / fiscal plan

NOTE-4 What is K-value

(The K value is necessary for calculating the effective water volume of the distribution reservoir)

① The Maximum K-value is the ratio of maximum hourly consumption (Inflowing) to average hourly consumption (Outflowing).
If K-value high means that in the time zone where demand is particularly high then the balance between the Inflowing and the Outflowing collapses, and the Outflowing increases more than Inflowing, so the stored amount in the distribution reservoir decreases.

② Obtained from current analysis of measurement data of distribution variation….**Refer to 9.2- (5)**

③ Calculation of K-value is shown in **Figure -21**

④ Seek from existing general reference materials・・**Refer to Item-11 (attached documents)**

⑥ Planned maximum hourly consumption in firefighting: Qp (m^3/h)………(6)

＝ Qn h max＋ Qf

(a) Assumptions;

・Qf (m^3/h) = Amount of fire-fighting water

(b) Application：

This formula serves as the basis for calculating the reference water volume for the scale determination of the water distribution network.

NOTE-5 Example of prediction of Fire Demands

① Comprehensively judge from regional population, hearing rate, house structure
(Example for 5000 area……………….1.0 m^3/min for 1.0 hour (Japan)

② Judge from population number …..Refer to **Table-1** (Japan)

③ **Refer to KENYA STD**
(Details : Practice Manual for Water Supply Services、Dec. 2005)
In urban /rural centers, Capacity for firefighting should not be less than **10 liter/sec during 2 hours** (0.6 m^3/min for 2 hours).

Table- 1 Examples of Fire Demands by population (Japan)

populations	Fire Demands (m^3)	populations	Fire Demands (m^3)
5,000	50	30,000	300
10,000	100	40,000	350
20,000	200	50,000	400

◆ **Determination of the minimum caliber of delivery and distribution pipes**

(a) In small water supply facilities, it is difficult to remove pebbles and gravels into pipes during construction, even if sufficient water delivery and distribution is possible with a caliber of about 20 to 25 mm in hydraulic calculations.

(b) The minimum bore size should be 40 - 50 mm or more.

◆ **Calculation of effective capacity of distribution reservoir V (m^3)**

(1) Formula：

⑦ Effective capacity of distribution reservoir: V (m^3)………………..(7)

= Qn h max × T

(a) Assumptions;

・Qn h max (m^3/h)= **Maximum hourly consumption**

・T(h) : Required retention hours = Tf + Sf

Tf（h）: Retention hours for adjustment of storage variation

＝8 to 12 hours (minimum 6 hours or more)

Sf: Safety factor

(b) Application：

This formula is the effective capacity (actually between the high water level HWL and the low water level LWL) that can be actually used out of the total capacity of the water supply reservoir, and it is the basis for calculating the adjustment capacity that can cope with the time variation of the water supply volume and abnormality.

◆NOTE-6 Example of how to determine the retention hours for adjusting the variation of the storage capacity: Tf (h)

(a) This retention hours is indicated per day by the ratio of the total storage reduction amount and the total Inflowing. **(Refer to item 9.2)**

Formula of Tf＝Decrease in daily storage ÷ Constant Inflow rate

Ex. Required retention hours :T (h) = 6.5h (Tf) ＋1~2 h (Sf)= 8.5 (h)（Refer to **Figure-14**）

（b） Effective Capacity (KENYA's STD)

(Details : Practice Manual for Water Supply Services in Kenya Dec. 2005)

Capacity of Water Storage in Rural and Urban Area are **50% of the daily water demand** of the area served by the tank.

◆ **Calculation of capacity of circular water distribution reservoir:** V (m^3)

(1) Formulas：

⑧ ***Capacity of circular water distribution reservoir: V (m^3)……….(8)***

＝(A × H) ÷ N

(a) Assumptions;

・Effective water depth: H (m)

・Number of reservoir: N (set)

・Cross sectional area: A (m 2) = R (radius) × R (radius) × 3.14

= R 2 × 3.14 or = V ÷ H

・Diameter: D(m) = 2 （√A/3.14） ＝ 2 R= R+R

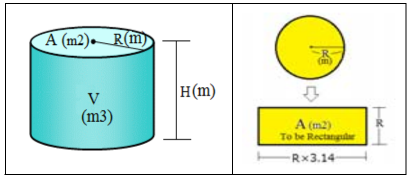


Figure-4 Dimension Chart of Cylinder

7. Outline of the Flowmeters / Water Level Gauges Used in the Survey

Basic data necessary for understanding water distribution management, fluctuation in both the Inflow capacity and the water level will utilize the existing measurement equipment

7.1 Flowmeters

The cumulative flow rate measurement of the both Inflow into reservoir and Outflow as consumption is recorded with a following flowmeters.

7.1.1 Points to Keep in Mind during Selection

Points to be noted when choosing the type of flowmeters are shown below.

(a) Flow metering can cover flow range of design value.

(b) Accumulated flow rate is displayed.

(c) The instantaneous flow rate is displayed.

(d) Accumulated flow rate and instantaneous flow rate data are saved.

(e) Head loss is low

(f) New flow meters and passed the performance test

· Test pressure (1.5 times) / Test duration (1 ~ 2 min.)

· Visual examination

· Operation inspection: meter operation, water hammer, water leakage

· Accuracy test: ISO 4064 / MID 2004/22 / EC

· Manufacturer's reputation is good

7.1.2 Types of Flowmeters

The accuracy of the flowmeter causes measurement errors due to the properties of the liquid, the material of the pipe, the amount of water in the pipe, installation conditions.

Select the optimum model by paying attention to the following items.

① Pipeline status

(a) Condition of water flow (Is the pipeline completely full?)

(b) "Securing the straight pipe part necessary for the flowmeter" on the upstream side and downstream side of the measurement part?

(c) Confirmation of aging situation of pipeline. (Influence of measuring accuracy due to corrosion inside and outside)

② Model · Selection of caliber:

(a) For selection, check design conditions such as measurement range and measurement accuracy.

③ Cost Comparison:

(a) Consider the total cost including the flowmeter and related equipment price, installation cost, maintenance cost etc.

④ Selection of standard products:

(a) Select a product that is certified for performance and that passes the test. And regularly verify performance every year.

⑤ Generation of pressure loss:

(a) Select pressure type loss caused by inserting the flowmeter, which is acceptable type.

⑥ Installation location

(a) Choose an installation location that is easy to inspect, dry and difficult to mix with sewage and has no risk of damage.

(2) Type of Flowmeters

① Ultrasonic Flowmeters

<u>Overview</u>

When the ultrasonic flowmeter transmits ultrasonic waves at an angle to the Inflow side in the liquid, there is a time difference of propagation reaching the sensor between the two points depending on the flow velocity.

From this difference average flow velocity is converted into flow rate.

The transmission of ultrasonic waves from the sensor is periodically alternately emitted in the direction opposite to the flow direction (A → B) (B → A), and the precision of the difference in the propagation time is increased. **(Refer to Figure 5)**

<u>Points to keep in mind</u>

Attention should be paid to considerations that affect the measurement accuracy of the ultrasonic flowmeter.

(a) A channel that is always filled with fluid and does not contain a large amount of bubbles (2% or more as a guideline).

(b) The aperture should be selected within the optimum flow range with an average flow velocity of 2 to 4 m / s.

(c) There is a flow speed and pipe diameter inside the pipe, and as the flow rate is slow (flow rate is small), the error becomes more likely to occur as the pipe diameter becomes smaller.

(d) If there are scales (deposits such as rust) on the inner surface of the pipe, volume of earth and sand, etc. the tube cross section changes and affects measurement accuracy.

(e) Especially when there is extreme scale adhesion or peeling of lining material, measurement becomes difficult.

(f) Measurement error will occur if the outer surface of the pipe is rough with a cast iron pipe.

(g) PVDF pipe (polyvinylidene fluoride resin) wall thickness of 9 mm or less, PP tube (polypropylene tube) with wall thickness of 15 mm or less.

(h) SGPW pipe [Galvanized steel pipe for water supply (commonly called white gas pipe) and lining pipe may have errors.

(i) Sensor installation Linear part (upstream: 10D to 50D) Downstream: 10D) is necessary, please confirm details with the manufacturer.

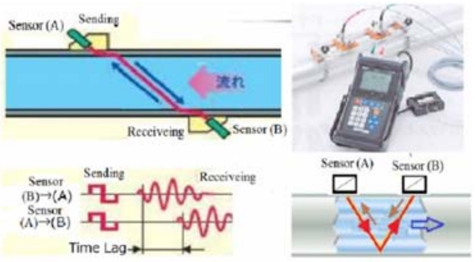


Figure-5 Principle of measurement by Ultrasonic Flow meters

② Electrometric Flowmeters

<u>Overview</u>

When the "water: electric conductor" crosses the inside of the magnetic field, the electromagnetic flowmeter generates an electromotive force proportional to the speed at both ends of the conductor. The electromotive force is calculated from the average flow velocity and the caliber.(**Refer to Figure 6**)

There is no malfunction due to friction or foreign matter because there are no rotating measuring instruments such as an impeller and a pointing gear that impede water flow inside the measurement.

<u>Points to keep in mind</u>

(a) The piping is always filled with fluid and water that does not contain a large amount of bubbles (2% or more as a guideline).

(b) The diameter is selected within the optimal flow range with average flow velocity of 2 to 4 m / s.

(c) When the average flow velocity is less than 1 m / sec, the electromotive force is small and the problem of accuracy tends to occur.

(d) The pressure loss is the same as the pipe of the same length and is "small".

(e) If the flow rate decreases if the diameter is the same as the pipe diameter, use a reduction pipe (reducer).

(f) Because turbulence and drift occurring at the fitting part of the pipe cause measurement errors, rectify and equalize.

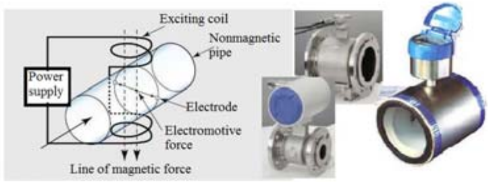


Figure-6 Principle of measurement by Electrometric Flow meters

③ Mechanical Flowmeters (Woltman Turbine Meters)

Overview

The axial flow type flowmeter is installed with a turbine wheel / blade wheel in the pipe flow, rotates at a speed substantially proportional to the flow rate, and integrates the flow rate from this rotation number.

For large flow rate applications, there are models that adopt a wind turbine impeller called a turbine type flow meter.

Classification of models

(a) Tangential flow type (vertical type): (**Refer to Figure- 7**)

- The axis of the impeller is installed perpendicular to the flow.
- Easy structure, easy to maintain ・
- Although the measurement accuracy is high, the performance in small a minute flow rate range is slightly inferior.
- It is suitable for large flow rate such as supplying water to a receiving tank or the like. (Diameter 50 to 1000 mm)
- The pressure loss is about 100 kpa (1 kg / cm ^{2}) at the maximum.

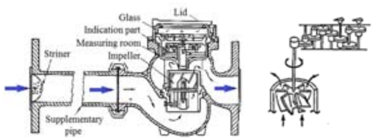


Figure-7 Principle of Tangential flow type Flow meters

(b) Axial flow type (horizontal type):

- Installed parallel to the flow. (**Refer to Figure-8**)
- Since the driving force can be made considerably large against the frictional force, it is possible to measure the flow rate with high accuracy.
- Although the measurement accuracy is high, the performance in small flow rate

range is slightly inferior.
- It is suitable for large flow rate such as supplying water to a receiving tank or the like. (Aperture 50 to 350 mm)
- It is also used as a flow meter for low viscosity petroleum trading.
- Pressure loss is about 30 kpa (0.3 kg / cm 2) at maximum.

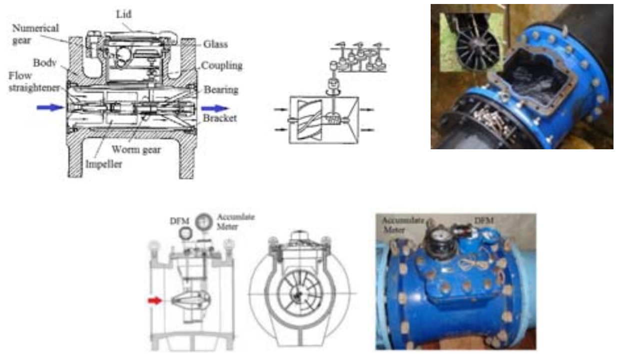


Figure –8 Example of Trbine meters

7.1.3 Estimation of Measurement Accuracy

A measurement accuracy varies depending on flow velocity in a pipe, air bubbles / air mixing rate, an installation position / angle, etc. **(Refer to Table-2)**

Especially the accuracy of the mechanical flowmeter deteriorates due to the wear condition of the rotor / gear.

Table -2 Example of Meters accuracy

	Type/Model	Approximate Accuracy Range
1	Ultrasonic Flow Meters	0.5~1.0 %
2	Electromagnetic Flow Meters	0.15~0.5 %
3	Mechanical Flow Meters (Woltman)	1.0~2.0 %
4	Venturi Meter	0.5~3.0 %

Source: JICA Module-1 Trainees Manual Aug 2013

7.1.4 Head Loss

In particular, the head loss of the mechanical flowmeter generally increases with increasing flow rate.

As the head loss increases, the accuracy of the measurement range of the small flow rate decreases particularly. **(Refer to Fgure-9 and 10)**

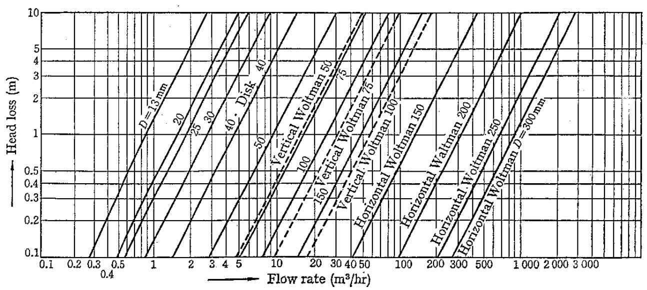


Figure-9 Head Loss in Small Water Meters (Source: JWWA Design Criteria 1978)

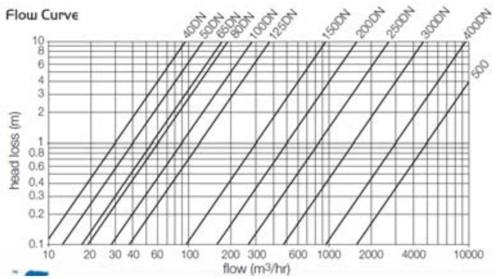


Figure-10 Head Loss in Large Water Meters (Source: ES-waterrnet 2018)

7.2 Water Level Gauges

The water gauge is a device that monitors and observes the difference (water level) between the Inflowing (A) and the Outflowing (B) in the water distribution reservoir. **(Refer to Figure-1)**

7.2.1 Points to Keep in Mind during Selection

Points to be noted when selecting the type of water level gauges are as follows.

(a) Determination of an appropriate measuring depth / height

(b) Consideration of fixing method / place of the water gauge

(c) Easy monitoring of water level value

(d) Maintenance-free for a long time

(e) Prevention of malfunction caused by shaking of the water surface caused by the impact of influent water

(f) Prevention of rainwater Inflow

(g) Waterproof specification, others

7.2.2 Types of Water Level Gauges

(1) Water level gages

Overview

In the method of measuring water pressure thrown into water, the pressure given to the diaphragm to the water surface is measured as the head pressure.

This method is easy to install, so there are many examples of use. **(Refer to Figure-11)**

Figure-11 Example of Hydraulic level gages

(2) Float level gages

Overview

This method is a measuring instrument that catches and measures the up-and-down motion of float floated on the water surface. (**Refer to Figure-12)**

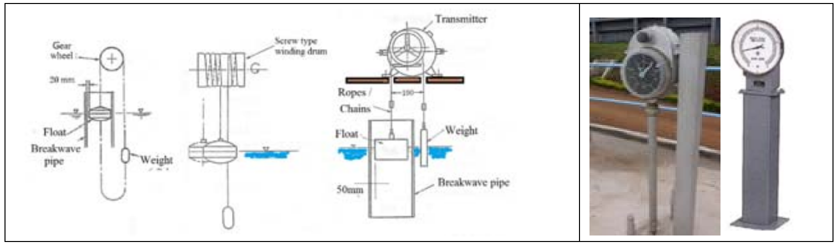


Figure-12 Example of Float level gages

(3) Ultrasonic level meters

Overview

This ultrasonic level meter is a meter that measures the water level from the time required until the ultrasonic pulse emitted from the ultrasonic sensor installed at the top of the water reservoir reflects off the surface of the water.

Figure-13 Example of Ultrasonic level meters

(4) Electrode level gages

Overview

This water gauge is a meter which uses the character in which electric capacity changes and measures a water level, when an electrode is infixed underwater and contact of the water surface and a pole bolt goes out.

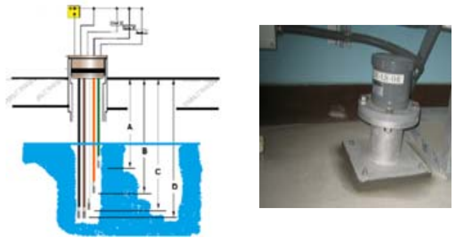


Figure-14 Example of Electrode level gages

8 Survey Methods

8.1 Survey of Leakage from Structures by Visual Inspection / Deterioration Inspection (Outline description)

8.1.1 Places to investigate

(Semi-underground / Underground / Ground – types distribution reservoirs)

① Floor (bottom) and side walls (inner-outer)

② Places where piping is laid in the concrete structure

8.1.2 Phenomenon of aging

① Leakage occurs

② Occurrence of cracks

③ Surface peeling occurred

④ Occurrence of internal-rebar corrosion, others

8.1.3 Items investigated

Survey items of water leakage from a simple structure are shown below.

① Confirmation of water leakage from "difference" between Inflow and Outflow

water volume,

② Verification of the leakage of water by the water analysis of the "puddle" which occurs around a civil structure,

③ Visual confirmation of deteriorated civil engineering structure / leakage location / piping installation site,

④ Confirm of internal deterioration of the distribution pond with chlorine-containing water vapor,

⑤ Confirmation by strength of civil structure by sampling by compression test, rebar corrosion, concrete chemical reaction analysis,

⑥ Confirmation of hammering sound by Hammering test and Schmitt hammer,

⑦ Verification by alkaline aggregate reaction survey,

⑧ Confirmation by reinforcing bar covering depth measurement,

⑨ Confirmation by sound listening survey, others

Figure-15 Example of Electrode Level Gages

8.1.4 Measures

Repair examples are shown below.

① Repair with concrete waterproof mortar (outer inner surface),

② Repair by eliminating defective concrete,

③ Repair or installing expansion joint (water stop plate)

④ Repair by construction of inner lining,

⑤ Repair by stainless steel / FRP lining, others

8.2 Watertight Survey of Distribution Reservoirs (Explanation of Overview)

In this method, after filling the distribution reservoir about 1 to 2 times / year, the A-inlet valve and B-outlet valve are "closed" and the water level variation is visually and measured with a water level gauge to judge leakage. **(Refer to Table-3)**

(1) Methods (in case of sealed distribution reservoirs)

① After filling the distribution reservoir by water, close the valves A / B and start the investigation in a sealed condition.

② Record the full water visually and record the water level gauge reading (m).

③ Record the water level (m) every hour.

④ Convert the water level (m) changed of the day into leakage volume. **(Refer to Figure-4)**

⑤ Water leakage inspection from structures is continued during watertight inspection.

Table-3 Data sheet of watertight survey

Itnterval of time (h)	Reading Water Level (cm)	Drop of a water level (cm)	Decline of amount of wate(m3)	Itnterval of time (h)	Reading Water Level (cm)	Drop of a water level (cm)	Decline of amount of wate(m3)
0～1				6～7			
1～2				7～8			
2～3				8～9			
3～4				9～10			
4～5				10～11			
5～6				11～12			
				Total			

8.3 Function of Measuring Equipment (Flowmeters / Water level gauges / Inflowing control valve / Inflowing valves / Outflowing valves)

(1) Places to investigate (Refer to Figure-1)

(a) Inflowing meter (FM-A) and Outflowing meter (FM-B)

(b) Water level gauge (W.L.)

(c) Water level adjustment valve (valve with float)

(d) Inflowing valve-A and Outflowing valve-B

(e) Other (Residual chlorine concentration meter)

(2) Negative effect of fault

(a) When the measurement accuracy of the flowmeter decreases, an error occurs in measurement of the cumulative water amount.

(b) If the water gauge malfunctions, the risk of Overflow increases

(c) If the function of the Inflow level adjustment valve (float valve) decreases, the risk of Overflow increases.

(d) If the function of the inlet valve / outlet valve fails, the error risk of water distribution management increases.

(3) Items to be investigated

(a) Operation check of a flow meter;

- Confirmation of the flowmeter accuracy test recording and frequency by Third party inspection agency and/or a Master flow meter

- Installation standard of flowmeter
- Installation conditions

(b) Operation check of a water level gauge;

- Calibration of measurement accuracy and a maintenance record.
- The display and alarm function
- Installation conditions

(c) Operation check of a water level adjustment valve;

- Maintenance record
- Float movements inside the distribution reservoir
- Installation conditions

(d) Operation check of an Inflowing valve / an Outflowing valve

- Leakage test
- Installation conditions

(4) Measures

(a) Acquisition of flowmeter performance test certificate

(b) Implementation of a performance test of a water gauge

(c) Improvement of water level adjustment valve

(d) Improvement of Inflow / Outflow valves

8.4 Installation Status of Piping (Inflow piping / Outflow piping / Overflow piping)

(1) Places to investigate

(a) Overflow piping installed and diameter

(b) Inflowing piping installed and diameter

(c) Outflowing piping installed and diameter

(2) Negative effect of fault

(a) Overflow risk increases

(b) Corrosion and dropout of Overflow piping

·Difficulty in water distribution management

·Overflow from upper opening of the distribution reservoir

(c) The performance risk of a flow meter increases by noise/vibration of an Outflowing piping

(d) When air mixing is measured, the accuracy of the actual flow rate decreases. (Correct water supply analysis is difficult)

(3) Items to be investigated

(a) Confirm Overflow frequency from outflowing piping and upper opening

(b) Check the installation status of Overflow piping

(c) Check the installation status and diameter of Inflowing piping

(d) Check the installation status and diameter of Outflowing piping

(e) Check the procedure of water supply management and water level balance record

(4) Measures

For example of piping installation criteria for a distribution reservoir is shown below. **(Refer to Figure.16)**

(a) Improvement of Overflow piping

(b) Improvement of Outflowing piping

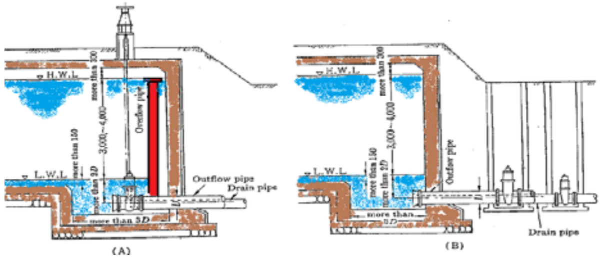
・Check the Outflow piping installed at a position where all the effective water volume can flow out

・Validation of spacing (2 times) between LWL and Outflowing piping (to prevent swirl occurring right above the Outflow piping)

(c) Expansion of effective capacity

(d) Preparation of hourly capacity fluctuation curve of Inflowing versus Outflowing.

(e) Preparation of hourly water level fluctuation curve.



Source: JWWA Design Criteria for Water Facilities

Figure-16 Typical Installation Requirements of an Outflow Piping of Water Reservoir

9. Examples of Evaluation of Monitoring Function of Water Distribution / Water Level Management (Introduction of Studies of Simulations)

9.1 Necessity for Monitoring of Distribution Management by Simulation Learning

In order to rationally and effectively maintain the monitoring function of water distribution management, it is necessary to properly measure the fluctuation of water demand (water volume / water level balance) at the time level every day, and to evaluate the trend of data in a timely, and it is necessary to learn an evaluation method (simulation) that predicts the occurrence of non-revenue water early.

The Case study of "Method of evaluation of monitoring function" is shown below.

9.1.1 Evaluation a graph of daily-hourly fluctuation of water distribution using the area method (Case-study-1);

① Calculation of actual K-value. (**Refer to NOTE-4**)

9.1.2 Evaluation a Curve Graph of daily-hourly fluctuation of water level (Case study-2);

① Understanding of the time period Overflow risk due to high water level,

② Understand the time of occurrence of air mixed water supply risk due to low water level.

9.1.3 Evaluation a Curve Graph of daily-hourly fluctuation of water level (Case Study-3)

9.2 Evaluation Method by a Graph of Daily-hourly Water Distribution by the Area Method (Case Study-1: Constant Inflowing)

By creating / analyzing an area graph, such as “area of hourly average inflowing” and “outflowing exceeding inflowing”, it is possible to understand/ grasp the prediction of increase / decrease in the amount of stored water.

9.2.1 Assumption:

(a) Hourly average Inflowing（Constant inflowing）:Q h av =300 m^3/h

9.2.2 Survey Procedures:

①Measure inflowing and outflowing (consumption) hourly simultaneously for 24 hours continuously,（**Refer toTable-4**）

② Show data in an "area method" graph, (**Refer to Figure-17**)

③ Understand the maintenance indexes from the created graph. **(Refer to Results of data analysis)**

(a) Prediction of maximum K-value,

(b) Forecast of the time period Overflow occurs,

(c) Prediction of maximum time zone of outflowing (consumption) (m^3/h),

(d) Prediction of actual consumption shortage volume (m^3)

(e) Prediction of required retention time (Tf) (h)

9.2.3 Measurement Equipment to be used:

① Flow meters (Inflowing and Outflowing)

Inflowing meter (FM-A) and outflowing meter (FM-B).

9.2.4 Data Sheet

A measurement item required for preparation of a data table is shown below. **(Refer to Table-4)**

① Hourly average Inflowing (Constant inflowing) :Q h av (m^3/h)

② Hourly Outflowing (Consumption) :q h (m^3/h)

Table-4 Example of Data Sheet of Water Distribution Hourly-change

Time interval	① Qhav: Hourly ave Inflowing (Constant) (m^3/h)	② qh: Hourly outflowing (Fluctuated) (m^3/h)	③ Cumulative outflowing (m^3/h)	④ Hourly fluctuation rate of Outflowing :② / ①	⑤ Incremented Inflow (m^3): ①−②	⑥ Decremented Inflow (m^3): ①−②	Time interval	⑦ Qhav: Hourly ave Inflowing (Constant) (m^3/h)	⑧ qh: Hourly outflowing (Fluctuated) (m^3/h)	⑨ Cumulative outflowing (m^3/h)	⑩ Hourly fluctuation rate of Outflowing: ② / ①	⑪ Incremented Inflow (m^3): ①−②	⑫ Decremented Inflow (m^3): ①−②
0～1	300	100	100	0.33	200	-	12～13	300	400	3,600	1.33	-	-100
1～2	300	100	200	0.33	200	-	13～14	300	400	4,000	1.33	-	-100
2～3	300	50	250	0.17	250	-	14～15	300	350	4,350	1.17	-	-50
3～4	300	50	300	0.17	250	-	15～16	300	350	4,700	1.17	-	-50
4～5	300	50	350	0.17	250	-	16～17	300	400	5,100	1.33	-	-100
5～6	300	100	450	0.33	200	-	17～18	300	450	5,550	1.50	-	-150
6～7	300	300	750	1.00	0	-	18～19	300	500	6,050	1.67	-	-200
7～8	300	400	1,150	1.33	-	-100	19～20	300	450	6,500	1.50	-	-150
8～9	300	500	1,650	1.67	-	-200	20～21	300	400	6,900	1.33	-	-100
9～10	300	550	2,200	**1.83**	-	-250	21～22	300	150	7,050	0.50	150	
10～11	300	500	2,700	1.67	-	-200	22～23	300	100	7,150	0.33	200	
11～12	300	500	3,200	1.67	-	-200	23～24	300	50	7,200	0.17	250	
				Sub-total	1,350	-950		Required effective capacity (hr)		(−1,950/300)	Sub-Total	600	−1,000
										−6.5	G-Total	1,950	−1,950

9.2.5 Preparation of an Area Graph

The composition of the graph to be created is shown below. (**Refer to Figure-17**)

① Inflowing (left) and Outflowing (right) on the vertical axes of coordinate、

② Measurement time on the horizontal axis of coordinate、

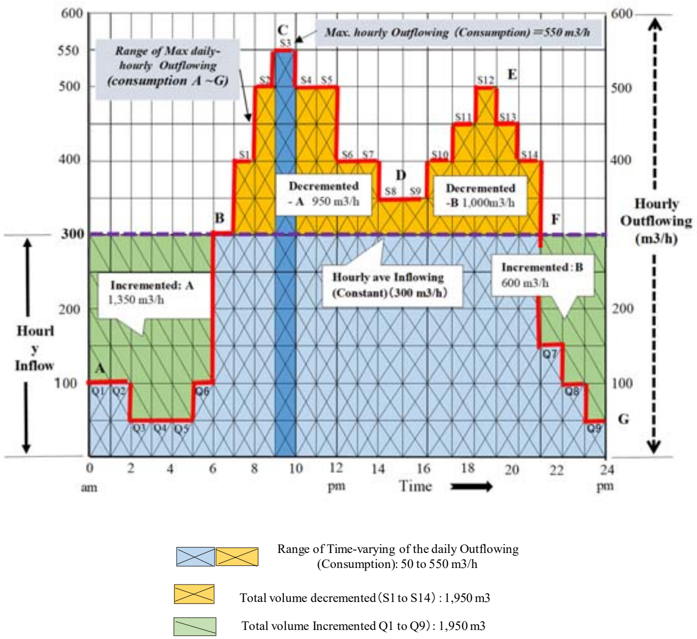


Figure-17 Hourly Capacity Fluctuation Graph of Inflowing versus Outflowing (by Area method)

9.2.6 Results of Data Analysis:

Analytical findings of the above-mentioned **Figure-17** are shown below.

① K-value (equivalent for maximum hourly outflowing /Consumption) rate-of-change
➡ 1.83 (Time zone: occurred at 9 to 10 am)

② Range-of- hourly fluctuation of K-value ➡ 0.17 ~ 1.83

③ Time zone with low water demand ➡ 23 - 24 pm

④ Time zone with high water demand ➡ 8 to 12 am and 17 to 21 pm (2 times /d)

⑤ Range of hourly Outflowing /Consumption) rate-of-change ➡ 50 to 550 m^3 /h

⑥ Reduction in storage occurring during periods with high water demand (S1 - S9)
➡ 1,950 (m^3)

⑦ Amount of water filled up during periods with low water demand (Q1 to Q9)
➡ 1,950 (m^3)

⑧ Retention hours for adjustment of storage variation: Tf (h)
= Total reduced water volume (⑥ ; S1 - S9) (m^3) ÷ Hourly- averaged inflowing rate (m^3 / h) ➡ 6.5 (h) or more (1,950 / 300 = 6.5 h)

9.2.7 Improvement of Monitoring System for Distribution Magement

① In particular, strengthening of the monitoring system and countermeasure team during the time period when outflowing is likely to occur (22 pm to 5 am)

② Reinforcement of monitoring system for inflowing during late night to early morning.

9.3 Evaluation Method by a Curve Graph of Daily-hourly Fluctuation of Water Level (Case Study-2; 50% of Total Inflowing)

By creating / analyzing an area Curve Graph, such as “hourly water level rate-of-change” and “hourly inflowing (constant and fluctuated) versus outflowing rate-of-change”, it is possible to understand / Grasp the prediction of the appropriate water level management of the distribution reservoirs.

9.3.1 Assumptions;

① **Hourly Inflowing** :

(a) In case of hourly inflowing rate –of-change (**Refer to Figure - 18**)

(b) In case of 50% of hourly inflowing continuously (**Refer to Figure - 19**)

9.3.2 Survey Procedures:

Based on the time variation data of the water level, it is possible to grasp the prediction of the optimum water distribution management for the day, such as "prediction of water supply balance" and "countermeasure against NRW."

① Measure water distribution amount (inflowing / outflowing) and water level at one hour interval simultaneously for 24 hours continuously、

② Create a Curve Graph、

③ Grasp indicators of maintenance from the Curve Graph,

(a) Prediction of the time zone which Outflowing may generate

(b) Prediction of the time zone which air mixing water supply may generate

(c) Prediction of the tendency to change the amount of water supply (inflow/outflow), and a water level

9.3.3 Measurement Equipment to be used:

① Flow meters (Inflowing and Outflowing)

Measure the inflowing meter (FM-A) and outflowing meter (FM-B)

② Water level gauges

9.3.4 Data Sheet:

A measurement item required for preparation of a data table is shown below.

(Refer to Table-5)

① Hourly Inflowing :Q h (m^3/h)

② Hourly Outflowing :q h (m^3/h)

③ Hourly Water levels: (m)

④ Confirmation of noise generated at Outflowing pipes

Table-5 Example of Reservoir Level Monitoring Sheet

Reservoir Name:					**Officer Name:**			**Date:**	
Specification:		Capacity (m3):			Surface area (m2):			Weather:	
		HWL (m):			Water depth (m):			Temperature(℃):	
		LWL (m):			Level of Outflow Pipe (m):			Number of outflow Piping (pcs)	No.1 Dia (m):
Type of Equipment		Inflow meters:			Water Leve gauge:				No.2 Dia (m):
TIME	Water Level (m)	Inflow Meter readings(m3/hr.)			Outflow Meter readings(m3/hr.)			Noise detection at Outflow Pipes	
		ND (No.1 meter)	ND(No.2 meter)	Acc Total (m3/hr.)	ND (No.1 meter)	ND(No.2 meter)	Acc Total (m3/hr.)	ND (No.1 meter)	ND(No.2 meter)
4:00									
5:00									
6:00									
7:00									
8:00									
9:00									
10:00									
11:00									
12:00									
13:00									
14:00									
16:00									
17:00									
18:00									
19:00									
20:00									
21:00									
22:00									
23:00									
24:00									
2:00									
4:00									

9.3.5 Preparation of an Curve Graphs

The composition of the Curve Graph to be created is shown below. (**Refer to Figures-18-19**)

① Inflowing and Outflowing on the vertical axis of coordinate,

② Water level on the vertical

③ Measurement time on the horizontal axis of coordinate、

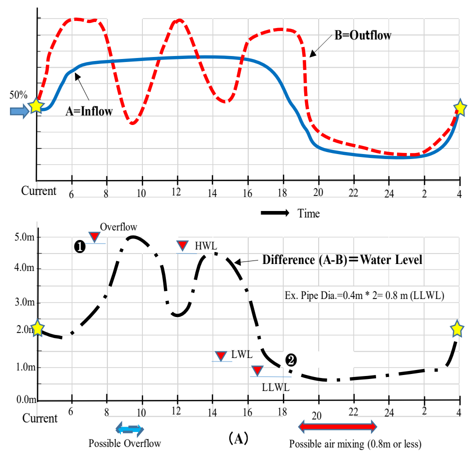


Figure-18 Temporal-change Curve of Water Level (Inflow rate 50% but fluctuated)

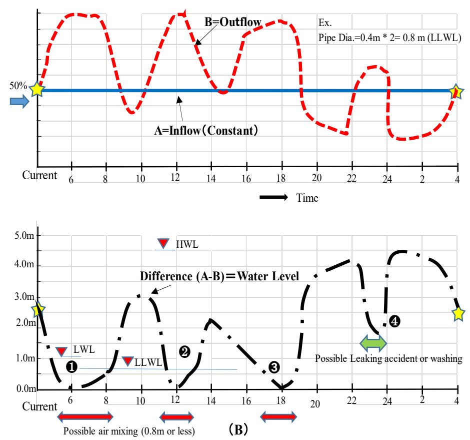


Figure-19 Temporal-change Curve of Water Llevel (Inflow rate 50% constantly)

9.3.6 Results of Data Analysis:

Analytical findings of the above-mentioned **Figures-18 & 19** are shown below.

(a) In case of hourly inflowing rate –of-change (Refer to Figure - 18)

① Time zone with possibility of overflow: ❶ 9: 00 ~ 10: 0,

② Time zone with possibility of air mixing due to low water level (LWL): ❷ 19: 00 ~ 23: 00

(b) In case of 50% of hourly inflowing continuously (**Refer to Figure - 19**)

① Time zone of low LWL where there is a risk of air mixing: ❶ 5: 00 ~ 8: 00, ❷ 11: 00 ~ 13: 00, ❸ 17: 00 ~ 19,

② Time zone of water level drops due to leakage accident or piping line washing: ❹ 23: 00 ~ 24: 00

9.3.7 Improvement of Monitoring System for Distribution Magement

(a) Strengthening of the water distribution management monitoring to prevent loss of purified water by comprehensively predicting and judging what kind of the curve of water level currently distribution reservoir changes with past experience.

(b) In the unlikely event that the balance of water level exceeds the allowable range, strengthen the management system that can accurately and rapidly communicate the abnormality of water level to the operator and recover stability at an early stage.

9.4 Evaluation Method by a Curve Graph of Daily-hourly Water Level Variation

(Case Study-3; 60% of total Inflowing)

By creating / analyzing an area Curve Graph, such as "hourly water level rate-of-change" and "hourly Inflowing constantly versus Outflowing rate-of-change", it is possible to understand / Grasp the prediction of the different water level management of the distribution reservoirs.

9.4.1 Assumption*;*

① Hourly Inflowing :

(a) In case of 60% of hourly inflowing continuously (Refer to Figure - 20),

9.4.2 Survey Procedures*:*

(a) Same as above, **9.3-(2),**

9.4.3 Measurement Equipment to be used:

(a) Same as above, **9.3-(3),**

9.4.4 Data Sheet:

(a) Same as above、 **(Refer to Table-5)**

9.4.5 Preparation of an Area Graph:

(a) Same as above、**(Refer to Figure-20)**

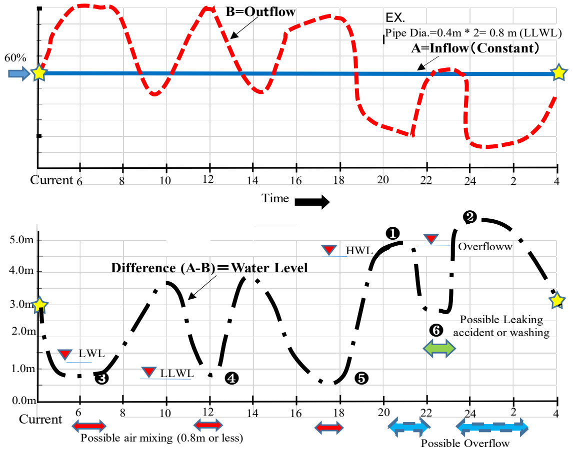


Figure-20 Temporal-change Curve of Water Level (Inflow rate 60% constantly)

9.4.6 Results of Data Analysis:

① Time zone with possibility of overflow: ❶20:00~❷3:00,

② Time zone with possibility of air mixing due to low water level (LWL): ❸6:00~7:00, ❹11:00~13:00, ❺17:00~19:00,

③ Time zone of water level drops due to leakage accident or piping line washing: ❹ 23: 00 ~ 24: 00

9.4.7 Improvement of Monitoring System for Distribution Magement

(a) Same as above、**9.3-(7),**

10 The Validation Method of Current Design Parameters (Case Study-4)

10.1 Necessity for Learning Exercises

Currently, it is required to evaluate whether the functions of existing distribution facilities are able to cope with expansion of water supply area, change of temperature / weather, change of living environment and change of water demand.

Also, it is indispensable to strengthen the ability for engineers to check the design specifications of water distribution reservoir, in order to formulate long-term non-revenue water reduction plans in distribution reservoirs.

The examples of simple calculation procedures of main design parameters and an assumption methods of constant numbers are shown below.

10.2 How to Determine the Maximum-daily Supply per Head：q l/head/d）

This water supply volume / consumption tends to increase or decrease every year depending on living environment and /or urban development situation, with daily maximum supply per head.

(1) Examples of **q** (l/head/d)

① In Japan: standard home (Medium size city＠2018)・・・200～400 l /head/d

② **In KENYA: Refer to Table-6 ・・・・・75.0 l /head/d**

Table-6 Water Consumption rates: q（KENYA STD）

Case of People with individual connections

Unit	Rural Areas			Urban Areas		
	High potential	Medium potential	Low potential	High potential	Medium potential	Low potential
l/head/d	60	50	40	250	150	**75**

(Details: Refer to the Practice Manual for Water Supply Services in Kenya Dec. 2005)

10.3 How to Determine the Planned Maximum-daily Consumption: Qd (m^3/d)

① Formula：**Qd (m^3/d)**＝ q × P × (1+Lf)

② Assumptions; (**Use KENIA STD In Rural Area**)

(a) Design daily maximum supply per head：q l/head/d)

= 75.0 l/head/d= 0.075 (m^3/head/d),

(b) Design population served: P=44,800

(c) Loss amount due to non-revenue water: Lf

＝20%＝**0.2** (**Refer to Note-2-③**)

③ Result of calculation：

(a) **Qd** = (q ×P) ×(1+Lf)

= (0.075 × 44,800) × (1+0.2) = (250) × (1.2) = **4,032 (m^3/d)**

10.4 How to Determine the Planned Maximum-hourly Consumption: Q h max (m^3/h)

① Formula：**Q h max (m3/h)** = Q / 24(h)

② Assumptions; Q = 4,032 (m^3/d)................................ **(Refer to 10.3-③)**

③ Result of calculation：**Q h max** = 4,032 /24＝**168 (m^3/h)**

10.5 How to Determine the Planned Daily Average Consumption: Q d av (m^3/d)

① Formula：**Q av (m^3/d)**= Q × Kf

② Assumptions; Q = 4,032 (m^3/d) .... **(Refer to 10.3-③)**

Kf= Coefficient＝0.8

③ Result of calculation：Q av = 4,032 × 0.8＝**3,226 (m^3/d)**

10.6 How to Determine the Planned Maximum-hourly Consumption in Normal Condition: Qn h max (m^3/h)

① Formula：**Qn h max (m^3/h)＝Q ×K**

(a) Maximum hourly consumption: Qn h av (m^3/h) =Q ÷ 24 (h)

(b) Average hourly Inflowing**: Qn h av (m^3/h)**

(c) Max. Hourly Outflowing: qn h max (m^3/h)

(d) Maximum hourly-variation coefficient: **K-value** = qn h max ÷ Qn h av

② Assumptions; **(After arraignment of Data sheet of water distribution hourly-change Refer to Figure-21)**

(a) Qn h av =4,032 ÷24= 168 (m^3/h)

(b)Assume; qn h max=307 (m^3/h) .... **(Refer to Figure-21)**

(c) K = 307÷168= 1.83

③ Result of calculation：Q n h max＝168×1.83＝**307 (m^3/h max)**

NOTE-7 General assumption method of K-value

(a) An examples of the assumed value of K - value (Maximum hourly - variation coefficient) are shown in **item 11 (Attached documents)**.

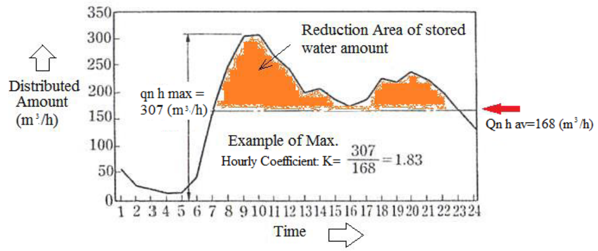


Figure-21 Find-out Example of a K-value from Fluctuation Graph of Inflowing versus Outflowing

10.7 How to Determine the Planned Maximum-hourly Consumption (Outflowing) During Fire fighting：Q p (m^3/h)

① Formula：Q p (m^3/h)＝ Q n h max＋ Qf h max

② Assumptions;

(a) Qf =Amount of firefighting= 0.6 m^3/min × 60 min =36 (m^3/h)

(Example of KENYA: Refer to NOTE-5)

(b) Qf h max (m^3/h): **Amount of hourly required fire-fighting water**

= 307 (m^3/h max)

③ Result of calculation : Q p = 36 + 307 = **343 (m^3/h)**

10.8 How to Determine the Effective Capacity of Distribution Reservoir: V (m^3)

① Formula：V(m^3)＝Qn h max ×T

(a) Hourly Inflowing: Q h av (m^3/h max)

(b) Required retention hours: T (h) = Tf + Sf

Tf (h): Retention hours for adjustment of storage variation

Sf (h): Safety factor (2~4)

② Assumptions;

(a) Q =4,032 (m^3/ d) .... **(Refer to 10.3, ③)**

(b) Q h av =4,032 ÷24＝168 (m^3/h).......... **(Refer to 10.6,②)**

(c) T= 6.5 +2 =8.5 (h)

* Tf =6.5 (h)...................**(Refer to 9.2,(5), ⑧)**

* Sf= 2.0 (h)

③ Result of calculation：V= 168 × 8.5 = **1,428 (m^3)**

10.9 How to Determine the Outside Dimension of Circular Water Distribution Reservoirs

① Formula：**V(m^3) =** A × H

(a) Sectional area: A (m^2) = V (m^3) ÷ H (m) ÷ N

= R (radius)×R(radius)×3.14 = R^2 × 3.14

(b) Diameter: D (m) = 2×(√A/3.14)＝ 2 R= R+R

② Assumptions;

(a) Capacity：V= 1,428 (m^3)…………..... **(Refer to 10.8, ③)**

(b) Effective water depth: H = 4 (m)

(c) Number of reservoir :N＝ 1 (unit)

③ Result of calculation：**(Refer to Figure-22)**

(a) A= 1,428 ÷4 = 357 (m^2)

(b) D = 2×(√ 357 / 3.14) = 21.4 (m)

(c) R =21.4 ÷2 =10.7 (m)

(c) H＝4.0 (m)

(d) N= 1 （unit)

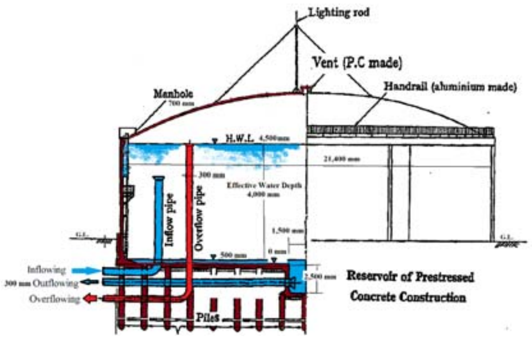


Figure-22 Example of Cross-sectional View of Circular Water Distribution Reservoir

11. Implementation of function evaluation of outflow pipe

11.1 Necessity

The occurrence of non-revenue water due to overflow of the distribution pond is considered to be difficult to control the water distribution balance if the outflow pipe diameter is smaller than the inflow pipe diameter.

In order to prepare and implement an appropriate water distribution management plan, it is indispensable to grasp the function of the water distribution pipe beforehand.

11.2 Basic items to be verified

(1) Confirmation items of current status

① Measurement of the maximum amount of water distribution and variation of water demand

② Confirm whether pressurized flow

(a) In the Pressurized or pumping flow

(b) In the Open channel Flow

③ Confirm the flow inside the pipe

(a) Flowing full

(b) Partially full

④ Confirmation of the water level of the distribution pipeline, pipe length / pipe diameter / type of material

⑤ Confirmation of design parameters such as hydraulic gradient and maximum flow rate

Hazen-Williams Coefficient

◆ Description of a technical terms required for hydraulic design calculation is shown **in 12-2.**

Table-7 Items of Design Specifications to be Verification

Type of Flow inside the pipe	Design conditions	Items to be confirmed / calculated
◆ Closed flow (Flowing full)	① Max. Flow rate：Q (m^3/sec)、 ② Hazen-Williams Coefficient : (Discharge coefficient):（C） ③ Hydraulic gradient or Slope: S (‰), ④ Pipe length :L (m)	① Item to be considered - Economical mean flow velocity: V (m / sec) ② Items to be calculated - Economical pipe diameter: D (m) - Cross-sectional Area of flow: A (m^2) - Wetted Perimeter: P (m) - Hydraulic Radius: R (m)、 - Friction Head Loss: f （m） ③ Items to be confirmed - Volumetric Flow Rate: Q (m^3/s) - Flow velocity : V (m/sec)
◆ Open channel （Partially full）	① Max. Flow rate : Q (m^3/sec)、 ② Manning Roughness Coefficient:(n） ③ Hydraulic gradient: S (‰), ④ Pipe length: L (m)	

11.3 Terminologies

① **Q (m^3/sec)** is the **Volumetric Flow Rate** passing through the pipe or channel.

② **A(m^2)** is the **Cross-sectional Area** of flow normal to the flow direction.

③ **f (m)** is the **Friction Head Loss** in which is loss of pressure or "head" that occurs in pipe or duct flow due to the effect of the fluid's viscosity near the surface of the pipe or duct.

④ **S** is the bottom slop of pipe or channel called the **Hydraulic Gradient**.

⑤ **n (-)** is a dimensional empirical constant called the **Manning Roughness Coefficient.**

⑥ **C (-)** is the Discharge Coefficient of the ratio of the actual discharge to the theoretical discharge, Call **Hazen-Williams Coefficient**.

⑦ **P (m)** is the Wetted Perimeter of the cross-sectional area of flow.

⑧ **R (m)** is the **Hydraulic Radius (= A/P)** in which is the area of the water prism in a pipe or channel divided by the wetted perimeter.

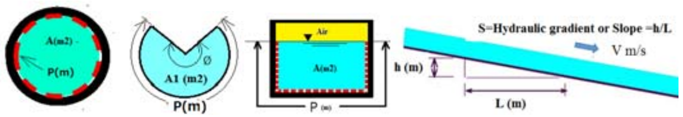


Figure- A

11.4 Formulas and /or Graphs used for hydration calculations

11.4.1 Use of Empirical Formulae and Equations 実験式

In water supply the following three equations are used most commonly.

(a) Weston formula (Applied to φ50mm or less)

(b) Hazen-Williams's formula (Applied to φ75 mm or more)

(c) Manning's formula (Applied to open channel flow only)

11.4.2 Use of Graphs of Flow (l/sec) vs Hydraulic gradient (‰)

The easiest method to check on whether flow rate is available or not is to make use of the Frictional Head Losses Graphs in which show the specific flow (l/sec) vs and amount of frictional head losses per unit length of pipe "Hydraulic gradient (‰)" at each pipe dimension.

11.5 Items to be proposed

(1) The most economical water distribution system

- It is to use the gravity flow velocity obtained from the Hydraulic Gradient.

(2) Expected effects by the combination of the most optimal economic flow rate and optimum pipe diameter

- Comparison of construction cost reduction by adopting the optimum pipe diameter / material
- Comparison of reduction of maintenance cost

◆If the planned flow rate is set to be earlier, the pipe diameter becomes smaller, but on the other hand, the loss of piping network such as pipeline / valve becomes higher, resulting in continuing increase in power cost, increase in repair cost of piping

(3) Estimated economic flow rate

Empirical reference values are shown in **Table-8**.

Table - 8 Example of Economic Flow Velocity

Flowing full in the Pipe	Pipe diameter（mm）		
	75~150	200~300	350~600
Gravity flow	0.7~1.0 (m/sec)	0.8~1.2 (m/sec)	0.9~1.4(m/sec)
Pressurized by pump	~ 2.0 (m/sec)	2.1~2.5 (m/sec)	

(4) Measures to reduce the occurrence frequency of overflow

(a) Review material / diameter / number of water distribution piping,

(b) Review of distribution pressure balance / pump facilities,

(c) Review of arrangement / capacity of water reservoirs (review of water supply zone, pipe network aiming at reduction of electricity consumption)

12. Attached Documents

12.1 Example of Selection of K-value (Maximum-hourly Variation-coefficient)

As for selection of the K-value, the following experience values are adopted in consideration of water supplied population, living environment conditions, etc.

12.1.1 Use of existing data

① Relationship between Design population served and Time coefficient,

(Example: the scale of 5,000 heads: **2.0** .... **Refer to Figure-23)**

② Relationship between Daily consumption and Time coefficient,

(Example: the scale of 10,000 heads: **1.6** .... **Refer to Figure-24)**

③ Relationship between Effective capacity and Time coefficient,

(Example: six hours: **1.8** .... **Refer to Figure-25)**

④ Trend of K-value to be changed

(a) If the distribution area becomes large scale, variation coefficient will be equalized and a K-value will become small.

(b) If the difference of temperature is small and there is no change in the climate, the K-value will tend to become small

(c) If the well is used and /or water distribution area is small, the K-value of the dry season will tend to increase.

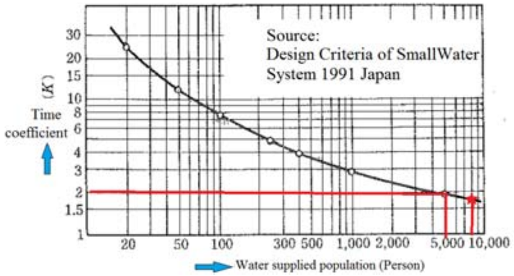


Figure-23 Example of Relationship between Design Populations Served and Time Coefficient (K)

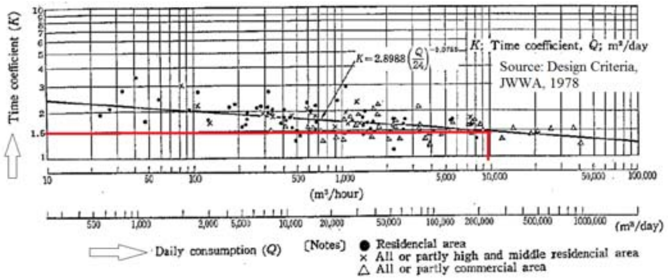
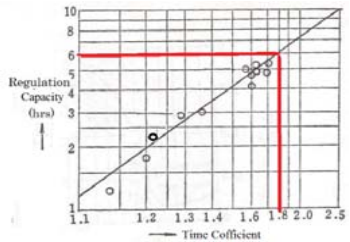


Figure-24 Example of Relationship between Daily Consumption and Time Coefficient (K)



Source：JWWA Design Criteria for Water Facilities 1966

Figure-25 Example of Relationship between Effective Capacities of Reservoir by Time Coefficient

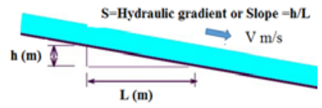
12.2 Basic knowledge of hydrology

12.2.2 Points to keep in mind when calculating hydration

(a) In order to prevent mistakes in calculation, the unit is unified with m, m^2, m^3, m^3/ s (or ℓ / s).

Table-9 How to Display Units

(1) Length	**(2) Area**	**(3) Volume**	**(4) Pressure (*W.Head:* *100 m=0.98 Mpa*)**
1 mm = 0.001m	*751 mm²*	*1 m³ = 1,000 ℓ*	*Water head 100 m = 1.0 Mpa =1,000 Kpa*
10 mm = 0.01m	*= 0.000751 m²*	*1 ℓ = 0.001 m³*	*Water head 10 m = 0.1 Mpa = 100 Kpa*
50 mm = 0.050 m		*200 ℓ = 0.2 m³*	*Water head 1m = 0.01 Mpa = 10 Kpa*
100 mm = 0.1m		*1,000 ℓ = 1.0 m³*	

(5) Flow rate	**(6) Hydraulic gradient = Loss head**	
Quantity of flow which flows through the inside of a pipe ;Q (m³/Sec) **Q = A (m²)÷ V(m/sec)**	*Hydraulic gradient (Slope);* **S (‰) = (h_L ÷ L)×1, 000**	
	1,000 ‰ = 100 % =1 *100 ‰ = 10 % =0. 1* *10 ‰ = 1 % =0.01*	*‰ (Per-mille) represents one thousandth.*
Cross-sectional area of a pipe; A (m²) **A= Q ÷ V (m/sec)**	*Loss head; h_L(m)* ***= (S×L) ÷ 1, 000***	
Average flow velocity in a pipe ; V (m/sec) **V = Q ÷ A(m²)**	*Pipe length : L (m)*	

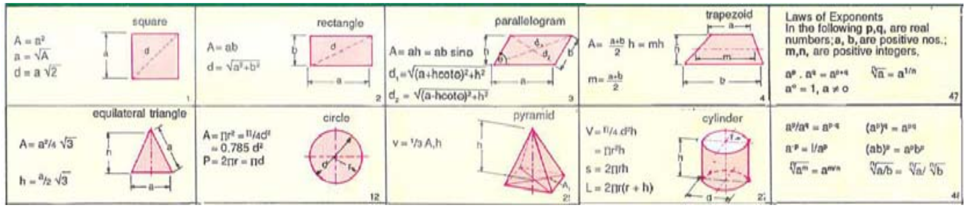


Figure -B Mathematical Formulas

12.3 Hydraulic Characteristic Value of Circular Pipe

12.3.1 Calculation formulas for Hydraulic design

The calculation of the cross-sectional area of a circular pipe can be obtained from a given condition of flow rate / hydraulic gradient use following formulas

(a) Hazen-Williams's formula

(b) Manning's formula

12.3.2 Hydraulic characteristic curve (Refer to Figure-26 and Table-10)

As shown below, the maximum flow rate and the maximum flow rate of hydraulic characteristics at full (1.0) are varied depending on the full water rate.

① Max. Flow rate

The full flow rate at which the maximum flow rate can be obtained is 0.938 (93.8%) → 1.074 times

② Max. Velocity

The full flow rate at which the maximum Velocity rate can be obtained is 0.81 (81.3%) → 1.124 times

◆ How to decide design flow values

The downward flow capacity of a circular pipe is calculated with full pipe considering safety.

Table-10 Change in hydraulic characteristic value

h/D	A/Afull	R/Rfull	V/Vfull	Q/Qfull
0.1	0.052	0.254	0.401	0.021
0.2	0.143	0.482	0.615	0.088
0.3	0.252	0.684	0.776	0.196
0.4	0.374	0.857	0.902	0.337
0.5	0.5	1.000	1.000	0.500
0.6	0.627	1.110	1.072	0.672
0.7	0.748	1.184	1.119	0.837
0.8	0.858	1.218	1.141	0.979
0.9	0.948	1.191	1.124	1.066
0.95	0.981	1.146	1.095	1.074
1.0	1.0	1.0	1.0	1.0

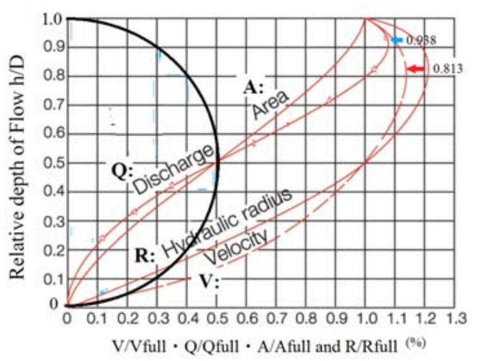


Figure-26 Characteristic Curve Diagram

12.4 Exercise in Hydration Calculation

12.4.1 Weston formula and Equation (Apply to φ50mm or less)

(1) Formula

Calculation for **Friction head loss in steel pipe**, in hard PVC, in polyethylene pipe under 50mm in diameter are made according to following Weston formula.

$$h = \left(0.0126 + \frac{0.01739 - 0.1087d}{\sqrt{v}}\right)\frac{L}{d}\cdot\frac{v^2}{2g} \quad \text{..........................}\textbf{(17)}$$

Q= A*V ....**(18)**

S= (h/L) *1000

Where

h; Friction head loss of pipe (m)

Q: Volumetric Flow rate (m^3/s)

V: Mean flow velocity in pipe (m/sec)

L: Pipe length (m)

d : Internal diameter of pipe (m) = （√ 4 Q） ÷ （π ＊V）

S: Hydraulic gradient or Head loss per unit length Slope (‰)

= (hf/L)*1000

Table-11 Example of the Values of Hydraulic Gradient :S (‰)

Diameters (mm)	Hydraulic grade (‰)	Diameters (mm)	Hydraulic grade (‰)
13	less than 400	40	less than 70
20	less than 200	50	less than 50
25	less than 150	75	less than 30
30	less than 110	100	less than 20

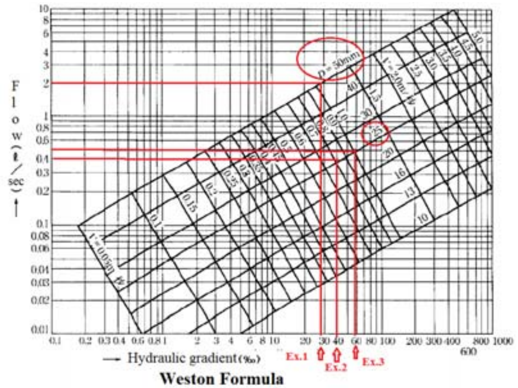


Figure-27 Example of the Head Loss Graph of the Service Pipe

◆ Practice Exercise-1 (50 mm water distribution pipe)

① Calculate a Total Friction Head Loss (m) and Hydraulic Gradient (‰) ?

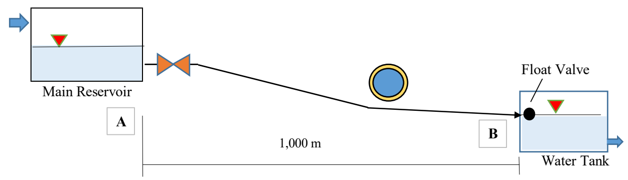


Figure-28 Service pipe line (50mm)

Table-12 Result of Calculation in Exercises -1

Weston Formula Ex-1

Item #	Conditions / Assumptions						
1	Volume flow rate: Q=	2	ℓ/sec	**0.002**	m^3/sec	**172.8**	m^3/d
2	Flow velocity: V =	**1.0**	**(m/sec)**				
3	Inside hydraulic diameter: d =	0.050	(m)				
4	A-B Total length of a pipeline ; L =	1,000	(m)				
5	Gravitational acceleration ; G=	9.81	(m/s^2)				
	Solution						
6	Friction Head Losses : h =	**((0.0126+((0.01739-(0.1087*d)/√v))*(L/d)*(V^2/2g)**)			24.7	(m)	
7	Other Friction Head Losses (10%); h1=	h * 0.1			2.5	(m)	
8	Tota Friction Head Losses Σf =	**Σh = h+ h1**			**27.2**	(m)	
9	**Hydraulic Gradient; S =**	(Σh/L)*1000			**27.2**	(‰)	
	Confirmation by **Figure-27 Ex.1**	**When S= 27.2 (‰) and Pipe dia 50mm →Q= 2.0 (ℓ/Sec)**			**OK**		

◆ Practice Exercise-2 (25 mm Service pipe)

① Calculate a Hydraulic Gradient or Head loss per unit length Slope (‰) ?

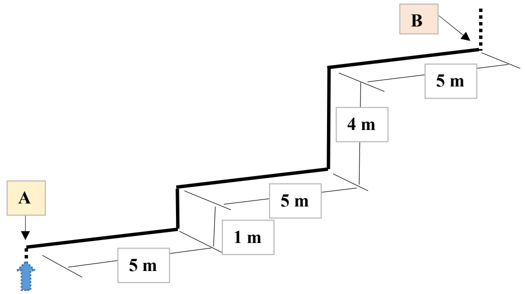


Figure-29 Service pipe line (25mm)

Table-13 Result of Calculation in Exercises -2

Weston Formula Ex-2

Item #	Conditions / Assumptions						
1	Volume flow rate : Q =	**0.4**	ℓ/sec	24	ℓ/min	**34.56**	m^3/d
2	Inside hydraulic diameter: d =	25	(mm)				
3	A-B Total length of a pipeline ; L =	20	(m)				
	Solution						
4	Hydraulic Gradient; S =	**From Figure -27 Ex. 1; d (25mm) →Q (0.4ℓ/sec)→**			**40.0**	(‰)	
5	**Friction Head Losses : h =**	**(L×S) /1,000**			**0.8**	(m)	
	Confirmation by **Figure-27 Ex.2**	**When S= 40.0 (‰) and Pipe dia 25mm →Q= 0.4 (ℓ/Sec)**			**OK**		

◆ Practice Exercise-3 (25 mm Service pipeline)

① Calculate a Volume flow rate Q (ℓ/sec) ?

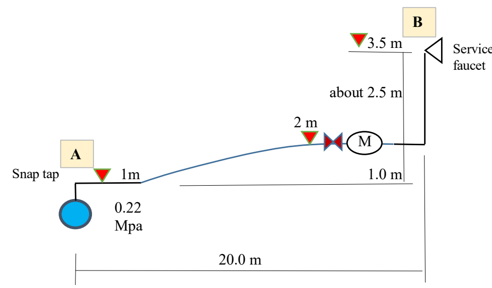


Figure-30 Service pipe line (25mm)

Table-14 Result of Calculation in Exercises -3

Weston Formula Ex-3

Item #	Conditions / Assumptions			
1	Volume flow rate: Q =	**?**	ℓ/sec	
2	Inside hydraulic diameter: d =	25	(mm)	
3	A-B Total length of a pipeline ; L =	20+2.5 =	22.5	(m)
4	Water level : h1 =	1+2.5=	3.5	(m)
5	Other Friction Head Losses (valves) ; h2 =	=	2.2	(m)
6	Loss of head of a margin (@ point B); h3 =		15	(m)
7	A-B Total Friction Head Losses ;Σh =	h1＋h2＋h3	20.7	(m)
8	Hydraulic pressure (@ point A) ; P =	22 Mpa	22	(m)
	Solution			
8	Friction water loss : h4 =	P - Σh	1.3	(m)
9	**Hydraulic Gradient; S =**	**S= (h4 /L) ×1,000**	**57.8**	(m)
	Find Volume flow rate			
11	**From Figure -27 Ex. 3 ; d (25mm) →S (57.8‰)→ Q = 0.50 (ℓ/sec)**			

12.4.2 Hazen-Williams formula and Equation (Pressure Flow: Apply to φ75 mm or more)

(1) Formula

The Hazen-Williams equation is an empirical formula and the most widely used method in the design of pipe lines for calculating how much the ambient pressure drops in water flowing through a pipe due to friction with the interior surface of the pipe, the pipe's interior diameter, and the velocity of flow rate for the water.

The equation is expressed as follows

$$h_f = \frac{10.67 \quad L \quad Q^{1.85}}{C^{1.85} \quad d^{4.87}} \quad \text{.......................................}\textbf{(19)}$$

Q = A×V

V= C √RS =C$R^{0.5}$* $S^{0.5}$

Where;

hf= Head loss (m)

L= Length of pipe (m)

Q= Volumetric Flow rate (m^3/s)

d = Internal diameter of pipe (m) = $(\sqrt{\ } 4Q) \div (\pi * V)$

C =Non dimensional Hazen-Williams Coefficient

S = Hydraulic gradient or Head loss per unit length Slope (‰)

= (hf/L)*1000

R = Hydraulic radius = (A/P)

A = Cross-section area of flow (m^2)

P = Wetted perimeter (m)

The Hazen-Williams loss coefficient, C, is non dimensional and has values which depending on the size, material of pie used, quality of water and age. Typical values of Hazen Williams's coefficient **C** for new pipe and values to be adopted for design purposes are shown in **Table -15.**

Table-15 Example of Hazen-Williams Coefficients "C"

Type of Pipe	Recommended values for		
	New Pipes	Design Purpose	Note
GI Pipe	120	100	After 20-year
Cast Iron	130	100	After 20-year
Steel Welded joints	140	110	-
Concrete	140	110	-
Plastic Pipe	140-150	110	-

Source: JWWA Design Criteria for Waterworks Facilities 1978

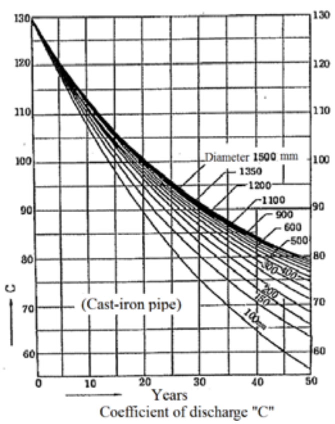


Figure-31 Typical Discharge Coefficient of CIP by Years

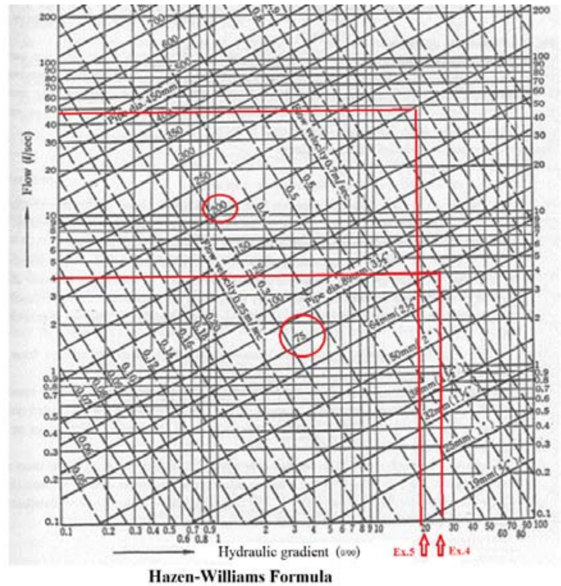


Figure-32 Head Loss Graph of Pressured Flow of Distribution Pipe line

◆ Practice Exercise-4 (75 mm Distribution pipeline)

① Calculate a Total Friction Head Loss (m) and Hydraulic Gradient (‰) ?

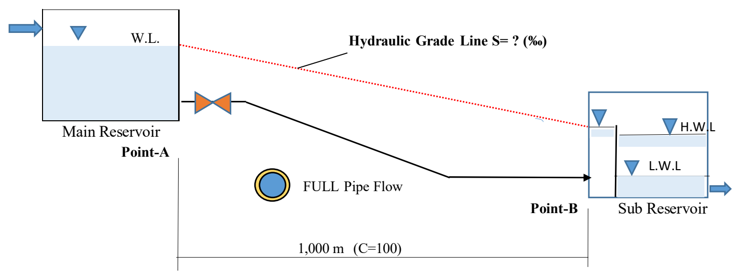


Figure-33 Distribution pipe line (75 mm)

Table-16 Result of Calculation in Exercises -4

	Hazen-Williams Formula	Ex.4	Use International System of Units (SI Units)				
Items	Conditions / Assumptions						
1	Volume flow rate: Q =		**0.004**	m³/sec	345.600	(m³/d)	
2	Flow velocity: V =	Table-9	=	1.0	(m/sec)		
3	Inside hydraulic diameter: d =	√（4Q）÷（π＊V）			0.071	(m) =	**0.075**
4	Cross-sectional area of flow; A=	Q/V	=	0.004	**(m2)**		
5	Total length of a pipeline ; L =		=	**1,000**	(m)		
6	**Discharge Coefficient : C=**		100				
	Solution						
7	A-B Friction Head Losses : hf	10.675*L*Q ^1.852 / C^1.852*d^4.87			=	23.0	(m)
8	Other Friction Head Losses (10%): ho =	0.1			=	2.3	(m)
9	A-B Total Friction Head Losses :Σh =	hf+ho			=	25.3	(m)
10	Hydraulic Gradient; S =	(Σ h/L)*1000			=	25.3	(‰)
	Confirmation						
11	Volume flow: Q =	**From Figure -32 (Ex.6); d (75 mm) →S (25.3 ‰) → Q =**				**4.0**	(ℓ/sec)
					OK	**0.004**	m³/sec

12.4.3 Case of pump distribution

The total head of the pump is calculated from the lowest hydraulic gradient (meaning the difference between the lowest water level of the distribution reservoir and the highest water level of the receiving pond) and the loss head of the pipe**.**

(1) Formula

$$h_f = \frac{10.67 \quad L \quad Q^{1.85}}{C^{1.85} \quad d^{4.87}}$$

$$\mathbf{H = h_1 + dH + hf_1 + f_2 + f_3}$$

Where

H ; Total pump head (m)

h_1 ; Actual head (m)

hf_1 ; Friction head loss of pipeline of pipeline(m)

(The Volume flow rate increases as the speed increases)

f_2 ~f_3 ; Friction head loss between f2 ~f3 piping material (m)

dH ; Terminal residual velocity head (m)

Sf ; safety factor = 15 (m) for pump flow

◆ Practice Exercise-5 (200 mm Distribution pipeline)

① Calculate a Total Friction Head Loss of pipe line (m) and Hydraulic Gradient (‰) ?

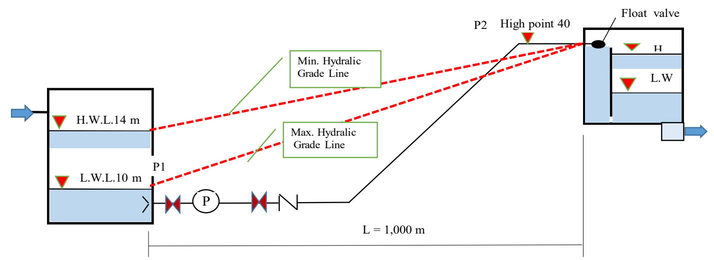


Figure-30 Distribution pipe by Pumping Flow

Table-16 Result of Calculation in Exercises -5

	Hazen-Williams Formula	Ex.5	Use International System of Units (SI Units)				
Item #	Conditions / Assumptions	m3/d	m3/hr	m3/min	m3/sec	(ℓ/sec)	
1	Volume flow rate: Q =	4,032	168.0	2.8	0.0467	**46.7**	
2	Flow velocity: V =	Table-9		=	**1.5**	(m/sec)	1.5-3.0
3	Cross-section area of flow A =	Q/V		=	0.031	(m²)	
4	Inside hydraulic diameter: d =	√（4Q）÷（π＊V）		=	0.199	**0.20**	(m)
5	Total length of a pipeline ; L =	=		1,000	(m)		
6	**Discharge Coefficient : C=**	100					
7	**G- forces g =**	**9.8**		m/s²			
	Solution						
8	Pump Capacity	4,032	(m³/day)	2.80	m³/min	0.0467	m³/sec
9	Quantity of pump (set)			1	sets + 1 set for stand-by		
10	Velosity V =			**1.5**	to	3	(m/sec)
11	Inside hydraulic diameter: d =	146 x (Q / v)(1 / 2)		199	to	141	(mm)
				200	to	150	(mm)
12	P1-P2 Requiered Elevation h1 =	(P2 - P1)+dH		=(40-10)+1.0		**30.5**	(m)
13	Dischargeing head dH =				=	**0.5**	(m)
13	Friction Head Losses : hf =	$= 10.6756 \times c^{(-1.85)} \times d^{(-4.87)} \times Q^{(1.85)} \times L$			=	**19.0**	(m)
14	Other Friction Head Losses ; h2 =	= f 2 x (v / 2g)			=	**0.20**	(m)
		f2 =	Where	Items	Q'ty	f/pc	f
			sluice valves		2	0.10	0.20
			reducer		0	0.03	0.00
			45º elbow		2	0.18	0.36
			Increase		0	0.48	0.00
			Check valve		1	1.00	1.00
			butterfly valve		1	0.20	0.20
			90deg		0	0.18	0.00
			Tee		0	1.15	0.00
						f 2 total	***1.76***
15	Other Friction Head Losses; h3 =	= f 3 x (v / 2g)			=	**0.58**	(m)
		f3	Where	Items	Q'ty	f/pc	f
			Float type butterfly valve		1.0	5.0	5.0
			Bellmouth		2.0	0.0	0.1
						f 3 total	5.08
16	**Total Friction Head Loss; h =**	**fh+F2+f3**		**=**	**19.78**	**(m)**	
17	**Total Head H =**	**Σ(h1+ hf + f2 + f3)**			**=**	**50.0**	(m)
18	**Hydraulic Gradient of pipeline; S =**	(Σh/L)*1000	((h1+h2+h3+dH)/L))*1000		=	**19.8**	**(‰)**
19	Motor Output (KW) =	(0.163 x r x Q x H /ηp) x (1 + s)		=	35	→	**37**
		r =specific gravity of water			=	1.00	(g/cm3)
		ηp=pump efficiency			0.75	75%	(%)
		s = safety factor			0.15	15%	(%)
20	Specification	Type	Centrifugal Pump				
		Diameter	200	(mm)			
		Capacity	2.8	(m3/min)			
		Head	50.0	(m)			
		Motor Output	37.0	(kw)			
		Quantity (sets)	2.0	(sets)	1for standby		

12.3.4 Manning's formula (Flow in an Open channel Flow)

(1) Formula

The Manning's formula or Chezy's formula is the most commonly used equation to analyze open channel flows, not flowing under pressure and was developed for uniform steady state flow. It is a semi-empirical equation for simulating water flows in channels (any shape - circular, rectangular, triangular, culverts) where the water is open to the atmosphere,

Only Manning equation is expressed as follows.

$$Q = A \times V = (K/n) \times A \times R^{2/3} \times S^{1/2} \text{ ....(20)}$$

> **NOTE**: **K** is a unit conversion factor: k=1.49 for English units (feet and seconds). k=1.0 for SI units (meters and seconds).

$$V = (1/n) \times R^{2/3} \times S^{1/2} \text{ ....(21)}$$

Where

(a) Q = Volume flow rate (l/sec)
(b) V = Cross-section mean velocity (m/sec)
(c) A = Cross-section area of flow (m^2)
(d) P = Wetted perimeter (m)
(e) R = Hydraulic radius (m) ; R =A/P
(f) n = Manning coefficient of roughness
(g) S = Hydraulic Gradient of pipeline or slope (m/m or ‰)

Table- 17Example of Manning coefficient of roughness（Factory products）

Channel inside Surfaces	Very smooth finish inside（FRP/PVC）	Medium finish inside (Steel pipe / cast iron pipe / mortar lining pipe)	Coarse, old Inner surface
n，Manning coefficient of roughness	0.010	＜ 0.013	＜ 0.015～

Source: Japan Sewage Works Association 1994

(2) How to calculate "R" depending on the structure of Channel

When Manning formula is used, calculation of R value is important.

Here are some examples of calculations.

(1) Formula

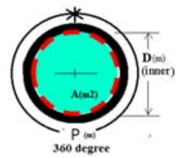
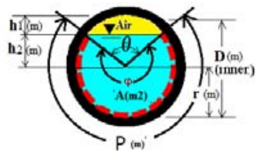
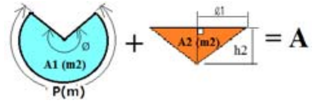
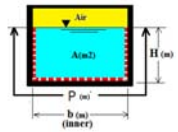
R=A/P

Where

A = Cross-section area of flow (m^2)

P = Wetted perimeter (m)

Table-18 Example of calculation method of R value

Shapes		Calculation forms of R = A/ P (m)
(A) Full pipe flow		A (m^2) = $\pi \times (D/2)^2$ P (m) = $\pi \times$(D) R (m) = A/P
(B) Partially full pipe flow		 A1 (m^2) = ($\pi \times (D/2)^2$) × （ϕ/360） A2 (m^2) = h2 ×ℓ 1 P (m) = (2×3.14×r)×(ϕ/360) R(m) = (A1+A2)/P
(C) Partially full rectangular –shape channel flow		A (m^2) = H ×b P (m) = b + (2 ×H) R (m) = A/P

◆ Practice Exercise-6 (300 mm, full water Open Distribution pipeline)

① In the case of n (0.013), obtain the Cross-section mean velocity (m / sec) of the full pipe, the hydraulic gradient (‰), and check the Volume flow rate (m^3 / sec).

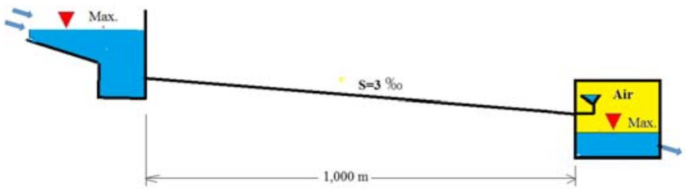
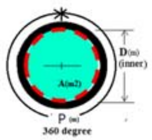


Figure-31 Image diagram of Open channel flow of Manning formula

Table-19 Result of Calculation in Exercises – 6

Manning's formula in a Open Full Pipe Flow **Ex.6**

Item #	Conditions / Assumptions	m^3/d	m^3/hr	m^3/min	m^3/sec	(ℓ/sec)
1	**Volume flow rate: Q =**	4,200	175.0	2.9	0.049	**48.6**
2	**Cross-section mean velocity : V = ??**	?	m/sec			
3	Inside hydraulic diameter: D =	0.300	(m)			
4	Radius: r =	0.150	(m)			
5	Total length of a pipeline : L =	1,000	(m)			
6	Friction head loss : hf =	3.0	(m)			
7	Manning Coefficient of Roughness : n =	**0.013**				



π =	3.1416
2/3 =	0.6667
1/2 =	0.5

Item #	Solution			
8	Cross-section area of flow : A=	π×(D/2)^2	0.071	(m^2)
9	Wetted perimeter : P =	π×(D)	0.942	(m)
10	Hydraulic radius : R =	A ÷ P	0.075	(m)
11	**Hydraulic Gradient of pipe : S =**	(hf/L) × 1,000	**3.00**	**(‰)**
12	**Mean flow velocity in pipe : V =**	$1/n \times R^{2/3} \times (S/1000)^{1/2}$	**0.749**	**(m/sec)**

Item #	Confirmation					
13	**Volume flow rate: Q =**	A×V	m^3/sec	**0.052**	**OK >**	**0.049**
14	YES: The planned amount of water can be distributed.					

Table-20 Quick Reference Matrix of Calculation in Exercises - 6

D: (m)	0.200		0.250		0.300		0.350		D: (m)
A: (m^2)	0.031		0.049		0.071		0.096		A: (m2)
P: (m)	0.628		0.785		0.942		1.100		P: (m)
R: (m)	0.050		0.063		0.075		0.088		R: (m)
S (‰)	V(m/sec)	Q(m^3/sec)	V(m/sec)	Q(m^3/sec)	V(m/sec)	Q(m^3/sec)	V(m/sec)	Q(m^3/sec)	S (‰)
0.02	0.047	0.0015	0.054	0.0027	0.061	0.0043	0.068	0.0065	0.02
0.04	0.066	0.0021	0.077	0.0038	0.087	0.0061	0.096	0.0092	0.04
0.06	0.081	0.0025	0.094	0.0046	0.106	0.0075	0.117	0.0113	0.06
0.08	0.093	0.0029	0.108	0.0053	0.122	0.0086	0.136	0.0130	0.08
0.10	0.104	0.0033	0.121	0.0059	0.137	0.0097	0.152	0.0146	0.10
0.20	0.148	0.0046	0.171	0.0084	0.193	0.0137	0.214	0.0206	0.20
0.30	0.181	0.0057	0.210	0.0103	0.237	0.0167	0.263	0.0253	0.30
0.40	0.209	0.0066	0.242	0.0119	0.274	0.0193	0.303	0.0292	0.40
0.50	0.233	0.0073	0.271	0.0133	0.306	0.0216	0.339	0.0326	0.50
0.60	0.256	0.0080	0.297	0.0146	0.335	0.0237	0.371	0.0357	0.60
0.70	0.276	0.0087	0.320	0.0157	0.362	0.0256	0.401	0.0386	0.70
0.80	0.295	0.0093	0.343	0.0168	0.387	0.0273	0.429	0.0413	0.80
0.90	0.313	0.0098	0.363	0.0178	0.410	0.0290	0.455	0.0438	0.90
1.00	0.330	0.0104	0.383	0.0188	0.433	0.0306	0.479	0.0461	1.00
1.10	0.346	0.0109	0.402	0.0197	0.454	0.0321	0.503	0.0484	1.10
1.20	0.362	0.0114	0.420	0.0206	0.474	0.0335	0.525	0.0505	1.20
1.30	0.376	0.0118	0.437	0.0214	0.493	0.0349	0.547	0.0526	1.30
1.40	0.391	0.0123	0.453	0.0222	0.512	0.0362	0.567	0.0546	1.40
1.50	0.404	0.0127	0.469	0.0230	0.530	0.0374	0.587	0.0565	1.50
1.60	0.418	0.0131	0.485	0.0238	0.547	0.0387	0.606	0.0583	1.60
1.70	0.430	0.0135	0.499	0.0245	0.564	0.0399	0.625	0.0601	1.70
1.80	0.443	0.0139	0.514	0.0252	0.580	0.0410	0.643	0.0619	1.80
1.90	0.455	0.0143	0.528	0.0259	0.596	0.0421	0.661	0.0636	1.90
2.00	0.467	0.0147	0.542	0.0266	0.612	0.0432	0.678	0.0652	2.00
2.10	0.478	0.0150	0.555	0.0272	0.627	0.0443	0.695	0.0668	2.10
2.20	0.490	0.0154	0.568	0.0279	0.642	0.0454	0.711	0.0684	2.20
2.30	0.501	0.0157	0.581	0.0285	0.656	0.0464	0.727	0.0699	2.30
2.40	0.511	0.0161	0.593	0.0291	0.670	0.0474	0.743	0.0715	2.40
2.50	0.522	0.0164	0.606	0.0297	0.684	0.0483	0.758	0.0729	2.50
2.60	0.532	0.0167	0.618	0.0303	0.698	0.0493	0.773	0.0744	2.60
2.70	0.542	0.0170	0.629	0.0309	0.711	0.0502	0.788	0.0758	2.70
2.80	0.552	0.0174	0.641	0.0315	0.724	0.0512	0.802	0.0772	2.80
2.90	0.562	0.0177	0.652	0.0320	0.737	0.0521	0.816	0.0785	2.90
3.00	0.572	0.0180	0.663	0.0326	0.749	0.0530	0.830	0.0799	3.00
3.20	0.591	0.0186	0.685	0.0336	0.774	0.0547	0.858	0.0825	3.20
3.40	0.609	0.0191	0.706	0.0347	0.798	0.0564	0.884	0.0850	3.40
3.60	0.626	0.0197	0.727	0.0357	0.821	0.0580	0.910	0.0875	3.60
3.80	0.644	0.0202	0.747	0.0367	0.843	0.0596	0.935	0.0899	3.80
4.00	0.660	0.0207	0.766	0.0376	0.865	0.0612	0.959	0.0922	4.00
4.20	0.677	0.0213	0.785	0.0385	0.887	0.0627	0.982	0.0945	4.20
4.50	0.700	0.0220	0.813	0.0399	0.918	0.0649	1.017	0.0978	4.50
5.00	0.738	0.0232	0.857	0.0420	0.967	0.0684	1.072	0.1031	5.00
5.50	0.774	0.0243	0.898	0.0441	1.014	0.0717	1.124	0.1082	5.50
6.00	0.809	0.0254	0.938	0.0461	1.060	0.0749	1.174	0.1130	6.00
6.50	0.842	0.0264	0.977	0.0479	1.103	0.0780	1.222	0.1176	6.50
7.00	0.873	0.0274	1.013	0.0497	1.144	0.0809	1.268	0.1220	7.00
7.50	0.904	0.0284	1.049	0.0515	1.185	0.0837	1.313	0.1263	7.50
8.00	0.934	0.0293	1.083	0.0532	1.224	0.0865	1.356	0.1305	8.00
8.50	0.962	0.0302	1.117	0.0548	1.261	0.0891	1.398	0.1345	8.50
9.00	0.990	0.0311	1.149	0.0564	1.298	0.0917	1.438	0.1384	9.00
10.00	1.044	0.0328	1.211	0.0595	1.368	0.0967	1.516	0.1459	10.00
11.00	1.095	0.0344	1.270	0.0624	1.435	0.1014	1.590	0.1530	11.00
12.00	1.144	0.0359	1.327	0.0651	1.498	0.1059	1.661	0.1598	12.00
13.00	1.190	0.0374	1.381	0.0678	1.560	0.1102	1.728	0.1663	13.00
14.00	1.235	0.0388	1.433	0.0704	1.619	0.1144	1.794	0.1726	14.00
15.00	1.279	0.0402	1.484	0.0728	1.675	0.1184	1.857	0.1786	15.00
16.00	1.320	0.0415	1.532	0.0752	1.730	0.1223	1.918	0.1845	16.00
17.00	1.361	0.0428	1.579	0.0775	1.784	0.1261	1.977	0.1902	17.00
18.00	1.401	0.0440	1.625	0.0798	1.835	0.1297	2.034	0.1957	18.00
19.00	1.439	0.0452	1.670	0.0820	1.886	0.1333	2.090	0.2010	19.00
20.00	1.476	0.0464	1.713	0.0841	1.935	0.1367	2.144	0.2063	20.00

Table-21 Quick Reference Matrix of PVC Pipe

PVC Pipe n = 0.010 (Manning)

Slope (%)	100 (mm) V m/sec	100 (mm) Q(m³/sec)	125 (mm) V m/sec	125 (mm) Q(m³/sec)	150 (mm) V m/sec	150 (mm) Q(m³/sec)	200 (mm) V m/sec	200 (mm) Q(m³/sec)
12.5	3.023	0.0237						
12.0	2.962	0.0233						
11.5	2.899	0.0228						
11.0	2.836	0.0223						
10.5	2.770	0.0218						
10.0	2.704	0.0212	3.137	0.0385				
8.0	2.418	0.0190	2.806	0.0344	3.169	0.0560		
7.0	2.262	0.0178	2.625	0.0322	2.964	0.0524		
6.0	2.094	0.0164	2.430	0.0298	2.744	0.0485		
5.0	1.912	0.0150	2.218	0.0272	2.505	0.0443	3.035	0.0953
4.0	1.710	0.0134	1.984	0.0243	2.241	0.0396	2.714	0.0853
3.4	1.577	0.0124	1.829	0.0224	2.066	0.0365	2.503	0.0786
2.8	1.431	0.0112	1.660	0.0204	1.875	0.0331	2.271	0.0713
2.3	1.297	0.0102	1.505	0.0185	1.699	0.0300	2.058	0.0647
2.0	1.209	0.0095	1.403	0.0172	1.584	0.0280	1.919	0.0603
1.9	1.179	0.0093	1.368	0.0168	1.544	0.0273	1.871	0.0588
1.8	1.147	0.0090	1.331	0.0163	1.503	0.0266	1.821	0.0572
1.7	1.115	0.0088	1.294	0.0159	1.461	0.0258	1.770	0.0556
1.6	1.081	0.0085	1.255	0.0154	1.417	0.0250	1.717	0.0539
1.5	1.047	0.0082	1.215	0.0149	1.372	0.0242	1.662	0.0522
1.4	1.012	0.0079	1.174	0.0144	1.326	0.0234	1.606	0.0505
1.3	0.975	0.0077	1.131	0.0139	1.277	0.0226	1.547	0.0486
1.2	0.937	0.0074	1.087	0.0133	1.227	0.0217	1.487	0.0467
1.1	0.897	0.0070	1.041	0.0128	1.175	0.0208	1.423	0.0447
1.0	0.855	0.0067	0.992	0.0122	1.120	0.0198	1.357	0.0426
0.9	0.811	0.0064	0.941	0.0115	1.063	0.0188	1.288	0.0405
0.8	0.765	0.0060	0.887	0.0109	1.002	0.0177	1.214	0.0381
0.7	0.715	0.0056	0.830	0.0102	0.937	0.0166	1.136	0.0357
0.6	0.662	0.0052	0.768	0.0094	0.868	0.0153	1.051	0.0330
0.5	0.605	0.0048	0.702	0.0086	0.792	0.0140	0.960	0.0302
0.4			0.627	0.0077	0.709	0.0125	0.858	0.0270
0.3					0.614	0.0109	0.743	0.0233

Source: Yokohama City WW

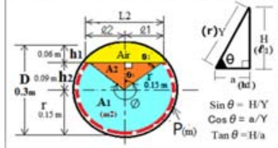
◆ Practice Exercise-7 (300 mm, partially full water Open Distribution pipeline)

① In the case of n (0.013), obtain the Cross-section mean velocity (m / sec) of the full pipe, the hydraulic gradient (‰), and check the Volume flow rate (m^3 / sec).

Table-22 Result of Calculation in Exercises – 7

Manning's formula in a Partially Full Open Pipe Flow **Ex.7**

Item #	Conditions / Assumptions	m³/d	m³/hr	m³/min	m³/sec	(ℓ/sec)	
1	Volume flow rate: Q =	4,200	175.0	2.9	**0.049**	**48.6**	
2	**Cross-section mean velocity: V = ??**	?	m/sec				
3	Inside hydraulic diameter : D =	0.300	(m)		π =	3.1416	
4	Radius: r =	0.150	(m)		2/3 =	0.6667	
5	Total length of a pipeline : L =	1,000	(m)		1/2 =	0.5	
6	Friction head loss : hf =	3.0	(m)				
7	Manning Coefficient of Roughness : n =	0.013					
	Solution						
8	**Cross-section area of flow : A=**	A1+A2		=	**0.061**	(m²)	
9	**Wetted perimeter : P =**	(2*3.14*r)*(φ/360)		=	**0.664**	(m)	
	面積計算						
10	(Use the Pythagorean Theorem : H2 +a2 =Y2)	h1 =	0.06	(m)			
		h2 =	r-h1	**0.09**	(m)		
		ACOSθ1 =	h2/r =	0.6	53.1	° **(Ref. Tbale-24)**	
		φ	360-(2 ×θ1) =		**253.7**	°	
		Base: ℓ1 =	$r^2 - h2^2 = ℓ_1^2$	**0.12**	(m)		
		A1 (m²) =	(π×(D/2)^2) ×(φ/360) =		**0.050**	(m²)	
			or	1/2×(P×r) =	**0.050**	(m²)	
		A2 (m²)=	(1/2)×(2×ℓ₁)×h₂ =		**0.011**	(m²)	
			or	$h_2 \times ℓ_1$ =	0.011	(m²)	



Item #							
10	**Hydraulic radius : R =**	A ÷ P		**0.0913**	(m)		
11	**Hydraulic Gradient of pipe : S =**	(hf/L) × 1,000		**3.00**	**(‰)**		
12	**Cross-section mean velocity: V =**	$1/n \times R^{2/3} \times (S/1000)^{1/2}$		**0.854**	**(m/sec)**	< 1.2 m/sec OK	
	Confirmation						
13	**Mean flow velocity in pipe : Q =**	A×V	m³/sec	**0.051**	**OK >**	0.049	
14	YES: The planned amount of water can be distributed.						

◆ Practice Exercise-8 (Partially full rectangular –shape open channel flow)

① In the case of n (0.013), obtain the Cross-section mean velocity (m / sec) of the rectangular channel, the hydraulic gradient (‰), and check the Volume flow rate (m^3 / sec).

Table-23 Result of Calculation in Exercises – 8

Manning's formula in a Partially Full Open Rectangular Channel Flow **Ex.8**

Item #	Conditions / Assumptions	m³/d	m³/hr	m³/min	m³/sec	(ℓ/sec)
1	Volume flow rate : Q =	4,200	175.0	2.9	**0.049**	**48.6**
2	**Cross-section mean velocity: V = ??**	?	m/sec			
3	Side wall height : H =	0.150	(m)			
4	Bottom length : b =	0.200	(m)			
5	Total length of a pipeline : L =	1,000	(m)			
6	Friction head loss : hf =	3.0	(m)			
7	Manning coefficient of roughness : n =	0.015				
	Solution					
8	Cross-section area of flow : A=	H ×b		=	0.030	(m²)
9	Wetted perimeter : P =	b+(2×H)		=	0.060	(m)
10	**Hydraulic radius : R =**	A ÷ P		=	**0.500**	(m)
11	**Hydraulic Gradient of Open Channnel**	(hf/L) × 1,000		=	3.00	**(‰)**
12	**Cross-section mean velocity : V =**	$1/n \times R^{2/3} \times (S/1000)^{1/2}$		=	**2.3**	**(m/sec)**
	Confirmation					
13	**Mean flow velocity in pipe : Q =**	A ×V	=	**0.069**	**OK >**	0.049
14	YES: The planned amount of water can be distributed.					

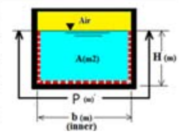


Table-24 Quick Reference Matrix of Trigonometric Functions

Angles°	SIN	COS	Tan	Radian	Angles°	SIN	COS	Tan	Radian	Angles°	SIN	COS	Tan	Radian	Angles°	SIN	COS	Tan	Radian	ASIN	ACOS	ATAN	ASIN	ACOS	ATAN
0	0.000	1.000	0.000	0	50	0.766	0.6428	1.1918	0.8727	100	0.985	-0.1736	-5.6713	1.7453	150	0.500	-0.8660	-0.577	2.6180	0.00	0.00	0.00	50.00	50.00	50.00
1	0.0175	0.9998	0.0175	0.0175	51	0.7771	0.6293	1.2349	0.8901	101	0.982	-0.1908	-5.1446	1.7628	151	0.485	-0.8746	-0.554	2.6354	1.00	1.00	1.00	51.00	51.00	51.00
2	0.0349	0.9994	0.0349	0.0349	52	0.7880	0.6157	1.2799	0.9076	102	0.978	-0.2079	-4.7046	1.7802	152	0.469	-0.8829	-0.532	2.6529	2.00	2.00	2.00	52.00	52.00	52.00
3	0.0523	0.9986	0.0524	0.0524	**53**	0.7986	**0.6018**	1.3270	0.9250	103	0.974	-0.2250	-4.3315	1.7977	153	0.454	-0.8910	-0.510	2.6704	3.00	3.00	3.00	53.00	**53.00**	53.00
4	0.0698	0.9976	0.0699	0.0698	54	0.8090	0.5878	1.3764	0.9425	104	0.970	-0.2419	-4.0108	1.8151	154	0.438	-0.8988	-0.488	2.6878	4.00	4.00	4.00	54.00	54.00	54.00
5	0.0872	0.9962	0.0875	0.0873	55	0.8192	0.5736	1.4281	0.9599	105	0.966	-0.2588	-3.7321	1.8326	155	0.423	-0.9063	-0.466	2.7053	5.00	5.00	5.00	55.00	55.00	55.00
6	0.1045	0.9945	0.1051	0.1047	56	0.8290	0.5592	1.4826	0.9774	106	0.961	-0.2756	-3.4874	1.8500	156	0.407	-0.9135	-0.445	2.7227	6.00	6.00	6.00	56.00	56.00	56.00
7	0.1219	0.9925	0.1228	0.1222	57	0.8387	0.5446	1.5399	0.9948	107	0.956	-0.2924	-3.2709	1.8675	157	0.391	-0.9205	-0.424	2.7402	7.00	7.00	7.00	57.00	57.00	57.00
8	0.1392	0.9903	0.1405	0.1396	58	0.8480	0.5299	1.6003	1.0123	108	0.951	-0.3090	-3.0777	1.8850	158	0.375	-0.9272	-0.404	2.7576	8.00	8.00	8.00	58.00	58.00	58.00
9	0.1564	0.9877	0.1584	0.1571	59	0.8572	0.5150	1.6643	1.0297	109	0.946	-0.3256	-2.9042	1.9024	159	0.358	-0.9336	-0.384	2.7751	9.00	9.00	9.00	59.00	59.00	59.00
10	0.1736	0.9848	0.1763	0.1745	**60**	**0.8660**	**0.5000**	**1.7321**	**1.0472**	110	0.940	-0.3420	-2.7475	1.9199	160	0.342	-0.9397	-0.364	2.7925	10.00	10.00	10.00	60.00	60.00	60.00
11	0.1908	0.9816	0.1944	0.1920	61	0.8746	0.4848	1.8040	1.0647	111	0.934	-0.3584	-2.6051	1.9373	161	0.326	-0.9455	-0.344	2.8100	11.00	11.00	11.00	61.00	61.00	61.00
12	0.2079	0.9781	0.2126	0.2094	62	0.8829	0.4695	1.8807	1.0821	112	0.927	-0.3746	-2.4751	1.9548	162	0.309	-0.9511	-0.325	2.8274	12.00	12.00	12.00	62.00	62.00	62.00
13	0.2250	0.9744	0.2309	0.2269	63	0.8910	0.4540	1.9626	1.0996	113	0.921	-0.3907	-2.3559	1.9722	163	0.292	-0.9563	-0.306	2.8449	13.00	13.00	13.00	63.00	63.00	63.00
14	0.2419	0.9703	0.2493	0.2443	64	0.8988	0.4384	2.0503	1.1170	114	0.914	-0.4067	-2.2460	1.9897	164	0.276	-0.9613	-0.287	2.8623	14.00	14.00	14.00	64.00	64.00	64.00
15	0.2588	0.9659	0.2679	0.2618	65	0.9063	0.4226	2.1445	1.1345	115	0.906	-0.4226	-2.1445	2.0071	165	0.259	-0.9659	-0.268	2.8798	15.00	15.00	15.00	65.00	65.00	65.00
16	0.2756	0.9613	0.2867	0.2793	66	0.9135	0.4067	2.2460	1.1519	116	0.899	-0.4384	-2.0503	2.0246	166	0.242	-0.9703	-0.249	2.8972	16.00	16.00	16.00	66.00	66.00	66.00
17	0.2924	0.9563	0.3057	0.2967	67	0.9205	0.3907	2.3559	1.1694	117	0.891	-0.4540	-1.9626	2.0420	167	0.225	-0.9744	-0.231	2.9147	17.00	17.00	17.00	67.00	67.00	67.00
18	0.3090	0.9511	0.3249	0.3142	68	0.9272	0.3746	2.4751	1.1868	118	0.883	-0.4695	-1.8807	2.0595	168	0.208	-0.9781	-0.213	2.9322	18.00	18.00	18.00	68.00	68.00	68.00
19	0.3256	0.9455	0.3443	0.3316	69	0.9336	0.3584	2.6051	1.2043	119	0.875	-0.4848	-1.8040	2.0769	169	0.191	-0.9816	-0.194	2.9496	19.00	19.00	19.00	69.00	69.00	69.00
20	0.3420	0.9397	0.3640	0.3491	70	0.9397	0.3420	2.7475	1.2217	120	0.866	-0.5000	-1.7321	2.0944	170	0.174	-0.9848	-0.176	2.9671	20.00	20.00	20.00	70.00	70.00	70.00
21	0.3584	0.9336	0.3839	0.3665	71	0.9455	0.3256	2.9042	1.2392	121	0.857	-0.5150	-1.6643	2.1118	171	0.156	-0.9877	-0.158	2.9845	21.00	21.00	21.00	71.00	71.00	71.00
22	0.3746	0.9272	0.4040	0.3840	72	0.9511	0.3090	3.0777	1.2566	122	0.848	-0.5299	-1.6003	2.1293	172	0.139	-0.9903	-0.141	3.0020	22.00	22.00	22.00	72.00	72.00	72.00
23	0.3907	0.9205	0.4245	0.4014	73	0.9563	0.2924	3.2709	1.2741	123	0.839	-0.5446	-1.5399	2.1468	173	0.122	-0.9925	-0.123	3.0194	23.00	23.00	23.00	73.00	73.00	73.00
24	0.4067	0.9135	0.4452	0.4189	74	0.9613	0.2756	3.4874	1.2915	124	0.829	-0.5592	-1.4826	2.1642	174	0.105	-0.9945	-0.105	3.0369	24.00	24.00	24.00	74.00	74.00	74.00
25	0.4226	0.9063	0.4663	0.4363	75	0.9659	0.2588	3.7321	1.3090	125	0.819	-0.5736	-1.4281	2.1817	175	0.087	-0.9962	-0.087	3.0543	25.00	25.00	25.00	75.00	75.00	75.00
26	0.4384	0.8988	0.4877	0.4538	76	0.9703	0.2419	4.0108	1.3265	126	0.809	-0.5878	-1.3764	2.1991	176	0.070	-0.9976	-0.070	3.0718	26.00	26.00	26.00	76.00	76.00	76.00
27	0.4540	0.8910	0.5095	0.4712	77	0.9744	0.2250	4.3315	1.3439	127	0.799	-0.6018	-1.3270	2.2166	177	0.052	-0.9986	-0.052	3.0892	27.00	27.00	27.00	77.00	77.00	77.00
28	0.4695	0.8829	0.5317	0.4887	78	0.9781	0.2079	4.7046	1.3614	128	0.788	-0.6157	-1.2799	2.2340	178	0.035	-0.9994	-0.035	3.1067	28.00	28.00	28.00	78.00	78.00	78.00
29	0.4848	0.8746	0.5543	0.5061	**79**	0.9816	0.1908	**5.1446**	1.3788	129	0.777	-0.6293	-1.2349	2.2515	179	0.017	-0.9998	-0.017	3.1241	29.00	29.00	29.00	79.00	79.00	79.00
30	**0.5000**	**0.8660**	**0.5774**	**0.5236**	80	0.9848	0.1736	5.6713	1.3963	130	0.766	-0.6428	-1.1918	2.2689	180	0.000	-1.0000	0.000	3.1416	30.00	30.00	30.00	80.00	80.00	80.00
31	0.5150	0.8572	0.6009	0.5411	81	0.9877	0.1564	6.3138	1.4137	131	0.755	-0.6561	-1.1504	2.2864	181	-0.017	-0.9998	0.017	3.1590	31.00	31.00	31.00	81.00	81.00	81.00
32	0.5299	0.8480	0.6249	0.5585	82	0.9903	0.1392	7.1154	1.4312	132	0.743	-0.6691	-1.1106	2.3038	182	-0.035	-0.9994	0.035	3.1765	32.00	32.00	32.00	82.00	82.00	82.00
33	0.5446	0.8387	0.6494	0.5760	83	0.9925	0.1219	8.1443	1.4486	133	0.731	-0.6820	-1.0724	2.3213	183	-0.052	-0.9986	0.052	3.1940	33.00	33.00	33.00	83.00	83.00	83.00
34	0.5592	0.8290	0.6745	0.5934	84	0.9945	0.1045	9.5144	1.4661	134	0.719	-0.6947	-1.0355	2.3387	184	-0.070	-0.9976	0.070	3.2114	34.00	34.00	34.00	84.00	84.00	84.00
35	0.5736	0.8192	0.7002	0.6109	85	0.9962	0.0872	11.4301	1.4835	135	0.707	-0.7071	-1.0000	2.3562	185	-0.087	-0.9962	0.087	3.2289	35.00	35.00	35.00	85.00	85.00	85.00
36	0.5878	0.8090	0.7265	0.6283	86	0.9976	0.0698	14.3007	1.5010	136	0.695	-0.7193	-0.9657	2.3736	186	-0.105	-0.9945	0.105	3.2463	36.00	36.00	36.00	86.00	86.00	86.00
37	0.6018	0.7986	0.7536	0.6458	87	0.9986	0.0523	19.0811	1.5184	137	0.682	-0.7314	-0.9325	2.3911	187	-0.122	-0.9925	0.123	3.2638	37.00	37.00	37.00	87.00	87.00	87.00
38	0.6157	0.7880	0.7813	0.6632	88	0.9994	0.0349	28.6363	1.5359	138	0.669	-0.7431	-0.9004	2.4086	188	-0.139	-0.9903	0.141	3.2812	38.00	38.00	38.00	88.00	88.00	88.00
39	0.6293	0.7771	0.8098	0.6807	89	0.9998	0.0175	57.2900	1.5533	139	0.656	-0.7547	-0.8693	2.4260	189	-0.156	-0.9877	0.158	3.2987	39.00	39.00	39.00	89.00	89.00	89.00
40	0.6428	0.7660	0.8391	0.6981	**90**	**1.0000**	**0.0000**	-	**1.5708**	140	0.643	-0.7660	-0.8391	2.4435	190	-0.174	-0.9848	0.176	3.3161	40.00	40.00	40.00	**90.00**	**90.00**	-
41	0.6561	0.7547	0.8693	0.7156	91	0.9998	-0.0175	-57.2900	1.5882	141	0.629	-0.7771	-0.8098	2.4609	200	-0.342	-0.9397	0.364	3.4907	41.00	41.00	41.00	89.00	91.00	-89.00
42	0.6691	0.7431	0.9004	0.7330	92	0.9994	-0.0349	-28.6363	1.6057	142	0.616	-0.7880	-0.7813	2.4784	240	-0.866	-0.5000	1.732	4.1888	42.00	42.00	42.00	88.00	92.00	-88.00
43	0.6820	0.7314	0.9325	0.7505	93	0.9986	-0.0523	-19.0811	1.6232	143	0.602	-0.7986	-0.7536	2.4958	260	-0.985	-0.1736	5.671	4.5379	43.00	43.00	43.00	87.00	93.00	-87.00
44	0.6947	0.7193	0.9657	0.7679	94	0.9976	-0.0698	-14.3007	1.6406	144	0.588	-0.8090	-0.7265	2.5133	280	-0.985	0.1736	-5.671	4.8869	44.00	44.00	44.00	86.00	94.00	-86.00
45	**0.7071**	**0.7071**	**1.0000**	**0.7854**	95	0.9962	-0.0872	-11.4301	1.6581	145	0.574	-0.8192	-0.7002	2.5307	300	-0.866	0.5000	-1.732	5.2360	45.00	45.00	45.00	85.00	95.00	-85.00
46	0.7193	0.6947	1.0355	0.8029	96	0.9945	-0.1045	-9.5144	1.6755	146	0.559	-0.8290	-0.6745	2.5482	320	-0.643	0.7660	-0.839	5.5851	46.00	46.00	46.00	84.00	96.00	-84.00
47	0.7314	0.6820	1.0724	0.8203	97	0.9925	-0.1219	-8.1443	1.6930	147	0.545	-0.8387	-0.6494	2.5656	340	-0.342	0.9397	-0.364	5.9341	47.00	47.00	47.00	83.00	97.00	-83.00
48	0.7431	0.6691	1.1106	0.8378	98	0.9903	-0.1392	-7.1154	1.7104	148	0.530	-0.8480	-0.6249	2.5831	350	-0.174	0.9848	-0.176	6.1087	48.00	48.00	48.00	82.00	98.00	-82.00
49	0.7547	0.6561	1.1504	0.8552	99	0.9877	-0.1564	-6.3138	1.7279	149	0.515	-0.8572	-0.6009	2.6005	360	0.000	1.0000	0.000	6.2832	49.00	49.00	49.00	81.00	99.00	-81.00
Notes:	**30º =π/6**	**Radians**	**45º =π/4**	**Radians**		**60º =π/3**	**Radians**	**90º =π/2**	**Radians**		**180º =π**	**Radians**	**360º =2 *π**	**Radians**		**π(3.14)**									

-END-

Internal Information

TEXT BOOK
FOR
JOINT TRAINING
（DRAFT）

WORK ETHICS/ COMPLIANCE

March, 2019

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)
Eng. Karugendo # 17

Assisted by JICA KENYA

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Original First Edition March, 2019

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1. Objectives (Out-put)

① Understand the necessity of Work Ethics
② Understand what is COMPLIANCE?
③ Understand what is GOVERNANCE?
④ Understanding the item of ethics of engineers
⑤ Understanding ethics items of Water company
⑥ Understanding the cause of ethics violations

2. Introductions

(1) Necessity of Work Ethics as Compliances

In order to realize a water company trusted by customers, it is to share / implement work Ethics/ Compliance values with all officials.

(2) Backgrounds

To continuously develop the water supply business and improve the water supply service, "Compliance with Work Ethics" and "maintenance of the management system" are indispensable to prevent the occurrence of scandals / corruption of water enterprises due to lack of Compliance.

In particular, there are many losses due to the loss of collection of water fees due to the violation of social norms / ethical norms by some staff, and the misconduct by "social listening" that "honest ones are lost".

As a result, it is in violation of the principle of fair burden of water fee (water rate regulation), which impedes sound independent profitability of water enterprises.

In order to solve these problems, it is important for all the staff to acquire basic knowledge of ethics, and reconsider the awareness of "monitoring and prevention of illegal acts".

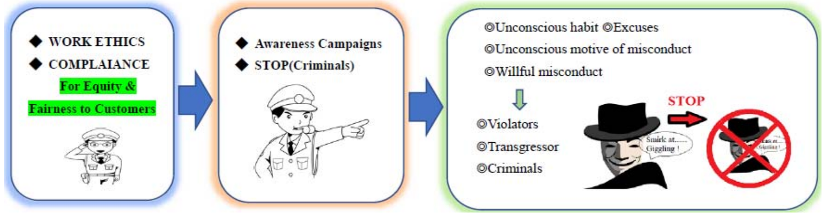

Figure-1 Image Figure of the Dissemination Effect of Compliance/Ethics

Experience of Mombasa WAG, Economic andSocial Rights centre,2016

3. Key words definition

What is Compliance activity ?	Staff are to understand the laws and regulations correctly, actively and act voluntarily, sincerely while self-training.
What is Governance activity ?	It is an organization for Implementation / management to maintain / promote / improve compliance.
What is the Work Ethics of Staff ?	Employees comply with ethics based on labor contracts / norms, maintain daily life with public interest, fairness, neutrality all the time, and refrain from acts of distrust and suspicion from customers.
What is Corporate Ethics?	The water company is to comply with corporate philosophy / corporate ethics, adapted to social demands.

4. What is the difference between Governance and Compliance?

The roles for continuously and effectively implementing compliance activities are shown below.

4-1 What is Governance?

The organization that implement specific and effective measures for compliance activities.

4-2 What is Compliance?

Understand the laws / norms established by Kenya, all staffs must demonstrate leadership with their strong wills and all employees have to implement the compliances.

4-3 Composition of compliances

The main configuration items are shown below.

(1) Rule of law

Regulations established by the administration, including laws, ordinances, legally binding rules.

(2) Social norms

This is, for example, habit / rule rules established by society / region / village, etc.

(3) Corporate norms

This is a company manual, office regulations, social responsibility / motto, etc, as determined by WSP.

(4) Ethical standards

This is corporate ethics that staff must comply with during social occupation and private life, and social ethics to be held as a person.

◆ What is the awareness of compliance that expected staff should be aware of ?

It is a person capable of observing the laws and ordinances of Kenya country, and being able to carry out duties according to the rules and regulations established by WSP, common sense and value that should be taken as a person in nature.

◆What is the figure of a company to be?

To implement WSP's Corporate Social Responsibility (CSR), it is to implement corporate regulations, organize risks systematically and implement risk management to avoid losses.

5. Establishment of Corporate Ethics / Legal Compliance Committee

The committee's activities are basically based on improvement in the PDCA cycle.

(1) Role of Corporate Ethics Officer

Make use of leadership by themselves, conduct investigations on causes of scandals / inappropriate conducts and implement concrete guidance to prevent recurrence.

(2) Role of person in charge of promotion

Guidance on day-to-day activities of officials based on the rules, and work on constructing human relations / workplace climate that is easy to consult.

(3) Role of the Third Organization

This institution promptly prepares a report on investigation / evaluation / measures of violation, and is responsible for accountability to the committee.

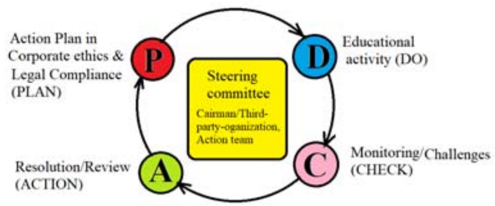

Figure-1 PDCA cycle

6. Activities to comply with compliance

6-1 Example of compliance violation

(1) Fraud / Inappropriate Accounting / Embezzlement of Public Payment,

(2) Personal data leakage,

(3) Tampering with public documents,

(4) leakage of Business information / bid information etc,

(5) lack of attention in working hours / duty negligence,

(6) Violation of gift-giving acts of money / money between staff and businesses / hand and glove act,

(7) Illegal connection by staff / awards of money, intentional water meter record mistake / negligence,

(8) Destruction / remodeling of intentional water meters,

(9) Intentional bypass connection of water pipe / water supply pipe,

(10) Illegal overtime / labor accident / long-term labor,

(11) Employees go to gambling during working hours

(12) Arrest of staff in act of sexual molester

(13) Staff Bicycle Theft

(14) Employee suicide by bullying (power harassment) and others.

6-2 Cause of occurrence

The causes of compliance violation are as follows.

(1) Deterioration of Organizational structure to monitor violating behavior due to loss of intention.

(2) Declining consciousness of staff toward compliance,

(3) "Honest men see fool" Lack of social morals,

(4) Mental illness

(5) Commercialization

(6) Poverty

(7) Antisocial activities, etc.

6.3 Expectations and illusions by strengthening governance

When maintaining compliance by strengthening governance, it is necessary to pay attention to the following issues.

◆ Compliance violations will not disappear by merely preparing legislation or ethics rules. Continued review by PDCA cycle is indispensable. **(Refer to Figure-1**)

① Promotion of reform may be stagnant by too much awareness of compliance and governance.

② By enriching the management system, there may be cases in which an environment where compliance violation can't be found is created in some cases.

③ There is a case that fraudulent activity will not stay in eyes by thinking that

"management system is thorough".

6-4 Effects of Implementation of Compliance and Governance

① The management structure of WSP will be evaluated from customers.

② The working environment / human relations of staff will be improved.

③ Healthy independent profitability of WSP will be improved.

④ The principle of fair share of water charges (water rate rule) will be improved.

⑤ Management of compliance violations across the organization will be improved.

⑥ Water supply management will be presented publicly.

6-5 Examples of compliance promotion activities

(1) Consultation window / installation of grievance box

However, the committee must observe maintenance of confidential information, and the secrecy of personal information so that the search for a criminal of the whistle-blower of harassment by an outsider does not happen.

(2) Implementation of training / educational activities

<u>**Classroom**</u>

Enlightenment/training program is examined taking a participant's understanding into consideration.

(For Example, Lecture/ group study / review of past cases/ comments surveys will be conducted regularly)

<u>**OJT**</u>

In OJT, a trainee creates a simulation code of conduct, creates the guideline of violation punishment, and experiences in a short play.

（For theme of group consultation example, Harassment, Awarding illegal money by illegal connection by staff, Intentional water meter record mistake / negligence Intentional illegal bypass construction, and Illegal overtime / labor accident / long-term labor, etc.)

7. Introduction of Engineering Ethics composition

7-1 Posture

(1) NRW reduction technicians fully recognize that effective use of water resources, inexpensive and stable supply of water supply services will have a serious impact on social life,
Contribute to the realization of water supply service that satisfies customers who can sustain performance.

(2) In order to fulfill its mission, engineers should strive to improve the quality as a Technician, encourage innovation of technology, observe this Code of Ethics from a wide range perspective, act fairly and sincerely is expected.

7-2 Structure of Important Ethical Items (Basic proposal)

(1) Priority of public interest;

Technicians consider public safety, health and well-being as a top priority.

(2) Ensuring sustainability;

① Engineers strive to ensure the sustainability of society of the future generations, such as conservation of the global environment.

② The engineer strives to minimize the impact on the environment that can be predicted in the work as much as possible.

(3) Engaged in work that demonstrates his / her own competence;

Engineers do not engage in uncertain field work.

(4) Securing the truth

Technicians make reports, explanations or presentations using objective and factual information.

(5) Fair and sincere implementation

Based on fair analysis and judgment, engineers will faithfully implement the committed business.

(6) Maintaining secrets

The technician does not disclose or divert the secret that he / she knew in business to others without any just cause.

(7) Maintaining credit

Engineers keep quality, do not act like losing credibility, such as deceptive acts, giving and receiving unfair remuneration.

(8) Mutual cooperation

Engineers will trust each other and strive to cooperate with respect to the position of the opponent.

(9) Compliance with laws and regulations

Technicians observe the laws and regulations of the area subject to work and respect the cultural value.

(10) Continued self-study

Engineers constantly enhance knowledge of expertise, related knowledge, and strive to develop human resources.

8. Suggestions

8.1 Creation own Work Ethics

Awareness-raising activities for nurturing sound engineers by good governance are national projects.
However, KEWI / WSPs has a great responsibility as an executing agency for educational activities of human resources with a sense of Governance/Work Ethics concerning water supply.

Particularly for the work Ethics of the WSP expected to be highly focused by customers, it is hoped that the establishment of a system that can set up its own ethics regulations and carry out review work continuously according to the environments of each WSP as soon as possible.

8.2 Typical Summery

Below is an outline of labor ethics of general engineers. （**Refer to Table-2** ）

Table-2 Typical Comparison of the Various Contents of Norms

Classifications (Vs. Staff)	7-Basic Norm principles	Principle Items of morality	Articles/ Simple description	IEA's ethical norms (International Eng. Alliance)	WSP's ethical norms
I. "Engr" Vs. "Public"	I-1. Public priority	Priority of public profits	· Prioritize public safety and health benefits,	·Public interest	
	I-2. Sustainability	Secure sustainability	· Minimize the predictable environmental impact, · Continue to secure the sustainability of society,	·Environmental impact	
II. "Engr" Vs. " customer"	II-3. Competent	Serious consideration on competence	· Study before starting work. ·Accurately display qualification / performance (do not apply false) · Working with other experts	·Qualification fraud ·Range of ability	
	II-4. Truth	Securing the truth	· For presentation uses objective / factual information	·Listen to expert opinion	
	II-5. Sincere	Fair and sincere fulfillment	· Analysis / judgment based on neutral fair · Responsible on responsiveness in scope-work	·Responsible in scope of work ·Fairness Analysis	
		Confidentiality	· Keeping a secret · Prohibition of diversion of information,	·Confidentiality	
	II-6 Honest	Maintaining trustworthiness	· Maintain quality · Prohibition of acts of losing trust / acceptance of unjust remuneration	·Qualification fraud ·Legitimate reward	
III. "Engr" Vs. "Engr"	III-7. Professional	Mutual cooperation	· Mutual trust · Respecting the position of the opponent	·Rights of those working together	
		Comply laws and regulations	· Respect local laws / cultural values	·Respect for human rights laws	
		Continuing training	· Self-improvement · Human resource development	·Maintain competence	

9. REFERENCE

9-1 Introduction of compliance Activity as a waterworks by Yokosuka City Waterworks and Sewerage Bureau in Japan * Source: Download from Internet

9.1.1 Management objectives

Always usable with confidence can't stop Water supply / Sewer System,

9.1.2 Basic policy

Basic policy to realize water and sewerage department trusted by customers.

① Clarification of policy,

② Initiatives to raise awareness,

③ Creating a mechanism for information gathering, sharing and transmission,

④ Improvement / review of laws and ordinances according to social demands,

⑤ Response when legal violation occurs,

9.1.3 Building a Promotion System

① Establishment of compliance consultation counter,

② Establishment of the Organizational Management Committee for Water and Sewerage Bureau,

③ Risk compliance manager, establishing promoters,

④ Establishment of risk and compliance promotion,

9.1.4 Evaluation System

(1) External evaluation

Evaluation and guidance on compliance is carried out by experts.

(2) Situation survey

This survey investigates compliance efforts by compliance officer.

9.1.5 The Main Action Agendas to Comply with (as Stuff)

(1) Review of laws and regulations,

(2) Law to protect as staff (service),

① Section 30 of Local Public Service Law: Basis Standard;

All officials work as public servants for public interests and must devote themselves to full efforts in carrying out their duties.

② Local Public Service Law Article 31: Oath of Service;

Employees shall take the oath of service in accordance with the ordinance.

③ Regional Public Service Law Article 32: Obligation to comply with laws / regulations and superiors' duties in their duties;

In carrying out its duties, staff members must abide by laws, ordinances, regulations prescribed by the agencies of local governments and faithfully obey the superior's duties.

④ Regional Public Service Law Article 33: Prohibition of Credit Crashing Act;

Staff should not act to hurt the credibility of the job or to become disgraceful of the whole job.

⑤ Section 34 of Local Public Service Law: Obligation to protect secrets

The officials should not disclose the secret they knew in terms of duties.
Even after I retire from that position, I shall do the same.

⑥ Section 35 of Local Public Service Law: Obligation to concentrate on duties

An official shall use all of his working hours and attentiveness in his / her duties for the performance of his / her duties, excluding cases where there are special provisions in laws or ordinances, and in the duties that the local public entity should have.

⑦ Section 37 of Local Public Service Law: Prohibition of Dispute Action;

Staff members shall not engage in acts of stubbornness, such as overtime, or acts of laziness to lower the activity efficiency of institutions of local public entities.

⑧ Regional Public Service Law Article 38: Restrictions on work by commercial enterprises and others;

An employee who is not authorized by the appointing persons may concurrently serve as an officer of a commercial enterprise, or may not engage in any business by running a profit enterprise himself or obtaining compensation.

9.1.6 Protect civil servant ethics

① Civil servant ethics

The starting point of civil servant ethics is the idea that "all civil servants are the whole ministrant, not some ministers".

We need to work to maintain public interest, equity, neutrality all the time.
While we do business, we need to be involved with various stakeholders, but in the relationship with these stakeholders as well as not doing disadvantageous handling for specific people and organizations, We must refrain from disbelief and suspicion from customers.

② What is the prohibited act with stakeholders?

Below are stakeholders.

a) Participants who operate under the permission and approval from the city、
b) Participants who engage in projects receiving subsidies from the city、
c) Parties concerned who have concluded contracts with the city, such as goods, construction etc., or persons who have the possibility of entering into a contract

Between the above stakeholders and staff members, certain actions such as receiving money and gifts of goods are prohibited and restricted.

◆ By observing the ethical ordinance, staff will not only gain the trust of customers from public service, but also the employees themselves will be protected from illegal acts and will be able to concentrate on their duties with confidence.

=END=

Internal Information

TEXT BOOK
FOR
JOINT TRAINING
（DRAFT）

Introduction of NRW Standards 2014/ Impact Report (WASREB)

R-1

May, 2019

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)

Eng. Hgugi（WASREB）# 18

Assisted by JICA KENYA

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Email: info@kewi.or.ke, Web: www.kewi.or.ke

Original Edition and First Edition May, 2019

Table of Contents

1. Objectives (Out-put)

1）WASREB's non-revenue water reduction awareness activities,

2) Contents of guidelines issued by WASREB

3) Contents of the IMPCT report issued by WSAREB

2. Outline

At the time of 2007, the Government of Kenya formulated the "National Water Supply Service Strategy 2007-2015" to reduce economic losses due to non-revenue water and to promote effective water resource activities.

And the target to reduce the NRW rate to 60% from 30% by 2015 was set.

The Kenyan government asked Japan for technical assistance to achieve the target. In response to the request of Kenya, the Japanese government implemented technical support for "The Project for Management of Non-Revenue Water in KENYA" from 2010 to 2014.

WASREB, the executing agency of the request, created the August 2014. "NRW Water Standards" as a result of this project "to promote NRW reduction promotion activities to WSPs in a wide area".

This NRW water standards consists of 4 volumes and was distributed to each WSP in 2014.

However, the current situation is that this outcome has not been effectively utilized due to insufficient budget of WSP / lack of human resources to activate NRW / insufficient enlightenment activity / inadequate basic information necessary for NRW reduction formulation.

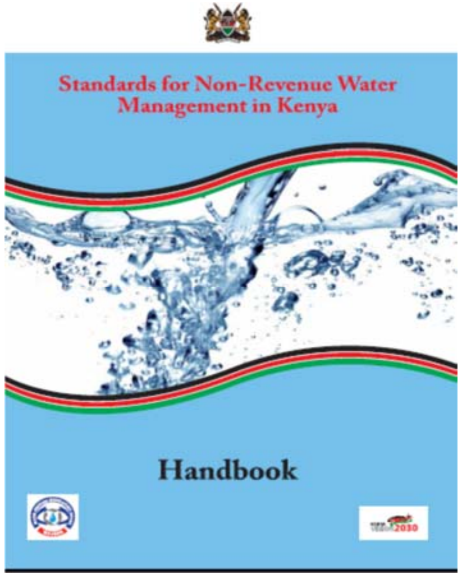
◆ WASREB has expected WSPs more to utilize NRW water standards.

On the other hand, WASREB has published the annual report "Impact report" in order to grasp the NRW reduction effect which each WSP is carrying out.

Discussions:

1. Do you know of the existence of NRW management standards published by WASREB in 2014?
2. Does your WSP use these standards?
3. Which of the four standards do you find relevant in your day to day work?
4. Are you aware of the current WASREB Impact report?
5. Are you aware of your WSPs NRW rating in the current WASREB impact report?
6. Do you think your WSPs NRW rating in the current WASREB impact report to be realistic?
7. **Others?**

3 Introduction of guidelines



This Handbook is to be a simplified NRW reduction manual with many illustrations and photos.

<u>**Target**</u>:
All staff contributing to NRW Management in the WSPs and specifically, the field technicians for use in their daily activities.

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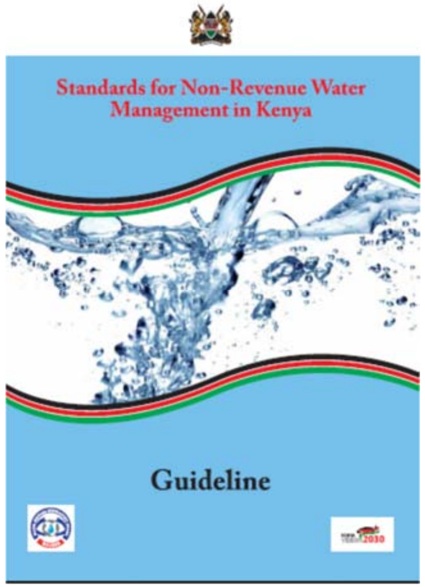
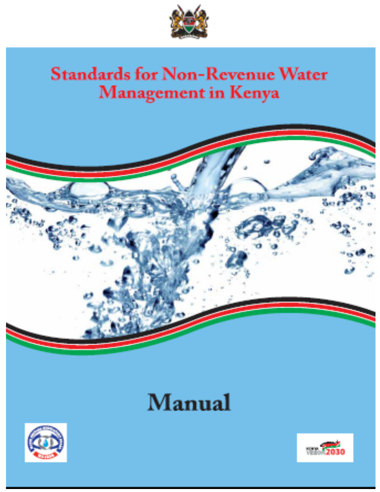
Introduction of NRW Standards 2014/ Impact Report (WASREB) March, 2109



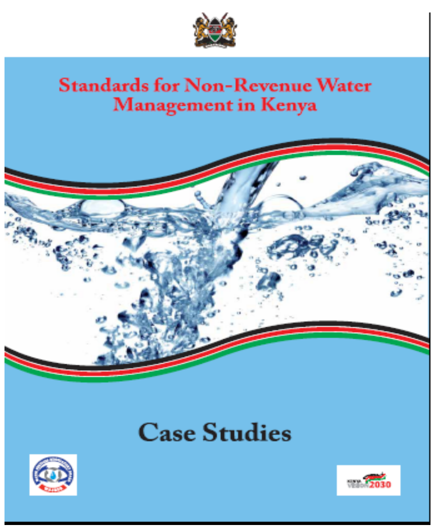
This Guideline is for use by WSB in Assessing and evaluating and guiding the NRW reduction activities implemented by WSPs.

<u>**Table of Contents**</u>



This Manual is for use by WSPs to introduce Basic concept of NRW Reduction Management.

<u>**Table of Contents**</u>



The Case Studies are to introduce actual activities of NRW management projects in Meru, Embu and Narok WSPs.

The case studies show that it is possible to identify a pilot area or most of the intervention can be applied and impact monitored.

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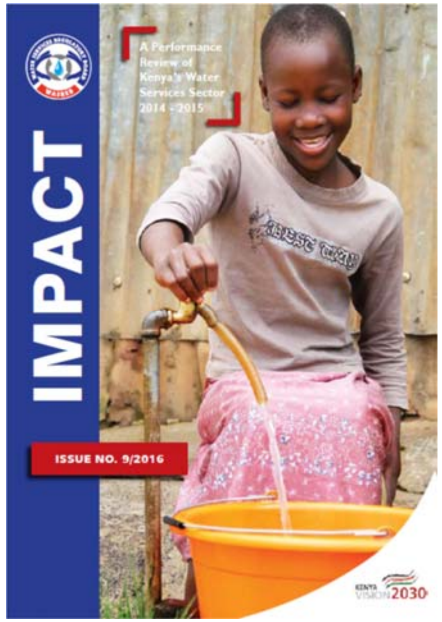
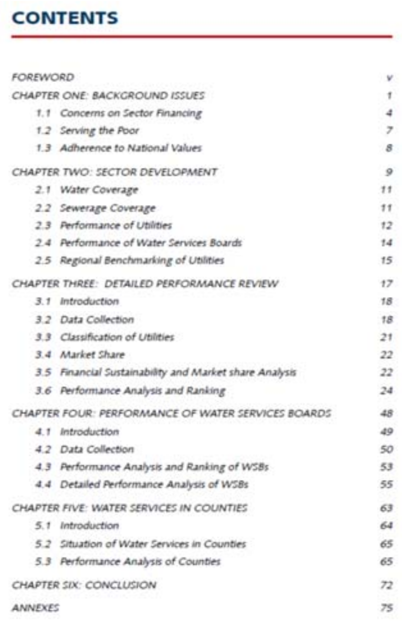
Introduction of NRW Standards 2014/ Impact Report (WASREB) March, 2109

4 Introduction of IMPACT Reports




CONTENTS

Introduction of NRW Standards 2014/ Impact Report (WASREB) March, 2109

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5 Introduction of Non-Revenue Water management, Annual Report 2017/2018

＝END＝

Internal Information

TEXTBOOK

FOR JOINT TRAINING

(DRAFT)

"PIPELINE MATERIALS USED IN WATER SUPPLY NETWORK"

May, 2019

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs

(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)

W. Moseti # 19

Assisted by JICA KENYA

Table of Contents

1 MODULE 1: PIPE LAYING & JOINTING

1 COMMON PIPES USED IN WATER SUPPLY

The common pipes used in pressurized water supply are plastic and metal pipes.

1 In most water supply systems the pipe materials used are galvanized Iron pipes (G.I) and poly-Vinyl-Chloride pipes (P.V.C) pipes. Also polyethylene pipes (P.E) are gaining popularity day by day

1) GALVANIZED IRON PIPES (G.I)

- Galvanized Iron pipes are made from mild carbon steel as either welded or seamless pipes.
- Both categories of pipes are normally manufactured in approximately 6.0m or 20feet lengths
- Unprotected /un-galvanized steel pipes(also called black pipes) rusts almost immediately upon exposure to the atmosphere and moisture.
- G.I pipes used in water supply have a protective coating of zinc.

Hot-dip galvanizing

In this process steel pipes are cleaned and then dipped into a hot bath of molten zinc

Galvanized Iron pipes are supplied in three classes

CLASS A - Light grade pipe-colour code yellow
CLASS B - Medium grade pipe-colour code blue
CLASS C - Heavy grade pipe-colour code red

Advantage of G.I pipes

- Pipes are strong and durable
- They may be used in rocky areas or where the pipeline is exposed
- They are protected from corrosion on both inside and outside with a layer of zinc coating
- They may be used when pipeline is passing or crossing under a road or stream

Disadvantage of G.I pipes

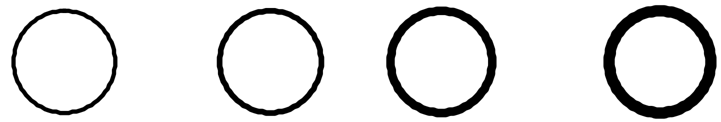
- Generally expensive.
- Corrode easily in salty/acidic condition.
- High friction losses.
- They are heavy, difficult to handle and transport.
- They are not flexible, hence difficult to cut, join and install.

2) POLY-VINYL-CHLORIDE (PVC)

Properties of PVC pipe

- Pipes are made of synthetic organic chemicals. The basic raw materials used being oil, natural gas and coal.
- The raw materials are made into resins that are generally classified as thermosetting and thermoplastic materials.
- Thermoplastic can be reformed repeated by application of heat.
- The pipes are normally manufactured in approximately 6.0m or 20 feet lengths.
- They are manufactured in two jointing forms
    - Flat sockets
    - Rubber-ring joint

PVC Classes, Colour code and Wall thickness



Class B	Class C	Class D	Class E
Code = red	Code = blue	Code = green	Code = brown
Press = 60m	Press = 90m	Press = 120m	Press = 150m

The thickness of the pipe determines its class and the pressure it can bear. Thick classes (D&E) have thick walls and can bear greater pressures than classes (B&C) but have smaller bore

KENYA STANDARD

SPECIFICATION FOR uPVC PIPES FOR COLD-WATER SERVICES

SCOPE AND FIELD OF APPLICATION

This part of this Kenya standard specifies nominal outside diameters calculated wall thickness and nominal pressure of circular section un-plasticized polyvinyl chloride (uPVC) pipes used for water services

It is intended to serve as a guide to manufacturers and users and as a basic for KS 06-149; part 1

OUTSIDE DIAMETER AND WALL THICKNESS

Pipes shall have outside diameters within one of the given ranges of outside diameter and calculated wall thickness given in table below.

DIMENSION OF UPVC WATER PRESSURE PIPES – METRIC SERIES

Nominal out side diameter mm	Outside diameter mm		Wall thickness mm							
			Red Class B P= 0.60 Mpa 6bars		Blue Class C P=0.90 Mpa 9 bars		Green Class D P=1.2 Mpa 12 bars		Brown Class E P= 1.5 Mpa 15 bars	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
20	20.0	20.3	-	-	-	-	1.40	1.80	1.40	1.80
25	25.0	25.3	-	-	-	-	1.40	1.80	1.60	2.00
32	32.0	32.0	-	-	1.40	1.80	1.70	2.10	2.10	2.60
40	40.0	40.3	-	-	1.60	2.00	2.10	2.60	2.60	3.10
50	50.0	50.3	1.40	1.80	2.00	2.40	2.60	3.10	3.20	3.80
63	63.0	63.3	1.70	2.10	2.50	3.00	3.30	3.90	4.10	4.80
75	75.0	75.3	2.00	2.40	3.00	3.50	3.90	4.50	4.80	5.50
90	90.0	90.3	2.40	2.90	3.60	4.20	4.70	5.40	5.80	6.60
110	110.0	110.4	3.00	3.50	4.40	5.10	5.80	6.40	7.10	8.00
125	125.0	125.4	3.40	4.00	5.00	5.70	6.50	7.40	8.00	9.00
140	140.0	140.4	3.80	4.40	5.50	6.30	7.30	8.30	9.00	10.30
160	160.0	160.5	4.30	5.00	6.30	7.20	8.30	9.40	10.30	11.60
200	200.0	200.6	4.80	5.50	7.10	8.00	9.40	10.60	11.60	13.00
225	225.0	225.7	5.40	6.20	8.00	9.00	10.50	11.80	13.00	14.50
250	250.0	250.8	6.00	6.80	8.90	10.00	11.70	13.10	14.40	16.00
280	280.0	280.9	6.70	7.60	9.90	11.10	13.10	14.70	16.20	18.10
315	315.0	316.0	7.60	8.60	11.20	12.60	14.70	16.40	18.20	20.20
355	355.0	356.1	8.50	9.60	12.60	14.10	16.60	18.50	20.50	22.80
400	400.0	401.2	9.60	10.80	14.20	15.90	18.70	20.80	23.10	25.70
450	450.0	451.4	10.80	12.10	16.00	17.80	21.00	23.30	26.00	28.80
500	500.0	501.7	12.00	13.40	17.70	19.70	23.40	26.00	28.90	32.00
560	560.0	561.9	13.40	15.00	19.90	22.10	26.20	29.00	32.30	35.80
630	630.0	632.0	15.10	16.90	22.30	24.80	29.40	32.60	36.40	40.30

NOTE: Design stress (σ) values are used as follows:

i. σ = 11 Mpa for d = 160mm
ii. σ = 12.3 Mpa for d = 200mm

Where d = minimum outside diameter

Advantages of PVC Pipes

- The pipes are lighter and easier to transport
- They are corrosion resistant
- They have low thermal conductivity
- They have low hydraulic resistance
- Good electric insulator
- Cheap in price compared to G.I pipes
- Easy to work with
- Are flexible
- Connecting sockets easily made in the field

Disadvantages of PVC Pipes

- They are brittle and cracks easily when exposed to sunlight
- They can be damaged by vibration and heavy weight of vehicles
- They are not rigid enough to be suspended across a stream/valley

Handling of PVC Pipes

Although these pipes are lighter and easy to work with, caution must be taken during transportation and storage

During Transportation

- Overhang of pipes should not be more than 0.6m
- Piling up should not exceed 1.5m high
- To avoid sagging support should be provided at an interval of not more than 1.2m spacing
- During loading and offloading care should be taken to avoid scratching of pipes
- Smaller pipes should be placed inside the bigger pipes
- Cover the pipes with sunlight excluding material

During storage

- Pipes must not be exposed (directly) to sunlight
- Pipes should be stored in stacks which should not exceed 1.5m high piling
- Ground on which the pipes will be stored should be flat and free from sharp objects and stones
- Pipes should be laid in a way that the sockets and the spigots alternate

3) POLYETHYLENE (PE) PIPES

These pipes are manufactured in three categories: -
Heavy density PEH- for high pressures
Medium density PEM- for medium pressures
Low density PEL- for low pressures
They are usually supplied in lengths of 100m
PE pipes are becoming popular day by day.

Advantages of PE pipes

- The similar advantages as uPVC pipes
- Smaller diameters are supplied in lengths of 100m, hence fewer joints
- They may be jointed through welding
- The are less expensive than uPVC
- The are of less weight than uPVC
- More flexible than uPVC
- Not affected by sunlight as uPVC

Disadvantages of PE Pipes

- They can be damaged by vibration and heavy weight of vehicles
- They are not rigid enough to be suspended across a stream/valley
- The PE fittings are less available and are relatively expensive than uPVC fittings
- Expand more than uPVC when subjected to high temperature

4) POLYPROPYLENE (PPR) PIPES

Presently PP-R pipes & fittings are most reliable in plumbing and water supply plants, due to their chemical features and fusion welding, which ensures the plumbing to have a perfect seal tight system.

Approved by the Health Organization, Eco-Friendly Quality, Temperature Resistance Quality etc, puts PP-R pipes & fittings as the best selection.

Pipe & Fitting Networks for:

- Cold & Hot installations, i.e. in Residences, Complexes, Apartments, Offices, Hospitals, Hotels, Schools etc.
- Industrial, i.e. transportation of corrosive fluids (like acids) and liquid foods etc.
- Agriculture and Horticulture.
- Compressed air plants.
- Swimming pools
- Rain Water harvesting and utilization systems.

The Salient Features:

- Extremely long life, 50 yr, service life
- Leak proof & Frost proof.
- Non-delayed & non-deforming
- Temperature resistance (800 C)
- Heat preservation and energy saving.
- No calcification.
- Unique and un-rivaled jointing technique with lifetime security.
- Low lying time & cost.
- Convenient & reliable installation.
- Good chemical resistance
- No reaction with salts & acids.
- Taste & odour-neutral.
- Eco-friendly-recyclable.

5) JOINTING OF PIPES

Jointing of pipes may be effected by pipe fittings or pipes may be moulded with spigot and socket ends to facilitate the jointing

G.I pipes have a big variety of fittings, used variably in;

- Jointing of pipes and valves
- Changing of direction
- Adapting of different pipes materials
- Connecting to tanks, etc

A variety of uPVC & PE fittings are also available nowadays. Some uPVC pipe fittings (eg sockets of small diameter pipes) are easily made in the field while PE pipes may be jointed by welding

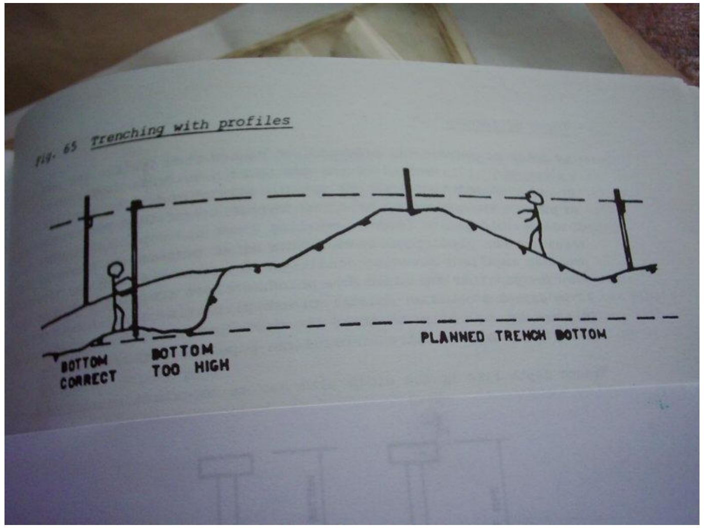
6) PLANNING FOR PIPE-LAYING

(i) Feasibility study:

Determine the pipe route as per demand requirements; usually pipeline will follow streets, farm boundaries, public paths, etc. Where possible the pipeline should be aligned to follow the shortest route

(ii) Survey work

Determines the pipeline length, the actual layout of the route plan and the levels along the pipeline. From survey work, working drawings are made and design & specifications of the water supply components established; that is, types, sizes & classes of pipes, appurtenances & pipe fittings, trench width & depth are known



Surveying and trench alignment

TRENCHING, PIPE LAYING & BACKFILLING

(i) Trenching

From working drawings and specifications, pipe route may be set on the ground by placing pegs along the pipe route at some intervals.
Trenching then commences. Trenching ensure that the pipeline is buried & covered by granular earth material. Covering of pipes, particularly plastic pipes are necessary to protect them from sunlight & possible mechanical damages as well as avoiding obstructions on the surface.

(ii) Width of trench

The width of the trench generally depends on:

- Diameter of pipes
- Soil type and conditions
- Allowance for working space
- Cost consideration

The recommended economical width of trench at pipe level is at least 600mm (2feet)
The trench has to be wider at bend than along a straight line, to allow the pipe jointing at the bend

(iii) Depth of trench

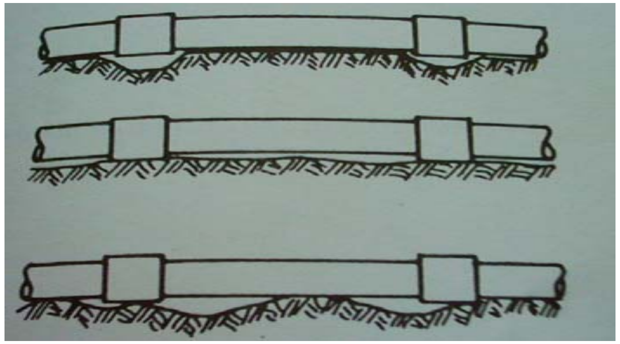
The recommended depth for pressure pipelines in different situations are:

- Though bush - 1000mm (min 600mm)
- Along roads - 1000mm
- Underneath roads - 1500mm

Put warning signs when trenching along road

(iv) Pipe laying

The pipe should be laid on firm ground or foundation in order to prevent uneven settlement, which may damage pipe joints. In rocky soils, rocks and stones should be cleared away from the bottom of the trenches for 150mm beyond pipes and should be replaced by plain earth, sand, fine gravel or concrete.
Just before lowering pipes into the trench the pipes should be inspected for any damages or other discontinuities of external protection of all pipes.
When laying pipes, assurance should be made that an individual pipe is supported over its entire length

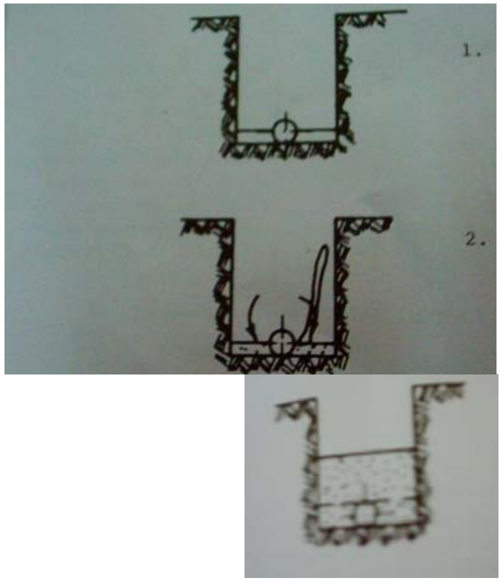


***Correct** the pipe is supported over its entire* length

***wrong** -the pipe is supported on two or few points only. Statically it acts like a beam. When backfilled the whole weight of the cover rests on the pipe, which may cause it to fracture in due course*

(v) Backfilling

Backfilling onto pipe requires as much care as preparing the trench. The material must be soft and must not contain lumps f rock or large stones. Once the pipe has been covered with 200mm of suitable material bulk filling of the remaining trench can be permitted Couplings or socket are normally left exposed until the line has been tested. After testing, the initial backfilling around the couplings should proceed until each coupling has been covered by at least 300mm of well selected material



Place soil p to ½ external diameter

Tamp soil under pipes and between pipeline and trench wall at both sides

3. Backfill by hand until 200mm over pipe. Tamp each 100mm layer

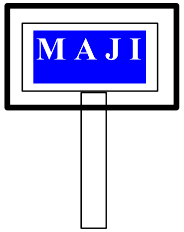
4. backfilling of the remaining trench

(vi) Marker posts

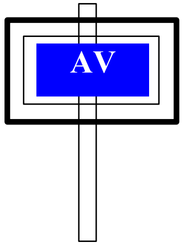
Markers posts are structures erected along the pipeline to indicate the location of the pipeline or/and pipe appurtenances. The are made of reinforced pre-cast concrete slab, 100x100x50mm and about 1000mm above ground level. Common markers posts are:

- MAJI = indicate water pipeline
- SV = indicate the location of sectional valve
- FH = indicate the location of fire hydrant
- AV = indicate the location of air valve
- WO = indicate the location of washout

Markers posts are very important to O&M team, they improve on efficiency and reduce time spent executing an O&M operation



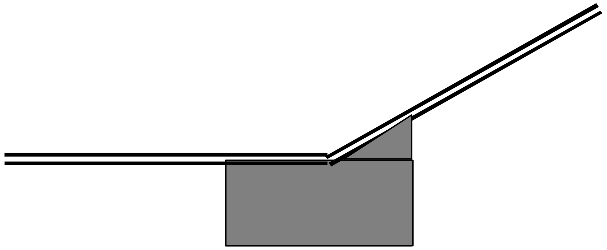
Markers post along a water pipeline



Markers post indicating the location of air valve on pipeline

(vii) Thrust blocks and anchoring

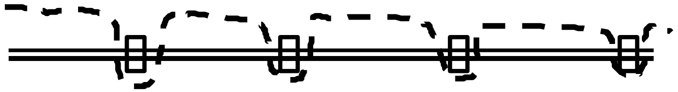
Thrust blocks are usually concrete structures used secure pipeline firmly on the ground. They are applicable at; bends, tees, valves, tapers and at branch take-off.
The size of the thrust block has to be decided on according to the external forces occurring during testing of the pipeline (at about 1.5x working pressure



Concrete anchor block

(viii) Pressure test of the pipeline

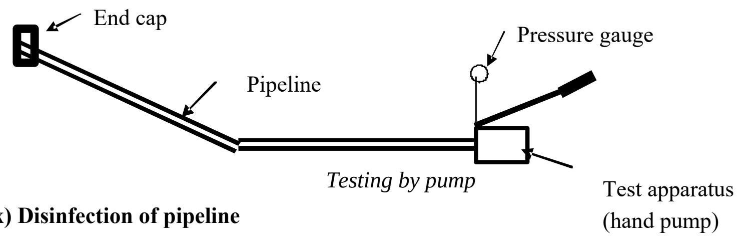
It is very important to test the pipeline before the trench is backfilled to discover in time leaks and damages on the pipes (e. g. cracks). After laying the pipes, the initial backfilling should be done as soon as possible



Initial backfilling for pressure testing

The initial backfilling prevents a movement of the pipe during the testing and protects the pipe from falling stones, trees etc.
Before the test can started, all changes of direction and slopes must be secured by thrust blocks & anchors.

Where lines cannot be tested under pressure in a single operation, they shall be tested in sections.
The test should be 20% to 50% of the working pressure of the pipeline



Testing by pump

(ix) Disinfection of pipeline

Disinfection of pipeline after installation (and a major repair work) is necessary to ensure germs free water supply. Disinfection may be facilitated by flashing with a concentrated (10%) solution of a hypochlorite compound, followed by flashing to waste with water.

7) JOINTING OF PIPES

(i) Jointing GI pipes:

GI pipes are usually jointed through threaded spigot ends. Otherwise, jointing may also be made by coupling on plain spigot ends.

(a) THREADING

Pipes are supplied with their both ends threaded. However, where cutting of pipe is necessary, the pipe must be threaded to facilitate jointing.
Threading procedure is as follows:

- Cut the pipe using hacksaw or wheel pipe cutter; the pipe must be held firmly when cutting
- File off the outside burrs and use a tapered pipe reamer to remove the insider burrs
- Taper the pipe end
- Thread the pipe ends using die stock

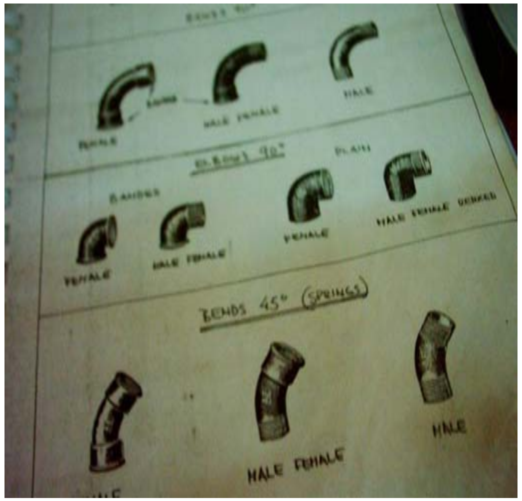
Adjustable diestock

(b) GI FITTINGS

A variety of GI fittings exist,

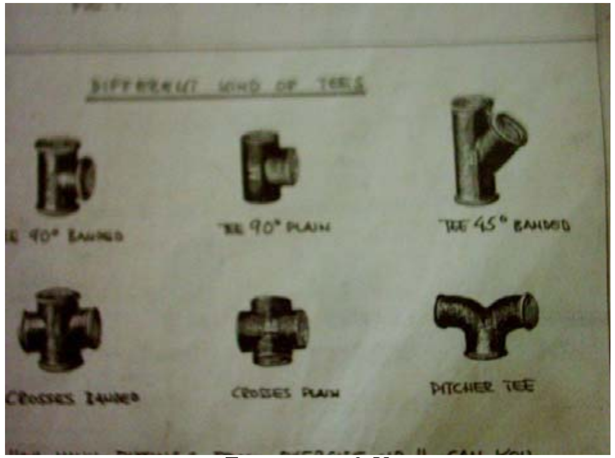
- ***Bends and elbows***

Used when changing direction either 90°, 45° or 22$^1/_2$°. You can of course bend the pipe if you have tools to do so, but the most common approach is to use fittings. Fittings are normally available in sizes up to 100mm (4in), and on special order up to 150mm.

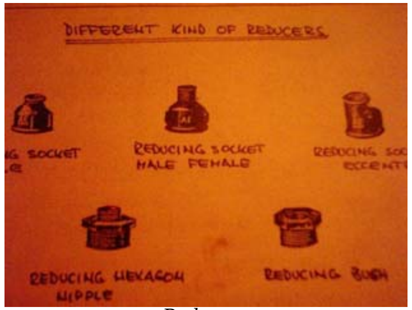


Bends & elbows of various angles

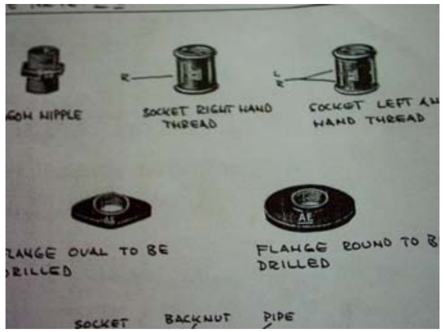
- ***Tees***



Tees, crosses & Ys



Reducers



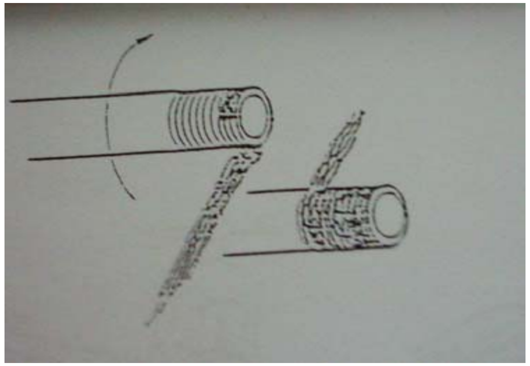
Sockets/ flanges

Plugs and caps

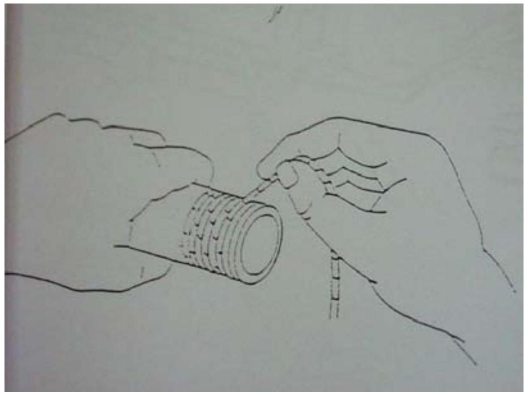
(c) PIPE JOINTING & JOINTING MATERIALS

To facilitate a water tight joints, the following materials are used on threaded joints

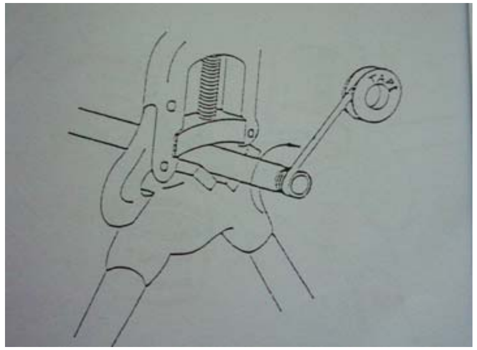
- Hemp – fibrous materials rubbed on the treaded spigot end
- Bosswhite – semi-solid material used together with hemp
- Thread tape – used in place of hemp on small diameter pipes



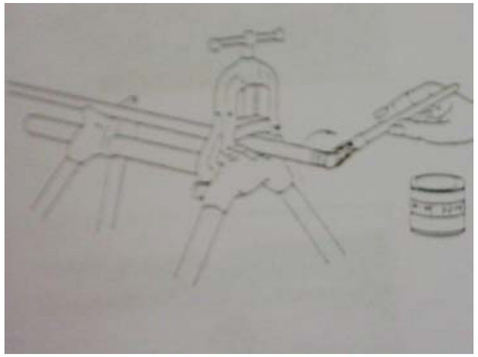
When winding hemp around the threads, the hemp must be frayed open and wrapped around direction of the threads until the thread is fully with hemp.



Note: Wind the hemp, string or other sealing material in the same direction as male threads.

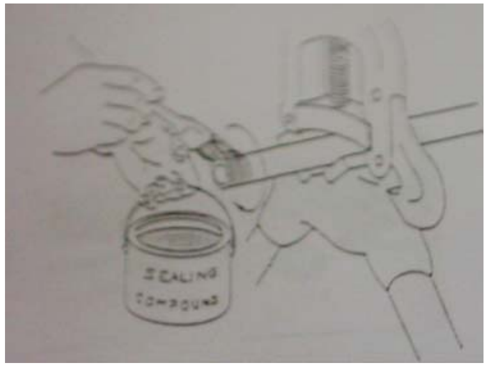


If using sealing tape, unroll a sufficient length of the tape and wrap it around the male thread and in the same direction as male threads.
Note: When sealing tape is used don't apply jointing compound to the joints.



Apply the joint sealing compound to the male thread after the hemp is wound on.

Note:
Use only approved sealing or jointing compounds.



The sealing or jointing compounds must also be applied in the same direction as the male thread

(ii) Jointing uPVC pipes

uPVC pipes have spigot and socket ends to facilitate jointing. Small diameter pipes (up to 60mm), have plain socket end, and are jointed by use of solvent cement, while bigger sizes have rubbered socket ends.

Where uPVC pipe pieces are used, jointing may be facilitated use of pipe sockets, which, for small diameter pipes may be made on site.

(a) uPVC FITTINGS

A variety of uPVC fittings do exist. They are made from heavy classes (classes D&E) and are generally expensive. Some uPVC fittings in the market are;

- Bends
- Rubbered sockets
- Threaded & flanged adaptors
- Caps

(b) JOINTING MATERIALS

To facilitate a water tight joints, the following materials are used on un-rubbered socket & spigot ends

- Cleaning fluid – to remove oils and dirt on pipe surfaces
- Solvent cement – thick liquid used to weld pipe ends together

To facilitate a water tight joints, the following materials are used on rubbered socket ends

- Cleaning fluid – to remove oils and dirt on pipe surfaces
- lubricant– thick liquid used to lubricate pipe ends

(iii) Jointing PE pipes

PE pipes are manufactured without socket ends. Small diameter pipes (up to 50mm), are supplies in 100m length, and hence have few joints,
Where PE pipe pieces are used, jointing may be facilitated by use of pipe sockets.

PE FITTINGS

A variety of PE fittings do exist. Some PE fittings in the market are;

- Bends
- Coupling/sockets
- Tees & crosses couplings
- Caps

(iv) Jointing other pipes

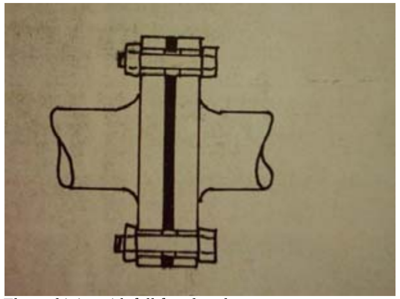
Asbestos cement (AC) pipes are supplied with spigot and rubbered socket ends. Special fittings are available for jointing AC pipe pieces. In most cases, the spigot ends of AC pipes require to be trimmed to facilitate jointing.
It is common practice to use VJ coupling for jointing AC pipe pieces
A variety of AC fittings do exist, they includes;

- Bends
- Rubbered sockets
- Caps

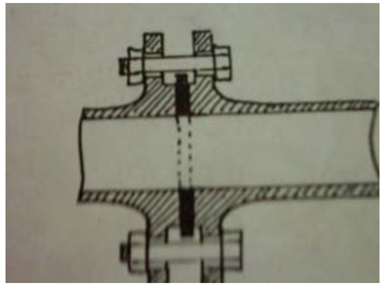
(iv) Other fittings used for jointing pipes

i. FLANGED JOINTS

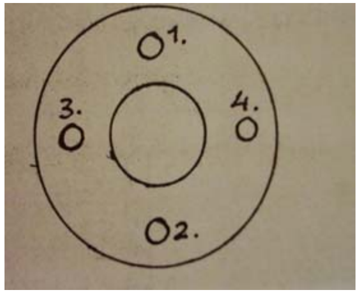
Flanged joint is a rigid joint
It is sealed by compressing a flat gasket
Bolts, nuts and washers are used

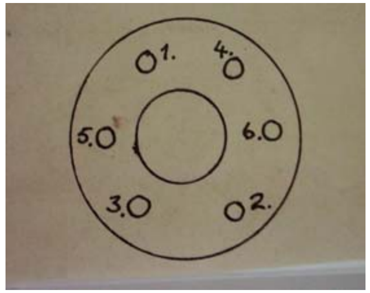


Flanged joint with full faced gasket



Inside bolt circle type





When fitting the bolts, screw them first by hand and tighten them using an open end or adjustable spanner. The bots should be tightened in the order shown

ii. COUPLINGS

Couplings joint pipes & fittings together and uses rubber-rings to ensure water-tight on the pipe joints

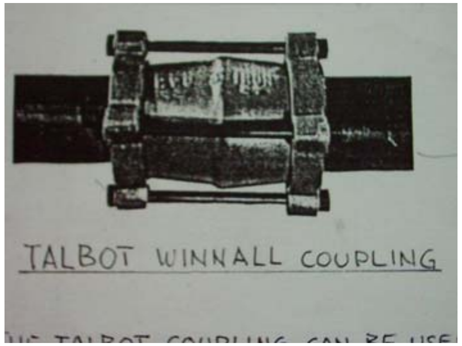
VIKING JOHNSON (VJ) COUPLING

This is used to joint the same pipe material
It is made from Cast Iron/mild steel

VJ –
Coupling

TALBOT WINNALL COUPLING
This may be used on almost all pipes steel, cast iron PVC & AC
It is made from Cast Iron/mild steel

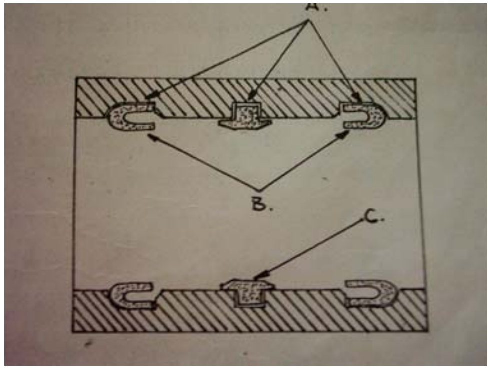
Talbot
coupling



KALTITE JOINT

This is used to joint A.C to A.C pipes
Consist of one Ac sleeve with three internal grooves, A,B, &C

Kaltite
joint



CLASS EXERCISES

1) List the main components of a water supply system

2) What are the common types pipes used in Kenya?

3) What are the advantages of PVC pipes over GI pipes

4) List the common GI fittings

5) How is pressure testing done on service line after installation

FIELD EXERCISES

1) Tapping water from main
   - Under pressure taping
   - Use of saddle clamp
   - Use of tees
2) Cutting, trimming & threading of GI pipes
   - Small pipes
   - Large pipes
3) Jointing of GI pipes
   - Using sockets
   - Using VJ coupling & others
4) Laying GI pipes
   - Trench alignment
   - Pipeline alignment

5) Cutting & jointing uPVC pipes
   - Small pipes – use solvent cement; making of sockets
   - Large pipes – use of rubber joints
   - Use of VJ coupling
6) Cutting & jointing of PE pipes
   - Use of PE fitting
   - Welding of PE pipes
7) Cutting & jointing of AC pipes
   - Trimming of AC pipes
   - Use of couplings
8) Installation & servicing of appurtenances
   - Installation, servicing & repair of air valves
   - Installation, servicing & repair of washouts
   - Installation, servicing & repair of fire hydrants
   - Installation, servicing & repair of non-return valves
   - Installation, servicing & repair of sluice & gate valves
   - Installation, servicing & repair of taps

9) Installation of a service line

INSTALLATION, SERVICING & REPAIR OF APPURTENANCES
DEFINITION OF APPURTENANCES

Appurtenances are valves and fittings used in controlling water supply system. Specific examples are: -

- Sluice valves
- Gate valves
- Air valves
- Non return valves
- Ball valves
- Taps

The purpose of this module is to enable the caretaker/community to install, operate and maintain the above – mentioned appurtenances for smooth running of the water supply system.

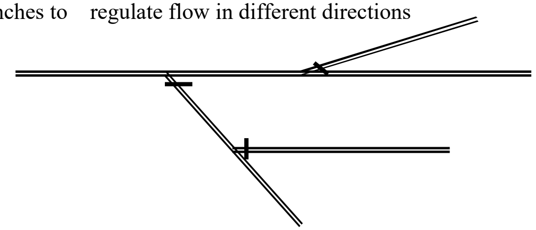
Some of the appurtenances used in water reticulation system

ITEM	APPURTENANCE	USES	USUAL LOCATION
1.	Sluice and gate valve (S.V)	- Control discharges in water system - Open and close flows	- At junctions of pipes - At storage tank outlets - At washouts - At air valves etc
2.	Butterfly valves	- Control discharges in water supply system - Open and closes flows	Mostly pumping station reservoir and treatment plant.
3	Ball or float valve	Control discharges of water entering a storage	At inlet to storage
4.	Non return valve (NRV)	Maintain flow in one direction	- At suction ends as foot valve - On the delivery end of pumping unit - Other places where flow is restricted to one direction.
5.	Air valves (A.V)	- Release air out of pipe network - Inlets air into pipe network	At high spots of pipe network
6.	Washout arrangements with sluice or gate valve	- To wash or deposits in water supply network	- At depressions of pipe network - At storage tanks
7.	Fire hydrant	- For fire fighting in urban areas	- At strategic points in urban area and on major main lines along streets
8.	Strainer	Strains out solid particles	- Before meters

SLUICE VALVES & GATE VALVES

1) Functions & locations of sluice & gate valves

Sluice and gate valves are used for controlling water in pipeline. They may used to open and shut off flow or just to throttle the flow. They are most applied in the distribution system at branches to regulate flow in different directions



Location of sluice & gate valves in the distribution system

Sluice and gate valves are also located storage tank's outlet and scour pipes

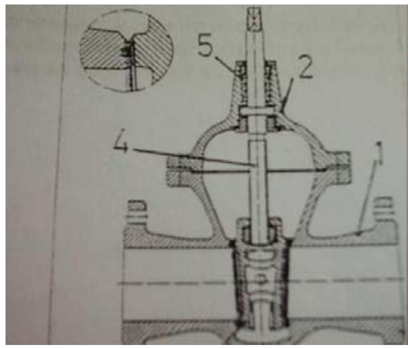
2) Make & types of sluice valves

The terms sluice & gate are exchangeable, but sluices valves are many times used to refer large diameter (>50mm) valves with flanged connections, and usually made from cast or ductile iron Gate valves are usually small (<50mm, but sizes up to 150mm are available) and are made of brass.

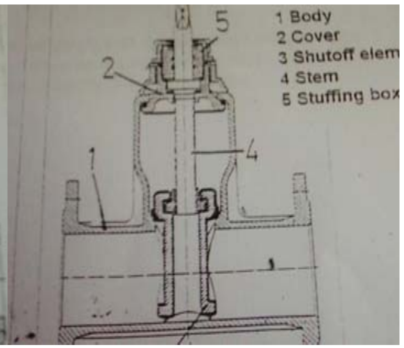
Sluice valve

Gate valves

3)Components of sluices

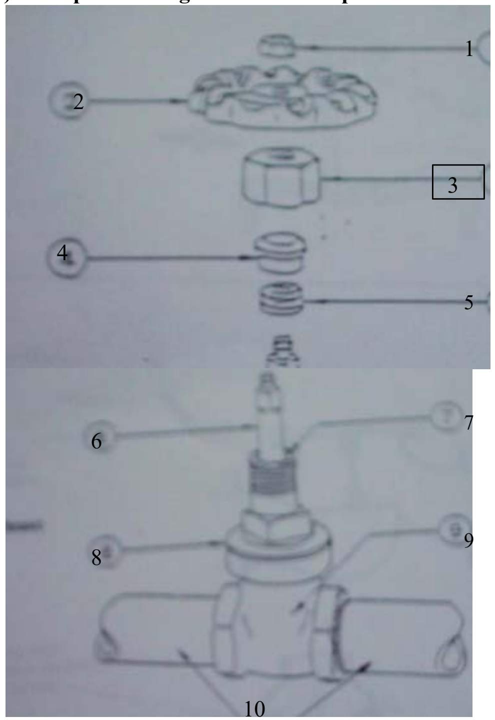


Wedge shaped gate



Soft sealing gate

3) Components of gate valves & stop cocks



1. hand-wheel nut
2. hand-wheel
3. Grand nut
4. Stuffing gland
5. Packing
6. shaft or spindle
7. Stuffing box
8. Bonnet
9. Gate valve body (brass)
10. GI pipe/valve socket.

Gate valves & stop cock are from ½'' to 6''

4) Maintenance problems of sluice & gate valves & their remedy

Problem	Causes	Remedies
Damage on the spindle	Due to long lasting leak at the gland packing	Replacement of spindle
Broken shutter	Due to overloading at the spindle by heavy objects	Replacement of shutter
Corrosion on body and shutter	Poor water quality & age of valve	▪ Open valve completely where possible ▪ Wash your system regularly ▪ Sedimentation on metal seal can be removed by operating the shutter
Erosion on body and shutter	By not opening the shutter fully	
Deposit of sediment	Suspended matter in water May cause damage to water meters	
Broken /non functioning shutter nuts	Wrong operation – of left hand spindle or due to excessive tightening of the spindle	Left hand operation need to be properly labeled indicate the direction of the operation so as to avoid breaking the nuts

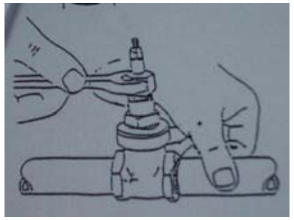
5) Repair and Maintenance of sluice valves

Repair of sluice valves	*Routine maintenance of sluice valves*
1) When the body is dismantled it has to be marked in order to place the same position as before dismantling *2) Keep all parts clean when assembling; most valves are broken due to the tendency the seat before reassembling* *3) Tighten evenly the bolts and nuts*	*Maintenance depends on type, age, use, & location of valves; On average it is recommended that inspection be done every 3-5 years and the following be checked* - *Accessibility of the valve* - *Correct sign/mark at the valve location* - *Water tightness – from leaks* - *Completeness of the valve* - *Valve set according to the operation instruction* - *Functionability of all parts* - *Obstruction to traffic* - *Completeness of the valve chamber* - *Soil movement and erosion* - *Location as per the block map*

Repair and Maintenance of gate valves

Close the gate valve by turning the hand wheel clockwise. This will keep firm the pipeline for valve to be repaired
Undo the nut above the hand wheel with small spanner and lift off the wheel

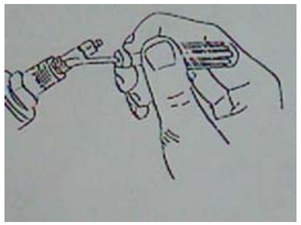
Remove the gland nut from the bonnet by turning it clockwise with spanner



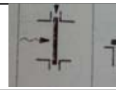
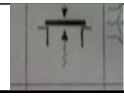
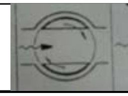
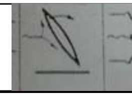
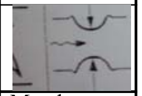
Lift off the staffing gland. If it is too tight press it out of the box with a small screwdriver

Using the same screwdriver clean the old packing in the stuffing box

Coil the new packing round the shaft or spindle and push it down with a small screwdriver



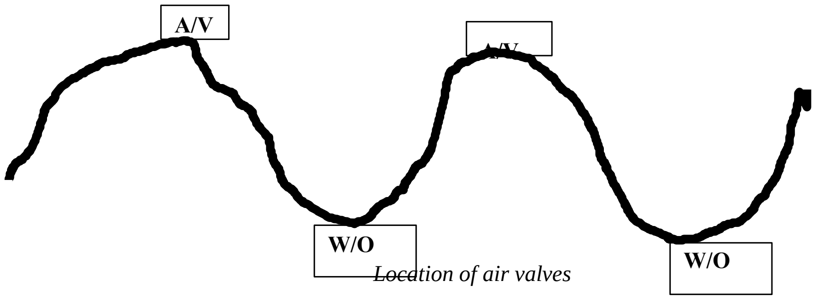
6) **Basic design of valves**

Type of closer devise	***Rigid***				***flexible***
Operational movement of the closer devise	Rectilinear		Rotational around axis Lateral to flow		According to type
Direction of flow	Lateral to movement	In the direction of the movement	Through the closed devise	Around the closed devise	According to type
Schematic representation					
Basic construction types	Gate valve	Globe valve	Cock valve	Butterfly valve	Membrane valve

AIR VALVES

1) Functions & locations of air valves

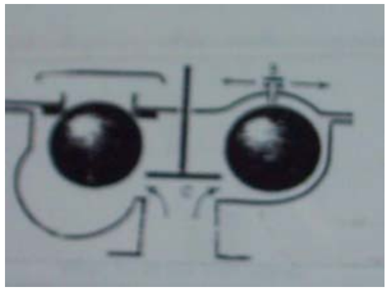
Air valves are located on high spots along a pipeline



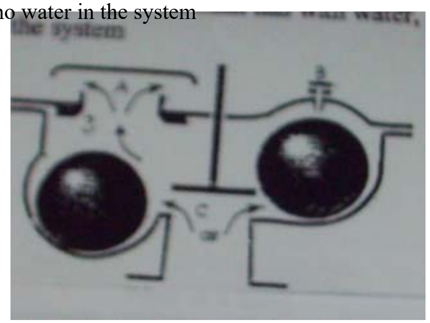
Location of air valves

Air valves have the following functions:

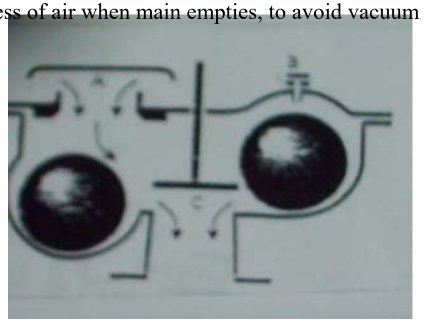
- Permanent degassing of the system during normal operation



- Automatic air venting as the main fills with water, say following a period of no water in the system



- Rapid ingress of air when main empties, to avoid vacuum conditions



2) **Make & types of air valve**

Air valves are made of cast iron or ductile iron. Plastic air valves are also available today.
Air valves are classed according to their sizes. Large air valves are fitted on to large pipelines, while small air valves are fitted onto small pipelines. Small air valves have single orifice while large air valve have double orifice

3) **Maintenance of air valves**

Maintenance depends on type, age, use, & location of valves; On average it is recommended that inspection be done every 3-5 years and the following be checked

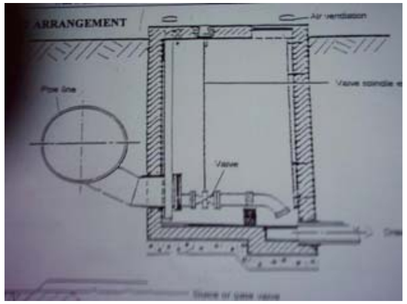
- *Accessibility of the valve*
- *Correct sign/mark at the valve location*
- *Water tightness – from leaks*
- *Completeness of the valve*
- *Valve set according to the operation instruction*
- *Functionality of all parts*
- *Obstruction to traffic*
- *Completeness of the valve chamber*
- *Soil movement and erosion*
- *Location as per the block map*

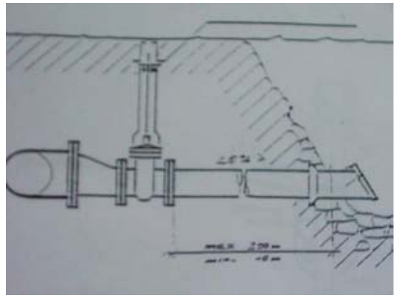
WASHOUTS

1) Functions & locations of washouts

Washouts are located on low/depressed spots along a pipeline (see clause 3.4 above), and as scour valves for storage reservoirs. They remove settled sediments from these low/depressed areas.

2) Washout arrangements





The arrangement should be as short as possible
The arrangement should be as low as possible in order to clear most of the settled materials
The spout should be as near as possible to notice when the cleaning process is over by looking at the clean water coming out.

3) Maintenance of washouts

Maintenance depends on type, age, use, & location of valves; On average it is recommended that inspection be done every 3-5 years and the following be checked

- *Accessibility of the valve*
- *Correct sign/mark at the valve location*
- *Water tightness – from leaks*
- *Completeness of the valve*
- *Valve set according to the operation instruction*
- *Functionality of all parts*
- *Obstruction to traffic*
- *Completeness of the valve chamber*
- *Soil movement and erosion*
- *Location as per the block map*

Washouts are operated according to worked out time schedule

FIRE HYDRANTS

1) Functions & locations of fire-hydrants

Fire hydrants are located at strategic places in water distribution systems. They are more concentrated in the highly valued districts in urban areas. They are for fire fighting and emergency uses.

2) Make & types of fire-hydrants

Hydrants are made from cast iron or ductile iron

Fire hydrant

3) Maintenance of fire-hydrants

Maintenance depends on type, age, use, & location of valves; On average it is recommended that inspection be done every 3-5 years and the following be checked

- *Accessibility of the valve*
- *Correct sign/mark at the valve location*
- *Water tightness – from leaks*
- *Completeness of the valve*
- *Valve set according to the operation instruction*
- *Functionality of all parts*
- *Obstruction to traffic*
- *Completeness of the valve chamber*
- *Soil movement and erosion*
- Location as per the block map

NON- RETURN VALVES

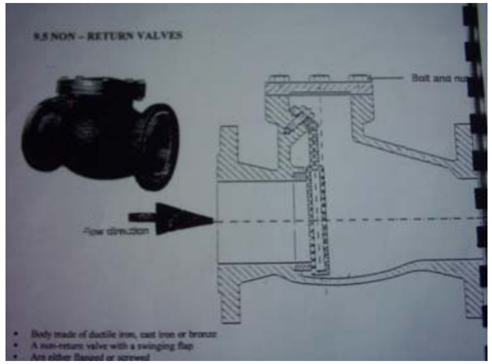
1) Functions & locations of non-return valves

Non-return valve only allows water in one direction. They may be used at:

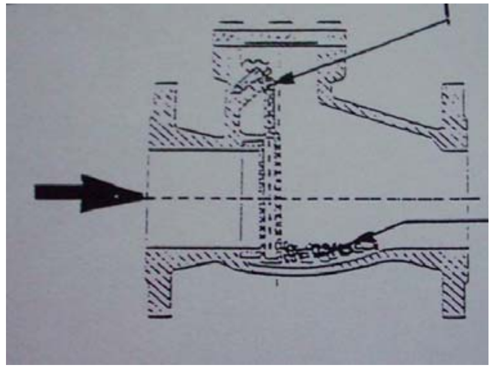
- At pumping station so as to retain water in the delivery pipe
- As a foot valve in a pumping system
- As integral part of other fitting where back flow is not desirable

2) Make & types of non-return valves

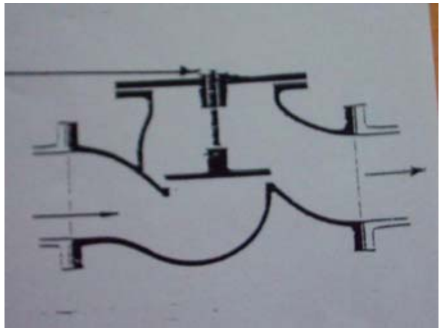
Non return valve may be made from cast iron, ductile iron or bronze
It has a swinging flap and are either flanged or screwed. It is important that the valve is installed correctly with the direction of flow as indicated on the body of the valve



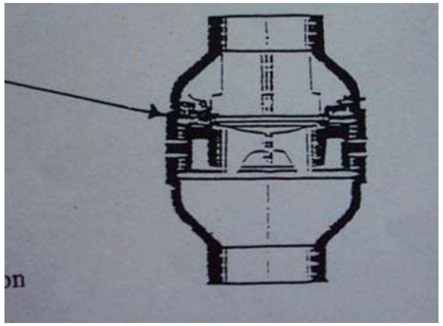
If the swing pin has rust or corrosion the flap will not close when in the open position
When the valve stay for too long without operating, the silt deposit will settle at the lower part and the flap will not open or if in open position will not close



If the valve is left without operating for long time the jumper pin will rust or will stick and will not lift up



If the valve is left for long time in operation the silt will block the jumper from either opening or closing



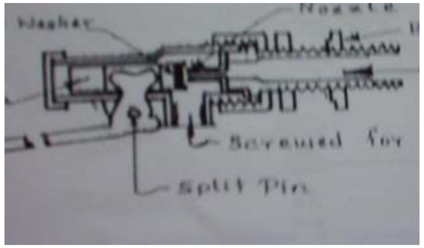
FLOAT/BALL VALVE

1) Functions & locations of ball valve

Float valves or ball valves are used to automatically close or open the flow into storage. Float valves are therefore placed at entrance of storage reservoirs.

Make & types of ball valve

Ball valves are made of brass body, with a plastic ball



STRAINERS

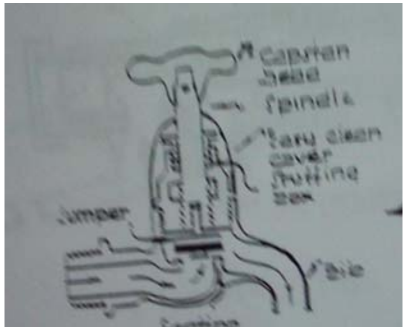
1) Functions & locations of strainers

Strainers prevents/ safe guards the clogging of meters, particularly master meters

2) Make & types of strainers

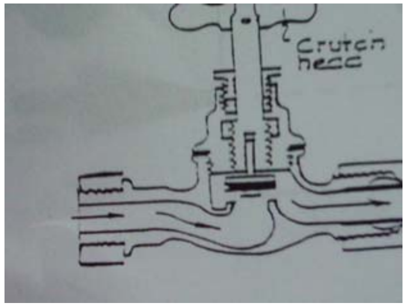
Strainer

OTHER APPURTENANCES



BIP TAP

PILLAR TAP



STOP COCK

Internal Information

TEXTBOOK

FOR JOINT TRAINING

（DRAFT）

"INTRODUCTION TO REHABILITAION PLAN OF PIPING NETWORK"

May, 2019

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs

(EMBU WATER AND SANITATION COMPANY AND MERU WATER AND SEWERAGE SERVICES)

Mr. W. Moseti / Mr. Kande ＃20

Assisted by JICA KENYA

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Original Edition May, 2019

Table of Contents

1. Objectives (Out-put)

① Understand the concept of rehabilitation plan of piping network,

② Understand the components on it,

③ Understand XXXXXXXX.

④ Understand XXXXXXX

2. Introduction

In order to implement NRW reduction effectively, it is important to formulate and implement a renewal plan.

In addition, the PDCA cycle of formulation/evaluation of the improvement plan of NRW reduction is shown in **Figure-1.**

As part of NRW reduction measures, partial temporary repair of old pipes / leakage pipes will soon cause leakage in other places, and leakage prevention cannot be implemented effectively.

Ideally, while conducting a water leakage survey (determination of the potential water leakage amount) of an aging pipe / water leakage frequent piping network, it will be evaluated by economic effects (cost-effectiveness), and a plan for a priority renewal piping network will be formulated.

◆ **NOTE**

In order to formulate an effective renewal plan, it is essential to maintain both the asset management register and maintenance information of the piping network of the piping network.

In this chapter, the basic knowledge required for NRW reduction planning is shown below.

① What is the management ledgers to be arranged?

② What is the implementation of additional investigations?

③What is the improvement methods of leaking pipeline?

③ What is the cost-effectiveness evaluation?

④ What is the evaluation of managemental indexes?

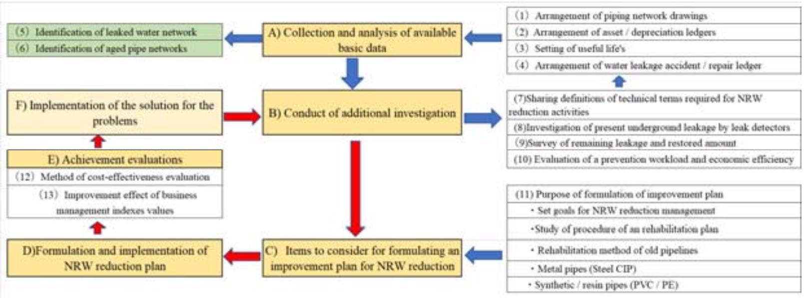


Figure-1 PDCA cycle to formulate effective NRW reduction and improvement plan

3. Key Words Definitions

What is the management ledger to be arranged?	It is an arrangement of basic information to effectively implement the improvement plan. (For example, location information of piping network, ledger of depreciation assets, ledger of leaked places and causes, ledger of repair records and expenses, etc.)
What is the improvement method of leaking pipeline?	Improvement methods include methods such as renewal (laying of new pipes), rehabilitation (reinforcement / improvement), repair / replacement, and change of piping routes.
What is the cost-effectiveness evaluation?	The priority of NRW reduction measures can be determined by comprehensively determining the balance between improvement costs and effects, priority leakage areas, political priorities, etc. Expense is the amount of investment for improvement work. The improvement effect is the expected benefit / benefit effect with the implementation of the improvement work.
What is the evaluation of managemental indexes?	The improvement effect is objectively evaluated by "management index values". Moreover, these indexes are important basic data for judging the directivity of a business project, and being outputted to timely is indispensable. (E.g., pipe renewal rate, water leakage rate / non-revenue water rate, ordinary profit, pipe accident rate, evaluation of commercial loss and physical loss, etc.

4. Collection and Analysis of Available Basic Data

4-1 Necessity for Arrangement of Piping Network Map

Piping network diagrams (including improvement / repair work drawings) from the past to the present managed by many WSPs are not rationally arranged for reasons such as a shortage of management personnel, a shortage of personal computers, and a lack of storage and storage standards.

However, in order to promote efficiency in planning and implementation of NRW reduction, the basic information, for example, drawing of piping network, boundary line of water distribution blocks, position diagram of meters, OM service / asset ledger information, etc., in the past and in present will be developed sequentially so that it can be expressed on a map, and in the future construction of a system that can be collectively managed on a computer is desired.

◆The following is an example of the arrangement procedure for the piping network map.

(1) Step-1 (Transfer the current drawing information to one topographic map)

① Transcription of handwritten / memo drawing information、

② Transcription of piping network of the completion map,

③Transcription of interview survey information from residents / construction personnel,

④ Transcription of survey information by the pipeline detector、

⑤ Describe the unknown piping route with a dotted line for the time being、

⑥ The following is an example of attribute data to be prepared;

For examples to be necessity of Basic data

a) Outline of construction year / construction scale,

b) Boundary / zone of water supply areas,

c) Quality control standards and items for piping installation works,

d) Location information of drinking water treatment facilities and their facilities capacities,

e) Location information of distribution facility and its facility capabilities,

f) Pip information (size / material / thickness / anticorrosion measures)

g) Piping connection/Joint methods,

h) Extension distance of laying pipeline, buried depth, laying position

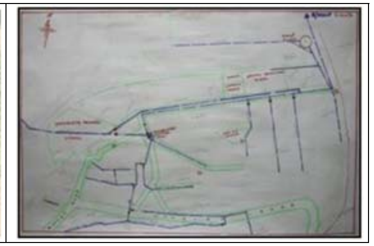
i) Water leak information (Name of location where it occurred, cause, frequency, repair cost, etc.)

j) Information of meter (place installed, registration number, customer name, time of installation work, diameter, model, etc.)

k) Meter reading information (reading obstruction/ error, cause of breakdown water consumption rate etc.)

l) Information on leakage survey results (time implemented, name of location / block, prediction of leakage loss water amount / potential leakage amount, indication of leakage point, cause, etc.)

n) Others (construction pictures, city planning maps, records of natural disasters, sewer network information, etc.)



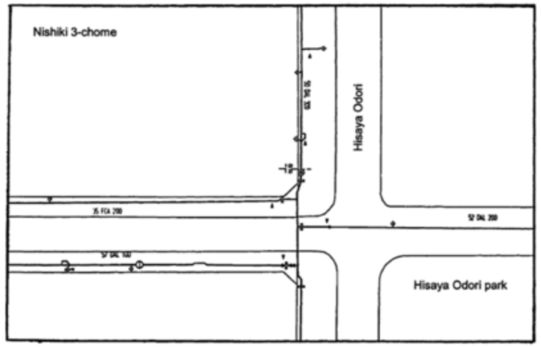
(2) Step-2 (Creation of Mapping on PC) ……**More detail Refer to Textbook-4 (5-3-6)**

① Digitize the basic information of Step-1 and input the digital information to the geographical map on the personal computer、

② Piping network information will be updated constantly、

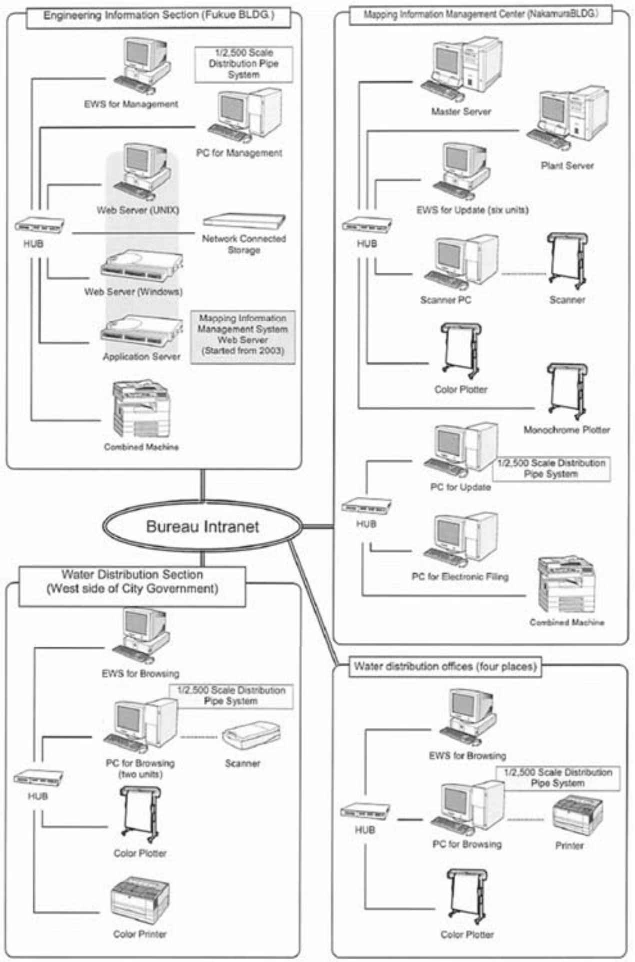
③ Regularly update the topographic map、

④Correct location information of basic information by GPS and/or actual measurement.



Source; JICA Textbook

Figure-2 Concept of Mapping Drawing



Source; JICA Textbook

Figure-3 Concept of Mapping Information Management System

(3) Step-3 (Creation of GIS on PC) ……**More detail: Refer to Textbook 4 (5-3-6)**

① Creating the Digitize the basic information of Step-1to input GIS system

② By combining flow rate information and water pressure information with hydraulic calculation software, the piping network can constantly monitor water pressure management, uniform water volume, leakage occurrence location and NRW rate on

the monitor screen.

③ The following outputs can be implemented in a timely manner.

(For example, water pressure distribution map, flow velocity distribution map, water supply distribution map, forecast map of water shortage area, water pollution prediction map, distribution plan in emergency, formulation of update priority, reporting of management index, etc.)

④ NRW reduction activities can be implemented effectively by displaying complaint information on the topographical map of PC (For example, confirmation of leak notification, confirmation of leak information, confirmation of repair status is easy)

⑤Other information management becomes easy (Sewage pipe network diagram, location information of communication line, fire hydrant information etc.)

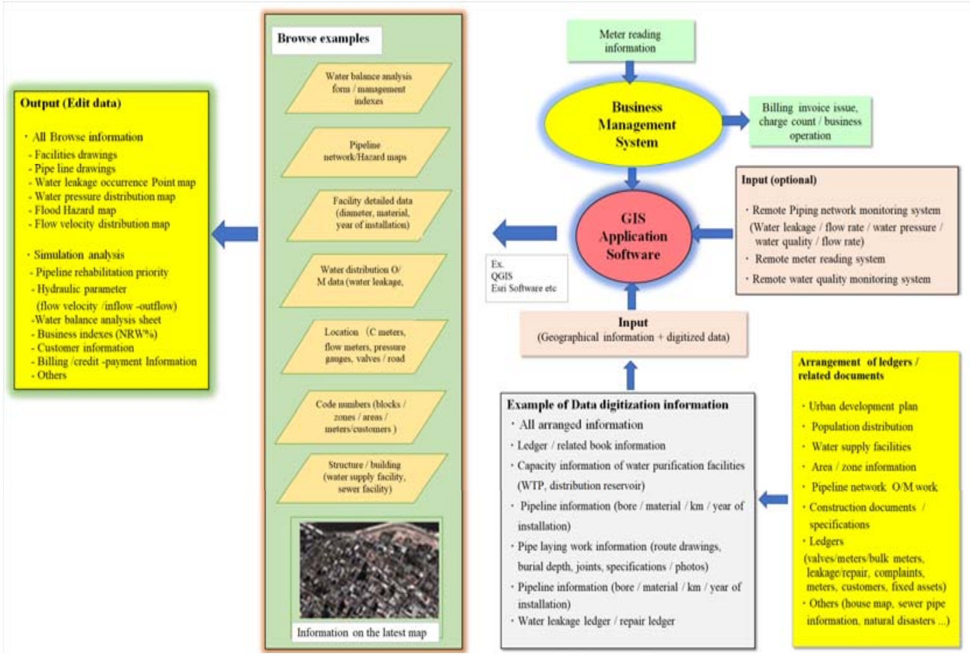
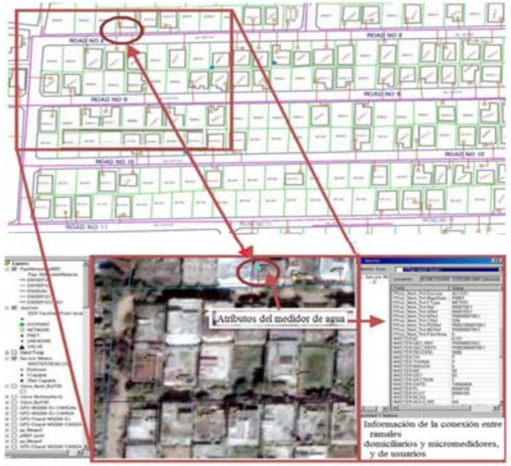


Figure-4 Concept of GIS system



Source; WASREB Manual

Figure-5 Concept of GIS Drawing

NOTE: Points to note in GIS

(1) GIS (Geographic Information Systems) is a system that links letters, numbers and images to maps, reproduces them on a computer, integrates various information from locations and places, analyzes them and expresses them in maps.

(2) As digital information necessary for GIS implementation, it is desirable to request a certification body of ISMS (Information Security Management System) in order to handle internal confidential information including personal information.

(3) In order to output accurate information from GIS, it is said that software renewal / capital investment / human investment amount is necessary for a long time in order to update constantly.

4-2 Arrangement of Fixed Asset Ledger

4-2-1 What is an asset?

Assets are classified into fixed assets (for example land, buildings, machines, facilities, facility usage rights, patent rights), current assets (for example, cash, savings, commodities, raw materials) and carry forward accounts (for example, bonds, expenses recovered by future earnings).

Fixed assets are further classified into tangible fixed assets (for example, Assets with a specific shape), intangible fixed assets (for example, patent right, Software, Goodwill) and investment assets (for example, Interest purpose etc.)

Introduction to Rehabilitation Plan of Piping Network (Draft) 2019 July

In this chapter, among tangible fixed assets, ledger creation of depreciable assets is described as follows.

4-2-2 What is a Fixed Assets Ledger?

In order to early predict the durability / aging of the piping network required to formulate the NRW reduction plan, each WSP needs to quickly create a ledger for the tangible fixed assets of the distribution facilities subject to depreciation according to the useful life.

NOTE:

① A tangible fixed asset means the properties used for a water service business over a long period of time.
(For example, buildings, buildings (water purification equipment, water distribution equipment), machinery / electric equipment (pumps, meters, other machinery, measurement equipment), vehicles, tools, etc.)

② Depreciable tangible fixed assets are tangible fixed assets that decrease in asset value each year of use.
(For example, piping materials, fittings, valves / gates, air valves, bulk meters / customer meters, saddle branches, pumps, water pressure gauges, check valves, surge tanks, water level gauges, middle chlorine injection equipment, automatic water quality monitoring devices, Electricity generation, instrumentation equipment, leak detection equipment / repair equipment / construction heavy equipment / transport vehicles, etc.)

③ For accountability purpose (Internal control)
To know which assets and location and who is responsible for daily administration.

4-2-3 Legal basis of depreciation and lifetime classifications

(1) For Kenyan regulations

(a) International Financial Reporting Standards (IFRS)

For examples;

①Sewer &water system：2.5%

②Motor vehicle：25%

③Furniture, fittings & equipment：12.5%

④Computer equipment：30%

⑤Tools; 33.3%

⑥Office equipment; 13%

⑦Generator;25%

(b) Kenya Revenue Authority (KRA)

Guide on Wear & Tear detection (Depreciation 2019)

For examples;

① Class A--37.50%：Heavy Machine (2.67 years)

② Class-B—30% : Computers & related accession as (3.33 years)

③ Class-C—25% :Saloon cars (Not heavy) :4 years

④ Class—D—12.5%: Furniture (8 years)

⑤ Industrial Building: 2.5 % (40 years)

＊＊ **All on reducing balance method thus No ZERO Witten down value**

(c) Practice manual for Water Supply services 2006 (MIW)

Asset part	Economic lifetime years	Annual maintenance cost in %
Dams	40	0.5
Intake works, including boreholes: Mass concrete structures, such as intakes, underground pits, culverts, etc.	40	1
Earthworks generally	40	1
Boreholes and well	20	1
Pumps:		
Hydrams and hydrostats	15	5
Other pumps	10	5
Power:		

Diesel engines	10	5
Engine and pump sets petrol paraffin	5	5
Electric motors, cables and switch gears	10	5
Piping; all types	30	1
Treatment works;		
Treatment works in masonry of reinforced concrete	30	1
Reservoirs;		
Storage tanks in masonry or reinforced concrete	30	1
Storage tanks, sectionally steel incl. towers	20	2
Storage tanks corrugated galvanized steel (C.G.S) on timber stands	10	2
Building;		
building (C.G.S.) on timber	20	1
Building masonry	30	1
Miscellaneous and items		
Communal water points (CWP)	10	5
Water kiosks, latrines, licensed retailer point etc.	20	2
Gantries, steel works etc.	20	2
Permanent tools and plant not mentioned elsewhere	10	2
Water meters	10	5
Chemical apparatus;		
Chemical dosing gears	10	5
Instruments and testing apparatus	5	5
Roads, fences etc.;		
Roads of access, general	30	1
Fence, G.S. wire or mesh on timber	10	1
Fence, G.S. wire or mesh on concrete posts	20	1

(2) For Japanese regulation (Refer to Tables-8/-9/-10)

(a) Water supply Act/Local Public Enterprise Law Enforcement Regulations (Article 7 / Article 8)

(b) Ministry of Health, Labor and Welfare

(c) Ministry of Finance/National Tax Agency

4-2-4 Purpose of creating fixed asset ledger

The purpose is shown below.

(1) Asset management purpose (determination of the lifetime of existing facilities)

In particular, with regard to NRW reduction, by collecting information on each asset, it is easy to identify the pipe type and quantity / km required when implementing measures to prevent aging (useful life) of existing pipes

In addition, it helps to manage the risk of water leakage caused by insufficient strength / construction failure of existing piping networks, and to improve water supply services.

(2) Accounting purpose

The tangible fixed asset ledger can be used to visualize the basis for calculating the carrying amount of each asset and the depreciation expense, and to confirm whether it has been calculated correctly.

(3) Tax purposes

The tax audit checks the fixed asset ledger and can correctly confirm the basis of depreciation used in tax calculation, wear and tear deduction.

This is a requirement from Kenya Revenue Authority (**KRA**)

NOTE：Points to remember
① Once you have decided on the asset register creation rules, start asset management immediately.
② When updating the ledger, it is necessary to consider the description method so that the process can be checked retrospectively.

4-2-5 Entry example of tangible purchased fixed assets

The following is an example of the items to be included in the ledger, but each WSP needs to determine the items to be focused on.

① Project name and execution number,

② Acquisition method,

(For example, purchase, production, acquisition by exchange, free transfer, acquisition by trade-in, description of rights exchanges etc.),

③ Year of acquisition / asset registration date,

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④ Tangible fixed asset registration number when applicable , e.g. serial number, registration number,

⑤ Purchase price or appraisal price / revaluation price,

⑥ Name, details, and quantity of a tangible fixed asset,

⑦ Asset location,（Installation place and storage place）

⑧ Description of legal service life by facility,

⑨ Clarification of calculation method of depreciation,

a) Description of the date to be depreciated,

b) Depreciation method of depreciation,

(This is the basis for calculating the present value of the fixed asset ledger held by WSP)

c) Description of residual value after the useful life or salvage value,

⑩ Registration number of design document and drawing,

⑪ Asset Management Department Name,

⑫ Other matters to be helpful,

4-2-6 Retention period of a fixed asset ledger

(1) Comply with statutory standards

Tax retention periods such as invoices conform to legal requirements.

(2) When there is no legal standard

For example, in Japan, it is seven years and two months of the end of the year.

4-2-7 Introduction of the format example of the asset ledger

(1) Fixed asset format

If the fixed asset register does not have a legal form, the necessary information is described according to the purpose of use of each WSP.

(2) How to create a simple fixed asset ledger

Use Excel to describe details such as fixed asset names on the vertical axis, and enter asset items on the horizontal axis.

The following basic information is described without omission.

(Fixed asset number, name, acquisition date, acquisition price, unamortized balance, depreciable balance, useful life, depreciation start date, asset type, accumulated depreciation expense, holding place, etc.)

<ins>Example of form-1</ins>

Table-1 Example of form-1

Ledger Example of Tangible Fixed Assets-1

Acquisition date (Y-M-D)	Registration date	Asset number	Name of assets	Specific	Quantity	Acquisition price(Ks)	Total Acquisition price(Ks)	Installation /use place	Storage locatios	Useful life (years)	Depreciation method	Book value(Ks)	Residual book-price (Ks)	• • • •
2019-Feb-01	2019-Feb-02	1	Valve	Butterfly valve: 50mm	5	20,000	100,000	Zone－5 , distributing pipe	-	20	straight-line method			
2019-Feb-02	2019-Feb-03	2	PE Pipe	PE-100* 6m	10	15,000	150,000	Zone－6 , distributing pipe	-	40	straight-line method			
:														
:														
:														

Example of form-2

Table-2 Example of form-2

Ledger Example of Tangible Fixed Assets-2

Name of WSP			No.	
Name of assets			Useful life (years)	
Classification			Depreciation ratio	
Quantity				
Depreciation method				
Date (Y-M-D)	Summary	Acquisition price(Ks)	Cost amortize(Ks)	Book value(Ks)

Example of form-3

Table-3 Example of form-3

Ledger Example of Tangible Fixed Assets-3

Name of assets		Reason of acquisition		Owned address (address)		Fixed asset number		
Configuration				Acquisition date		Storage location		
Figuration/Dimension						Classification	Main	
				Useful life (years)			Middle items	
Capacity				Depreciation rate			Small items	
Use application				Annual depreciation amount (Ks)		Project number		
Others				Residual price (Ks)		Drawing number		

Date (Y-M-D)	Summary	Book-cost						Accumulated depreciation			Book balance (Ks)	Disposal	
		Debtor		Creditor		Remaining value							
		Quantity	Amount (Ks)	Quantity	Amount (Ks)	Quantity	Amount (Ks)	Debtor (Ks)	Credito (Ks)	Cumulative total(Ks)		Amount(Ks)	Profit or Loss (△) (Ks)

Example of form-4

NOTE: IFRS guideline in Kenya

① The Financial Management Act of Kenya must use both of International Financial Reporting Standards (IFRS) 2008 as a guideline and Kenya Revenue Authority (KRA)

② Each WSP is obligated to prepare an "Assets Report" every three to five years.

③ However, if the Tangible assets that still have asset value beyond the useful life are re-evaluated their residual value by a third-party financial manager and their useful life is further extended by 3 to 5 years.

Table-4 Summary of KEWI Case (Based on IFRS Guideline)

Example of Ditailed Depreciation Rate on Fixed Assets(Straight line) Source: KEWI @2019 March

Yearly Depreciation (Tangible Assets)	Property, plant and equipment							Note
	Land	Buildings	Motor vehicles	Furniture and fittings	Plant and Equipment	Computers	Total	Intangible Assets
Cost	Shs	Shs	Shs	Shs	Shs	Shs	Shs	Shs
At 1st July 2016	1,044,642,000	485,738,475	23,700,000	9,575,397	82,854,946	12,155,879	1,658,666,697	-
Additions	0	1,562,614	0	0	144,200	0	1,706,814	-
Disposals	0	0	0	0	0	0	0	-
At 30th June 2017	1,044,642,000	487,301,089	23,700,000	9,575,397	82,999,146	12,155,879	1,660,373,511	-
Additions	0	0	0	0	135,345	0	135,345	-
Disposals	0	0	0	0	0	0	0	-
At 30th June 2018	1,044,642,000	487,301,089	23,700,000	9,575,397	83,134,491	12,155,879	1,660,508,856	-
Depreciation								-
At 1st July 2016	0	29,144,309	11,820,000	2,776,679	20,332,505	9,437,985	73,511,478	-
Depreciation (4)	0	9,746,022	4,740,000	957,540	10,374,893	3,646,764	0	-
On Disposals	0	0	0	0	0	0	0	-
At 30th June 2017	0	38,890,331	16,560,000	3,734,219	30,707,398	13,084,748	73,511,478	-
Depreciation	0	9,746,022	4,740,000	957,540	10,391,811	3,646,764	29,482,137	-
At 30th June 2018	0	48,636,353	21,300,000	4,691,759	41,099,210	16,731,512	102,993,615	-
Net book values								
At 30 June 2018	1,044,642,000	438,664,736	2,400,000	4,883,638	42,035,281	-4,575,633	1,557,515,241	-
At 30 June 2017	1,044,642,000	448,410,758	7,140,000	5,841,178	52,291,748	-928,869	1,586,862,033	-
Rates	**Nil**	**2%**	**20%**	**10%**	**12.50%**	**30.00%**	**-**	**20%**
Useful life's (Years)	**-**	**50.0**	**5.0**	**10.0**	**8.0**	**3.3**	**-**	**5.0**

Example of form-5

Table-5 Summary of Nyahururu Case (Based on IFRS Guideline)

Example of Detailed depreciation rate on Fixed Assets(Straight line) Source: Nyahururu WSP @2019 March

Yearly Depreciation (Tangible Assets)	Property, plant and equipment							
	Sewer &water system	Motor vehicle	Furniture, fittings & equipment	Computer equipment	Tools	Office equipment	Generator	Total
	Inc. Pipes	-	-	-	-	-	Inc. Pumps	
Cost	Shs	Shs	Shs	Shs	Shs	Shs	Shs	Shs
At 1st July 2017	95,444,818	7,009,720	3,921,107	11,231,100	4,022,869	20,000	1,591,756	123,241,370
Additions	2,502,514	675,000	1,014,861	6,049,740	112,445	-	-	10,354,560
At 30th June 2018	97,947,332	7,684,720	4,935,968	17,280,840	4,135,314	20,000	1,591,756	133,595,930
Depreciation								
At 1st July 2017	26,344,394	6,074,634	2,706,695	8,274,128	3,623,579	-	1,432,401	48,455,831
Charge for the Period	1,790,073	402,521	278,659	2,702,014	170,408	-	39,839	5,383,514
At 30th June 2018	28,134,467	6,477,155	2,985,354	10,976,142	3,793,987	0	1,472,240	53,839,345
At 1st July 2017	69,100,424	935,086	1,214,412	2,956,972	399,290	20,000	159,355	74,785,539
At 30th June 2018	69,812,865	1,207,564	1,950,614	6,304,699	341,327	20,000	119,516	79,756,585
Rates	**2.50%**	**25.00%**	**12.50%**	**30.00%**	**33.30%**	**13%**	**25%**	**-**
Useful life's (Years)	**40.0**	**4.0**	**8.0**	**3.3**	**3.0**	**8.0**	**4.0**	**-**

Note: After a depreciation period, asset value is again estimated as about 40% of asset value by the third party, and lustrum extension of the useful life is carried out.

Example of form-6

Table-6 Summary of Nakuru Case (Based on IFRS Guideline)

Example of Detailed depreciation rate on Fixed Assets(Straight line) Nakuru WSP@2019 April

Yearly Depreciation (Tangible Assets)	Property, plant and equipment													Intangible Assets
	Motor vehicle	Computer equipment	Pumps and motors	Furniture, fittings & equipment	Water meters	Network Extensions	CWIP	Leasehold	Moter vehicles and Cycles	Prepaid Water Meters	Office Block	Electric fence	Total	
	-	-	-	-	-	Meter/Valve	-	Civil /Buil	-	-	-	-		Software
Cost	Shs	Shs	Shs	Shs	Shs	Shs	Shs	Shs	Shs	Shs	Shs	Shs	Shs	Shs
As at 1st July 2016	11,968,871	11,281,655	41,141,211	7,334,474	58,576,554	9,386,435	83,633,237	-	-	-	-	-	223,322,437	-
additions	590,000	1,118,932	10,246,597	292,845	5,207,690	-	4,846,785	-	-	-	-	-	22,302,849	-
At 30th June 2017	12,558,871	12,400,587	51,387,808	7,627,319	63,784,244	9,386,435	88,480,022	-	-	-	-	-	245,625,286	-
Depreciation														
As at 1st July 2016	-10,906,934	-10,032,100	-28,715,864	-4,431,447	-38,540,030	-9,386,435	-	-	-	-	-	-	- 102,012,810	-
Charge for the Year grants	-	-	-862,405	-	-2,227,419	-	-	-	-	-	-	-	- 3,089,824	-
Charge for the Year	-533,146	-1,130,327	-5,732,447	-727,788	-5,871,654	-	-	-	-	-	-	-	- 13,995,362	-
At 30th June 2017	-11,440,080	-11,162,427	-35,310,716	-5,159,235	-46,639,103	-9,386,435	-	-	-	-	-	-	-119,097,996	-
Cost or Valuation														
As at 1st July 2017	**12,558,871**	**12,400,587**	**51,387,808**	**7,627,319**	**63,784,244**	**9,386,435**	**88,480,022**	-	-	-	-	-	245,625,286	-
CWIP	-	-	-	4842785	-	83637237	-88,489,923	-	-	-	-	-	-	-
Additions	-	780,360	7,798,924	1,970,354	8,504,545	3,149	-	-	-	-	-	-	19,057,332	-
Grant CGN	-	-	-	4,950,950	-	-	-	-	-	-	-	-	4,950,950	-
At 30th June 2018	12,558,871	13,180,947	59,186,732	19,391,408	72,288,789	93,026,821	-	-	-	-	-	-	257,074,697	-
Depreciation														
As at 1st July 2017	-11,440,080	-11,162,427	-35,310,716	-5,159,235	-46,639,103	-9,386,434	-	-	-	-	-	-	-119,097,995	-
Charge for the Year gra	-	-	-1,125,403	-618,869	-	-16,728,077	-	-	-	-	-	-	-18,472,349	-
Charge for the Year	-485,646	-1,125,016	-6,738,638	-1,490,219	-6,324,321	-	-	-	-	-	-	-	-16,163,840	-
At 30th June 2018	-11,925,726	-12,287,443	-43,174,757	-7,268,323	-52,963,424	-26,114,511	-	-	-	-	-	-	-153,734,184	-
Net Book value														
As at 39th June 2018	635,145	893,504	15,863,975	12,123,083	19,325,384	66,912,309	-	-	-	-	-	-	115,753,400	-
As at 39th June 2017	1,118,791	1,238,160	16,079,093	2,468,084	17,145,140	-	88,489,923	-	-	-	-	-	126,539,191	-
Rates	**25.00%**	**33.50%**	**20.00%**	**12.50%**	**14.20%**	**20.00%**	**-**	**20.00%**	**25.00%**	**20.00%**	**2.00%**	**13%**	**-**	**34%**
Useful life's (Years)	**4.0**	**3.0**	**5.0**	**8.0**	**7.0**	**5.0**	**-**	**5.0**	**4.0**	**5.0**	**50.0**	**8.0**	**-**	**3.0**

Note; Depreciation expenses for the first year and the last year are calculated in the year without considering the purchase month and/or date. The asset value of inventory goods is determined from the current market price.

4-3 Example of Depreciation Expense Calculation

Calculation of a depreciation expense makes the purchase years of facilities 100%, and is calculated from tenure of use and a useful life.

The example of the simple calculation method of the depreciation expense by fixed amount method is shown below.

◆ Example of calculation by Fixed amount method

This Fixed amount method is a simple calculation method that depreciates equally every year for the useful life.

(1) Formula

Annual depreciation expense = (book cost-residual price) / useful life (years)

☆ Conditions

-Vehicle purchase price = 3.0 MKs

- Useful life = 10 years

- Remaining book value (after 10 years of useful life) = 1.0 Ks

☆ Therefor

- Average depreciation for 10 years = 3.0 MKs / 10 years = 300,000 Ks / year
- However, depreciation expense at 10th year = 300,000 Ks-1.0 Ks = 299, 999 Ks.
- The residual value after 10 years is 1.0 Ks and/or 0 Ks will be remained until it is disposed of.

Table-7 Computation Example of Depreciation Amortization (in Japan)

Property number	Name of assets	Area / Quantity	Acquisition date (Y-M-D)	Acquisition price(Ks)	Amount to be the basis of amortization (Ks)	Depreciation method	Useful life (Years)	Depreciation ratio	Amortization period during the current year per year (Mn/12)	Amortization expenses for this year(Ks)	Special depreciation (Ks)	Sum total of the depreciation expenses of this year (Ks)	Rate of the use only for a business (%)	Necessary expenses for this year(Ks)	Amortized balance (term-end balance) (Ks)	Brief /Note
				①	②	—	—	③	④	⑤	⑥	⑦	⑧	⑨	⑩	
				—	—	—	—	—	—	②×③×④	—	⑤+⑥		⑦×⑧	②−⑨	
1	Stope Valves (50 mm, Cast Iron)	100	2019/1/10	600,000	600,000	Fixed amount paymen	15	0.0667	1.000	40,000	0	40,000	1.0	40,000	560,000	Construction car
2	200mmX6m(PE-100)	20	2019/9/2	600,000	600,000	Fixed amount paymen	40	0.0250	0.333	5,000	0	5,000	1.0	5,000	595,000	Reserve supply
Total				1,200,000	1,200,000					45,000		45,000		45,000	1,155,000	

NOTE; In Kenya

①Option-1 Depreciate; Full depreciation on the year of acquisition and None (Zero) at year of disposal,

②Option-2; Like Japan.

Table -8 Depreciation Ratio by Fixed Amount (Straight-line) Method

Useful life in years	Depreciation rate Straight-line method	Useful life in years	Depreciation rate Straight-line method	Useful life in years	Depreciation rate Straight-line method	Useful life in years	Depreciation rate Straight-line method	Useful life in years	Depreciation rate Straight-line method
-	-	11	0.091	21	0.048	31	0.032	41	0.024
2	0.500	12	0.083	22	0.045	32	0.031	42	0.024
3	0.333	13	0.077	23	0.043	33	0.030	43	0.023
4	0.250	14	0.071	24	0.042	34	0.029	44	0.023
5	0.200	15	0.067	25	0.040	35	0.029	45	0.022
6	0.167	16	0.063	26	0.038	36	0.028	46	0.022
7	0.143	17	0.059	27	0.037	37	0.027	47	0.021
8	0.125	18	0.056	28	0.036	38	0.026	48	0.021
9	0.111	19	0.053	29	0.034	39	0.026	49	0.020
10	0.100	20	0.050	30	0.033	40	0.025	50	0.020

4-4 Necessity of Setting Improvement Standards (useful life) of Facilities

The setting of this improvement/renewal standard (the useful life) is essential for guiding the aging of facilities and for managing the tangible fixed asset ledger.

In general, the renewal criteria are set as the "legal service life" which indicates the usage period to maintain the standard stable performance of each facility.

However, the reality is that once the facility is properly maintained and managed, the facility is used even after the legal period.

NOTE: Necessity of setting

① To formulate an implementation plan for NRW reduction measures, based on the update standard value described in the asset register of the distribution facility, determine whether the distribution network near the due date of a legal period and/or piping network with many leaks as aged pipe.

② By setting own renewal time and extending the legal service-life- span, equipment investment can be reduced.

③ In order for WSP to continue stable water supply, it is necessary to set up a renewal standard immediately.

4-4-1 Points to be considered in setting of own new renewal standard by life extension

(1) Points to be considered

Setting of own new renewal time is differences from depended on setting environment of facilities/ pipelines, leak occurrence frequency, deterioration situation, importance of facilities, facility, piping material / quality standard being used, quality of piping construction standards, maintenance situation (strengthen by repair / reinforcement).

But it needs to be carefully set based on the past results / investigations.

In addition, in the examination of the renewal plan, it is essential to strengthen the financial resources and the organizational system, and to formulate the renewal plan aiming at the

continuation of stable water supply and the longevity of the facility.

(2) Related information items required

We will consider the new renewal year by organizing and analyzing the data of daily and regular inspections.

① Classification of priority of renewal facilities considering the urgency of repair work and importance of facilities,

② Setting the number of years of extension when the construction for extending the life is carried out,

③ Establish a new renewal year so that the project cost can be reduced while reviewing the scale of facilities optimum for future water demand, actively promoting integration of facilities, and strengthening ease of maintenance and management。

4-4-2 Setting example of useful life

The following shows the major renewal items and their useful lives.

(1) Civil and architectural structures

To renewal of civil and building structures is as deterioration of the structure and/or solve the shortage of capacity.

Table-9 Useful Life Example of Civil and Architectural Structures

Name of assets	In Japan's case(years) (Source: JWRC 2015-10, Partial reviewed)		In Kenya / WSP case (years)			
			Leagal Stds.		Expected life	
	Legal Standards	Expected life	International Financial Reporting Standards (IFRS)	Kenya Revenue Authorities (KRA)	Nyahururu	Nakuru
General Civil structures	60	65～90				
Civil structure (Water purification plant)	60	50~100		18		
Civil structure (water distribution facilities)	60					
Stainless steel distribution reservoir	45	—				
General architectural structures	50	65～75				

(2) Mechanical and electrical equipment

Renewal of mechanical / electrical equipment is carried out to eliminate deterioration due to corrosion and wear, lack of capacity, and model obsolescence of facilities, but when maintenance is good, it tends to be used longer than the statutory period.

The new renewal service life is often set based on manufacturer recommendations /

failure results.

Table-10 Useful Life of Machine and Electric Equipment

Name of assets	In Japan's case(years) (Source: JWRC 2015-10, Partial reviewed)		In Kenya / WSP case (years)			
			Leagal Stds.		Expected life	
	Legal Standards	Expected life	International Financial Reporting Standards (IFRS)	Kenya Revenue Authorities (KRA)	Nyahururu	Nakuru
Pumps	15	20～30				
Sterilization equipment	10	15～25				
Chemical injection equipment	15	15～30				
Pressure reducing valve (metal)	17					
Sedimentation, filtration equipment		20～30				
Sludge treatment facilities		20～40				
Substation /electric distribution equipment	15	20～40				
DC power supply equipment		6～20				
Emergency power supply equipment		15～40				
Flow meters, water level gauges, water quality meters		10～25				
Monitoring equipment/ transmission equipment		15～30				

(3) Pipeline

The common update reason for pipelines is often implemented in order to cope with lack of diameter / integration of pipelines / construction failure.

The reasons for updating the pipe line for each pipe type are shown below.

① Cast iron pipes and steel pipes

Deterioration of physical strength due to corrosion of outer and inner surfaces.

② Asbestos pipes and non-ferrous metal material pipes

Deterioration in strength due to aging and damage due to external load.

In addition, there is a tendency that it is used longer than the statutory period if promotion the improvement of the old pipe/ repair works/ pipeline cleaning/ flush out, are properly carried out.

The new renewal service life is set for each pipe type (40 to 80 years) based on pipe line strength survey, record of operation and management, existence of anticorrosion measures, corrosiveness of soil, leak occurrence frequency, leak cause investigation and so on.

NOTE: Need to check the quality of products used in Kenya

Since the service life of the pipeline / pipe depends largely on the quality / standard used, it is necessary to confirm the quality / standard of the product used.

(1) Quality of the procured product,
(2) Condition of use,
(3) Maintenance,
(4) Expected usage of the assets,
(5) Technical obsolescence,
(6) Legal limits for intangible assets, e.g. patent right

With these factors, you develop depreciation policy -NB KRA rates, should not be contradicted for commercial enterprises.

Table-11 Useful Life of Pipeline and Type of Pipe Materials

Name of assets	In Japan's case(years) (Source: JWRC 2015-10, Partial reviewed)		In Kenya / WSP case (years)			
			Leagal Stds.		Expected life	
	Legal Standards	Expected life	International Financial Reporting Standards (IFRS)	Kenya Revenue Authorities (KRA)	Nyahururu	Nakuru
Cast iron pips	40	50				
Ductile cast iron pipe		60～80				
Steel pipes (welded joint)		70				
Steel pipes (flange joint, etc.)		40				
Asbestos cement pips		40				
Hard PVC pipes		40～60				
Polyethylene pipes (High density, heat fusion joint)		60				
Polyethylene pipes (others)		40				
Stainless pipes		40～60				
Distribution water pipeline(CIP)	40	25～100				
Distribution water pipeline(Others)	25	-				
Distribution pipe attachment facility	30	-				
Water service pipelines	15	25～50				
Valves	30 (Recommended)	10～40				
Bulk Flow meters	15～20	-				
Customer Water meters	8	-				

4-5 Arrangement of Water Leakage Accident / Repair Ledger

In order to analyze the cause / actual condition of water distribution network with frequent occurrence of water leakage, it is necessary to organize the results of the cases of water leakage that occurred in the past and to understand the water leakage phenomenon well.

In particular, the physical deterioration of the water distribution network can be identified by examining the frequency of recurrence of water leakage from the ledger.

4-5-1 Information Collection Period

The collection of information on water leaks should be made within the past 5 to 10 years (the piping status may be different if the information is too old).

4-5-2 Confirmation of the history information on a leakage-of-water accident

The items to grasp the past leakage tendency in advance are shown below.

In particular, the leaked pipeline, once generated, often leaks again, even if it is partially repaired.

(1) Water leakage place and its discovery day, water leakage point (address), type of pipe, bore diameter, year of construction, others,

(2) Situation of leaked water; Amount of leaked water, scale of leaked water, cause of leaked water,

(3) Water leakage measures; Repair method, time required, cost, construction photograph, correction procedure of existing pipeline map, etc.

4-5-3 Example of items to be listed in the ledger

(1) Classification of the information provider **(Refer to Table-6)**

① Residents and passers、

② Road manager, electric worker, telephone worker, sewage worker

③ Pipeline patrol

④ Leakage investigation

(2) Occurrence time /leaking point / block / address

(3) Election of the leak control person in charge

(4) Repair date and time / Repair method / Repair time

(5) Prediction of leakage amount / Prediction of loss cost

(6) Estimate of repair cost

(7) Number of workers / Calculation of Personnel Cost

(8) Cause of water leakage

Table-12 Example of **Water Leakage Accident / Repair Ledger**

Receipt number	Reception date (Y-M-D)	Information provider	Leaking location	Repairman	Number of workers	Repair method	Repair time required (hr)	Repair completion date (Y-M-D)	Water loss (m3)	Leakage cause	Construction cost (Ks)	Customer / resident comments
1												
2												
3												
4												
·												
·												

4-5-4 Digitization of ledger information

Combining the GIS / mapping topographical map and the digitized ledger information enables the complaint reception operator to immediately input the leak notification into the map information on the PC, enabling sharing of the information on the PC screen. As a result, it can contribute to NRW reduction by carrying out repair work promptly. The format of the ledger is created in accordance with the key monitoring items of each WSP. More detail, Refer to **Textbook -5 and Textbook-6, (8)**

Table-13 Example of leakage-of-water survey Sheet

Water distribution main Pipe			Water supply device		
Name of facility	Number of leaks	Amount of leaked water (m3)	Name of facility	Number of leaks	Amount of leaked water (m3)
1.Pipe			1.Pipe		
2. Pipe damaged			2.Joint		
3.Pipe da			3.Stop cock		
4.Valve' s gland packing			4.Union		
5. Hydrant			5.Packing		
6.Slice valve			6.Elbow		
7.Air valve			7.Coupling		
8.Others			8.T-bend		
Sub-distributing pipe			9.Socket		
1.Upper part of pipe			10.Saddle		
2.Joint			11. Customer Meter		
3.Valve' s gland packing			12.Others		
4. Hydrant					
5.Slice valve					
6.Air valve					
7.Others					

Item to be analyzed

Leakage-of-water spots		Number of cases (%).	Water Loss amount (m3/h) (%)
Water distribution Pipe	Upper part of pipe		
	Pipe damaged		
	Joint		
	Diverging point		
	Slice valve		
	Bulk Meters		
	Others		
	Subtotal		
Water-supply Pipe	Upper part pipe		
	Joint		
	Stop cock		
	Customer Meter		
	Others		
	Subtotal		
Sum total		xxxxx (100)	xxxxx (100)

Table-14 Example of Annual Report on water leak repaired

Cause	Material of pipe	Distributing pipe (Cause of leakage)				Service pipe (Cause of leakage)			
		2013	2014	2015	2016	2013	2014	2015	2016
Aged pipe	Cast iron pipe								
	Vinyl pipe								
	Galvanized steel pipe								
	Steel pipe								
	PE pipe								
	Total								
Corrosion	Fittings								
	Bolts								
	Snap taps								
	Saddle branched								
	Total								
Joining problems	Vinyl pipe fittings								
	DCI pipe								
	Sockets								
	Rubber seal								
	Other								
	Total								
Gland	Gate valves								
packings	Water shutoff valves								
	Snap taps								
	Others								
	Total								
Dynamic load pressure/vibration/Corrosive soil	Ductile cast iron pipe								
	Steel pipe								
	Vinyl pipe								
	Asbestos pipe								
	Total								
Left piping abandoned	Disposal piping								
	Total								
Water pressure	Crack of Pipe								
	Detachable								
	Total								
G. Total									






5. Implementation of Additional Investigation

If it is difficult to formulate an NRW reduction plan based on the analysis of available information, additional research will be considered for the following items.

(For details, refer to Textbook-6 and 7)

(1) Sharing definitions of technical terms required for NRW reduction activities

(2) Investigation of present underground leakage by leak detectors,

(3) Survey of remaining leakage and restored amount in each piping networks,

(4) Evaluation of leakage prevention work volume and economic efficiency.

5-1 Sharing Definitions of Technical Terms Required for NRW Reduction Activities

5-1-1 What is revenue water?

Revenue water is defined as the amount of water input into the distribution system and is translated to revenue.

5-1-2 What is Non-revenue water?

Non-Revenue water is defined as the amount of water input, is not translated to revenue.

> ◆ **NOTE:**
> **NRW(m^3) = SYSTEM INPUT VOLUME(m^3) – BILLED AUTHORISED CONSUMPTION(m^3)**

Non-Revenue water ratio is the percentage of the amount of water not billed against the amount of water input into the distribution system.

$$\text{NRW}(\%) = \frac{\text{System Input Volume} - \text{Billed Authorized Consumption}}{\text{System Input Volume}} \times 100$$

5-1-3 Types of leaked water generated

(1) Preventable leakage **(Refer to Figure 3)**

It is the amount of water leakage that can be prevented by the survey technology.

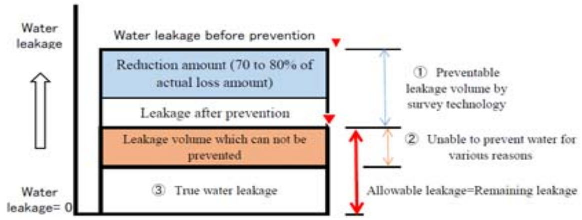
(2) Unpreventable water quantity (Permissible water leakage quantity)

The allowable amount of water leakage should be, as much as possible, “zero amount of water leakage,” but it cannot be prevented for many reasons. (for example, the NRW reduction rate determines the target allowable leakage rate considering cost effectiveness)

(3) True leakage:

It is the amount of leakage that cannot be prevented even if any leakage prevention measures are taken (estimated, 2 to 4%), for example, it is difficult to find leaked water

due to a slight amount of leaked water at the connection, evaporation, soil adsorption, etc.)



Source: Yokosuka city waterworks & sewerage bureau

Figure-6 Concept of total water leakage

5-1-4 Breakdown of NRW

Non-revenue water = Not billed authorized consumption + Water losses

Water losses = Apparent losses + Real losses

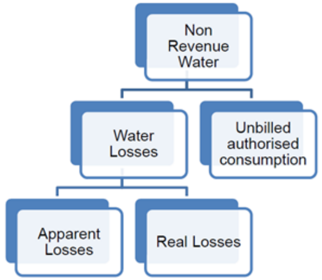


Figure-7 Components of Non-Revenue Water

Table-15 Water Balance analysis (IWA STD)

Q1: System Input Volume (m^3)	**D1:** Authorized Consumption (m^3)	V1: **Billed Authorized Consumption (m^3)**	① Billed Metered Consumption (including water exported) **(m^3)**	**Q2: Revenue Water(m^3)**
			② Billed Nan-metered Consumption**(m^3)**	
		V2: Unbilled Authorized Consumption**(m^3)**	③ Unbilled Metered Consumption**(m^3)**	**Q3: Nan-Revenue Water(m^3)**
			④ Unbilled Non-metered Consumption**(m^3)**	
	D2: Water Losses(m^3)	V3: Apparent Losses**(m^3)**	⑤ Unauthorized Consumption**(m^3)**	
			⑥ Metering Inaccuracies **(m^3)**	
		V4: Real Loases **(m^3)**	⑦Leakage on Transmission and /or Distribution Mains **(m^3)**	
			⑧Leakage and Overflows at utility’s Storage Tanks **(m^3)**	
			⑨ Leakage on Service Connections up to Customers ‘Meters **(m^3)**	

Source：IWA: International Water Association Standard

5-1-5 Breakdown of leakage in piping network measured by survey technology

◆Amount of leaked water

= leaked water from piping network + illegal / stolen water + other

5-1-6 Preventable water leakage

◆ Water leakage from distribution network = 70 to 80%

= Surface leakage + Underground leakage

5-1-7 Remaining leakage

The residual water leakage amount is the “minimum water leakage amount” immediately after the water leakage construction measures, and the restoration amount is added with the passage of time, and the leakage water amount (total water leakage amount) will increase. (**Refer to Figure 4**)

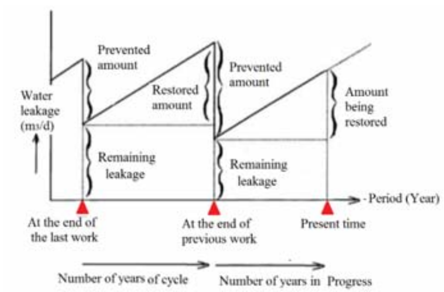
5-1-8 Restored amount of leaked water

Even if it repairs once, it is a phenomenon where new leakage of water occurs again with the passage of time.

Leakage is constantly emerging and growing due to complex factors, and when prevention measures are delayed, leakage increases with time.

NOTE: Recovery Index （restored amount）

In general, the amount of restoration refers to an increase in leakage per year per 1 km of water distribution pipe, and the unit is expressed as (m^3 / day · km · year) or (m^3 / day / km / year).



Source: (Water leakage survey for practitioners: From planning to implementation 1995, JPRC

Figure-8 Concept of Leakage Recurrence

5-1-9 Measurement of minimum night flow rate daily (criteria for judgment of leakage)

As a method of estimating the amount of leaked water in the piping network, the minimum daily flow is measured, and this minimum flow is assumed as the amount of leaked water. The time when demand is low is at midnight, which is the minimum flow (minimum night water), but the maximum flow is recorded during the day when demand is high.

Judgment criteria of pipe line deterioration is judged based on this nighttime minimum flow rate.

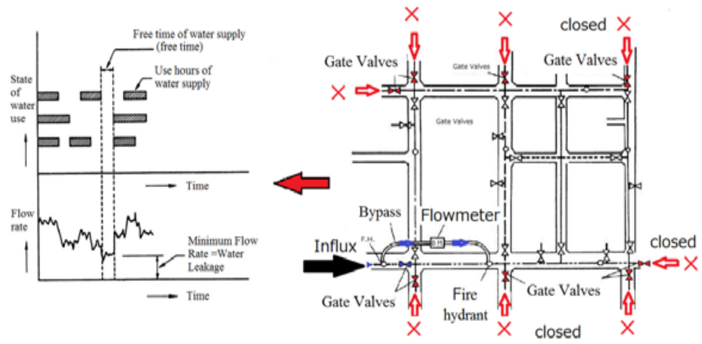
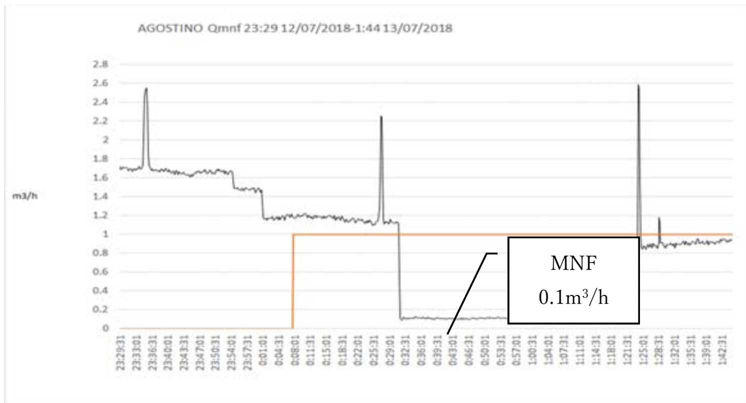


Figure-9 Example of water use "free time" and variation in the minimum night flow



Source: NYAHUWASCO 2018, August.

Figure-10Example of Flow variation in the Minimum Night Flow (MNF)

5-2 Conduct Survey of Underground Leaked Water by Leak Detectors

(For details, refer to Textbook-5)

5-2-1 Type of leakage from pipeline

There are two types of water leakage from pipeline

There are two types of water leakage from pipeline

Table-16 Comparison of Surface leakage and Underground leakage

Items	Surface leakage	Underground leakage
Classification of magnitude of leakage	If there is a large amount of water leakage, it is easy to go to the ground surface.	Small amount leakage is likely to be underground leakage without going to the ground surface.
Geological condition	Clay and loam are easy to go to the ground surface	Sand and the like are prone to underground leakage
Pavement, sewerage etc.	Leakage is easy on the ground surface in areas not equipped with high-grade pavement and sewerage	Underground leakage is likely in areas with high quality pavement and sewerage
Impact on leakage rate	Although the number of leaks is large, it is discovered early, so the duration of leaks per case is short, and the number of leaks is large.	Although the number is small, it is difficult to find and there is a tendency for leakage, accumulation and growth for a long time. The scale of leakage is small to medium and various
Type of damages	It causes direct damage such as road collapse, sediment runoff, traffic problems, house flooding, road surface freezing, sewage suction, etc.	Indirect economic damage such as loss of water volume, yield loss, water pressure reduction, sewage suction (water pollution), damage to the foundation of the facility, etc.

5-2-2 Characteristics of surface leakage

(1) Utilization of leak detection technology

The application of exploration technology is not particularly required as it is easy to find / identify the location of the leak.

(2) Water quality test

However, it is necessary to determine whether it is potable water supplied by WSP by the chlorine color identification test of the water leakage source.

(3) Scale of damage caused by lost water

The amount of leaked water on the surface varies depending on pipe diameter / water pressure, but tends to be as follows.

① In the case of large diameter;

Runoff loss of large-scale tap water causes damage such as flood / sinking of roads, but the frequency of occurrence of water leakage accident is small.

② In the case of small diameter

Many small amounts of water leakage occur at junctions from water distribution pipes and water service pipes. etc., but detection is easy.

When repair work is carried out quickly, the amount of water loss is small.

5-2-3 Characteristics of Underground leakage

(1) Utilization of leak detection technology

Because it is difficult to detect and identify underground leakage, conducting leakage investigations by combining exploration techniques will increase the number of leakage detections.

(a) Pipeline Locating / Tracing equipment

(b) Leak detection equipment

(c) Flow rate measurement equipment

(d) Pressure measuring equipment

(2) Water quality test

However, it is necessary to determine whether it is from potable water supplied by WSP by the chlorine color identification test of the water leakage source.

(3) Scale of damage caused by lost water

The amount of leakage of underground leakage varies depending on pipe diameter / water pressure, but tends to be as follows.

(a) large diameter

Large-scale, high-pressure underground leaks cause large-scale surface leakage, but this causes ground subsidence and causes roads to collapse. Underground leaks that do not lead to above-ground leaks cause infiltration into sewage manholes and/or generation of spring water due to natural flow downstream, but it is difficult to detect this phenomenon early.

(b) Small diameter

Although a large number of small leaks from water distribution pipes /

water service line are generated, it is difficult to detect, leaks continue for a long time, and the amount of lost water is said to account for 60 to 80% of the total leaked water.

NOTE: Suggestions for regular water leak investigation
In order to confirm the existence of underground leakage early, it is desirable to conduct a general leakage survey periodically (3 to 4 years / time) with Leak detectors by zone.

5-2-4 Example of exploration equipment used in water leakage survey (For details, refer to Textbook-7)

The basis of the specific investigation of water leakage occurring in the water distribution area is the detailed investigation (point detections) of each piping network sequentially from the wide areas (surface detections).

Table 17 Concept of water leakage survey

Classification	Purpose of survey	Equipment used
(A) Surface detection	Calculation on leakage volume / NRW rate in medium blocks	Flow meter at distribution pond (Electromagnetic flowmeter, etc.)
	Calculation on leakage rate / NRW rate in small blocks	Portable flowmeter (Ultrasonic)
(B) Line detection	Survey of identification leakage location at Stop-cock /Valve	Acoustic noise detectors (Acoustic rods, electric acoustic rods, water leak detectors, etc.)
	Survey of identification leakage point on pipeline	Leak noise correlation, sonic type pipeline detectors, impact wave type, underground radar, etc.
(C) Point detection	Acoustic survey of leakage on water service pipeline	Correlation surveys and/or acoustic surveys
	Acoustic survey of leakage on stopcock / meters	Acoustic nose detectors
	Final confirmation survey of water leakage place	Visual inspection, boring bar, trial excavation

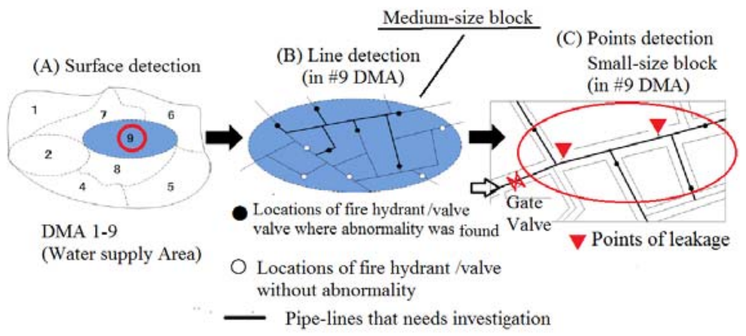


Figure 11 Concept of how to identify leak location

5-3 Conduct of Specific Investigation of Leaked Quantity (Remaining Leakage / Restored Quantity) and Leaking Points (For details, refer to Textbook-7)

The outline of the survey procedure is shown below.

5-3-1 Step-1 (Extraction of leaking pipe networks)

Extract the piping network with a large amount leakage from past information analysis.

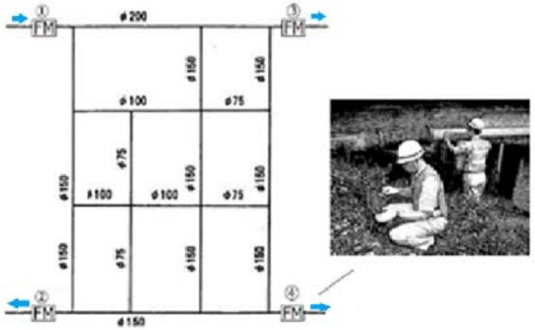
(a) Areas / piping networks where NRW are high,
(b) Piping routes with high leakage frequency,
(c) Piping routes with high water pressure,

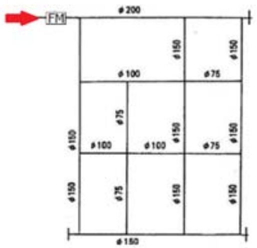
5-3-2 Step-2 (Measurement of inflow / water pressure of each block)

Measure the flow rate / water pressure of the piping network continuously for a long period of time, and automatically measure the minimum daily water volume and water pressure.

If the amount of leakage is relatively small, install a bypass pipeline on the water distribution line and record the small flow rate & water pressure automatically.

NOTE;
From the daily minimum flow rate and measured water pressure, estimate the amount of water leakage in each block.





Flow measurement in isolated DMA

5-3-3 Step-3 (Narrow down a search area leaking pipelines by Step test)

The step test is a survey that divides the main water distribution pipe route (block) into smaller parts, measures / compares the nighttime minimum flow rate of the small blocks in order, and identifies the water leakage area in which small pipes are leaking.

Bypass line & Flow meter

5-3-4 Step-4 (Check of water leakage point)

After the leak piping line is identified, and the leak occurrence point is determined.

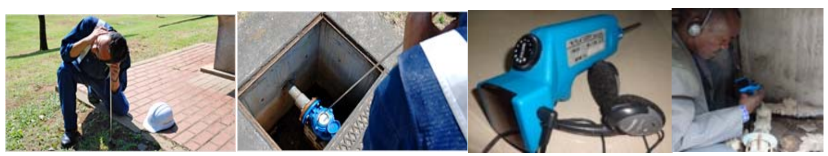
（1） Leakage survey with equipment to be used

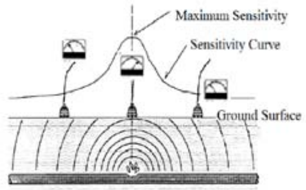
① Listening stick / digital listening stick.

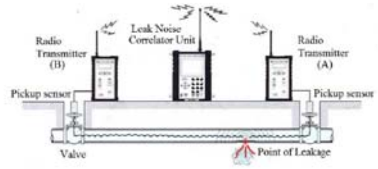
② Time integrated type leak detector

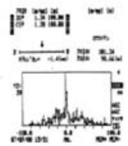
③ Road surface digital noise leak detector, others

④ Leak noise correlator









(2) Confirm the leakage point with equipment to be used

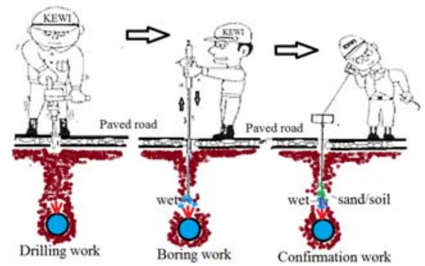
(a) Bowling equipment (electric drill, hammer drill, boring bar),

(b) Listening stick / digital listening stick, others

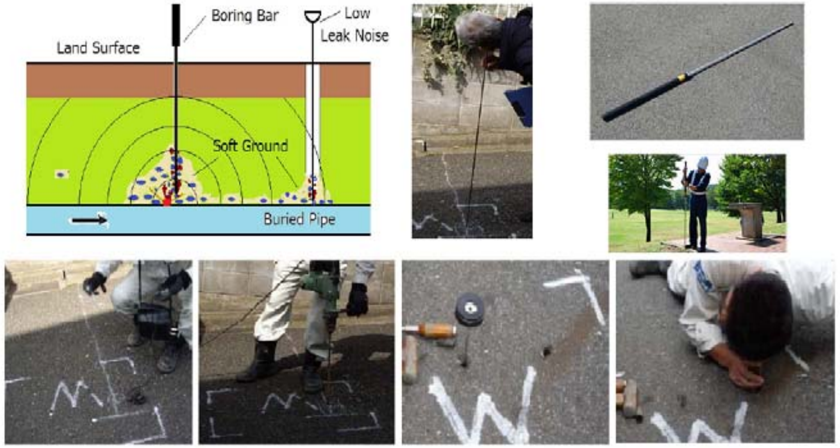
(c) Road surface digital noise leak detector

(d) Leak noise correlator, Metallic pipe locator/Metal locator

(e)Reagent of Residual chlorine (DPD)、tool、Survey vehicles, others



Source: JICA-Nagoya City Edit NRW Textbook



Source:Yokosuka cityWWSB Working on Paved roadway

(5) Step-5 (Implementation for improvement work)

Renovation and improvement of distribution pipes will be carried out where the location of water leakage has been identified.

(6) Step-6 (Implementation of measurement of remaining leakage)

Immediately after completion of the improvement work, measure the amount of leakage (remaining leakage) and compare it with the amount of leakage (remaining leakage) before improvement to calculate the amount of prevention.

(7) Step-7 (Determine the priority of improvement work by grasping the relationship between restored amount and recovery period)

If the amount of leakage (the amount of residual leakage) is periodically measured each year, the amount of increase in leakage (restoration amount) can be grasped in time series.

This data will help to develop an optimal update plan.

5-4 Evaluation of a Prevention Workload and Economic Efficiency

As for the leakage prevention work item, the amount of work will be large depending on the extent to which the current NRW occurrence cause is known.

As the amount of work increases, collected data increases, but the cost also increases.

In addition, since water leakage increases daily, the data gets older with time, so it is more

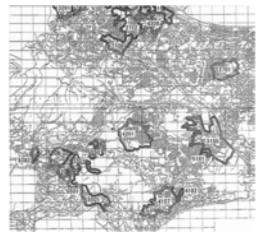
practical to repeat the minimum survey in line with the survey purpose.

5-4-1 Implementation of initial survey

In general, the water supply areas will be divided, and the survey will be conducted according to the decision of the prior leakage area according to the implementation budget.

The following is an example of a simple leak investigation item.

Table 18 Example of the Contents of Simple Initial Survey

A) Work contents	①Target area; Residential area (mainly listening to music, L ＝150ｋｍ＋50ｋｍ) ②Number of houses: 15,000 ③Survey period: 2 months ④Investigation time: (a) Sound listening bars investigation (24 hours) (b) Road surface hearing investigation / Leak noise correlators (22 pm to 5am) (c) Minimum Night flow rate measurement (22om to 5am)		
B) Door-to-door acoustic-survey(150km)	Investigate stopcocks and customer water meters	By Listening sticks / digital listening sticks.	-Mark the spot with spray. -3 to 4 km / person / day
	Investigate Gate valves, fire hydrants etc.		
C) Water supply and distribution pipeline leak investigation (50 km)	Investigate leakage on pipeline	By Road surface digital noise leak detectors &, Leak noise correlators	Identification of leak locations
	Measurement of restored amount (leakage)	By flow meter	Measurement of Minimum Night Flow rate (m^3/d/km)
D) Confirmation survey of all leaking locations		By Visually and/or boring bars, etc.	
E) Report submission (150km, 50km)		- List of leaking location/Address / water registration number / customer registration number, - Expected water leakage, - Create a drawing showing the position	

5-4-2 Survey cycle years and Economic

The relationship between the contents of the leakage survey and the cost is shown below.

(1) In general, if the number of circulation years is long, the survey distance of one-time / year will be shortened and the cost will decrease, but a late detection can increase the amount of leakage

(2) Conversely, if the circulation period is shortened, the cost will be increased, but early detection can reduce the amount of leakage.

(3) Calculation method of economic circulation years,

Therefore, it is preferable to set a circulation period in which the sum of the leakage prevention work cost (X n) and the leakage loss cost (Q n) is minimized.

> NOTE; Evaluation method:
>
> **X n + Q n = minimum value (Shs)**
>
> Here;
>
> X n: One-year leak prevention cost during X-year circulation
>
> Q n: One-year loss cost during X-year circulation

(4) Estimation of average circulation years

Generally, the average number of cycles is set within 4 to 5 years, and the priority district is set within 2 to 3 years.

The number of circulation years will be periodically reviewed based on the results of the survey.

5-4-3 Judgment example Whether additional investigation required

Based on the Minimum Nighttime Flow (restored amount) results obtained in the preliminary survey, an additional water leakage survey plan that takes into account the economics is required.

In addition, in order to decide whether or not to carry out rehabilitation work, it is indispensable to set the allowable leakage amount to formulate the improvement plan. (**Described in the next Item- 6**)

Table 19 Evaluation Example of Judgment Level of Leakage

Rank	Results of Minimum Night flow rate	Allowable leakage	Determining the need for additional research
A	12m^3/d/km or less	12m^3/d/km or less	Do not conduct survey work
B	12m^3/d/km~24m^3/d/km or less		Focus survey on pipelines & door-to-door survey by acoustic-survey.
C	24m^3/d/km ~50m^3/d/km or less		Focus survey on pipeline door to door by combination of acoustic and Leak noise correlators
D	50m^3/d/km and more		Focus survey on distribution pipeline by combination of sounding survey and leakage use of flow meters

Source: Prevention of leakage in water pipelines manual, Yokosuka city WSB, Partial edited

5-5 Confirming the Cost Effectiveness on the Survey

Benefit effects including leakage survey costs and economics are assessed in the following manner.

> **NOTE; Benefit effect should be greater than the total investment cost.**
>
> Total investigation cost **(Shs)** < Benefit effect (leakage prevention cost **(Shs)** + social benefit of improvement of living environment)

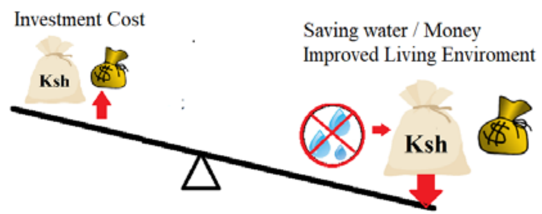


Table 18 Image Showing the Evaluation of Investment Effect

6. Items to Consider for Formulating an Improvement Plan

6-1 Purpose of Formulation of Improvement Plan

If the improvement work of the aging facilities is slower than the aging rate, declines in water supply service, increase of customer complaints, rise of water rates, deficit management, etc. occur, and the water supply company raises "mission of philosophy / motto", It will be difficult to achieve.

(1) General improvement goals

① Safe / stable water supply level improvement
② Improvement of water supply financial income
③ Business management sound
④ Extending the useful life of the facility
⑤ Improvement of technical skills for maintenance, etc.

(2) Items to be considered

① Setting of non-revenue water rate (%)
② Setting of allowable water leakage (m3 / km)
③ Setting criteria of priority
④ Confirmation of improvement / update construction method
⑤ Securing a budget

6-2 Points to Keep in Mind

6-2-1 Setting NRW rate (%)

Realistically, set the "non-revenue water rate" from the "reduction amount" that can be reduced "within budget"

6-2-2 Setting allowable water leakage

(1) Overview

That is, in the case where the water leakage rate is promptly improved, the allowable water leakage amount is suppressed to a low value (for example, the pipe extension distance is set to 30 m3 / day / km or less).
In practice, it is important to set “small” in stages, taking into consideration the amount of water leakage at present.

(2) General trends

(a) If there is a large allowable amount of water, the leakage reduction effect will be small, but the reduction investment will be cheaper.

(b) If the allowable amount of water is small, the leakage reduction effect is high, but the reduction investment amount will be high.

(c) Examination of set value by objective judgment

・Set from the "reduction amount" equivalent to the "expected budget equivalent to the benefit amount"

・Set from the amount of water that can ensure the shortage of water.

・Set from the amount of reduction expected after the improvement of leakage pipeline.

(3) Evaluation method

The evaluation method is shown below.

① Leak amount per day per 1 km of distribution piping (m3 / day / km)
②Water leakage per hour (m3 / h / km),etc.

(4) Example of setting allowable water leakage (in Japan)

The concept of setting is shown below.

①About 20 to 10% of total leakage (0.5 to 1.2 m^3/ h/ km).
②15m^3/ day/ km with water pressure 2kgf / cm^2 regardless of pipe diameter
③14 m^3 / day / km per water distribution pipe

6-2-3 Priority setting

The results of water leakage prevention will immediately appear in the management index if the aged pipe is actively improved.
However, due to financial limitations or construction capacity constraints, priority will be determined and implemented.

The following is an example of priority evaluation items.

① A pipeline that can expect investment effects (cost-effectiveness)
② Importance of facility
③ Deterioration level
④ Leakage amount
⑤ Hydraulic condition / piping laying condition
⑥ Distribution pipe with deteriorated water supply service (Water pressure / water volume / water quality)
⑦If a water leakage accident occurs, the pipeline where the disaster will increase
⑧Pipelines with frequent illegal connections, etc.

Table 20 Setting example of management target values / indexes

Nos	Items	2018 (eg)	2019	2020	Targets/indexes	Remarks
1	Population water supply dissemination rate (%))	58%			-	
2	Dissemination rate of water supply district (%)	86.9		—	-	
3	Non-revenue water rate (%)	46.0	-	-	-	
4	Water meter dissemination rate (%)	75.0	-	-	-	
5	Water leakage rate (%)	24.6	-	-	-	
6	Accounted for water rate (%)	53.2	-	-	-	
7	Commercial loss (%)	16.6	-	-	-	

6-3 Examination procedure of rehabilitation plan

The survey procedure for creating an effective improvement plan is shown below.

6-3-1 Evaluation of Survey Results (Water Leakage, Piping Route, Service Life of Facility)

The following analysis of prior information is required.

(1) Survey of distribution pipes

① Piping strength / cause of pipe line with reduced function (pipe type, age, number of accidents, etc.)

② Leakage amount

③ Pipeline where water pollution occurred

④ Pipeline where water leakage has come back.

⑤ Scale of pipeline to be improved

⑥ construction site (pipeline where improvement work is difficult)

(2) Water service pipe

① Cause of lack of strength in the pipeline

② Cause of decreased water supply service (flow, water pressure, water quality)

③ Identification of water supply areas with many leaks.

④ Scale of pipeline to be improved

⑤ Construction site (pipeline where improvement construction is difficult)

If multiple old water service pipes are installed, they will be integrated to simplify the pipeline.

(3) Useful life of the facility

Facilities that have reached their useful lives are subject to rehabilitation plans.

Table 21 Example of Useful Life of Distribution Pipeline Facilities

Name of assets	In Japan's case(years) (Source: JWRC 2015-10, Partial reviewed)		In Kenya / WSP case (years)			
			Leagal Stds.		Expected life	
	Legal Standards	Expected life	International Financial Reporting Standards (IFRS)	Kenya Revenue Authorities (KRA)	Nyahururu	Nakuru
Cast iron pips		50				
Ductile cast iron pipe		60～80				
Steel pipes (welded joint)		70				
Steel pipes (flange joint, etc.)		40				
Asbestos cement pips		40				
Hard PVC pipes	40	40～60				
Polyethylene pipes						
(High density, heat fusion joint)		60				
Polyethylene pipes (others)		40				
Stainless pipes		40～60				
Distribution water pipeline(CIP)	40	25～100				
Distribution water pipeline(Others)	25	-				
Distribution pipe attachment facility	30	-				
Water service pipelines	15	25～50				
Valves	30 (Recommended)	10～40				
Bulk Flow meters	15～20	-				
Customer Water meters	8	-				

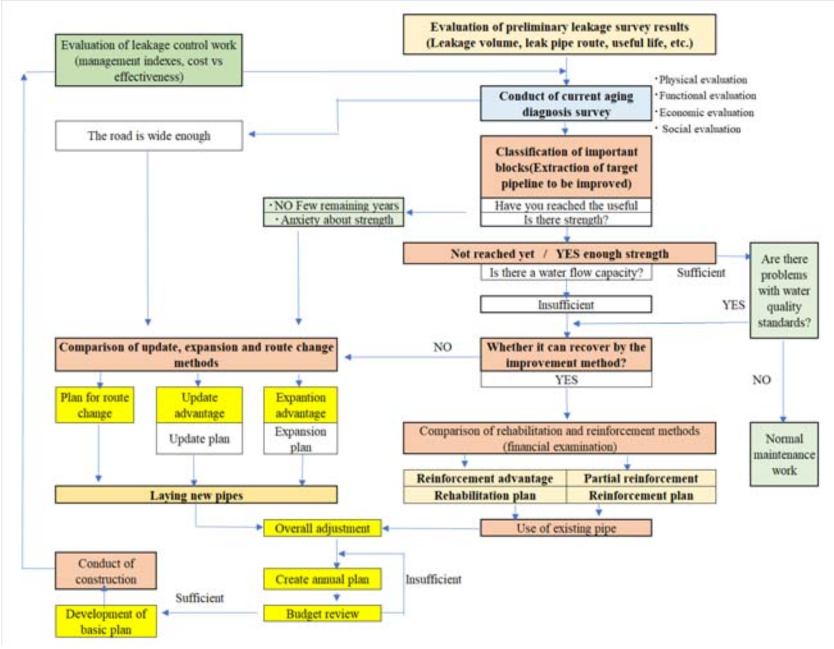


Figure-19 Procedure of Rehabilitation Plan for Distribution Pipeline

6-4 Improvement method of pipeline

The features of the improvement method are shown below.

(1) Update (replacement to new pipe)

・It is effective for measures of the pipeline which has a large amount of water leakage chronically (planned improvement can be implemented)

・Long-term construction work

・Water leakage can be prevented for a long time (NRW reduction effect is high)

・Measures cost will be high

(2) Rehabilitation (reinforcement of old pipe)

・Same as above

(3) Partial repair / partial replacement

・Effective for sudden surface leakage control (implementation of immediate improvement)

・ Short-term water leakage stop work

・Temporarily improve (NRW reduction effect is low because leakage occurs immediately in other areas)

・The cost of measures is cheap

(4) Change of piping route

・Effective for pipeline measures where improvement work is difficult (Conduct systematically)

・Long-term construction work

・Long-term leakage can be prevented (NRW reduction effect is high)

6-4-1 Rehabilitation method by replacing with new pipe

This improvement method is most often adopted.

The method is divided into open cut method and Non-open cut method.

These construction methods are determined from the viewpoint of site conditions and economy.

(1) What is the open cut method?

(a) This method digs from the ground and removes old pipes and restores all functions by installing new pipes.

(b) With this method, except for special cases in the field conditions, it can be installed reliably without choosing the type of pipe.

(c)The piping materials frequently used are shown below.

・Type of Metal pipe （Steel pipe、Cast iron pipe）

・Type of Resin pipe（PVC pipe, Polyethylene pipe, Polypropylene pipe）

・Stainless pipe

NOTE, Confirmation of product specifications
The caliber / product specification will vary, t is desirable to contact the product catalog directly with the company.

(2) What is the Non-cutting method?

(a) In this method, a new pipe (steel pipe / resin pipe) is inserted into the existing underground old pipe to improve the function of old pipe.

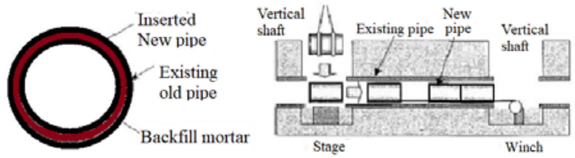


Figure-20 Image example of the method of inserting new steel pipe (Pipe in pipe) (800mm or more)

Figure-21 Image example of the method of inserting new Shrunk pipe (800 mm or more)

6-4-2 What is the rehabilitation method by reinforcement?

This method is a Non-open-cut method to improve the deteriorated function by inserting a resin-based reinforcing material (linings) into the underground aged pipe.

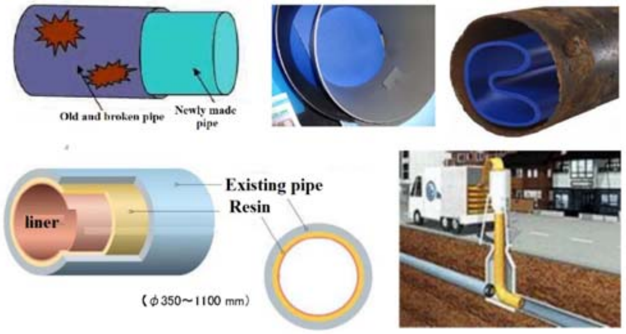


Figure-22 Image example of covering material insertion method

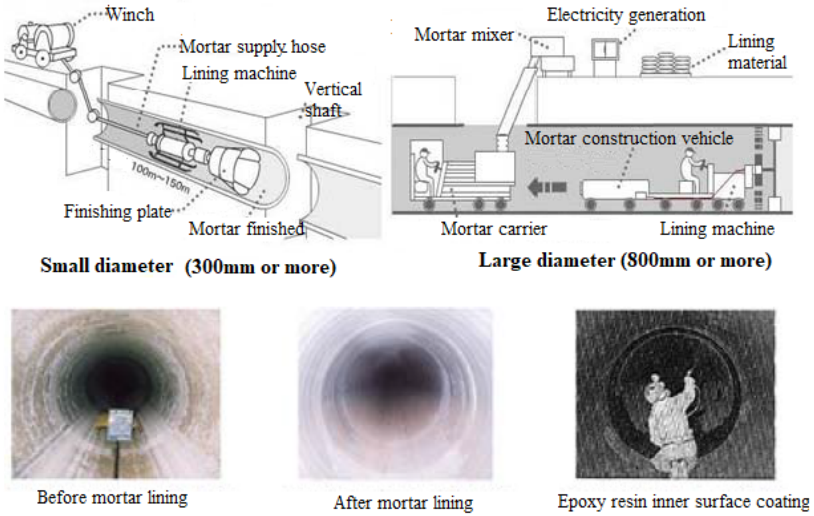


Figure-23 Image example of coating method （φ300～2000 mm）

6-4-3 Partial Repair Method (Replacement)

Partial repair is effective as a temporary emergency measure (temporary repair).
In particular, there is no significant deterioration in the pipe body, and the cause of water leakage is deterioration and/or damage of the joint and/or packing.

Replacement is performed to prevent water leakage or to partially repair the pipeline to cope with the problem.

6-4-4 Modification Method of Piping Route

This method is effective for pressure management, stable water supply, and leakage reduction measures by changing the piping route with new pipes.
In particular, the pipeline is covered with a building, and the topography of the installation is changed, and it is often applied to a place where it is difficult to improve by the ordinary improvement method.

6-5 Metal Pipes

The Corrosion of metal piping is the cause of NRW due to the occurrence of underground / ground leakage from the pipe network.

The method of suppressing the occurrence of this corrosion is shown below.

① Use corrosion resistant piping materials.
② Regularly take measures to prevent metal corrosion on the inner and outer surfaces.
③ Regular removal of deposits in piping (natural corrosion, bacterial corrosion)
④ Carry out early repair work so that corrosion does not progress with a small amount of water leakage.
⑤ pH neutralization of buried soil, etc.

In this chapter, we discuss the mechanism of occurrence of corrosion and corrosion protection.

6-5-1 Influence of metal corrosion on water distribution pipes

The influence on the "rust" generated on the inner / outer surface is shown below.

① Physical loss (NRW) due to occurrence of water leakage increases.
② Decrease the diameter of the inner diameter of the pipe and the roughness coefficient.
As a result, stable water supply (water volume / water pressure) and stable water quality (red water generation) become difficult.
③ Physical strength decreases with decreasing wall thickness.

As a result, the deterioration of the pipelines and the risk of occurrence of water leakage increase, the function of the water distribution network declines, and the possibility that the water supply service decreases.

④ The service life of the facility is reduced.

As a result, the renewal time of the facilities becomes earlier, and also the maintenance costs are increased, so the water charges are reflected in the increase.

6-5-2 Mechanism of occurrence of corrosion

(1) What is rusting (corrosion)?

The corrosion of the metal material is the action of the metal in an attempt to return to the ore (oxide) before refining, and in particular, the metal body buried in the ground is strongly affected by the action of this natural corrosion.

That is, corrosion is a phenomenon in which metals are chemically attacked by the action of the environment and return to nature

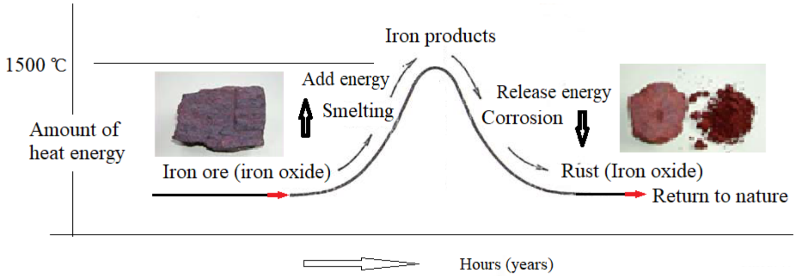


Figure-24 Image figure of process that refined steel gets rusted and returns to nature

(2) Progress rate of rust

The corrosion rate of common metal tubes is predicted to be 1.0 mm / year.

An example of evaluation of the corrosion rate is shown below.

Table-22 Corrosion (rust) Speed and Rating

	Thickness reduction	Judgment
Corrosion (rust) speed	1.0 mm/year or more	It cannot be used for most purposes
	0.01mm/year or less	It can be used for most purposes
	0.01 mm /Year or less	It can be used for aesthetically purposes

NOTE What is corrosion protection technology?

A general anticorrosion technology is a method of blocking the corrosive substance by coating (coating, plating) the surface of the metal in order to reduce the corrosion rate to

1.0 mm / year or less and approach 0.01 mm / year.

In addition, it can be said that using a material with excellent corrosion resistance is also a corrosion protection method.

6-5-3 Occurrence of corrosion due to destruction of oxide film (self-protective film)

The surface of the metallic material placed in the atmosphere is an ultra-thin film (2 to 5 nm thickness) of any material (Transparent metallic luster).

This ultra-thin oxide film protects the metal surface from corrosion.

(1) Corrosion that occurs under high temperature (Dry corrosion)

Dry corrosion is corrosion that proceeds in the absence of water at high temperatures (high temperature corrosion).

This is a corrosion phenomenon in which a metal directly reacts with a reactive gas such as oxygen in air (in the absence of water) to form a solid film of a reaction product (oxide) on the metal surface, and the corrosion resistance is high.

For example, the surface of polished iron placed in the air (including oxygen) grows in thickness of oxide film (black color) as the temperature is raised (several hundred degrees Celsius).

When the temperature is high and the oxide of iron exceeds 500 nm, a high temperature oxide film (30 to 500 nm) called scale is formed.

(2) Corrosion that occurs in the presence of water (wet corrosion)

Wet eating is corrosion that assumes the presence of water

The presence of water (Including materials related to corrosion reaction such as oxygen / acid etc.) is essential for corrosion occurring at normal temperature.

In particular, since the inner / outer surface of the water distribution pipe is used in the presence of water / the presence of moist soil, corrosion due to electrochemical action occurs.

(3) Classification by type of corrosion **(Refer to Figure-25)**

The general classification of occurrence of corrosion is shown below.

Table- Classification by type of corrosion.

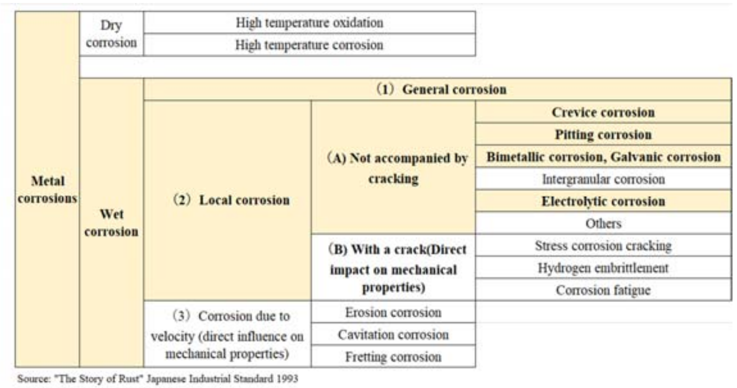


Figure-25 Classification by Type of Corrosion

(4) Classification of causes of corrosion occurring in buried pipes (**Refer to Figure 26**)

Generally, the corrosion that occurs on the inner and outer surfaces of the water distribution pipe is natural corrosion.

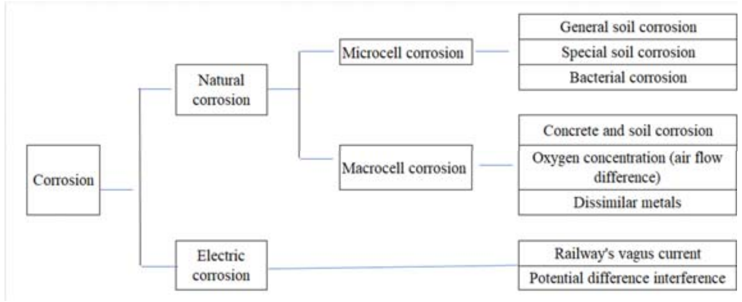
Natural corrosion

Natural corrosion is electrochemical corrosion.

The cause of natural corrosion is the contact between a minute foreign metal attached to the metal surface and the soil, electrochemical corrosion such as minute local cell action (potential difference), and anaerobic bacteria (sulfate reducing bacteria), Very small corrosion (0.1 mm / y).

The corrosion first causes small pitting (Pitting pin holes) on the surface of the metal, and corrosion (microcell corrosion) proceeds inside the metal.

In addition, electric corrosion (macro corrosion) due to electric corrosion due to stray current from train rails and generation of a potential difference due to PH difference between concrete and soil grows with time.



Source: Water supply facility design guidelines 2000 modified

Figure-26 Classification of Corrosion Occurring in Buried Pipe

(5) Main cause of corrosion

The factors that cause corrosion in laying piping are related to one another in a complex manner by several factors.

Table-23 Example of Main Factors Cause of Corrosion

Location	Outer surface corrosion	Inner surface corrosion
Causal factors	・Dissolved salinity ・Water / wetness ・pH ・Soil particles etc.	・Water temperature, ・ Water quality (Electrical conductivity, chlorine / turbidity, pH) ・ Flow rate ・ Sediments ・Bacteria, etc.

(6) Occurrence of corrosion

The occurrence of corrosion (rust) is shown below.

-There is a yellow product on the metal surface.

-There is no product left, but the metal surface is broken down (melted).

-The metal surface is broken by large and small corrosion holes.



(7) Several examples of corrosion mechanisms

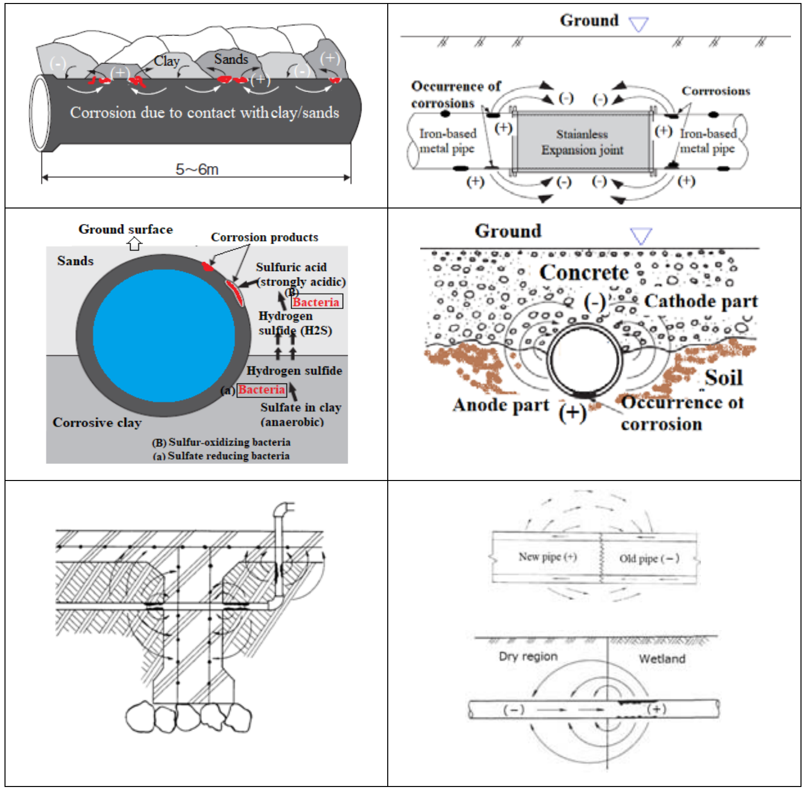


Table-24 Relationship between pH Value of Soil and Levels of Corrosion of Iron

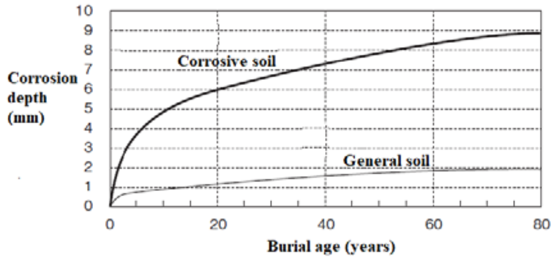
pH value		Degree of corrosion
4.5 or less	Acidity	Very corrosive
4.5 to 6.5	Mild acidity	Corrosive
6.5 to 8.5	Neutral or slightly alkaline	Non-corrosive
8.5 or more	Alkalinity	Unknown

Source: Japan Ductile Iron Pipe Association Technical Data (JDPA T 11)On the Corrosion Gain of Buried Pipeline and Its Corrosion Protection

6-5-4 Example of corrosion rate

(a) External corrosion due to soil pH

The example of the corrosion rate by the change of soil pH is shown below.



Source: Japan Ductile Iron Pipe Association Technical Data (JDPA T 11)

Figure-31 Corrosion Depth Prediction (cast iron pipe)

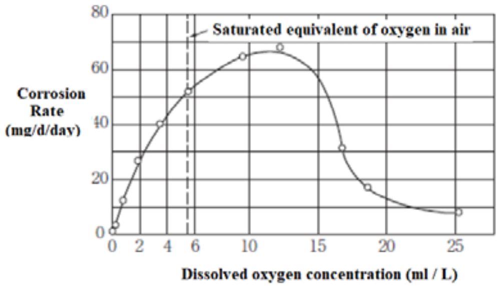
(b) Internal corrosion due to water flow

①For dissolved oxygen, the corrosion rate of metal tubes at neutral pH water differs depending on the amount of dissolved oxygen.
When the amount of dissolved oxygen is high, the corrosion rate of iron decreases.

②As for the water temperature, the corrosion rate rises to 80 ° C, but at higher water temperatures, the rate of corrosion decreases because the amount of dissolved oxygen decreases.

③As for the flow rate, corrosion increases as the flow rate increases because the concentration of oxygen supplied to the metal surface increases.
However, when the flow rate is further increased, the corrosion rate is reduced, but the oxide film and the corrosion products are mechanically broken and the cavitation is damaged.

④In the case of hard water, the higher the concentration of calcium carbonate (Langelier’s index) on the inner surface of the metal pipe, the less the formation of red water due to corrosion because a sediment layer is formed on the inner surface(scale formation).



Source: Japan Ductile Iron Pipe Association Technical Data (JDPA T 11)

Figuer-32 Relationship between dissolved oxygen concentration and corrosion rate (cast iron pipe)

6-5-5 Definition of Corrosion Rate

When a water leakage accident occurs, there is a method of calculating the rate of corrosion as a standard to determine whether the cause is microcell corrosion or macro-cell corrosion.

$$\text{Formula} \ldots \text{Corrosion rate (mm / Year)} = \frac{\text{Thickness reduction (mm)}}{\text{Buried age (years)}}$$

NOTE; Judgment index for corrosion condition
Declare 0.03 mm / year or more as macro-cell corrosion

Source: Pipe and Environmental Survey Manual

6-6 Countermeasures Against Corrosions

Corrosion protection is a means to slow the rate at which metal pipes return to their natural state (**Refer to Figure-24**).

6-6-1 General Corrosion protection methods

(1) Method of coating the surface of metal to block the contact of corrosion factors.]

① Painting / coating method

<u>Feature</u>

(a) It is a commonly used anticorrosion measure.

(b) The inside and / or outside of the metal tube is protected by coating or covering materials.

(c) The on-site painting operation should prevent the occurrence of pinholes that may cause deterioration / corrosion of the coating.

Table-25 Example of Various Anticorrosion methods and Applicability

By diameter	Medium and large diameter pipes		Small diameter pipes	Cast iron pipes	
Corrosion protection method	Inside	Outer surface	Inside	Inside	Outer surface
	Water supply	Underground	Water service	Water supply	Underground
Liquid epoxy coating	Excellent	—	—	Excellent (300μm)	Excellent
Coal tar epoxy coating	Good	—	—	Excellent	Excellent
Vinyl chloride lining	—	—	Excellent	—	—
Polyethylene powder sintered lining	Excellent (2.0~0.5 mm)	—	Excellent (0.3~0.4 mm)	—	—
Acrylic resin lining	Excellent			—	—
Mortar lining	Excellent	—	—	Excellent	Excellent
Zinc plating(Galvanized steel pipes)	OK (550~600g/m² or more)	—	Good(550~600g/m² or more)	—	—
Asphalt Vinylon cloth coating	—	Excellent (3.0~7.5 mm)	—	—	—
Coal tar Etemel glass cloth coating	—	Excellent (3.0~7.5 mm)	—	Excellent	—
Polyethylene coating	—	Excellent	—	—	Excellent
Polyurethane coating	—	Excellent	—	—	Excellent
Electric corrosion protection	—	Excellent	—	—	—
Coating and electric corrosion protection	—	Excellent	—	—	—

NOTE: Selection of type of paints
Because there are many types of paint used for corrosion protection and also the required film thickness, it is desirable to select the specifications by referring to the opinions of specialized manufacturers.

② Method of galvanizing inner and/or outer surfaces

<u>Feature</u>

Galvanization is impervious to oxygen and water and has good adhesion to iron.

Corrosion rate of zinc plating is very low

Table-26 Erosion Rate of Various Metallic Materials in Natural Environment (mm / year)

Environment	Copper	Zinc	Aluminum
Atmosphere (industrial zone)	0.002	0.005	< 0.001
Sea water	0.015	0.015	0.002
Buried pipe (soil)	0.003	0.015	< 0.001

Source: Japan Standards Association "Story of Rust" 1993

(2) Methods using resin tube with excellent corrosion resistance (e.g. PE Pipe, PVC pipe)

Features:

No need for plating and painting.

(3) Method of using metal with excellent corrosion resistance (e.g. SUS, titanium pipe,etc.)

Features:

No need for plating and painting.

(4) Electric corrosion protection (External power supply method, current anode method, stray current corrosion discharge method)

Features:

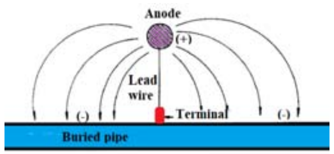
Characteristics: The corrosion protection can protect metal piping where paint and plating cannot be performed.

6-6-2 Introduction of Electric corrosion protections

(1) Principle

In non-ferrous piping buried in the water or in the ground, current flows out in the process of "rusting" to form a corrosion circuit.

According to this principle, if current flows from the ground to the buried pipe through the anode plate (zinc, magnesium, aluminum, etc.), the anode plate is consumed, but no corrosion occurs because no electrical displacement occurs in the piping.



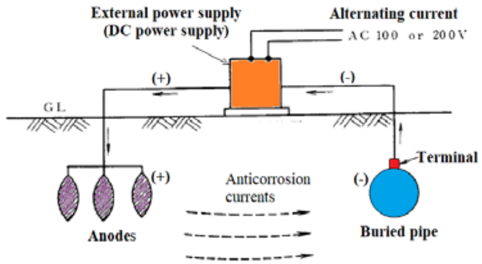
Figuer-33 Principle of Electric Corrosion Protection

(2) External power supply method

A common AC power supply is converted to DC with a DC power supply, and corrosion current is supplied from the underground anode electrode to the piping.

It is used for anticorrosion measures of relatively large equipment.

In addition, power supply is necessary,



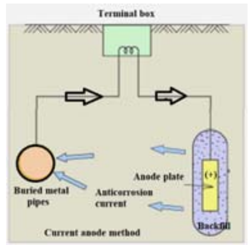
Figuer-34 Principle of External Power Supply Method

(3) Current anode method

This is a method of generating a corrosion prevention current by utilizing the potential difference between an anode metal body (Al, Zn, Mg) softer than a buried steel pipe and a dissimilar metal generated in the buried pipe.

Anti-corrosive objects are mainly used for anti-corrosion measures of relatively small equipment.

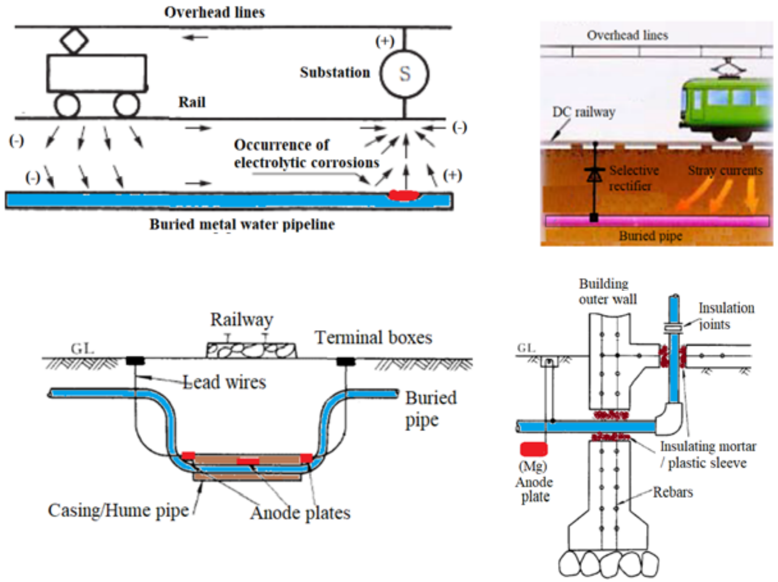
Although the power supply is unnecessary, the anode plate is consumed, so regular inspection is necessary.



Figuer-35 Principle of Current Anode Method

(4) Stray current corrosion

At the place where the underground piping is electrolytically corroded by the leakage current (stray current) from the DC rail, a selective return rectifier that returns the leakage current to the rail is connected to the rail to prevent the electrolytic corrosion.



Figuer-36 Principle of Stray Current Corrosion Protections

7. Non-ferrous Metal Pipes (Synthetic Resin Pipes)

7-1 Overview

A nonferrous metal pipe is a pipe made of a material (eg, stainless steel pipe, synthetic resin pipe, concrete pipe, asbestos pipe, etc.) and is defined as excluding steel pipe / cast iron pipe.

In recent years, among non-ferrous metal pipes, synthetic resin pipes (eg, PE, PVC) are frequently used as piping materials having physical strength and suitable for corrosion prevention.

In addition, if the asbestos pipe is used for a long period of time, its physical strength deteriorates, and it is likely to cause a water leakage accident due to damage.

Figuer-37 Damaged Asbestos-cement Pipe

7-2 Classification of Synthetic Resin Pipes

The Synthetic resin pipes used for water supply are manufactured from thermoplastic resins (which soften when heated) as polyethylene（PE）pipes, unplasticized polyvinyl chloride (uPVC) pipes, and Polybutene (PB) pipes etc..

(1) Features

① No rust or electrolytic corrosion.

② No water pollution due to the occurrence of red rust.

③ No elution of harmful substances and hygienic,

④ Low coefficient of friction and hard to scale,

⑤ Good for construction characteristic

⑥ When heated to the melting point, it becomes soft and can be easily formed by piping.

(2) Points to remember

① Creep phenomenon(When stress is applied to piping, strain increases with time)

② Large thermal expansion coefficient /linear expansion coefficient (As temperature rises, length and volume increase))

③ Restrictions on operating pressure and temperature conditions、

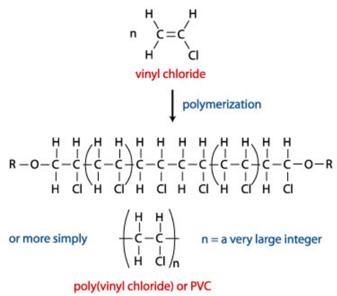
④ Deteriorated by heat and ultraviolet light,

7-2-1 Polyvinyl chloride (PVC) Pipes

(1) Chemical formula

The chemical formula of PVC is (-CH2-CHCl-) n, and in vinyl chloride, part of hydrogen is chlorine.

The molecular structure is shown below.



Figuer-38 Molecular Structure of PVC

(2) Features

① Molecular structure is the polymerization of a basic unit in which one chlorine is attached to a vinyl group (Amorphous resin：Molecular chain randomly present),

② Flame retardant and excellent electrical insulation,

③ Operating temperature limit is 60 ° C,

④ Low temperature may cause brittle fracture,

⑤ It exhibits self-extinguishing properties but emits irritating gas at the time of combustion,

⑥ Good chemical resistance, well resistant to acids and alkalis,

⑦ Very stable especially to chlorine and chloride,

⑧ Dissolves in nitrobenzene etc.,

⑨ Relatively high tensile strength compared to other tree species,

⑩ PVC has soft PVC and hard PVC products,

(3) Classification of hard polyvinyl chloride

(a) Hard PVC (PVC-U/uPVC): Most frequently used for distribution pipes.

(b) Impact resistant PVC (PVC-HI)

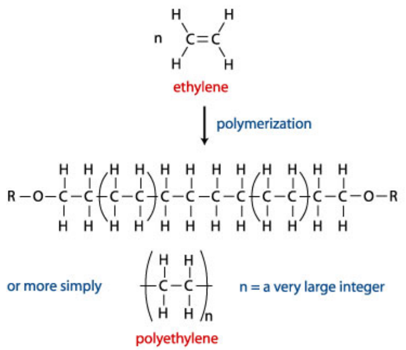
(c) Heat resistant polyvinyl chloride (PVC-C)

7-2-2 Polyethylene (PE) pipes

(1) Chemical formula

The chemical formula of PE is (-CH2-CH2-) n, ethylene (CH2 = CH2) is polymerized, and it consists only of C and H.

The molecular structure is shown below.



Figuer-39 Molecular Structure of PE

(2) Features

① One molecular structure is the simplest form composed of a straight chain of carbon and hydrogen (Crystalline resin；Molecular chain is regularly present),

② Excellent in flexibility, impact resistance, low temperature characteristics, earthquake resistance,

③ Absorbs water hammer pressure of water hammer,

④ Excellent compression recovery,

⑤ Highly corrosive,

⑥ Very small amount, but gas permeability is observed

⑦ The value of molding shrinkage is large

⑧ In oil / volatile soil, the resin deteriorates and the mechanical strength decreases,

(3) Classification of PE

(a) Low density polyethylene (LDPE)

(b) Medium density polyethylene (MDPE)

(c) High density polyethylene (HDPE)

7-2-3 Polybutene (PB) pipe

Because of its flexibility and strength, it is used in the field of domestic water supply pipes.

(1) Feature

① Easy to install and economical

② Excellent heat resistance (90 ° C)

③ Excellent heat retention effect

④ Waste materials do not produce harmful substances such as dioxin

⑤ Excellent chemical resistance

⑥ Absorbs water hammer pressure of water hammer,

⑦ The inner surface of the pipe is smooth

7-3 Cause of Water Leakage in Synthetic Resin Pipe

Water leakage occurs due to the overlap of the following causes.

(1) Mistake in material selection of joints in piping materials (occurrence of water leakage due to age-related corrosion)
(2) Joint work error
(3) Damage due to lack of burial depth
(4) Use of mismatch of material and usage condition
(5) Use of non-quality products、
(6) Use of degraded materials due to heat / ultraviolet light due to lack of storage control,
(7) Use of damaged pipe by lack of attention at the time of 6 transportation, etc.

7-4 Introduction to Product Standards

7-4-1 Example of PVC Pipes Quality Standards

The quality / installation of PVC pipes water piping products is standardized as follows.

(1) Example of Kenya standards
① Polypropylene Random (PPR) pipes (KS-ISO 15874),
② Unplasticized polyvinyl chloride (UVCU / uPVC) pipes (KS-ISO-1452 & EN 1452),

(2) Example of international standards
①International Organization for Standardization (ISO442-1～5 PVC),
②Japanese Industrial Standards (JIS Standard),
・Japanese Industrial Standards (JIS K 6742 to 6743),
・Japan Water Works Association (JWWA),
・Japan Industrial Water Association (JIWA),
・-Vinyl chloride pipe-Fittings association standards etc.
③Others
・API (American Petroleum Institute) standards,
・ASME (American Society of Mechanical Engineering) standards,
・ASTM (American Society for Testing and Materials) standards、

・British Standards (BS),
・India Standards (IS), etc.

7-4-2 Example of PE Pipes Quality Standards

The quality / installation of PE pipes water piping products is standardized as follows.

(1) Example of Kenya standards
① High-density polyethylene (HDPE) pipe (KS-ISO 4427),

(2) Example of international standards
① International Organization and Japan Standards
・ISO 4427－1996 / equality JWWA K144 ~JWWA K145
・ISO 4427-1-2-3-5 / equality JIS K 6761~6762
・ISO／DIS 4427-1994 (Safety factor)
・ISO 1167-1-2 /ISO 1133 / JIS K6778, JIS K6775(Test method)

②Others
・WIS－4－32－13（British Standard for safety factor）
・CEN-TC 155（European standard for safety factor）
・DIN 8075 （German standard for Testing）etc.

8. Unplasticized polyvinyl chloride pipes (uPVC)

8-1 Introduction of Resin Pipe Manufacturing Plant

A typical resin (PVC / PE) pipe manufacturing process (example Apexwater KAP Plastic Co., in Kenya) is shown below.

(1) Manufacturing process
The material of polyvinyl chloride pipe is added with a stabilizer / pigment to a high quality resin resistant to corrosion, uniformly stirred, heated and extruded in an injection molding machine.


(2) Product example

① uPVC Water distribution pipes / water service pipes

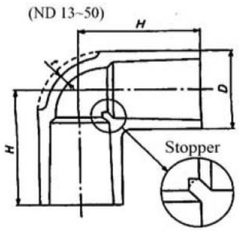
② uPVC Sewer pipes / drainage pipes / electric conduit pipes

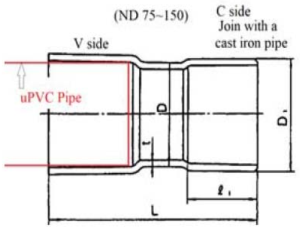


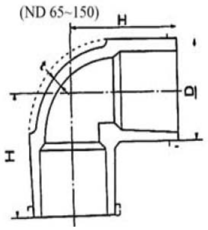
8-2 Overview of Piping connection method (medium-sized diameter)

The main connection methods of uPVC pipes using for medium-scale piping networks are introduced below.

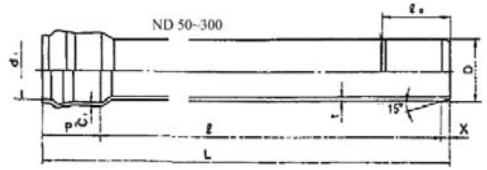
8-2-1 Example of Adhesive Joints

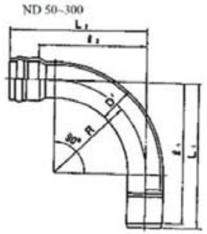


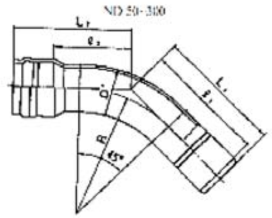




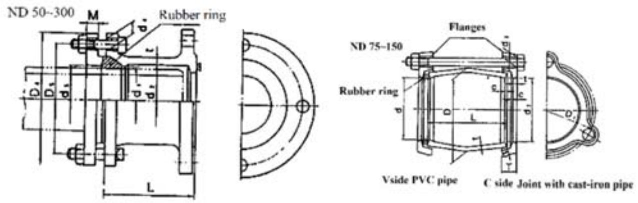
8-2-2 Slip-in Type Rubber Ring Joints

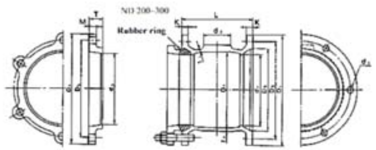







8-2-3 Others (dresser type joints, flange type joints, etc.





8-3 Details of Adhesive Bonding Method

Although this method is used in a wide range from small diameter to medium diameter, it often causes water leakage due to poor connection.

8-3-1 Principle

Adhesive bonding is the principle of making the socket of the joint tapered and swelling the surface of the polyvinyl chloride resin by applying a special adhesive for polyvinyl chloride pipe and bonding / drying.

When the adhesive is applied to both surfaces of the pipe and the joint, there are formed respective swelling layers of about 0.1 mm in thickness on the surface, and the pipe is fluidly inserted by these layers.

After insertion, the swelling layers of the pipe and the joint entangle and unite the bonding surface, and the solvent in the adhesive evaporates and dries to secure the bonding strength and the water tightness.

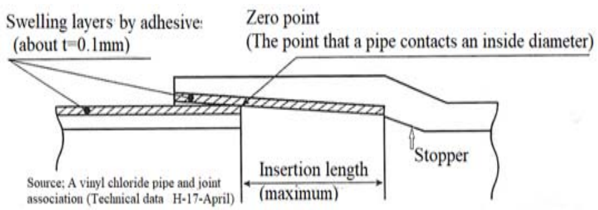


Figure-40 Principle of Adhesion Junction

8-3-2 Adhesive Bonding Points to Remember

(1) Remove dirt (oil, water, mud) on the connection surface (outside of pipe / inside of fitting)

(2) Remove the burrs (eq. with a trimmer) on the cut surface of the joint pipe.

(3) Be sure to use new connection pipes.

(4) Pipes are cut at right angles with a dedicated cutter.

(5) Securely insert the connecting pipe up to the stopper inside the joint.

(6) While bonding, let it stand (secure bonding time enough)

(7) The adhesive (use of standard product) is sufficiently applied to both sides cleaned (moisture removal, dust removal) and connected immediately.

Introduction to Rehabilitation Plan of Piping Network (Draft) 2019 July

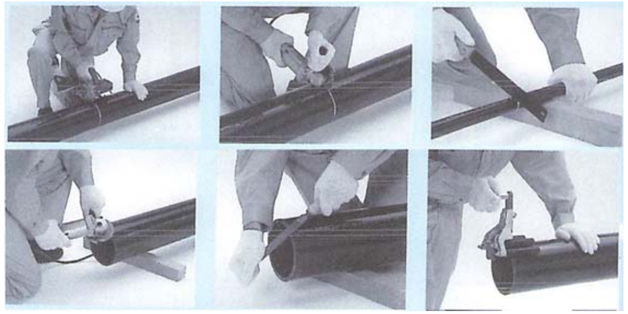


Figure-41 Methods of Cutting and Burr Removal (PVC)

NOTE:	
The fire adhesion method frequently **leaks** water due to the rise of water pressure, insufficient strength of the structural adhesion surface, insufficient adhesion time, etc., and is **not suitable for the repair method**.	 

8-3-3 Adhesive Specifications

Below are examples of adhesive specifications.

Table-27 Standard of Adhesives (JWWA S 101)

Adhesive types			Low viscosity	High viscosity
Display	Symbols		A	B
	Container color		Blue	Red
Adhesive force	Pull in at 20°C , size of N D13	After 15 min.	1.25 Mpa or more	1.25 Mpa or more
		2 hours later	2.50 Mpa or more	2.50 Mpa or more
Dry weight loss	In a 60-mm diameter weighing bottle, 10 g of the adhesive is placed in a thermostat at 60 ° C. and the loss on drying is measured every 30 minutes.		30～50%	30～50%
Viscosity	Measured with a rotational viscometer at 20 ° C		Less than 100-500 cp	Less than 500～3000 cp
Leachability	Taste		Not abnormal	
	Odor		Not abnormal	
	color		0.5 degree or less	
	Turbidity		0.2 degrees or less	
	Organic matter (TOC)		0.5 mg / L or less	
	Loss of residual chlorine		0.7 mg / L or less	

8-3-4 Required Bonding Time

The adhesion strength increases as the adhesion time increases.

An example of the required bonding time is shown below.

Table-28 Result of an Examination of change of Adhesive Strength by Time (Unit; Mpa)

Nominal Diameter (mm)		25 mm		75mm		150mm	
Ambient Temperature(°C)		0	20	0	20	0	20
Adhesive time	15 min.	4.66(Mpa)	5.83(Mpa)	1.91(Mpa)	2.16(Mpa)	2.16(Mpa)	2.55(Mpa)
	30min.	5.15	7.85	2.40	3.14	2.45	3.24
	1 hr	7.35	8.58	2.70	4.31	3.33	3.82
	2 hr	9.07	10.05	3.78	5.74	4.31	4.31
	3 hr	12.01(Mpa)	14.96(Mpa)	7.45(Mpa)	7.21(Mpa)	5.49(Mpa)	6.18(Mpa)

Source; Hard polyvinyl chloride pipe for water supply technical data Vinyl chloride pipe and joint association H17-04

8-3-5 Performance evaluation of adhesively bonded water distribution pipelines

(1) Tensile yield strength / molecular distribution measurement,

(2) The performance as a joint pipeline is evaluated by a water pressure test,

(3) Evaluate the adhesive strength of the adhesive (ultrasonic sensor).

(4) Evaluate degradation due to adhesive,

(5) Joint tensile yield strength test (50 to 65 Mpa @ 10 ~30 years old),

(6) Water pressure resistance test of joints (1.2 to 4.4 Mpa @ 25 to 34 years old years),

(7) Fitting molecular weight analysis measurement,

8-3-6 About discoloration

(1) Bleaching phenomenon

The surface of the polyvinyl chloride pipe is whitened by the oxidation chemical reaction due to the rise of the outside air temperature in the natural environment (air, pollutants, oxygen, ultraviolet light, ozone) in the hard polyvinyl chloride pipe, thereby surface deterioration (surface layer 0.1 to 0.2 mm), and as a result, the impact resistance tends to decrease.

(2) Black change phenomenon

It is believed that lead-based heat stabilizers used in PVC pipes react with sulfur in the soil to form lead sulfide and turn black (about 12 μm) and do not affect the strength.

9. Polyethylene Pipes (PE)

9-1 Introduction of Manufacturing Plant

9-1-1 Manufacturing Process

The material of the polyethylene tube is a polyethylene resin made from a low molecular weight compound (ethylene) as a polymer base, a pigment excellent in chlorine water resistance, an antioxidant, a weathering stabilizer, and uniformly heated after being stirred, It is extrusion molded by an injection molding machine.



9-1-2 Classification of Materials and Product Applications of Polyethylene Resin

Polyethylene products are classified into four types according to the quality of raw resin, reaction time, temperature, and mixing conditions of additives.

In addition, generally PE pipes for water supply use high performance (PE 100) mostly.

Table-29 Classification of Polyethylene Materials and Product Applications

Name of polyethylene pipes	Type of polyethylene material	Product name of polyethylene pipes
L-LDPE	Linear low density polyethylene	Polyethylene double-layer pipe for water supply
MDPE （PE80）	Medium density polyethylene	Polyethylene pipe for gas
HDPE	High density polyethylene	Polyethylene pipe for general use
PE100	**High-performance polyethylene (high density)**	General purpose high density polyethylene pipes
		Polyethylene pipe for water distribution

9-1-3 Composition of Crystal and Tie-molecules (Bonding/ link between crystals)

Physical properties of polyethylene (long-term creep strength, impact resistance, flexibility, impact resistance, compression recovery property, etc.) are influenced by the crystal structure and the "composition /volume of Tie-molecules" which bonds it

(1) Crystal and tie-molecules structure that constitute high-quality PE pipe (eq PE100)

The conditions of the structure of a crystal and Tie-molecules are shown below.

① The higher the density of crystals, the better the strength (stiffness),

② Tie-molecules is long and short branches,

③ There are many " Tie-molecular weights" which paste up a crystal portion and an amorphous part (space).

④ When there are many Tie-molecular weights, long age strength (creep, etc.) is excellent.

(2) Crystal and tie-molecules structure that constitute low-quality PE pipe (eq LDPE)

The conditions of the structure of a crystal and Tie-molecules are shown below.

① Low density crystals are easily broken and inferior in strength (stiffness),

② Tie-molecular is short,

③ There are little " Tie molecular weights" which paste up a crystal portion and an amorphous part (space).

④ When there are little "Tie-molecular weights", long age strength (creep, etc.) is poor.

◆In the past, low-carbon (LDPE) tubes containing carbon have had a history of causing the impact resistance of PE tubes to be significantly reduced due to the effects of chlorine water and aging, causing internal peeling, and causing many water leaks.

◆The current PE 100 uses a high-density polyethylene material (natural resin), and thus is excellent in creep resistance / impact strength / chlorination resistance.

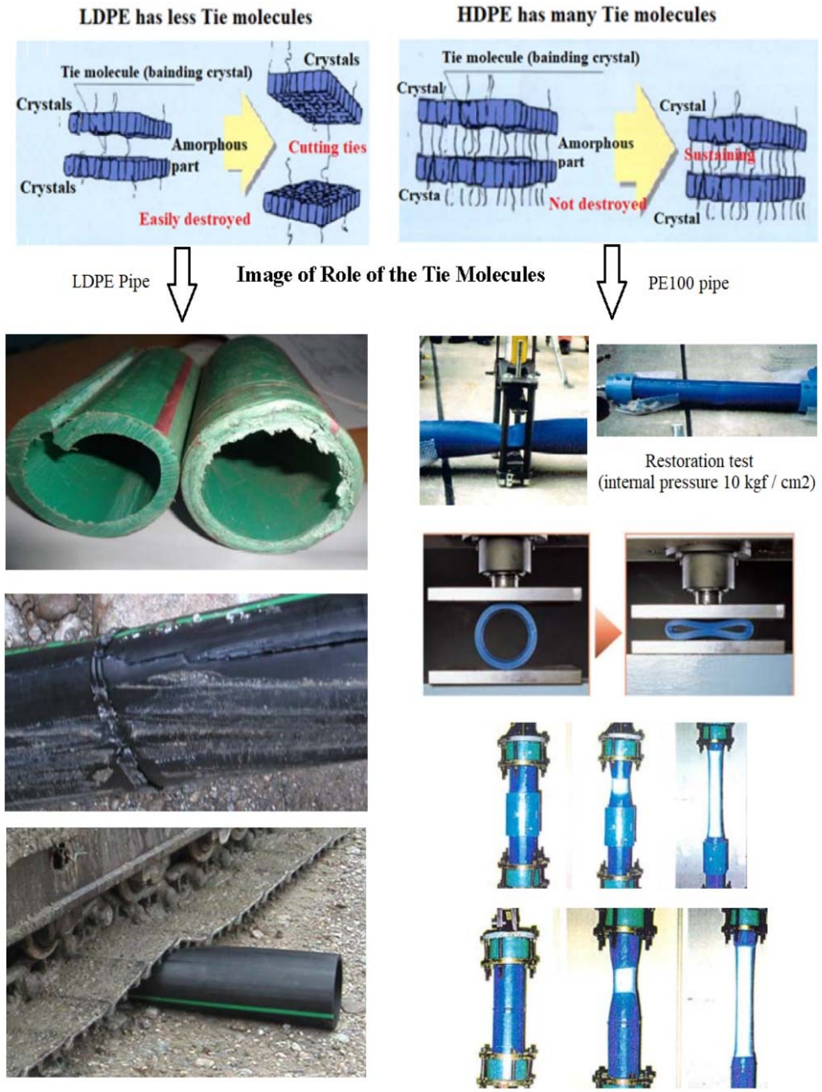
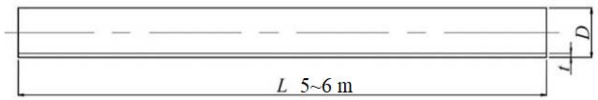


Figure-42 Example of PE Quality Strength Comparison

9-2 PE Pipe Products

The general straight pipe shape is shown below (50 to 300 mm).

(1) Straight-end Type



(2) EF end Type

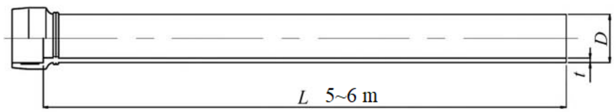


Figure-43 PE Pipe Ends

9-3 Overview of PE Piping Joint Methods (medium-sized diameter)

9-3-1 Thermal Heat Fusion Joint Methods

The principle of heat fusion is to heat two surfaces to a designated temperature, then fuse them together by application of a sufficient force. This force causes the melted materials to flow and mix, tie molecules thereby resulting in fusion. The joint area becomes as strong as, or stronger than, the pipe itself in both tensile and pressure properties and properly fused joints are leak proof, and as soon as the joint cools to near ambient temperature, it is ready for handling.

There are two types of conventional heat fusion joints currently uses in the WSPs; Butt fusion (BF) and Electrofusion (EF).

(1) Butt fusion (BF) joint

It is widely used as a PE joint method.

This is a method in which the bonding surface is melted with a hot plate, butted and pressure-welded. **(Details will be described in item 9-5**)

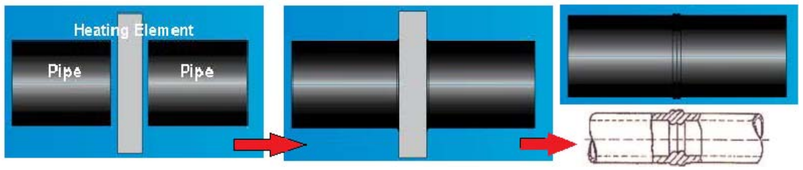
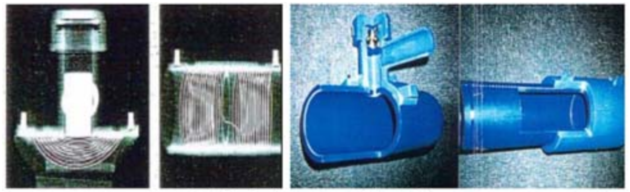


Figure-44 Butt Fusion Joint Process

(2) Electrofusion (EF) joint

EF is a joint method that heats fuses-heating wires in a coupling / saddle branching. **(Details will be described in Item 9-6**)



Saddle fusion and Coupling fusion

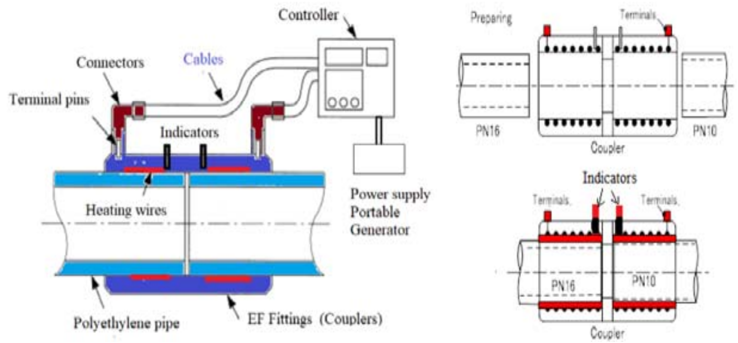


Figure-45 Electrofusion Joint Process

9-3-2 Mechanical Connections/Joints

There are many types and varieties of mechanical couplings / joints are available to joint PE to PE or other types of pipe; PVC, steel pipe and cast-iron pipes.

Figure-46 Example of Mechanical joint Methods

9-3-3 Others (Flange etc.)

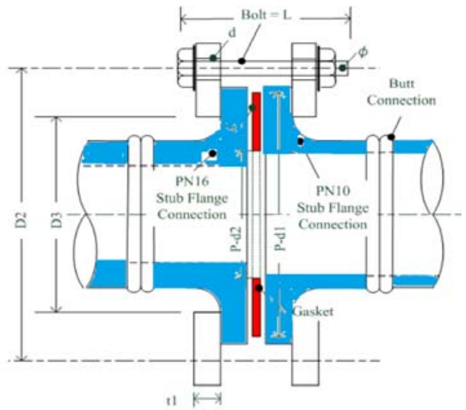


Figure-47 Example of Flange Joint Methods

9-4 PE Pipe Standard Products

9-4-1 Classification by ISO standards

Although PE 40 to PE 100 are specified, PE 100 (SDR = 11 to 17) is often used as pressure piping that withstands the maximum pressure (10.0 kgf / cm 2) of the piping network when it is used as water piping.

Coloring

Color of the PE pipe is either Blue or Black.

Table-30 Comparative Example of ISO 4427 and JWWA K 144

Standards		ISO 4427				JWWAK 144
PE classification		PE 100	PE 80	PE 63	PE 40	PE100
Minimum required strength (MPa)		10.0	8.0	6.3	4.0	10.0
Safety ratio		1.25 or more				2.0
Maximum design stress value (MPa)		8.0	6.3	5.0	3.2	5.0
Design water pressure (MPa)	SDR =6	—	2.5	—	—	—
	SDR =7.5	2.5	2.0	—	1.0	—
	SDR =9	2.0	1.6	—	0.8	—
	SDR =11	1.6	1.25	1.0	-	1.0
	SDR =13.6	1.25	1.0	0.8	0.5	—
	SDR =17	1.0	0.8	—	0.4	—
	SDR =21	0.8	0.6	0.5	0.32	—
	SDR =26	0.6	0.5	0.4	0.25	—
	SDR =33	0.5	0.4	0.32	—	—
	SDR =41	().4	0.32	025	—	—

Table-31 Material Designation and Corresponding Maximum Design Stress Values (ISO4427)

Designation	Minimum required strength (MRS) MPa	σ_s MPa
PE 100	10,0	8,0
PE 80	8,0	6,3
PE 63	6,3	5,0
PE 40	4,0	3,2
Design stress, σ_s, is derived from the MRS by application of the overall service (design) coefficient, C = 1,25. NOTE A higher value for C can be used; for example, if C = 1,6, this gives a design stress of 5,0 MPa for PE 80 materials. A higher value for C can also be obtained by choosing a higher PN class.		

Table-32 Example of Dimension Table for HDP Pipe/PE100 (ISO 4427)

Material: HDPE/ PE 100 (Design Stress 8.0 N/mm²)

DN	Wall Series S - 12.5			S – 10			S – 8			S - 6.3			S - 5		
	Standard Dimension Ratio SDR 26			SDR 21			SDR 17			SDR 13.6			SDR 11		
	Pressure Class PN 6.3			PN 8			PN 10			PN 12.5			PN 16		
de mm	e mm	ID mm	ml kg./m.	e mm	ID mm	ml kg./m.	e mm	ID mm	ml kg./m.	e mm	ID mm	ml kg./m.	e mm	ID mm	ml kg./m.
32	-	-	-	-	-	-	-	-	-	-	-	-	3.00	26.0	0.28
40	-	-	-	-	-	-	-	-	-	-	-	-	3.70	32.6	0.44
50	-	-	-	-	-	-	-	-	-	-	-	-	4.60	40.8	0.68
63	-	-	-	3.00	57.0	0.59	-	-	-	4.70	53.6	0.90	5.80	51.4	1.08
75	-	-	-	3.57	67.9	0.84	4.50	66.0	1.03	5.60	63.8	1.26	6.80	61.4	1.51
90	3.46	83.08	0.99	4.29	81.4	1.20	5.40	79.2	1.49	6.70	76.6	1.82	8.20	73.6	2.18
110	4.23	101.54	1.45	5.24	99.5	1.80	6.60	96.8	2.21	8.10	93.8	2.69	10.00	90.0	3.23
125	4.81	115.38	1.89	5.95	113.1	2.32	7.40	110.2	2.84	9.20	106.6	3.45	11.40	102.2	4.20
140	5.38	129.24	2.38	6.67	126.7	2.92	8.30	123.4	3.55	10.30	119.4	4.34	12.70	114.6	5.25
160	6.15	147.7	3.11	7.62	144.8	3.82	9.50	141.0	4.65	11.80	136.4	5.67	14.60	130.8	6.87
180	6.92	166.16	3.90	8.57	162.9	4.79	10.70	158.6	5.90	13.30	153.4	7.18	16.40	147.2	8.84
200	7.69	184.62	4.82	9.52	181.0	5.95	11.90	176.2	7.26	14.70	170.6	8.85	18.20	163.6	10.91
225	8.65	207.7	6.05	10.71	203.6	7.53	13.40	198.2	9.22	16.60	191.8	11.44	20.50	184.0	13.81
250	9.62	230.76	7.52	11.90	226.2	9.20	14.80	220.4	11.31	18.40	213.2	14.07	22.70	204.6	17.02
280	10.77	258.46	9.40	13.33	253.3	11.63	16.60	246.8	14.48	20.60	238.8	17.67	25.40	229.2	21.32
315	12.12	290.76	11.94	15.00	285.0	14.63	18.70	277.6	18.34	23.20	268.6	22.38	28.60	257.8	27.04
355	13.65	327.7	15.11	16.90	321.2	18.91	21.10	312.8	23.33	26.10	302.8	28.38	32.20	290.6	34.31
400	15.38	369.24	19.12	19.05	361.9	24.12	23.70	352.6	29.52	29.40	341.2	35.99	36.30	327.4	43.55

9-4-2 Characteristics of PE100

(1) Molecular structure

As described above, the quality of PE 100, which is used as a water distribution pipe material, improves long-term hydrostatic pressure strength and stress crack resistance by increasing the number of tie molecules connecting crystal structures (reinforcing between crystals), It is a resin pipe that improves impact resistance and has appropriate flexibility.

(2) Physical properties

Examples of general physical properties of polyethylene resins (materials) are shown below, but the range of strength of physical properties differs depending on the production process / quality standard of each country.

Table-33 Example of Typical Physical Properties of Resins (Raw material)

(Legends; ● is V. good, ○ is Good , ▲ is so-so

Items	Low density PE (LDPE)	Medium density PE (M D P E)	High density PE (HDPE)	High-performance density PE (HPPE: PE100)
Density	0.91～0.93	0.93～0.941	0.942～0.945	0.9-0.958
Tensile yield strength (kgf / cm2)	6～160	100～250	200～400	250
Tensile elongation at break (%)	90～800	50～700	50～800	500 or more
Environmental stress cracking	●	●	○	●
Heat-resistant	20～40℃	20～40℃	20～40℃	20～50℃
Embrittlement temperature	—	—	-18℃	-71℃
Impact strength	●	●	○	●
Flexibility	●	○	▲	▲
Chemical resistance	●	●	●	●

Table-34 Comparative example of Performance by Other Pipes

(Legends; ● is V. good, ○ is Good , ▲ is so-so

Items	HPPE pipes	Duc・cast iron pipes	PVC pipes
Weight (kg)	●	▲	●
Workability	●	▲	●
Repairability	○	○	○
Uninterrupted water diversion	○	○	○
Earthquake resistance	●	○	○
Pressure resistance	●	●	○
Corrosion and chemical resistance	●	▲	○
Tensile strength	●	●	○
Breaking point	●	▲	○
Weatherability	○	●	●
Dissolution	●	●	●
Comprehensive evaluation	●	○	○

(3) Performance guarantee

Even after 50 years of use at 20 ° C., it has been proved to be a polyethylene material which can withstand a constant stress value of 10.0 MPa (102 kgf / cm 2) or more.

In fact, durability (lifetime) of over 100 years has been verified / confirmed.

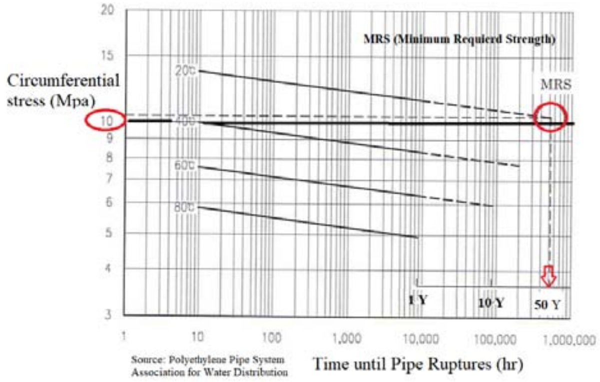


Figure-48 Creep Curve in Heat and Internal Pressure by Time

9-5 Design

9-5-1 Points to Note in Design

Points to keep in mind are shown below.

(1) The standard useful life is at least 50 years if the water temperature is 20 degrees,

(2) The maximum pressure (static pressure 7.5kgf / cm^2 + water hammer pressure 2.5kgf / cm^2) shall be 10kgf / cm^2 (10 bar),

(3) The working water temperature shall be 30 to 40 degrees or less,

(4) The wall thickness of the PE tube depends on the permitted internal pressure value,

(5) For joining with different types of tubes, check the outer diameter,

(6) Burial work in areas contaminated with organic solvents (gasoline, etc.) requires protection of the outer surface of PE.

(2) Safety factor

(a) For the safety factor, consider the wall thickness safety factor at 2.0 to 1.25 times under conditions such as high internal pressure, high water temperature, severe deterioration due to soil contamination, and high external pressure.

(b) ISO standard recommends 1.25.

(3) Permissible pressure (durability standard)

(a) The maximum allowable pressure (PMS) of the pipe is 10 kgf / cm2 (10 bar, 1.0 Mpa).

(b) The calculation method of Standard Dimension Ratio (SDR) is shown below.

$$\textbf{SDR} = \frac{\textbf{DN}\text{(Nominal outside diameter)}}{\textbf{t}\text{(Minimum wall thickness at any point)}}$$

◆ Example; DN = 280 mm, t = 25.4 mm → SDR = 280 / 25.4 = 11

9-6 Detailed Explanation of Butt Fusion (BF) Joint Method

9-6-1 Principle

The most widely used method for joining individual lengths of PE pipe and pipe to PE fittings is by heat fusion of the pipe butt ends as illustrated in **Figure-44 and Figure-49.**

According to the BF principle, the outer surface of the polyethylene pipe to be connected is melted by a hot plate (electrical type), and then the fusion melt surface is pressure jointed immediately.

Quality butt fusion joints are produced by using trained operators and quality butt fusion machines in good condition.

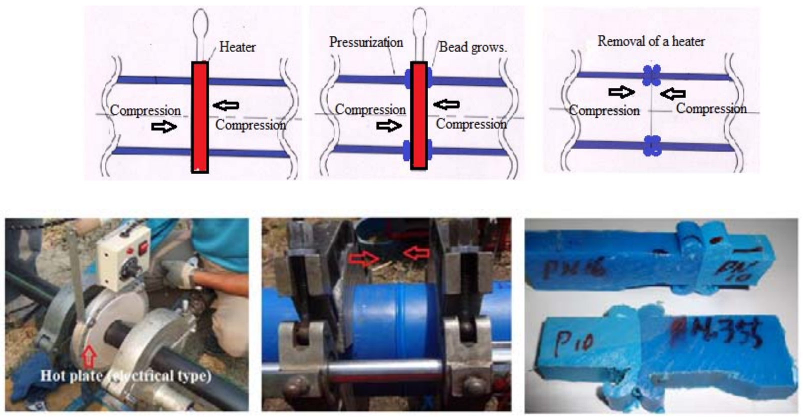


Figure-49 Topical Butt Fusion Joint

9-6-2 Related standards (BF)

① ISO 11414- 1996-06-01

② ASTM D3261-16

③ DVS-2207-1 (Germany) Others

9-6-3 Fusion Equipment and Work Schedule (BF)

(1) Management of heating plate temperature

Since the heating conditions are affected by the on-site climatic conditions, periodic thermal plate temperature control (about 210 ° C. or more) is essential.

(2) Required Capability of BF machine

- Aligning the pipe ends and Clamping the pipe
- Peeling both side pipe ends
- Facing the pipe ends parallel and square to the centerline
- Heating the pipe ends and Applying the proper fusion force

(3) Required BF joint devices

① Saw / Electric peeling machine/ Clamps,

② Electric heating plate for Heating the pipe ends,

③ Operating machine of crimp clamp for applying the proper fusion force,

④ Power supply (5kva Portable Generator) / Tool Box, etc.

Figure-50 Typical BF Joint Equipment

Table-35 Estimation of Manpower required

Exampl of Manpower List		
1.	Plumber Forman	1 person
2.	Butt Fusion Machine Operator	1 person
3.	Helper	3 person

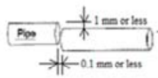
Table-36 Example of BF Joint and Cooling time Required

				Ambient temp (30℃)	Ambient temp (35℃)		
Pipe Size (mm)	Setting Time	Trimming Time	Fusion Time	Cooling Time (1)	Cooling Time (2)	**Total Time/joint (1)**	**Total Time/joint (2)**
50-100	6～10 min.	5 min.	5 min.	20~30 min.	40～50min.	**35 ～50min.**	**50～80 min.**
100-150	8～15 min.	5 min.	5 min.	20~30 min.	40～50min.	**35 ～50min.**	**55～66min.**
150-200	12 ～15min.	5 min.	5 min.	25 ~30min.	45~50min.	**40~60 min.**	**65~90 min.**
200-250	15～20 min.	5 min.	5 min.	35~50 min.	45~60min.	**50～70 min.**	**70～90min.**

Table-37 Example of Procedure of BF Joint

Example of Conditions Of Welding for PE80/100

Step	**Items**	**DN (Pipe outside diameter)**			
		100	**150**	**150~200**	**200~250**
1	**Setting up Pipe** • Clean Pipe Inside and outside properly • Check damage, scratch and crack on pipe surface • Check straightness, roundness of pipe.				
2	**Peeling of both Pipe surfaces by motor- cutter** • Peel both side pipe of oxidised surfaces.(peeling depth requered 0.3~ 0.5mm) • Confirm a smoothed-out surfaces.				
3	**Adjustment of Pipe Centerline** • Adjustment of Pipe centerline				
4	**Cleaning Inside Pipe** • Clean up inside of pipe • Don't touch tpeeled surface, if touch it then trim again • Clean up with clean cloth				
5	**Adjustment of Temperature** • Adjust temperature 210°c (±10°c) • Make sure heating plate face is not dirty				
6	**Set Heating Temperature (Depend on OAT)**	(210±10)°C	(210±10)°C	(210±10)°C	(210±10)°C
7	**Set Melting Time (Sec)**	90~100	120~150	120~200	160~200
8	**Melting Pressure(Kg/cm²)**	15	15	15	20
9	**Additional pressure Time (Sec)**	60	60	60~90	60~90
10	**Removing Heating Plate time (Sec) (With in) Don't touch other surface of pipe**	5	5	5	5
11	**Joint Pressure (kg/cm²)**	20	20	25	28
12	**Compression Time (Sec) (Zero Pressure)**	90	120	120	160
13	**Cooling Time(Minutes)**	20~30	20~30	25~30	35~50
14	**Observation (Check bead width and height)**				
14-1	Bead Height(H:mm)	2.2~4.6	2.6~6.5	3.0~7.0	3.0~7.0
14-2	Bead Width(W:mm)	5.5~10.5	6.5~15.0	7.0~16.0	7.0~16.0



9-6-4 Quality Control Method (BF)

The quality control method of BF junction is shown below.

① Fused beads inspection,

② Hammering inspection,

③ Sampling Physical inspection,

④ Water leakage test by Hydraulic test.

(1) Fusion beat inspection

Generally, In-situ quality control methods are implemented by bead inspection and hammering inspection.

The following shows how to test the grown beads with a gauge. **(Refer to Table-37,14-1 and 14-2)**

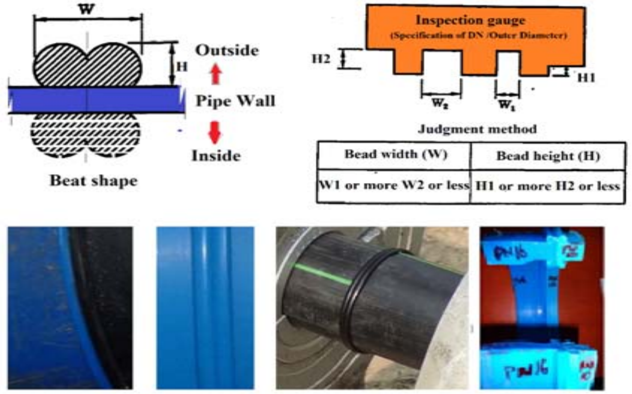


Figure-51 BF Bead Inspection by Gauge and Normal Fusion Bead

(2) Water leakage test by Hydraulic test.

① Example of Hydraulic test by BF connection test piece

In the water pressure test with the BF connection test piece, a water pressure of over 6 bar is applied to the test pipe, and the change in water pressure thereafter is recorded for 24 hours.

Since the PE pipe has the ability to absorb pressure, the hydraulic pressure change decreases gradually with time, but eventually the hydraulic pressure stabilizes.

From the connection part, the leak test evaluation is judged by whether or not a rapid drop in water pressure occurs.

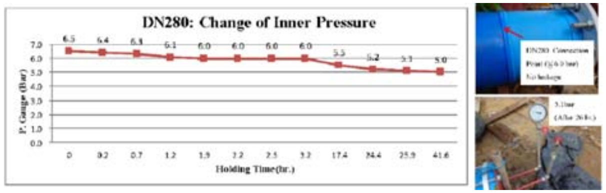


Figure-52 Example of Hydraulic test by BF Joint Test Piece

② Example of procedure of Hydraulic test of laying PE pipeline

(a) Water flow will start one hour or more after completion of EF bonding,

(b) Clean the inside of the pipe and confirm that the air in the pipe has been completely removed,

(c) Hydraulic test shall be implemented a section up to 500 m / one test,

(d) In the Hydraulic test, the water pressure in the pipe is increased to 0.80 MPa, lowered to 0.75 MPa, and the water pressure after 24 hours is confirmed,

(e) Evaluation (after 24 hours)

・When it is 0.5MPa or more, it is considered as a pass.

・If it is less than 0.5MPa, it will be rejected and re-tested.

9-6-5 Troubleshoot (BF)

Typical the causes and measures of fusion defects (beat irregularities) are shown below.

Table-38 Troubleshoot (BF joint)

Phenomena	Causes	Measures
PE pipe faces to be fused do not become parallel	Deformation of Pipe core circle,	Replace/change the pipe,
	No match Wall thickness (SDR is different),	Use others joint method (Mechanical joint),
	Uneven clamp tightening,	Adjust the clamp tightening,
Fused surface does not adhere	Both connecting faces are not at right angles,	Peel / grind enough,
	Cannot peel,	Sharpen or replace Cutters/Check the fixing clamp,
	Not tighten clamps,	Fix at the position where the fusion side contacts,
	Dirty Connection surfaces,	Peel the deeper / remove dirt,
Insufficient beat height and width	Insufficient heating temperature and/or heating time,	Review of fusion process, Heating plate repair/repair,
Slow Beat growth	Insufficient crimping force, Insufficient crimping time, Material quality of PE pipe is different,	Accuracy check of control, Use material quality of PE pipe,

9-7 Detailed Explanation of Electrofusion (EF) Joint Method

9-7-1 Principle

This technique of heat fusion joining is somewhat different from the conventional fusion (BF) joining thus far described. The main difference between conventional heat fusion (BF) and electrofusion (EF) is the method by which the heat is applied.

EF joint is heated internally, either by a conductor at the interface of the joint or, as in one design, by a conductive polymer. Heat is created as an electric current is applied to the conductive material in the fitting. **Figure-45 and Figure-53** illustrate a typical electrofusion joint.

PE pipe to pipe connections made using the electrofusion process require the use of electrofusion couplings, saddle fusion etc.

SIZE (d)	D	Z	L
20	34	38	80
25	39	40	84
32	46	38	80
40	55	43	90
50	66	48	100
63	82	62	128
75	98	61.5	127
90	117	65.5	135
110	142	70.5	145
125	162	82	168
140	173	86	175
160	203	88	180
180	226	95	194
200	251	102.5	205
225	280	113	226
250	312	117.5	235
280	347	127	254
315	389	132.5	265

* All unit measurement are base on (mm)

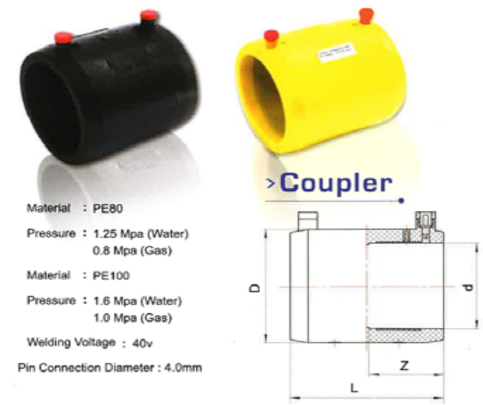


Figure-53 Example of Selection chart of Electrofusion Couplings

9-7-2 Related standards (EF)

① ISO 12176-2/3/4:2008

② ASTM F1055 - 16a

③ DIN 14963/8074/8075, others

9-7-3 Fusion Equipment and Work Schedule (EF)

(1) EF joint work in rain

Establish a rain protection facility.

(2) Required Capability of EF machine

(a) Fusion process

The fusion process is controlled by a controller.

(b) EF control method

It is divided into the automatic method (eg, pressure detection / temperature detection, control of the power on time) and the semi-automatic method (bar code method).

Welding equipment has to supply the required voltage for the electro-fusion-joint.

(c) Pressure detection method

A commonly used EF control system is an energized self-control system (pressure sensing type).

The pressure system detects the rising pressure of the rising melt indicators, and that device must switch off automatically when the melt indicator is raised by pressure

(3) Example of controller specification for pressure sensing method

(a) Enter the fusing conditions from the barcode into the controller。

・Setting of fusion time

・ Fusion temperature and calibration of environmental temperature (heating temperature of nichrome wire；200 to 250 ° C:)

(b) Required controller voltage output （Japan Standard)

・ Primary side: 60 to 130 V

・ Secondary side: 39.5 to 75 V ± 2.5%

(d) Weather conditions used

・- 5~-40 ℃

(e) Power generation capability (for controller only)

・ Single phase AC 100V (Japan Standard)

DN	20～40	50～150	200	250～300
Output	0.9 KV or more	2.0KVA or more	2.8KVA or more	3.5KVA or more

(4) Required EF joint devices

・Pipe cutters

・Electric peeler / scraper

・Clams /Controllers/ Power supply, generator

・Cleaning goods for fusion surfaces and others

Figure-54 Typical EF joint Equipment

NOTE: Fusion and cooling time determination
The required fusion time and cooling time are different depending on the EF manufacturing company and must be confirmed.

Table-55 Example of EF Joint time Required

Nominal diameter (A)		Fusion time (Seconds)						
		25	30	50	75	100	150	200
Coupling /Socket		60~75	60~90	75~110	115~120	200~240	260~360	460~510
Fitting Cheese		60~75	60~90	80~110	120~160	200~240	220~260	300~460
90° Elbow		60~75	60~76	75~110	120~140	200~240	260~360	460~550
Cap		50~75	60~90	100~110	100~180	160~190	200~220	300~350
Deformed cheese	30 x 25	60~65		110~120		250~300		—
Deformed elbow	30 x 25	—	85~90	—	—	—	—	—
Deformed coupling	30 x 26	—	85~90	—	—	—	—	—
Deformed Reducer	50 x 30	—	—	9~110	—	—	—	—
	75 x 50	—	—	—	155~170	—	—	—
	100 x 75	—	—	—	—	170~190	—	—
Saddle branch fittings	25	—	—	120~150				
Repair saddle	50	—	—	—	120			—

Table-56 Example of EF Cooling time Required

Coupling cooling time	
Nominal diameter (A)	(minutes)
25	
30	**5**
50	
75	
100	**10**
150	
200	

Saddle cooling time	
Nominal diameter (A)	(minutes)
50 x 25・30	
75 x 25 ・ 30 ・50	
100 x 25 ・30・ 50	**5**
150 x 30 ・ 50	
200 x 30 ・ 50	
150 x 75	**10**
200 x 75	

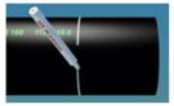
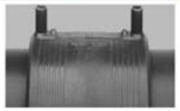
Steps	Items
A	EF Joint works
A-1	Fill in the insertion length of the insert on the pipe and Mark the fused surface with a wavy line.    
A-2	Peel cutting of the face to be fused ((Screped with 0.1 ~ 0.2mm thickness)  
A-3	Cleaning of fused surface (pipe outer surface and coupling inner surface; use Ethanol paper,etc. to remoe water, oil and mud)   
A-4	Confirmation of insertion depth 
A-5	After combining the pipe, align and restrain pipe and fitting, fix firmly to clamp.    
A-6	Enter fusion conditions from the barcode into the controller、    
A-7	Implementation of fusion (Apply the electrofusion),Temperature of junction environment; 30 to -10 ° C, rain protection is necessary)    
A-8	Check the status of raised melt indicator after welding   
A-9	Confirm fusion end time and cooling end time (Clamp remains fixed)
A-10	Removal of clamp (completion of fusion work) and document the fusion process

Figure-55 Example of Procedure of EF Joint

9-7-4 Quality Control Method (EF)

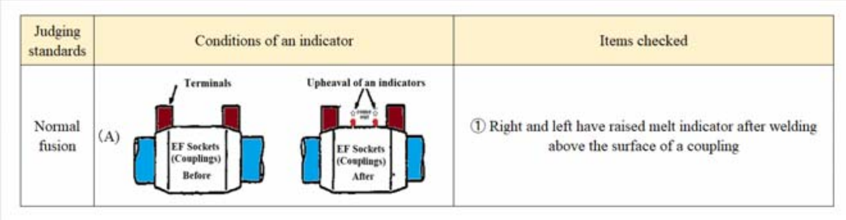
The confidence of the EF junction is higher than BF.

The quality control method is shown below.

<u>Test method</u>

It is similar to the examination of BF.

In the field, it judges by the uplift situation of the both melting indicators.

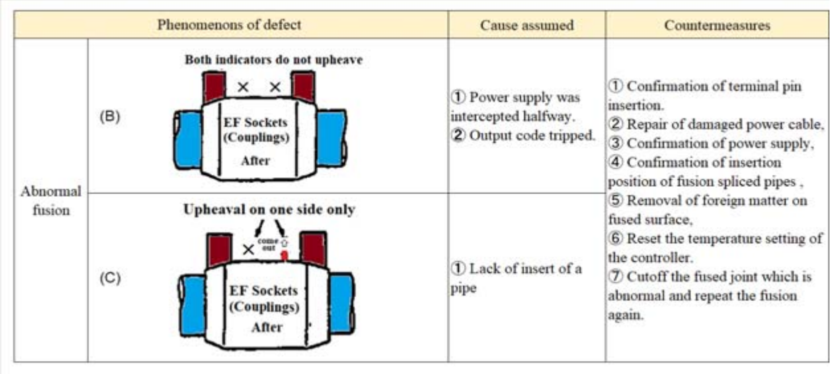


Judging standards	Conditions of an indicator	Items checked
Normal fusion	(A) Terminals; EF Sockets (Couplings) Before / Upheaval of an indicators; EF Sockets (Couplings) After	① Right and left have raised melt indicator after welding above the surface of a coupling

Figure-56 Quality Control Method (PE joint)

9-7-5 Troubleshoot (EF)

Typical the causes and measures of fusion defects (rising melt indicators irregularities) are shown below.



Phenomenons of defect		Cause assumed	Countermeasures
Abnormal fusion	(B) Both indicators do not upheave; EF Sockets (Couplings) After	① Power supply was intercepted halfway. ② Output code tripped.	① Confirmation of terminal pin insertion. ② Repair of damaged power cable, ③ Confirmation of power supply, ④ Confirmation of insertion position of fusion spliced pipes , ⑤ Removal of foreign matter on fused surface, ⑥ Reset the temperature setting of the controller. ⑦ Cutoff the fused joint which is abnormal and repeat the fusion again.
	(C) Upheaval on one side only; come out; EF Sockets (Couplings) After	① Lack of insert of a pipe	

Figure-57 Troubleshoot (PE joint)

10. Evaluation of achievement level

10-1 Necessity of Evaluation of Achievement Level

In managing the progress of NRW reduction, it is important to periodically evaluate the “achievement of the plan” in the formulation and implementation of the reduction plan in the PDCA cycle.

Achievement assessments implemented in “CHECK” of PDCA cycle are divided into the following.

(1) Evaluation of "cost-effectiveness",

(2) Administration indexes of improved management.

As an index to grasp these achievement level evaluations accurately and quantitatively, it is closely related to the reduction results whether or not the NRW reduction plan were efficiently achieved.

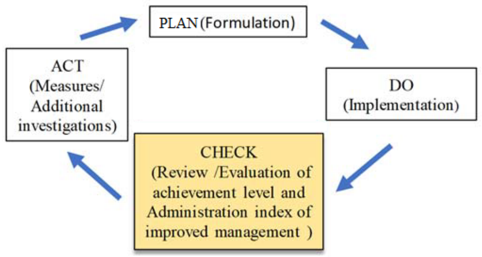


Figure- PDCA Cycle

10-2 Cost-effectiveness

10-2-1 What is the cost-effectiveness?

Cost-effectiveness is the evaluation of how much benefit (including non-revenue water reduction / other benefits) is gained by spending (including labor and equipment costs) for NRW reduction activities.

Cost-effectiveness evaluation is basically used in various situations.

For example, at the time of NRW reduction planning, it is also used for estimation at the time of planning how much the various costs such as labor cost / raw materials / construction cost, lead to profit.

The benefit effect is the effect of the reduction of the amount of leaked water and the cost of operation and management that can be expected within a fixed short-term (excluded effects such as improvement of water supply service, economic revitalization)

> **NOTE: The difference between cost-effectiveness and return on investment.**
> ① Cost-effectiveness means that if you stop investing costs, you will not receive the expected benefits / results within a certain period of time.
> ② Return on investment means to invest in expectation of future profit.

10-2-2 Evaluation Method of Cost-effectiveness

It is important to compare the balance between the total cost and the benefit numerically as to whether there is an effect (benefit).

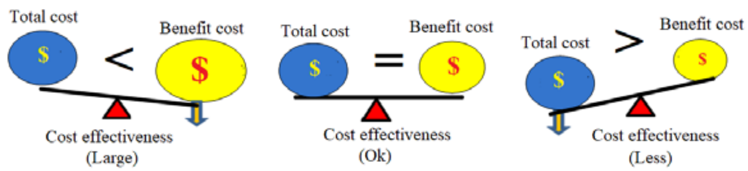


Figure- Concept of Cost-benefit Evaluation

10-2-3 Introduction of Breakdown Example of Total Cost and Benefit Cost

Below is a breakdown of total costs and benefit costs.

(1) Total cost items

① Personnel and maintenance office expenses,
② Purchase cost of NRW water prevention exploration equipment,
③ Division valve equipment cost of water distribution / leakage control blocks,
④ Cost of installation of flow meters and water pressure meters,
⑤ Material cost / installation cost of old pipe rehabilitation
⑥ Customer meters replacement cost
⑦ Water leakage and repair costs, etc.

(2) Item of benefit amount

① Profit from reduced non-revenue water,
② Profit from reduction of water meter reading error,
③ Profit of reduction of O / M expenses of water facilities raw water,
④ Reduction cost of new water source development,
⑤ Reduction cost of expansion work / connection pipe construction,
⑥ Reduction costs of secondary disasters due to water leakage, etc.

10-2-4 How to Calculate Cost-Effectiveness

(1) Difference in cost-effectiveness

This evaluation is a method to judge from the difference between the water supply profit (benefit) and the total cost due to the reduction effect from the "actual data".

◆ Formula (1)

Difference (\$ / m^3) = [real prevention water volume; m^3 / year × water supply cost; \$ / m^3] - (total cost; \$)

∴The priority for improvement work is the order with the largest amount of reduction.

(2) Unit of leakage prevention volume

This evaluation is a method of judging the unite of the total cost (\$) and the reduction volume (m^3) from the "actual data" as a leakage prevention unit per water distribution pipe distance (km).

◆Formula (2)

Leakage prevention unit rate (\$ / m^3 · km) =

Total cost (\$ / year) ÷ Real volume prevented (m^3 / year)

∴The priority for improvement work is the order with the smallest leakage prevention unit ratio.

(3) Prediction of investment effect by NPV index (net present value)

This evaluation is a method to quantitatively predict the validity of the "Return on investment" by converting the benefit effect into the current money price in the future (after N years).

(a) Net present value (NPV) forecast of profit after N years

◆Formula (3)

$$NPV = \triangle CF0 + CF1/1-r)\ 1 + CF2/1-r)\ 2 + \cdot\cdot\cdot CFN/1-r)\ N$$

Here,

- CF0: Investment amount (project cost)
- CF1: Benefit amount (after 1 year)
- CF2: Benefit amount (after 2 years)
- CFN: Benefit amount (after N years)
- R: Discount rate (Assumption; 5%) ... Interest rate to pay
- N: Life of the facility (years)

∴If NPV is a positive number, it is judged that there is business potential (benefit).

(b) Calculation from benefit ratio (B / C)

◆Formula (4)

Cost-benefit ratio (B/C) = Amount of benefit (B) ÷ cost (C)

∴If B/C ratio is 1.0 or more, it is judged that there is business potential (benefit).

NOTE: Reliability of NPV indicator **Because the NPV index estimates the Return on investment based on the many assumptions such as discount rate, useful life, price fluctuation, tax rate, etc., the evaluated value of the benefit effect is an expected value only.**

10-3 Admonitive indexes of Improved Management

10-3-1 What are Management-administration Indexes?

This indicator is a numerical value by the current analysis method to correctly allocate "human resources, facilities, budget / finance" and to judge the management achievement of the NRW reduction target.

The following are Indexes of the current situation analysis.

① Financial Management indexes with Financial Statements,

② Business management indexes.

10-3-2 Administrative Purpose in Financial Indexes

① Compare sale price (water tariff) with other WSP in water supply unit price (KS/m^3).

② Compare production costs with other WSPs at water supply costs (Ks/m^3).

③ Judge management trends from the financial statements.

10-3-3 Administrative Purpose in Business Management Indexes

① Judge the business result per business scale / staff,

② Understand water tariff and water bill collection rate,

③ Judge the stability of business management,

④ Judge the water leakage situation,

⑤ Judge the others (water quality etc.).

In addition, the formulation of the non-revenue water reduction measures plan of each WSP should comprehensively evaluate these present indexes, and carry out the formulation of the plan according to the financial situation.

10-4 Circulation of Operating Funds

The basics of sound and sustainable water supply business management is the capital circulation by appropriate "capital investment (for example, construction of water facilities, operation management of facilities)" and "recovery of water charges".

The conditions for the smooth implementation of this capital cycle are shown below.

①Produced "water" can be supplied to customers without waste.

②The water supplied should be accurately measured by a water meter.

③"The payment for water" consumed should be "recovered" quickly.

④Collected "cash" is effectively used for daily working capital.

⑤The profit is to be used systematically for future business plans.

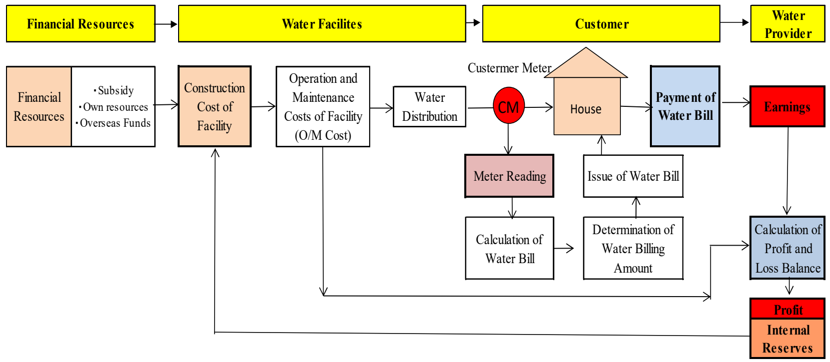
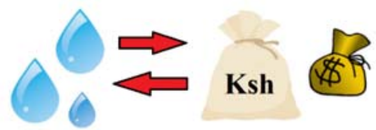


Figure- Principle of Fund Circulation

NOTE: Water service is a public service industry.

Water supply management consists of water charges paid by customers.



②As a water manufacturing company, it is important for all WSP staff (including engineers) to integrate organizational power / individual ability to continuously provide safety, security and stability services, and build a relationship of trust with customers.

10-5 Example of Analysis of Indexes

10-5-1 Financial Management Indexes with Financial Statements

The financial management situation can be simply judged from the balance index of water supply unit price (sales price) and water supply costs (production unit price). Generally, if a manufacture unit price is low, the selling price will also become low. Meanwhile, the income balance tends to be as follows.

(a) Production unit price = Sales unit price… Balanced
(Sound management is possible)
(b) Production unit price > Sales unit price… deficit management
(subsidy required),
(c) Production unit price < sales unit price…surplus finance
(Sound management is possible)

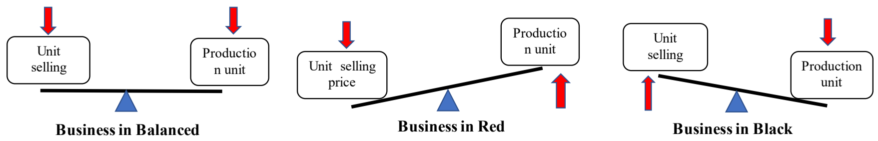


Figure- Image of Balance Trend of Water Supply Management

Here

(1) Unit price of water supply

This index is the "sales unit price" shown in the Water tariff.

◆ Formula (1)

Unit price of water supply (Ks/m^3) =

Total Water supply income (Ks/year) ÷ revenue earning water (m^3/year)

∴The lower the selling price is the better.

(2) Water supply cost

This index is the production cost required to supply tap water.

◆ Formula (2)

Water supply cost (Ks/m^3) =

Total manufacturing cost (Ks/year)÷/ revenue earning water (m^3/year)

∴The lower the production cost is the better.

(3) Administrative indexes by analysis of financial statements

When the water saved by NRW measures is converted to “revenue earning water”, the revenue (finance) is increased.

This effect is shown to improve in the financial statements (Revenue balance sheet, Capital account balance sheet, Balance sheet).

◆ Indexes shown in the Revenue balance sheet

Purpose: To diagnose the business profit or loss (red or black) from the income and expense balance.

①Example of index showing improvement effect of finance

(a) Business income

“Profit from water supply” will increase with the achievement of NRW countermeasures.

(b) Cost reduction

If "the amount of non-revenue water decreases", the water supply facility utilization rate will increase, "the efficiency of the staff" will become high, and as a result, "the operating expenses" will decrease.

(c) Increase in profit

As the profit and loss balance is improved, the “net income for the current year” will increase.

(d) Sound management

With the improvement of the profit and loss balance, there is a possibility of making the business independent and profitable.

(e) Improving cash flow

As “operating income” increases, monthly cash income (water charge) increases, so “cash flow” improves.

② Business management indexes to be evaluated

(a) Evaluation of the efficiency of utilization of facilities (yield, facility utilization rate)

(b) Evaluation of water tariff level and unit cost (sales unit price / production cost)

(c) Evaluation of management stability (revenue and expenses balance)

Table- Example of Income and Expenditure Statement -Ratio

	Business Expenses	Component ratio (%)		Business Income	Component ratio (%)
	Operating expenses			Operating revenues	
	(1) Personnel expense	14.7		(1) Water supply incomes	90.6
1	(2) Power cost	1.7		(2) Contracted construction incomes	1.6
	(3) Chemical charges	0.2		(3) Other operating incomes	2.5
	(4) Repair costs	7.9		Non-operating incomes	
	(5) Material costs	0.5	1	(1) Water service entry fee	2.6
2	(6) Commission fees	5.8		(2) Interest income and dividends	0.1
	(7) Depreciations	31.2		(3) Other accounting subsidies	0.3
	(8) Others asset depletion	26.9		(4) Miscellaneous incomes	2.0
				Extraordinary incomes	0.3
3	Non-operating expenses	6.0	2	(1) Gain sales of fixed assets	-
	Surplus	5.1	3	(2) Gain and losses of previous years	-
	Total	**100.0**		**Total**	**100.0**

Source: Japan's case (population: 500,000, water supply: about 200,000m³ / day, number of water taps: 163,000 taps, profit: about 113 B yen)

◆ Indexes shown in the Capital account balance sheet

Purpose: To diagnose the balance of investment necessary to obtain future earnings.

① Example of index showing improvement effect of business budget

(a) Details of the improvement work and the amount of borrowing

It is possible to evaluate the contents of construction such as repair costs and renewal costs of piping networks for NRW countermeasures and the amount of borrowing.

② Example of management index to be evaluated

(a) Appropriate investment amount for non-revenue water measures

(Capital account balance, facility capacity).

Table- Example of Capital Balance Sheet

Spending			**Incomes**		
Bills	**Account items**	Component ratio (%)	**Bills**	**Account items**	Component ratio (%)
1. Property Plant and Equipment			1Financial resources	(1) Revenue reserve	76.4
(1) Facilities		8.7	2. Long –Term financing		
(2) Piping network construction cost		40.2	(1) Debenture stock		18.6
2. Investments		2.9	(2) Capital reserves		5.0
3. Other Investment-Treasury bonds		48.2	(3) Revaluation reserves		
Total		**100.0**	**Total**		**100.0**

Source: Japan's case (population: 500,000, water supply: about 200,000m3 / day, number of water taps: 163,000 taps, profit: about 113 B yen)

◆ Indexes shown on the balance sheet

Purpose: To diagnose the stability of water supply business management from the breakdown of property, debt and capital.

In particular, understand the budget amount of investment from the change in depreciation costs of assets.

① Example of index showing improvement effect of business trend

(a) Stability of short-term management

- When operating revenue increases, cash flow improves and management stability increases.

(b) Ability of repayment funds

- If there is a large amount of borrowing funds (corporate bonds, etc.) and the repayment amount (spending) increases, it will become difficult for management to secure repayment funds and become unstable.
- Long-term financial repayment becomes stable when the equity ratio is high.

(c) Increase in repayments (including principal and interest) on large corporate bonds (e.g. up to 30 years) will put pressure on management.

② Example of management index to be evaluated

(a) Assessment of short-term management stability and soundness (current ratio)

(b) Evaluation of long-term management stability (equity capital ratio/self-capital ratio)

Table- Example of Balance sheet example

Assets		**Liabilities**		
Account items	**Component ratio (%)**	**Account items**		**Component ratio (%)**
1. Fixed assets		Liabilities	1. Fixed liabilities	1.0
(1) Tangible fixed assets			2. Current liabilities	1.6
a Land, standing trees, buildings			**(1) Accounts payables**	-
b. Buildings	10.4		(2) Accrued expenses	-
c. Machinery & equipment	20.9		(3) Advance received	-
d. Vehicles & delivery equipment	0.1		(4) Deposit moneys	-
e. Tools, furniture & fixtures	1.3		(5) Deposit-guaranteed securities	-
f. Accumulated depreciation	48.5	Shareholders' equity	**3.Capital stocks**	
(2) Intangible fixed assets	0.1		**(1) Equity capitals**	30.7
(3) Investments	12.5		**(2) Borrowed capitals**	18.9
2. Current assets			(Corporate debt)	3.9
(1) Cash & cash equivalents	4.6		**4. Surpluses**	42.9
(2) Accrued revenue	1.1		(1) Capital surplus	
(3) Storage investment securities	0.5		(2) Legal retained earnings	1.0
Total	**100.0**	**Total**		**100.0**

Source: Japan's case (population: 500,000, water supply: about 200,000m3 / day, number of water taps: 163,000 taps, profit: about 113 B yen)

10-5-2 Example of Business Management Indexes of Non-revenue Water Measures

This management index is a management index that summarizes the following.

① Maintenance indexes for pipeline,

② Administrative indexes for Financial / Business Management.

The WSP needs to create management indicators that are suitable for its own priority tasks.

For example, an index for setting a kiosk, illegal connection detected, reading errors, failure meters, aged meters, meter theft, meter calibration, meter boxes and etc.

The following is an example of Japanese business indexes. **(Extract edited from "JWWA 2007 guidelines")**

Table Contents of JWWA2007 guidelines

Items	Contents	Remarks (WSP priority items)
1) Safe	①Conservation of water sources	-
	②Water quality management	
2) Stable	①Stable supply	-
	②Preparation for the future	
	③Risk management	
3) Sustainability	①Strengthening of operating base	-
	②Staff	
	③Improvement of water supply service	
4) Environmental protection	①Global environmental protection	-
	② Sound water circulation	
5) Management (business operation / OM)	①Proper business operation	-
	②Proper maintenance	

Source: JWWA (water supply business guidelines 2007 edited)

Items	No.	Business indexes	Units	Calculation methods	Target values (directions)	WSP
1. Safe (a) Water source conservation	1002	Allowance of water source	%	[(Retained water source / maximum daily water distribution) -1] * 100	Higher is better	-
	1003	Effective utilization rate of raw water	%	(Annual effective water volume / annual intake volume) * 100	Higher one is better	-
(b) Water quality management	1104	Failure rate of water quality standards	%	(Number of nonconformity of water quality standards / total number of inspections) * 100	Lower one is better	-
2. Stable (a)Stable supply	2001	Amount of stored drinking water per person	L/head	[(Distribution reservoir total capacity * 1/2 + emergency water storage tank capacity) / water supply population] * 1000	3 L or more	-
	2002	Unit of Water volume per water supply population	L/d/head	(Average daily water distribution / water supply population) * 1000	Better to have more	-
	2004	Reservoir capacity	Day	Distribution reservoir total capacity / daily distribution of water	0.5 day or more	-
	2005	Number of water supply restrictions	Day	Number of annual water supply limit days	Lower one is better	-
	2006	Dissemination rate (population)	%	(People in the water / people in the water area) * 100	98% or more	-
	2007	Distribution pipe extension density	km/km2	Distribution pipe length / water supply area	Higher one is better	-
	2008	Water meters density	number/km	Number of water meters / water pipe length	Higher one is better	-
(b)Preparation for the future	2102	Rate of Aging facilities	%	(The number of electrical and mechanical equipment over useful life / total number of electrical and mechanical equipment) * 100	Lower one is better	-
	2103	Rate of Aging pipelines	%	(Pipelines over useful life / pipeline length)*100	1~20%	-
	2104	Rate of renewal pipelines	%	(Renewed pipeline length / total pipeline length) * 100	1~2（%）or less	-
	2105	Rate of Pipeline rehabilitations	%	Number of leak detections / survey distance) * 100	Higher one is better	-
	2106	Rate of Valve update	%	(Number of updated valves / number of installed valves) * 100	1~25%	-
	2107	Rate of new pipeline installation	%	(New pipeline length / total pipeline length) * 100	Higher one is better	-
		Number of leak detection per 1 km in distribution pipe survey	numbers/km	Number of leaks found / Survey water pipe distribution length	Higher one is better,0.02 (numbers/km)	-
		Number of leaks found per 1km in water service pipe survey	numbers/km	Number of leaks found / Survey water service pipe length	Higher one is better,0.72 (numbers/km)	-
		Number of leaks found per 1km in water service line at water meter boxes	numbers/km	Number of leak detection / survey water service line at water meter-boxes	Higher one is better,0.3 (numbers/km)	-
(c)Risk management	2201	Number of water quality accidents at the water source	numbers	Number of water quality incidents of annual water source	Lower one is better	-
	2202	Accident rate of main distribution pipelines	numbers/100km	(Number of accidents on main distribution pipelines / Total length of main distribution pipeline) * 100	5~20（numbers/100km)	-
	2213	Number of water tank trucks	unit/1000head	(Number of water tank vehicles / water supply person) * 1000	Higher one is better	-

Items	No.	Business indexes	Units	Calculation methods	Target values (directions)	WSP
3. Sustainability (a)Strengthening of operating base	3001	Operating balance ratio	%	(Operating revenue / operating expenses) * 100	105% or more	-
	3002	Current account ratio	%	[(Operating income + non-operating income) / (operating cost + non-operating cost)] * 100	100%or more	-
	3003	Total balance ratio総収支比率	%	(Total Revenue / Total Cost) * 100	100%or more	-
		Cash flow	Times	Balance of corporate bonds / income of water supply	6	-
	3013	Charge recovery rate	%	(Sales unit price / manufacturing cost) * 100	Higher one is better	-
	3014	Unit of Water supply (selling price)	JY/m3	Sales profit / Accounted-for water ratio	Lower one is better (160-230JY/m3)	-
	3015	Water supply cost (manufacturing cost)	JY/m3	[current earnings-(consignment construction cost + cost of selling materials and non-essential items + incidental business cost)] / Accounted-for water	Lower one is better(150-220 JY/m3)	-
	3016	Charge of household per month (@10m3)	JY	Basic fee for general household use (dia. 13 mm) per month + usage fee of 10m3	Lower one is better	-
	3018	Accounted-for water as persent of total	%	(Accounted -for water/Water supply)*100	Higher one is better (90%or more)	-
		NRW rate	%	(Annual input volume / annual accounted-for water) * 100	Lower one is better (10%or less)	-
	3019	Facility utilization rate	%	(Average daily water service supply / daily water service supply capacity) * 100	Higher one is better(50-70% or more)	-
	3020	Maximum operation rate of facility	%	(Maximum daily water supply capacity / daily water supply capacity) * 100	Higher one is better(60% or more)	-
(b)Staff	3103	External training time	Hr.	(Time and number of staff members who received external training) / Total number of staff members	Larger one is better	-
	3104	Internal training time	Hr.	(Time and number of staff members who received internal training) / Total number of staff members	Larger one is better	-
	3105	Technical staff rate	%	(Total number of technical staff / Total number of staff) * 100	Higher one is better	-
	3109	Distribution amount per staff member	m3/Head	Annual water distribution / total number of staff	Better to have more	-
	3110	Number of meters per staff member	number/Head	Number of water meters / total number of staff	—	-
	3111	Public injury rate	%	[(Total number of people who have been absent from public injury* number of days) / (Number of all staff * number of annual public service days)] * 100	Lower one is better	-
	3204	The number of visitors of water supply facilities	Head/1000 Heads	(Number of visitors / water supply person) * 1000	Better to have more	-
	3205	Complaint rate for water service	Number /1000 numbers	(Number of water service complaints / number of water connections) * 1 OOO	Lower one is better	-
	3207	Complaint rate for water tariff	number/1000 numbers	(The number of water tariff complaints / number of water connections) * 1000	Lower one is better	-
4. Environmental protection (a) Global environmental protection	4001	Electricity consumption per 1 m3 of water distribution	kWh/m3	Electricity consumption of all facilities / annual water distribution	ower one is better (0.1~0.5	-
	4003	Renewable energy utilization rate	%	(Power consumption of renewable energy equipment / Power consumption of all facilities) * 100	Better to have more	-
(b)sound water circulation	4101	Groundwater rate	%	(Groundwater pumping / water source utilization) * 100	—	-
5. Managements (a) Proper business operation	5001	Improper rate of water supply pressure	%	[(Incorrect pressure measurement point * number of days) / (total number of pressure measurement points * yearly number of days)] * 100	Lower one is better	-
	5004	Reading error rate	number/1000 numbers	(Number of false readings / total number of readings) * 1000	Little one is better	-
	5005	Billing error rate	number/1000 number	(Number of false charges / Total number of charges) * 1000	Little one is better (0-0.5)	-
	5006	Unpaid rate	%	(Year-end unpaid rate / Total fee income) * 100	Little one is better (5-15)	-
	5007	Water supply stop rate	number/1000 numbers	(Number of water supply stops / number of water supply connections) * 1000	Lower one is better	-
(b) Proper maintenance	5102	Ductile iron pipe and steel pipe ratio	%	[(Ductile cast iron pipe length + steel pipe length) / total pipeline length] * 100	—	-
	5103	Accident rate of pipelines	number /100km	(Number of pipe line accidents / total pipeline length) * 100	Lower one is better	-
	5104	Accident rate of steel pipelines	number/100km	(Number of accidents on steel pipelines / Total length of steel pipelines) * 100	Lower one is better	-
	5105	Accident rate of non-ferrous pipelines	number/100km	(Number of accidents on non-ferrous pipelines / Total length of non-ferrous pipelines) * 100	Lower one is better	-
	5106	Accident rate of water service pipelines	number/1000 numbers	(Number of accident of water supply pipe / number of water service connections) * 1000	Lower one is better	-
	5107	Water leakage rate	%	(Annual leaked volumer / annual distributed water) * 100	Lower one is better	-
	5108	Water leakage volume per number of water service pipelines	m3 /year/number	Annual water leakage / number of water connections	Lower one is better	-
	5109	Suspended water / turbid water time	Hr.	(Suspension of water * Turbid water time * Sustained water * Turbid water area water supply person) / Water supply person	Lower one is better	-
	5111	Pipeline inspection rate	%	(Inspected pipeline length / total pipeline length) * 100	Higher one is better	-
	5112	Valve installation density	number/km	Number of installed valves / total length of pipeline	Higher one is better (7-20)	-

-END-

Internal Information

Final Draft 2017-06-30

JOINT NON REVENUE WATER REDUCTION

FIELD TRAINING (OJT) AT EWASCO

MANUAL FOR IMPLEMENTATION LEVEL

FOR

NON-REVENUE WATER REDUCTION UNITS

（Field Technician）

(DRAFT)

19TH - 24TH JUNE 2017

Implemented by

KENYA WATER INSTITUTE AND LEAD WSPs
(EMBU WATER AND SEWERAGE SERVICES COMPANY AND MERU WATER AND SEWERAGE SERVICES)

Assisted by JICA KENYA

Table of contents

1. Outline of training DMA

(1) Area: about 83,000 m2

(2) Number of Customer meters: 150 pieces

(3) Extended pipe-line: Diameter 63~100 mm (PVC)

Diameter 20 mm (PVC)

Diameter 32~50 mm (HDPRE)

(4 Total length:2,500 m

(5) MAP of DMA

In the DMA diagram, position information such as a gate valve for isolating the DMA, route of pipeline, diameter, material, flowmeters, air valves, drain valves, water meters, etc. are described. **(Refer to Figure 1)**

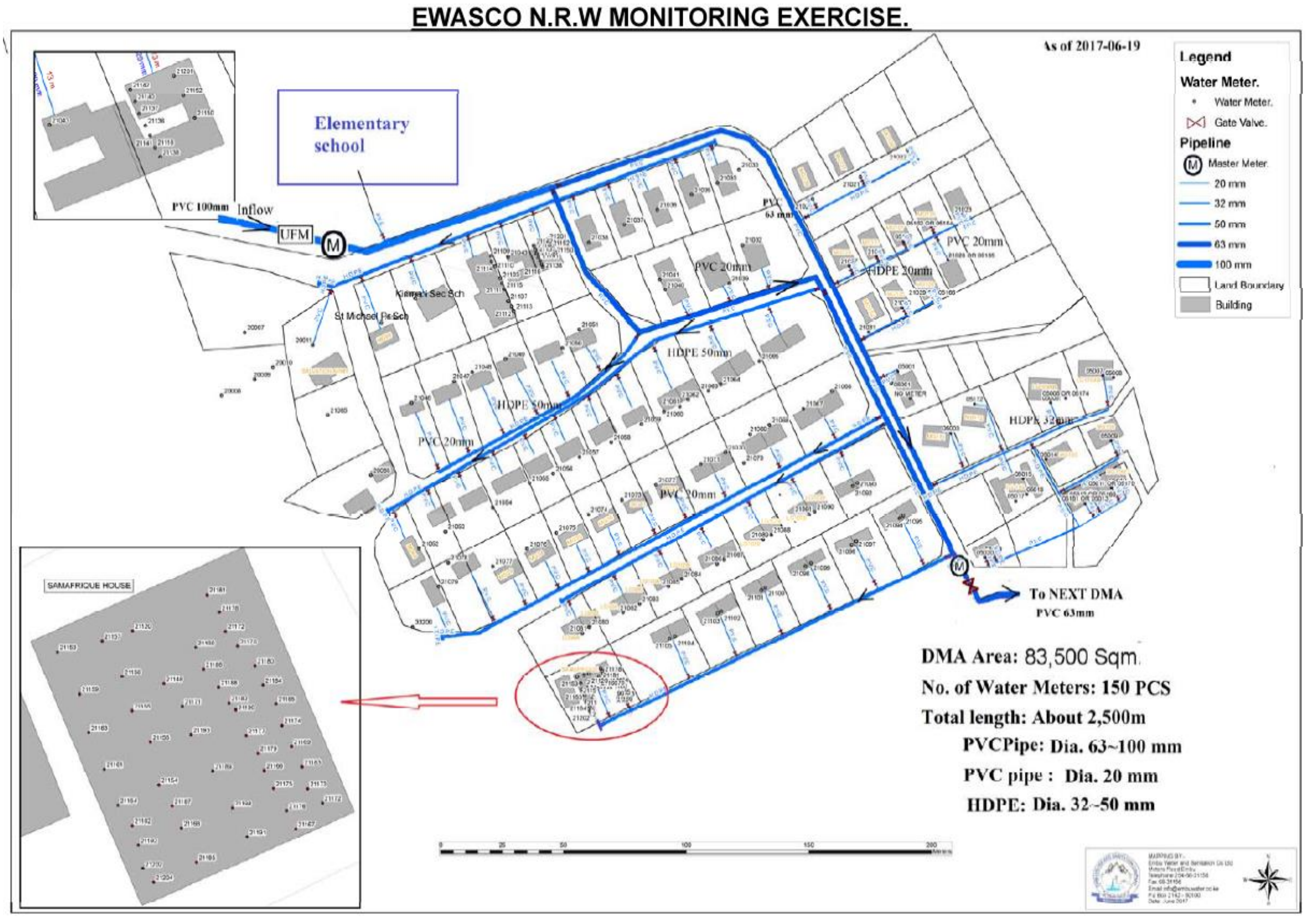


Figure 1 Example of DMA for Training at EMBU

2. Causes of pipe damage

The causes of the leakage which occurred on a buried pipeline are shown below.

Table -1 Causes of pipe damage

Quality of pipe material	① Shortage of strength (pipe, joint, valve and etc.) ② Lack of corrosion-resistant ③ Rapid progress of physical aging
Technic of pipe laying	④ Poor pipe jointing ⑤ Poor backfilling ⑥ Touch with the other pipe and the other facilities
Condition of water	⑦ Unsuitable water pressure ⑧ Water hammering ⑨ Corrosion by water quality ⑩ Rapid change of water temperature ⑪ Neglect of leakage
Environment of pipe laying	⑫ Increase of traffic accidents ⑬ Movement of soil around pipe (freezing, upheaval, and etc.) ⑭ Corrodent soil for backfill ⑮ Change of temperature
Other utilities' construction work and disasters	⑯ Damage as the result of construction works ⑰ Damage of the road by earthquake

Source：JICA-Nagoya NRW training

3. How to detect water leakage

3.1 Leakage exploration technology

① Acoustic noise detector (detection of sounds generated from leak points)

② Inject gas with no adverse effects to water quality in~~to~~ the water pipe

Currently, acoustic detection technology is the most common method used in leak detection.

3.2 Leakage detection by leakage sound

1) Features of leak noise

Leakage sound that jets out of the pipe from the water leak hole generates continuous vibration sound.

However, this vibration sound changes under the following conditions.

①Characteristics of the leak point (eg leak hole, pipe material, water pressure, surrounding condition etc.)

②Propagation path (eg, earth, concrete, pipe material, etc.)

③Propagation distance from the leak point

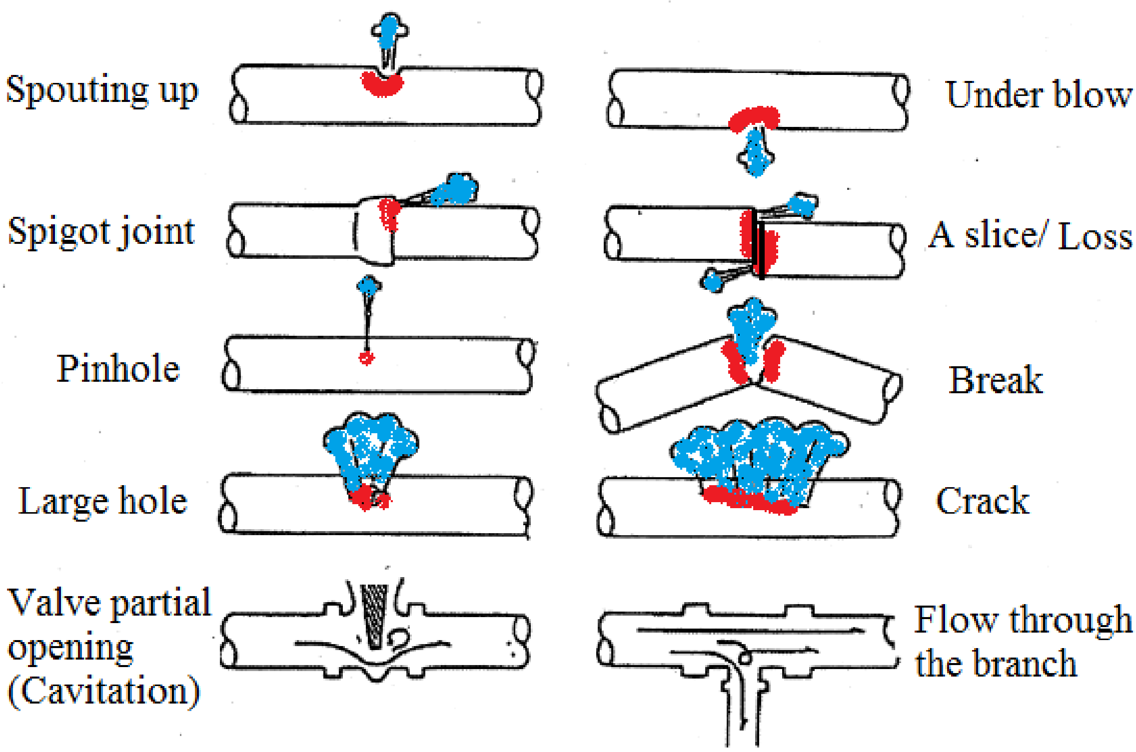
①Leakage sound depends on generation condition. **②The propagation of the vibration sound is gradually attenuated from the generation point.**

2) Decay rate

In general, vinyl chloride pipe (VP) has higher attenuation with distance than cast iron pipe (CIP) and lead pipe (LP). (**Refer to Table-2~3 and Figure 2**)

Table-2 Example of decrement of pipe classification (At 10m point)

Pipe Kind	Quality of material	Sound of leakage	Decay rate
Distributing ~~water~~ pipe	CIP φ100 mm dia	Low frequency	About 1/10
		High frequency	About 1/6
	VP φ75 mm dia	Low frequency	About 1/8
		High frequency	About 1/28 at 2m point
~~Feed water pipe~~ Service line	LP φ13 mm dia	Low frequency	Hardly decrease
		High frequency	About 1/3
	VP φ13 mm dia	Low frequency	About 1/2
		High frequency	About 1/44



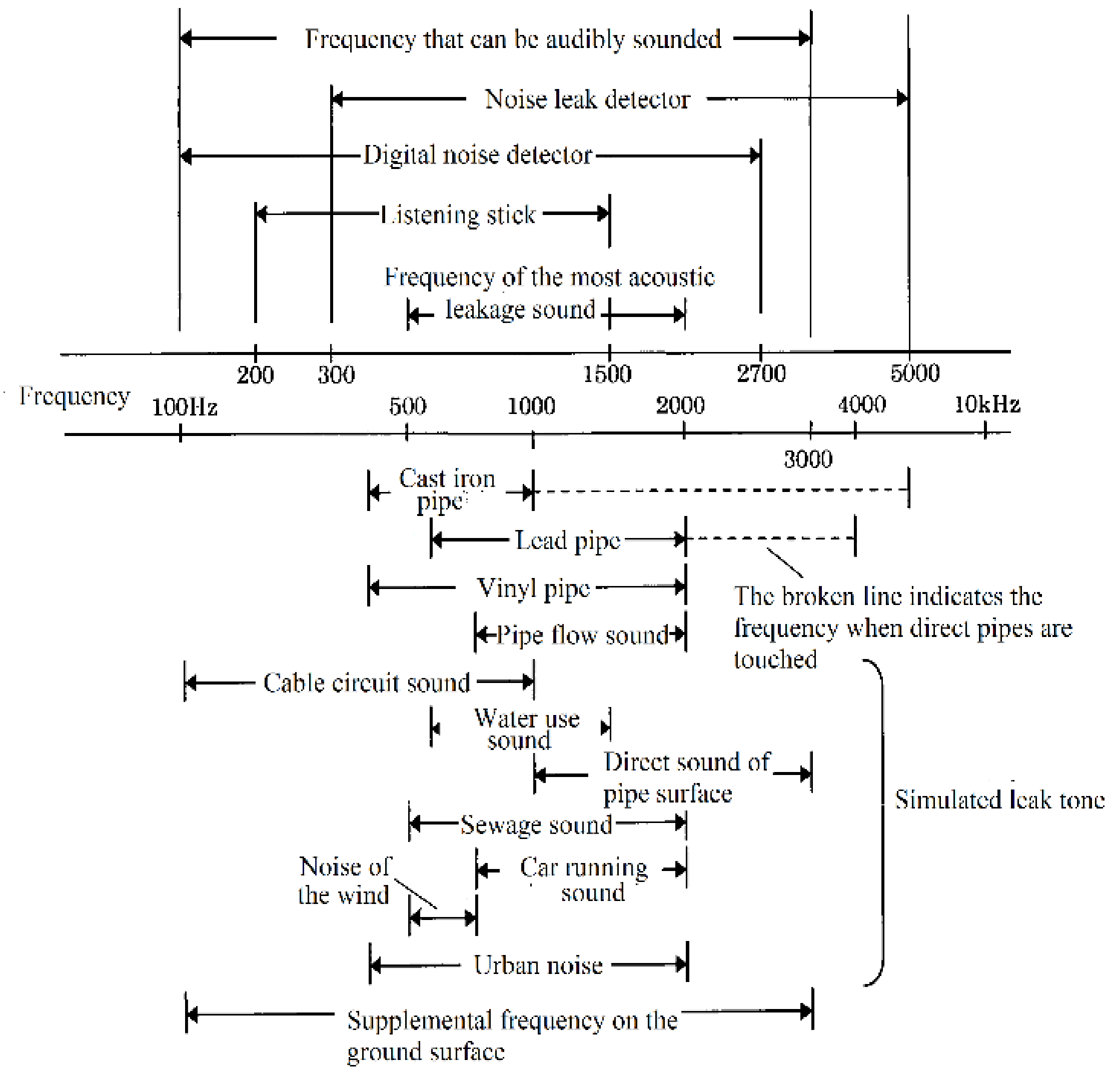


Figure 2 Changes in leak noise

Table-3 Example of Typical leak noise sound

Conditions		**Impact on investigation.**	**Note**
Depth of burial	Shallow	Good	Attention to echo etc.
	Depth	Bad	The deeper the depth the more the leakage sound attenuates.
Density of soil	Rough	Bad	The damping of leaky sound is bigger and dense.
	Dense	Good	-
Pipe material	Soft	Caution	Soft pipes such as vinyl pipes and polyethylene pipes attenuate the leakage noise during propagation, so care is taken because the range to be captured is narrow
	Hard	Small impact	
Pipe diameter	Small	No effect	-
	large	Effected	Pipe vibration is less likely to occur as the larger diameter.
Amount of leakage	A little	Difficulty	Minor leakage water leakage sound is small and difficult to grasp.
	Much	Easy	Pay attention to the water pool near the leak hole.
Water pressure	Low	Bad	Usually 1.5 kef / cm 2 or more.
	High	Good	Generally, leakage noise is higher as high water pressure.

Source : JWRC

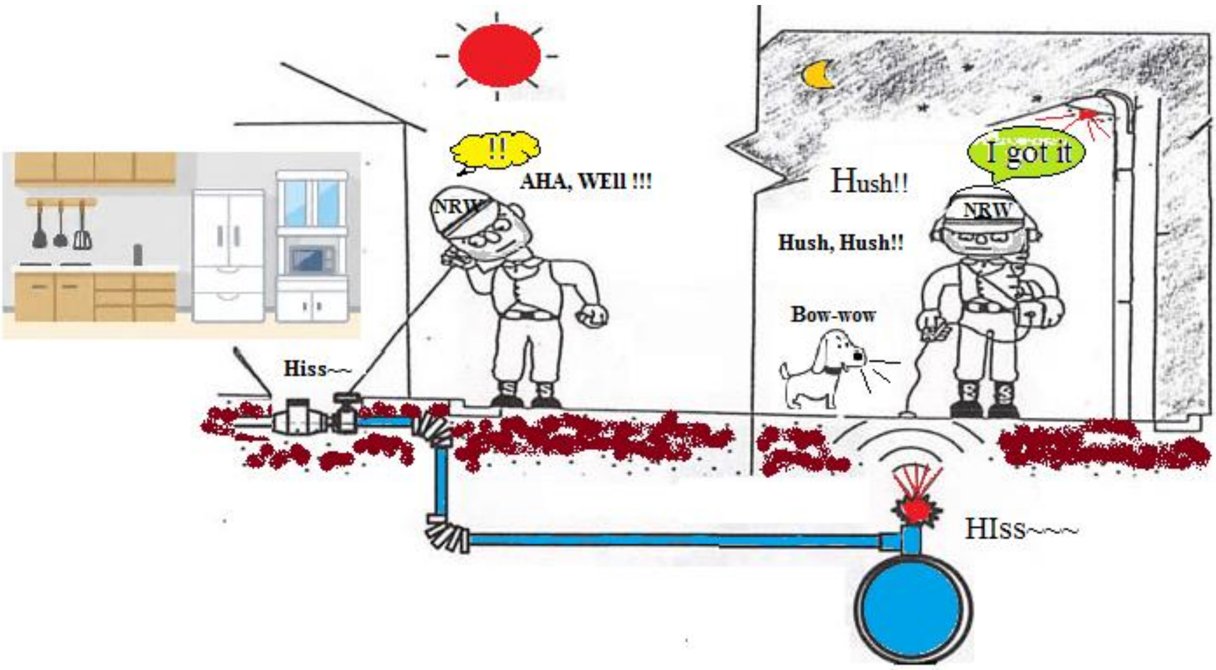
3) False sound

Since the road surface digital noise leak detector is susceptible to the influence of the simulated sound, it is necessary to confirm the location of the dummy sound in advance.

4) Working time

Since DMA area for survey had comparatively little traffic flow, the acoustic noise detection Survey ~~is~~ was conducted at daytime. **(Refer to Figure 3)**

Basically;（In urban area）
① At Daytime …..Door to door survey
② At Late night…..Road surface survey



Source: Edited, Training Handout (2017-May) at Bureau of Waterworks, Tokyo Metropolitan Government

Figure 3 Working Time for water leakage survey by acoustic noise detectors

4. Concept of how to identify leak location

The process of water leakage detection is basically based on narrowing down the order of surface, line and point.(**Refer to Figure -4**)

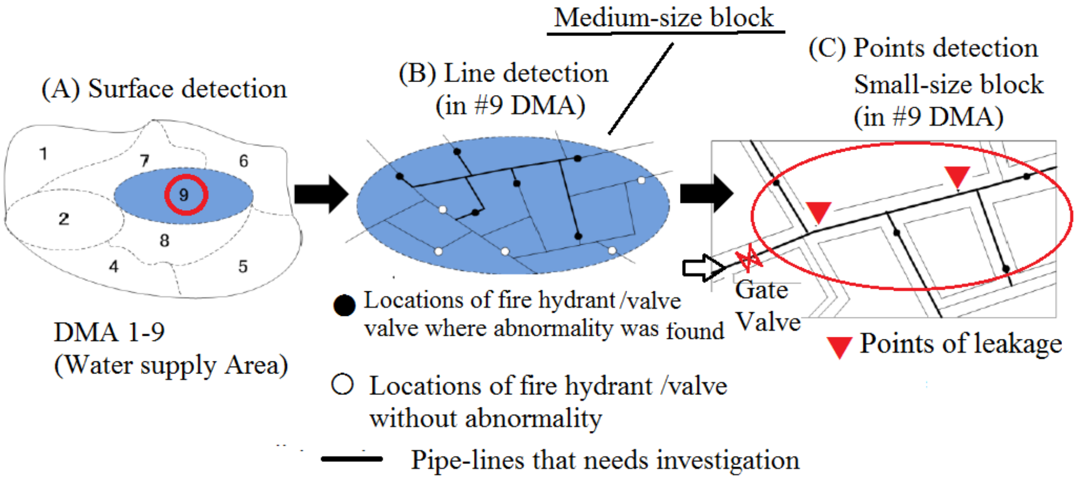


Figure 4 Concept of how to identify leak location

5.Content of leakage investigation work （Procedure of a standard survey）

5-1 Procedure for leakage survey

The flow of leakage investigation work is as follows:

Basic work procedure in leak detection survey

Step-1 : **Formulation of work plan** (Confirmation of work content, confirmation of work method, confirmation of notes, **Preparation of working process & Map) (Refer to Figure 1/5~6 Table 4)**

⬇

Step-2: Conducting preliminary inspections on site with **detail route map of pipe laying** (confirmation of consistency between drawing and site, confirmation of work method, confirmation of machine used)



⬇

Step-3: Implementation of Door to door survey (Discovery of water leakage sound from Faucet valves/ shutoff valve/ distribution pipes with listening sticks, mainly daytime work because of work in the residential area,)

⬇



Step-4: Implementation of road surface detection (Discovery of water leakage sound of distribution pipes at night with digital leak detector / listening sticks, etc)



Step-5: Confirmation of leakage point survey (Check with/by boring equipment / excavation / listening sticks / digital leak detectors / buried pipe detectors/ leak noise correlators, DPD reagent etc. to make sure whether the location of leakage, etc.)



Step-6: Preparation of a report (Arrangement of survey data, analyze survey results) (**Refer to Form -1 to 3**)

Table-4 Example of Working schedule

Name of waterworks office(Name＋Sign) ; Date and time ;

Name of the investigation area ;

Scope of work (Investigation time zone): Door-to door survey （160 km : 16,000 Customer meters) ::::8:30AM to17:00 / Stop valves / stop-cocks Caustic noise survey (150 km);;;;;8:30AM to17.00 / Road surface survey (160 km);;;;22 PM to 5AM

Duration of the survey ;

Name of the researcher ;

No.	Activities	June				July				August				September			
(1)	Work plan																
(2)	Preliminary site survey																
(3)	Survey on door-to-door survey																
(4)	Survey on road-surface																
(5)	Verification work																
(6)	Preparation of report																

Supervisor （Name +Sign) ;

Figure -5 Example of piping rout map in survey area

Figure-6 Sample of detailed rout map of pipe laying

6 Equipment required for leak investigation

6-1 Listening sticks

(1) Object of achievement

a) In this practice, use a sound hearing bar, bring the vibration sensing rod into contact with a faucet and a meter, and experience the presence or absence of water leakage sound.

b) In order to distinguish leakage sounds, it is necessary that the participant concentrates and focus on the point of investigation.

c) Mark the position where suspicion of leakage is suspected on the map and on the ground.

d) Have the consultation on the findings. (**Form-1 to 3**)

(2) Points of concern

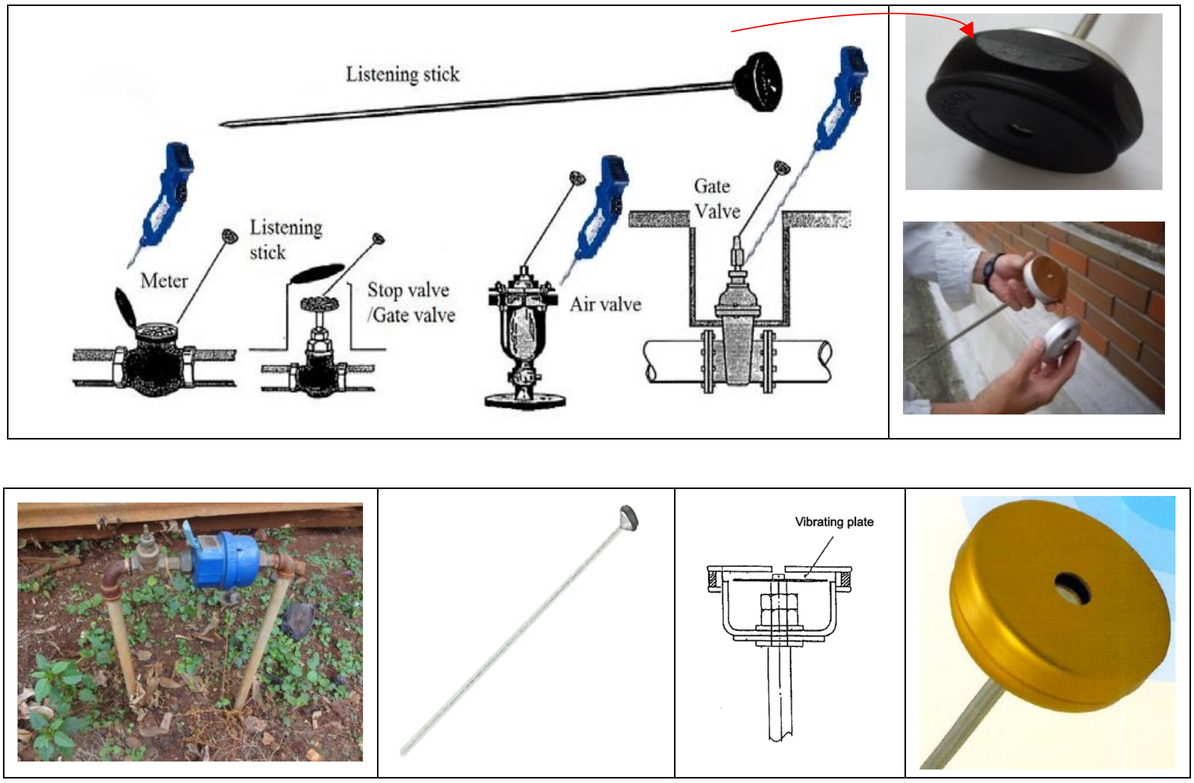
a) If necessary, close the consumer tap and check whether leak noise is generated before and after the meter.

b) Mark the position suspected leakage.

(3) Equipment used

a) A Listening stick、(**Refer to Figure-7**)

b) A Digital noise leak detector



Fifure-7 Configuration of Listening stick

6-2 Road surface digital noise leak detector

(1) Object of achievement

a) In this practice, as a result of a **Listening stick** survey, the leakage position is searched by a road surface digital noise detector and/or a **Listening stick** on a pipeline where leakage is suspected.

b) Mark the position where suspicion of leakage is suspected on the map and the ground.

c) Confirm the leakage location by excavating.

d) Have the consultation on the findings. (**Form-1 to 3**)

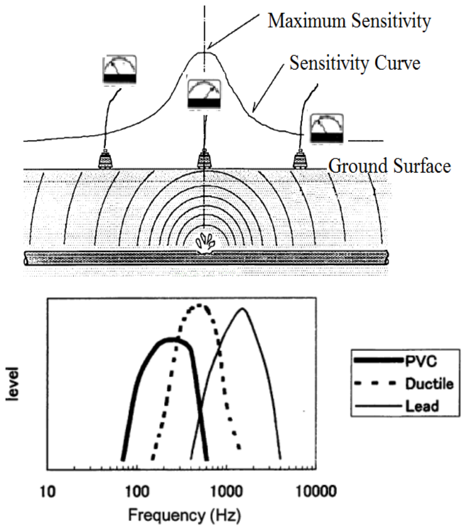
(2) Points of concern

a) Since this investigation is influenced by dummy sounds, it is necessary to check the occurrence of noise beforehand.

b) Recording of data (**Form-1 to 3**)

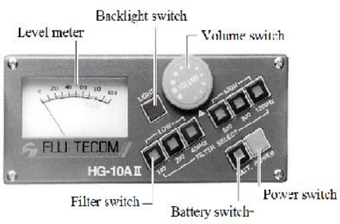
(3) Equipment used

a) A Road surface digital noise leak detector (**Refer to Figure-8**)



The following four (4) Filter Band Widths are recommended as the basic selection on site.

Pipes \ Hz	100	200	400	600	800	1200
Distribution Pipe of Cast Iron Pipe.		◎ ← - - -	- - -	- - -	- - → ◎	
Distribution Pipe of Vinyl Pipe.	◎ ← - - -	- - -	- - -	- - → ◎		
Service Pipe of Vinyl Pipe.		◎ ← - - -	- - -	- - -	- - → ◎	
Service Pipe of Galvanized Pipe.			◎ ← - - -	- - -	- - -	- - → ◎



Nine(9)ways of Filter Combination are selectable as follows. Those Filtering Ranges enable the Operator to distinguish the leak sound from other noise.

LOW 100	LOW 200	LOW 400Hz	HIGH 600	HIGH 800	HIGH 1200Hz	Filter Combination
▣			▣			100Hz ~ 600Hz
▣				▣		100Hz ~ 800Hz
▣					▣	100Hz ~1200Hz
	▣		▣			200Hz ~ 600Hz
	▣			▣		200Hz ~ 800Hz
	▣				▣	400Hz ~1200Hz
		▣	▣			400Hz ~ 600Hz
		▣		▣		400Hz ~ 800Hz
		▣			▣	400Hz ~1200Hz

e

Figure-8 Overview of Road surface digital noise leak detector

6-3 Leak noise correlator

(1) Object of achievement

a) In this method, the equipment specifies the leak position where leakage is suspected in the buried (metal pipe / nonmetal pipe) pipe.

b) Mark the position where suspicion of leakage is suspected on the map and the ground.

c) Have the consultation on the findings.

(2) Points of concern

a) Secure the sensor installed at two points on the piping fixed.

b) Water leakage position is specified from the waveform displayed on the monitor of the main unit.

c) The location of water leak is ~~final~~ finally checked by boring or excavation.

(3) Equipment used

a) Leak noise correlator (**Refer to Figure-9**)

b) Tool for attaching sensor

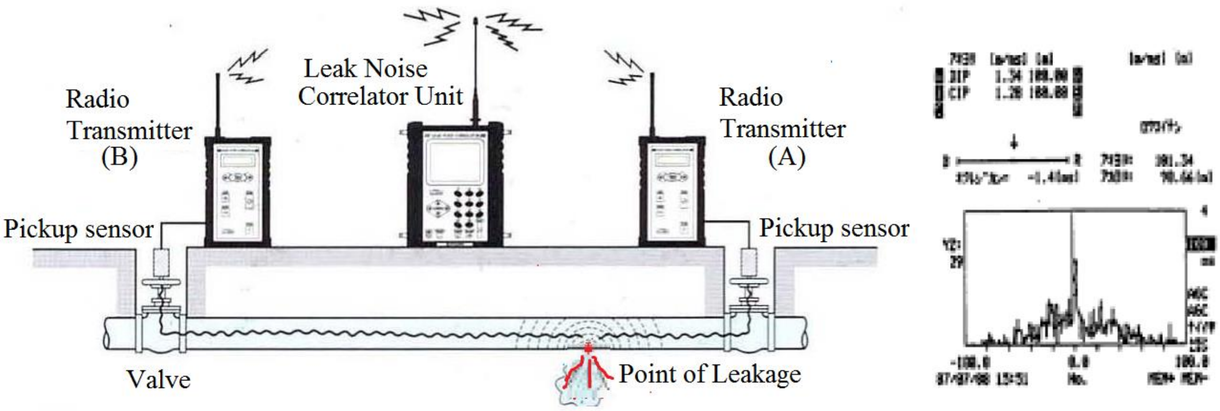


Figure-9 Overview of Leak noise correlator

6-4 Verification Work

(1) Object of achievement

(a) Understand how to check where leakage is suspected by leakage exploration by Excavation. **(Refer to Figure-10)**

(b) Introduction of Boring work method **(Refer to Figure-11)**

(2) Points of concern (by Boring work)

a) Boring work needs to be investigated carefully so as not to damage the buried pipe.

b) The water leakage position is determined by drilling a number of holes with a boring tool and judging from the strength of the leak sound while moving the Listening sticks to the number of holes.

c) Moreover, it is possible to specify the water leakage position from the situation of water and soil / attaching to the boring bar and/ or a Listening stick.

d) Boring bar is a tool that punctures hard surface.

(3) Equipment used (by Boring work:**Refer to Figure-11**)

a) A Electric drill (used for drilling pavement surface)

b) A Boring bar

c) A Listening stick

d) A Road surface digital noise leak detector

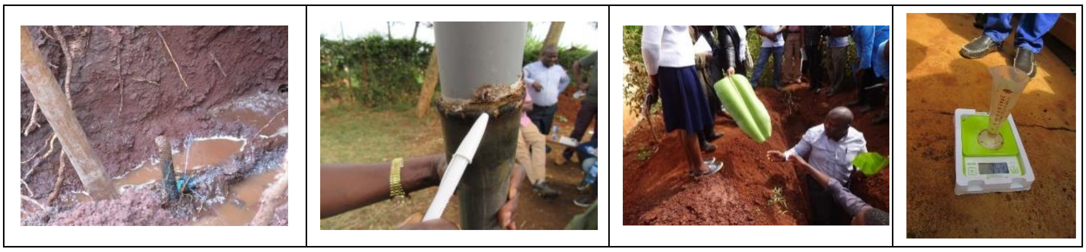
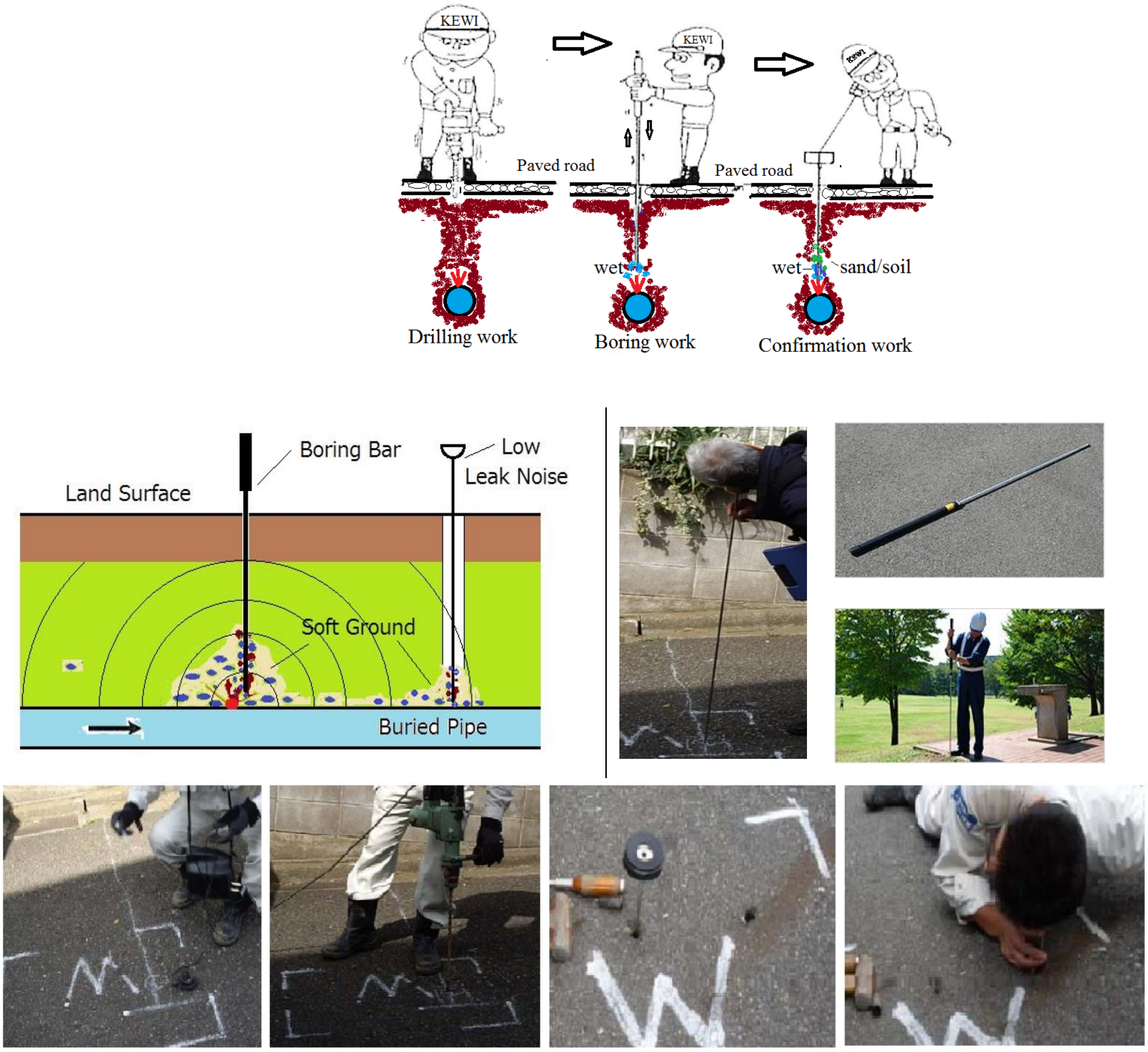


Figure-11 Overview of Verification work by Excavation



Source:Yokosuka cityWWSB Working on Paved roadway

Figure-11 Overview of Verification work by Boring work

7. Equipment required of survey for Buried pipe detection

7-1 Electromagnetic induction detectors (For metallic pipes)

(1) Object of achievement

a) The objective of this practice is to understand the operation method of the equipment to specify the position of the buried pipe (Metal pipe)

b) Have the consultation on the findings.

(2**) Points of concern**

a) Detection is difficult if the burial depth is deep.

b) Since it also reacts with piping which is not currently used (buried disposal), it is necessary to follow up to the connecting part of piping currently in use.

(3) Equipment used

a) Direct metallic pipe detector (**Refer to Figure-12**)

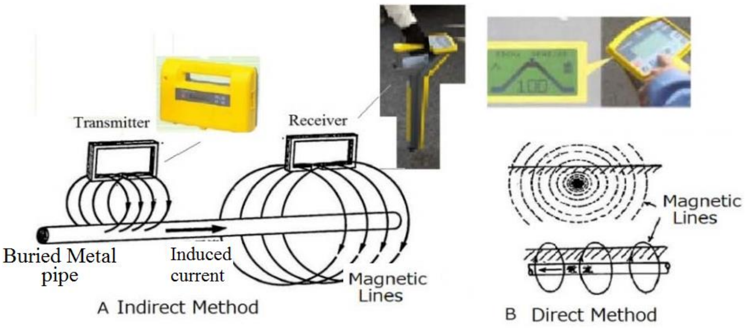


Figure-12 Overview of Electromagnetic detectors

7-2 Vibration-wave water instrument

(1) Object of achievement

a) This practice is to understand the operation method of the equipment to specify the position of the buried pipe (Metal and Non-metal pipe)

b) Have the consultation on the findings.

(2) Points of concern

a) Since pulsation is generated and the vibration sound is investigated by listening to the sound on the ground, there is a possibility of damaging the broken tube with a shock wave.

b) Although it is applied to the investigation of a relatively small diameter and a short distance, if the burial depth is deep, the search becomes difficult

(3) Equipment used

a) Vibration-wave water instrument (**Refer to Figure-13**)

b) Listening stick

c) Road surface digital noise leak detector

Figure-13 Overview of Vibration-wave water detector

8. Measurement of leakage volume

8-1 Measurement of minimum night flow a night minimum flow

(1) Object of achievement

a) This practice will make you understand the concept of estimating the amount of water used during the night time when water demand is lowest in the isolated DMA and is assumed to be the water leakage amount.

b) Identify the night-time minimum flow rate from the collected data.

c) Have the consultation on the findings.

(2) Points of concern

a) Measure the amount of water flowing into the partitioned DMA. (**Refer to Figures 14-15**).

b) Leakage, legitimate consumption and theft are included in the measured minimum flow rate.

c) In order to investigate the actual leakage volume, further investigation is necessary according to the items of the water distribution analysis table.

d) Customer cooperation is indispensable for accurate water leakage survey.

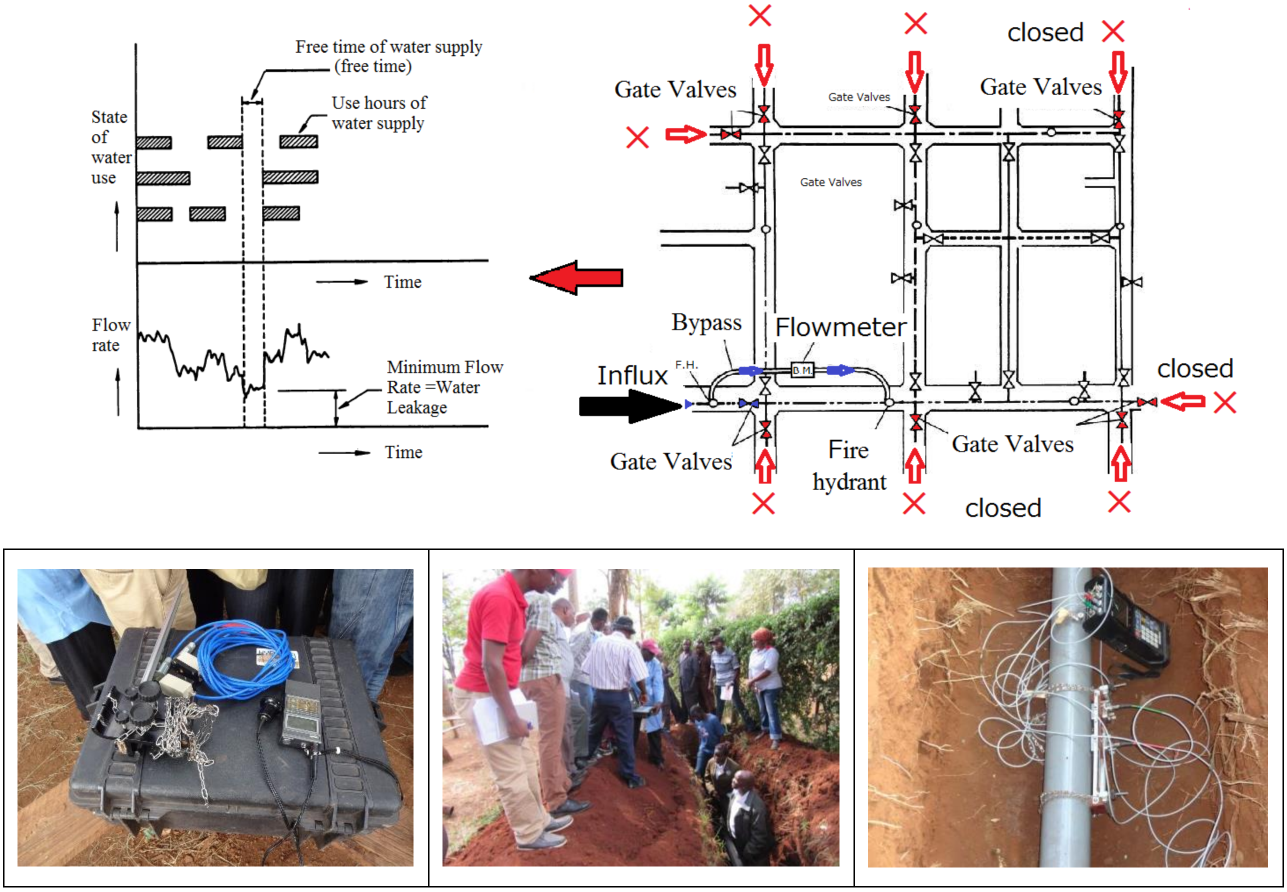


Figure-14 Flow measurement in isolated DMA

(3) Procedure ~~of~~ for flow measurement survey

a) Confirm that the amount of water flowing into the survey target DMA is from one location.

b) Install a clamp type ultrasonic flowmeter on the inflow pipe.

c) Manage the gate valve of the outflow pipe into the adjacent DMA.

d) Investigate with the water faucet in the "open" state.

e) Data timer setting: every 5 minutes

f) Survey time

- AM 9: 00:…...……Preparation for measurement
- AM 10:00 ………Start flowmeter survey (Read BFM).

↓ Keep opening gate vale at outflow pipe send to adjacent DMA (Automatic recording of data)

- PM 11: 00 ~ AM 05; 00: "**Close**" the gate valve at outflow pipe.

↓ (Start measurement of nighttime minimum flow rate)

- AM 05: 30 - AM 06: 00: End of measurement and Set the gate valve to "**Open**".& Set another UFM on the outflow pipe. (To ripen long water supply stop)

↓

- AM 05: 00 to AM 10: 00;. Measurement of daily minimum flow rate
- AM 10; 00: ….End of survey

↓

- PM 16: 00:…..Output by graphing

h) Example output of nighttime minimum water graph (**Refer to Figure-13**)

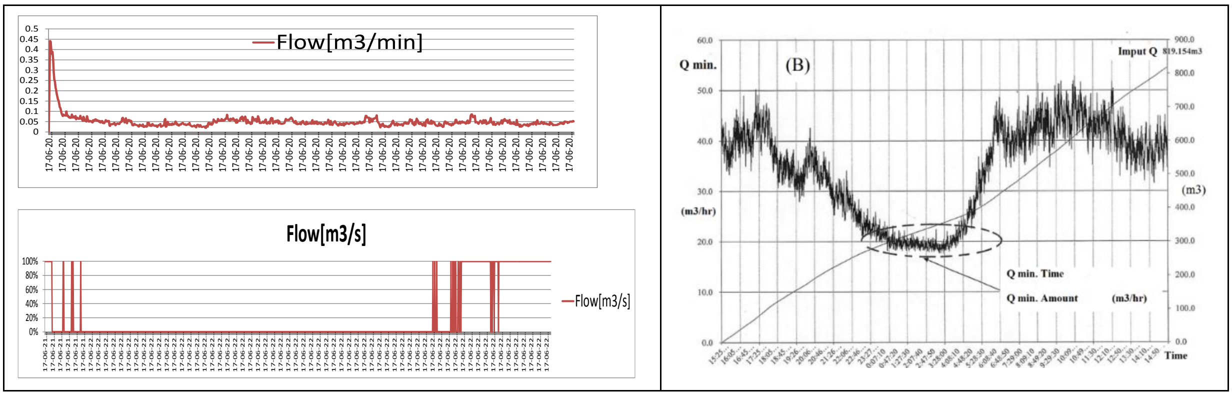


Figure-15 Example of nighttime minimum flow rate

(4) Equipment used

(a) Ultrasonic flow meter **(Refer to Figure-16)**

(b) Tool

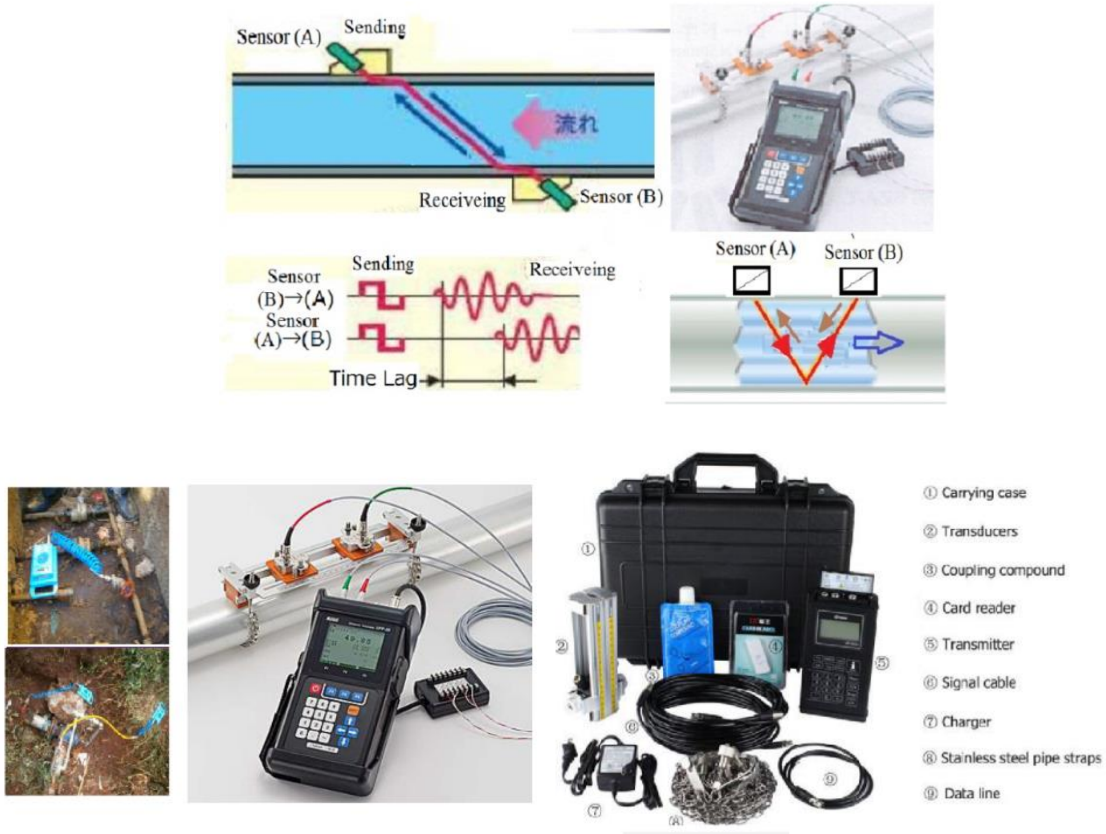


Figure-16 Overview of Ultrasonic flow meter

8-2 Measurement of Water pressure gauge

(1) Object of achievement

a) The objective of this exercise is to monitor the 24-hour pressure variations in order to understand the characteristics of the nighttime minimum flow rate.

b) It is also possible to grasp the relationship between the minimum flow rate at night and pressure fluctuation.

c) Have the consultation on the findings.(**Form 4**)

(2) Points of concern

a) Record the water pressure on the recording paper at intervals of 5 minutes. (For reading)

b) Recording of data (**Form 4**)

(3) Equipment used

a) Digital pressure data logger

b) Mechanical pressure gauge

8-3 Portable electronic test meter

(1) Object of achievement

a) The objective of this training is to determine the measurement error of the installed customer meter by connecting the electronic meter testers and the consumer meter in series and comparing the volumes recorded through each meter.

b) Check the measurement error (numerical value) of the existing meter.

c) Have the consultation on the findings. (**Form-5-6**)

(2) Points to remember

a)The electronic meter (tangential impeller) must always be calibrated to record accurate measurements.

b) Measurement of flow rate other than set flow rate increases measurement error.

c) Do not bring strong magnets close to the electronic meter during measurements.

(3) Measurement range

a) Maximum flow rate 1.0 m^3 / hr, intermediate flow rate 0.2 m^3 / hr, minimum flow rate 0.1 m^3 /hr,

b) Measurement accuracy ± 2.0% for intermediate and high flows and ±5% on the lower flow rate.

(4) Equipment to be used

a) Portable electronic meter …1 set **(Refer to Figure-17)**

b) Hose · Connecting device · · · ·1 set

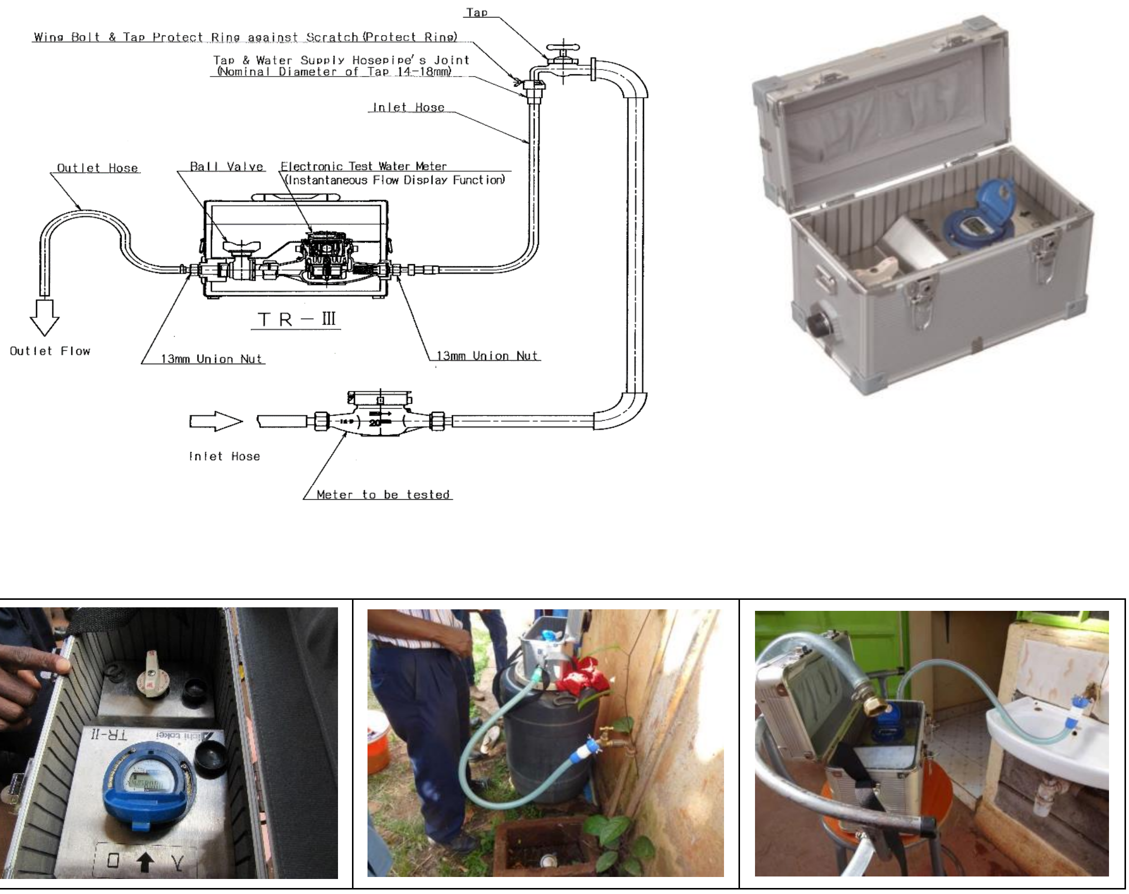


Figure 17 Installation drawing of electronic meter

9. Survey of Customer meter reading &meter condition

(1) Object of achievement

a) The objective of this survey is investigate the measurement accuracy of the customer meter.

b) Have the consultation on the findings. (**Form-7**)

(2) Procedure of survey

a) 5 EMBU staff will guide 5 groups of trainees (5-6 people / group) on site.

b) The number of customer meters surveyed by each team is about 20 to 40 for each group.

c) Each group will use the Listening Stick placed on the water meter / stopcock and listens to the characteristic leak sound.

10. Water meter bench test

(1) Object of achievement

a) The objective of this training is to accurately determine water measurement error caused by deterioration of customer's water meter and insufficient maintenance.

b) Observe the demonstration of the water meter test method and recognize the malfunction of the meter and recording data (**Form-8**)

c) Have the consultation on the findings.

(2) Measurement procedure (demonstration by EMBU staff)

a) "Instrument difference" of the customer's water meter is compared with "measured value" passed through the test water meter and the passed water volume with "capacity of the standard tank".

b) Select 8 to 10 customer meters to be inspected (aged), meters with different usage conditions.

c) Meter difference is evaluated by 3-point flow performance test. (Qmin. = 30 liters, QT = 120liters Qn = 1.5 m 3 ... For Class B)

d) Note: Conversion formula from old standard Class-B to new standard (R)

- **For example: ISO B Class**

  R=ISO B=Q3/Q1=1.5/0.03 =50

  *** ISO-B（old STD） = R50(New STD)**

The standard of a Japanese customer meter is R100.

（The larger the R value, the lower the measurement error of the water meter.）

e) How to find **Qn** numbers? (**Refer to Figure-18**)

item	ISO 4064-1993
Manufacturer.	LAO(Brazil)
Model,	M6011B
	Multi-jet-Dry-Tangential flow impeller
quality standard,	Classe-B
caliber（mm）	15
Qn(m^3/h)	1.5
Qmin(m^3/h)	0.030
Display version	

Figure-18 Example of Old ISO-STD (Class-B)

f) Computation method of each flow rate in a measurement point (**Refer to Figure-19**)

- **For example: ISO B Class (Qn=1.5m^{3}/hr) (Refer to Table-5)**

  ①Minimum flow rate(Qmin.)=(Q1)=1.5 x **0.02**=30 liters/hr

  ②Transfer flow rate (Qt) = (Q2)=1.5 x **0.08**=120 liter/hr

  ③Nominal flow rate (Qn =(Q3)= 1.5 m3/hr

  ④Maximum flow rate(Qmax)=(Q4)=1.5 x **2.0**=3.0 m3/hr

Table-5 Typical ccalculation table of test water volume

ISO4064-1993 Class	Qmin＝Q1	Q t＝Q2	Q n ＝Q3	Qmax＝Q4
A	Qn x 0.04	Qn x 0.10	-	Qn x 2.0
B	Qn x 0.02	Qn x 0.080	-	Qn x 2.0
C	Qn x 0.01	Qn x 0.015	-	Qn x 2.0

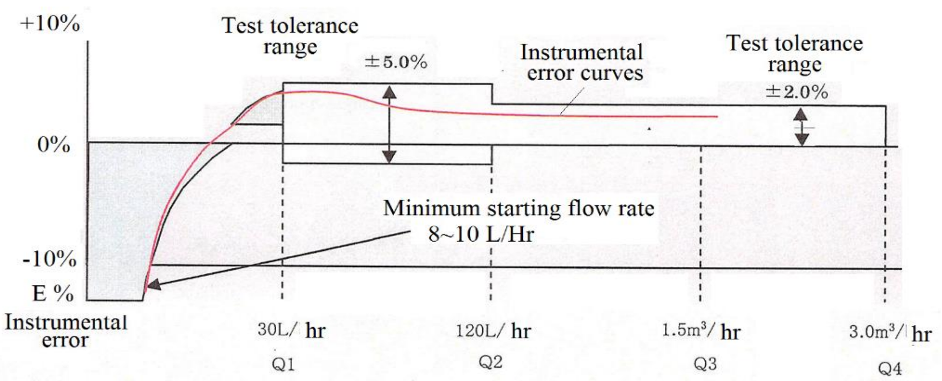


Figure-19 Typical Instrumental error curve at 3- flow rate (Class B)

- Determination of allowable error of test water quantity **(Refer to Table-6-7)**

Table- 6 Typical Allowable tolerance (For New meter)

Test tolerance			Flow area
①Rated minimum flow rate	Q1 and above	**±5 %**	Small flow rate range
②Transfer flow rate	Below Q2		
③Maximum rated flow rate	Q3 and above	**±2 %** (Water temperature : less than 30 degrees)	High flow rate range
④Limiting flow rate	Below Q4		

Table-7 Typical Working tolerance（Using customer meters）

Test tolerance			Flow area
①Rated minimum flow rate	Q1 and above	**±10 %**	Small flow rate range
②Transfer flow rate	Below Q2		
③Maximum rated flow rate	Q3 and above	**±4 %** (Water temperature : less than 30 degrees)	High flow rate range
④Limiting flow rate	Below Q4		

(3) Points of concern

① Always calibrate measurement precision with a flow meter.

② Check that the pressure gauge on the outflow side always has a back pressure of 0.05 KPa (0.51 kgf/cm^2 =0.00005 bar) or more.(1kpa=0.01 bar)

③Water temperature :less than 30 degrees

(4) Equipment used **(Refer to Figures 20-21)**

①Water meter test bench,

②Water tank (small: 100 to 500 liters, large size: 1 m ^{3} or more) · · 1 set

③Flow meter (3 to 4 types L/h): 5 to 100, 100 to 1000, 1,000 to 100,000) · 1 set

④Pressure gauge · · · · · · · · · · · · 2sets

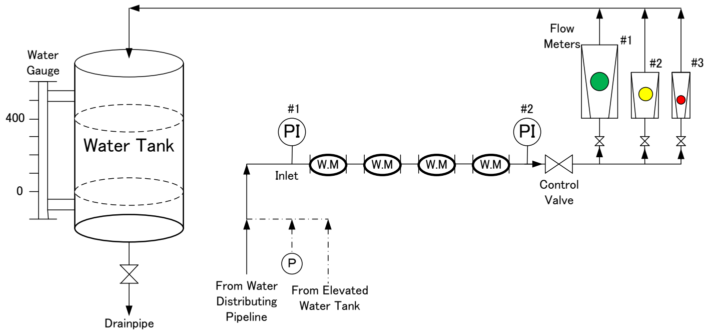
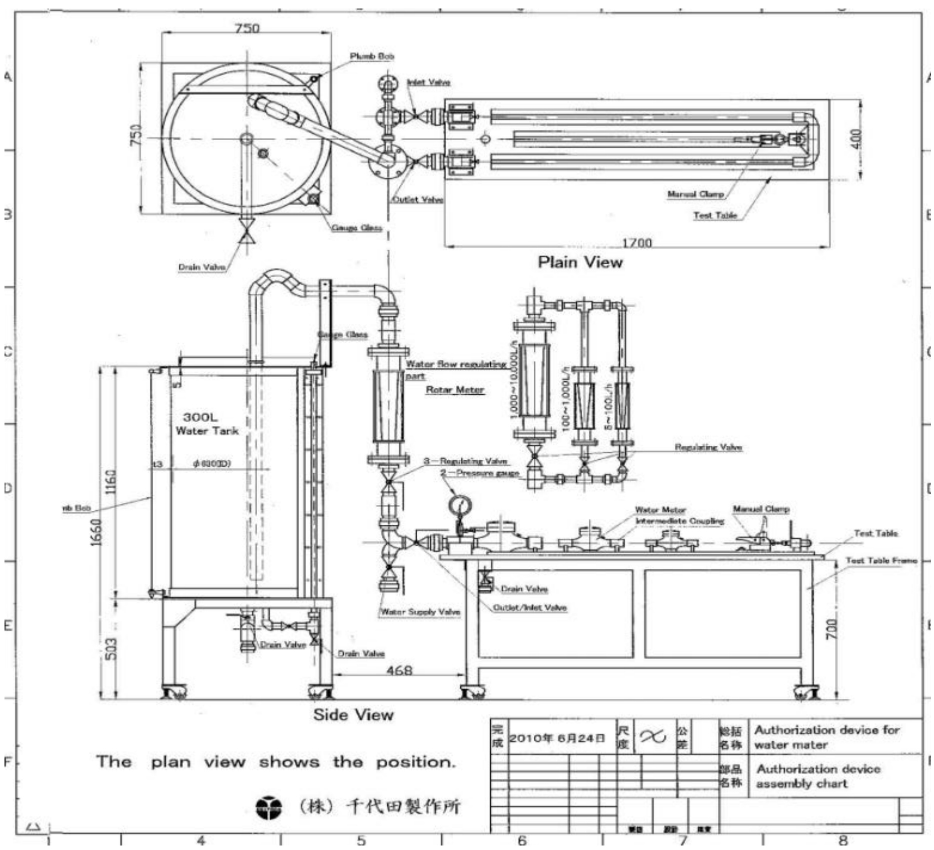


Figure-20 Principle of the water meter test apparatus method (volume method)



Fugue-21 Plan of EMBU's water meter test bench

11. Water Quality Equipment

(1) Object of achievement

a) to determine the water quality of tap water and leak flow.

b) Have the consultation on the findings. (**Form-9**)

11-1 Determination of residual chlorine by colorimetric method

(1) Object of achievement

The objective is to conduct color discrimination analysis technique with chlorine agent, from water leakage or tap household use water supply (illegal connection), to customers in the field.

(2) Reactive color

(a) Normally there is residual chlorine in tap water.

(b) In the colorimetric method, a reagent is added to the test water, and the leak source is judged from the reaction color.

(c) Generally, the DPD method is used. (**Refer to figures 22-23**)

(3) Reacted color

a) Diethyl Para Phenylene diamine (DPD) method)

· ●Peach →change to peach red discoloration

b) Orthotolidine (OT) method

●Light yellow → change to yellowish brown

NOTE: Note: The use of OT method is currently banned in some countries due to suspected carcinogenic health concerns.

DPD reagent used

OT reagent used

Figure-22 Colorimetric reaction with residual chlorine

(3) Appliance used

Powder / solid DPD reagents

Residual chlorine analyzer

Spectrophotometric residual chlorine analyzer

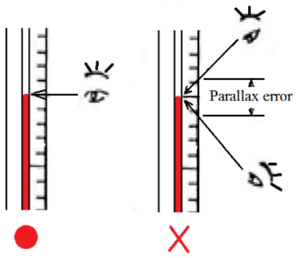
Figure-23 Measurement equipment

11-2 Water temperature gauge

（1） Object of achievement

a) In this training, skills to measure the temperature of leakage/tap water is learned.

(Refer to Figure-24)



How to read the water temperature gauge

Rod-like red liquid thermometer

Figure-24 Measurement of Water temperature

11-3 Conductivity meter

(1) Object of achievement

In this training, skills to measure the conductivity of leakage will be learned.

(Refer to Figure-25)

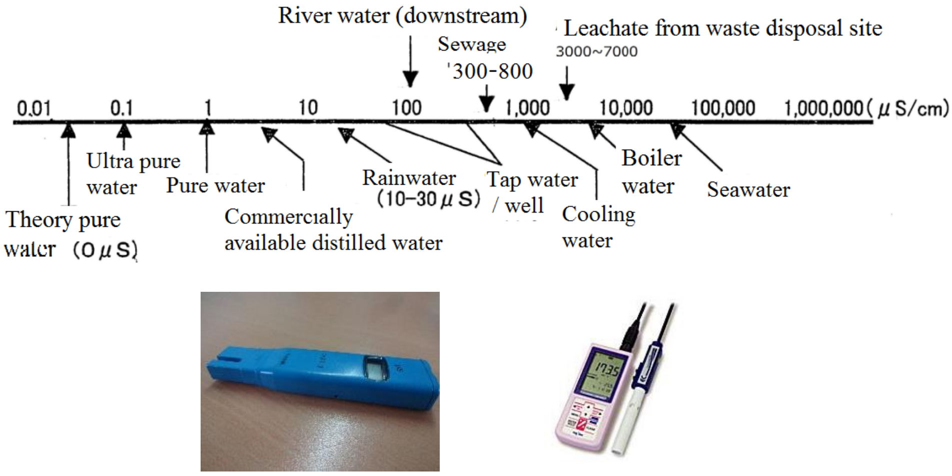


Figure-25 Measurement of Water Conductivity

11-4 pH measuring instruments

(1) pH meters

(1) Object of achievement

In this training, skills to measure pH from a leak will be learned.

(Refer to Figure 26-27)

Table 8 pH classification

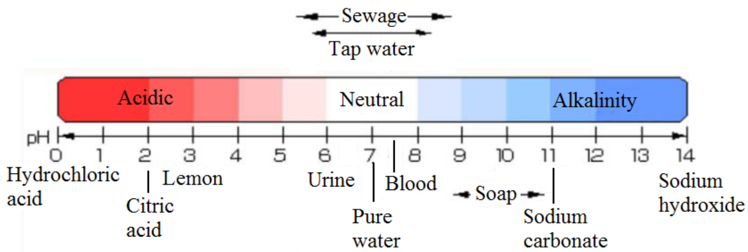
pH	Nature of the liquid
0～3.0	Acidic
3.0～6.0	Mild acidity
6.0～8.0	Neutral
8.0～11.0	Weakly alkaline
11.0～14	Alkaline

Figure-26 pH meters

(2) Litmus papers

(a) Object of achievement

In this training, skills to measure pH with litmus paper are learned.



Roll Type

Book Type

Figure-27 Measurement of Water pH

12. Measurement of flowing water from a water tap

(1) Object of achievement

a) In this training, measure the amount of water flowing from the faucet so that the amount of water loss at the leak point can be easily and quickly determined on site.

b) Have the consultation on the findings. (**Form-10**)

(2) Survey procedure

a) Capture the amount of water from the tap against a given time and save it in a container.

b) Measure the water in the container with a measuring cup or weight and convert it to the amount of water.

c) Measure the pressure at the outlet of the water supply tap.

d) Record the survey results.

e) Photograph the flow of water.

(3) Relationship between weight of water and volume (volume)

Formula : W = R × V

Here

W = Weight (g)

R = Density g / cm ^{3} = Specific gravity (water = 1)

V = Volume (Capacity) L, cc, mL

Table-9 Conversion table (Water Specific gravity = 1)

Volume		Weight		Note
L (liter)	mL(mill-liter)	g (gram)	mg(milligram)	
1.0	1,000	1,000	1,000,000	
0.5	500	500	500,000	
0.1	100	100	100,000	
0.01	10	10	10,000	

(4) Equipment used (In the case of small leakage) (**Refer to Figure- 28)**

a) Measurement cup,

b) Bucket,

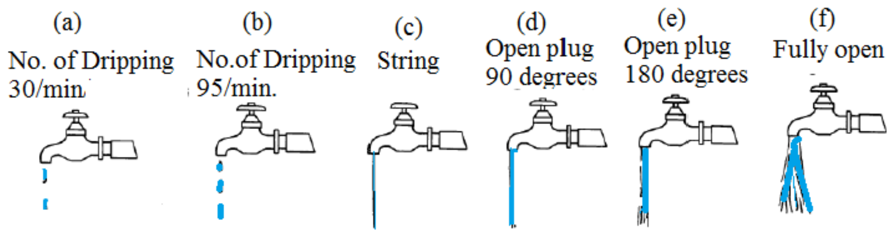
c) Weight scale

d) Stopwatch,

Figure- 28 Equipment for instrumentation

(5) Example

① Water faucet (Dia. 13m/m,5kgf/cm2)



Source: JPRC 1995 #20

	Items	W. Leakage	(a)	(b)	(c)	(d)	(e)	(f)
①	Faucet	m^3/d	0.011	0.036	0.09	309	39.6	56.8

Figure-27 Understanding water leakage (flowing from water faucet)

13. Formats

(Form-1) Leak survey

(1) CUSTOMER METER: Registry number___________________________

(2) Location____

(3) Type of Meter____

(4) Number of operating months____________________________________

(5) Name of test staff____

(6) Date_______________________________

Sheet No,___________________

Classification	No. of cases	%	Estimated W. leakage (m^3/hr.)	%	Remarks
1/2”-1” on the distribution pipe	20.0	7.3%	4.6	9.6%	
Air vale	30.0	11.0%	2.5	5.2%	
11/2”- 2” on the distribution pipe	30.0	11.0%	15.0	31.3%	
Stope cock	70.0	25.6%	5.2	10.8%	
Gate valve	15.0	5.5%	3.2	6.7%	
Other valve	5.0	1.8%	4.2	8.8%	
B. Meter	6.0	2.2%	5.8	12.1%	
C. Meter	62.0	22.7%	0.7	1.4%	
Inside the house	30.0	11.0%	3.1	6.5%	
Other	5.0	1.8%	3.7	7.7%	
Total	273.0	100.0%	48.0	100.0%	

(Form-2) Leak survey

LEAKAGE REPORT

<table>
<tr><td colspan="5">KENYA WATER INSTITUTE</td></tr>
<tr><td colspan="5">LEAKAGE REPORT</td></tr>
<tr><td colspan="2">DATE:</td><td colspan="3">ROAD:</td></tr>
<tr><td colspan="2">BLOCKMAP No.:</td><td colspan="3">REPORT No:</td></tr>
<tr><td rowspan="5">Method of finding:</td><td>LEAKAGE ON:</td><td>X</td><td>DN</td><td>Material</td></tr>
<tr><td>Service Connection</td><td></td><td></td><td></td></tr>
<tr><td>Main Pipe</td><td></td><td></td><td></td></tr>
<tr><td>Pipe Saddle or Ferrule</td><td></td><td></td><td></td></tr>
<tr><td>Pipe Fitting</td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Estimated loss:
(m3 /hr.)</td><td>Valve</td><td></td><td></td><td></td></tr>
<tr><td>Hydrant</td><td></td><td></td><td></td></tr>
<tr><td>Air Valve</td><td></td><td></td><td></td></tr>
<tr><td>Bulk Meter</td><td></td><td></td><td></td></tr>
<tr><td>Pump</td><td></td><td></td><td></td></tr>
<tr><td>COMMENTS:</td><td></td><td></td><td></td><td></td></tr>
<tr><td>SKETCH of LOCATION:</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Report issued</td><td colspan="2">Report approved</td><td>Work Instruction to</td><td>Work done</td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td></tr>
</table>

(Form-3) Leak survey

(1) CUSTOMER METER: Registry number___________________________

(2) Location____

(3) Type of Meter____

(4) Number of operating months____________________________________

(5) Name of test staff____

(6) Date________________________________

Sheet No,____________________

Result sheet

Year	Survey method	Distance of survey conducted (㎞)		Number of discoveries(Cases)				Total
		Distance of acoustic detection	Distance of flow investigation	In public road	Before the meter	In the meter box	After meter	
2017 June (DMA-1)	Surface leakage			438	631	163	1,159	2,391
	Discovered by survey (underground)	543	12.84	140	261	357	24	782
	Total	543	12.84	578	892	520	1,183	3,173
2017 June (DMA-1)	Surface leakage			396	740	102	1,142	2,380
	Discovered by survey (underground)	639	15.13	202	381	218	27	828
	Total	639	15.13	598	1,121	320	1,169	3,208

Source：Yokosuka City waterworks and sewerage bureau, Water leakage prevention

(Form-4) Pressure test

Time	Pressure (kg.cm2)	Acuml. Flow (m3	Note	Time	Pressure (kg.cm2)	Acuml. Flow (m3	Note
AM 10:30				**23:00**			
11;00				**23:30**			
11:30				**24:00**			
12:00				**0;30**			
12:30				**1:00**			
13:00				**1:30**			
13:30				**2:00**			
14:00				**2:30**			
14:30				**3:00**			
15:00				**3:30**			
15:30				**4:00**			
16:00				**4:30**			
16:30				**5:00**			
17:00				**5:30**			
17;30				**6:00**			
18;00				**6:30**			
18:30				**7:00**			
19:00				**7:30**			
19:30				**8:00**			
20:00				**8:30**			
20:30				**9:00**			
21:00				**9:30**			
21:30				**10:00**			
22:00				**10:30**			
22:30				**AM11:00**			

(Form-5) Accuracy survey of Customer meter with Master Meter

(1) Custer meter (Registry number)___________________________

(2) Location____

(3) Type of Meter____

(4) Number of operating months____________________________________

(5) Name of test staff____

(6) Date_______________________________

Sheet No,___________________

Flow rate (L/min)	Time interval (min,)	Reading Customer meter (liters)			MASTER METER (liters)			Difference (liters)	Error (%)	Commentss
		Start	End	Total	Start	End	Total			
20 l/hr	1									
	2									
	3									
	4									
	5									
	10									
50 l/hr	1									
	2									
	3									
	4									
	5									
100 l/hr	1									
	2									
	3									
	4									
	5									
200 l/hr	1									
	2									
	3									
	4									
	5									

(Form-6) Accuracy survey of Customer meter with Master Meter

Date________________ & Name of staff_________________________

#	Meter R/N	Type of Meter	Maker	Record Customer meter (liters)			Read Master Meter (liters)			Difference (liters)	Error (%)	Comment	
				Start	End	Total	Start	End	Total			pass-fail	
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													

(Form-7) Customer meter reading &meter condition

Date_________________ & Name of staff__________________________

Sheet No._____________

#	Meter R/N	Type of Meter	Maker	Recording Time (min.)			Reading Meter (liters)			Consumption amount (liters)	Meter Conditions	Presence of a leakage W/ LS
				Start	End	Difference	Start	End	Difference			
1				10:30	10:30	～24 Hr.						
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												

#	Mete r R/N	Type of Meter	Maker	Recording Time (min.)			Reading Meter (liters)			Consumption amount (liters)	Meter Conditions	Presence of a leakage w/ LS
				Start	End	Difference	Start	End	Difference			

(Form-8) Water meter test bench

Sample of Water Meter Testing at EWASCO's Test Bench													2017/6/22	
No.1														
P1 Inlet Pressure = bars							P2 Outlet Pressure= bars						ISO STD	Your STD
No	Classification	Meter sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Total accumulated water (m3)	Appearance situation	Flow Qn (1500 l/h)					Comments (4% or less)	Comments
								Total flow vol. = 200 lts (Water Tank volume)						
								START	END	DIFRENCE		Fluctuation in error %		
Volume used 200 lts=0.2 m3						0.2		R1 (m3)	R2 (m3)	R2-R1=(m3)	%			
						R1 (m3)								
1	old													
2	stuck													
3	serviced													
4	customer													
5	customer													
6	above 1000													
7	above 500													
8	new													
9														
10														

No-2														
P1 Inlet pressure = 0.4 bars							P2 Outlet Pressure= bars						ISO STD	Your STD
No	Classification	Meter sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Total accumulated water (m3)	Appearance situation	Flow Qt (120 l/h)					Comments (4% or less)	Comments
								Total flow vol.=50 lts (Water Tank Volume)						
								START	END	DIFRENCE		Fluctuation in error %		
Volume used 50 lts=0.05 (m3)						0.05		R2 (m3)	R3 (m3)	R3-R2=(m3)	%			
						R2(m3)								
1	old													
2	stuck													
3	serviced													
4	customer													
5	customer													
6	above 1000													
7	above 500													
8	new													
9														
10														

No3

P1 Inlet pressure = 0.4 bars							P2 Outlet Pressure= bars						ISO STD	Your STD
No	Classification	Meter sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Total accumulated water (m3)	Appearance situation	Flow Qmin (30 l/h)					Comments (10% or less)	Comments
								Total flow vol.= 20 lts (Water Tank Volume)						
								START	END	DIFRENCE		Fluctuation in error %		
Volume used 20 lts= 0.020 (m3)						0.02		R3 (m3)	R4 (m3)	R4-R3=(m3)	%			
						R3(m3)								
1	old													
2	stuck													
3	serviced													
4	customer													
5	customer													
6	above 1000													
7	above 500													
8	new													
9														
10														

Error table

No.	Registration number	Name of manufacturer	Sr.No.	Model	Year of manufacture	Year of use	Caliber (mm)	Total accumulated water (m 3)	Appearance situation	Flow Qn(1,500 L/h)			Flow Qn(120L/h)			Flow Qn(30L/h)		
										Total Flow Vol (100L)			Total Flow Vol (100L)			Total Flow Vol (100L)		
										Start	End	%	Start	End	%	Start	End	%
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		

Sample of Water Meter Testing at EWASCO's Test Bench														2017/6/15
P1 Inlet Pressure = 0.4 bars							P2 Outlet Pressure= 0.05 bars						ISO STD	EMBU STD
No	Classfication	Meter sr.no	Model/ STD	Year of manufacturer	Caliber (mm)	Total accumalated water (m3)	Appearance situation	Flow Qn (1500 l/h) Total flow vol. = 200 lts (Water Tank volume) START	END	DIFRENCE		Fluctuation in error %	Comments (4% or less)	Comments (5% or less)
Volume used 200 lts=0.2 m3						0.2 R1 (m3)		R1 (m3)	R2 (m3)	R2-R1=(m3)	%			
1	old	H570960	kss/CB		20	2779.09		2779.09	2779.301	0.211	105%	5%	Pass	Pass
2	stuck	2010050430	psm/CB		20	49.4941		49.4941	49.4941	0	0%	-100%	NO	NO
3	serviced	1045307	psm/CB		20	0.4674		0.4674	0.6654	0.198	99%	-1%	Pass	Pass
4	customer	16003525	inf/CB		20	127.2445		127.2445	127.4468	0.2023	96%	-4%	Pass	Pass
5	customer	15074292	inf/CB		20	608.5141		608.5141	608.7122	0.1981	99%	-1%	Pass	Pass
6	over 1000	04-1359428	kss/CB		20	1463.6		1463.6	1463.758	0.1578	79%	-21%	NO	NO
7	over 500	2010050697	psm/CB		20	963.903		963.903	964.0919	0.1889	94%	-6%	NO	NO
8	new	AC-447853	psm/CB		20	0.105		0.105	0.303	0.198	99%	-1%	Pass	Pass

P1 Inlet pressure = 0.4 bars							P2 Outlet Pressure= bars						ISO STD	EMBU STD
No	Classification	Meter sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Total accumalated water (m3)	Appearance situation	Flow Qt (120 l/h) Total flow vol.=50 lts (Water Tank) START	END	DIFRENCE		Fluctuation in error %	Comments (4% or less)	Comments (5% or less)
Volume used 50 lts=0.05 (m3)						0.05 R2(m3)		R2 (m3)	R3 (m3)	R3-R2=(m3)	%			
1	old	H570960	kss/CB		20	2779.301		2779.301	2779.35	0.049	98%	-2%	Pass	Pass
2	stuck	2010050430	psm/CB		20	49.4941		49.4941	49.4941	0	0%	-100%	No	No
3	serviced	1045307	psm/CB		20	0.6654		0.6654	0.7171	0.0517	103%	3%	Pass	Pass
4	customer	16003525	inf/CB		20	127.4468		127.4468	127.497	0.0502	102%	2%	Pass	Pass
5	customer	15074292	inf/CB		20	608.7122		608.7122	608.7594	0.0472	94%	-6%	No	No
6	over 1000	04-1359428	kss/CB		20	1463.7578		1463.758	1463.807	0.0488	98%	-2%	Pass	Pass
7	over 500	2010050697	psm/CB		20	964.0919		964.0919	964.1396	0.0477	95%	-5%	No	Pass
8	new	AC-447853	psm/CB		20	0.303		0.303	0.352	0.049	98%	-2%	Pass	Pass

P1 Inlet pressure = 0.4 bars							P2 Outlet Pressure= bars						ISO STD	EMBU STD
No	Classification	Meter sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Total accumalated water (m3)	Appearance situation	Flow Qmin (30 l/h) Total flow vol (21) START	END	DIFRENCE		Fluctuation in error %	Comments (10% or less)	Not decided yet
Volume used 21 lts= 0.021 (m3) …... (20 lts)						0.021 R3(m3)		R3 (m3)	R4 (m3)	R4-R3=(m3)	%			
1	old	H570960	kss/CB		20	2779.35		2779.35	2779.371	0.021	100%	0%	Pass	Pass
2	stuck	2010050430	psm/CB		20	49.4941		49.4941	49.4941	0	0%	-100%	No	Pass
3	serviced	1045307	psm/CB		20	0.7171		0.7171	0.7381	0.021	100%	0%	Pass	Pass
4	customer	16003525	inf/CB		20	127.497		127.497	127.5162	0.0192	91%	-9%	No	Pass
5	customer	15074292	inf/CB		20	608.7594		608.7594	608.7594	0	0%	-100%	No	Pass
6	over 1000	04-1359428	kss/CB		20	1463.8066		1463.807	1463.825	0.0181	86%	-14%	No	Pass
7	over 500	2010050697	psm/CB		20	964.1396		964.1396	964.1584	0.0188	90%	-10%	No	Pass
8	new	AC-447853	psm/CB		20	0.352		0.352	0.369	0.017	81%	-19%	No	Pass

(Form-9) Water quality test

(1) CUSTOMER METER: Registry number_____________________________

(2) Location____

(3) Type of Meter____

(4) Number of operating months_______________________________________

(5) Name of test staff____

(6) Date_________________________________

Sheet No,____________________

No. of sample	Location	Colorimetric reaction by DPD	Numerical value of Conductivity	Numerical value of pH	Date

(Form-10) Measurement of flowing water

(1) Custer meter (Registry number)______________________________

(2) Diameter of a water tap;__________ mm

(3) Pressure___________________ (Kg/cm^2)

(4) Name of test staff____

(5) Date______________________

Sheet No. ______________________

Weight (g/min)	Flow Velocity (liters/ min)	Volume of flowing water (liters)				Photo
		60 min	1 day	365 days		
						5 liters/hr
						10,
						20,
						30
						40
						50,
						70
						100,
						200

14 Conversion Table

14- 1Pressure

	ata (kg/cm^2)	mm water (4℃)	bar	Mpa	Kpa	PSI(lb/in)
ata (kg/cm^2)	1	10,000.03	0.981	0.0981	98.07	14.22
mm water (4℃)	9.99×10^{-5}	1	9.81×10^{-5}	9.81×10^{-6}	9.81×10^{-3}	1.422×10^{-3}
bar	1.02	101197.44	1	0.1	100	14.5
Mpa	10.2	101,974.42	10	1	1,000	14.5
Kpa	0.01	101.97	0.01	0.001	1	0.145
PSI(lb/in)	0.07	703, 09	0.0689	6、893 x 10^{-3}	6,863	1

14-2 Volume Vs Weight (Water Specific gravity = 1)

Volume		Weight		Note(500mg)
L (liter)	mL(mill-liter)	g (gram)	mg(milligram)	
1.0	1,000	1,000	1,000,000	
0.5	500	500	500,000	
0.1	100	100	100,000	
0.01	10	10	10,000	

14-3 Water density

Water density (g/cm^3)

Temp.(℃)	After the decimal point									
	0	1	2	3	4	5	6	7	8	9
0	0. 999841	0. 999847	0. 999854	0. 999860	0. 999866	0. 999872	0. 999878	0. 999884	0. 999889	0. 999895
1	0. 999900	0. 999905	0. 999909	0. 999914	0. 999918	0. 999923	0. 999927	0. 999930	0. 999934	0. 999938
2	0. 999941	0. 999944	0. 999947	0. 999950	0. 999953	0. 999955	0. 999958	0. 999960	0. 999962	0. 999964
3	0. 999965	0. 999967	0. 999968	0. 999969	0. 999970	0. 999971	0. 999972	0. 999972	0. 999973	0. 999973
4	0. 999973	0. 999973	0. 999973	0. 999972	0. 999972	0. 999972	0. 999970	0. 999969	0. 999968	0. 999966
5	0. 999965	0. 999963	0. 999961	0. 999959	0. 999957	0. 999955	0. 999952	0. 999950	0. 999947	0. 999944
6	0. 999941	0. 999938	0. 999935	0. 999931	0. 999927	0. 999924	0. 999920	0. 999916	0. 999911	0. 999907
7	0. 999902	0. 999898	0. 999893	0. 999888	0. 999883	0. 999877	0. 999872	0. 999866	0. 999861	0. 999855
8	0. 999849	0. 999843	0. 999837	0. 999830	0. 999824	0. 999817	0. 999810	0. 999803	0. 999796	0. 999789
9	0. 999781	0. 999774	0. 999766	0. 999758	0. 999751	0. 999742	0. 999734	0. 999726	0. 999717	0. 999709
10	0. 999700	0. 999691	0. 999682	0. 999673	0. 999664	0. 999654	0. 999645	0. 999635	0. 999625	0. 999615
11	0. 999605	0. 999595	0. 999585	0. 999574	0. 999564	0. 999553	0. 999542	0. 999531	0. 999520	0. 999509
12	0. 999498	0. 999486	0. 999475	0. 999463	0. 999451	0. 999439	0. 999427	0. 999415	0. 999402	0. 999390
13	0. 999377	0. 999364	0. 999352	0. 999339	0. 999326	0. 999312	0. 999299	0. 999285	0. 999272	0. 999258
14	0. 999244	0. 999230	0. 999216	0. 999202	0. 999188	0. 999173	0. 999159	0. 999144	0. 999129	0. 999114
15	0. 999099	0. 999084	0. 999069	0. 999054	0. 999038	0. 999023	0. 999007	0. 998991	0. 998975	0. 998959
16	0. 998943	0. 998926	0. 998910	0. 998893	0. 998877	0. 998860	0. 998843	0. 998826	0. 998809	0. 998792
17	0. 998774	0. 998757	0. 998739	0. 998722	0. 998704	0. 998686	0. 998668	0. 998650	0. 998632	0. 998613
18	0. 998595	0. 998576	0. 998558	0. 998539	0. 998520	0. 998501	0. 998482	0. 998463	0. 998444	0. 998424
19	0. 998405	0. 998385	0. 998365	0. 998345	0. 998325	0. 998305	0. 998285	0. 998265	0. 998244	0. 998224
20	0. 998203	0. 998183	0. 998162	0. 998141	0. 998120	0. 998099	0. 998078	0. 998056	0. 998035	0. 998013
21	0. 997992	0. 997970	0. 997948	0. 997926	0. 997904	0. 997882	0. 997860	0. 997837	0. 997815	0. 997792
22	0. 997770	0. 997747	0. 997724	0. 997701	0. 997678	0. 997655	0. 997632	0. 997608	0. 997585	0. 997561
23	0. 997538	0. 997514	0. 997490	0. 997466	0. 997442	0. 997418	0. 997394	0. 997369	0. 997345	0. 997320
24	0. 997296	0. 997271	0. 997246	0. 997221	0. 997196	0. 997171	0. 997146	0. 997120	0. 997095	0. 997069
25	0. 997044	0. 997018	0. 996992	0. 996967	0. 996941	0. 996914	0. 996888	0. 996862	0. 996836	0. 996809
26	0. 996783	0. 996756	0. 996729	0. 996703	0. 996676	0. 996649	0. 996621	0. 996594	0. 996567	0. 996540
27	0. 996512	0. 996485	0. 996457	0. 996429	0. 996401	0. 996373	0. 996345	0. 996317	0. 996289	0. 996261
28	0. 996232	0. 996204	0. 996175	0. 996147	0. 996118	0. 996089	0. 996060	0. 996031	0. 996002	0. 995973
29	0. 995944	0. 995914	0. 995885	0. 995855	0. 995826	0. 995796	0. 995766	0. 995736	0. 995706	0. 995676
30	0. 995646	0. 995616	0. 995586	0. 995555	0. 995525	0. 995494	0. 995464	0. 995433	0. 995402	0. 995371

～END-

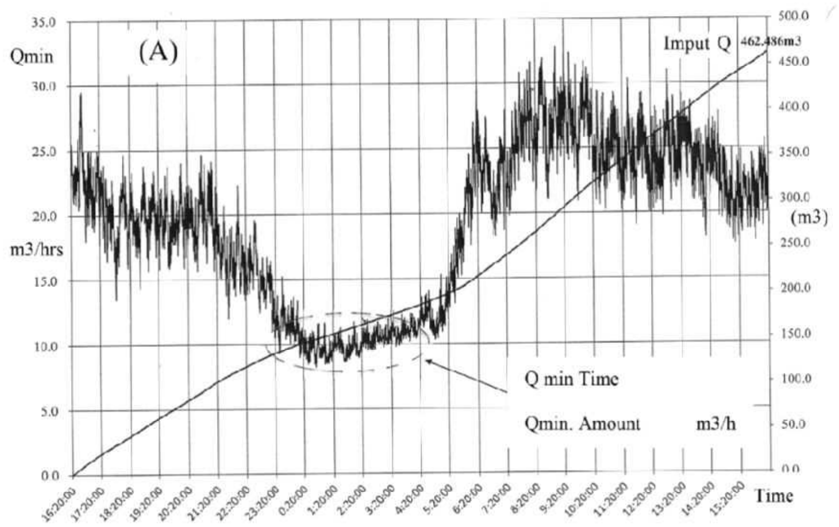
Exercises:-1

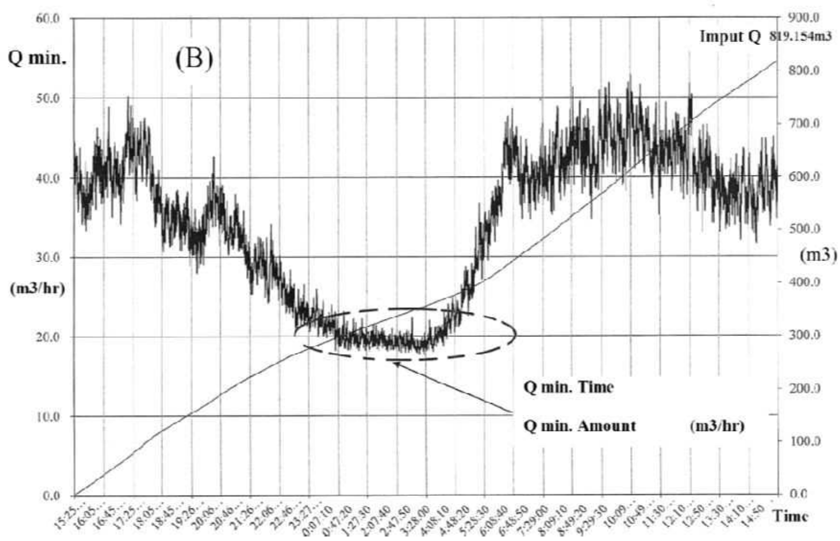
①When is the minimum water volume($m^{3/}$hrs.) and time ( ) of each table?

②Which minimum flow rate should be estimated as leakage amount?

③Why was there a difference in minimum flow value?

④How does "water pressure, weather, day of the week" not specified for this data be influenced by the minimum flow rate survey?





Exercises-2

①Describe how to proceed with additional survey, measuring the minimum flow rate at night at main distribution pipe line, dia.200mm~500 mm.

.

Rank	Night minimum flow rate value	Contents of additional survey
A	$12m^3$/d/㎞ or less	
B	$12m^3$/d/㎞~$24m^3$/d/㎞ or less	
C	$24m^3$/d/km ~$50m^3$/d/km or less	
D	$50m^3$/d/ ㎞ more	

(6-3) Step test

In this method, the inside of the DMA is subdivided, for example, by piping branch lines, the smallest nighttime flow rate of the small section is measured in order, and the leakage amount is assumed from the total of the leakage sections.

In addition, it is possible to specify the section with the smallest flow rate.

Total MFR = MFR at small section (a) + small section (b)+ …….

Exercises-3

①We measured the nighttime minimum flow rate in each small district, but from which area should we implement leakage countermeasures?

②What is the NRW rate of each section?

③What is the total leakage amount in this surveyed residential zone ?

④How to deal with it?

Partition number	Input water (m3/d)	Loss amount (m^3/d)	**NRW (%)**	Piping distance (m)	No. of faucets (pcs)	Expected leakage amount (m^3/m/ d)
No.1	75	45	**60**	2,500	125	0.018
No.2	60	18		2,000	100	0.009
No.3	45	22.5		1,500	75	0.015
No4	54	43		1,800	90	0.024
No.5	60	21		2,000	100	0.011
No.6	105	63		3,500	175	0.018
Total	399	212.7	**Ave.**	13,300	665	

5) Exercises-4

(a) We measured the weight of water leakage, but what is the equation for calculating the leakage volume?

Formula for calculation of water leakage: V =

(b) What is the unit indicating weight?

(c) What is the unit indicating the quantity?

(d) Calculate leakage amount by measured weight

Figure 7-25 Different bottles weigh

Table 7-11 Answer sheet

Container		Weight		Volume	
Type	Empty container (g)	g (gram) Including BOT	mg (milligram)	L (liter)	mL (mill-liter)
Measure cup	31.0	131			
		42			
Bottle	15.0	130			
		99			

Exercises:-5

Practice for finding water leakage

(3-1) Overview

In this method, when it is difficult to measure the leakage of the high water pressure distribution pipe, water leakage amount (range from 1.0 cm to 0.01 cm) is converted to surface area (cm^2) and water leakage amount is predicted from the "quick catch table". (**Refer to Table 7-13**)

(3-2) Conditions

① Leakage hole diameter: 1.12 cm (radius = 0.564 cm)

② Leakage area: $3.14 \times radius^2 = 3.14 \times (0.564)^2 = 1.0\ cm^2$

③ Hydraulic pressure: assumed to be 3.0 kef / $cm^{2.}$

(3-4) Calculation

Select the "pore area 1.0 cm^2 and water pressure 3.0 kef / cm^2" of "Quick Reference Tables".

∴Leakage volume is estimated to be about

$\underline{76.0\ m^3 / d = 3.16\ m^3 / min = 52.8\ L / min}$

Dia. (cm^2)		Water Pressure (kgf/cm^2)			
		3.0	4.0	5.0	6.0
1.00	Water leakage (m^3/d)	**76.0**	88.0	98.0	107.0
0.60	Water leakage (m^3/d)	54.0	63.0	70.0	76.0
0.50	Water leakage (m^3/d)	52.0	60.0	67.0	73.0
0.40	Water leakage (m^3/d)	50.0	57.0	64.0	70.0
0.30	Water leakage (m^3/d)	33.0	38.0	43.0	47.0
0.20	Water leakage (m^3/d)	27.0	31.0	35.0	38.0
0.10	Water leakage (m^3/d)	17.0	20.0	22.0	24.0
0.08	Water leakage (m^3/d)	15.5	18.0	20.0	22.0
0.06	Water leakage (m^3/d)	11.6	13.4	15.0	16.4
0.04	Water leakage (m^3/d)	7.7	8.9	10.0	11.0
0.02	Water leakage (m^3/d)	3.9	4.5	5.0	5.5
0.01	Water leakage (m^3/d)	1.3	1.6	1.8	2.0

Source: JPRC 1995 #20

Table 7-14 Quick looking table (leakage and water pressure)

3) -2 Classroom Teaching Material for Text Book

KENYA WATER INSTITUTE

INTRODUCTION TO NON-REVENUE WATER CONCEPT #1(R-2)

W.MOSETI
JUNE 2019
(KEWI)

1. Objectives

① Understand the concept of Non-Revenue Water Reduction.

② Understand the components of Non-Revenue water

③ Understand Vicious circle.

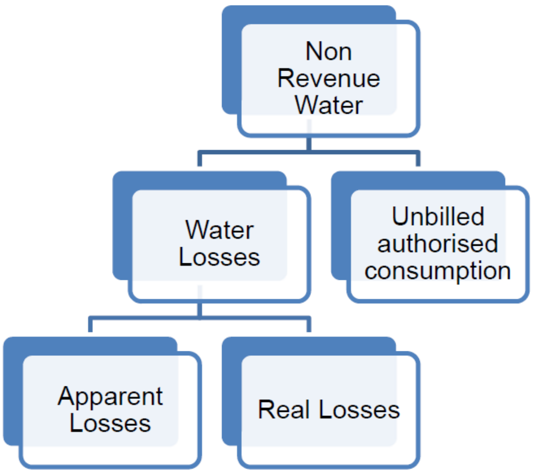
④ The benefits of NRW management.

2. What is Revenue Water?

- Non-Revenue water is defined as the amount of water input into the distribution system and is not translated to revenue.

$$\text{NRW (\%)} = \frac{\text{System input volume} - \text{billed authorized consumption}}{\text{System input volume}} \times 100$$

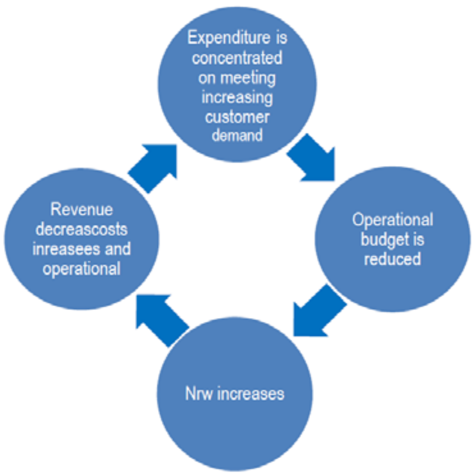
3. Components of Non-Revenue water



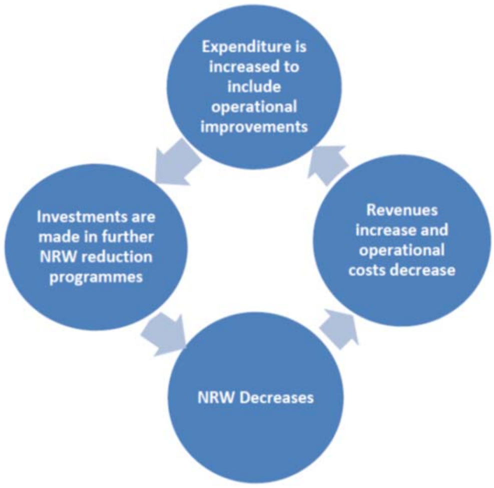
4. Challenges

- Dilapidated infrastructure with high leakage levels
- Poor operations and maintenance policy, including ineffective record
- Poor governance
- Limited skills in non-revenue water management and technology
- Financial constraints, including ineffective and inefficient revenue
- collection
- Weak enabling environment and performance incentives
- Political, cultural, and social influences
- A higher incidence of commercial water losses, particularly illegal connections.

5. **Vicious circle for Non-Revenue water**



6. Challenge into Virtuous Circle



7. Challenges that contribute to this vicious cycle

- **Denial:** The water utility denies the effects of NRW, with reasons like, *«we meet the norm or standard NRW figures, so there is no problem»*
- **Illegal consumption:** Utilities claim that it's mostly illegal connections that result in unknown consumption.
- **Network Age:** aging water network and associated systems need total replacement and this can be expensive.
- **Political interference:** Politicians don't allow disconnection for non-payment.
- **New installations easier:** Network Capacity/expansion is politically more important than rehabilitation – it is easier to serve new areas than it is to carry out repairs.
- **Skills competence:** A utility does not have the right kind of staff.
- **Intermittent versus sustained supply:** Intermittent or rationed supply keeps water losses low at the expense of customer service.

8. Benefits of NRW-Management

- Reduces energy and treatment chemical costs
- Reduces water treatment and pumping costs
- Defers capital expenditures
- Reduces damage to infrastructure
- Improves systems hydraulics and utility efficiency
- Reduces unauthorized usage
- Reduces potential claims due to water damage
- Improves public awareness of water's value
- Improves environmental protection as water resources become scarcer.

9. Addressing NRW

Implementation of solutions that are practicable and achievable to reduce NRW.

(1) The first step is to learn about the network and operating practices. Typical questions during this process include:

- How much water is being lost?
- Where are losses occurring?
- What strategies can be introduced to reduce losses and improve performance?
- How can we maintain the strategy and sustain the achievements gained?

Cont

(2) NRW management is not a one-off activity, but one requiring a long-term commitment and involvement of all water utility departments. There is need for utility managers to have access to information on the entire network, which would enable them to fully understand the nature of NRW and its impact on utility operations, its financial health, and customer satisfaction.

Cont

- Asset management
- Operation and maintenance of the infrastructure
- Customer support
- Financial allocation to support NRW strategy or efforts
- Management support
- Capacity know how – network and non-revenue water
- Commercial operations

10. Elements to NRW Reduction

KENYA WATER INSTITUTE

HOW TO CONDUCT WATER BALANCE #3(R-1)

W.MOSETI
JUNE 2019
(KEWI)

1. Objectives

① Understand objective of water balance

② Understand components of the Water Balance

③ Understand Water Balance Terms.

④ Understand how to calculate NRW ratio

2. What is Water Balance?

- A water balance aims to track and account every component of water that is supplied to and extracted from a water supply system within a defined period of time.
- A clearly defined water balance is the first step in assessing Non-revenue water and managing leakage in water distribution networks.

3. Water Balance analysis (IWA STD)

System input volume Q_I	Authorised consumption Q_A	Billed authorised consumption Q_{BA}	Billed water exported	Revenue water
			Billed metered consumption	
			Billed unmetered consumption	
		Unbilled authorised consumption Q_{UA}	Unbilled metered consumption	Non-revenue water
			Unbilled unmetered consumption	
	Water losses Q_L	Apparent losses Q_{AL}	Unauthorised consumption	
			Customer meter inaccuracies and data handling errors	
		Real losses Q_{RL}	Leakage on transmission and distribution mains	
			Leakage and overflows at storage tanks	
			Leakage on service connections up to point of customer meter	

4. Components of Water Balance

Box 9.1 International Water Association Water Balance

The following are definitions of principal components of IWA water balance.

- ***System Input Volume*** *is the annual volume put into the part of a water supply system that relates to water balance calculation.*
- ***Authorized Consumption*** *is the annual volume of metered and/or non-metered water taken by registered customers, water suppliers, and others who are implicitly or explicitly authorized to do so for residential, commercial, and industrial purposes. It includes water that is exported.*
- ***Water Losses*** *can be identified by calculating the difference between system input volume and authorized consumption. They consist of apparent losses and real losses.*
- ***Apparent Losses*** *result from unauthorized consumption and all types of inaccuracies associated with metering.*
- ***Real Losses*** *result from losses at mains, service reservoirs, and service connections (up to the point of customer metering). The annual volume lost through all types of leaks, bursts, and overflows depends on their individual frequencies, flow rates, and duration.*
- ***Non-Revenue Water*** *is the difference between system input volume and billed authorized consumption, and it consists of the following:*
  - *Unbilled Authorized Consumption (usually a minor component of water balance),*
  - *Apparent Losses, and*
  - *Real Losses.*

5. Index on water balance analysis

For the management index,

(a) The Non-Revenue Water rate,

(b) The Revenue Water.

This are calculated from the water distribution analysis table. **(Water Balance)**

6. Calculation of indicator

a) Calculation formula of water quantity(m^3)

1) Q1=Q2+Q3
2) Q3=Q1-Q2
3) Q2=Q1-Q3

b）Formula for calculating percentage (%)

1) Q3(%)＝(Q3÷Q1)×100
2) Q2(%) =(Q2÷Q1)×100
3) Q3(%)＝(Q3÷Q1)×100

7. Points to note in Water Balance Analysis

(1) Preliminary preparation items

①Is the measurements accurate and flow meter appropriate?
②Is the measurement point / appropriate?
③Is the flow rate calculation method appropriate?

(2) Procedure for measuring and recording flow rates

①System Input Volume
②Water volume of each distribution Zone (DMA) block
③Billed Authorized Consumption

8. Benefits of NRW-Management

(3) Revenue Water volume

① Whether the amount of water in the fixed rate tariff is appropriate?

② What is the insensitive amount of water (measurement error) of the meter?

③ Is the amount of water per one stopper of the fixed rate tariff appropriate?

④ Is there a mistake in the presence of illegal connections, or the amount of water used for free tariff?

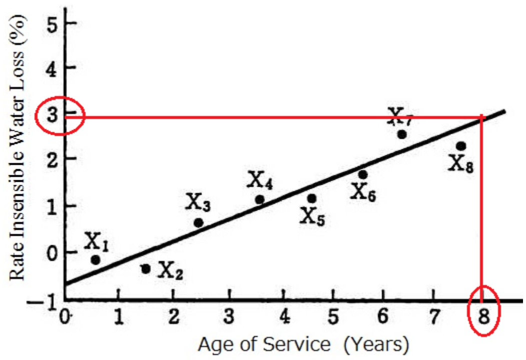
(4) Un received water quantity

① The amount of non-revenue water shall be the amount of water obtained by subtracting the amount of total collected water from the total water distribution.

9. What is the insensitive water volume of the water meter?

It is the amount of water that cannot be measured with a meter due to a small flow rate ***(called initial water flow)*** that cannot be measured by a water meter and measurement accuracy of the meter ***(called instrumental error).***

10. Year of use of meter and insensitive water rate (%)



KENYA WATER INSTITUTE

HOW TO MANAGE DISTRIBUTION NETWORK #4(R-1)

W.MOSETI
JUNE 2019
(KEWI)

1. Objectives

Understand:-

① The role of the distribution pipe network.

②The components of the pipeline that constitutes the water supply facility.

③The layout of water distribution network

④The role and managing of water distribution network

⑤The challenges of managing water distribution network in Kenya

2. Introduction

- The distribution pipe network has the function of **transporting**, **distributing**, and supplying purified water, and it is necessary that the water supply is stably supplied at an **appropriate water pressure** at all times, and in order to be able to maintain the supply of water at **emergency**.
- Since most of the water distribution pipes are laid under the ground, it is necessary to construct a piping network in which **Operation** and **Maintenance** is easy and water **quality** in the pipe can be maintained

3. Key Words

1) Raw water Pipe (channel)
2) Main water distribution pipe （Transmission pipe）
3) Water distribution pipe
4) Water service pipe
5) Gravity flow method
6) Pumping method
7) Combined method
8) Blocking / Zoning
9) Hydraulic control
10) Water hammer
11) Mapping
12) GIS

4. Facility function and roles of the water distribution network

The role of the water distribution network is to provide water supply service that enables the following basic elements to be fairly safe and secure to all beneficiaries.

① *Water volume* (Provide adequate amount of water)

② *Hydraulic pressure* (maintenance of steady pipe water pressure)

③ *Water quality* (Provide safe water quality conforming to water quality standards)

5. management of water distribution network

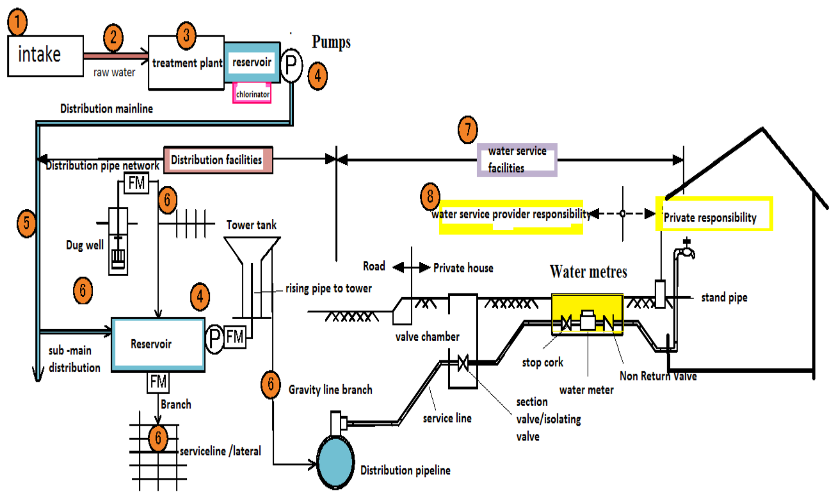
Main items to be implemented for maintaining the function of the water distribution network are:-

① Facility management that can cope with an increase in water demand

② Maintenance and management of the flexibility of pipeline that can provide stable (safe and secure) water supply service even in leakage / water cutoff

③ Sustainability maintenance of the service life of the distribution

7. Flow of Constituent Facilities of Water Supply Facilities



8. Challenges in Kenya

①Occurrence of unfair balance of water distribution and water rationing
②Unplanned expansion work
③Insufficient number of control/ Isolation valves
④Illegal connections
⑤Mapping or GIS/ Asset ledger
⑥Inadequate of proper repair materials used
⑦Improper construction supervision
⑧Insufficient maintenance of function monitoring system
⑨Insufficient investigation of underground leakage
⑩Insufficient cleaning of pipe network

9. Focus on improving maintenance function of piping network

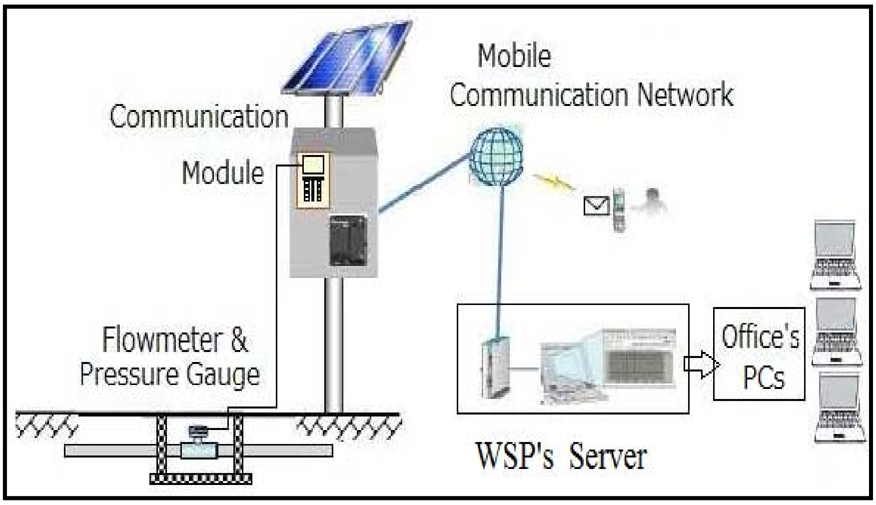
Improvement on the following:-

1) Blocking and zoning of distribution areas,
2) Monitoring system in water distribution network
3) Water pressure management
4) Water distribution regularly
5) Water hammer reduction
6) Pipeline drawing arrangement (by mapping)
7) Pipeline/ Implementation of physical evaluation

Cont:

8) Water leakage survey by leak detectors,
9)The operations and maintenance of distributing reservoirs
10) Confirmation of functions of valves
11) Rehabilitation and renewal of distribution pipes
12) Upgrading of ledger (pipe ledger, valve ledger, asset ledger, leakage accident ledger)
13) Upgrading store stock yard management of materials / equipment
14) Offer maintenance records of underground buried pipe

Cont: Appliance of an automatic pressure monitor



Cont: Typical monitoring system of Flow meter, water pressure gauges and chlorine sensor

KENYA WATER INSTITUTE

CONCEPT OF PHYSICAL LOSSES

#5(R-1)

W.MOSETI
JUNE 2019
(KEWI)

#5 Physical Losses

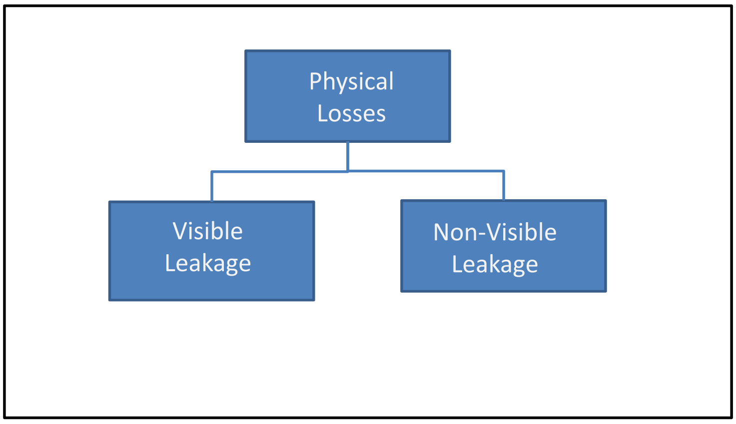
1. Objective

① Understand how reduction of physical losses
② Understand the components of physical losses
③ Understand the sources of physical losses
④ Understand the causes of physical losses
⑤ Understand the factors that influence leakage occurrence
⑥ Understand the layout of water facilities
⑦ Understand the importance of leak records
⑧ Understand pipe laying procedures
⑨ Understand on how to detect water leakages

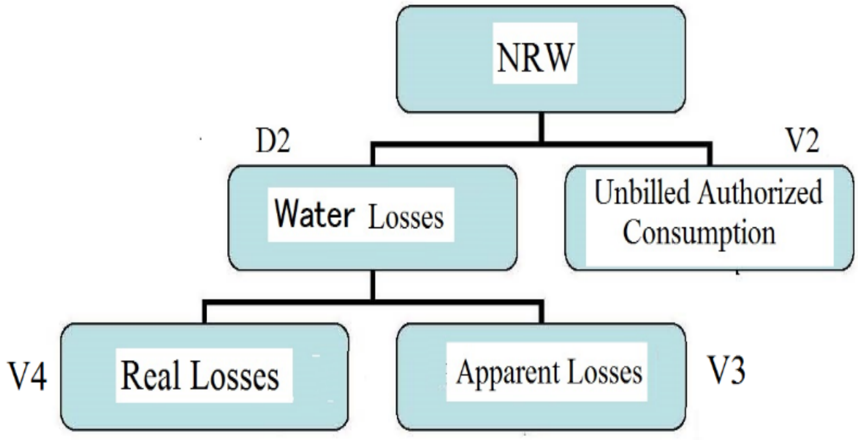
2. Introduction

Water losses occur in all distribution networks, even new ones. Physical Water Losses sometimes called 'real losses' or 'leakage' includes the total volume of water losses minus commercial losses.

3. Component of Physical (Real) Losses



4. Component of non-revenue water



5. Causes of Physical Losses

1. Poor network design
   - Wrong Initial piping and construction works.
   - Poor Jointing and fittings.
   - Lack of / wrong positioning of appurtenances.
   - Inappropriate pipe laying and backfilling

Cont

2. Pipe Material
   - Wrong choice of pipe material
   - Defects on pipe material
   - Deterioration due to age

Cont

3. Internal Pipe Conditions
   - Poor water quality may lead to interior pipe damage.
   - Very high water pressures causing bursts.
   - Vacuum pressures that may collapse the pipe.

Cont

4. External Conditions
   - Excessive traffic loading and vibrations
   - Interference from other public works e.g roads and cable installation requiring excavations.
   - Corrosive soils
   - Agricultural and Animal activities.

Cont

5. Natural Calamities
   - Floods, mudslides and landslides
   - Earth movements e.g. Earthquakes

Samples of leak points


Cont






KENYA WATER INSTITUTE

CONCEPT OF PHYSICAL LOSSES

#6(R-2)

T.WALELA
JUNE 2019
(KEWI)

Objectives

- ①Understand what is Leak prevention work
- ② Understand Main basic countermeasure work against leakage
- ③ Understand Concept of Leakage Recurrence
- ④ Understand Concept of compositional unit of total water leakage
- ⑤ Understand Concept of Record sheet of leakage survey

Introduction

- Water leaks can be either surface or underground.
- When water leaks to the surface, it can be seen & repaired quickly.
- If it does not appear on the surface, it will continue to leak for a long time.

Introduction

- Most leak losses by volume over time occur on customer service connection piping – not water mains
- Policies that place the burden on customers to repair leaks on their service connections are often inefficient
- New policies/programs to address service line leakage are needed to economically reduce this leakage

Key words

- Surface Leakage :- Visible Leakage
- Underground Leakage :- Non-Visible Leakage
- Leakage Recurrence :- Amount of leakage which increased with time from remaining leakage
- Remaining leakage :- Amount of the minimum leakage amount, immediately after the measure
  against leakage
- Total water leakage :- Restored amount + Remaining leakage =Preventable leakage by technology +
  unable to prevent leakage + True water leakage= Allowable water leakage +
- Allowable leakage :- Quantity which admits the amount of leakage of water
- Electrolytic corrosion :- Is an accelerated corrosion when a metal is in contact with
  another in presence of electric current
- Peatlands :- Accumulation of partially decayed vegetation or organic matter unique
  to natural areas

Objectives of Basic concept of leakage prevention work

To understand the need;-

(1) To Increase efficiency in O&M of our water schemes

(2) To Increase knowledge of our networks (via Mapping and /or GIS systems, computer modelling) and consumption patterns (via metering)

Objectives of Basic concept of leakage prevention work

(3) For Value for money by deferring capital expenditure on new water supply schemes through improved supply and reduced consumption

(4) For Environmental protection by deferring new water sources

Objectives of Basic concept of leakage prevention work

(5) To Improve supply service to our consumers

(6) For PR of the need for water conservation.

Leak prevention works

Guidelines for leak prevention

In formulating the water leak prevention plan, it is necessary to consider economic efficiency considering the water demand plan of each city,

the actual condition of water resources,

facility size,

etc.

Water leak prevention measures

Leakage countermeasures work is divided into three categories

1. Implementation of Collection / analysis of basic information
2. Implementation of Survey of leakage volume
3. Implementation of Preventive measures

Implementation of Collection / analysis of basic information

The **main basic countermeasure work** is collection of information necessary for action against leakage and analysis of the result.

(1) Creating pipeline drawings

(a) Creating pipeline

(b) Mapping - Creating a GIS diagram

Implementation of Collection / analysis of basic information

(2) Implementation of water distribution analysis, others
(a) DMA conversion
(b) Installation of bulk meter and customer meter
(c) Analysis of leak occurrence records, others

Implementation of Survey of leak volume

Investigation of leaks (surface and underground) from buried pipeline, and survey of water leakage and implementation of early repair work.

(1) Method of leakage survey work

- Mobility investigation work
- (a) Repair ground leakage discovered by notification from the citizen and patrolling.
- (b) Correspond in principle on the same day repair.

Implementation of Survey of leak volume

- Planning survey work
  The method for investigating water leakage can be divided into two.

(a) Selection measurement work

(Determine leakage abundance in the survey area beforehand and conduct detailed leakage survey)

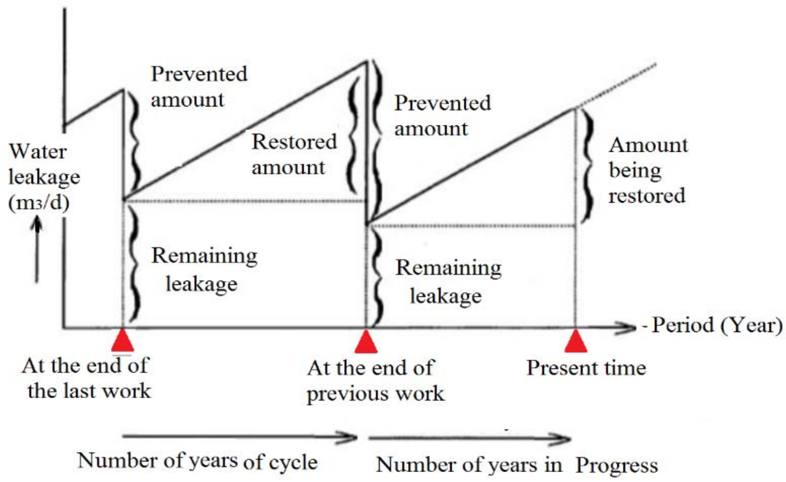
(b) Cyclic measurement work

(Do not measure the leakage abundance of the survey section beforehand and conduct the leakage investigation directly in order)

Implementation of Survey of leak volume

- ① **Survey of restored water volume**
  Regardless of once repairing water leakage, new leakage occurs as time passes (called restoration of leakage), so regularly investigate this restoration leakage
  ∴Control index of recovery volume (m^3 / day·/ km / year)

Implementation of Survey of leak volume



Implementation of Survey of leak volume

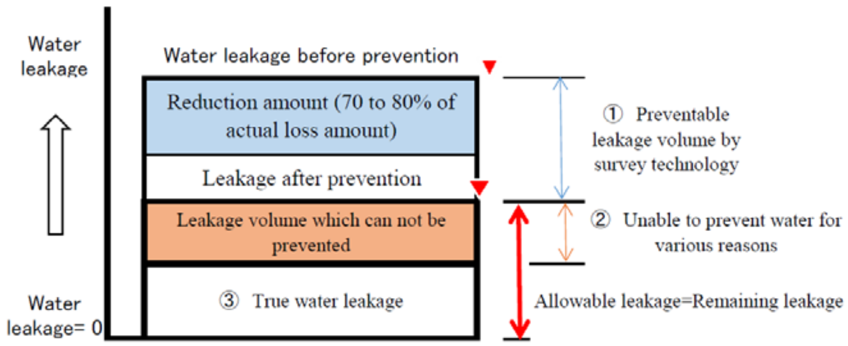
② Selection of an investigation area

- (a) When doing leakage-of-water prevention work, it is necessary to select the area which should be investigated first in the order of priority.
- (b) In selection of an investigation area, you have to take into consideration the number of ~~the~~ past leaks repaired in the area, the age of the pipeline, the depth of the water table, the status of preparation of a sewer, etc.

Implementation of Survey of leak volume

- **③Evaluation of effectiveness and economy**
- The economics of leakage prevention needs to be evaluated from the following.
- Frequency of investigation
- Amount of work involved ~~in~~ conducting the survey

Implementation of Survey of leak volume



Implementation of Preventive measures

- Based on the results of leakage survey, repair and updated facilities, reduce leakage rate. The main outlines of the study are as follows.
  ① **Create a plan**

●Draw up an effective facility improvement plans

●Upgrading of equipment in piping network of water supply equipment

●Strengthening O/M organization and monitoring system of distribution network

Implementation of Preventive measures

② Implementation of repair / renewal of distribution facilities

- ●Repair of water supply equipment and measures
- ●Replacing the installation of the water supply pipe ... From the branch point to the meter, partial repair leaves the factor of recurrence.
- ●Removal of public water stop cock
- ●Disposal of remaining pipes
- ●Optimization of burial depth
- ● Consideration of used piping type
- ●Construction management of backfill soil
- ●Collection of pipeline information

Implementation of Preventive measures

③ Structural improvement of water supply equipment

● Integration of multilayer pipes

●Elimination of road crossing pipe

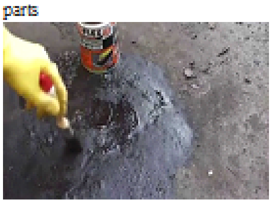
●Examination of material used、Pipe caliber used

●Review of meter installation, etc.

Case study of leak occurrence(surface leakage)

- An example of a typical site of water leakage is shown below.
  Incidentally, the number of small water leakage from the water supply pipe is large, and when left for a long time the leakage volume increases.

Case study of leak occurrence(surface leakage)

①Leakage point of water distribution valves	① Leakage point of water supply pipe	
	Small leakage	Large leakage
Water control valves / valves - Fire hydrants, Air valves, Pressure reducing valve - Water pipe	Stopcocks / water taps Meter installation locations Joint to water supply pipes / Joint parts	Branch part from the water distribution pipe Insufficient material strength of the water supply pipe, poor construction part
		

Capture the actual condition of leakage and keep records

- **Capture the actual condition**

  In order to prevent water leakage, it is necessary to first analyze the results of leaks occurred in the past, to analyze the actual condition of leakage and causes, and to better understand the leakage phenomenon.

Capture the actual condition of leakage and keep records

- **Utilization of records**
  The record of leakage survey is important for future planning of piping network update plan and piping network management by GIS, so it is important to capture and keep records

Capture the actual condition of leakage and keep records

- **Example of recording form**

(1) Water leakage occurrence record by facility
We organize the number of water leaks and the amount of water leakage every place where leakage occurred (by district, by leakage survey block by block, address, survey execution time, facility part, caliber, etc.).

The amount of water leakage is an estimation from leak points, leakage noise, wet condition in the ground, etc. at the times of checking leakage.

Example of recording form

Distribution main pipe			Water supply equipment		
Name of facility	Number of water leaks	Water leakage (m3)	Name of facility	Number of water leaks	Water leakage (m3)
1. Top of Pipe 2. Fittings 3. G. packing of valve			1. Top of Pipe 2. Fittings 3. Water faucets		
4. Fire hydrants 5. Gate valves			4. Stop valves (union) 5. Water faucets (union)		
6. Air valves 7. Drain			6. Stop valve (G. packing) 7. stop cock		
8. Other			8. Meter (Union)		
Distribution branch			9 Parts (elbow)		
1. Top of Pipe 2. Fittings			10. Parts (cheese) 11. Parts		
3. G. packing of valve 4. Fire hydrants			12. Water Meter 13. Parts (Saddle		
5. Gate valves 6. Air valves			14. Parts (socket) 15. Ball taps		
7. Drain 8. Other			16. Other		

Capture the actual condition of leakage and keep records

(2) Record of leakage survey

There is a record of the repair situation as a method to know the actual condition of water leakage.

Record Table of Leakage Repair

ause	Material of pipe	Distributing pipe Number of water leaks	Leakage (m^3)	Cost	Photo	Water supply pipe Number of water leaks	Leakage (m^3)	Cost	Photo
	Cast ironpipe (mm)								
	Vinyl pipe(mm)								
	Galvanized steel pipe(mm)								
	Steel pipe(mm)								
	Lead pipe(mm)								
	Total								
	Fittings								
	Bolts								
rosion	Snap taps								
	Vinyl pipe fittings								
	Total								
	Vinyl pipe fittings								
g m	Ductile cast iron pipe								
	Sockets								
	Lead pipe								
	Other								
	Total								
	Gate valves								
	Air valves								
land kings	Snap taps								
	Water shutoff valves								
	Total								
	Ductile cast iron pipe								
nic load ssure/ ration/ sive soil ther	Steel pipe								
	Vinyl pipe								
	Asbestos pipe								
	Total								
piping doned	Disposal piping								
	Total								
	Crack of Pipe								
ater ssure	Detachable								
	Total								
	Corrosive soil (pH)								
llation onment	Groundwater quality								
	High groundwater level								
	Total								
G. Total									

Record Table of Investigation of laying condition

Investigation of laying condition	Distributing pipe Number of water leaks	Leakage (m^3)	Cost	Photo	Water supply pipe Number of water leaks	Leakage (m^3)	Cost	Photo
Distribution of corrosive buried environment								
Painting condition of buried pipe line								
Corrosion situation of pipe line								
Distribution of water leakage accident								

Preparation of management indicators by leakage area

For effective data for leakage prevention work, it is desirable to set / record-management indicators and to be reflected in the project management plan.

Eg:

- (a) Leakage per 1 km of distribution branch (m^3 / day / km) by region or by section
- (b) Number of water leakage repairs (cases / km)
- (c) Other indicators

Corrosion occurrence Investigation

(a) Inner surface

- Rust bumps etc. occur on the inner surface of the pipe of the aged pipe, and the friction resistance of the pipe line increases or decreases, and there is a situation where it is impossible to supply sufficient water pressure and water supply amount.

Survey items on occurrence of inner surface (corrosion bumps)

No.	Survey item	Contents
1	No lining pipe (inner surface)	Location/diameter/ caliber/ Number of years passed
2	Non-corrosive protective pipe (inner surface)	Location/diameter/ caliber/ Number of years passed
3	Investigation of flow velocity (m / s)	Distributing pipe/ Water supply pipe
4	Survey of flow rate (m^3 / d)	Distributing pipe/ Water supply pipe/ Water taps
5	Survey of water pressure (kg/cm^2)	Distributing pipe/ Water supply pipe/ Water taps
6	Frequency of maintenance	Drain frequency/Drain pipe diameter / internal repair
7	Survey of water quality (unusual taste/red water/ Residual chlorine/others)	Distributing pipe/ Water supply pipe/ Water taps

Corrosion of the inner surface

Corrosion occurrence Investigation

(b) Outer surface (laying conditions

- This item is a survey on the actual condition of "deterioration of pipeline due to pipeline installation conditions".

Corrosion occurrence Investigation

No.	Survey item	Contents
1	Distribution of corrosive buried environment	Place/cause of corrosive environment
2	Painting condition of buried pipeline	Material/caliber/number of years passed, total length (km)
3	Corrosion situation of pipeline	Corrosion condition of pipeline/ rust condition of bolt/pipe thickness
4	Distribution of water leakage accident	Location/caliber/corrosion status of leak pipe/leakage area/ water pressure

Corrosion occurrence Investigation

(c) **Cause of metal buried pipe corrosion**

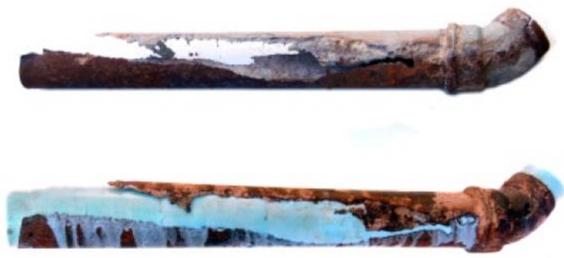
- When a metal pipe which is not properly protected against corrosion, laid under corrosive soil conditions, outer surface will corrosion quickly and the strength of the pipe remarkably lowered, which causes water leakage.

Cause of metal buried pipe corrosion

The laying conditions under which corrosion
easily occurs are:-

- Where electrolytic corrosion occurs
- The pipeline is dirty (mud may cause pipes to corrode)
- Place where liquid acidic factory waste penetrates underground
- Places where corrosion progresses under the ground water table
- Places containing salt in the groundwater
- Acid soil (pH 4 or less),
- Even in the alkaline range of pH 8.5 or higher, (so-called natural alkaline soil) may be susceptible to corrosion
- Peatlands and waste landfill areas

Cause of metal buried pipe corrosion



Electrolytic Corrosion of mild steel pipe

KENYA WATER INSTITUTE

WATERLEAKAGE SURVEY METHODS

#7(R-2)

T.WALELA
JUNE 2019
(KEWI)

1.Objectives

①Understand why reduce leakage?
② Understand concept of how to identify leak location
③ Understand type of noise
④ Understand type of leakage detectors
⑤Understand general purpose of Preliminary survey
⑥Understand general purpose of flowrate survey of MNF
⑦Understand measuring method of the amount of leakage
⑧Understand concept of relationship between leakage and pressure

2. Introduction

2-1.What is leakage?

- Leakage occurs when the water your system produces leaves the system before it reaches your customers.

“leakage” includes:

- Physical or “real losses” such as water lost from main breaks and tank overflows.
- Inaccurate meters, accounting errors and theft. Many people call these losses, “apparent losses.”
- All unauthorized uses and any water you cannot account for.

2-2.Why reduce leakage?

- Reducing leaks has many benefits for water systems and customers including greater reliability through an efficient water system, reduced costs for pumping, treating, and transporting water, and preserving water supplies for future use.

4. Procedure of the NRW reduction measures

4-1Outline

- Discover leakage of "water distribution network" at an early stage.
- It is important to implement repair work as soon as possible and to prevent water leakage beforehand
- Improvement measures of many waterworks facilities are planned to replace the old ones

Examination method of a leakage

① Method of identifying water leakage location by leakage sound (listening stick, correlation method, time integral type leakage detector, etc.)

② Method of measuring leakage volume (Night minimum flow rate measurement method, others)

(2) Concept of leakage

- Measurement of "leakage" in general means the measurement of the total water leakage.
- "Recovery water leakage amount" is obtained from the following calculation formula.

∴**Total leakage volume** = (Restored leakage) + (Allowable leakage)

∴**Restored leakage volume** (Remaining leakage)

= (Total leakage) – (Acceptable leakage)

(3) Main effective basic policy of leakage preventive measures

- Leakage survey is the collection of basic information indispensable for formulation of NRW reduction plan.
- Activities to prevent water leakage means to continually investigate changes in the piping facility situation and to permanently take measures against water leakage at the facility.

Cont

- The main activities are shown below.
- ① Detection of leak points early
- ② Measuring water leakage
- ③ Improvement of old pipeline quickly and systematically
- ④ Simplification of multiple small pipes,

(4) Precondition of leakage examination

①Upgrading of piping network diagram
②Installation of isolation valves for DMA
③Installation of measuring instrument (bulk meter)
④Installation of customer meter
⑤ Install water level in the water reservoir

4-2 Outline of an investigation procedure

(1) Observation survey (preliminary survey)

Outline of work

①Survey of door to door is a process of bringing with Listening stick / time integral type leakage detector into contact with all customer meters

Purpose
The leakage measurement work is a work to grasp the amount of the NRW of the small piping in stages from the trunk water distribution pipe in the DMA and to specify the wat

Investigation procedure Cont

②In the night-time when the traffic low, identify the location of leakage on the road surface with the digital leak detector.

③Selection of the DMA, consideration of past leakage occurrence situation and the aging pipes.

④In places suspected of leakage from survey work, specify the position with paint.

Investigation procedure Cont

(2) Leakage measurement work (full-scale survey)

①Measurement is carried out in order to accurately grasp the amount of leakage of each DMA. (For example, conduct with Night minimum flow rate measurement)

②Thenumber of faucets to be investigated is limited to 300 plugs to 400 plugs or less.

Investigation procedure Cont

- ③Prediction of water leakage in all water supply districts is estimated from leakage amount of each DMA.
- ④ Survey of leakage volume of each DMA will be used for consideration with priorities of effective detailed investigation.

Investigation procedure Cont

(3) Confirmation of water leakage location

- <u>Outline of work</u>

①Investigate the position of the detected abnormal sound again and judge the presence or absence of leakage.

② If it is confirmed as a water leakage point, further work out the central point.

③ To determine the position of the water leakage sound hole, drill a hole in the road surface, insert a sound hearing bar, and check the leakage

Investigation procedure Cont

(4) Improvement of old pipe

① Renewal

② Rehabilitation

③ Partial repair

④ Change of pipe route

Investigation procedure Cont

(5) Points to be aware of when selecting piping improvement method

①Confirmation of the cause of the functionally damaged pipeline (pipe type, years of use, frequent occurrence of accidents, etc.)

②Confirmation of the scale of leakage pipeline

③ Confirmation of the work environment at the site (difficult to improve)

④Securing construction costs, others

Investigation procedure Cont

4-3 Approach of leakage investigation

(1) Approach to narrow down a water-leakage area

(A)"Surface detection"; (by Circuit investigation “preliminary survey”)
This is a survey that specifies the leakage volume generated in DMA as "rough".

Investigation procedure Cont

(B) "Line detection": (leakage measurement work: full-scale survey)
This is a survey to identify the location of the leak pipe route in the DMA rail.

(C) "Point detection"; (Confirmation work on leakage points)
It is a survey to confirm the leakage location of the specified leakage pipe

Investigation procedure Cont

Classification	Items to investigate	Equipment used
(A) Surface detection	Calculation on medium blocks (leakage volume / NRW rate	Flow meter at distribution pond (Electromagnetic flow meter, etc.)
	Calculation on small blocks (leakage rate / NRW rate)	Portable flow meter (Ultrasonic)
(B) Line detection	Survey of acoustic noise of stop-cock /Valve (identification of leakage location)	Water leak detector
	Leak pressure level detector (Identification of leak location)	Correlation noise leak detector
(C) Point detection	Correlation survey (confirmation of leakage point)	
	Survey of water leakage sound on pipeline (Confirmation of water leakage point)	
	Acoustic survey of stop-cock (confirmation of water leakage point)	

5. Specificity of leakage sound

5-1. Generation of leak noise

Leak noise or vibration sound:-

① Fricative sound when water spouts from the leak hole to the outside of the pipe

② Impact sound that the jetted water collides with the surroundings

③ Frictional sound or turbulent sound flowing in the pipe

④ Synthesized sound / vibration waveform

5-2. Leak Sound Characteristic

- ① Leakage sound depends on the state of its generation point (depth of leakage point, direction of leakage point, leak hole, damage shape, water pressure, tube material, valve opening, water pressure, surrounding pipeline state, etc.)

Leak Sound Characteristic

② "Level" of leakage sound is influenced by pipe type, flow speed in pipe, leak hole-diameter, etc. There is a limit in leak detection ability depending on the type of detector.

③ Leakage sound varies depending on the propagation path (soil, concrete, pipe material etc.) and propagation distance.

Leak Sound Characteristic

④ The leakage sound attenuates as it propagates from the generation point.
In particular, non-metallic tubes such as VP pipes tend to have more remarkable attenuation in the high frequency range than metals such as cast iron pipes.

Leak Sound Characteristic

⑤ Changes in water leakage sound due to water leak hole, water pressure, etc、tend to increase leak noise usually when the water pressure is high.

⑥ Water leakage noise in a low water pressure network (about 0.05 MPa: water column 5 m or less) is "low", so leakage detection may be difficult.

5-3. Pseudo leakage sound

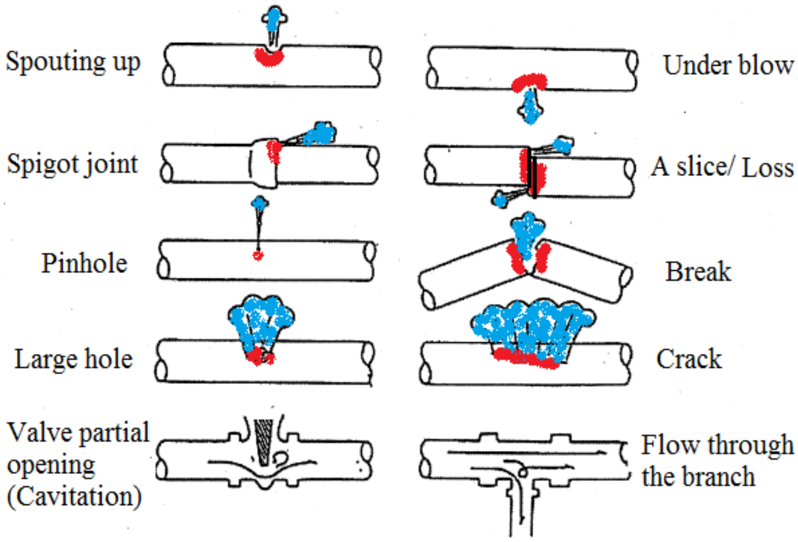
- Noise or simulated noise (pseudo leakage sound) similar to leaky sound is often a problem in detection of hearing performed at midnight.

Pseudo leakage sound

(1) Cause of pseudo noise

① Running water sound in the water pipe
② User tone of water supply
③ Circuit sound such as power cable
④ Vibration noise of power transformer
⑤ Motor vibration sound of vending machine / air conditioning equipment
⑥ Sewage flowing water sound
⑦ Water drop sound falling into the manholes
⑧ Vehicle vibration noise, wind noise
⑨ Noise of work
⑩ Urban noise, others

ground leakage point



6. How to apply leakage detectors

6.1 Detection methods of point of leakage and leakage volume

- The investigation methods for checking the presence or absence of water leak include the method of identifying the water leakage position (e.g., sound listening, correlation method, time integral formula) and measurement of water leakage (e.g., nighttime minimum flow rate).

(1) Procedure for water leakage survey

① Formulation of survey plan

a) Preliminary survey

b) Full investigation

c) Confirmation survey

②Formulation of survey methods on leakage point and volume

Equipment

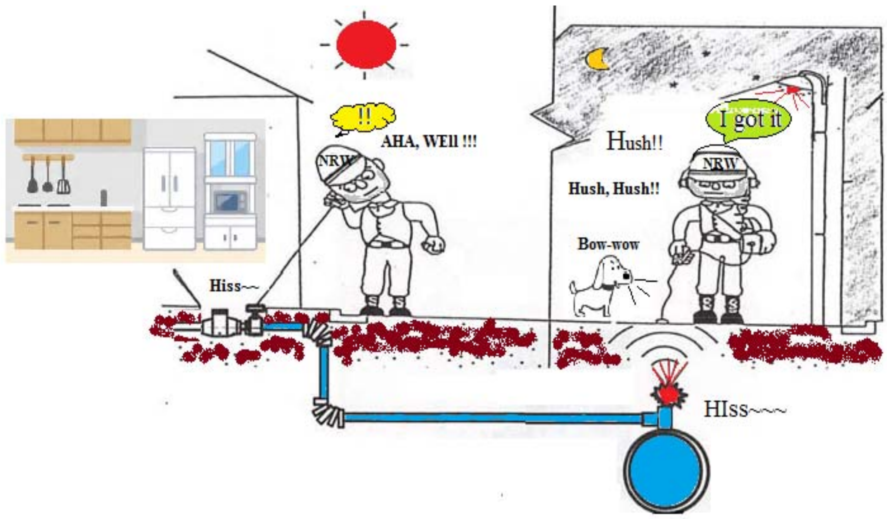
a) Specific investigation of water leakage location (e.g., a listening stick, correlation method, time integral equation)

b) Measurement of water leakage (e.g., minimum nighttime flow rate by flow meter).

c)Confirmation of leakage point (e.g., boring equipment)

③Evaluation criteria for frequency rank of acoustic noise detection survey and leakage volume survey

- Frequency rank of implementation of acoustic noise detection survey
- As for the evaluation of the leakage survey frequency in the water supply district, it is important to formulate the ranking of the survey frequency in advance by referring to the number of water leaks so far



7. Preliminary survey method with Acoustic leak detectors

7-1. planningfor preliminary survey

(a) Purpose

The preliminary survey is carried out to grasp the current state of water leakage in order to formulate a full-scale research plan

Preliminary survey method with Acoustic leak detectors

(b) Survey method

- It is carried out with the most basic leakage survey method called "standard survey method" centered on tone survey In addition, many leakage investigations are applied by combining this survey method.

Preliminary survey method with Acoustic leak detectors

7-3. Outline of work

(1)Creation of work plan

- The work plan is composed of preparation of plans necessary for investigation, process control and selection of workers and so on.

Preliminary survey method with Acoustic leak detectors

Main work contents

(a) Creating a work plan

- Understanding the contents of the survey
-·Confirmation of the drawing in the survey area
-·Establishment of survey formation team
- Create a process chart
- Function check of used equipment

Preliminary survey method with Acoustic leak detectors

(b) To hold a preliminary meeting with workers.

(c) Consider how to compile daily work results.

(2) Items to be checked in advance

(a)Check documents to be submitted.
(b) Information disclosure to inhabitants and announcement
(c) Correction of incomplete drawing
(d) Confirmation of work contents
(e) Confirmation of the form of the report.

survey method with Acoustic leak detectors

7-4. Implementation of preliminary site survey

In-situ preview survey is to conduct survey on-site in the survey target DMA in advance, to understand the accuracy of the piping drawing, the situation of the water distribution facility, the road surface condition, and as a result so that proper and accurate this survey can be carried out

survey method with Acoustic leak detectors

survey method with Acoustic leak detectors

(1) Main work

①Confirmation of buried piping route
② Check the location where valves are installed,
③ Confirmation of the source of trouble vibration given to sound listening test of stop valve
④ Survey of position unknown valves and piping routes, confirmation of these places in the office
⑤ Confirm embedment status of electricity, gas, communication facilities etc.

survey method with Acoustic leak detectors

（2）Equipment to be used

① Listening stick
② Digital noise leak noise detectors, others

survey method with Acoustic leak detectors

7-5. Implementation of survey on door-to-door by acoustic noise detection

- The door-to-door listening survey is a process in which all water supply devices (including customer meters / stopcocks) and piping (including exposed parts such as gate valves, fire hydrants and water pipe bridges) in the DMA where are subjected to water leakage detection and visual confirmation .

survey method with Acoustic leak detectors

(1) Main work

① Acoustic surveillance with a plug valve
This survey is to check the presence or absence of leakage with a listening stick to the spindles part of the gate valve installed in the water distribution pipe, a fire hydrant valve, an opening / closing stopper, an air valve.

② Acoustic surveillance with a meter / a stop-cock
This survey is to check the presence or absence of leakage with a listening stick to a stop-cock, a customer meter.

survey method with Acoustic leak detectors

- If it is recognized as a leaky sound, close the stopcock for a short time and check again for leaky sound

Survey method with Acoustic leak detectors

③When checking abnormal sounds, check marks are given on the drawing and survey points.
It is subject to the road surface tone survey conducted at a later date.

④ Leakage sound confirmed with a meter or a stopcock is different in the magnitude of sound that can be heard depending on leakage condition / place / water pressure. Care must be taken in identifying leak points.

Survey method with Acoustic leak detectors

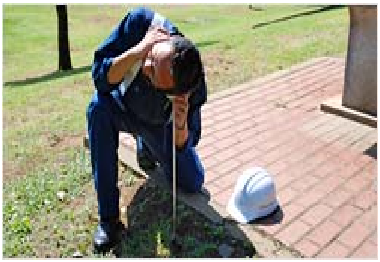
⑤ If you need to enter the residential area, always wear an identity card and armband so that you do not have trouble with the residents. We also request advance inquiries and cooperation to the residents in advance

Survey method with Acoustic leak detectors

(2) Equipment to be used

① Listening stick / digital listening stick.
② Time integrated type leak detector
③ Road surface digital noise leak detector, others

Survey method with Acoustic leak detectors



Survey method with Acoustic leak detectors

7-6. Implementation of survey on road surface by acoustic noise detection

- This survey is a walking survey on roads where buried pipes are laid by Road surface digital noise leak detection sensors at intervals of 0.5 to 1.0 m, and explores leakage sites.
  The survey is carried out during the time period (nighttime) which is not affected by dummy sounds such as noise and water used, but it is susceptible to weather conditions such as wind and rain and traffic vehicles.

Survey method with Acoustic leak detectors

(1) Main work

① If you have confirmed abnormal sounds, put a check mark on the road (white stain) and drawing, and make a detailed confirmation investigation.

②As an auxiliary work, listen to a water stop valve, a water control valve, a fire hydrant with a listening stick

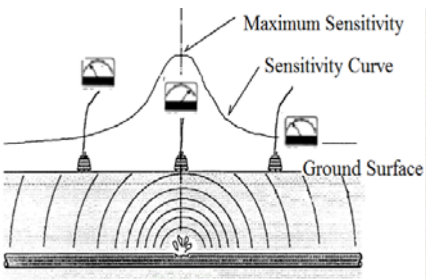
Survey method with Acoustic leak detectors

(2) Equipment to be used

① Road surface digital noise leak detector

②Listening stick / digital listening stick, others

③ Tool



verification survey

Survey method with Acoustic leak detectors

7-7. Implementation of verification survey

Confirmation survey is the work at the final stage of the leakage investigation to further examine the location of the abnormal sounds found from the previous survey, to determine whether there is water leakage and the water leakage point

Implementation of verification survey

(1) Main work

- ① In the drilling operation, to identify the leakage position under a hard road surface, open 2 to 4 holes with a diameter of about 15 to 20 mm. Using the several openings, drill holes to near the buried pipe predicted by the boring bar. (Be careful not to damage the buried pipe)

Implementation of verification survey

② To determine the final water leakage position, move the listening stick bar to 3 to 4 holes, confirm the water / sand condition adhering to the bar, the wet condition of the soil and the sound of weak noise, and then determine the water leakage position.

Implementation of verification survey

③The determined leakage position is marked on the road surface with paint, recorded and reported to the responsible person.

④ If ground exploration is difficult, a Correlation survey or Leak zone tester will be carried out

⑤ It may be confirmed by residual chlorine reaction as a survey of the spill where leakage flows out.

Implementation of verification survey

⑥ As an auxiliary work, explore the location of buried pipes and buried faucets with metal detectors

⑦ The survey worker needs to pay sufficient attention so as not to damage other buried pipes and other business facilities (e.g. Electricity, gas, communication facilities).

⑧ Mainly work on the roads will be more frequent, so be sure to implement safety measures thoroughly.

Implementation of verification survey

(2) Equipment to be used

① Bowling equipment (electric drill, hammer drill, boring bar),

② Listening stick / digital listening stick, others

③ Road surface digital noise leak detector

④Leak noise correlator, Metallic pipe locator/Metal locator

⑤Reagent of Residual chlorine (DPD)、tool、Survey vehicles, others

7-8. Arrangement of results of an investigation

This activity is performing results of an investigation for arrangement, an analysis, a consideration, etc.

Results of an investigation

(1) Main work

① Drawing showing water leakage point
② Daily reports and weekly reports
③ Photo collection
④A tabulation of a leakage occurrence spot, a data reduction, a taxonomy
⑤The table of contents of a report is as follows.
･Introduction /Summary of survey/Content of survey/Result of investigation / Discussion / Postscript

Investigation Results

（2）Collection and analysis of an information by investigation obtained

Data obtained by the survey activities (e.g. Leakage cause, number of leaks per pipe type, leakage restoration situation, are collected and analyzed to help prevent water leakage.

8-1. Procedure of leak detection by flow rate

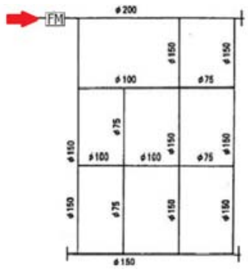
(1) Measurement category

The method of estimating the amount of water leakage from the flow measurement is largely divided into two categories:

- Prolonged 24 hour sequence measuring method and
- Midnight measuring method.

Prolonged 24 hour sequence measuring method

This measurement method is based on estimating the amount of water flowing into DMA for 24 hours in a row for a certain period of time and assuming the amount of water leakage from the minimum amount of water.



Midnight measuring method

This method is based on the flow rate (leakage amount) flowing into the DMA **in the midnight time zone** in which the usage amount by customers is generally small in the normal water supply state is measured with the flow meter. This flowmeter is installed in the only main water pipe flowing into the DMA and is "completely isolated from the adjacent section" and assumes the water leakage amount from the minimum water amount in a state that it is not affected by the adjacent pipeline

Assume; MFR = Leakage amount

(3) Step test

In this method, the inside of the DMA is subdivided, for example, by piping branch lines, the smallest nighttime flow rate of the small section is measured in order, and the leakage amount is assumed from the total of the leakage sections.

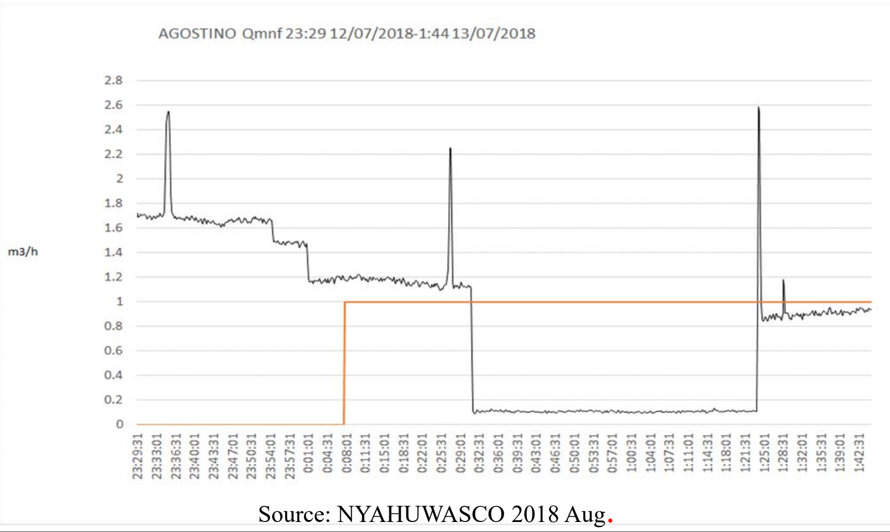
Estimated amount from water used

In this method, leakage is calculated from the difference between the amount of water distributed for a certain period of time and the revenue water amount and assumed.

Exercises:-1

① When is the minimum water volume(m^3/hrs.) generated ?

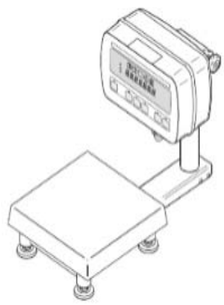
② Which minimum flow rate should be estimated as leakage amount?

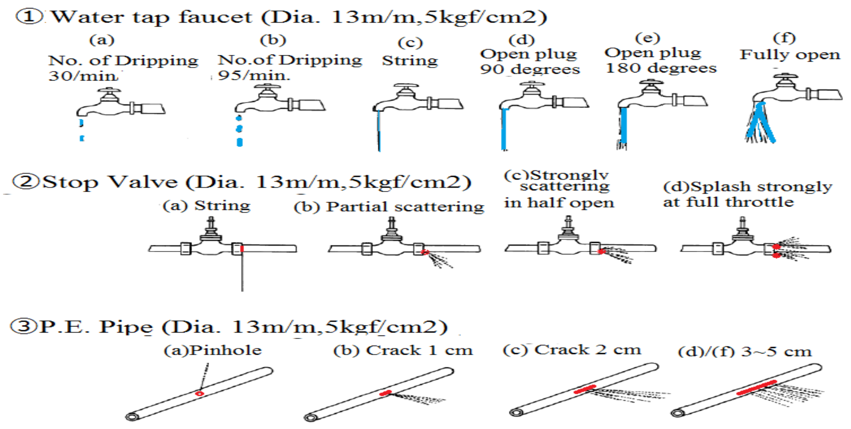


Source: NYAHUWASCO 2018 Aug.

leak volume

Method of getting the amount of water leakage, it is divided into two categories by measurement such as actual flow rate and by visual observation.
Leak water measurement measures the total water leakage directly while measuring the time before repairing the part





Items		W. Leakage	(a)	(b)	(c)	(d)	(e)	(f)
①	Faucet	m³/d	0.011	0.036	0.09	309	39.6	56.8
②	Stop valve	m³/d	0.045	2.3	3.0	7.2	-	-
③	P.E. pipe	m³/d	0.03~0.05	2.7	15.4	28.4	43.8	68.8

KENYA WATER INSTITUTE

USE OF NONREVENUEWATER INVESTIGATION EQUIPMENT #8(R-2)

T.WALELA/J.MAINA
JUNE 2019
(KEWI/EWASCO)

introduction

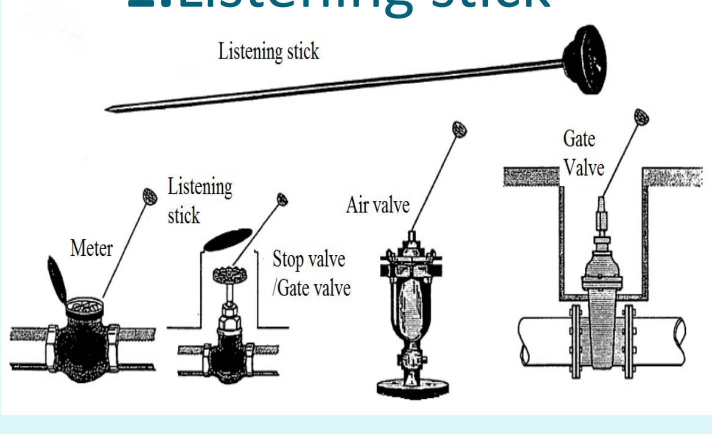
- To manage Non-Revenue Water one needs to understand the components and then lay strategies on how to manage them.
- From the understanding that there are two main components to deal with, mainly Physical and Commercial losses.
- Non-Revenue water investigating equipment are used to deal with physical losses, accuracy of meters and pressure management.
- This presentation will deal with equipment used for pipe location, flow measurement and leak detections

Objectives

- Understand Leak detecting equipment
- Understand Water flow measurement equipment
- Understand Water pressure measuring equipment
- Understand Pipelines locating/ tracing equipment
- Water quality analysis to determine theft

Leak Detecting Equipment

1.Listening stick



Listening stick…….

- ***(1) Principle of operation and application***
- Sounds of leakage can be heard by directly touching the end of the rod to valves, hydrants and pipes

Leakage survey

2.Electronic acoustic rod

Principle of operation and application

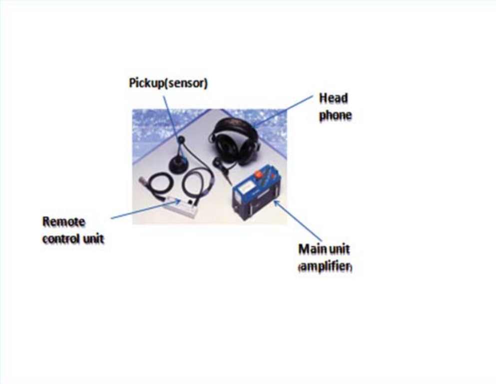
By directly touching a water supply facility element, the sound of leakage (vibration) is numerically shown on the indicator.

It takes a combination of excellent service and quality water Leak Detection equipment to detect a hidden leak.

Time Integral Type Leak Detector

This equipment is a kind of tiny leak detector to automatically detect whether or not a leak exists in a certain area in a short time by contacting the tip of the acceleration sensor to the target customer meter or the nearest exposed service pipe.

3.digital water leak detector



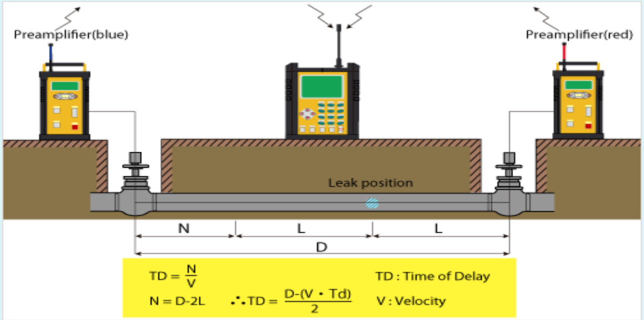
3.Water Leak Detector

(1) Principle of operation and application

•Leak detector catches the leak noise electrically. The principle is that a vibration pick-up is placed on the ground detects the vibration sound of leakage transmitted underground.

•This vibration energy is converted to electrical energy and is amplified for meter indication or detection by a headphone.

4.Digital Leak Noise Correlator



4.Leak noise Correlator

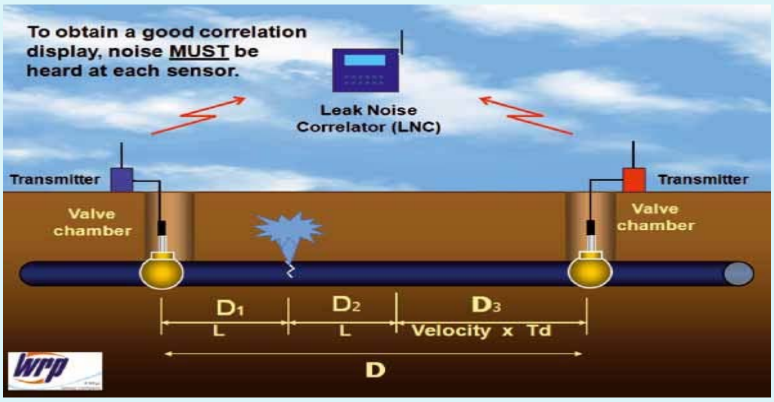
Principle of operation and application

•The leak noise Correlator is a device used to locate the point of leakage at underground water pipes.

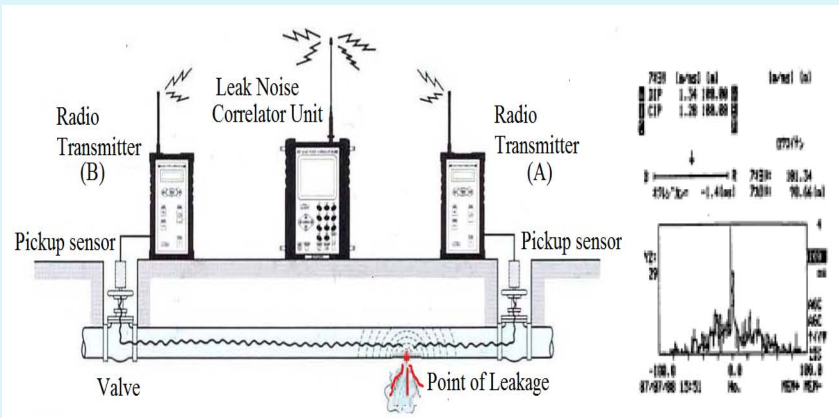
•Pickup sensors are placed at two measuring points on the pipeline through which the sound of leakage transmitted.

•The distance to the point of leakage from each pickup sensor is determined by calculating the difference in the time it takes for the sound to reach each pickup sensor.

4.Digital Leak Noise Correlator



Digital Leak Noise Correlator



Direct Measurement of Leakage Volume

In case that leakage is detected, measure the leakage volume before repairing it.
By multiplying this leakage volume by the number of leakage points,
Estimate the total leakage volume.

Direct measurement of leakage volume

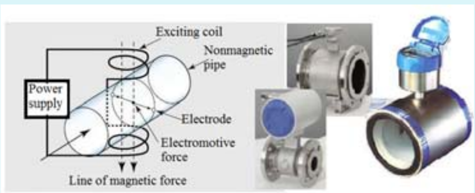
Flow Rate Measurement Equipment

1. Electromagnetic flow meter

Principle of operation and application

The electromagnetic flow meter is capable of measuring the flow volume of a fluid by applying a magnetic field to the fluid from the outside.

As the conductive fluid flows through the magnetic field, an electromotive force is generated perpendicularly to both the flowing direction of the conductive fluid and the direction of magnetic field.



Ultrasonic flow meter

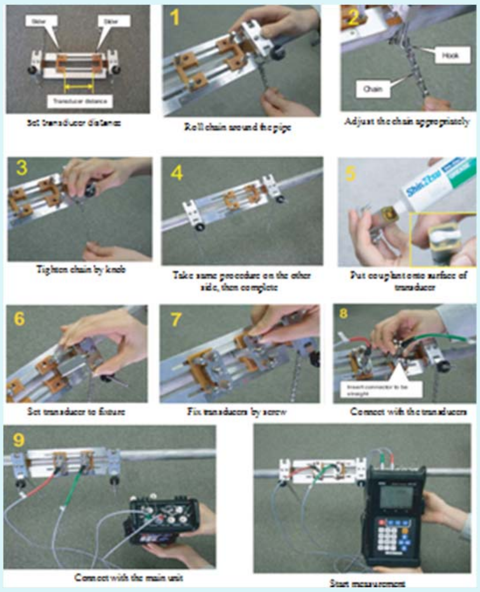
2.Ultrasonic flow meter

Principle of operation and application

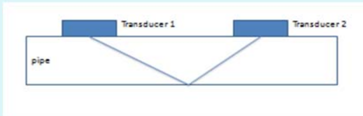
The ultrasonic flow meter operates based on the difference in time required for ultrasonic waves to be transmitted through a fluid.

It consists of two transducers mounted on the outer wall of a pipe and measures the flow rate from the transmission velocity of ultrasonic waves generated and received by itself through the fluid

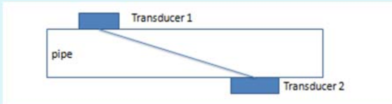
Ultrasonic flow meter



V Method



Z Method

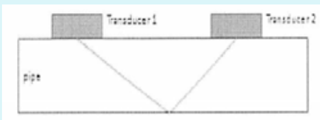


W Method (not commonly used)

Electromagnetic flow meter -*Transducer Mounting Methods*

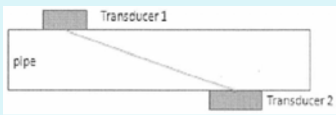
V Method

The V method is considered as the standard method. It usually gives a more accurate reading and is used on pipe diameters ranging from 50mm to 400mm (2"-16") approximately. Also, it is convenient to use, but still requires proper installation of the transducer, contact on the pipe at the pipe's centreline and equal spacing on either side of the centreline



Z Method

The signal transmitted in a Z method installation has less attenuation than a signal transmitted with the V method. This is because the Z method utilizes a directly transmitted (rather than reflected) signal which transverses the liquid only once. the Z method is able to measure on pipe diameters ranging from 25mm to 1200mm (1"-48") approximately.



Electromagnetic flow meter -*Transducer Mounting Methods*

W-Method (not commonly used)

With the W method. the sound waves traverse the fluid twice and bounce three times off the pipe walls. It is suitable for small pipe diameter measurement.

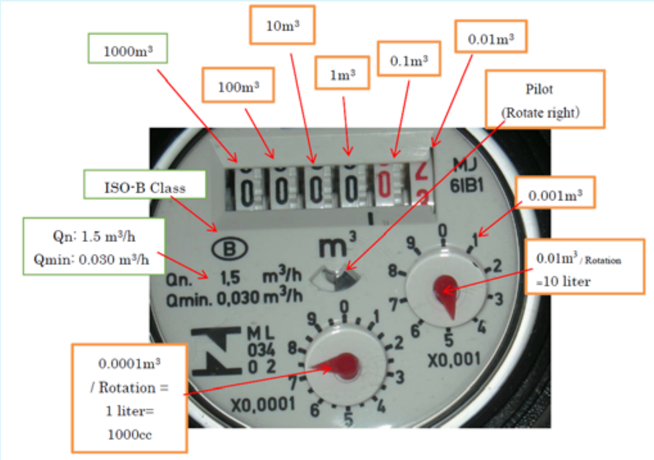
The measurement accuracy can be improved by extending the transit distance with the W method

Portable insert type flow meter

It is Used to measure flow rates, fluid velocity, flowing direction, and water pressure by inserting it to a pipeline.

A connection has to be done on the pipeline

water meters



water meters

Classification of Pilot-indicators

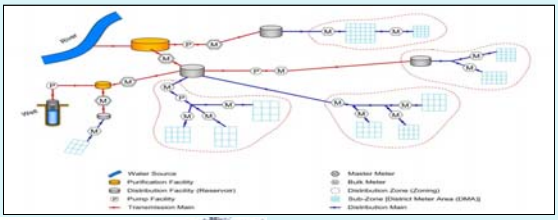
(a) Monitoring gauge indicating whether or not the meter is sensing (counting)

(b) Leakage monitoring




26

Master meters



Schematic layout of typical water flow : Understanding water flow to water intake, purification facility, pump facility, distribution reservoir, distribution network, distribution zone (zoning) and water meter

It is important to install Bulk Meter and register daily volume of distributed water.

Date	Time	Water Volume m^3/day
7/1	07:00	123
7/2	07:00	153
…	…	…
7/30	07:00	141
Total per month		4124 m^3/month

2

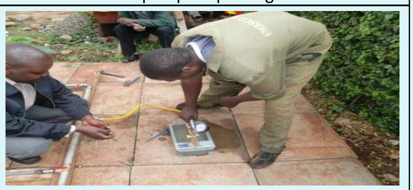
3. Pressure Measuring Equipments

self-recording water pressure device

- ***Principle of operation and application***
- Used to record water pressure in the pipeline and record by plotting on a paper provided

Hydraulic tester

5-4 Water Pressure Test

 Water Pressure Test Pump	 Hand pump for packing test
 Leakage from bad connection point	 Connect pump with pipe and place water pressure

Check water tight after repair or replacing new pipes by Water Pressure Test Pump.

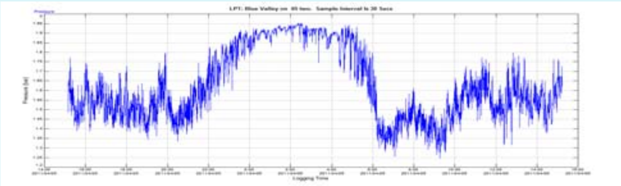
12

Bourdon-tube pressure gauge

PRESSURE DATA LOGGER

Principle of operation and application

Used to record water pressure changes over an extended period



Pressure Reducing Equipment (BPT･Pressure Reducing Valve)

BPT (Break Pressure Tank)

Pressure Reducing Valve (automatic adjustment)

Installation of Pressure Reducing Valve (small)

Based on the distribution map of water pressure, examine introduction points of pressure reducing equipment such as BPT (Break Pressure Tank) and pressure reducing valve.

21

4. pipelines Locating/ Tracing Equipment

- 1Metallic Iron pipe locator

Principle of operation and application

They compose of Transmitter & Receiver

Metallic Pipe Locator

Traces any continuous metal, such as; iron, steel & copper water lines, gas lines, tracer wire by plastic pipe, telephone/TV cables, copper &aluminium wire, conduit, and Power lines whether energized or not.

Non-Metallic Pipe Locator

pipe location of non-metallic pipes such as polyvinyl chloride, polyethylene and asbestos cement pipes, and metallic pipes with slip-on type connections being electrically insulated, is carried out by using a sonic type pipe locator.

Principle of operation and application
Low frequency sound waves are generated by the sonic vibrator, which are transmitted through the water in the non-metal pipe, then received by the pickup sensor of the sound wave detector placed on the ground surface.

Water quality analysis to determine theft

Comparison of pH values

DPD reagent

Quantifying the leakage

(5) Other related equipment

①Under-pressure Pipe tapping machine
②Portable Meter tester
③Portable Pressure tester
④Pipe Thickness meter
⑤Pressure Reducing/ Control valve
⑥GPS
⑦Residual chlorine meter
⑧Conductivity meter

The End

Thank you for your attention

KENYA WATER INSTITUTE

BASIC CONCEPT OF COMMERCIAL LOSSES

#9(R-1)

J.KIHARA
JUNE 2019
(KEWI)

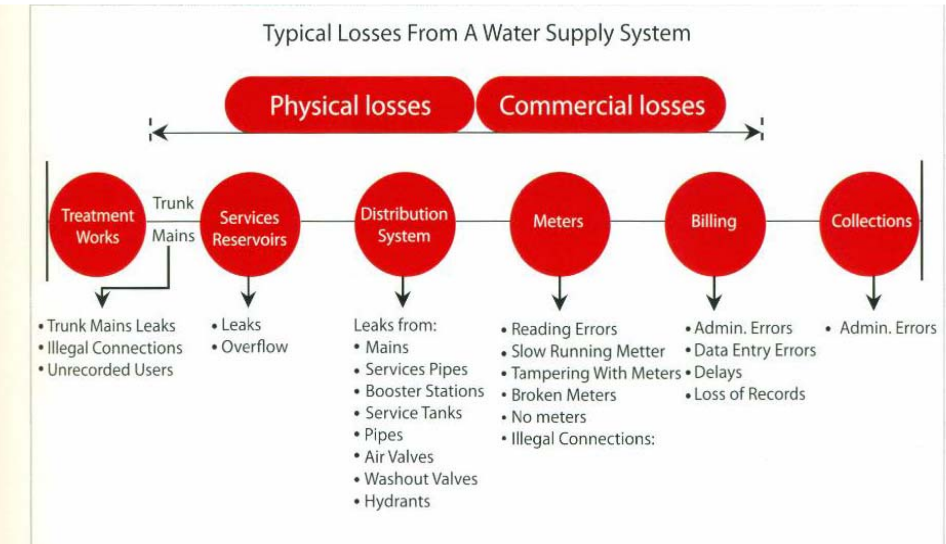
Outline

- Introduction
- Objectives of Water Loss Management
- Focusing on Apparent Losses (AL)
- Reducing Apparent (Commercial) Losses
- How to address Customer Meter Inaccuracy
- Installing Meters Properly
- Monitoring Water Quality
- Meter servicing
- Monitoring Intermittent Water Supply
- Sizing Meters Properly
- Maintaining and Replacing Meters
- Addressing Meter Tampering
- How to Minimize Meter Under- Registration.
- Unauthorized Consumption
  - How to find and Reduce Illegal Connections
  - How to Tackle Meter Bypassing
  - Preventing Illegal Use of Fire Hydrants
  - How to Reduce Water Theft
  - How to Avoiding Corrupt Meter Readers
  - Actively Checking the Customer Billing System
  - *Meter Reading Errors*
- *Data Handling and Accounting Errors*

Objectives of this this presentation are:-

1. To promote an apparent loss (AL) reduction approach based on the reduction of four main AL components:-
   Meter Under-Registration,
   Illegal Consumption,
   Meter Reading Errors and
   Water Accounting Errors.
2. To enable participants identify and reduce commercial water losses in their utilities,
3. To define the various types of apparent losses that can be classified within the four AL components,
4. To give special emphasis on water under-registration and other metering issues,
5. To review current methods and techniques to reduce the various components of apparent loss to a minimum achievable level.
6. To give recommendations to establish a cost effective programme to reduce AL to economically acceptable level, and
7. To give recommendations on how to get sustainable results on AL management

Water Losses from a Typical Water Supply System



Participants activity

- **Brainstorm on the objectives of Water Loss Management for a WSP.**
- **List the answers on a flip chart**

Objectives of Water Loss Management

- **Operating cost efficiency:** a well-maintained water distribution system will require fewer repairs.
- **Capital cost efficiency:** a lack of maintenance and intermittent operation increase wear and tear on pipes, valves and meters. Improved supply will extend the service life of the system components and lead to lower fixed costs for the water utility in the long run.
- **Improved metering and billing:** fewer leaks and an improved supply situation may minimize metering errors.
- **Reduced health risks:** sewage and other pollutants can infiltrate the pipe system through leaks and trigger water-borne diseases in low-pressure systems or in the case of intermittent operation.
- **Reduced ecological stress:** In the case of scarce or over-exploited water resources, water losses reduction strategy should be enhanced to reduce or decrease the stress on these resources.

Objectives of Water Loss Management

- **Increased security of supply:** a well-maintained system with fewer leaks and bursts will increase the supply guarantee.
- **Less infrastructural damages:** leakage might create voids below ground which can lead roads and buildings to collapse.
- **Reduced loads on sewers:** infiltration of water lost to sewers places an additional load on sewer pipes and wastewater treatment plants.
- **Improved consumer satisfaction:** in addition to poor water quality, inadequate quantity and health risks, leakages also decrease the pressure at customers' appliances. Enhancing the supply service will improve customer satisfaction and willingness to pay.
- **Publicity and willingness to pay:** fewer bursts, increased security of supply and hygienic conditions will enhance the public's perception of the water utility. This may also positively affect the consumers' willingness to pay.

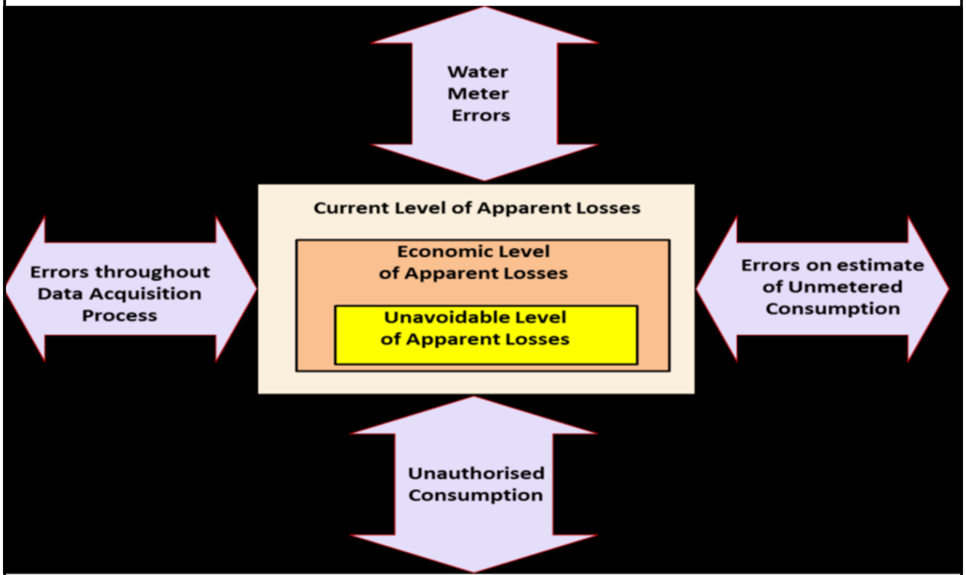
Focusing on Apparent Losses (AL)

- Apparent losses are classified as follows:- **unauthorized consumption, customer metering errors, errors in estimates of unmetered consumption,** and **errors linked to the data acquisition process**.
- **Table 2 lists and describes different causes.**
- Its important to note that measurement is the core issue in terms of apparent losses. Defective measurement generates apparent losses:-
  - Meter error relates to water meter precision and uncertainty
  - Poor estimate of unmetered consumption relates to the lack of water meter on the service connections
  - Unauthorized consumption is generally not metered
  - Data handling errors are due to measurement errors at the various stage of the data acquisition process: data capture, data collection; data transmittance, data processing and manipulation.

Reducing Apparent (Commercial) Losses

- The elements of commercial losses are:-
  - Customer meter inaccuracies
  - Unauthorized consumption; illegal connections, theft and fraud
  - Customer data base (accounting) errors
  - Data collection (meter reading) and data transfer errors.

Elements of Commercial Losses



How to address Customer Meter Inaccuracy

How to address Customer Meter Inaccuracy

- Inaccurate meters tend to under-register water consumption—leading to reduced sales and reduced revenue.
- Utilities should focus initially on large customers, such as industrial or commercial users.
- Using data from accurate meters to bill customers, ensures that customers are charged according to their actual consumption and encourages them to preserve water.

The following are common problems with customer meter accuracies and solutions for utilities.

- **Installing Meters Properly**
- **Monitoring Water Quality**
- **Meter servicing**
- **Monitoring Intermittent Water Supply**
- **Sizing Meters Properly**
- **Maintaining and Replacing Meters Properly**
- **Addressing Meter Tampering**

How to Minimize Meter Under- Registration.

- These measures can prevent or minimize meter under- registration:-
  - Choose meters that are known for quality and durability
  - Choose the right size meter for the customer flow: meters that are too large may not register all of the flow
  - Install meters according to manufacturer's specifications in convenient locations
  - Regularly monitor water quality and clean mechanical meters to promote accurate meter measurements
  - Avoid intermittent supply
  - Replace meters systematically, beginning with the oldest meters and those in the worst condition.
- The initial focus should be on large customers, such as industrial or commercial users who will likely prove beneficial since they consume a larger volume of water and often pay a higher tariff.

Unauthorized Consumption

- Unauthorized consumption includes illegal connections, meter bypassing, illegal use of hydrants, and poor billing collection systems.

How to Reduce Water Theft

- People steal water when they make an illegal connection to the network or tamper with the meter. The techniques one can use in order to reduce water theft include:-

1. Use tamper resistant meters (see Meter Reading Errors) or install seals that indicate tampering has occurred.
2. Remove meter by-passes. A bypass pipe is often buried and very difficult to detect. This type of unauthorized consumption is usually committed by industrial and commercial premises, where only a small volume of the consumption goes through the meter and the rest through the bypass pipe. The discrepancy will show up when the utility conducts a flow balance analysis.
3. Find and reduce illegal connections. They can occur during the installation of a new supply connection, or sometimes the customer's supply is cut off after non-payment he or she cannot afford, or does not want to pay, to be reconnected.
4. Prevent illegal use of fire hydrants. Some use them illegally to fill tankers (normally at night) or to provide water supply to construction sites. Encourage customers to report cases of illegal uses of fire hydrants.

How to Avoiding Corrupt Meter Readers

- Corrupt meter readers can significantly impact a utility’s monthly billed consumption. For instance, the same meter reader who walks the same route for an extended period of time, thus becoming familiar with the customers and their monthly billed consumption, may collude with those customers to record lower meter readings in exchange for a monetary incentive.
- To reduce this risk, the manager needs to rotate meter readers to different routes on a regular basis.

Actively Checking the Customer Billing System

- Sometimes connections are made legally, but the billing department is not notified of the new connection; therefore, the customer is never billed.
- These unregistered customers can be detected during the regular meter reading cycle when diligent meter readers find meters that are not in their reading book.
- Note:- this process may not identify all the errors in the billing system.

Meter Reading Errors

- The success of meter reading, billing and collecting revenues depends on accuracy, check & balances and diligence. The goal is-:

1. to ensure that all people who use water are connected and in the utility's information system,
2. that usage is metered accurately,
3. that the meter readings result in accurate bills to customers and
4. That the billed amounts are collected on a timely basis.

- At any step in this process, inaccuracies or errors will result in NRW.

How to Improve Accuracy and Eliminate Errors:

- Conduct customer surveys to make sure that every user is a registered customer and that the utility's records are accurate as to address, name of owner, customer number and meter information.
- Analyze flows in areas of suspected high commercial losses, in order to pinpoint problem areas.
- Compare the usage metered to the usage billed for each billing cycle.
- Ensure that all amounts that are billed are collected.
- Arrange the functions (metering, billing and collection) so that one person is not responsible for all of them.
- A **robust billing database** is one of the key elements of minimizing accounting errors. State- of-the-art billing software has built-in analysis functions that can identify potential data handling errors, zero readings, and report them for verification

Data Handling and Accounting Errors

- The success of meter reading, billing and collecting revenues depends on accuracy, check & balances and diligence. The goal is:

1. to ensure that all people who use water are connected and in the utility's information system,
2. that usage is metered accurately,
3. that the meter readings result in accurate bills to customers and
4. That the billed amounts are collected on a timely basis.

- At any step in this process, inaccuracies or errors will result in NRW.

Steps to Improve Accuracy and Eliminate Errors:-

1. Conduct customer surveys to make sure that every user is a registered customer and that the utility's records are accurate as to address, name of owner, customer number and meter information.
2. Analyze flows in areas of suspected high commercial losses, in order to pinpoint problem areas.
3. Compare the usage metered to the usage billed for each billing cycle.
4. Ensure that all amounts that are billed are collected.
5. Arrange the functions (metering, billing and collection) so that one person is not responsible for all of them.

Implementing an Apparent Loss Reduction Program

- Key Elements of a Program to Reduce Apparent Losses

1. Improve the customer database
2. Improve estimates used for billing
3. Introduce/improve customer metering
4. Detect illegal consumption, theft and fraud
5. Control meter reading, billing corruption
6. Communicate with customers
7. Reduce wastage at public taps

Apparent Loss Reduction: First Priority in NRW Reduction Effort

- Just like a wise person starts by picking the low lying fruits before embarking on the fruits high up on the tree.
- **Always Start NRW Reduction with Apparent Loss Reduction**

What is your comments ? （１）

Stealing water? Illegality or legality? Effective use of water？
What is the method of investigating whether or not it is stolen? Countermeasure?

What is your comments (2)

(A Booster pump)

Thank you

Kihara

KENYA WATER INSTITUTE

HOW TO IMPROVE BILLING IN WATER FACILITIES

#10(R-1)

J.KIHARA
JUNE 2019
(KEWI)

How to Improve Billing in Water Utilities

Content Outline

- Objectives
- Introduction
- Key Words -Definitions
- Objective of Billing System
- Why is Effective Billing and Collection Necessary?
- Billing and Revenue Strategies
  - Monthly Billing System Based on a Volumetric Structure
  - Computerized System of Billing
  - 100 Percent Customer Metering and 100 Percent Billing
  - Prepaid Meters
  - Automatic Meter Reading
  - Outsourcing the Billing and Collection Function
  - Incentives for Meter Readers
  - Regular and On-Time Payments
  - Delinquent / Erroneous Accounts
  - Managing Debt

Objectives:-

The participants will be able to:-

① Appreciate the need for an effective billing system for a water service provider.

② Appreciate the importance of effective revenue collection for the utility

③ Appreciate the billing process

④ Apply strategies in order to improve billing and revenue collection practices in their utilities

Introduction

- Effective billing and collection systems are a critical components for ensuring the **viability** of a service provider. Improving these has an immediate impact on the **revenue streams** of a service provider that can, in turn, help in **improving services**.

Key Words –Definitions

Participants - brainstorm on the following terms:-

- ✓**Billing** –
- ✓**Revenue** -
- ✓**Viability** of a service provider.
- ✓ **Revenue streams** of a service provider.
- ✓ **Sustainability** of a service provider.
- ✓ C**ommercial** and **operational efficiencies in WSP**
- ✓ **Reliable**, and **sustainable services in WSP.**

Objectives of Billing and the Billing System

Participants to discuss:-

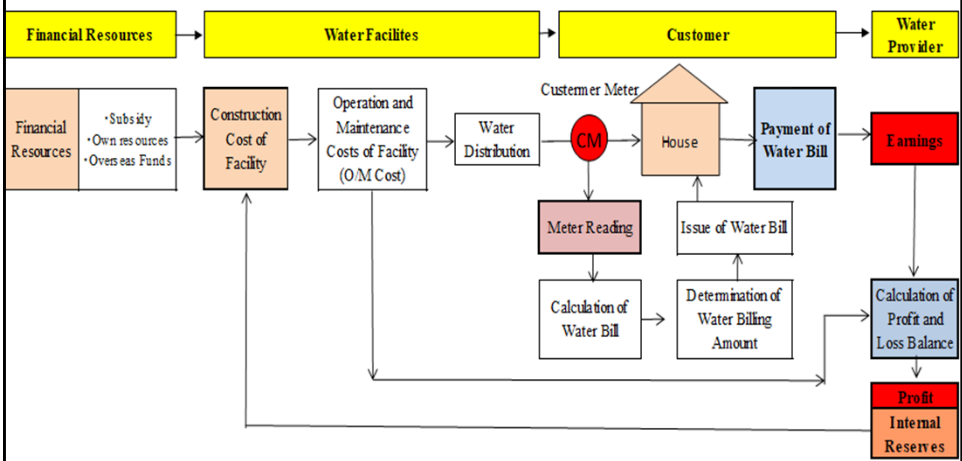
i. **The Objective of Billing**

ii. **The Objective of Billing System**

List the possible answers on flip chart

The Billing Process

Figure 1: Billing Process



Billing and Revenue Strategies

Billing and Revenue Strategies Cont.

- A strategy involves using all the forces of a company to execute approved plans as efficiently and as effectively as possible. It’s a plan of action intended to accomplish a specific goal.
- Water Companies must improve their billing and collection practices if they are to become **financially viable**, **sustainable** and **deliver quality** and **standard services**.
- Each WSP will need to focus on **specific steps** for it to **achieve service** and **revenue improvements**.

Billing and Revenue Strategies Cont.

- The WSPs should adopt the following principles that govern an efficient billing and revenue collection system:-
  - Ensure up to date customer databases,
  - Strive to achieve the highest level of metering i.e. 100% metering and avoid un-metered service provision,
  - Develop clear billing structures and cycles,
  - Enhance practices on delivery of bills and revenue collection,
  - Develop staff capacity and enhance their involvement, and
  - Facilities customer payments by making it convenient and conducive.

Strategies that Determine Effective Billing and Revenue Collection

1. Monthly Billing System Based on a Volumetric Structure
2. Computerized System of Billing
3. 100 Percent Customer metering, 100 Percent Billing and 100 Percent revenue collection
4. Prepaid Meters and Automatic Meter Reading
5. Outsourcing the Billing and Collection Function
6. Incentives for Meter Readers
7. Regular and On-Time Payments
8. Resolving Customer Grievances
9. Delinquent / erroneous Accounts
10. Managing Debt

Monthly Billing System Based on a Volumetric Structure

- An effective billing system must have a billing cycle that bills customers on a monthly basis. In so doing, companies must give adequate details to ensure appropriate and structured monthly billing.
- The billing system should be based on a volumetric structure. This ensures that customers are billed for the water that they have consumed. Volumetric charges are based on:
  - a uniform volumetric charge;
  - a rising block tariff where the unit charge is specified over a range of water use for a specific customers and then increases as water consumption increases; and
  - An increasing linear tariff where the unit charge increases linearly as water usage increases.
- All volumetric charging are based on meter readings. This requires that customers have metered connections. Therefore companies must make sure that the meters work properly and are read on a periodic basis. Billing practices are based on different pricing mechanisms:
  - Flat rate charging,
  - Volumetric charging or flat and volumetric-based charging.
  - Water service providers can have different billing cycles (bi-monthly, monthly, quarterly or yearly).

Computerized System of Billing

- A computerized system of billing and an updated and complete customer database is a must for a water company seeking to maintain high billing efficiency. This is done by ensuring that customer databases are updated and computerized, through vigorous accounting and recordkeeping.
  - A computerized system customer database allows:
    - Generation of reliable data that can inform the decision-making process of the water company,
    - The utility to track customer records by its respective management unit (that is, by zone, ward, district, etc.).
    - Monitor and track exceptions in billing records.
    - Tracking billing exceptions allows for a thorough investigation for the reasons behind the exception leading to redressal of the situation.

100 Percent Customer Metering and 100 Percent Billing

- Volumetric charging is effective if all connections are metered and all meters are working properly. It means the billed invoices are based on metered consumption. An effective metering practice depends on:
- Customers who cannot cheat the system by tampering or damaging the meters,
- Repairs and replacement policy of the utility ,
- timely identification of faulty meters and
- Installation of meters even in poor and low-income settlements etc.

100 Percent Customer Metering and 100 Percent Billing - Cont.

- **Service provider's needs to check on:**
  - The accuracy of meters on a systematic basis so that there are no problems.
  - The bill whether the meter is in working condition or its defective.
- **The service provider must:**
  - authorize a single point from where customers can purchase their meters
  - provide the meters themselves, so that a standardized meter is authorized by the service provider
  - Have a meter checking, maintenance, and repair policy in place so that any faults as identified by meter readers at the time of meter reading can be reported and addressed.
  - A responsible staff who could single out problem cases, especially those of incorrect consumption units recorded (data entered could indicate unrealistic consumption units such as negative units or excessive figures).
  - Set in place appropriate incentives such that meter readers actually read the meter and do not cheat the system by reporting average consumption figures at the time of meter reading.

Prepaid Meters

- The basic idea behind the use of prepaid meters is to facilitate those who may be denied access to water because they cannot pay upfront.
- It gives the concerned persons the flexibility to avail of water services even if they have not made an upfront connection payment for a fixed water connection.

Automatic Meter Reading

Automatic Meter Reading - Cont.

- Automatic meter reading technology allows for automatic collection of data from the water meter and transfers it to a central database for billing.
- For Nairobi Water, handheld data loggers enable meter readers to record readings easily. They are preloaded with set information, based on which the water meter data needs to be collected. Data loggers generate alerts for incorrect entries or anomalies. For example, in case meter readers enter erroneous data or if they do not read the meter but continues to generate readings.
- The data loggers give meter readers two options for generating bills:
  - **Spot billing,** where they could generate bills on the spot and hand them over to the customers once the meter readings are entered in the data loggers.
  - **Batch billing**, where meter readers can collect the required data and, at the end of the day download the data in their office computers. In the office, master database gets updated and bills are generated according to the billing cycle.
- Innovations of using data loggers could prevent malpractices / corruption and, help confirm with the customers all bill details on the spot.

Outsourcing the Billing and Collection Function

Outsourcing the Billing and Collection Function – Cont.

- Water Companies are using improved billing technologies by outsourcing the entire billing and collection process to companies with proven expertise in such fields as illustrated by Nairobi Water partnering with Safari Com, Equity bank, Post office etc. Benefits of outsourcing are:
- the experts provide a fully managed service starting from bill generation and payment collection, to credit and debt management,
- the experts use improved technology, systems, and processes to realize improvements in billing and collection,
- Collections from customers are also monitored regularly by tracking revenue indicators like gain in net cash generation, new-billed revenue, costs to undertake billing and collection etc.
- The time saved and a reduced need for in-house systems and staff for billing practices.
- Outsourcing billing and collection is cost-effective since the system of competitive tendering gives the job to the most efficient and specialized providers.
- It also leads to better cost control since the provider knows the exact price of the outsourced services and such services can be monitored more strictly.

Incentives for Meter Readers

Incentives for Meter Readers – Cont.

- Water companies need to encourage efficiency in billing practices. This can be achieved by developing a system that gives incentives to meter readers.
- If there is a perceived risk of meter readers engaging in malpractices, such as colluding with customers and forging consumption details in the areas that they are operating, they could be rotated from time to time to avoid such risks.
- Some companies give incentives to their staff by linking improvements and efficiency in billing directly to staff remunerations. The meter reader pay is based on the number of bills delivered in the month. Many water companies set monthly targets and then reward the best performer.

Regular and On-Time Payments

Regular and On-Time Payments - Cont.

- Incentives for customers: Billing and revenue collection efficiencies are hindered by illegal connections and deliberate non-payment's by customers. Water Companies should encourage customers to connect to the network by setting up plans for regularization of connections through an incentive on the connection fee.
- Continuous default, non-payment and cases of illegal connections, using sanctions, such as water connection cut-offs, should be exercised.
- Credible disconnection policies - some water companies have used credible disconnection policies and have been able to exercise this sanction more often for defaulting and illegal customers. Water utilities could send a notification for payment and, if not adhered to, resort to then cutting off the water connection.

Regular and On-Time Payments - Cont.

- **Incentive for customers** – water companies could develop incentive schemes for customers who have huge arrears in their bills. **Discounts, instalment facilities for payment** etc, could be designed such that customers are encouraged to settle their bills once and for all.
- **Disincentive**s - utilities could also use disincentives for late and irregular payments through disconnection of water, or imposition of heavy fines etc., that deter customers from such habits.
- **Customer conveniences to pay**: Water utilities must encourage customers to pay on time for services by simplifying the payment process. They should set up payment agreements for customers to **pay at banks, post offices or convenience stores,** or put up their own conveniences for easy bill payments such as customer care centres, collection centres, online payment facilities etc.

Regular and On-Time Payments - Cont.

- When setting up centres for collection of water bills, companies should ensure that these centres are **convenient for the customers**. The location of the centres **should be planned to serve the entire service area**. They should be located at **prominent places** that are **convenient to access by customers**.
- For the poor - Water companies should give **options like instalment payments to ensure poor people** are encouraged to take individual connections and keep paying for them for continued service delivery.

Delinquent / erroneous Accounts

Delinquent / erroneous Accounts – Cont.

- Many water companies have to deal with an overdue or unpaid account at some point or another. The following steps can help your WSP improve its receivables.
  - **Don't grant credit**
  - **Require deposits**
  - Utilities can ask for advance payments. Water providers may ask for 30 to 50% up front, depending on the client, with remaining payments due later.
  - **Offer credit terms**
  - Credit terms outline how you expect to get paid, and what interest or penalties you charge for late payment. State these clearly on your contracts and invoices.
  - **Get a signed agreement**
  - Never extend credit without getting something in writing. Review payment deadlines with clients and express that you expect to be paid on time. Point out the terms for late payment.

Delinquent / erroneous Accounts – Cont.

- **Check credit**
  - Collect the information you'll need to run a credit check on a "new customer form." For customers, this data includes name, address, phone numbers, I.D and bank account numbers, tax pin number, at least two credit references.
- **Create a billing / overdue notification system**
  - You should know how much is owed to you and when it is due. For this, your system should alert you on overdue accounts. Most accounting software programs do this automatically.

Managing Debt

- For water company, its reasonable to have a manageable level of debt. Growth and **expansion** often demands considerable capital which may require you to seek a bank loan. For this, you may need the following guidelines:
  - Explore your reasons for borrowing / seeking a loan include:
  - Working capital - when you're looking to increase your utility's work force or boost your stock.
  - Expanding into new areas or markets.

Participants Activity

- **Sit according to your company / organization,**
  - **Identify at least two strategies which when embraced by your WSP will have a large impact on revenue collection with minimal additional financial requirements. Identify the person or persons responsible for implementation of the action plan**
  - **Identify resources required [budget] to achieve the above,**
  - **Indicate time line/time frame on when these can be accomplished/achieved.**
  - **List on the flip chart the steps you would put in place to realize this impact.**
  - **Make a presentation to the rest of participants.**

Thank you

Kihara

What is your comments ?　（1）

Stealing water?　Illegality or legality?　Effective use of water？
What is the method of investigating whether or not it is stolen?　Countermeasure?

What is your comments (2)

(A Booster pump)

KENYA WATER INSTITUTE

HOW TO USE WATER TEST BENCH #12(R-1)

T.WALELA
JUNE 2019
(KEWI)

Presentation on use of meter test bench

- PRESENTED BY: Joseph Maina
- 6th June 2019
- Kewi Nairobi Kenya

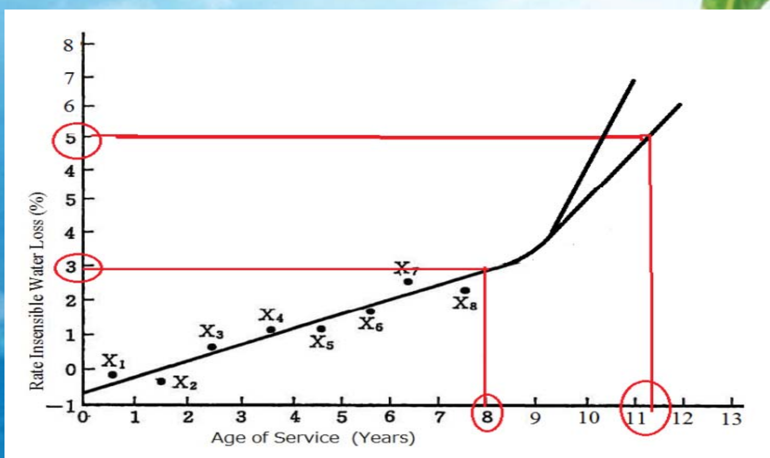
8/15/2019

Causes of commercial losses

- Insensitive water meters
- Illegal connection / Water theft
- Meter reading/billing and accounting errors

.arrears in payments that leads to bad debt write offs.

Year of use of meter and insensitive water rate (%)



Why is water meter test bench necessary?

- Prediction of meter insensitive water amount
- Impact on revenue collection
- Non-revenue reduction effect by replacement of faulty meter tested
- As a tool for efficiency
- Dispute solving

Standards of water meter accuracy test

<u>Kenya Standards (KEBS)</u>

The standard for water meters in Kenya is a joint standard of British standard, EN and ISO which **KEBS recommends. (ISO 4064-1-2-3-4-5 2014/OIML R-49: 2013: standards are the basis)**

(2) The test methods conform to ISO 4064-1: 2014 / OIML R 49-1: 2013.

Various types of meter test methods in field

- Master-meter / calibrated meter method
- Measurement method of actual flow rate (with container i.e.(the calibrated bucket)
- **Water meter test bench method**
- Electronic potable meter test method
- Dedicated water flow device **(at the meter factory)**
- Calibrated flow device i.e. (the ufm)

8/15/2019

(1) Master-meter/ calibrated meter method

In this method, "existing water meter" and "master meter: tested meter" are connected in series at the site, the difference between the flow volume values of both is calculated, and the instrumental error is measured.

<u>Point to remember</u>

Make sure to calibrate the measurement precision for the master meter.(KBS CERTIFICATE)

8/15/2019

J Maina NRWM EXPERT

Point to remember

Make sure to calibrate the measurement precision for the master meter.

Features

①Equipment difference is calculated at a flow rate close to actual usage.

②Continuous investigation is possible without disturbing residents (without stopping water supply).

2) Measurement method of actual flow volume (container method)

In this method, the amount of water of the existing faucet is stored in a container

the amount of water passed by the existing meter and the actual volume (amount of water of the container) are compared on the spot.

2) Measurement method of actual flow volume (container method) Con't

Points to remember

① When converting the weight of water into a volume, it is necessary to consider water temperature difference "specific gravity difference".

Features

① Equipment difference can be calculated with a flow rate close to actual usage.

② Measurement is possible in a short time without disturbing residents (without stopping water supply).

Equipment to be used

① Water receiving container (Eg, bucket) · · 1 piece

② Weight scale 1 piece

③ Water temperature gauge 1 piece

8/15/2019

J Maina NRWM EXPERT

Active Replacement & Accuracy Check of Large Customer Meters

Using 1) potable ultrasonic flow meter, 2) low-cost potable meter tester (plastic piston meter of 1 inch) and 3) calibrated buckets on site

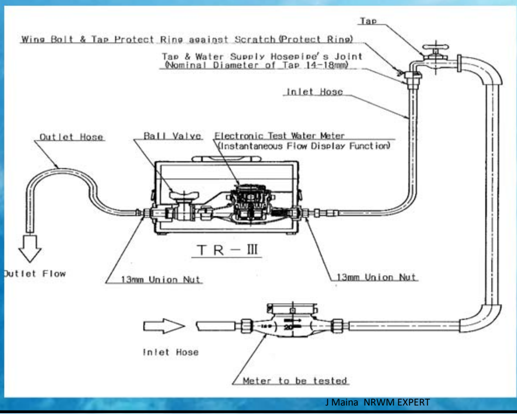
In addition to the conventional accuracy tests with the existing meter test bench after removing customer meters temporally.

Showing our practices in KEWI's OJT

9

(3) Electronic test meter method

In this method, "electronic meter (certified meter)" is connected in series to the existing meter and the "equipment difference" is measured from the difference between "existing meter value" and "actual flow value of electronic meter" at the site is there.



portable meter tester (a) Points to remember

①The electronic meter must always be calibrated for measurement accuracy.

② Measurement of flow rate other than set flow rate increases measurement error.

③ Do not bring strong magnets closer to the electronic meter during measurement.

Have different measurement range and easy to use at customers point

4.WATER METER TEST BENCH METHOD

Have different measurement range and easy to use at customers point

The test method can be divided into three methods Depending on the standard machine.

	Methods	Standard Equipment
1	**Volume**	**Water tank/ container, and etc.**
2	Weighing	Weight/ water tank/ density meter
3	Comparison with flow rate	Master meter and etc.

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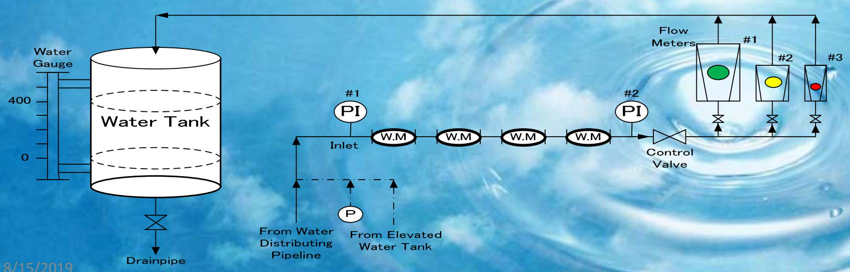
(1) Volume method

This method measures the capacity of a standard water tank

The test water is sent to the meter under inspection, and "instrument difference" is measured from the difference between "measured value of the test meter" and "actual flow volume of the tank".



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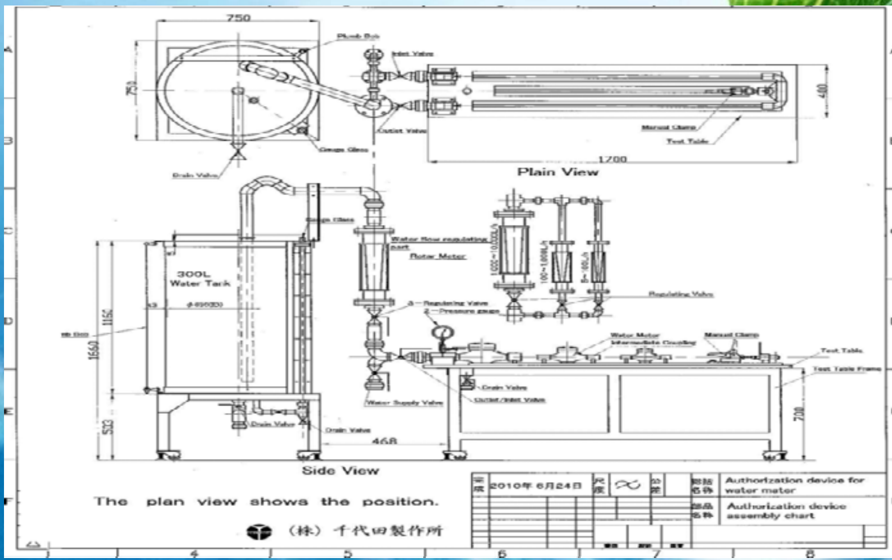
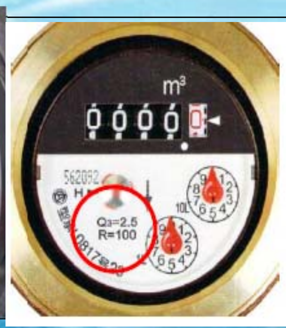
Component of a sample meter Test bench



Water Meter Test Bench to be used (EMBU Delivered model)

. Confirmation of water meter specification to be inspected before test (ISO-Class)

	ISO 4064-1993 (Old Standard)	JIS B 857-2013/ISO 4064-2005 (New)
Type	Multi jet-Dry-Radial vane	Single jet-Dry-Radial vane
Class	C	R-100= (Qn / Qmin)
DN (mm)	15	13
Qn (m3/hr)	1.5	2.5
Display		

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Conditions of a perfect test

① Temperature of water used: 20 ± 5 ℃

② Water Quality:

・The test water shall be tap water or equivalent water quality.

・Do not include objects (e.g. air bubbles, floating objects, etc.) that will adversely affect the meter operation.

③ Water pressure: A positive pressure of at least 0.03 Mpa at the meter outlet can be secured steadily

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Conditions of a perfect test

④Ambient temperature range: 15 ℃ to 35 ℃

⑤Range of peripheral relative humidity: 25 ° C to 75 ° C

⑦Scope of measurement (R value):

⑧The pressure loss of the water meter shall be within the operating conditions and shall not exceed 0.063 MPa (6.3 m = 0.63 kg · cm 2) at rated maximum water flow.

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Meter test range of flow rate

Accuracy measurement of the meter is tested at three flow rate points.

①Rated minimum flow rate Q1 = Qmin = 30 L / h

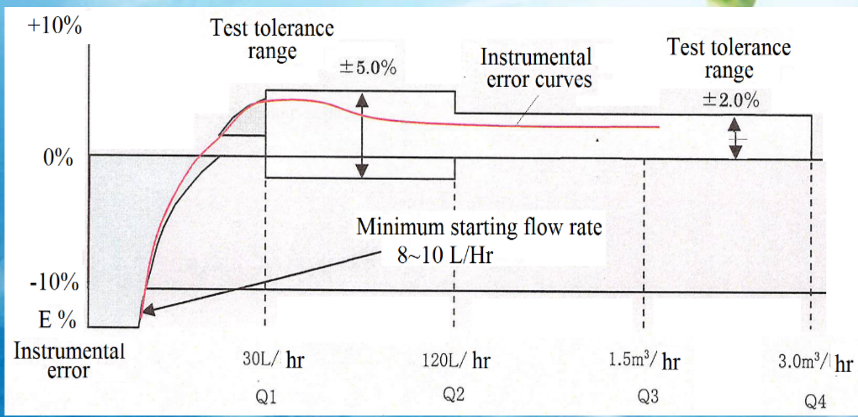
②Transitional flow rate Q 2 = Qt = 120 l / h

③Nominal flow rate Q3 = Qn = 1,500 L / h

④Limiting flow rate Q 4 = Qmax = 3,000 L/h

Performance curve

Example of Performance Curve (Class B)



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Result of Joint OJT at EMBU 2017-June-22 @ EWASCO

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	Flow Rate: Qn (1500 l/h) Total flow vol = 200 lts START	END	DIFRENCE		Error	Comments ±4 % (in use)	Comments
Volume used ; 200 lts=0.2 m3						0.2	R1 (m3)	R2 (m3)	R2-R1	%	100%		
1	Old	AC175298	PSM		15	3576.782	3576.782	3576.974	0.192	96%	-4%	Pass	
2	Customer	13081721	psm		15	2355.6125	2355.6125	2355.8089	0.1964	98%	-2%	Pass	
3	**New**	**15-05855**	**MJET**	**Kiambu WSP**	**15**	**0.4081**	**0.4081**	**0.6058**	**0.1977**	**99%**	**-1%**	**Pass**	**±2 % (New)**
4	Customer	7090712	psm		15	163.3051	163.3051	163.5014	0.1963	98%	-2%	Pass	
5	**New**	**15-05853**	**MJET**	**Kiambu WSP**	**15**	**0.3868**	**0.3868**	**0.5848**	**0.198**	**99%**	**-1%**	**Pass**	**±2 % (New)**
6	Above 1000	H570060	SJET		15	2779.702	2779.702	2779.891	0.189	94%	-6%	**Reject**	
7	Above 500	05-1059537	SJET		15	686.1175	686.1175	686.1175	0	0%	-100%	**Reject**	
8	In Service	8024018	psm		15	0.7072	0.7072	0.9016	0.1944	97%	-3%	Pass	

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	Flow Rate: Qt (120 l/h) Total flow vol= 50 lts START	END	DIFRENCE		Error	Comments ±10% (in use)	Comments
Volume used: 50 lts= 0.05 m3						0.05	R2	R3	R3-R2	%	100%		
1	Old	AC175298	PSM		15	3576.974	3576.974	3576.975	0.001	2%	-98%	**Reject**	
2	Customer	13081721	psm		15	2355.8089	2355.8089	2355.8585	0.0496	99%	-1%	Pass	
3	**New**	**15-05855**	**MJET**	**Kiambu WSP**	**15**	**0.6058**	**0.6058**	**0.6562**	**0.0504**	**101%**	**1%**	**Pass**	**±5 % (New)**
4	Customer	7090712	psm		15	163.5014	163.5014	163.5525	0.0511	102%	2%	Pass	
5	**New**	**15-05853**	**MJET**	**Kiambu WSP**	**15**	**0.5848**	**0.5848**	**0.6355**	**0.0507**	**101%**	**1%**	**Pass**	**±5 % (New)**
6	Above 1000	H570060	SJET		15	2779.891	2779.891	2779.938	0.047	94%	-6%	Pass	
7	Above 500	05-1059537	SJET		15	686.1175	686.1175	686.11	-0.0075	??	??	**Reject**	
8	In Service	8024018	psm		15	0.9016	0.9016	0.9524	0.0508	102%	2%	Pass	

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	Flow Rate: Qmin (30 l/h) Total flow vol = 20 lts START	END	DIFRENCE		Error	Comments ±10% (in use)	Comments
Volume used: 20 lts						0.02	R3	R4	R4-R3	%	100%		
1	Old	AC175298	PSM		15	3576.975	3576.975	3576.974	-0.001	??	??	**Reject**	
2	Customer	13081721	psm		15	2355.8585	2355.8585	2355.8585	0	0%	-100%	**Reject**	
3	**New**	**15-05855**	**MJET**	**Kiambu WSP**	15	**0.6562**	**0.6562**	**0.6756**	**0.0194**	**97%**	-3%	**Pass**	**±5% (New)**
4	Customer	7090712	psm		15	163.5525	163.5525	163.5716	0.0191	95%	-5%	Pass	
5	**New**	**15-05853**	**MJET**	**Kiambu WSP**	15	**0.6355**	**0.6355**	**0.6541**	**0.0186**	**93%**	-7%	Pass	**±5% (New)**
6	Above 1000	H570060	SJET		15	2779.938	2779.938	2779.958	0.02	100%	0%	Pass	
7	Above 500	05-1059537	SJET		15	686.11	686.11	686.11	0	0%	-100%	**Reject**	
8	In Service	8024018	psm		15	0.9524	0.9524	0.9718	0.0194	97%	-3%	Pass	

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Result of Joint OJT at EMBU (30th August 2018)

P1 inlet pressure - 4 bars						P2 outlet pressure = 0.1 bar							
No	Classification	Sr.no	Model/ type	Qn of meter	Caliber (mm)	Quantity of accumulated total (m3)	Flow Rate: Qn (1500 l/h) Total flow vol = 200 lts START	END	DIFRENCE			error	Comments+-2…test bench stds
Volume used ; 200 lts=0.2 m3						0.2	R1 (m3)	R2 (m3)	R2-R1	%	100%		
1	NAWASCO	17179050		1.5	15	31.515	0.19455	0.38335	0.1888	94%	-6%	-6	fail
2	48170	17045605		1.5	15	0.1725	0.20935	0.41152	0.20217	101%	1%	1	pass
3	170017	17005470		1.5	15	2429.072	0.63962	0.84127	0.20165	101%	1%	1	pass
4	47007	14014313		1.5	15	0.2603	1250.50032	1250.70105	0.20073	100%	0%	0	pass
5	48173	17045608		1.5	15	0.1189	0.1778	0.37878	0.20098	100%	0%	0	pass
6	New	185000065		1.5	15	0.3044	0.74851	0.94795	0.19944	100%	0%	0	pass
7	NAWASCO	17080260		1.5	15	0.5042	24.42569	24.62706	0.20137	101%	1%	1	pass
8	Iron Monger	1115190005		1.5	15	8189.5025	1.19064	1.39678	0.20614	103%	3%	3	fail

P1 inlet pressure - 4 bars						P2 outlet pressure = 0.1 bar							
No	Classification	Sr.no	Model/ type	QN of meter	Caliber (mm)	Quantity of accumulated total (m3)	Flow Rate: Qt (120 l/h) Total flow vol= 50 lts START	END	DIFRENCE			error	Comments+-2…test bench stds
Volume used: 50 lts= 0.05 m3						0.05	R2	R3	R3-R2	%	100%		
1	NAWASCO	17179050		1.5	15	31.7163	0.38482	0.43247	0.04765	95%	-5%	-5	fail
2	48170	17045605		1.5	15	0.3763	0.41198	0.4522	0.04022	80%	-20%	-20	fail
3	170017	17005470		1.5	15	2429.2751	0.84165	0.89315	0.0515	103%	3%	3	fail
4	47007	14014313		1.5	15	0.4689	1250.70147	1250.75221	0.05074	101%	1%	1	pass
5	48173	17045608		1.5	15	0.3793	0.3792	0.42998	0.05078	102%	2%	2	pass
6	New	185000065		1.5	15	0.5063	0.94835	0.99927	0.05092	102%	2%	2	pass
7	NAWASCO	17080260		1.5	15	0.7064	24.62752	24.67684	0.04932	99%	-1%	-1	pass
8	Iron Monger	1115190005		1.5	15	8100.7054	1.39725	1.44934	0.05209	104%	4%	4	fail

P1 inlet pressure - 0.4 bars						P2 outlet pressure = 0.1 bar							
							Flow Rate: Qmin (30 l/h)						
							Total flow vol = 20 lts						
No	Classification	Sr.no	Model/ type	Qn of meter	Caliber (mm)	Quantity of accumulated total (m3)	START	END	DIFRENCE			error	Comments+-2…test bench stds
Volume used: 20 lts						0.02	R3	R4	R4-R3	%	100%		
1	NAWASCO	17179050		1.5	15	31.7675	0.43291	0.4524	0.01949	97%	-3%	-3	fail
2	48170	17045605		1.5	15	0.4262	0.45258	0.48239	0.02981	149%	49%	-49	fail
3	170017	17005470		1.5	15	2429.3226	0.89345	0.91376	0.02031	102%	2%	2	pass
4	47007	14014313		1.5	15	0.518	1250.75255	1250.771	0.01845	92%	-8%	-8	fail
5	48173	17045608		1.5	15	0.4294	0.43032	0.44905	0.01873	94%	-6%	-6	fail
6	New	185000065		1.5	15	0.5569	0.99957	1.01978	0.02021	101%	1%	1	pass
7	NAWASCO	17080260		1.5	15	0.757	24.67724	24.69735	0.02011	101%	1%	1	pass
8	Iron Monger	1115190005		1.5	15	8100.7057	1.44975	1.46955	0.0198	99%	-1%	-1	pass

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In summary….meter testing is a base for…..

① Examination of cost effectiveness

② Examination of the timing of meter replacement

③ Confirmation method of investment effect

④ Future improvement plan

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Thank you
宜しくお願い致します

KENYA WATER INSTITUTE

NON REVENUE WATER PLANNING&IMPLEMENTATION

#14(R-1)

Eng.D.Ngugi
JUNE 2019
(WASREB)

Presentation Outline

- ❑ Strategic Plan of the WSP
- ❑ Strategic Objective on reduction of NRW
- ❑ Non Revenue Water Reduction Plan (dvpt)
- ❑ Non Revenue Water Self Assessment
- ❑ Non Revenue Water Reduction Plan and Implementation Status
- ❑ Non Revenue Water Data Analysis
- ❑ Non Revenue Water Quarterly Reports

Strategic Plan of the WSP

This is the Blue Print of the WSP that demonstrates and articulates its intention and plan of actions which if systematically implemented to the latter shall lead to realization of a set of diverse objectives

Strategic Objective on Reduction of NRW

Very specific NRW results that a Water Service Provider aims to achieve within a specific time-frame and with availability of explicitly clear resources.

There must therefore be a baseline that becomes the basis of the targeted results to be realized - hence situational analysis becomes a necessity for NRW.

Non Revenue Water Reduction Plan (dvpt)

Self Assessment Tool/template:

NRW Standards framework situation analysis for each of the five key issues/areas and their sub-issues/areas in the context of five potential levels to each sub-area from basic to high.

Non Revenue Water Self Assessment

NON REVENUE WATER SELF-ASSESMENT

Name of WSP:

Date: As at 30th June 2018

No	Level Issues	1 Basic	2	3	4	5 High	Level Achieved (1-5)
1	**Water Balance, Flow and Pressure Monitoring, Mapping**						
1.1	Water Balance	We have not established a water balance table	We have tried to establish a water balance table but gave up since we don't know the split in physical and commercial losses	We have established a water balance table following our own format	We have established an annual water balance table in accordance with the international format	We have established an annual water balance table in accordance with the international format	3
1.2	System Input Metering	Most of our system input is not metered	Not all, but less than 50% of our system input is not metered	Our system input is metered but we are not sure about the accuracy of the meter readings	Our system input is metered with mechanical and/or magnetic flow meters that are rarely calibrated	Our system input is metered with magnetic flow meters that are regularly calibrated	2
1.3	Pressure Monitoring	We do not have any pressure recorders installed	We have a few pressure recorders installed at pumping stations and treatment plants	We have a few pressure recorders installed at pumping stations and treatment plants and sporadically measure pressure in the distribution network with pressure gauges	We have a few pressure recorders installed at pumping stations and treatment plants and sporadically measure pressure in the distribution network with pressure loggers	We have permanently installed pressure loggers and continuously monitor pressure in the distribution network	5
1.4	Maps/GIS	We do not have maps at all	We have maps, but they are not updated	We have started to update our maps	Our maps are updated but do not include GIS	We use GIS based on updated maps	3
2	**Leak Repair Records**						
2.1	Leak Repair Records	We have no records of leak repairs	The only way to know the number of leaks repaired is to look into the customer complaints book	We keep basic leak repair records that only tell us weather the leak was on a main pipe or a service connection	We keep detailed records that indicate location, pipe diameter, material and type of lead as well date of detection and date and duration of repair	We keep detailed records that indicate location, pipe diameter, material and type of leak, date of detection, date and duration of repair and have linked this to our GIS	4
3	**Performance Indicators**						
3.1	Performance Indicators	The only Performance Indicator used is % NRW	We have tried to calculate water loss performance indicators	We regularly calculate physical losses performance indicators	We regularly calculate physical and commercial losses performance indicators	We regularly calculate physical and commercial losses performance indicators and publish them in our annual report	3
4	**Active leakage control**						
4.1	Active leakage control	We only repair physical leaks	We have leak detection equipment but we do not use it	We carry out leak detection occasionally if there is a specific problem in an area	We have started to do regular leak surveys	We cover the network by leakage survey at least once a year	5
4.2	District Meter Areas (DMAs)	We have no DMAs and have no plans to establish DMAs	We have started to establish the first DMAs	The first DMAs are established and we have already obtained the first results	We have several DMAs and sporadically check and analyse inflow data	We have several DMAs and monitor flow and pressure on a regular basis	4
4.3	Leak Repair - Distribution Pipes(Repair Time)	We have no records and therefore don't know how fast our leaks are repaired	Our average repair time is more than 7 days per leak	Our average repair time is between 7 and 3 days per leak	Our average repair time is between 3 and 1.5 days per leak	Our average repair time is less than 1.5 days per leak	5
4.4	Leak Repair - House Connections	We have no records and therefore don't know how fast our leaks are repaired	Our average repair time is more than 14 days per leak	Our average repair time is between 14 and 7 days per leak	Our average repair time is between 7 and 2 days per leak	Our average repair time is less than 2 days per leak	5
5	**Customer Metering**						
5.1	Customer Metering	We have no customer metering	Only large customers are metered	We have started with universal customer meters but at present not all customers are metered	Nearly all our customers are metered, except public fountains, stand pipes and connections of similar nature	100% of our customers are metered	2
5.2	Customer Meter Replacement and Age	We do not have reliable information on the age of our customer meters	Many of our meters are older than 10 years, we have not yet introduced meter replacement policy	We only change or replace meters if they stop functioning	We have a meter replacement policy but have not been able to replace all meters so some of our customer meters are still older than 10 years	We strictly follow our customer replacement policy and replace ALL meters which are 5 - 7 years old	3
5.3	Customer Meter Class	All customer meters are class B	All customer meters are class B and C	All customer meters are class C	All customer meters are class C and D	All customer meters are class D	3
5.4	Customer Database	Our customer database has not been updated for a long time	We sporadically update our customer database	We are in the process of updating our customer database	We regularly update our customer database by conducting house to house surveys and inspections	We have an updated customer data base that is linked to the GIS	5
5.5	Customer Meter Reading	We have no special system of controlling meter readers	We only rotate meter readers if we are suspicious of inaccuracies	We regularly rotate meter readers	We regularly rotate meter readers and often make spot checks	Our meter readers use handheld meter reading devices	1
5.6	Illegal Connections, meter tampering, bypasses	We have not made any assessment and have no program to deal with water theft	We occasionally detect illegal connections	We occasionally detect illegal connections and other forms of fraud	We have a thorough illegal connection detection program	We have a thorough illegal connection detection program and also identify bypasses	3

Non Revenue Water Reduction Plan and Implementation Status

NRW REDUCTION PLAN BY WSP & IMPLEMENTATION STATUS — Form-5-1 (Phase-1)

Name of WSP — Date: As at 30th June 2018

	Issues / Questions	Current Status	Desired Status / Target	Short Term Measure	Resources Required (Ksh)	By Whom	By When	Remarks Activities executed and Progress
1	**Water Balance, Flow and Pressure Monitoring, Mapping**							
1.1	**Water Balance**	2	3	Progressively split between physical and commercial losses by frequently analysing the water balance.	500,000	TM	Dec-18	
1.2	System Input Metering	3	4	Renewal of 5No production meters	5,000,000	NRW officer	Sep-18	
1.3	Pressure Monitoring	1	2	Purchase/hire and start using of pressure and data loggers (5 No.)	1,000,000	NRW officer	Nov-18	
1.4	Maps/GIS	3	4	Finish capture of all supply and distribution lines to have them all mapped	500,000	GIS Officer	Dec-18	
2	**Leak Repair Records**							
2.1	Leak Repair Records	3	4	To develop and enhance a reporting and record keeping procedure (use of job cards)	-	O&M Manager	Jan-19	
3	**Performance Indicators**							
3.1	Performance Indicators	1	3	Installation of pressure gauges and measurement of MNF and diversify modes of determining NRW using several KPIs.	1,000,000	TM	Apr-19	
4	**Active leakage control**							
4.1	Active leakage control	1	3	Purchase of the Leak Detection Equipment for use and doing line patrols for familiarisation of equipment by the teams.	1,200,000	NRW Officer	Aug-18	
4.2	District Meter Areas (DMAs)	2	3	Finish master meters installation, zero readings and first measurments for 5No. DMAs.	1,500,000	NRW Officer	Oct-18	
4.3	Leak Repair - Distribution Pipes(Repair Time)	5	5	Enhancing the leak reporting and repair mechanism by tracking progress on turn around times (TAT)	-	O&M Manager	Feb-18	
4.4	Leak Repair - House Connections (Repair Time)	5	5	Enhancing the leak reporting and repair mechanism by tracking progress on turn around times (TAT)	-	O&M Manager	May-19	
5	**Customer Metering**							
5.1	Customer Metering	5	5	Maintaining 100% metering ratio with at least 95% confidence level of the accuracy of the meters.	1,000,000	CM	Nov-18	
5.2	Customer Meter Replacement and Age	3	4	Continuously implement the meter replacement policy	2,000,000	P&Eng Manager	Jun-19	
5.3	Customer Meter Class	2	3	Audit of all existing class B meters for replacement	100,000	Meter Readers	Mar-19	
5.4	Customer Database	2	3	Customer Identification Survey and continuous data entry in GIS.	500,000	CM	Jun-18	
5.5	Customer Meter Reading	3	4	Implementation of the meter spot checking policy through systematic and consistent sampling and documenting results	-	Meter Readers	Jun-19	
5.6	Illegal Connections, meter tampering, bypasses	3	4	Proactive scouting for illegal connections by the established inspection team and securing penalties and prosecutions	500,000	NRW Officer	Apr-19	
					14,800,000			

Non Revenue Water Reduction Plan and Implementation Status-cont'd

- NRW Reduction Plan – Issues up to the indication of time line
- NRW Reduction Implementation Status – the last column on remarks - indicative summary of progress in strategies/activities implementation

Non Revenue Water Data Analysis

Water Service Provider

2nd Quarter 2018/19 Non Revenue Water Data

Oct-18			Nov-18			Dec-18			2nd Quarter 2018/2019			Half Year 2018/2019		
Water Produced M^3	Water Billed M^3	NRW Ave. %	Water Produced M^3	Water Billed M^3	NRW Ave. %	Water Produced M^3	Water Billed M^3	NRW Ave. %	Water Produced M^3	Water Billed M^3	NRW Ave. %	Water Produced M^3	Water Billed M^3	NRW Ave. %
443,570	351,727	**20.71**	466,968	343,591	**26.42**	458,394	372,631	**18.71**	1,368,932	1,067,949	**21.99**	2,737,864	2,135,898	21.9867
334,413	209,802	**37.26**	359,416	234,605	**34.73**	364,751	234,825	**35.62**	1,058,580	679,232	**35.84**	2,117,160	1,358,464	35.8356
189,799	140,364	**26.05**	197,327	156,986	**20.44**	189,489	144,664	**23.66**	576,615	442,014	**23.34**	1,153,230	884,028	23.3433
126,320	77,976	**38.27**	125,040	75,490	**39.63**	127,320	77,866	**38.84**	378,680	231,332	**38.91**	757,360	462,664	38.911
121,390	85,676	**29.42**	154,150	106,130	**31.15**	249,000	165,370	**33.59**	524,540	357,176	**31.91**	1,049,080	714,352	31.9068
48,634	33,984	**30.12**	48,634	37,241	**23.43**	48,634	36,902	**24.12**	145,902	108,127	**25.89**	291,804	216,254	25.8907
497,455	170,415	**65.74**	494,042	171,365	**65.31**	447,792	160,197	**64.23**	1,439,289	501,977	**65.12**	2,878,578	1,003,954	65.1233
92,060	50,840	**44.78**	95,441	54,703	**42.68**	105,645	56,526	**46.49**	293,146	162,069	**44.71**	586,292	324,138	44.7139
96,979	55,000	**43.29**	100,170	50,274	**49.81**	110,893	59,022	**46.78**	308,042	164,296	**46.66**	616,084	328,592	46.6644
16,225	9,952	**38.66**	35,445	25,663	**27.60**	34203	25,444	**25.61**	85,873	61,059	**28.90**	171,746	122,118	28.8962
1,966,845	**1,185,736**	**39.7%**	**2,076,633**	**1,256,048**	**39.5%**	**2,136,121**	**1,333,447**	**37.6%**	**6,179,599**	**3,775,231**	**38.9%**	**12,359,198**	**7,550,462**	**38.9%**

Non Revenue Water Quarterly Reports

- Mandatory obligation on the part of WSPs
- Is a set of at least three distinct and logical documents namely;
  - i. Self assessment
  - ii. NRW reduction plan and implementation status
  - iii. NRW data analysis

Thanking you for
your attention

KENYA WATER INSTITUTE

FIELD ON JOB TRAINING

#15-1(R-3)

W.MOSETI
JUNE 2019
(KEWI)

#15 On-the-Job Training Outline

(1) Area: about 83,000 m2

(2) Number of Customer meters: 150 pieces

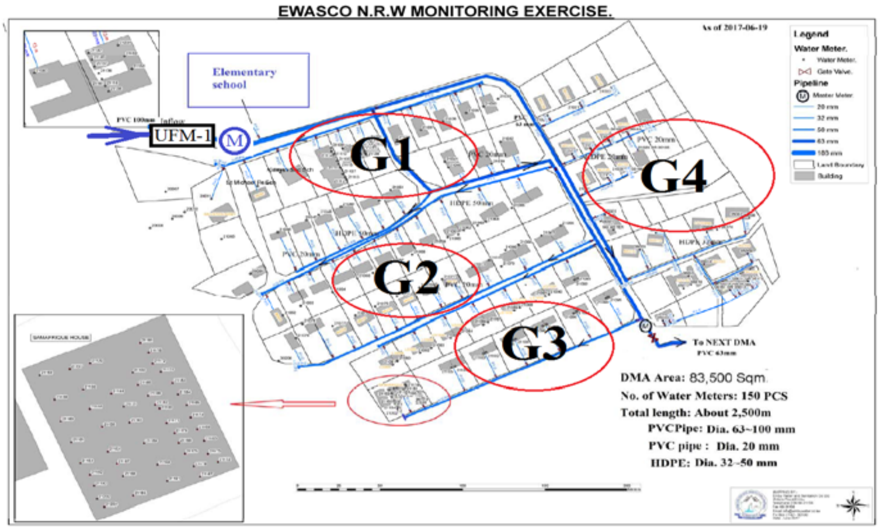
(3) Extended pipe-line: Diameter 63~100 mm (PVC)

Diameter 20 mm (PVC)

Diameter 32~50 mm (HDPRE)

(4) Total length:2,500 m

MAP of DMA

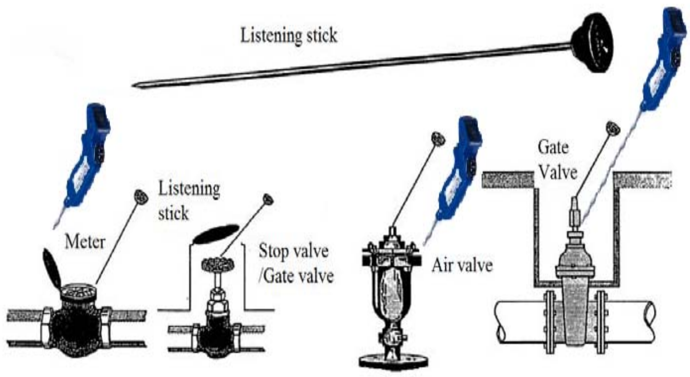


Causes of pipe damage

Quality of pipe material	① Shortage of strength (pipe, joint, valve and etc.) ② Lack of corrosion-resistant ③ Rapid progress of physical aging
Technic of pipe laying	④ Poor pipe jointing ⑤ Poor backfilling ⑥ Touch with the other pipe and the other facilities
Condition of water	⑦ Unsuitable water pressure ⑧ Water hammering ⑨ Corrosion by water quality ⑩ Rapid change of water temperature ⑪ Neglect of leakage
Environment of pipe laying	⑫ Increase of traffic accidents ⑬ Movement of soil around pipe (freezing, upheaval, and etc.) ⑭ Corrodent soil for backfill ⑮ Change of temperature
Other utilities' construction work and disasters	⑯ Damage as the result of construction works ⑰ Damage of the road by earthquake

Outline of OJT

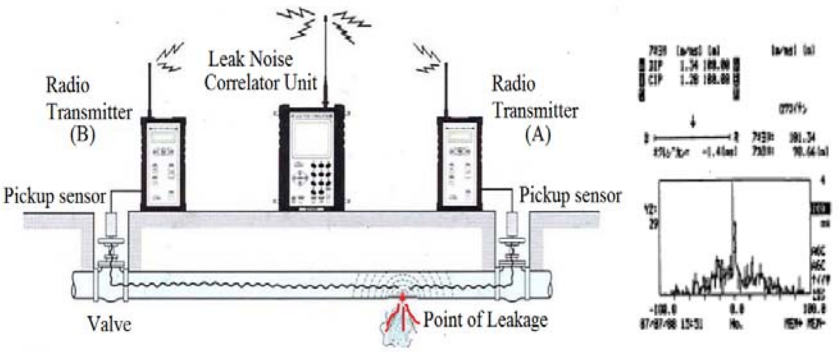
1) **How to detect water leakage detection by leakage sound**



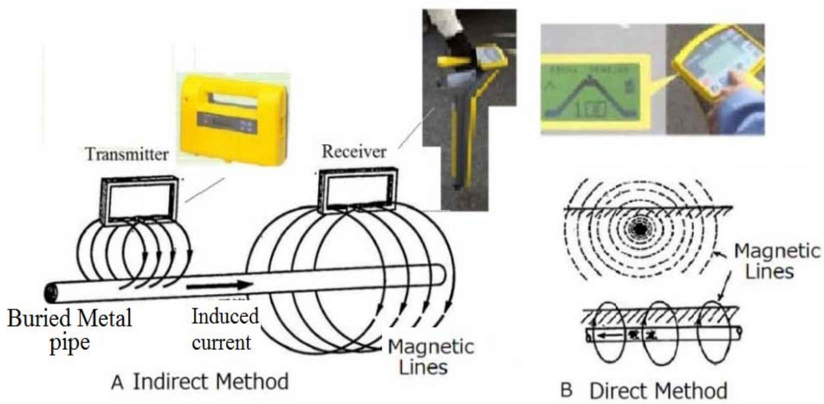
Digital noise leak detector

① Amplifier ······ 1
② Hand-set with Sensor ······ 1
③ Headphones ······ 1
④ Soft Case for Amplifier ······ 1
⑤ Shoulder Belt ······ 1
⑥ Carrying Case ······ 1
⑦ Operation Manual ······ 1
⑧ 3-Section Contact Bar with Sensor Table (Option)

Leak noise correlator



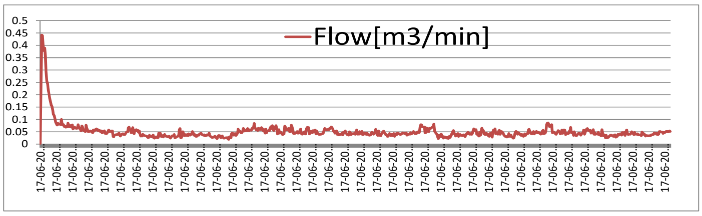
Metallic pipe location



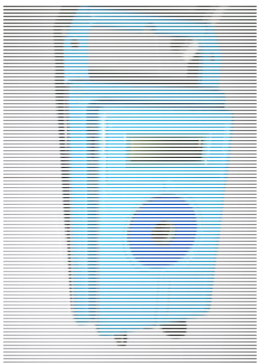
Non metallic pipe location


Measurement of leakage volume

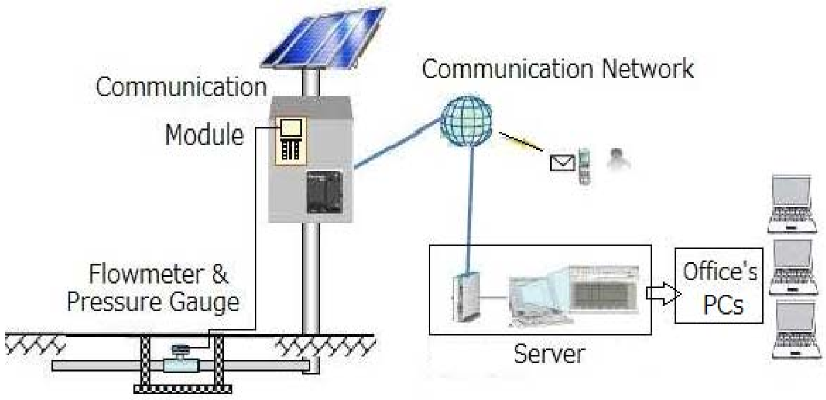

MNF Graph



Measurement of Water pressure gauge



Monitoring system



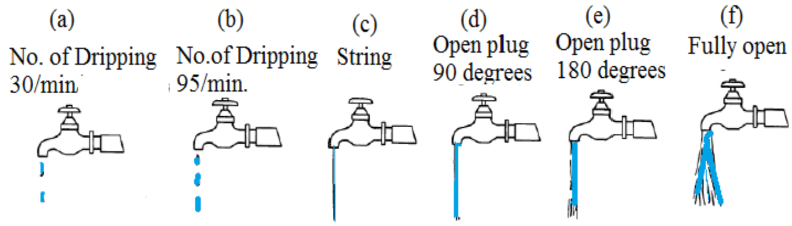
Electronic Portable water Meter

Meter Testing Bench

Water Quality Tests

Measurement of Flowing Water from a Water tap

① Water faucet (Dia. 13m/m,5kgf/cm2)



On-the-Job Joint Training

Kindly Lets All meet at Embu on 17th June 2019

KENYA WATER INSTITUTE

CONCEPT OF HEARING ABILITY

#15-2(R-1)

W.MOSETI
JUNE 2019
(KEWI)

Outline of the Presentation

- Definitions
- Objectives of the lesson
- The Structure of the human ear
- Hearing
- Defects of the ear
- Testing listening capability
- Hearing in leak detection
- Conclusion

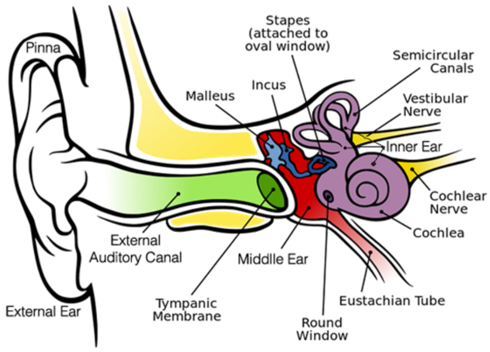
Definitions

- Hearing- the ability to perceive sounds made by someone or something with the ear
- Listening-giving one's attention to sound. It requires focus and attention
- Decibels (dB)- the unit used to measure the intensity of sounds or degree of loudness
- Herzt (HZ)- the unit of frequency of sound waves

Objectives of the lesson

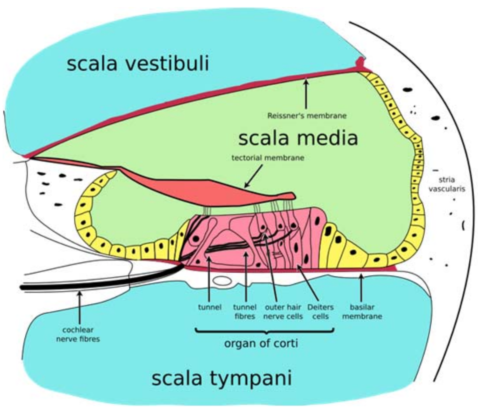
1. To understand the concept of hearing in human beings
2. To relate capability of hearing with leak detection/ surveys

The Structure of the human ear



- Outer ear (pinna and External Auditory canal)
- Middle ear (three ossicles- Malleus, incus and stapes)
- Inner ear (the vestibule, the semicircular canals, and the cochlea)
- Auditory nerve (cochlea nerve)

Cochlea



- Three canals
  - Vestibular
  - Median
  - Tympanic
- Organ of Corti
- Brain (auditory cortex)

Defects of the ear

- **Conductive deafness**
  - Blockage of the external canal with wax
  - Perforated eardrum (infection of middle ear of mechanical injury)
  - Hearing aid can be used to amplify sound waves before they enter into the inner ear

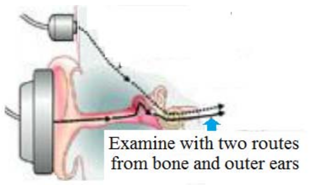
Defects of the ear

- **Perceptive/ sensorineural deafness**
  - Malfunction of the cochlea and auditory nerve
    - Exposure to excess noise > 85 decibels
    - Injury
    - Inherited
    - Explosions/gun shorts
    - Infection
    - Presbycusis (Aging)

Testing listening capability

- **Pure- tone Audiometry or hearing test**

It measures a person's ability to hear different sounds, pitches, or frequencies

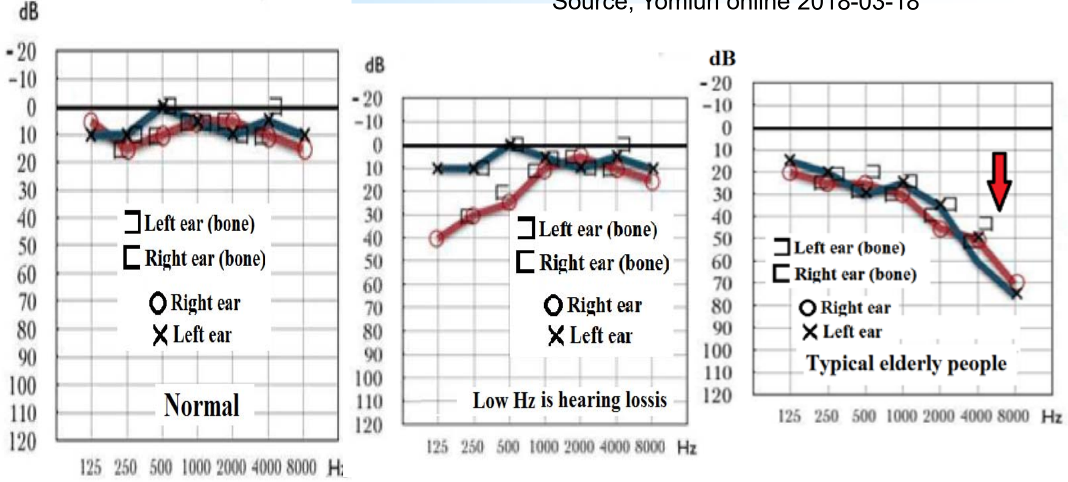


Testing listening capability

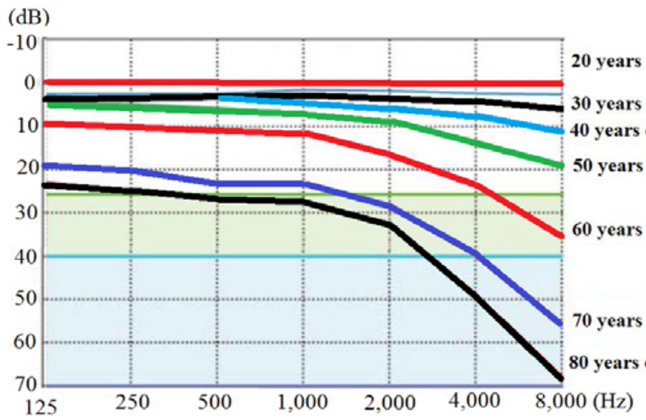
- **Pure-tone audiometry**
  - (a) Inspect the combination sound of Hz and dB produced from an eardrum.
  - (b) Inspect the strength of occurring Hz from the bone of an ear.
  - (c) The relation between Hz and dB is represented in a graph

Typical Patterns (Oscillogram)

Source, Yomiuri online 2018-03-18

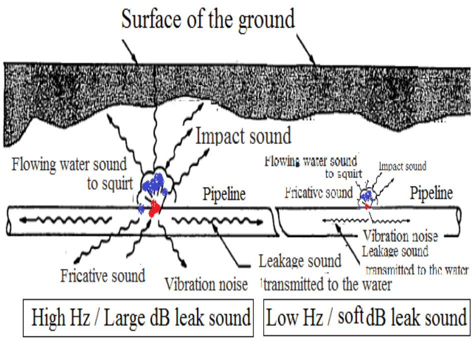


Hearing loss vs age among Japanese



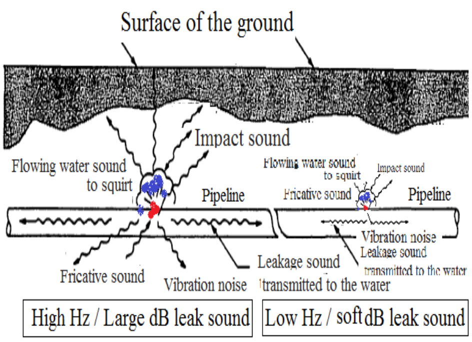
Hearing in leak detection

- Fricative sound - water spurts out of the pipe from a hole
- Impact sound -jetted water collides with the surroundings
- Flowing water sound – water squirts out of the pipe



Hearing in leak detection

- Fricative sound generated by running water flowing out
- Leakage sound transmitted to the water
- Vibration noise of pipes generated by running water flowing out



Hearing in leak detection

Levels of hearing loss	Evaluated dB level (Average)	Descriptions	Ability of sound hearing
Good sensitivity	3～7	Even small leak noise/ flow running sound can be detected. (Experience required)	Optimal
Normal	8～20	Leak noise/flow running sound can be detect (Experience required)	Suitable
Mild hearing loss	25～39	Even small leak noise/flow running sound can be detected.	Amplified detectors required
Moderate hearing loss	40 or more	Difficult to detect leak noise/ flow running sound	Inappropriate

Where to test

Conclusion

- The equipment to be used for leakage detection needs to be selected according to an investigator's listening capability
- The need to periodically get a hearing test

The End

Thank you for your attention

KENYA WATER INSTITUTE

HOW TO MONITOR NON REVENUE WATER IN RESERVOIRS

#16(DRAFT)

A.KARISA
JUNE 2019
(KEWI)

LEARNING OBJECTIVES

- Understand the general distribution system
- Understand the typical inflow and outflow patterns
- Understand the type of Non-Revenue water caused from distribution reservoirs
- Understand the roles of flow meters and water gauges
- Understand the concept of how to investigate the change in inflow volume hourly
- Understand the concept of how to investigate the change in water level hourly

2

INTRODUCTION

- The non-revenue water (Physical - Real Losses) generated in the water reservoir is mainly caused by:

(a) degradation of the function of the distribution reservoirs

(b) loss of purified water

(c) water pollution caused by invasion of contaminated wastewater from the outside.

INVESTIGATION METHODS OF WATER LEAKAGE

- **Study of structure of distribution reservoirs;**
  - **(a) Inspection of visual and deterioration,**
  - **(b) Watertight survey of the distribution reservoirs,**
- **Study of evaluation of measuring equipment functions and piping installation status,**
- **Implementation of evaluation for monitoring function of water distribution / water level management**
- **Confirmation of current design specifications**

The places where NRW occur

- Main body of structure
- Near the penetration pipe of the wall
- Outflow Piping
- Others (measuring instrument for water distribution

KEY WORDS DEFINITIONS

- **Service/Distribution reservoirs**
  It is a reservoir for temporarily storing purified water in order to properly distribute water according to demand in the water supply area.
- **Water distribution management**
  It is to accurately predict the hourly fluctuation of demand from well-balanced water volume & water level management and to carry out safety, rational and efficient operation management
- **Effective capacity of distribution reservoir**
  It is the capacity between HWL and LW.L of the distribution reservoirs.
  (Usually 6 to 12 hours of maximum daily consumption)
- **Planned maximum daily consumption**
  It is the maximum amount of water supply per day.　（Service population × Max. supply per day per head ×Safety factor）
- **planned maximum hourly consumption**
  It is the maximum water consumption during the year's hourly consumption.（It is 1.5 to 2.0 times the average daily consumption）
- **Hourly-variation graph of daily water distribution**
  Predict water distribution change per hour by comparing the balance of "Inflowing" and "Outflowing"in a bar chart.
- **Hourly-variation curve graph of daily water level.**
  To predict water distribution change per hour, the "difference (water level)" between the Inflowing amount and the Out flowing is represented by a curve graph.
  (Predicts the risk time zone of Overflow and Air mixed water supply)

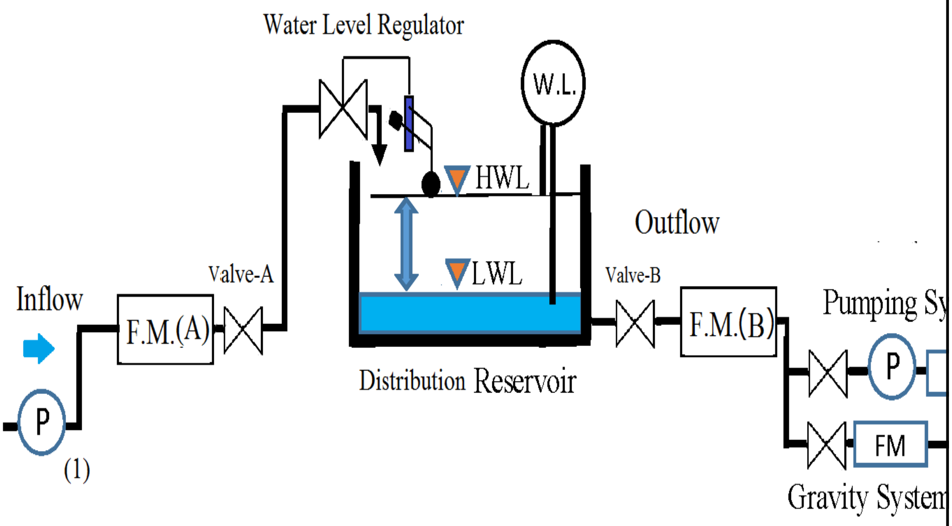
WHAT IS THE FUNCTION OF THE DISTRIBUTION RESERVOIRS？

- The function of the water supply reservoir provides stable water supply service even in the increasing water supply demand time during the daytime.
- In particular, it has the ability to store the amount of consumption required during the daytime during the night when the water consumption is low.
- Also, there is no loss of purified water, the structure of the reservoir is not polluted by sewage or groundwater invasion and normal maintenance is required.

What is Water Distribution Management?

- Distribution management is to maintain the balance of the day's balance according to changes in demand.
- The simple management method is to measure "the difference in water level" between Inflow (A) and Outflow (B) over a period of 24 hours every hour.
- In other words, proper water distribution management, timely the "simulation graph" is created / analyzed from the measurement data of the current water level change, so that the water level of the water distribution reservoir will not become zero and not Out flowing while predicting the demand trend by hourly. As a result, it is possible to reduce non-revenue water by Overflow etc.

CONCEPT OF FLOW METER AND WATER LEVEL MEASUREMENT IN WATER DISTRIBUTION MANAGEMENT



OUTLINE OF DISTRIBUTION FACILITIES

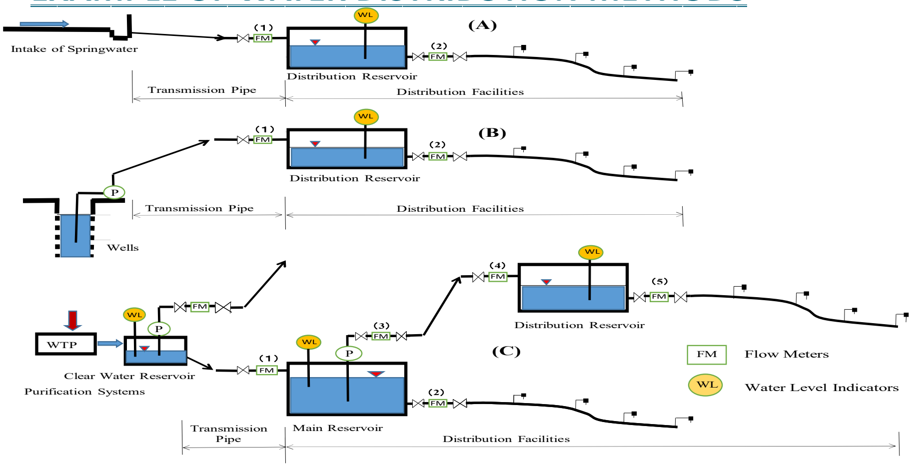
- **Types of Distribution Methods**
  - There are two types of water distribution system, gravity type and pump pressure type.
- **Patterns of Inflowing and Out flowing**
  - In general, the water distributed from the water purification plant is constantly Inflowing into the distribution reservoirs, but the Out flowing as consumption from the distribution reservoir fluctuates irregularly in the state of use of consumption in the water supply area.
- **Patterns of Inflowing**
  - Purified water is usually distributed to a water distribution pond at a constant quantity for 24 hours.
  - A certain WSP operates the water purification plant only during the daytime and does not operate the Outflowing valve at night, so the Out flowing stops or the Out flowing decreases / becomes zero.

10

PATTERNS OF OUT FLOWING

- Demand for annual water supply volume fluctuates with time due to the following factors.
- Change in scale / area of water distribution system
- Change in application of water supply area
- Changes in water distribution by weekday / holiday
- Change in temperature / season / relationship between weather and water distribution
- Status of change of replacement / expansion work of piping

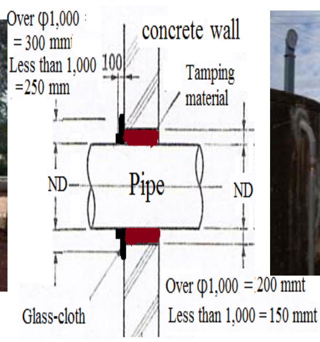
EXAMPLE OF WATER DISTRIBUTION METHODS



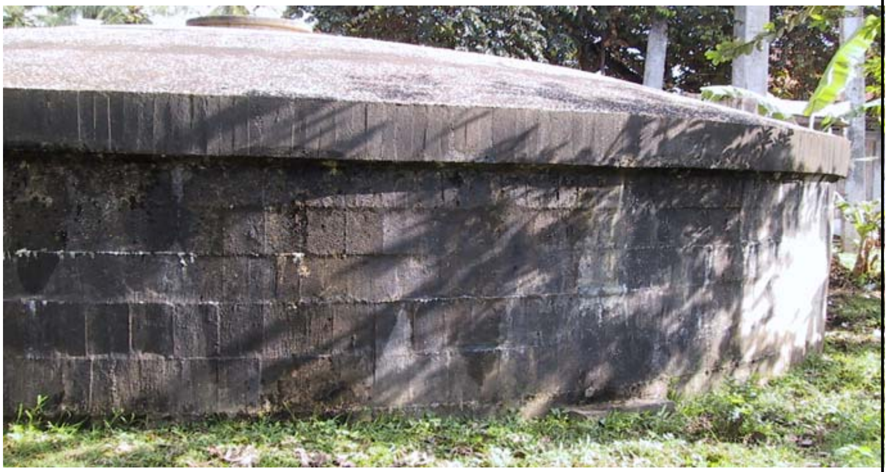
TYPES OF DISTRIBUTION RESERVOIRS

- There are ground type, semi-underground type, and underground type in large-capacity distribution reservoirs.
- In addition, the elevated tank is used as a small scale distribution tank

TYPES OF DISTRIBUTION RESERVOIRS



EXAMPLE OF A CONCRETE-TYPE DISTRIBUTION RESERVOIRS



EXAMPLE OF A CONCRETE-TYPE DISTRIBUTION RESERVOIRS

CONCEPT OF DESIGN CRITERIA

➢Necessity for a Review

The formulas of design criteria for evaluating the current water distribution function due to changes in the distribution environment are :

- ❑ Changes in water demand
- ❖ Generation of non-revenue water
- ❖ Appropriate effective capacity (increase of fire extinguishing water quantity)

CALCULATION FORMULAS OF DESIGN CRITERIA

- ❖ **Calculation of planned water distribution**

(1) Formulas :

①Design daily maximum supply per head :q (l/capita/d)……………….(1)

(a)Assumptions; This amount of water supply (water supply volume) is the demand amount (m^3 / d) assuming that all customers in the planned distribution area use water concurrently during that time zone.

(b) Application :

This formula serves as the basis for calculating the basic water volume for the planned maximum daily consumption.

Design cont'

② Planned maximum daily consumption: Qd (m^3/d) ……………….(2)
$= q \times P \times (1+Lf)$
(a) Assumptions;

q (l/head/d)= daily maximum supply per head
- P (head) ＝Design population served
- Lf = Loss amount due to non-revenue water

(b) Application :

This formula serves as the basis for calculating the basic water volume for waterworks' scale determination

Design cont'

③Planned maximum hourly consumption Qhmax (m^3/h)……………….(3)

$= Q / 24(h)$

(a) Application :

This formula serves as the basis for calculating the basic water volume for determining the equipment specifications

Design cont'

- ***⑤Planned maximum hourly consumption in normal condition : Qn h max (m^3/h)……………….(5)***
- ＝Qn h max× K

  (a) Assumptions;

・K-value: Maximum hourly-variation factor

＝(Qh max(m^3/h) ÷ Average hourly consumption (Q h av: m^3/h)

(b) Application：

This formula serves as the basis for calculating the basic water volume of the water distribution facility plan / fiscal plan

Design cont'

④Planned daily average consumption: Qd av(m^3/d) ……………….(4)

＝ **Qd av**× (70~80%)

(a) Application：

This formula serves as a basis for calculating the basic water volume of the water supply finance plan, including the calculation of chemicals / electricity consumption / maintenance and maintenance cost / water fee etc.

Design cont'

⑥Planned maximum hourly consumption in firefighting:Qp(m³/h)………(6)

＝Qnh max＋Qf

(a) Assumptions;

・Qf (m^3/h) =Amount of fire-fighting water

(b) Application：

This formula serves as the basis for calculating the reference water volume for the scale determination of the water distribution network.

CONCEPT OF FIRE DEMAND

- **NOTE-5Example of prediction of Fire Demands**

①Comprehensively judge from regional population, hearing rate, housestructure (Example for 5000 area………………1.0 m^3/min for 1.0 hour (Japan)

② Judge from population number …..Refer to **Table-1** (Japan)

③ **Refer to KENYA STD**

(Details : Practice Manual for Water Supply Services、Dec. 2005)

In urban /rural centers, Capacity for firefighting should not be less than **10 liter/sec during 2 hours** (0.6 m^3/min for 2 hours).

Design cont'

- **Calculation of capacity of circular water distribution reservoir:** V(m^3)

  (1) Formulas:

  ⑧Capacity of circular water distribution reservoir: V(m^3)……….(8)

＝(A × H)÷N

(a)Assumptions;

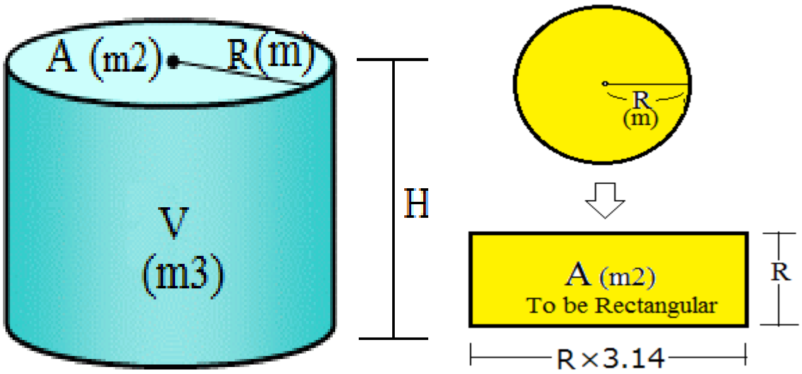
・Effective water depth: H (m)

・Number of reservoir: N (set)

・Cross sectional area: A (m 2) = R (radius) × R (radius) × 3.14
= R 2 × 3.14 or = V ÷ H

・Diameter: D(m) =2（√A/3.14）＝2R= R+R

Dimension Chart of Cylinder



FLOW METERS/WATER LEVEL GAUGES USED IN THE SURVEY

- Basic data necessary for understanding water distribution management, fluctuation in both the Inflow capacity and the water level will utilize the existing measurement equipment

Flow meters

The cumulative flow rate measurement of the both Inflow into reservoir and Outflow as consumption is recorded with a following flow meters

FLOW METERS

1Points to Keep in Mind during Selection

- Points to be noted when choosing the type of flow meters are shown below.

(a) Flow metering can cover flow range of design value.
(b) Accumulated flow rate is displayed.
(c) The instantaneous flow rate is displayed.
(d) Accumulated flow rate and instantaneous flow rate data are saved.
(e) Head loss is low
(f) New flow meters and passed the performance test
Test pressure (1.5 times) / Test duration (1 ~ 2 min.)
· Visual examination
· Operation inspection: meter operation, water hammer, water leakage
· Accuracy test: ISO 4064 / MID 2004/22 / EC
· Manufacturer's reputation is good

Types of Flow meters

- **Types of Flow meters**
- The accuracy of the flow meter causes measurement errors due to the properties of the liquid, the material of the pipe, the amount of water in the pipe, installation conditions.
- Select the optimum model by paying attention to the following items.
-
- ① Pipeline status
- (a) Condition of water flow (Is the pipeline completely full?)
- (b)"Securing the straight pipe part necessary for the flow meter" on the upstream side and downstream side of the measurement part?

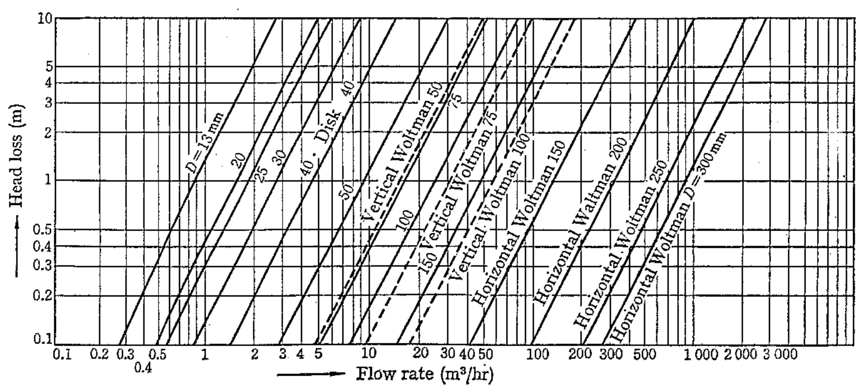
Flow meters cont'

- (c) Confirmation of aging situation of pipeline. (Influence of measuring accuracy due to corrosion inside and outside)
- ② Model · Selection of caliber:
- (a) For selection, check design conditions such as measurement range and measurement accuracy.
- ③Cost Comparison:
- (a)Consider the total cost including the flowmeter and related equipment price, installation cost, maintenance cost etc.
- ④Selection of standard products:
- (a)Select a product that is certified for performance and that passes the test. And regularly verify performance every year.
- ⑤Generation of pressure loss:
- (a)Select pressure type loss caused by inserting the flowmeter, which is acceptable type.
- ⑥ Installation location
- (a)Choose an installation location that is easy to inspect, dry and difficult to mix with sewage and has no risk of damage.

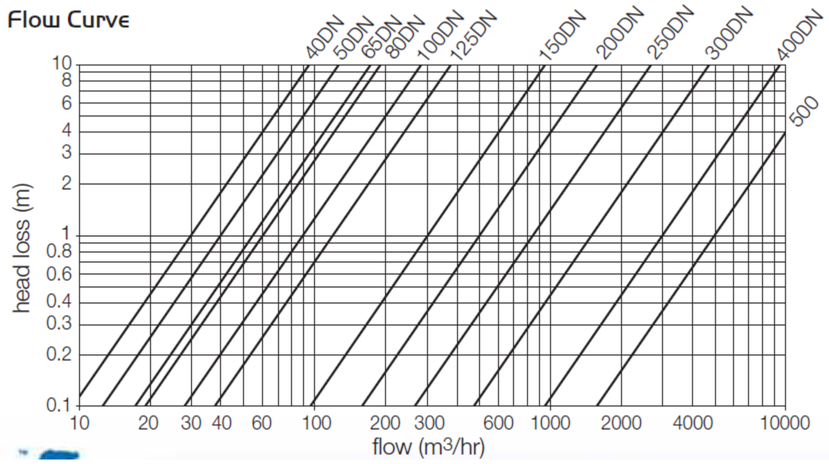
Head Loss

- In particular, the head loss of the mechanical flow meter generally increases with increasing flow rate.
- As the head loss increases, the accuracy of the measurement range of the small flow rate decreasesparticularly.

Head loss in small water meters



Head loss in large water meters



Hydraulic design calculations

- **Terminologies**
- ①**Q (m³/sec)** is the **Volumetric Flow Rate** passing through the pipe or channel.
- ②**A(m²)** is the **Cross-sectional Area** of flow normal to the flow direction.
- ③**f (m)** is the**Friction Head Loss** in which is loss of pressure or "head" that occurs in pipe or duct flow due to the effect of the fluid's viscosity near the surface of the pipe or duct.
- ④**S** is the bottom slop of pipe or channel called the **Hydraulic Gradient**.
- ⑤**n (-)** is a dimensional empirical constant called the **Manning Roughness Coefficient.**
- ⑥ **C (-)** is the Discharge Coefficient of the ratio of the actual discharge to the theoretical discharge,
- Call **Hazen-Williams Coefficient**.

Hydraulic design terminologies

⑦**P (m)** is the Wetted Perimeter of the cross-sectional area of flow.

⑧ **R (m)** is the **Hydraulic Radius (= A/P)** in which is the area of the water prism in a pipe or channel divided by the wetted perimeter.

Formulas and /or Graphs used for hydration calculations

11.4.1Use of Empirical Formulae and Equations

- In water supply the following three equations are used most commonly.

(a) Weston formula (Applied to ϕ50mm or less)

(b) Hazen-Williams' formula (Applied to ϕ75 mm or more)

(c) Manning's formula (Applied to open channel flow only)

11.4.2 Use of Graphs of Flow (l/sec) vs Hydraulic gradient (‰)

The easiest method to check on whether flow rate is available or not is to make use of the Frictional Head Losses Graphs in which show the specific flow (l/sec)vs and amount of frictional head losses per unit length of pipe" Hydraulic gradient (‰)" at each pipe dimension.

END

KENYA WATER INSTITUTE

WORK ETHICS AND COMPLIANCE FOR WSPs STAFF

#17(DRAFT)

Eng.H.Karugendo
JUNE 2019
(EWASCO)

WORK ETHICS AND REDUCTION OF NRW: DEFINATION

WORK ETHICS: Could variously be defined as follows:

- A set of moral principles a person uses in their work
- A societal believe that hard work and diligence have a moral benefit and inherent ability /virtue to strengthen character and individual ability
- A set of values centered on importance of work and manifested by determination or desire to work hard

WORK ETHICS AND NRW: DEFINATION

Factors that demonstrate strong work ethics include:

- Integrity
- Absence of corruption
- Professionalisms; emphasis on quality and timeliness
- Discipline which enhances a sense of commitment, respect, flexibility, humility, creativity, team work, cooperation etc.

WORK ETHICS AND NRW: DEFINATION

FURTHER DEFINATIONS:

- ***Integrity;*** a word derived from a Latin word; integer-meaning whole or complete. It's a state of being honest, having strong moral principle, fairness and doing the right things.
- ***Corruption;*** abuse of entrusted power for private gain, illegal, dishonest behaviour by people in power. In accordance to Kenyan law: corruption means any action by a public officer that leads to offences of bribery, fraud, embezzlement or breach of trust in use of public resources

WORK ETHICS AND NRW: ETHICAL *CULTURE*

BUILDING AN ETHICAL CULTURE

To build a strong work ethics parties involved; the Employer and the Employee need to be committed and each to act their part:

- ***Employer:*** Top management need to walk the talk of ethics. It must create a culture that supports ethical behavior and rewards effort. Management must respond to improper behavior through sanctions that are consistently applied.
- ***Employee:*** employees should be dedicated and committed to their employers goals. They should do their assigned duties in a professional and timely manner

A strong work ethic creates an environment of dependability and accountability between the parties

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WORK ETHICS AND NRW: ETHICs & NRW

THE EMPLOYERS ROLE S Include:

- Contract well trained, skilled and ethical top managers
- Create an ethical working environment
- Recruit /train staff on reduction of NRW skills
- Provide material resources towards reduction of NRW
- Reward performance and punish indiscipline
- Enhance cordial and friendly relationship with the customer thro education

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WORK ETHICS AND NRW: ETHICS & NRW

Role Of The Employee Includes:-

- Managers to create ethical work environment, monitor, evaluate and enforce policy. To reward performance and sanction indiscipline. Ensure harmonious employer/customer relationship
- Supervisors to superintend and enforce implementation of assignments within agreed timelines. To support management in matters of rewarding, sanctioning and customer relationship.
- Lower cadre to perform their assignments with integrity, diligence, respect and portray a positive image to customer.
- customer feedback on tariff and water supply nework intergrity.

WORK ETHICS AND NRW: ETHICs & NRW

Role of Customer / Client includes:-

- Support the Employer by maintaining integrity
- Pay for services on time
- Provide a feedback on the quality of services.
- Report malfeasance by neighbors or employees.
- Report incidences like bursts

WORK ETHICS AND NRW: ETHICs & NRW

Malfeasance and NRW

NRW Is in a big way related to poor work ethics as amplified in matters centered on integrity as follows:

- Physical water losses
  - Water lost due to delayed attendance to bursts
  - Water lost due to non-reporting by customers
  - Water lost due to employees negligence of their duties: no patrols, poor workmanship etc
  - Water lost as a result of use of poor materials: poor specifications /poor controls/fraud
  - Etc.

WORK ETHICS AND NRW: ETHICs & NRW

Malfeasance and NRW continued

- Illegal Connections
  - Perpetrated by staff in collusion with customers
  - Perpetrated by customer but remain undetected through negligence of duty by staff or / customer
  - Deliberate tapering with water meters: customers alone or in collusion with employees
  - Etc.
- Systems and Billing Fraud
  - Distorted meter readings: gates locked, meters buried etc
  - Wrong billing data entries: deliberate or carelessness
  - Hacking into systems data base and manipulation of data therein

WORK ETHICS AND NRW: ETHICs & NRW

CONCLUDING REMARKS

Strong Work Ethics is a major contributor to reduction of NRW water, for where work ethics are poor, integrity and commitment to duty are a challenge and the two combined lead to large NRW.

ASANTENI SANA (THANK YOU)

EK1

スライド 12

EK1 Eng Karugendo, 2017/10/27

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AWARENESS OF WASREB NON REVENUE WATER STANDARDS

#18(R-1)

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JUNE 2019
(WASREB)

Wait a minute

- Do you know of the existence of NRW management standards published by WASREB in 2014?
- Does your WSP use these standards?
- Which of the four standards do you find relevant in your day to day work?
- Are you aware of the WASREB Impact reports?
- Are you aware of your WSP's NRW rating in the latest WASREB impact report?
- Do you think your WSP's NRW rating in the WASREB impact report is realistic?

Presentation Outline

- ❑ NRW definition
- ❑ NRW components
- ❑ National trend in NRW
- ❑ NRW challenge indictment
- ❑ NRW diagnostic approach - critical questions
- ❑ NRW standards development
- ❑ NRW standards Key Issues
- ❑ Regulatory actions to manage NRW through NRW standards

Non Revenue Water

❑ Definition

NRW = SYSTEM INPUT VOLUME - BILLED AUTHORISED CONSUMPTION

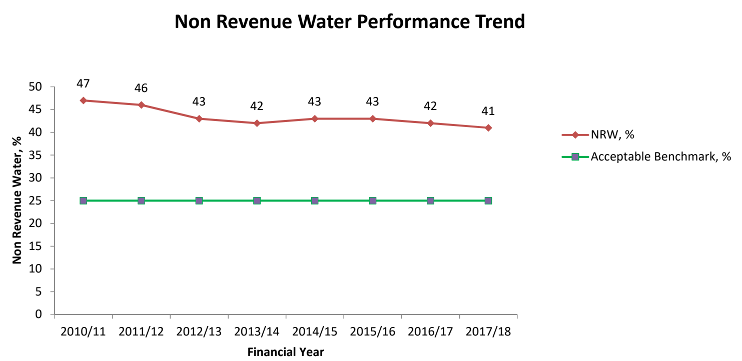
(The difference between the amount of water put into the distribution system and the amount of water billed as authorized consumption)

NRW Components

IWA Water Balance Table

System input Volume (corrected for known errors)	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Unmetered Consumption (e.g. flat rates not billed)	Non-Revenue Water
	Water Losses	Commercial (apparent) Losses	Estimations and Data Handing Errors	
			Customer Metering Inaccuracies	
			Unauthorized Consumption (e.g. Illegal connections)	
		Physical (Real) Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and overflows at Utility Storage Tanks	
			Leakage on Service Connections up to point of Customer Use	

National Trend in NRW



Turnover – Kshs 19.7 Billion
Sector Benchmark - 20%
Monetary NRW after allowing benchmark > Kshs 7 Billion

NRW Challenge Indictment

- High NRW levels indicate poor management in form of either;

- Poor governance practices - Integrity, illegal connections, outright theft, omission/commission…
- Poor commercial practices - management, estimations, metering inaccuracies, adjustments,…
- Poor infrastructure/maintenance - System inputs/production meters, pipelines(rehabilitation, renewal, quality, workmanship…)

NRW Diagnostic Approach
Critical Questions

Basic Logical Flow:

1. How much water is being lost?
2. Where is it being lost from?
3. Why is it being lost?
4. What strategies can be introduced/intensified to reduce losses and improve performance?
5. How can we maintain the strategy and sustain the achievements gained?

NRW Standards Development

- ❖ Need for an elaborate mechanism to systematically guide proper management of NRW reduction hence the NRW mgt standards.
- ❖ NRW mgt standards comprises of; Manual, guideline, handbook and case studies. Made via a stakeholder engagement process over 4yrs (2010 – 2014) with pilot WSPs (Meru, Embu, Narok and Kapsabet Nandi)
- ❖ Manual, handbook and case studies for use by WSPs and Guideline by WSB
- ✓ Manual - WSP - Guides understanding of NRW components and how to deal with them, NRW reduction plan development and implementation modalities
- ✓ Handbook - simplified NRW reduction manual with illustrations/photos for use by technicians and field personnel
- ✓ Case studies - actual work carried out in the pilot WSPs (Meru, Embu and Narok) developing and implementing reduction plans where interventions identified are prioritized
- ✓ Guideline - WSB - assess & evaluate WSPs and give direction to WSPs in NRW reduction activities' implementation (previous legal framework)

NRW Standards Development – cont'd

- ❖ WSP makes custom made (contextual) NRW reduction plan as guided in the standards framework hence best suited to reduce NRW effectively
- ❖ NRW mgt standards developed to provide practical approaches to reducing NRW in Kenya (contextualized) despite many other international standards existing
- ❖ NRW mgt standards not yet effectively utilized to lead to significant reduction of NRW
- ❖ CoK - right to water - Obligation on state agencies….WSPs at primary level

NRW Standards Key Issues (framework)

No	NRW Standards - Five Key Issues /Areas	Sub Issues/Areas
1	Water Balance, Flow and Pressure Monitoring, Mapping	Water Balance, System Input Metering, Pressure Monitoring, Maps/GIS
2	Leak Repair Records	Leak Repair Records (Turn Around Time, materials, methods, …)
3	Performance Indicators	Performance Indicators
4	Active leakage control	Active leakage control, District Meter Areas (DMAs), Leak Repair - Distribution Pipes(Repair Time), Leak Repair - House Connections
5	Customer Metering	Customer Metering, Customer Meter Replacement and Age, Customer Meter Class, Customer Database, Customer Meter Reading, Illegal Connections, meter tampering, bypasses

Regulatory Actions to Manage NRW through NRW Standards

- Enforcing implementation of the NRW standards/guideline (establishing strategic NRW management function in organogram, NRW reduction planning, quarterly reports submissions for review…..)
- Setting targets on reduction of NRW under Minimum Service Levels commitments (Licence and RTA conditions)
- Provision of resources in the Tariff for effective NRW management (capacity building, specific NRW reduction investments, Performance Based Contracts, …)
- Reporting to the public on progress in NRW management struggle (stakeholder engagement for support and accountability…)

Thanking you for
your attention

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UNDERSTANDING OF REHABILITATION PLAN OF NETWORKS

#20(R-1)

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JUNE 2019
(KEWI)

1. Objectives

① Understand the concept of rehabilitation plan of piping network,

② Understand the components on it,

③ Understand corrosion mechanisms to metallic pipe materials,

④ Understand the Non Metallic pipe production, classification and jointing methods.

2. Introduction

- In order to implement NRW reduction effectively, it is important to formulate and implement a renewal plan.
- In addition, the PDCA cycle of formulation/evaluation of the improvement plan of NRW reduction

Basic knowledge required for NRW reduction planning

① What is the management ledgers to be arranged?

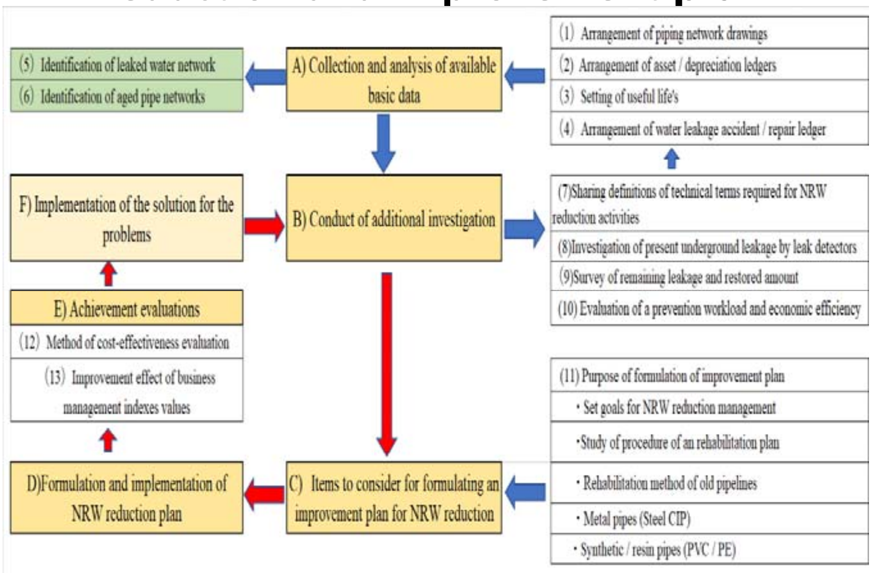
② What is the implementation of additional investigations?

③What is the improvement methods of leaking pipeline?

③ What is the cost-effectiveness evaluation?

④ What is the evaluation of management indexes?

PDCA cycle to formulate effective NRW reduction and improvement plan



4. Collection and Analysis of Available Basic Data

4-1 Necessity for Arrangement of Piping Network Map

Step-1 (Transfer the current drawing information to one topographic map)

Step-2 (Creation of Mapping on PC)

Step-3 (Creation of GIS on PC)

Cont

4-2 Arrangement of Fixed Asset Ledger

4-2-1 What is an asset?

Assets are classified into fixed assets (for example land, buildings, machines, facilities, facility usage rights, patent rights), current assets (for example, cash, savings, commodities, raw materials) and carry forward accounts (for example, bonds, expenses recovered by future earnings).

Cont

4-2-2 What is a Fixed Assets Ledger?

In order to early predict the durability / aging of the piping network required to formulate the NRW reduction plan, each WSP needs to quickly create a ledger for the tangible fixed assets of the distribution facilities subject to depreciation according to the useful life.

Cont

4-2-3 Legal basis of depreciation and lifetime classifications

For Kenyan regulations

(a) International Financial Reporting Standards (IFRS)

Examples:- (Sewer & water system : 2.5%, Motor vehicle : 25%, Furniture, fittings & equipment : 12.5%, Computer equipment : 30%, Tools; 33.3%, Office equipment; 13%. Generator;25%

(b) Kenya Revenue Authority (KRA)

Guide on Wear & Tear detection (Depreciation 2019)

Examples:- (*Class A*--37.50% : Heavy Machine (2.67 years), *Class-B*—30% : Computers & related accession as (3.33 years) , *Class-C*—25% :Saloon cars (Not heavy) :4 years, Class—D—12.5%: Furniture (8 years), Industrial Building: 2.5 % (40 years)

4-2-4 Purpose of creating fixed asset ledger

(1) Asset management purpose (determination of the lifetime of existing facilities)

(2) Accounting purpose

（3）Tax purposes

NOTE :Points to remember

① Once you have decided on the asset register creation rules, start asset management immediately.

② When updating the ledger, it is necessary to consider the description method so that the process can be checked retrospectively.

4-2-5 Entry example of tangible purchased fixed assets

① Project name and execution number,
② Acquisition method,
③ Year of acquisition / asset registration date,
④ Tangible fixed asset registration number when applicable , e.g. serial number, registration number,
⑤ Purchase price or appraisal price / revaluation price,
⑥ Name, details, and quantity of a tangible fixed asset,
⑦ Asset location,（Installation place and storage place）
⑧ Description of legal service life by facility,
⑨ Clarification of calculation method of depreciation,
⑩ Registration number of design document and drawing,
⑪ Asset Management Department Name,
⑫ Other matters to be helpful,

4-2-6 Retention period of a fixed asset ledger

(1) Comply with statutory standards

- Tax retention periods such as invoices conform to legal requirements.

(2) When there is no legal standard

- For example, in Japan, it is seven years and two months of the end of the year.

4-2-7 Introduction of the format example of the asset ledger

(1) Fixed asset format

(2) How to create a simple fixed asset ledger

Example of Annual Report on water leak repaired

Types of leaked water generated

（1）Preventable leakage

It is the amount of water leakage that can be prevented by the survey technology.

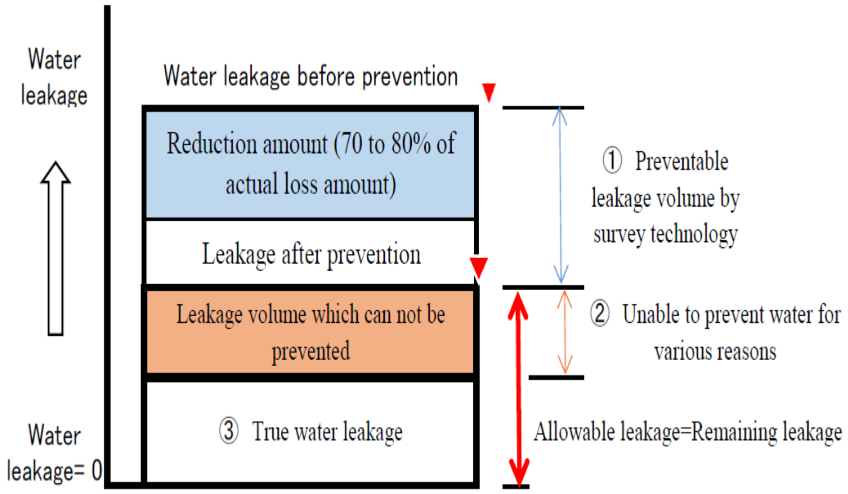
（2）Unpreventable water quantity (Permissible water leakage quantity)

for example, the NRW reduction rate determines the target allowable leakage rate considering cost effectiveness

(3) True leakage:

It is the amount of leakage that cannot be prevented even if any leakage prevention measures are taken

Concept of total water leakage



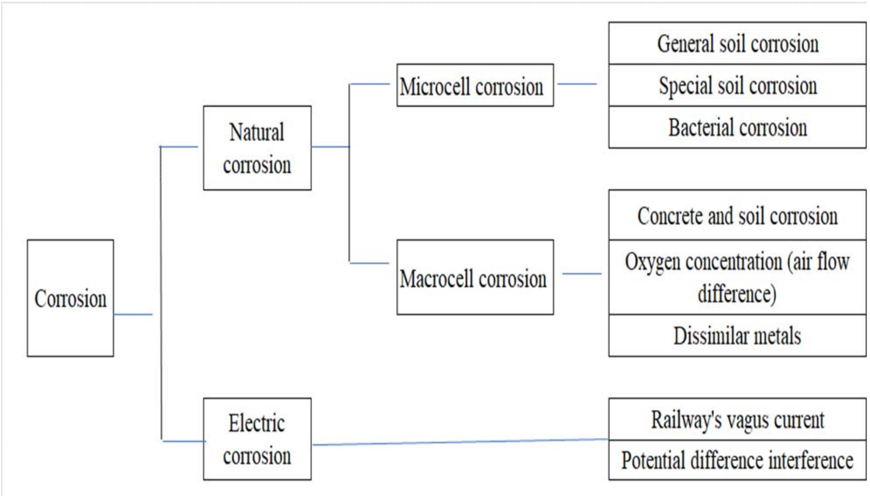
Characteristics of surface leakage and Underground leakage

(1) Utilization of leak detection technology
(2) Water quality test
(3) Scale of damage caused by lost water

Improvement method of pipeline

（1） Update (replacement to new pipe)
（2）Rehabilitation (reinforcement of old pipe)
（3）Partial repair / partial replacement
（4）Change of piping route

Classification of Corrosion Occurring in Buried Pipe



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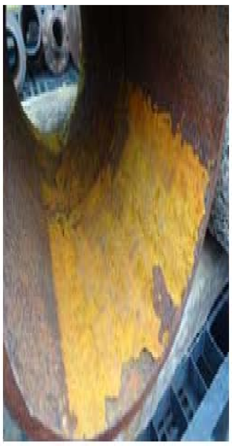

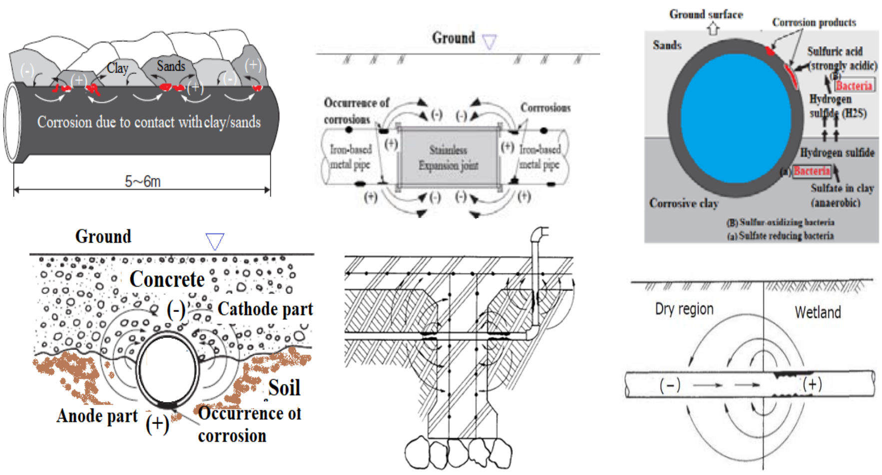

Relationship between pH Value of Soil and Levels of Corrosion of Iron

pH value		Degree of corrosion
4.5 or less	Acidity	Very corrosive
4.5 to 6.5	Mild acidity	Corrosive
6.5 to 8.5	Neutral or slightly alkaline	Non-corrosive
8.5 or more	Alkalinity	Unknown

Unplasticized polyvinyl chloride pipes (uPVC) Pipe Manufacturing


NOTE:

The fire adhesion method frequently **leaks** water due to the rise of water pressure, insufficient strength of the structural adhesion surface, insufficient adhesion time, etc., and is **not suitable for the repair method**.

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WORK FLOW APPROACH TO NRW

#21(R-3)

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JUNE 2019
(JICA)

Perspectives of Output 4 (Pilot WSPs) on which the Work Flow Approach proposed at the beginning of Phase 2 is based.

- Sustainable application of knowledge & technical skills in a real work environment of WSP (i.e. NRW Management)
- Starting with easy & highly effective activities (e.g. checking customer meter accuracy with portable tools such as calibrated buckets)
- Trying to avoid components which will or may cause a significant delay of NRW reduction activities (e.g. a large facility investment)
- Importance of work flow management for NRW reduction (e.g. use of Open Data Kit (ODK))

2

Restructure of the TA Plan (trials) for Phase 2

based on the Work Flow Approach

Trials of the Previous TA Plan used in Phase 1 & their Corresponding Activity Groups of this Approach (Example of Embu WSP)

Six Aspects and Trial Menu of the Technical Assistance		Intensity of Support	Grouping of the Trials for Easy Implementation
1. Planning and Implementation of NRW reduction (yearly cycle based on a mid-term vision)	a) Participatory planning using sample templates and Google Drive	●	Planning (P)+DCA Cycle
	b) Plan-do-check-adjust (PDCA) Cycle	●	
	c) Introduction of HDPE pipe and elimination of asbestos pipe, etc.	●	3rd Priority Activities (mainly related to pipelines and GIS improvement)
	d) Setting priority activities to be completed without failure as commitment targets	●	Planning (P)+DCA Cycle
	e) Inclusion of NRW-related training	●	
2. GIS Preparation and Applications	a) Open source utilization for fast GIS development and wider access/applications of GIS (including participatory mapping)	●	PDCA / 1st / 2nd / 3rd
	b) Linking GIS with customer/billing data for special analysis on meter problems and illegal connections	●	1st Priority Activities (mainly related to customer meters)
	c) Use of GIS for assessing pipe conditions including mapping of leaks, bursts and aged pipes	●	3rd Priority Activities
3. Zoning and NRW Monitoring (monthly and weekly NRW management cycles)	a) Planning of strategic zoning to monitor NRW ratio of different areas and control pressure based on hydraulic analysis and field measurements	●	2nd Priority Activities (mainly related to bulk meters)
	b) Confirmation of the isolation and inflow metering of each area and the consistency of the customers in each area between GIS and billing system	●	
	c) Establishment of easy and sustainable monitoring of NRW ratio, water balance (MNF), and abnormal flow using billing system, loggers, etc.	●	
	d) Periodical analysis and discussions to prioritize areas for different activities	●	PDCA / 1st / 2nd / 3rd
4. Leakage Management	a) Spread of the daily use of listening sticks over many field staff against leakage	●	1st Priority Activities
	b) Implementation of strategic track down of under ground leakage	●	3rd Priority Activities
	c) Measurement and optimization of pressure distribution (other than zoning)	●	
	d) Reduction of spaghetti service connections	-	
	e) Pressure tests with hand pump for checking installation quality of service connections	-	
5. Customer Meter Management	a) Achieving 100% in metering ratio	-	
	b) Preparation and implementation of meter replacement/relocation strategies	-	
	c) Focused management of large consumption customers with high accuracy meter, smart meter or additional meter.	●	1st Priority Activities
6. Illegal Use Management	a) Active patrol for finding illegal water use	●	1st Priority Activities / 3rd Priority Activities
	b) Inclusion of a penalizing mechanism against water theft in the county's water act	●	
	c) Enhancement of law enforcement against water theft with support from the county	●	

NOTE: ●: Trial agreed to carry out through discussion between each pilot WSP and JICA experts (●: The trial which the JICA experts think would especially attract attention at each WSP).

Expected Intensity of Required Support: High | Medium | Low

The agreed trials have been reorganized into the Four Groups of Activities for Easy Implementation of TA with Clear Steps based on the Proposed Work Flow Approach of NRW Management

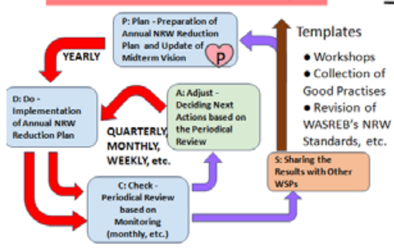
Components of New TA Plan for Phase 2 & 3 (Embu)

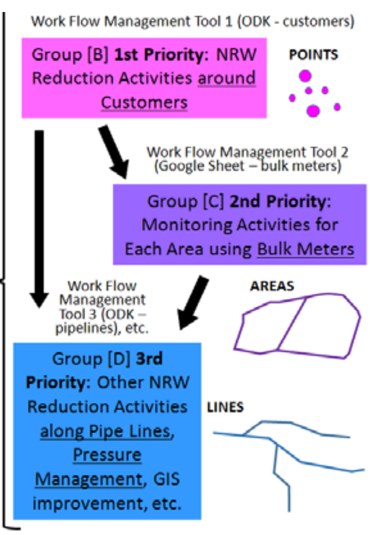
Group of Activities	Steps of TA for Each Group of Activities [Relevant Trials from the Previous TA Plan used in Phase 1]	Potential Outcomes sharable with Other WSPs	Intensity of Support
[A] Planning & Implementation of NRW Reduction (PDCA Cycle including yearly cycle based on a mid-term vision, monthly cycle based on internal performance monitoring, and sharing of experiences with other WSPs)	1) Preparation of annual plan & update of mid-term plan (P: Plan) [related to Trials 1-a to e]	Realistic examples of NRW reduction plans	●
	2) Implementation of the annual plan (D: Do) [Trial 1-b]	Daily submissions of ODK-guided activity results	●
	3) Periodical (e.g. monthly) discussion on the progress (C: Check + A: Adjust) [Trials 1-b & 3-d]	Materials prepared for monthly discussion	●
	4) Review of the annual plan and reporting (C: Check) [Trial 1-b]	Annual review/report	●
	5) Sharing of the experiences with other WSPs (S: Share) [Trial 1-b]	Selected materials used for the activities & PPTs	●
[B] 1st Priority: Customer-related Activities such as checking meter accuracy, leakage, illegal connection, faulty fittings, etc. around customer meters. (mainly against commercial losses, with a least-required GIS data set for searching targets and a single ODK form)	1) Preparation of a ODK form for checking meter accuracy, leakage with listening stick, illegal connection, etc. and recoding repairs [Trials 1-c, 2-a, 4-a & b, 5-a to c & 6-a]	Draft ODK form for the activities around customers	●
	2) Confirmation of the consistency between their main metering strategies and the contents of ODK form [Trial 5-b]	List of their confirmed main metering strategies	-
	3) Preparation for prioritizing certain types of customers (by categorization) and searching their location using GIS labels [Trials 2-b & Trial 5-c]	Example of customer categorization and labeling	●
	4) Filed trials of the ODK form for the activities around customers (by relevant unit & sections) using ODK & MAPinr [Trials 1-c, 2-a & b, 4-a & b, 5-a to c & 6-a to c]	Improved ODK form for the activities around customers	●
	5) Trial for monthly reporting and discussion using the accumulated data downloaded from ODK Aggregate at the end of each month [Trials 1-b & 3-d]	Tables prepared for monthly discussion	●
[C] 2nd Priority: Bulk meter-related Activities such as zoning with minor network modification, accuracy check of bulk meters, monthly monitoring of NRW ratios, detection of abnormal flow (using Google Sheet mainly)	1) Preparation of a simple flow diagram for the consideration of a realistic zoning improvement [Trials 3-a]	Flow diagram	●
	2) Field work for zoning improvement (minor work including isolation check and bulk meter accuracy check at distribution zone level, etc.) [Trial 3-b & c]	List of main bulk meters checked and replaced	●
	3) Addition of one or two data fields in the existing billing system to enter hydraulically isolated areas' ID for each customer and the data entry [Trial 3-c]	The improved billing system	●
	4) Establishment of easy and accurate monthly NRW ratio calculation procedure for each area with Google Sheet. [Trial 3-c]	Google Sheet for monthly NRW ratio calculation	●
	5) Establishment of an easy bulk meter reading procedure for abnormal flow detection with Google Sheet (optional) [Trial 3-c]	Google Sheet for abnormal flow detection	●
	6) Trial for monthly reporting and discussion using the results of monthly NRW ratio calculation and abnormal flow monitoring [Trial 1-b & 3-d]	Note comparing the ratios and activities in the month.	●
[D] 3rd Priority: Other Activities (including General GIS Improvement and Pipe/Pressure-related Activities) (mainly against physical losses, various tools required)	1-1) Pressure measurement over a large area using pressure gauges with max pointer [Trial 4-c]	Map showing the pressure variation over the areas	●
	1-2) Consideration of minor facility modification for pressure reduction based on the pressure measurement, etc. [Trial 4-c]	Selection of improvement measure & priority location	●
	1-3) Scheduling of minor facility modification for pressure reduction (e.g. replacing some of the malfunctioning PRVs for boilers with BPTs) [Trial 4-c]	Schedule of minor facility modification	●
	2-1) Preparation of a ODK form for facility patrol along pipelines & underground line survey (for leak and illegal use) & follow-up repairs [Trials 4-b & d & 6-a]	Draft ODK form for the activities along pipelines	●
	2-2) Filed trials of the ODK form for the activities along pipelines (by NRW unit and O&M Section) using ODK software, QField/SW Maps, etc. [Trials 4-b & d & 6-a]	Improved ODK form for the activities along pipelines	●
	2-3) Trial for monthly reporting and discussion using the accumulated data downloaded from ODK Aggregate [Trials 1-b & 3-d]	Tables prepared for monthly discussion	●
	2-4) Trial for considering pipe replacement using the accumulated records of leakage, illegal connection & repair downloaded from ODK (optional) [Trials 1-c & 2-c]	Preliminary results of the consideration	●
	3) Conduct hand pump tests for leakage control on service connections [Trial 4-e]	Calculated pass rate	●
	4) Various GIS improvement for NRW reduction activities (pipe alignment, pipe attributes, valve location, etc.) with QField [Trial 2-a]	Improved GIS layers as good examples	3
	5) Enhancement of cooperation with the county against illegal connections [Trials 6-b & c]	Examples of implemented cooperation	●

Review of Schedule and TA Plan

Work Flow Approach: Multiplex targeting & easy implementation of activities over all the service area, using a work flow management system (consisting of free software such as mobile GIS and ODK, cloud server, smartphones etc.) in order to reduce the overall NRW ratio of each WSP

Group [A] **Base**: Activities for the Establishment of PDCA Cycle





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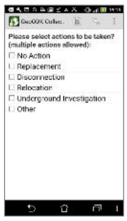
Progress and Activity Report

【B】Customer related Activity



Purpose：The main purpose of undertaking this kind of activities is;

1). To enable multiplex targeting not only by area e.g. DMA.

2). Easy implementation of activity over all service area using workflow management system, GeoODK and MAPinr.

The activities under this group include;

a) Checking of underground leakage sound with the listening stick.

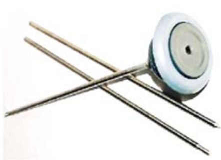
b) Meter accuracy check using the calibrated bucket or the portable meter tester.

Use of Listening stick

Use of portable meter tester

5

Many Low-cost Tools for Quick Results



Listening Stick (HWM: ST20 – 1m)

Listening Sticks

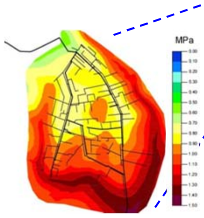
Kent V110 (Volumetric Plastic Meter)

Volumetric Plastic Meters (high accuracy and antitheft)

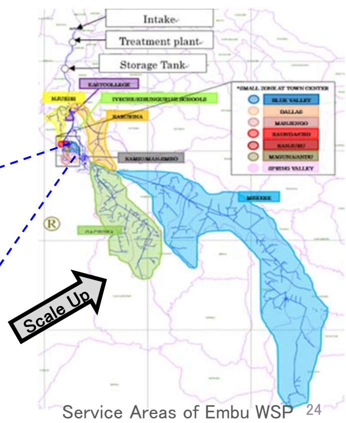
Calibrated Bucket

Maximum Reading Pointer

Pressure Gauges



Pressure Map of Blue Valley DMA of Embu WSP (before control)



Service Areas of Embu WSP (before recent expansion)

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Progress and Activity Report

【B】Customer related Activity

c) Checking of surface leakage from service connections
d) Illegal connection check
e) Meter replacement and relocation
f) Pipe fitting repair and faulty fitting check and follow up.

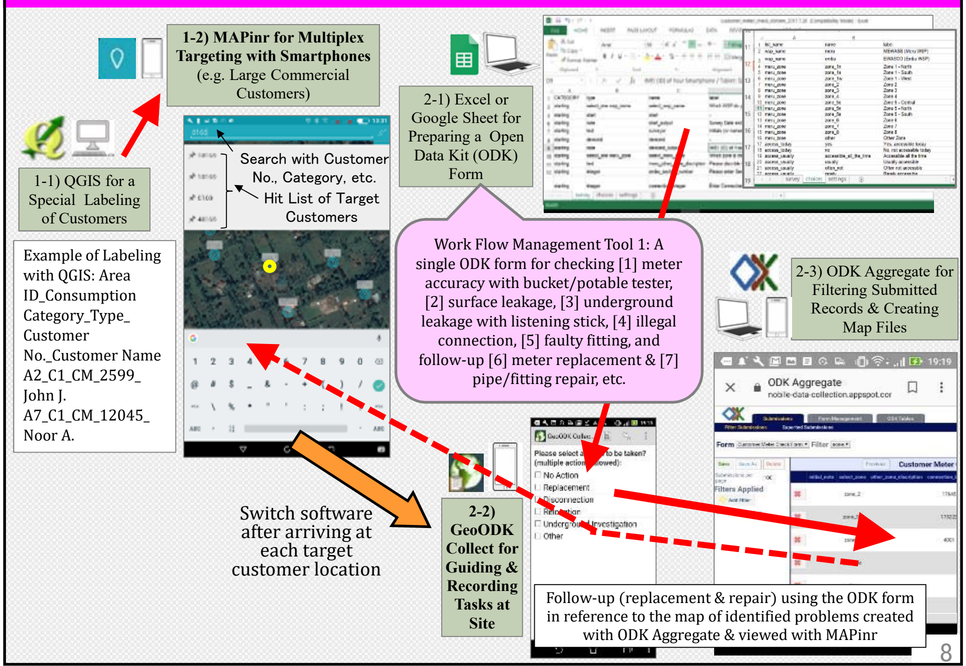
Progress made

- ❑ Trained on how to check meter accuracy using the calibrated bucket and also the portable meter tester.
- ❑ An ODK form for meter accuracy and sound check has already been established and have been trained on how to use it.

ODK registration

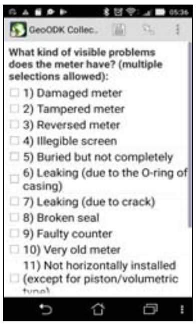
7

Software for Group [B] 1st Priority Activities around Customers



8

Use of Free Mobile GIS Solutions with Smartphones for the Activities around Customers



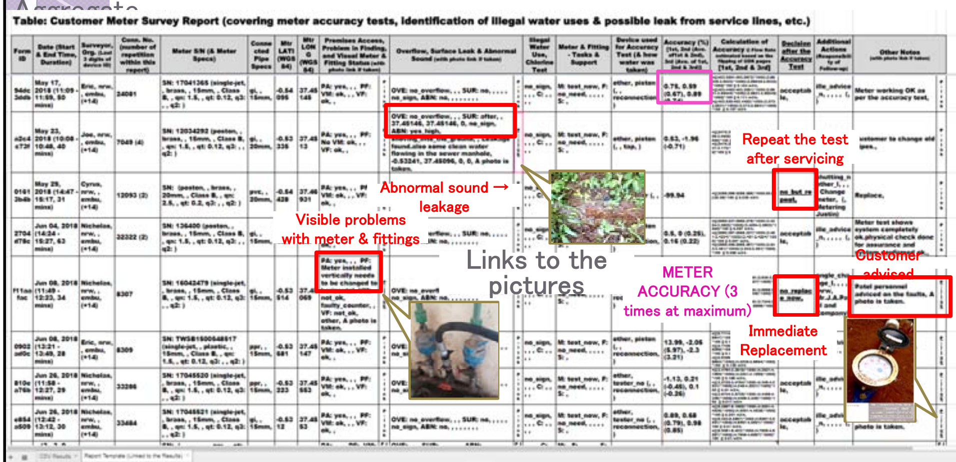
ODK Form for Various Activities around Customers

Customers, categorized with Different Icons for Prioritization, shown with MAPinr

Geo-tagged Photo taken with GPS Map Camera

9

Results: Customized Report for the Various NRW Activities around Customer Meters with Easy-links to the Data exported from ODK Aggregate



Progress and Activity Report

【B】Customer related Activity – Analysis using Billing Data

Customer meter reading data analysis is also very crucial so as to know which customer belongs to which zone or DMA. Other analysis can also be done based on the customer type, consumption pattern, consumption fluctuation, meter age etc.

Shown below is an example of billing on estimate of large consumers in Embu WSP as part of the on-going data analysis in both Meru and Embu.

Name	Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
EMBU LEVEL FIVE HOSPITAL	5849.5								→ 3508	→ 3051		
GK PRISON,	4053.0						→ 7959		0 → 0			
PROVINCIAL POLICE	3887.8											
ADMINISTRATION POLICE LINE EMBU	1558.2											
NATIONAL INTELLIGENCE SERVICE	1356.3			→ 1241								
MEDICAL TRAINING CENTRE	1342.3											
EMBU UNIVERSITY COLLEGE.	1279.3							→ 11208				
KANGARU GIRLS SCHOOL	1243.4											
EMBU COUNTY GOVERNMENT C/O MIN	1153.7	→ 9999							→ 9999			0 ↑ 655
K.POLICE LINE C/O OCPD EMBU	1029.7				→ 619	→ 818	→ 775	→ 9742				
EMBU UNIVERSITY COLLEGE.	964.4	0 ↑ 784	→ 8865									
EMBU COLLEGE LTD.	960.3				→ 984	→ 1002	0 ↑ 1003		0 → 0	→ 568	- 858	
EMBU HOTEL LTD	914.0			→ 362					→ 9513			
EMBU UNIVERSITY COLLEGE-SCH	906.8							→ 10504				
EMBU UNIVESITY COLLEGE.	887.8							→ 4207				
MOI STADIUM EMBU	884.4	→ 1536	→ 1534	→ 1570	→ 1465	→ 1231	0 ↑ 1192	→ 1078		→ 814	→ 336	
EMBU UNIVERSITY COLLEGE.	878.1											
RWIKA TECHNICAL INSTITUTE	805.6											
GOVERNMENT TRAINING INSTITUTE C/0	784.8						→ 447					
JUSTUS KINYUA MUGO C/O MOUNTAIN	591.3											

Estimation of Billed Consumption (m3/month) (Example of Large Customers, Embu WSP)

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Result of Billing Data Analysis

・Meru

Table: Categorization of Customers for the Prioritization in NRW Reduction Activities

Customer Categories by Consumption Level and Times of Estimation in 2017	No Estimation ○		1 Estimation [1]		2 Estimations [2]		3 or More Estimations [X]		Total	
	Num. of Customers	Percentage	Num. of Customers	Percentage	Num. of Customers	Percentage	Num. of Customers	Percentage	Num. of Customers	Percentage
C1: > 300 m3/month	2	11%	9	50%	2	11%	5	28%	**18**	0%
C2: 101-300 m3/month	63	54%	18	15%	27	23%	9	8%	**117**	1%
C3: 51-100 m3/month	166	52%	41	13%	64	20%	50	16%	321	2%
C4: 21-50 m3/month	727	49%	180	12%	317	21%	268	18%	1,492	11%
C5: 7-20 m3/month	3,207	48%	1,171	17%	1,100	16%	1,242	18%	6,720	50%
C6: 0-6 m3/month	2,324	48%	1,013	21%	633	13%	888	18%	4,858	36%
Total	6,489	48%	2,432	18%	2,143	16%	2,462	18%	13,526	100%

・Embu

Table: Categorization of Customers for the Prioritization in NRW Reduction Activities

Customer Categories by Consumption Level and Times of Estimation in 2017	No Estimation ◇		1 or 2 Estimations (f)		3 or More Estimations [m]		Total	
	Num. of Customers	Percentage	Num. of Customers	Percentage	Num. of Customers	Percentage	Num. of Customers	Percentage
C1: > 300 m3/month	20	45%	16	36%	8	18%	**44**	0.2%
C2: 101-300 m3/month	142	63%	53	23%	31	14%	**226**	0.8%
C3: 51-100 m3/month	413	63%	142	22%	96	15%	651	2.4%
C4: 21-50 m3/month	1,870	56%	845	25%	630	19%	3,345	12%
C5: 7-20 m3/month	6,086	49%	2,868	23%	3,342	27%	12,296	45%
C6: 0-6 m3/month	5,611	53%	2,460	23%	2,552	24%	10,623	39%
Total	14,142	52%	6,384	23%	6,659	24%	27,185	100%
Other Customers without Billing Data in 2017 (mostly inactive or disconnected)							4,292	+16%

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The CI & C2 Customers (>100m3/month) which Experienced More than 3 Estimates in 2017

Account No.	Customer Type	C: Average of Billed Consumption (m3/month)	Consumption Category	Estimation (metered consumption →billed consumption) - Jan	est-Feb	est-Mar	est-Apr	est-May	est-Jun	est-Jul	est-Aug	est-Sep	est-Oct	est-Nov	est-Dec	E: Total Count of Estimate (times)	Total Difference made by Estimation (m3/year)
88006	PUBLIC SCHOOL	1,694.9	C1: > 300					+ 14083	+ 1260	+ 1546	+ 3731		0 ↑ 1656	0 ↑ 1512	0 ↑ 1512	7	25,300
19026	G.O.K.	1,072.7	C1: > 300				+ 619	+ 818	+ 775	+ 9742						4	11,954
22798	EMBU COUNTY GOVT	1,054.4	C1: > 300	+ 9999							+ 9999			0 ↑ 655	0 ↑ 655	4	21,308
20078	PRIVATE SCHOOL	919.1	C1: > 300				+ 984	+ 1002	0 ↑ 1003		0 → 0	+ 568	- 858			5	2,699
18002	EMBU COUNTY GOVT	836.1	C1: > 300	+ 1536	+ 1534	+ 1570	+ 1465	+ 1231	0 ↑ 1192	+ 1078		+ 814	+ 336		0 ↑ 612	10	11,368
20223	COMMERCIAL OTHERS	385.8	C1: > 300				0 ↑ 266	0 ↑ 266	0 ↑ 266	+ 3217						4	4,015
44711	COMMERCIAL OTHERS	348.3	C1: > 300	0 ↑ 4	- 29		0 → 0	0 → 0	0 → 0	0 → 0	0 ↑ 6	0 ↑ 6	- 12	255 ↓ 0	+ 249	7	224
06160	PUBLIC SCHOOL	303.8	C1: > 300					+ 230	+ 199	+ 241						3	670
64040	PUBLIC SCHOOL	244.0	C2: 101-300		0 ↑ 142								0 ↑ 245	0 ↑ 245		3	632
64003	WATER KIOSKS	210.8	C2: 101-300										0 ↑ 10	0 ↑ 10	0 ↑ 197	3	217
58133	PUBLIC SCHOOL	201.2	C2: 101-300	+ 620	+ 485						0 ↑ 6			0 ↑ 6	0 ↑ 6	5	1,123
22643	RESIDENTIAL	194.2	C2: 101-300				0 ↑ 151						0 ↑ 227	0 ↑ 227	0 ↑ 217	4	822
35246	RESIDENTIAL	193.3	C2: 101-300										0 ↑ 234	0 ↑ 6	0 ↑ 6	3	246
26375	COMMERCIAL HOTEL/BAR	183.0	C2: 101-300				+ 178	0 ↑ 174							+ 729	3	1,081
22611	RESIDENTIAL	170.5	C2: 101-300					0 ↑ 144	0 ↑ 144	+ 8070						3	8,358
06167	PUBLIC SCHOOL	170.0	C2: 101-300	0 ↑ 10	0 ↑ 10	- 20										3	0
02026	G.O.K.	169.0	C2: 101-300							0 ↑ 189	0 ↑ 176	0 ↑ 176	0 ↑ 189	0 ↑ 189	+ 8621	6	9,540
17136	EMBU COUNTY GOVT	166.8	C2: 101-300	+ 244	+ 9999			0 ↑ 37	0 ↑ 37							4	10,317
27270	COMMERCIAL CARWASH	163.9	C2: 101-300	0 ↑ 117	0 ↑ 118	- 195										3	40
29743	COMMERCIAL CARWASH	151.9	C2: 101-300			0 ↑ 100	0 ↑ 172	0 ↑ 163						+ 483	+ 2521	5	3,439
97020	WATER KIOSKS	145.8	C2: 101-300	0 ↑ 241	0 ↑ 6	0 ↑ 6	0 ↑ 6	- 259				0 ↑ 179	- 179			7	0
40179	RESIDENTIAL	134.8	C2: 101-300						0 ↑ 114	0 ↑ 114	0 ↑ 114		0 ↑ 114	0 ↑ 114		5	570
46930	RESIDENTIAL	130.6	C2: 101-300										+ 911	0 ↑ 138	- 983	3	66
39182	RESIDENTIAL	130.3	C2: 101-300										- 941	0 ↑ 151	0 ↑ 122	3	-668
46977	RESIDENTIAL	129.9	C2: 101-300			- 801					- 339		- 457	- 801		4	-2,398
88062	RESIDENTIAL	128.9	C2: 101-300	- 335		+ 1038	- 370	- 1491						0 → 0		4	-1,158
17015	COMMERCIAL HOTEL/BAR	124.3	C2: 101-300	0 ↑ 140	+ 6140	- 5956										3	324
45248	RESIDENTIAL	123.8	C2: 101-300								- 2414	0 ↑ 172	0 ↑ 172	0 ↑ 172		4	-1,898
59001	PUBLIC SCHOOL	117.8	C2: 101-300								0 ↑ 6	0 ↑ 6	0 ↑ 3	- 18		4	-3
46356	RESIDENTIAL	112.0	C2: 101-300				0 ↑ 6	- 4						0 ↑ 158		3	160
36011	RESIDENTIAL	111.6	C2: 101-300							+ 168				0 ↑ 110	- 712	3	-434
461113	RESIDENTIAL	107.6	C2: 101-300								+ 3			+ 38	0 ↑ 19	3	60
86108	RESIDENTIAL	106.4	C2: 101-300					+ 2189	0 ↑ 109	- 2298			+ 3071		0 ↑ 33	5	3,104
99057	WATER KIOSKS	106.3	C2: 101-300	0 ↑ 574	0 ↑ 80	0 ↑ 80	0 ↑ 80	0 ↑ 80	0 ↑ 80	0 ↑ 80	- 361	0 ↑ 6		0 ↑ 70	0 ↑ 70	11	839
97005	WATER KIOSKS	104.4	C2: 101-300	- 62				0 ↑ 10						0 ↑ 83	0 ↑ 83	4	114
53581	RESIDENTIAL	101.8	C2: 101-300							0 ↑ 6	0 ↑ 6	- 12				3	0
53149	RESIDENTIAL	100.7	C2: 101-300			0 ↑ 7	0 ↑ 106	0 ↑ 49							0 ↑ 61	4	223
53079	RESIDENTIAL	100.1	C2: 101-300		+ 89		0 ↑ 6		0 ↑ 72					0 ↑ 156		4	323

Results: Large Revenue Increase

18 examples from the 500 already checked

No.	Meter No.	Action Taken	Average Bill before Action (Ksh./month)	Average Bill after Action / Change (Ksh./month)	Revenue Increase (Ksh./month)	Increase Ratio (%)
1	15057	Faulty changed	1,900	9,000	7,100	374%
2	31087	Serviced	260	8,000	7,740	2977%
3	18232	Serviced	800	1,300	500	63%
4	36333	Faulty changed	260	600	340	131%
5	18193	Faulty changed	1,500	4,000	2,500	167%
6	35176	Faulty changed	260	1,000	740	285%
7	35101	Faulty changed	260	1,000	740	285%
8	46024	Faulty changed	260	1,700	1,440	554%
9	32022	Faulty changed	260	5,000	4,740	1823%
10	o6167	Faulty changed	**490**	**20,000**	**19,510**	**3982%**
11	o6085	Faulty changed	260	500	240	92%
12	o6114	Faulty changed	260	500	240	92%
13	o6079	Faulty changed	260	500	240	92%
14	o6093	Faulty changed	260	400	140	54%
15	o7069	Faulty changed	2,000	7,000	5,000	250%
16	43400	Serviced	**39,000**	**116,000**	**77,000**	**197%**
17	o1027	Serviced	**63,000**	**200,000**	**137,000**	**217%**
18	44006	Faulty changed	8,000	32,000	24,000	300%
	Total		119,290	408,500	**289,210**	**242%**

Progress and Activity Report

【C】Monitoring Activities for each Area using Bulk Meters

Purpose: The main purpose of this activity is to be used as a monitoring tool to detect abnormal flow to an established zone or DMA immediately it occurs and identify areas with high-NRW ratios.

This involves the use of bulk meters to monitor activities within a demarcated Zone or DMA e.g. For;

- Monthly NRW calculation in each zone and DMA
- Continuous monitoring of abnormal flow at each bulk meter.

The zoning of distribution network to form operational Zones and DMAs for NRW monitoring at both Embu and Meru WSPs is on-going (already done on GIS. Currently focusing on the replacement of faulty bulk meters) .

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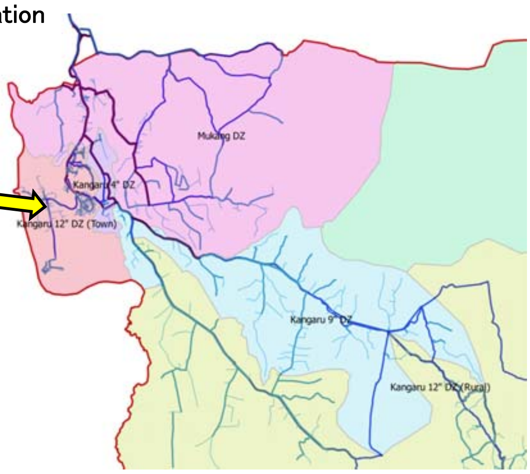
Progress and Activity Report

【C】Monitoring Activities for each Area using Bulk Meters

Zoning Illustration

Existing Work Zone (Not Hydraulic), Embu WSP



Identified Existing Distribution Zones, Embu WSP

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Progress and Activity Report

【D】Other NRW Reduction Activities along Pipeline

The main purpose of involving these activities along pipeline is to reduce physical losses.

These activities include;

- Underground leakage detection , surface leak patrol and repair of bursts.
- Pressure measurement.
- GIS improvement.
- Handpump use for testing new connections

Pressure Measurement

Handpump use for new connections

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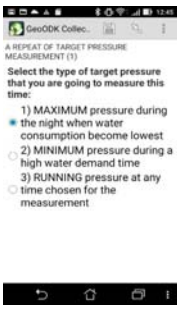
Progress and Activity Report

【D】Other NRW Reduction Activities along Pipeline

So far, the two leading WSPs (Embu and Meru) have come up with a plan for pressure measurements which will be used to manage pressure within their zones or DMAs and to determine where best to position pressure reducing valves or to construct break pressure tanks.

Planned Pressure Measurement in Zone 3, Meru WSP



ODK Form for Pressure Measurement with Pressure Gauges with Maximum Pressure Pointer

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Thank you for
your attention.
宜しくお願い
致します