添付資料６：研修ガイドライン

Training Guideline

1. Leak Detection

a. Underground Leakage Survey

Table of contents

1 Outline

1.1 Purpose

Purpose of training	The primary purpose of leak detection training is to share knowledge of investigation of leaks among the operation and management staff in order to establish their own leak detection team, reduce the road damages when carryout leak repairs and help pipeline controllers to detect and localize leaks. Also, related data helps pipeline controllers to assist decision-making. Pipeline leak detection systems can also enhance productivity and system reliability thanks to reduced downtime and inspection time.
Training Contents	➢ Leaking point survey of distribution and service pipe with acoustic listening stick and electric leak detection

1.2 Flow of training with time schedule

The total time is 2 hours and 5 minutes.

No.	Activity	Required time	Venue
1	Lecture	30 min.	Lecture room
	1. Initial introduction about instruments and application 2. Why is the leak detection required? 3. Basic elements of the instruments 4. Similar technologies and instruments		
2	Move to TY	5 min.	TY & Warehouse (Leak survey area)  
3	Preparation for practical training	10 min.	
	*Acoustic listening stick *Electric leak detection *Activate pump of TY *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse   		
4	Practical training	50 min.	TY
	*Details are described in "3Practice (Page 15)" ➢ Leaking point survey of distribution and service pipe with acoustic listening stick and electric leak detection		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse  ⇨ 
6	Move to lecture room	5 min.	Lecture room
8	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

➢ All members must wear safety equipment in TY. RP should order to participants wearing suitable item

➢ Do not sit on the pipes or put your foot on.

➢ Do not touch the installed equipment unnecessarily.



➢ Do not eat food in the TY.



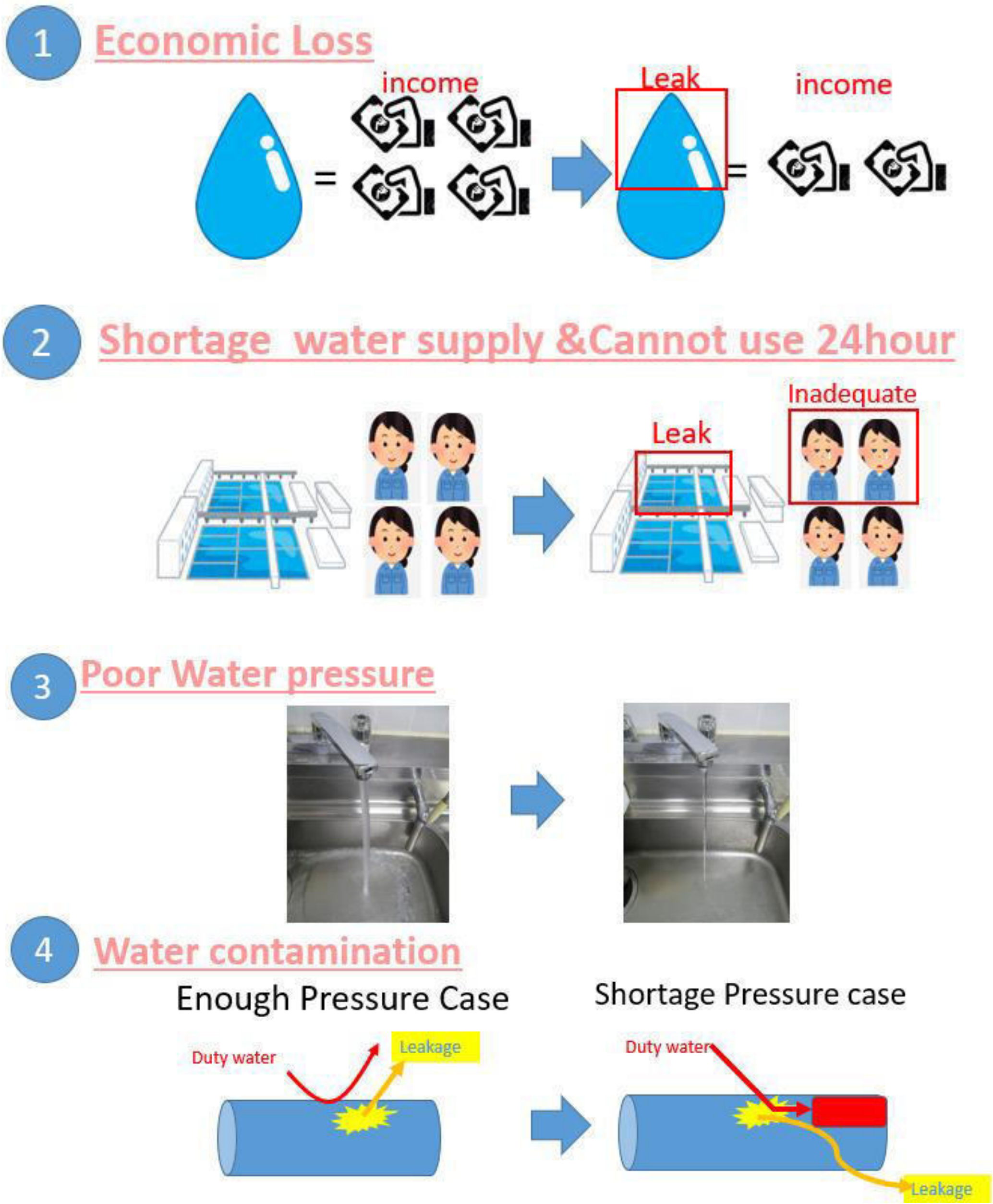
2 Knowledge acquisition

2.1 Type of leakage

The typical type of leakage and its characteristic are as below.

2.2 Influence of Leakage

General influences of leakage are as below.



5 Second Disaster Outbreak

Tall Fountain

Submerged Road
→ Traffic Jam

A roadway cave-in

6 Environmental Load

Waste of ...

Pump driving → CO_2 Discharge

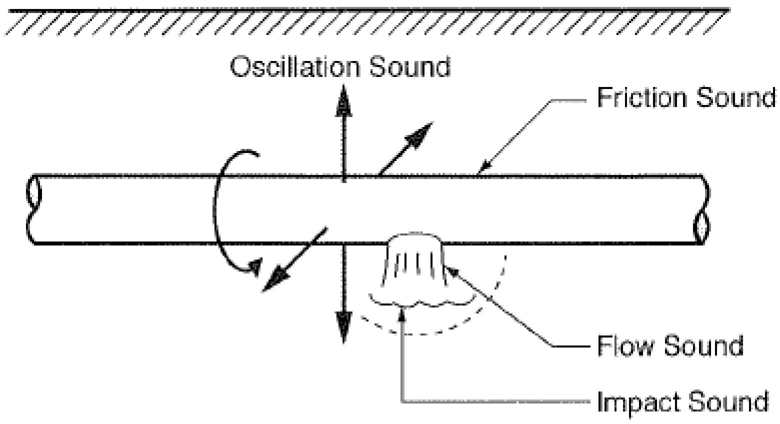
Medicine dosage

And more ...

Stagnation of Economic Activity

2.3 Characteristic of Leakage

Typical sound generated by leakage is as below.



The leakage condition and its detectability are as below.

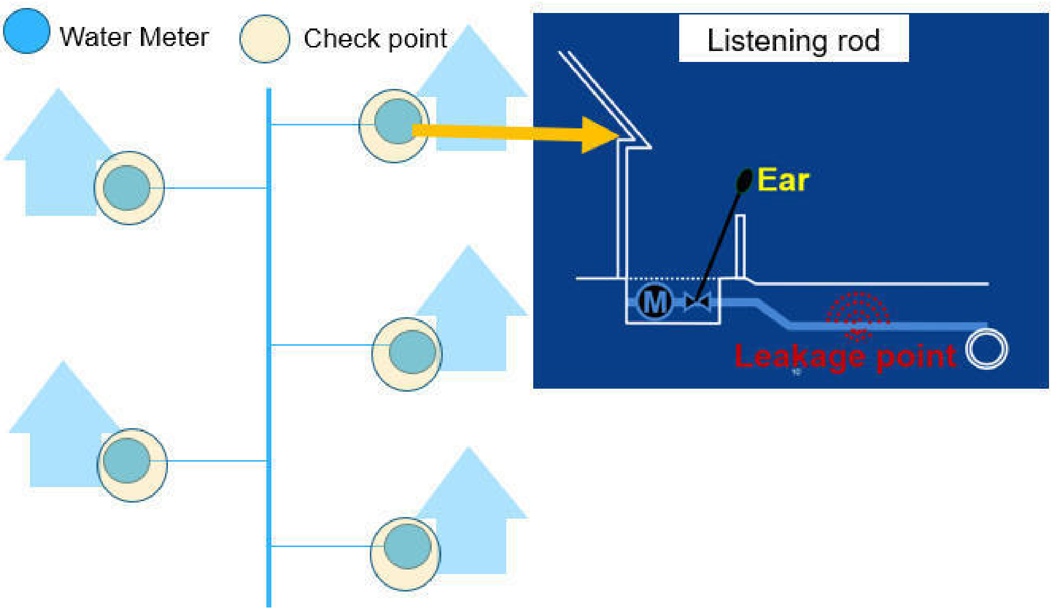
Leakage condition		Detectability	Note
Pipe depth	Shallow	Easy	
	Deep	Difficult	Noise of water leakage attenuates as the depth increases
Soil density	Rough	Difficult	Noise of water leakage attenuates as density increases
	Dense	Easy	
Pipe material	Soft	Normal	
	Hard	A little difficult	Hard pipes do not vibrate
	Metal	Easy	
	Non-metal	Difficult	Non-metallic Pipes do not transmit water leak sound far
Pipe diameter	Small	Normal	
	Large	A little hard	Large diameter pipes do not vibrate
Leak volume	Small	Difficult	Cannot catch the leak sound
	Big	Easy	
Pressure	Low	Difficult	Cannot catch the leak sound
	High	Easy	
Leak direction	Above	Easy	
	Side	Normal	
	Bottom	Very Difficult	It is difficult to catch water leak sounds on the ground

*Please show leak sound video collected in Output 2 activities.

2.4 Equipment & flow of leak detection

2.4.1 Equipment & flow for service pipe survey

Target leakage is following service pipe.



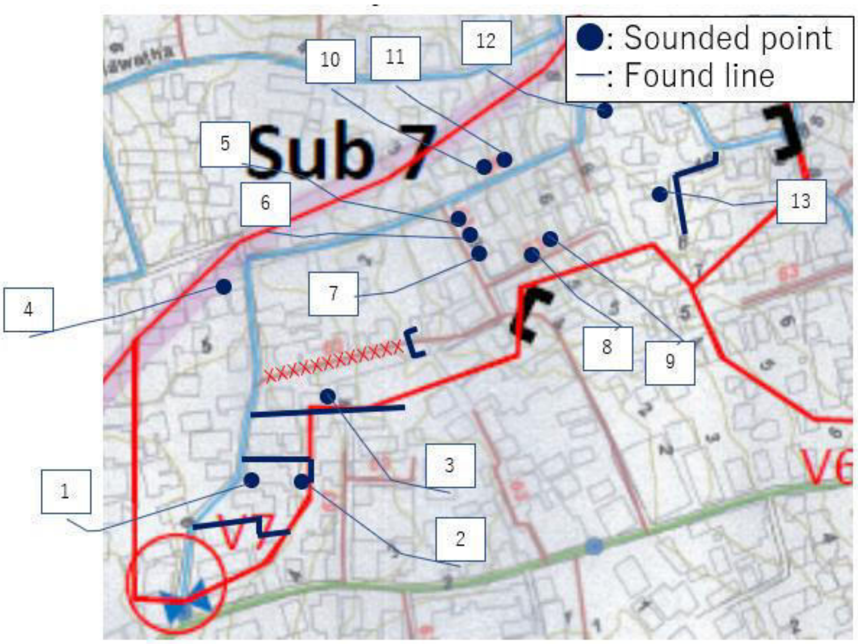
Equipment for service pipe survey is as below.

- Acoustic listening stick

Flow of leakage survey for service pipes is as below.

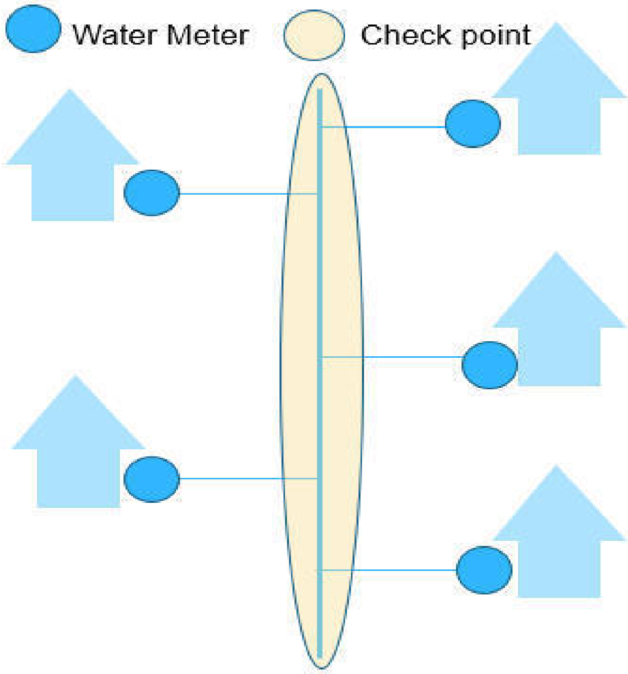
i. Visit each house to check whether leakage sound exists or not with acoustic bar.	
ii. Before leakage survey, confirm that the consumer is not using water and water tank is not filled. If necessary, stop valve should be closed.	
iii. In case that leakage sound exists or doubtful, guess the leakage location or the distance from the sounding point by the sound volume. If not, move to next house. Notes: ➢ Do not grip a bar of acoustic listening stick ➢ Put the tip of the rod on the metal part of upstream side of the meter	

The result of survey must be recorded as below.



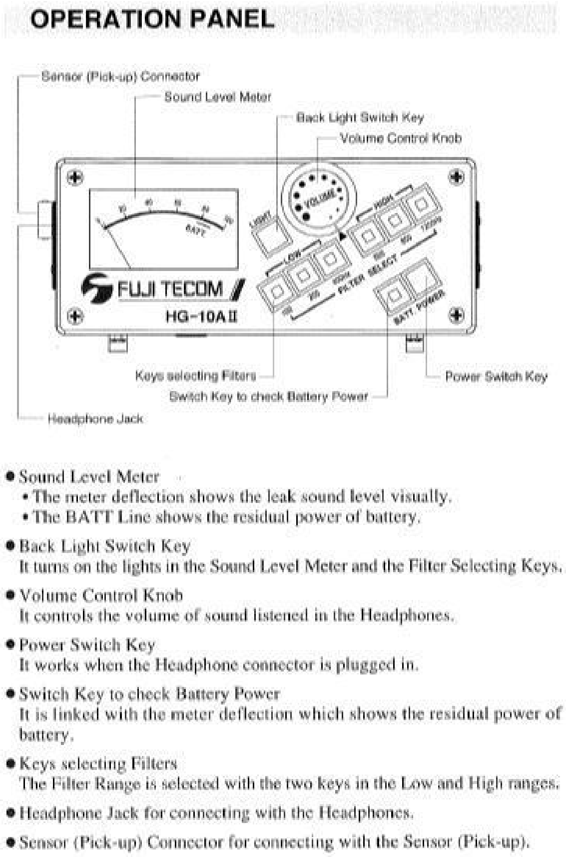
2.4.2 Equipment & flow for distribution pipe survey

Target leakage is following distribution pipe.



Equipment for distribution pipes survey is as below.

➢ Electric leak detection

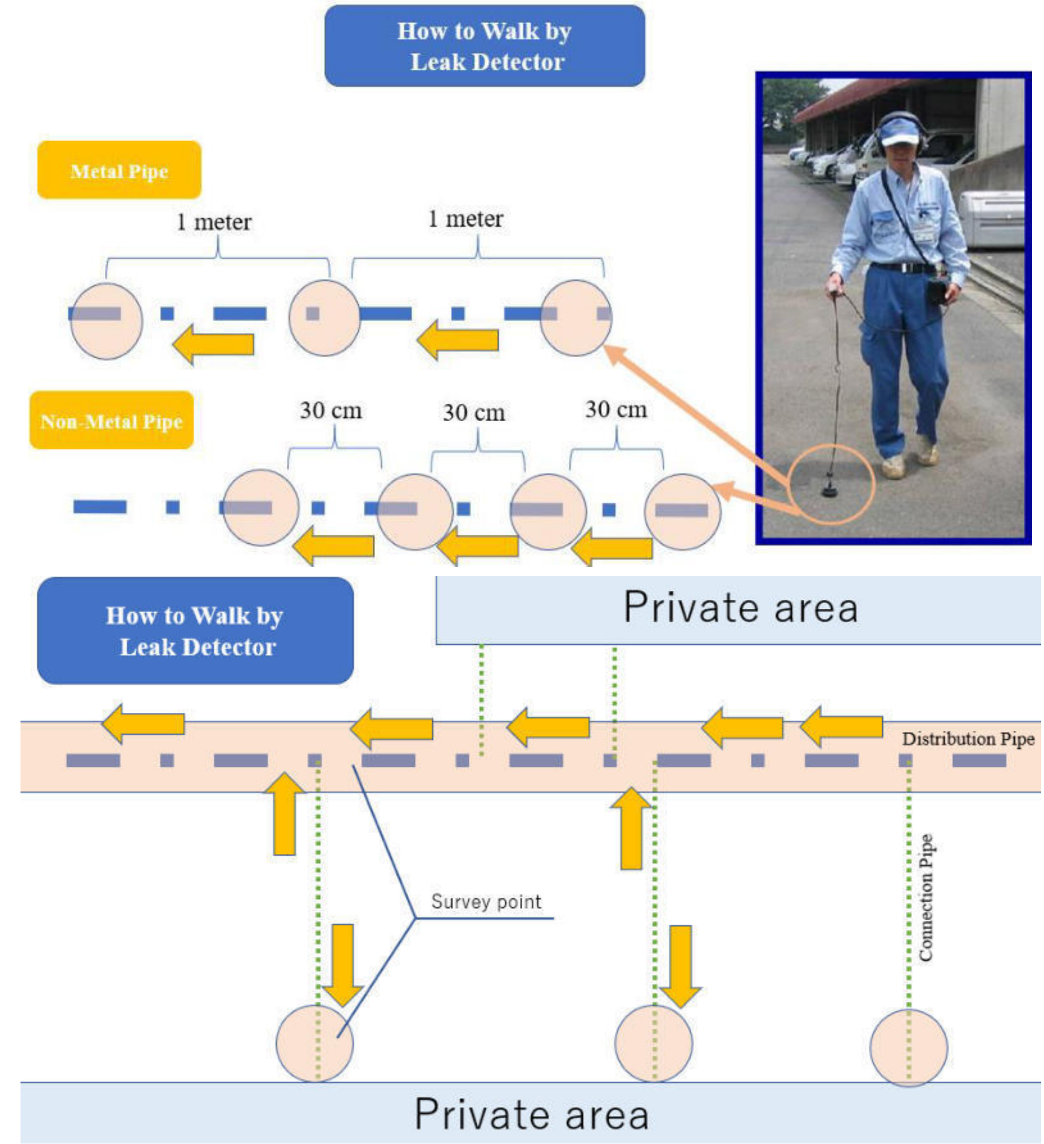


Flow of leakage survey for distribution pipes is as below.

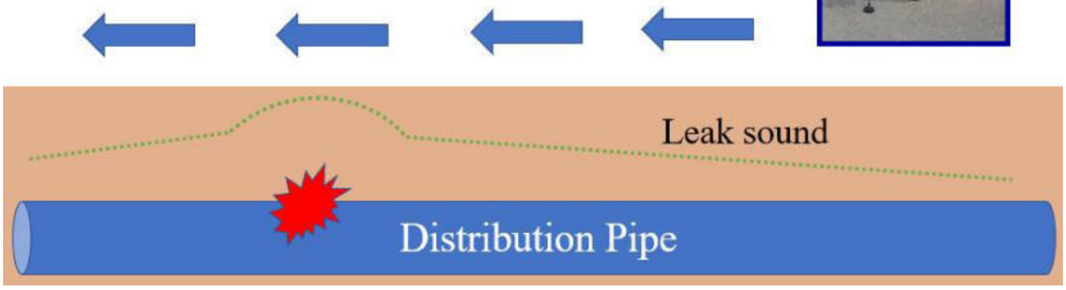
i. Walk on the road that distribution pipes are buried, identify the existence of leak sounds by putting the microphone on the ground in every a few meters. Note: Remove water and mud from sensor after survey	

The result of survey must be recorded as below.

The details for distribution survey is as below.

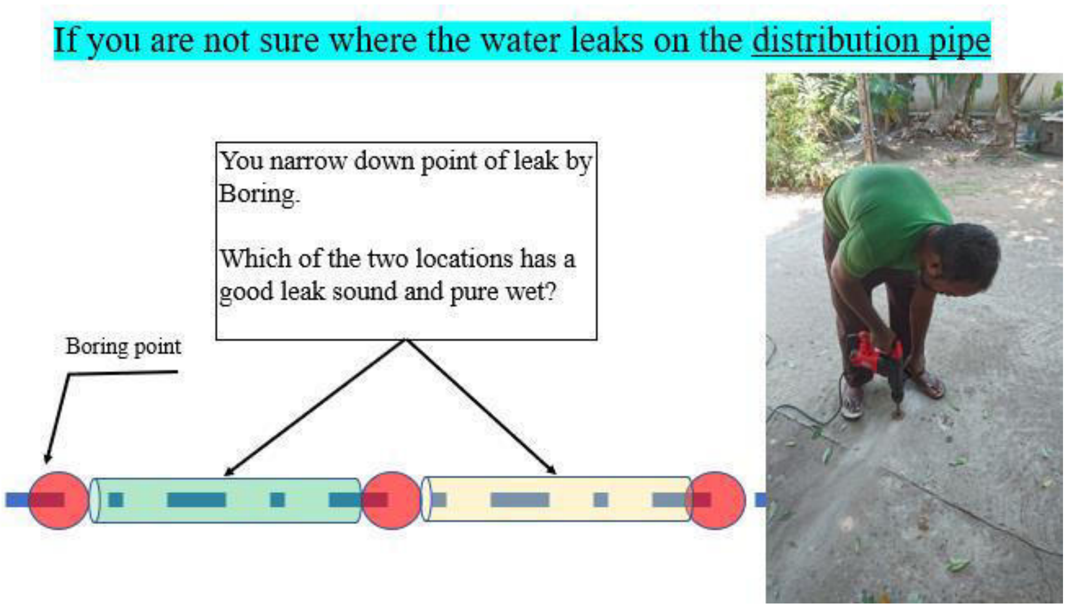


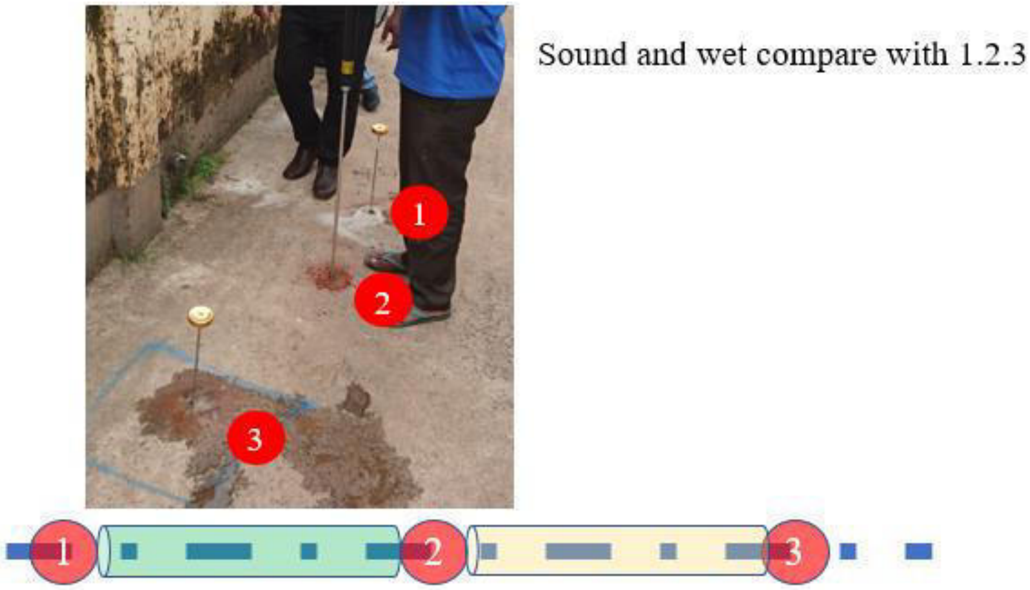
About Leak sound
-Stabilize sound
-Propagate distance: Metal pipe- Long, Non-metal pipe- short



2.4.3 Flow for identification of leak point

Flow of identification of leak point is as below.





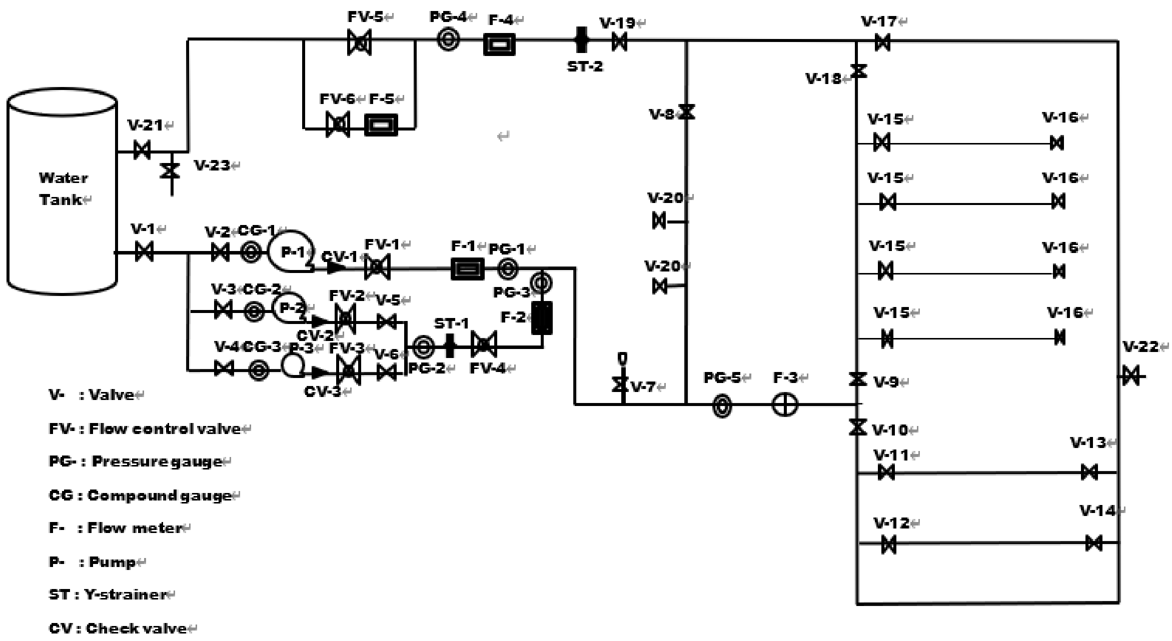
3 Practice

Practical training is conducted for distribution pipe and service pipe in TY.

The flow of training is as below.

Step	Target	Check point	Purpose	Bar
1	Service pipe	Meter & Stop Valve	Listen & Memorize leak sound (Trainees know which pipe is leaking)	4
2	Service pipe	Meter & Stop Valve	Find out which pipe is leaking (Trainees do not know which pipe is leaking)	4
3	Distribution pipe	Pipeline	Listen & Memorize leak sound (Trainees know which pipe is leaking)	4
4	Distribution pipe	Pipeline	Find out which pipe is leaking (Trainees do not know which pipe is leaking)	4
5	Repeat step 1-4		Learn the difference in water leak noise due to the difference in water pressure	2
6	Repeat step 1-4			1

Please refer to the following figure of valves of TY for the training.



*One leak point is enough to identify leak sound and more leak points will be a distraction for trainee

*It is suggested to open DI line valve at first to listen leak sound. After that PVC connection under concrete layer should be open to identify the leak sound variation since the sound propagation through Concrete material is considerably high.

*Trainees who identify the leak sound from the acoustic sound machine can proceed to detect same location from the manual listening sticks. Then let the trainees to identify sound variation in material (PVC/PE/DI) vise and media (Concrete/ Asphalt) vise. As a final stage let trainees to identify unknown leak points and instruct them to write down distance from the valve point to their leak point then check with the actual point

Training Guideline

1. Leak Detection

b. Valve, Metal Pipe & Non-Metal Pipe Locating

Table of contents

1 Outline

1.1 Purpose

Purpose of training	The primary purpose of Valve and pipe training is to share knowledge of tracing underground utility services which are covered by asphalt or other surface cover. You can learn the way to find out buried valves or pipes to maintain proper distribution system and reduce the unnecessary excavation works of road surface.
Training Contents	➢ Valve and leakage pit locating ➢ Service pipe & Distribution pipe locating

1.2 Flow of training with time schedule

The total time is 2 hours and 20 minutes.

No.	Activity	Required time	Venue
1	Lecture	45 min.	Lecture room
	1. Why is the valve & pipe tracing required? 2. Initial introduction about equipment & application 3. Basic elements of the instruments 4. Similar technologies and instruments		
2	Move to TY	5 min.	TY & Warehouse (Leak survey area)  
3	Preparation for practical training	10 min.	
	* Metal detector * Pipe locator *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse   		
4	Practical training	50 min.	TY
	*Details are described in "3Practice (Page 18)" ➢ Valve and leakage pit locating ➢ Service pipe & Distribution pipe locating		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse ⇨ 
6	Move to lecture room	5 min.	Lecture room
8	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.



- Do not eat food in the TY.



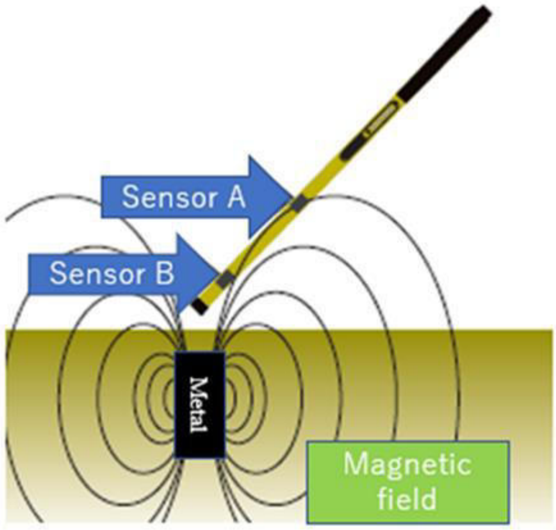
2 Knowledge acquisition

2.1 Valve locating

2.1.1 Detail of equipment

Metal locator is used for this training.

"Magnetic Locator GA-3S" detects buried unknown metal objects and it is suitable for deep depth exploration. Also, it can detect the rough size and length of metal objects also.

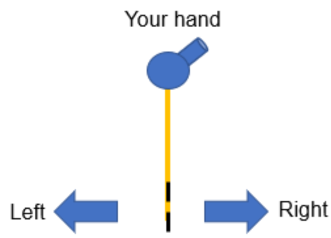


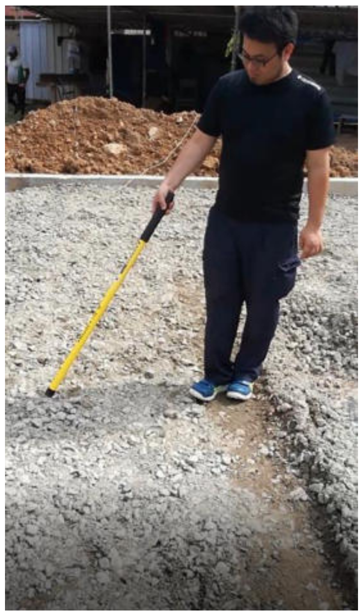
As shown in the figure, when the locator approaches the magnetic field, the magnetic field hits the sensor B more strongly than the sensor A.

As a result, the magnetic field balance between the sensors A and B is lost, and the sound is captured to detect the location of the object.

In addition, the structure of this equipment has a built-in vertical sensor, which is more effective for detecting objects buried vertically than the objects buried horizontally.

2.1.2 Procedures of survey

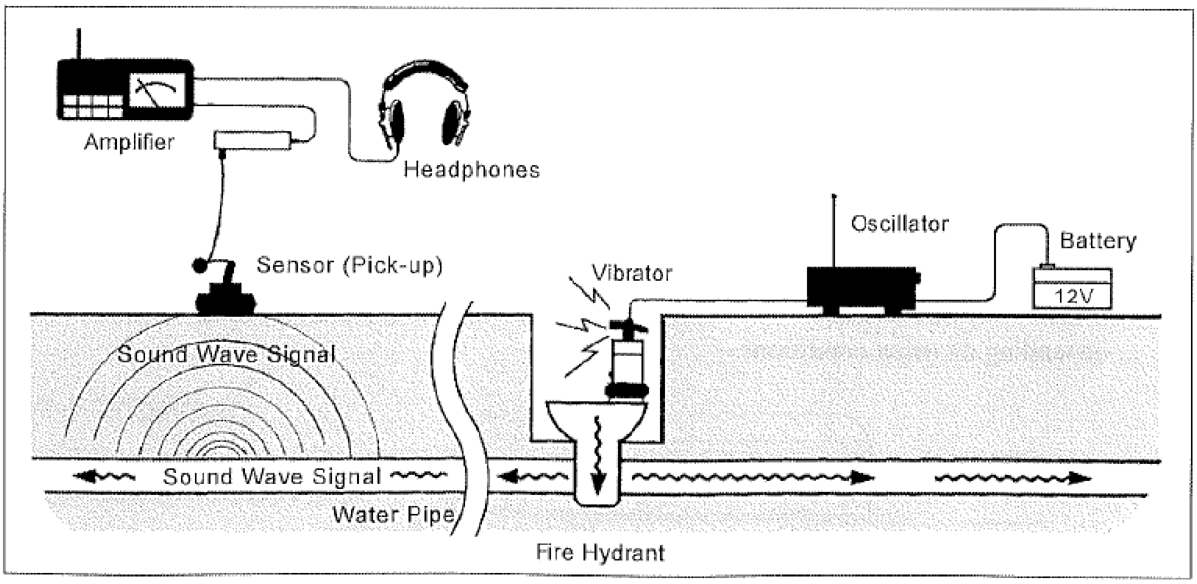
<table>
<tr>
<td>i. Turn on Switch (Push 4 button of picture)
Adjust Gain (Push 5 & 6 button of picture)
Adjust Zero (Push 3 button of picture) *if need</td>
<td>
</td>
</tr>
<tr>
<td>ii. Explore the surface of ground while waving a stick
Find the place where the sound of the equipment. A valve is buried in the place shown in the right photo.
<u>Note</u>:
If the locator responds everywhere in TY, please reduce the gain of the locator.</td>
<td>

</td>
</tr>
<tr>
<td>iii. Record the point where the locator responded most strongly.</td>
<td></td>
</tr>
</table>

2.2 Pipe and non-metal pipe locating

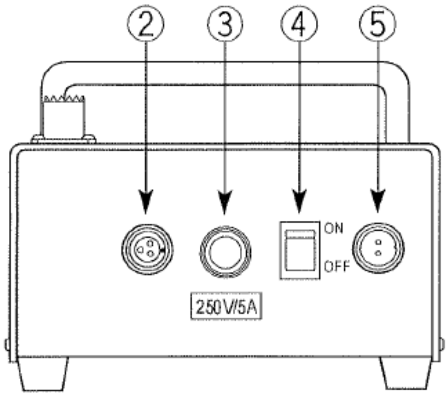
2.2.1 Details of equipment

Pipe locator is used for this training. This equipment use vibration to detect pipe location.



Details of this equipment is as below.

Transmitter



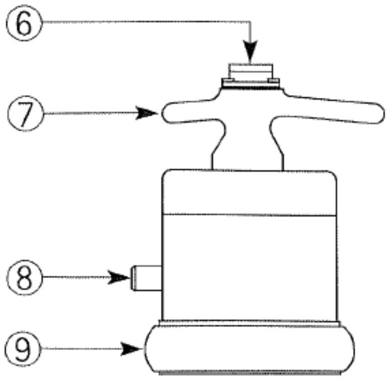
②Output jack
used for connecting to the vibrator with the 5-meter-long vibrator cable.

③Fuse box
will break at 5A or more.

④Power switch (O : OFF I : ON)
used for operating the transmitter unit.

⑤Power jack
used for connecting to the 7-meter-long power supply cable.

Vibrator



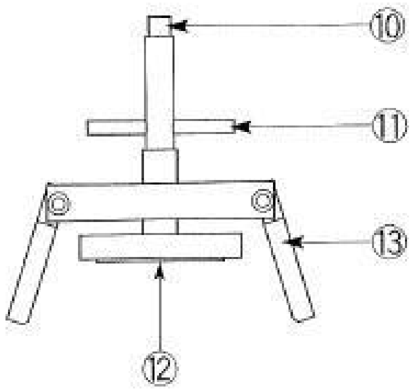
⑥Connector Output jack
used for connecting to the oscillator with the 5-meter-long vibrator cable.

⑦Handle
used when attaching to and removing from the fire hydrant.

⑧Air bleeding knob
used for taking out the air bubble inside of the vibrator.

⑨Fuji coupler
meets all of the outlet of the domestic fire hydrants.

Adaptor



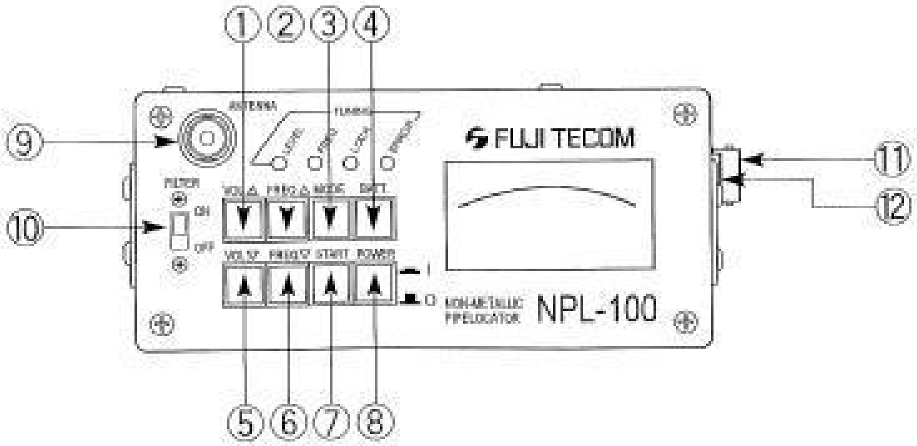
⑩Screw head
jointed at the centor of the speaker of the vibrator.

⑪Handle
push down the disk on the face of the water meter.

⑫Disk
fixed on the face of the water meter for trans-mitting the sound wave signal into the water

⑬Clamp
clamps the flange of the water meter.

Receiver unit



①Volume UP key
used for controlling the meter needle and turning up the volume in the headphones.

②Frequency UP key
used for tuning in the resonance frequency of the higher frequency.

③Mode key
used for changing over between the continuous sound signal mode and the intermittent sound signal mode.

④Battery check key
used for checking the battery power.

⑤Volume DOWN key
used for controlling the meter needle and turning down the volume in the headphones.

⑥Frequency DOWN key
used for tuning in the resonance requency of the lower frequency.

⑦Start key
used for commencing the automatic adjustment function.

⑧Power switch key (: OFF : ON)
used for turning on and off power.

⑨Antenna connector
used for connecting to the transmitting antenna.

⑩Filter switch
used for tuning on and off the filter.

⑪Sensor (Pick-up) jack
used for connecting to the sensc (Pick-up).

⑫Headphone jack
used for connecting to the headphones

- ✧ Automatic adjust frequency (can be change manual)
- ✧ 2 vibrate pattern
- ✧ Can be utilize Leak detector

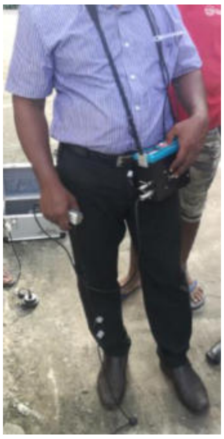
2.2.2 Procedures of survey

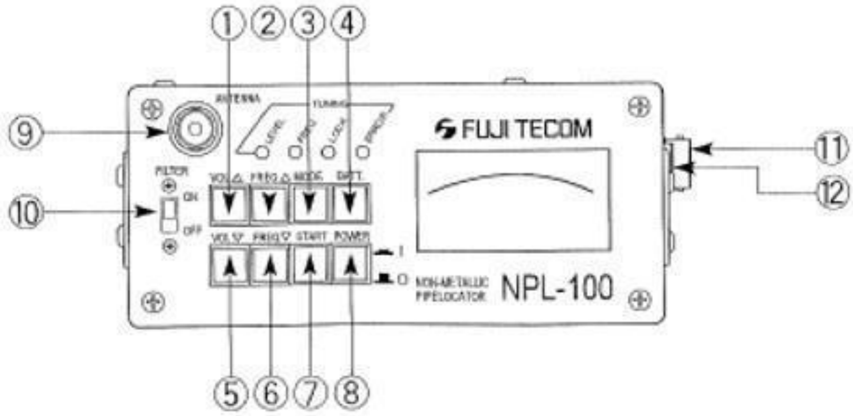
i. Attach the vibrator on exposed parts of target pipe such as service pipe, fire hydrant and valves

ii. Connect Vibrator-Transmitter-Battery

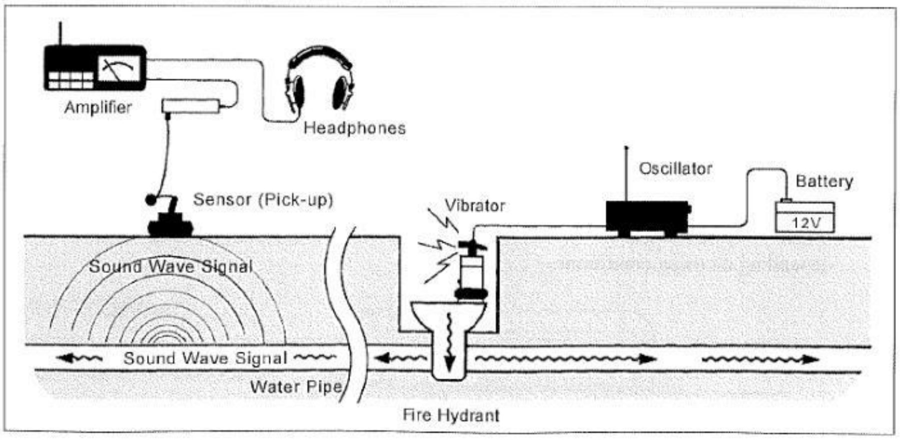
iii. Power on Transmitter

iv. Put the receiver on and power on it (Button 7)

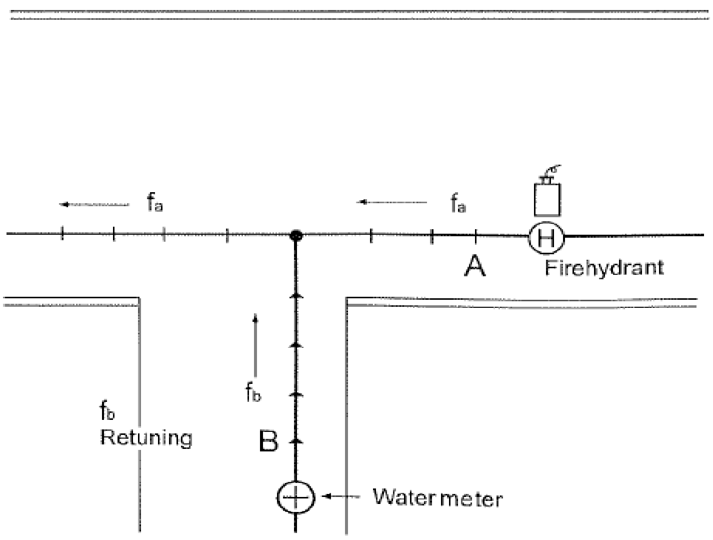




v. Start Vibration by receiver



vi. Trace the sound wave

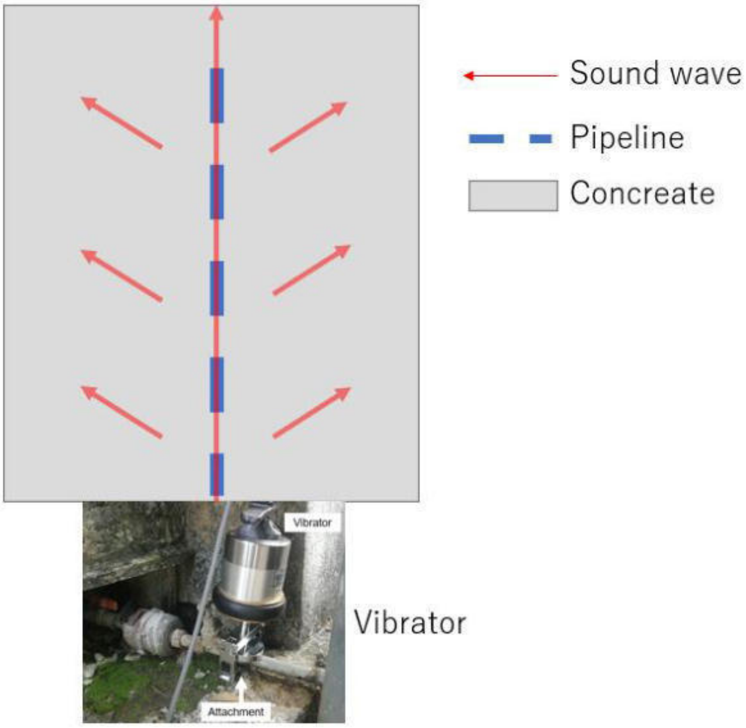


vii. Record the line of buried pipe

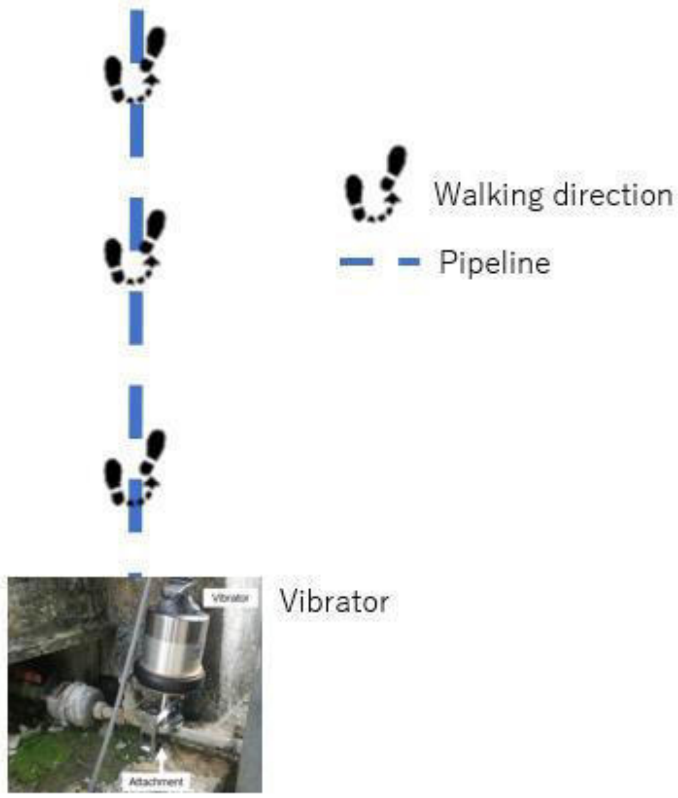
2.2.3 Methods and Approaches for Surveying Different Road Conditions

(1) Soil

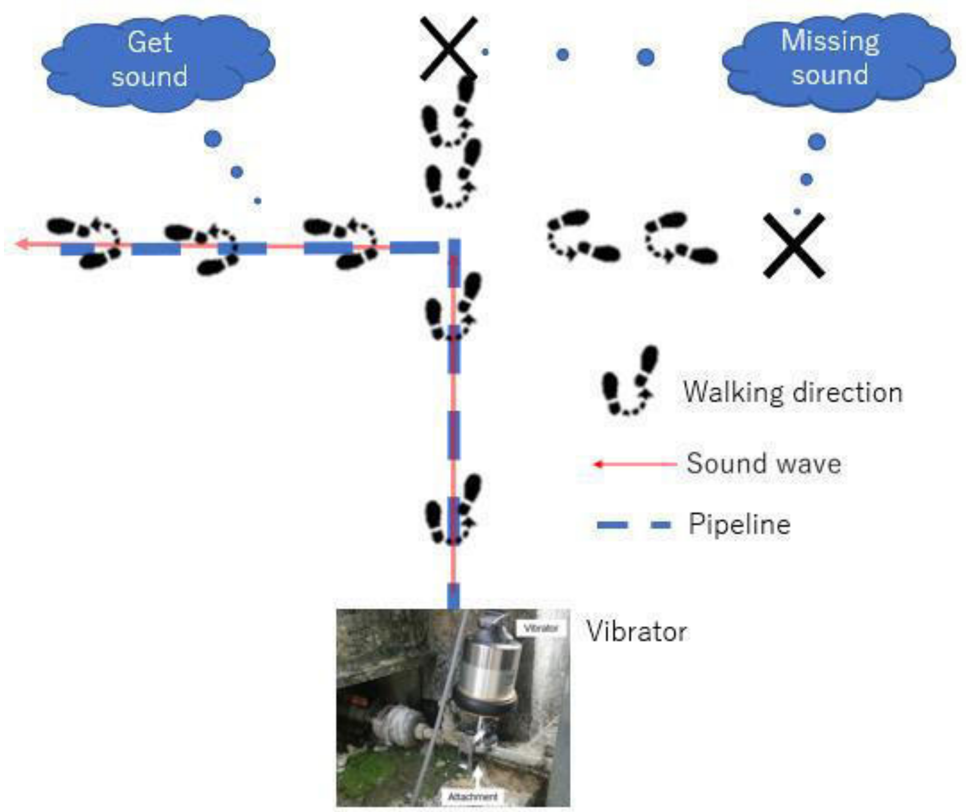
i. If the road surface to be investigated is soil, the vibration extends straight from the pipeline.



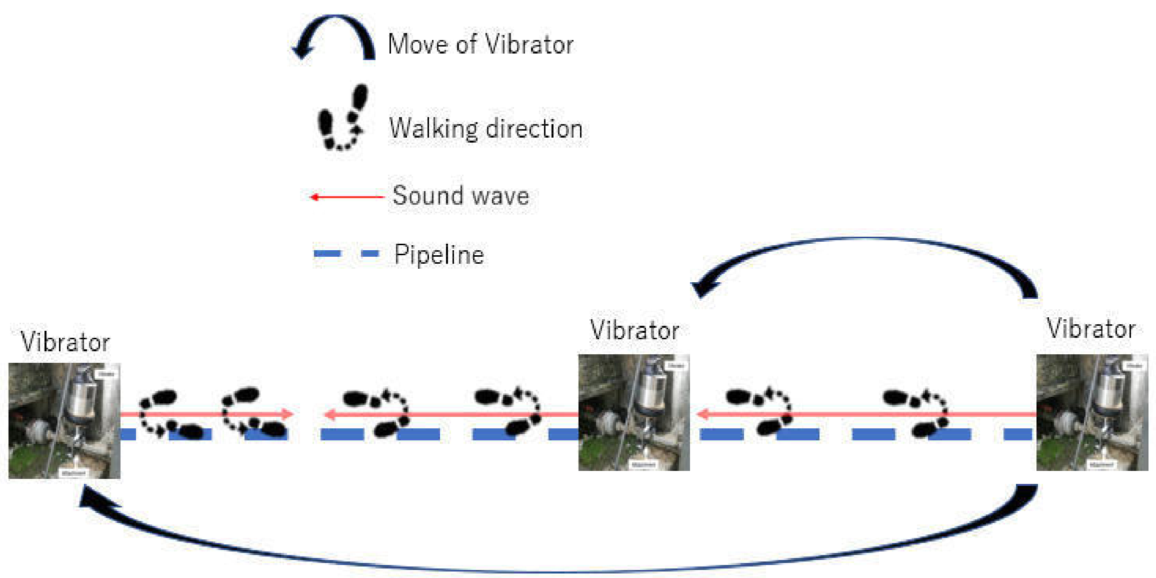
ii. The investigator tracks the line of sound



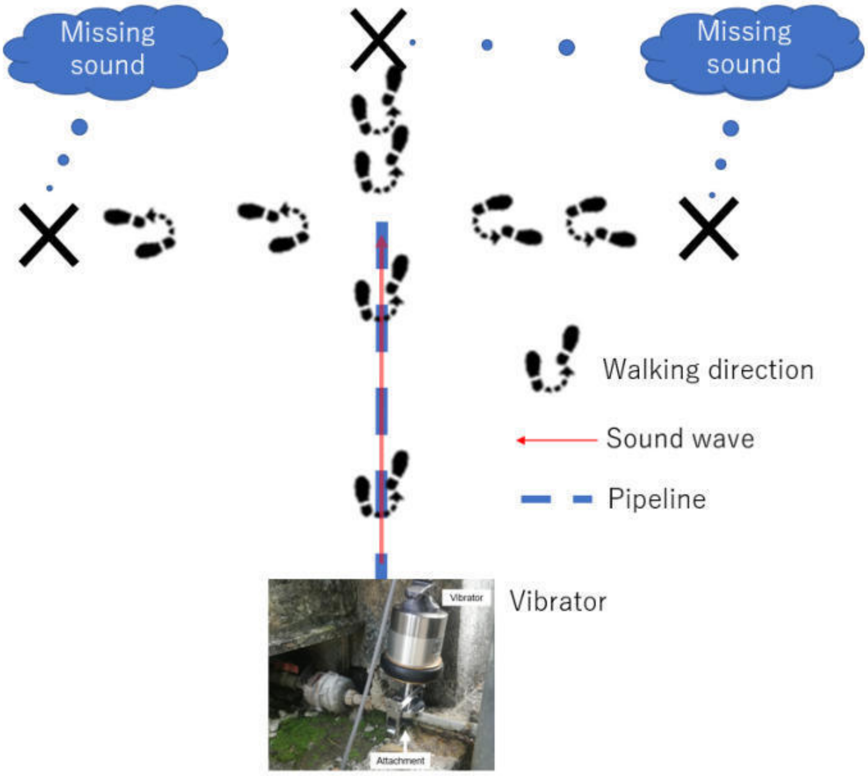
iii. If you miss the sound, move the pickup left or right. Then it goes in the direction of the sound.



iv. While chasing the sound, the sound may gradually fade and become inaudible. This is because the vibration of the vibrator has stopped reaching. In this case, install a vibrator on the pipe in the middle. Or install a vibrator on the other side of the pipe to track the sound from the other side.

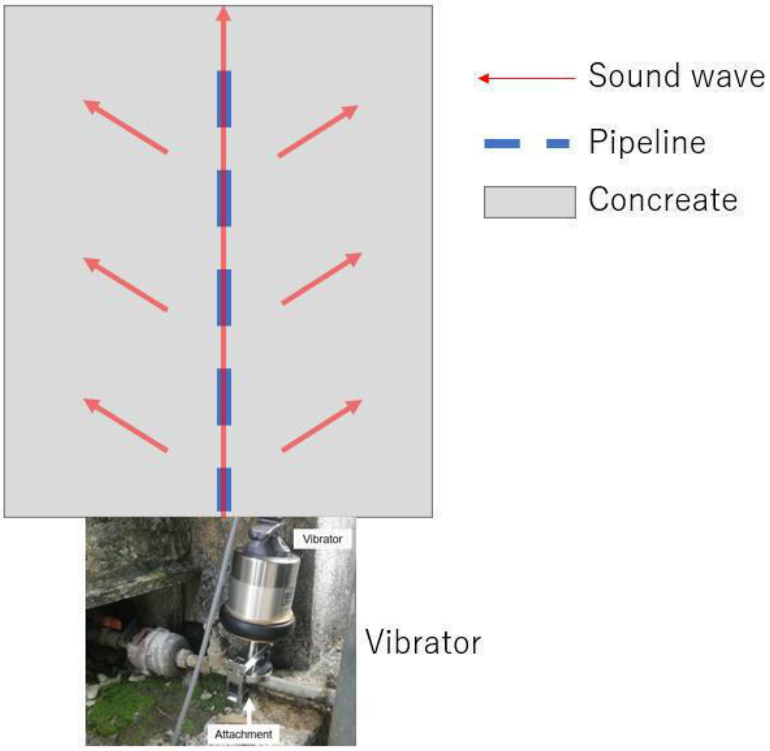


v. If the sound suddenly disappears and there is no sound on the left or right, it is highly likely that it is a pipe end.

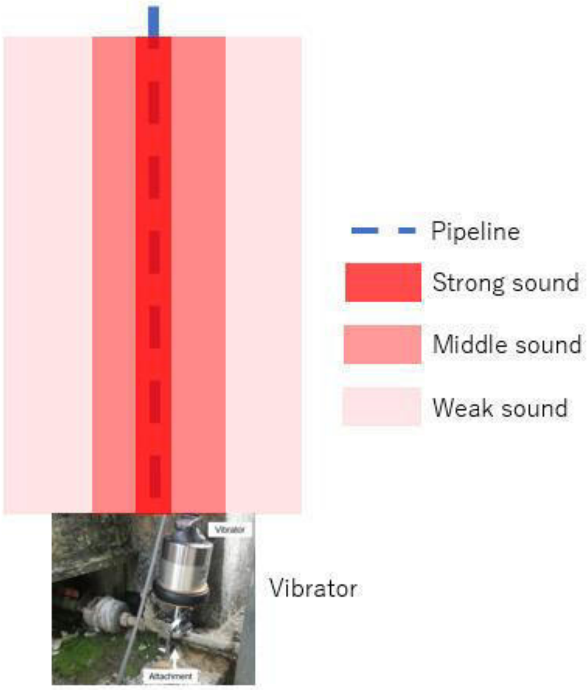


(2) Concreate

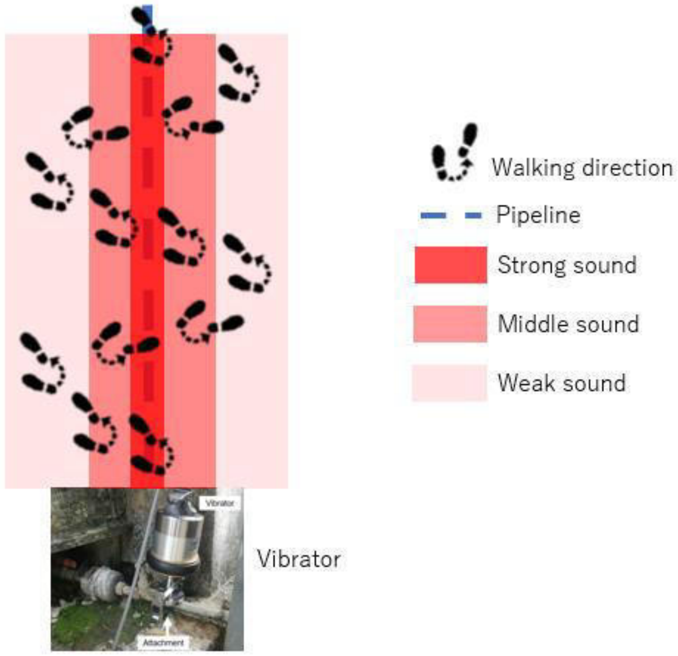
i. When survey on concrete pavement, the difficulty of surveying is high. The sound wave propagate to the concrete pavement and diffuses through it.Therefore, in order to find a pipe line, the sound on the pipe line must be compared to the sound diffused on the concrete to determine which sound is on the pipe..



ii. In this case, sound propagates as shown in the image below. The deep color part is the area where the sound propagates strongly.



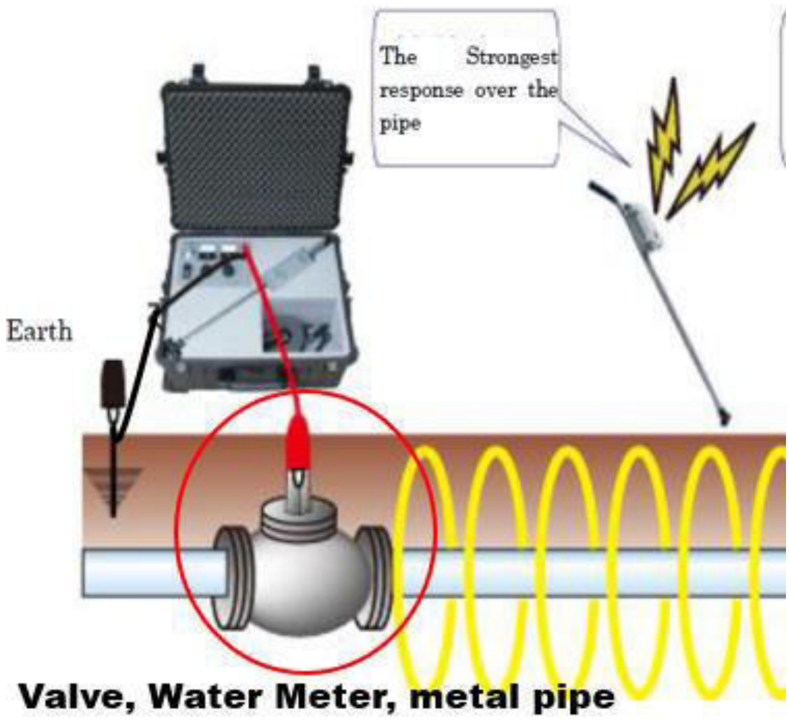
iii. When investigating on concrete pavement, walk in a zig-zag fashion based on where the sound is strongest, as shown in the figure below. Then, when the sound gets quiet, return to the center of the pavement and repeat the process.



iv. The idea when there is no sound is the same as for soil.

2.2.4 Other method for pipe locating

(1) Magnetic wave method



(2) Dowsing method

3 Practice

Practical training is conducted for buried valve and pipes in TY.

3.1 Valve locating

The target point of valve locating is as the figure of next page. A valve is buried in the target point. The flow of training is as below.

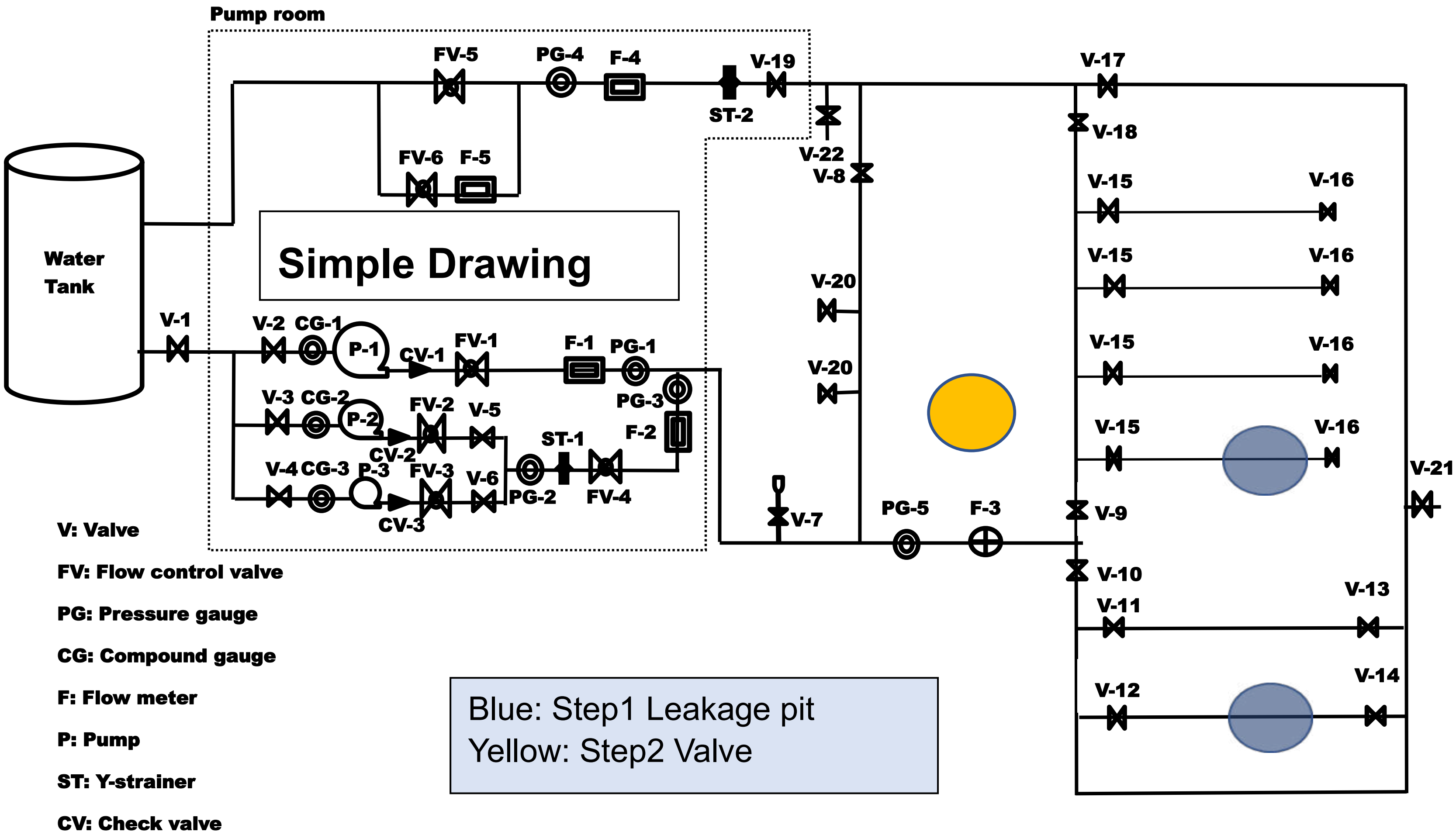
Step	Target	Check point	Purpose
1	Leakage pit	Blue circle	Detect buried leakage pits
2	Valve	Yellow circle	Detect buried valves

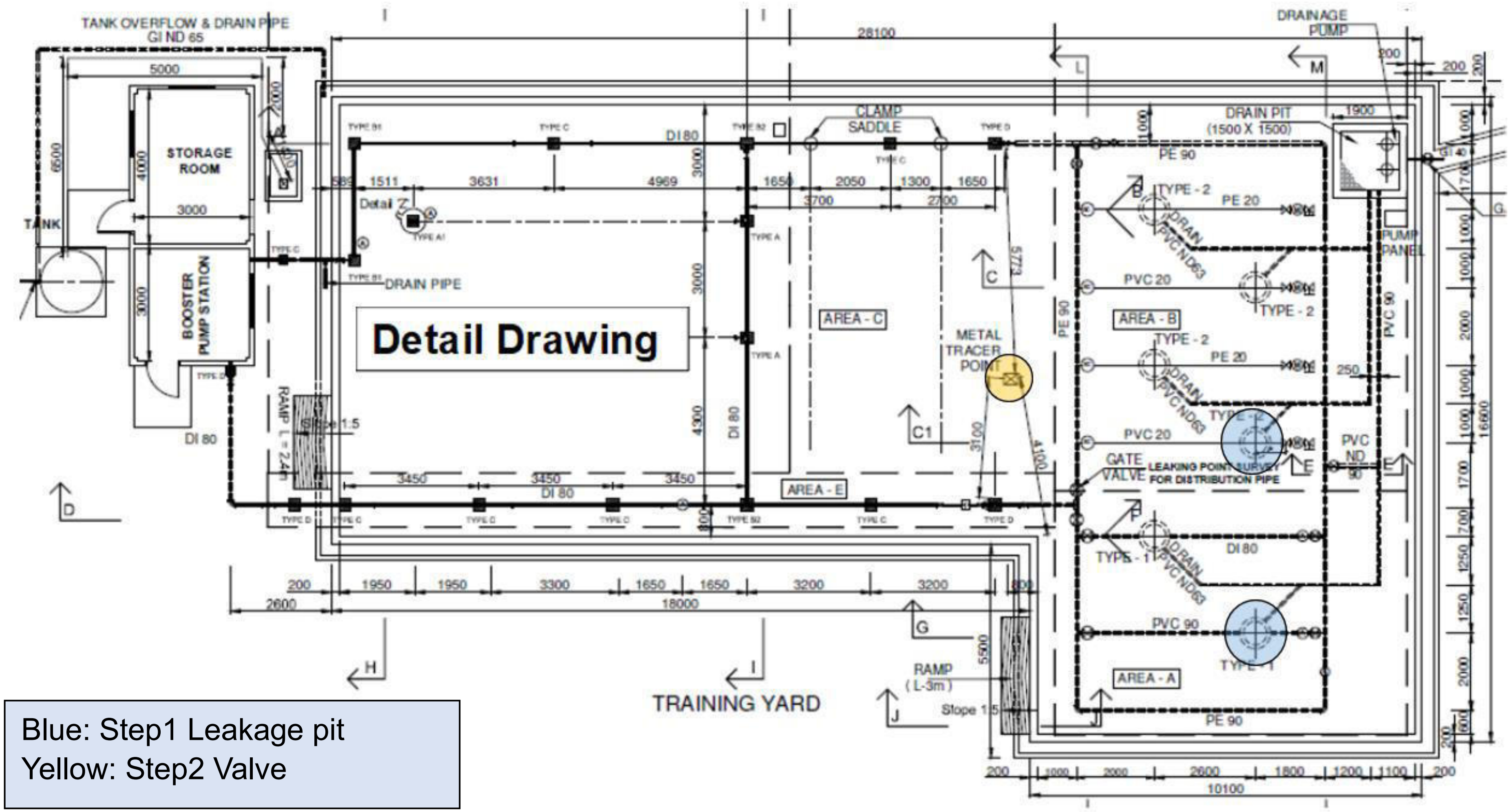
Step1:

Blue places are easy to detect. Initially, this is where you will learn how to use the equipment and investigate.

Step:2

After gaining experience in the blue area, train in the yellow area.


Pump room
Water Tank
Simple Drawing
V-1
V-2 CG-1 P-1
CV-1 FV-1 F-1 PG-1
V-3 CG-2 P-2
CV-2 FV-2 V-5
PG-3 F-2 ST-1
V-4 CG-3 P-3 FV-3 V-6 PG-2 FV-4
CV-3
FV-5 PG-4 F-4 V-19 ST-2
FV-6 F-5
V-22 V-8 V-20 V-20 V-7
PG-5 F-3
V-17 V-18 V-15 V-16 V-9 V-10 V-11 V-13 V-12 V-14 V-21
V: Valve
FV: Flow control valve
PG: Pressure gauge
CG: Compound gauge
F: Flow meter
P: Pump
ST: Y-strainer
CV: Check valve
Blue: Step1 Leakage pit
Yellow: Step2 Valve



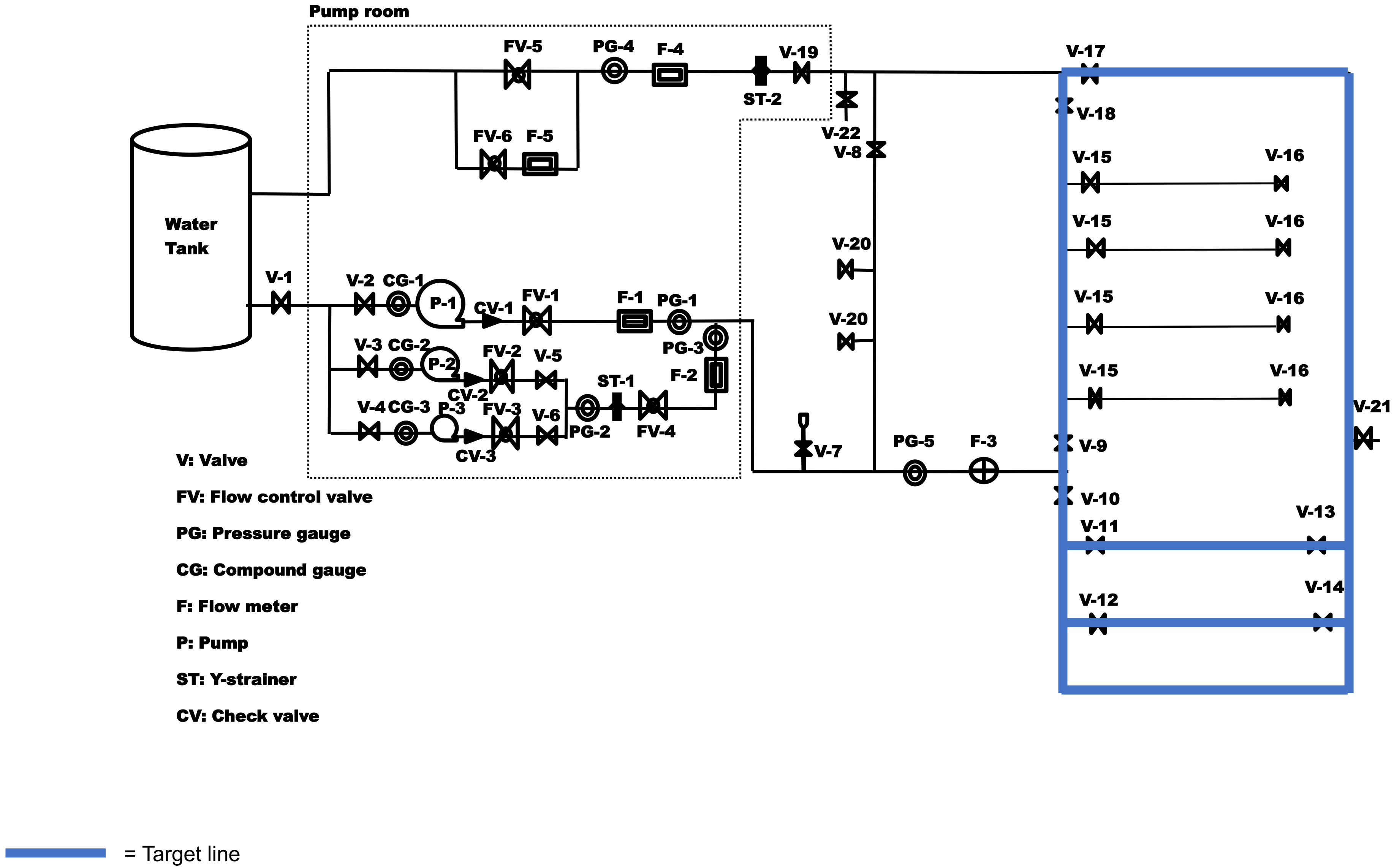
Blue: Step1 Leakage pit
Yellow: Step2 Valve

3.2 Pipe locating

The target line locating is as the figure of next page.

The flow of training is as below.

Step	Target	Check point	Purpose
1	Metal pipe	Line where V-11 locates	Learn the way of metal pipe tracing
2	Non-metal	Other lines	Learn the way of non-metal pipe tracing

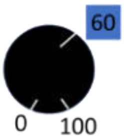
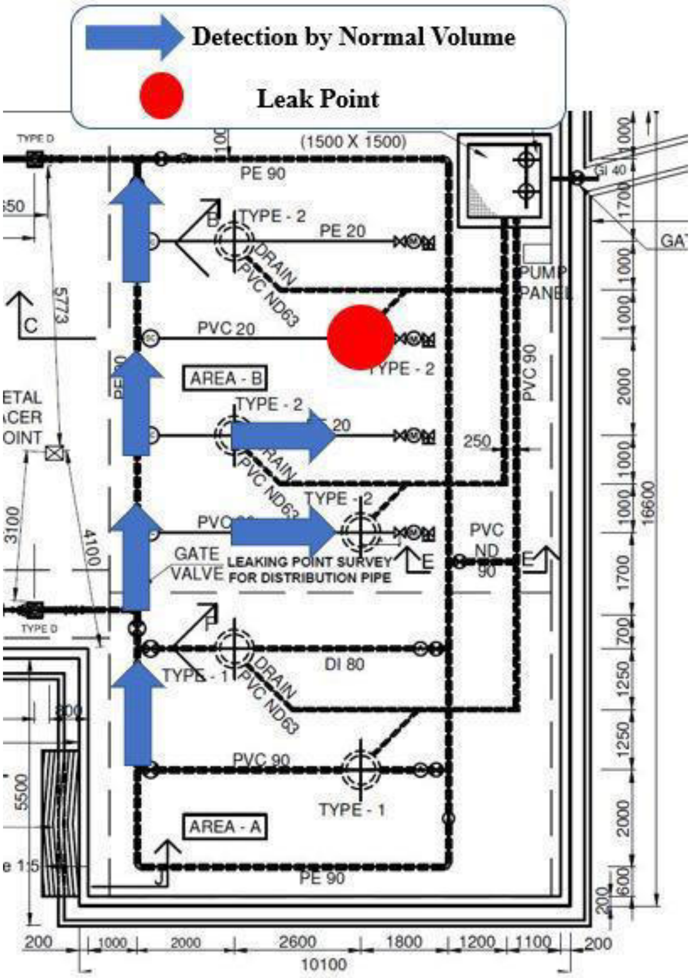

Pump room
FV-5
PG-4
F-4
V-19
ST-2
V-17
V-18
FV-6
F-5
V-22
V-8
V-15
V-16
Water
Tank
V-20
V-1
V-2
CG-1
P-1
CV-1
FV-1
F-1
PG-1
V-3
CG-2
P-2
FV-2
V-5
PG-3
F-2
ST-1
CV-2
V-4
CG-3
P-3
FV-3
V-6
PG-2
FV-4
CV-3
V-7
PG-5
F-3
V-9
V-21
V-10
V-11
V-13
V-12
V-14
V: Valve
FV: Flow control valve
PG: Pressure gauge
CG: Compound gauge
F: Flow meter
P: Pump
ST: Y-strainer
CV: Check valve
= Target line

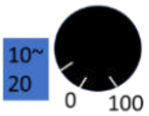
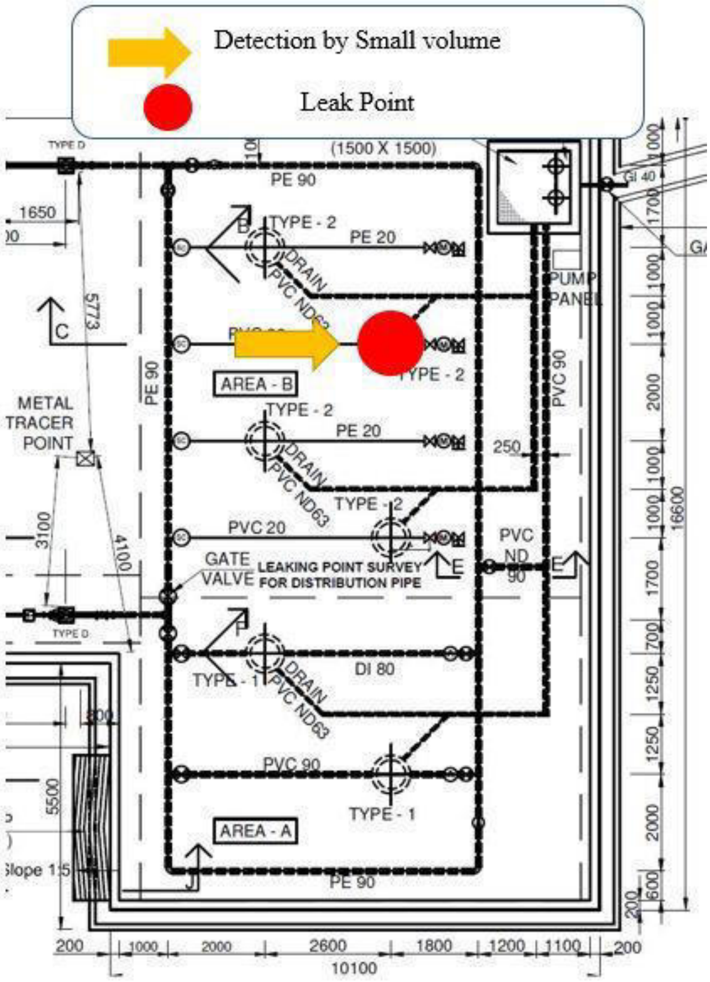
<u>Result of the Leak detection & Line Trace training.</u>

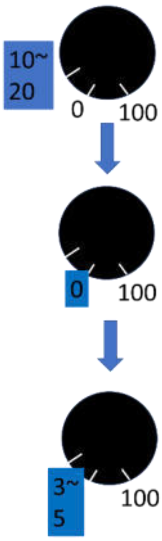
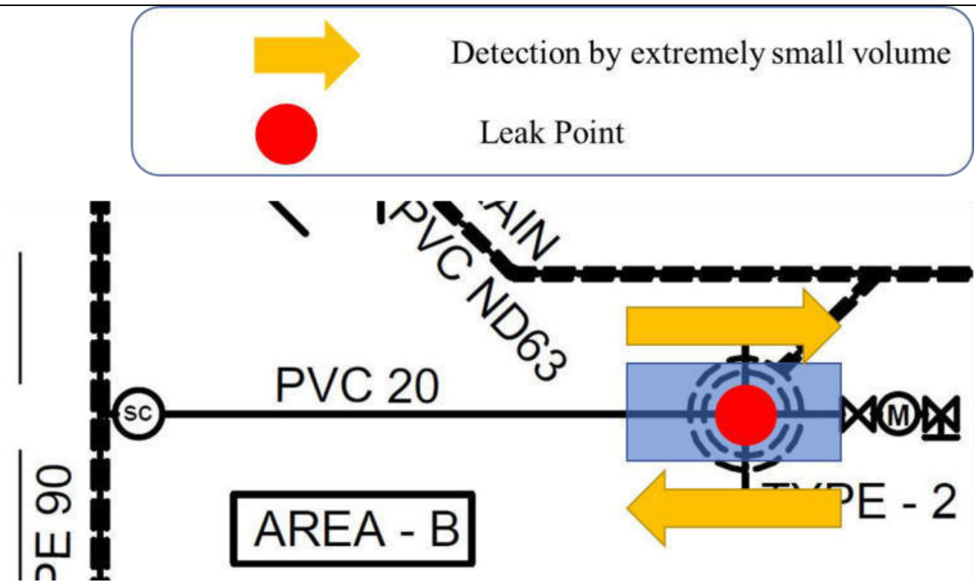
(1) Leak detection on concrete surface

Issue	The sound of the leak is too difficult to identify the point of the leak, <u>especially under high pressure.</u>
Suggestion	Turn the volume of the Leak Detector down during the survey. In this way, you will hear the leak only near the pinpoint location. However, in the actual site survey, you must detect for leaks that we do not know where they are. At that time, if the volume is reduced from the beginning, it may not be possible to detect the leakage. Therefore, at the actual site, the survey is conducted according to the following procedure. JET recommend that you follow the same procedure at TY.
Result	• NWSDB R/P followed the recommended methods. • But the issue is the same as previous, because R/P said that they can easily identified the leak area but it very hard to pinpoint the leakage.

Step 1	Survey starts away from the leak point and identify leaking pipe

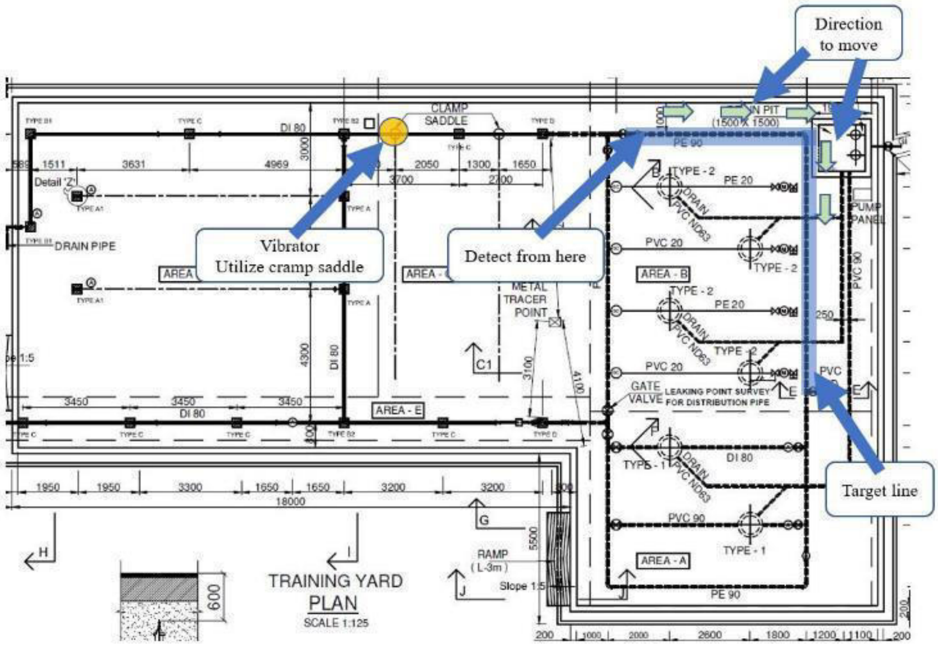
<table>
<tr>
<td>Volume 60%

</td>
<td>
</td>
</tr>
<tr>
<td>Step 2</td>
<td>Identify leaking point by reducing the volume of the Detector.</td>
</tr>
</table>

Volume 10~20% 	
Additional Step	Q: When they come closer to the leaking point, they reduce the sound volume of the equipment, but they cannot narrow down the area less than 1.5 m of radius. Please give them the advice. A: In cases where it is not possible to narrow down the pinpoint in step 2, reduce the volume further.
	Reduce the volume further when you can narrow down to 1.5m. Instead of gradually lowering the volume, set volume to 0 and gradually increase volume to investigate. [For example] Volume 3 and investigate a range of 1.5 m (blue area in below figure).

	 1) If there is no sound anywhere, the volume is too low. Please increase the volume a little and investigate. 2) If all the sounds in the blue area sound the same, it means the volume is too high to detect. Please reduce the volume and investigate again. By repeating steps 1) and 2), you will hear the sound only at the pinpoint location of the leak. In this way, you can identify the location of the leak by finely adjusting the volume.
Tips of work	1) CP members seem to mainly keep attention on the display but use your ears to judge the change in sound, not the needles on the display. Ear sense is very important in this method. 2) Leak surveying is a skill that usually takes hundreds of iterations to master. Therefore, you need to challenge yourself many times during training to get used to the survey method and the sound of leak. Getting closer to the pinpoint of leaks with less training is a rare case for the Japanese and even for other countries. If you can continue this training, you will be a good trainer.

Issue	There is not enough distance between the vibrator and receiver so that the sound can be heard from the whole area and cannot be line trace.
Suggestion 1 At TY	Keep the distance between the vibrator and the receiver. Start from a small volume
Suggestion 2 At outside TY	Use the pipe that WB has already tried.
Result	• NWSDB R/P said that Suggestion 1 is not applicable because sound of the vibrator is disturbing to continue the test. • Suggestion 2 is OK to proceed.

At TY	Install vibrators on valves and other parts of the repair area to detect buried pipes. If the vibrator is still loud, turn the volume down to start. If it is difficult to hear even if you install the vibrator in the location shown in the figure below, install it further away.

	
Out of TY	Use the pipe that WB has already tried.
	

Q: The noise of vibrator is very noisy. I wonder it is appropriate. I uploaded the movie at the site at following link, please check and give your comment.

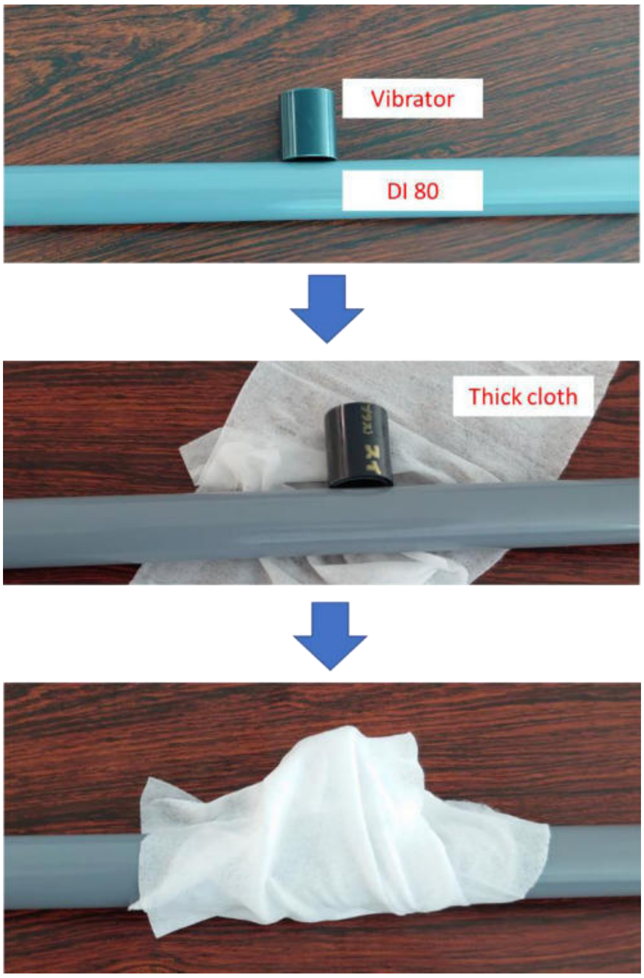
https://kfs.kddi.ne.jp/public/3tTcgAxPlkhAcUABL0l36kb2dE0yYGr1y5-6oXLLGTk4

Pass word: 0rqUSLosIREE

A: We conducted a trial and were able to eliminate the noise of the vibrator. However, it is difficult to carry out the training because of another echo on the surface.

Therefore, try to perform TOT in the place where you have succeeded in detecting the pipe.

Countermeasures for dealing with noise of vibrator at the site are as follows.

Cause of noise	Vibrator is normal. 1) Since it is installed directly on the iron pipe, it is echoing. 2) Since there is no shield between the investigator and the vibrator, the echoed sound interferes with the investigation.
Additional Countermeasures	[Prevent Vibrator sound] After the equipment is installed, please cover the pipe and machine with several layers of thick cloth. You can reduce the noise generated by the vibrator considerably. 

【Photo of test on 22 Apr 2021】

[Vibrator setting]　*In the training yard, we were able to reduce the noise by wrapping it in the cloth. Therefore, we will advise on the appropriate installation angle at the site.

By installing the vibrator sideways, the vibrator itself is tilted. This will create a gap between the pipe and the vibrator, which will generate extra noise.

<table>
<tr><td>Horizontal

</td><td>➡</td><td>Vertical

</td></tr>
</table>

1) Install the sensor vertically
2) Place a thin cloth between the pipeline (accessory) and the vibrator (metal fittings) to eliminate the gap.

	[Others] The engine of the truck is running beside at TY in the video. When conducting a listening survey, make sure that there is no other noise. Please turn off the engine next time.
Tips of work	There is also a lot of noise in the field. It is important to reduce the sound other than that heard from the detector.

Q: Also the maximum signal is found at the different position from the pipe buried. Why?

Above photos show the maximum signal points they detected.

Investigation of the cause	The noise of the vibrator may affect it. After reducing the noise of the vibrator, I investigated it again. As a result, the sound was reduced, but it was found to be a little higher than the location on the nearby pipeline.
Cause of Peak sound (Possibility)	A1: Sound is echoing in the side gutter A2: Sound echoing in the buried rebar A3: Some of the above factors mixed.

Training Guideline

2. Distribution Pipe Installation

a. HDPE Distribution Pipe Installation

Table of contents

1 Outline

1.1 Purpose

Purpose of training	The purpose of this training is to provide a practical training on installation of HDPE distribution pipes, pressure Tapping and pressure test. Also, it is important to share the knowledge of this training with not only the staff of NWSDB but also contractors.
Training Contents	➢ Butt fusion joint ➢ Flange joint ➢ Under Pressure Tapping ➢ Pressure test

1.2 Flow of training with time schedule

The total time is 3 hours and 30 minutes.

No.	Activity	Required time	Venue
1	Lecture	45 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse
3	Preparation for practical training	10 min.	(Distribution pipe or Service pipe connection area)  
	*Details are described in “3 Practice (Page 7)” *Activate pump of TY *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse 		
4	Practical training	120 min	TY
	*Details are described in “3 Practice (Page 7)” ➢ Butt fusion joint ➢ Flange joint ➢ Under Pressure Tapping ➢ Pressure test		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse 
6	Move to lecture room	5 min.	Lecture room
7	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.



- Do not eat food in the TY.



2 Knowledge acquisition

2.1 Outline of HDPE

- Standard of HDPE pipes
  - ISO 21307: 2011 Plastics pipes and fittings, butt fusion jointing procedures for polyethylene (PE) pipes and fittings used in the construction of gas and water distribution systems.
- Handle with care not to make scratch
- Keep away from ultraviolet
- Use proper jointing tools or cutters which are dedicated to HDPE pipes
- Advantages and disadvantage of HDPE pipe

Advantage
· Excellent corrosion resistance, flexibility, cold and impact resistance 
· Almost all pipes used in current pipe new installations are PE pipe
· Greater strength and can handle higher temperatures than other pipe materials
· The life cycle and construction cost of PE pipe can be less than other metal pipes
· Connection method by fusion welding forms leak-free joints that are as strong as, or stronger than, the pipe itself
· PE pipe installations are cost-effective and have long-term cost advantages due to the pipe's physical properties, leak-free joint and reduced maintenance costs
Disadvantage
· Connection method by fusion welding requires a high skill
· Vulnerable to external wounds and heat
· Vulnerable to the penetration of chemicals from the outside, such as gasoline and solvent

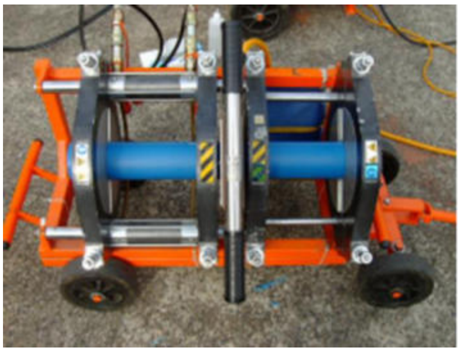
- Marking of pipe

  Each pipe shall be legibly and indelibly marked at intervals not more than 3m with the followings:
  - Manufacturer's name or registered trademark
  - Material
  - Nominal outside diameter, wall thickness
  - Maximum allowable pressure at 30 degree Celsius, PNT
  - Batch number
  - Intended use (e.g. W/P)
  - Angle of bending of bends
  - Diameter of both ends in reducers and specials

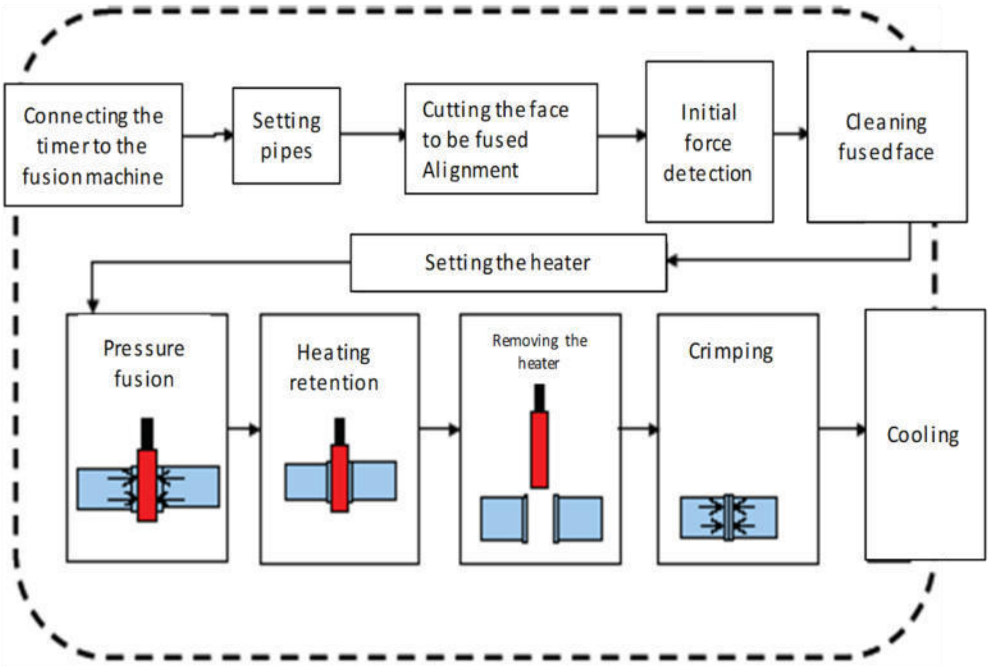
2.2 Jointing method

There are mainly three jointing method for HDPE distribution pipes: Butt fusion, Flange joint and Electro fusion joint.

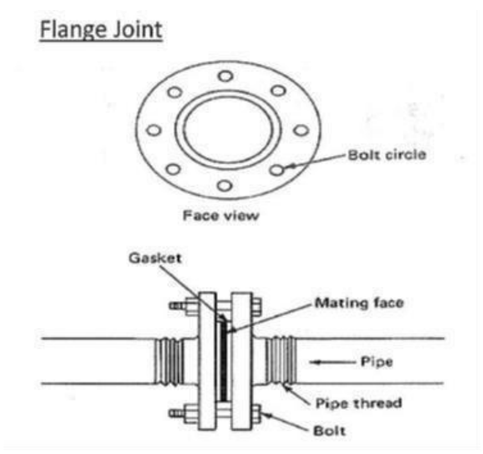
2.2.1 Butt fusion joint

Butt fusion joint	Details
	Butt fusion should only be used for jointing pipes of same outer diameter and standardized dimension. Dissimilar wall thicknesses must not be jointed.

➢ Procedures of butt fusion jointing



2.2.2 Flange joint

Flange joint	Details
	Flange joint is used for many installations on the ground and other specialized applications. A flange jointing is a method for connecting pipes, valves, pumps and other equipment to form a piping system. A flange joint is rigid and can bear both tension & compression as well as limited degree of shear & bending. Flanged joints are made by bolting two flanges with a gasket between them to provide a seal.

2.2.3 Electro fusion joint

Electro fusion joint	Details
	Electro fusion is a method of jointing MDPE, HDPE and other plastic pipes using special fittings that have built in electric heating elements which are used to weld the joint for connection. It must not be used when raining or high ground water level.

2.3 Construction management

Followings are important points for construction management

- Material Inspection
- Pre inspection
- Post inspection
- Safety arrangement
- Supervision
- Backfilling
- Pressure Testing

3 Practice

3.1 Butt fusion joint

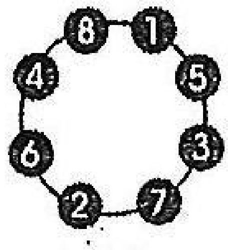
Preparation			
Item	Butt fusion welding machine	1	
	Generator	1	
	HDPE pipe (Dia. 90mm)	1	
	HDPE pipe cutter	1	

- Adjust straight pipe length to install it to butt fusion welding machine by HDPE pipe cutter
- Fusion setting should be stared before explanation

3.2 Flange joint

Preparation			
Item	Flange joint	1	
	HDPE pipe (Dia. 90mm)	2	
	Torque wrench	1	
	Bolts and nuts	8	
	Gasket	1	

<table>
<tr><th>Steps</th><th>Procedures</th></tr>
<tr><td>1</td><td>Clean flange faces, bolts, nuts and a gasket to prevent foreign matters</td></tr>
<tr><td>2</td><td>Tighten all bolts by hand and ensure that adjoining flanges and gasket are correctly aligned. Lightly tighten the bolts using a calibrated torque wrench in the correct sequence. (see the illustration). Tighten gradually by torque wrench and ensure all bolts reached specified torque.



8 Bolts</td></tr>
<tr><td>3</td><td>Visually confirm that flange faces are joined in parallel each other without gap and the gasket is precisely positioned</td></tr>
<tr><td>4</td><td>Execute every jointing work by filling necessary items in a check sheet. The example of check sheet is shown below.</td></tr>
</table>

date, year (   )

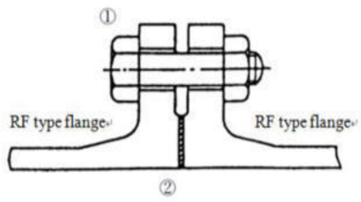
Flange joint check sheet

Construction name (   )

Observation point (   )

Diameter, Pipe materials (   )

Plumber (   )



Product Name and Shape								
Product No.								
Diagram								

Joint No.								
Cleaning								
① Bolt	Quantity							
	Torque (N·m)							
② Position of gasket								
Determination								

Determination criteria	① Bolt fastening torque:	Based on the standard fastening torque in Table .
	② Position of gasket:	Parallel joining of flange faces without misalignment of gasket.

3.3 Under Pressure Tapping

Preparation			
Item	Tapping machine	1	
	HDPE pipe (Dia. 90mm)	1	

- Mark the tapping point on the HDPE pipe
- Conduct tapping and ferrule installation

3.4 Pressure test

Preparation			
Item	Water pressure test pump	1	
	HDPE pipe (Dia. 90mm)	1	

Steps	Procedures
1	Connect the high pressure hose with Water pressure test pump (Be careful to put rubber ring at the end of hose). Then, fill the water tank of pump with clear water, pull off the plug, fasten the pressure relief valve. Then, connect the other end of the high pressure hose to the test pipe.
2	Apply pressure up to the prescribed pressure level by Water pressure test pump (4bar, 1-2minutes) and observe the pressure gauge to check the pressure decrease or increase.
3	Visual check of leaks. If visible leaks found repair it.
4	After testing, loosen pressure relief valve, release the pressure and remove the high pressure hose.
5	Make sure there is no drop of water remaining in the machine, clear it for next use.
6	Record the pressure test. The example of pressure testing report is as below.

PRESURE TESTING REPORT

LAYING OF uPVC PIPES & SPECIALS

Contractor : SD & CC

Contract No :

Road/ Note : Dehiwala Maharagama

Date : 17/05/2017

Time : 10.30 p.m.

01. Location Data

Change From : 0+045 LHS

Change To : 0+170 LHS

Pipe Diameter : 160 mm

Type : uPVC

IL of Lowest Point :

Distance :

IL of Highest Point :

Class :

Elevation of Pressure Guage :

Couplings :

Fittings :

02. Working pressure (t= 24 hr)

Date : 17/05/2017

Time From : 10.30 p.m.

Pressure 6 Bar

Temperature : °C

Date : 18/05/2017

Pressure 6 Bar

Temperature : °C

Time To : 11.30 p.m.

03. Test Pressure (t= 2 hr)

Date : 18/05/2017

Time/ Pressure 11.30 p.m / 9 bar

Time	Pressure (Bar)	Pressure Loss(Bar)	Temperature (°C)
11.30 p.m.	9	-	
12.00 a.m.	9	-	
12.30 a.m	9	-	
1.00 a.m.	9	-	
1.30 a.m.	9	-	

Test Result : Passed : Passed Failed :

04. Filled Leakage Test $Qm = \frac{L \times D \times \sqrt{P}}{795,000}$

Test Duration	Additional Water Volume (L)	
	Actual	Allowable

Qm	=	Allowable leakage in litters per hour (1/hr)
L	=	Length of pipe tested in meters
D	=	Nominal diameter of the pipe in millimeters (mm)
P	=	Average test pressure during test in Kilopascals(kPa)

Test Result

Passed : ✓

Failed :

Test Performed By ; [signature]

Name / Signature of Contractors

Witnessed By; [signature]

Name / Signature of Engineer

Training Guideline

2. Distribution Pipe Installation

b. PVC Distribution Pipe Installation

Table of contents

1 Outline

1.1 Purpose

Purpose of training	To reconfirm the uPVC pipe connection procedures through a practical training program and utilize the experience and knowledge in providing guidance to the contractors at the time of supervising distribution pipe laying.
Training Contents	➢ Rubber ring joint ➢ Solvent cement joint

1.2 Flow of training with time schedule

The total time is 2 hours and 15 minutes.

No.	Activity	Required time	Venue
1	Lecture	30 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Distribution pipe or Service pipe connection area)  
3	Preparation for practical training	10 min.	
	*Details are described in “3 Practice (Page 7)” *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse 		
4	Practical training	60 min	TY
	*Details are described in “3 Practice (Page 7)” ➢ Rubber ring joint ➢ Solvent cement joint		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse 
6	Move to lecture room	5 min.	Lecture room
7	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.



- Do not eat food in the TY.



2 Knowledge acquisition

2.1 Outline of PVC

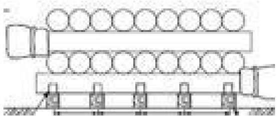
- Standard of PVC pipes
  - SLS 147:2013 - Unplasticized poly (vinyl chloride) pipes for water supply and for buried and above ground drainage and sewerage under pressure
  - ISO 1452:2009 - Plastic piping systems for water supply and for buried and above ground drainage and sewerage under pressure—Unplasticized poly (vinyl chloride) (UPVC-U)
- Advantages and disadvantage of PVC pipe

Advantage
· Anti- corrosion (except for some solvent) · High stiffness · Low weight · Cost effectiveness 
Disadvantage
· Pressure resistance is not as good as DI pipes. · Flexibility is not as good as HDPE pipes. · Lifespan is more than 20 years but less than DI pipes. · Vulnerable to external wounds and heat · Low UV resistance · Low toughness · Lower strength than other pipes

- Marking of pipe

  Each pipe shall be legibly and indelibly marked at intervals not more than 3m with the followings:
  - Manufacturer's name or registered trademark
  - Material
  - Nominal outside diameter, wall thickness
  - Maximum allowable pressure at 30 degree Celsius, PNT
  - Batch number
  - Intended use (e.g. W/P)
  - Angle of bending of bends
  - Diameter of both ends in reducers and specials

➢ Handling

Situation	Details
Transport 	To prevent damage or deformation to pipe, fit cushioning between pipe and platform, between rope and pipe, and at pipe ends.
Storage 	Pipe should be stored indoors if possible. When storing pipe outside, build a portable roof or cover with breathable sheeting to prevent exposure to direct sunlight, and maintain good airflow to prevent heat retention.

2.2 Jointing method

There are mainly two jointing method for PVC distribution pipes: Rubber ring joint and Solvent cement joint.

2.2.1 Rubber ring joint

Rubber ring joint	Details
	Rubber ring joint is used for the installation of long span of buried pipelines with few accessories. Integral socket and spigot ends are jointed, or two spigot ends are jointed with a double bell coupling.

2.2.2 Solvent cement joint

Rubber ring joint	Details
	Solvent cements for pipes and fittings are flammable, so there should be no smoking or other source of heat or flame in working or storage areas. Be sure to work only in a well-ventilated space and avoid unnecessary skin contact with all solvents.

2.3 Construction management

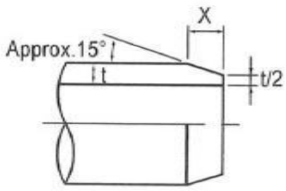
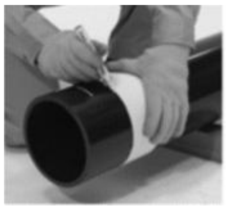
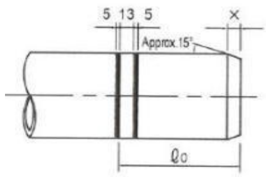
Followings are important points for construction management

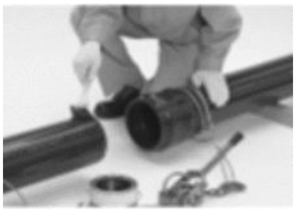
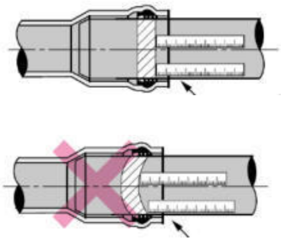
- Factory Inspection
- Post inspection
- Quality Assurance and Testing
- Safety arrangement
  - Use of proper safety tools
  - Ventilate enough when using adhesive
- Supervision
- Backfilling and compaction
- Pressure Testing

3 Practice

3.1 Rubber ring joint

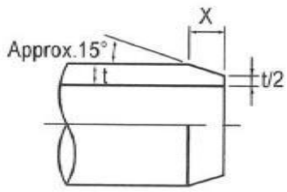
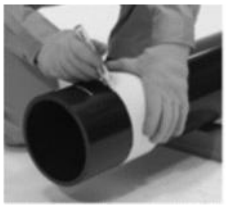
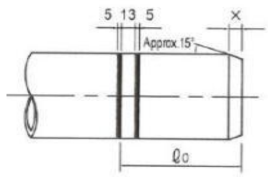
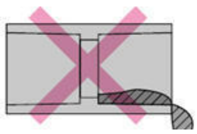
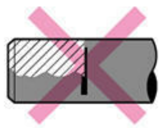
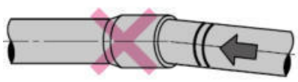
Preparation			
Item	Socket end pipe	1	
	PVC pipe	1	
	Pipe cutter	1	
	Lubricant	1	
	Chamfer	1	
	Marker	1	
	Dry cloth	1	
	Check gauge	1	

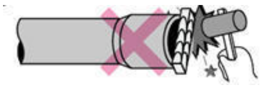
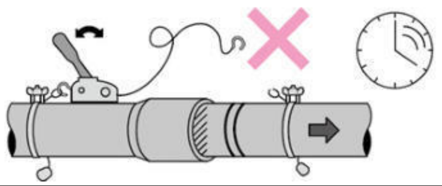
Steps	Procedures	
1	Draw a cut line around the pipe. Cut the pipe along the cut line at right angle to its longitudinal axis. If the cut was not made in a straight line, perform the cutting again.	
2	Use a pipe chamfering tool to chamfer the outer surface of the cut edge.	
3	Use a marker to draw two marker lines around the full circumference of the pipe to indicate the depth of insertion.	 
4	Clean the inner surface of the socket and the outer surface of cut pipe with dry cloth.	

5	Thoroughly apply the lubricant evenly along the circumference of the rubber ring at the socket Apply lubricant to the full circumference of the pipe being inserted, from the edge of the cut pipe to the marker lines. Especially be sure to completely coat the chamfered part.	
6	If you use a ratchet clamp to perform the insertion, loosely fit the chamfered part of the pipe to be inserted into the rubber ring at the socket, and then use an insertion machine, etc. to insert the pipe up to marker lines.	
7	After insertion, use the check gauge to confirm that the rubber ring is positioned correctly. If it is not correctly inserted, promptly pull out the pipe and re-perform the work.	 

3.2 Solvent cement joint

Preparation			
Item	Socket	1	
	PVC pipe	1	
	Pipe cutter	1	
	Adhesive	1	
	Chamfer	1	
	Marker	1	
	Dry cloth	1	

Steps	Procedures	
1	Draw a cut line around the pipe. Cut the pipe along the cut line at right angle to its longitudinal axis. If the cut was not made in a straight line, perform the cutting again.	
2	Use a pipe chamfering tool to chamfer the outer surface of the cut edge.	
3	Use a marker to draw two marker lines around the full circumference of the pipe to indicate the depth of insertion.	 
4	Clean the inner surface of the socket and the outer surface of cut pipe with dry cloth.	
5	Apply adhesive evenly from the interior of the fitting to the cut pipe.	 
6	After applying adhesives, insert the pipe straightly into the fitting until the gauge line and hold.	

		
7	Remove excess adhesive from the pipe immediately after jointing, and do not apply pressure to the jointed area.	

Training Guideline

2. Distribution Pipe Installation

c. DI Distribution Pipe Installation

Table of contents

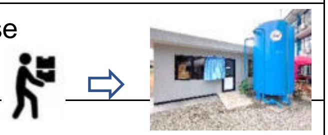
1 Outline

1.1 Purpose

Purpose of training	The purpose of this training is to provide a practical training on installation of DI distribution pipes, pressure tapping and pressure test. Also, it is important to share the knowledge of this training with not only the staff of NWSDB but also contractors.
Training Contents	➢ Push fit joint ➢ Flange joint ➢ Under Pressure Tapping ➢ Pressure test

1.2 Flow of training with time schedule

The total time is 3 hours and 30 minutes.

No.	Activity	Required time	Venue
1	Lecture 	45 min.	Lecture room
2	Move to TY 	5 min.	TY & Warehouse
3	Preparation for practical training	10 min.	(Distribution pipe or Service pipe connection area)  
	*Details are described in “3 Practice (Page 6)” *Activate pump of TY *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse 		
4	Practical training	120 min	TY
	*Details are described in “3 Practice (Page 6)” ➢ Push fit joint ➢ Flange joint ➢ Under Pressure Tapping ➢ Pressure test		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse 
6	Move to lecture room 	5 min.	Lecture room
7	Q & A & evaluation 	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.

- Do not eat food in the TY.

2 Knowledge acquisition

2.1 Outline of DI

- Standard of DI pipes
  - ISO 2531 : 2009 Ductile iron pipes, fittings and accessories for pressure pipe lines
  - EN 545 : 2010 Ductile Iron pipes, fittings, accessories and their joints for water pipelines. Requirements and test methods.
- Advantages and disadvantage of PVC pipe

Advantage	
· High strength, high toughness · It is resistant to corrosion and has high electric resistance, so it is not easily affected by electrolytic corrosion. · Good workability	
Disadvantage	
· Relatively heavy weight · If the soil is corrosive, external corrosion protection is required · It is easy to corrode if the internal or external anticorrosion protection is damaged	

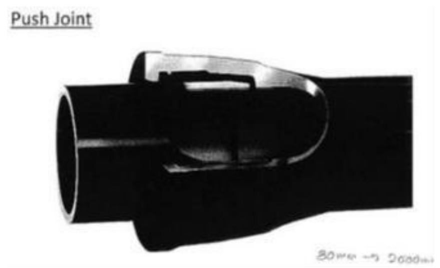
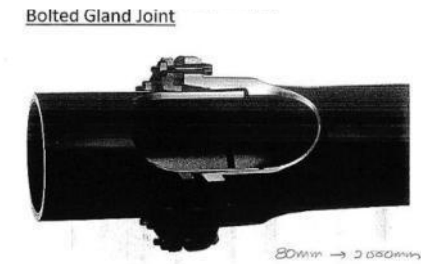
- Marking of pipe

  Each pipe shall be legibly and indelibly marked at intervals not more than 3m with the followings:
  - Manufacturer's name or registered trademark
  - Material
  - Nominal outside diameter, wall thickness
  - Maximum allowable pressure at 30 degree Celsius, PNT
  - Batch number
  - Intended use (e.g. W/P)
  - Angle of bending of bends
  - Diameter of both ends in reducers and specials

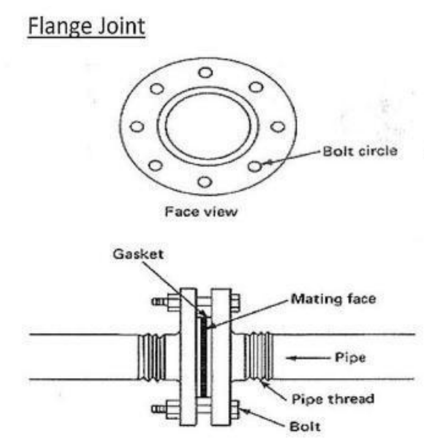
2.2 Jointing method

- There are mainly two jointing method for DI distribution pipes: Push fit joint and Flange joint.

2.2.1 Push fit joint

Push fit joint	Details
 	The most popular, quickest and easiest to assemble joint for DI pipe and fittings in underground applications is the push fit joint. Assembly of the push fit joint is simple, more economical, faster to install, more trouble-free, and offers better service than mechanical joints. Push fit joint of modern DI pipe systems are particularly effective in preventing problems of infiltration and leakage.

2.2.2 Flange joint

Flange joint	Details
	Flange joint is used for many plant installations on the ground and other specialized applications. A flange jointing is a method for connecting pipes, valves, pumps and other equipment to form a piping system. A flange joint is rigid and can bear both tension & compression as well as limited degree of shear & bending. Flange joints are made by bolting two flanges with a gasket between them to provide a seal.

2.3 Construction management

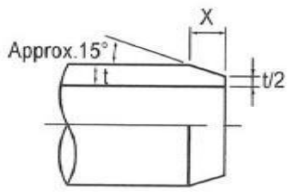
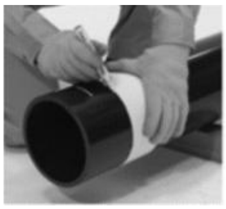
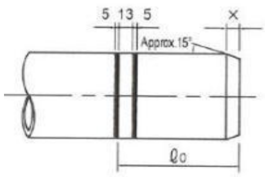
Followings are important points for construction management

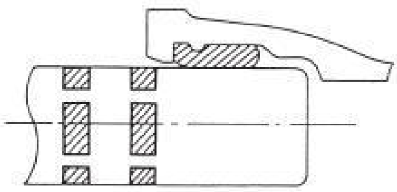
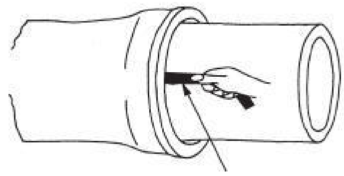
- Material Inspection
- Pre inspection
- Post inspection
- Safety arrangement
- Supervision
- Backfilling
- Pressure Testing

3 Practice

3.1 Push fit joint

Preparation			
Item	Socket end pipe	1	
	DI pipe	1	
	Pipe cutter	1	
	Lubricant	1	
	Chamfer	1	
	Marker	1	
	Dry cloth	1	
	Check gauge	1	

Steps	Procedures	
1	Draw a cut line around the pipe. Cut the pipe along the cut line at right angle to its longitudinal axis. If the cut was not made in a straight line, perform the cutting again.	
2	Use a pipe chamfering tool to chamfer the outer surface of the cut edge.	
3	Use a marker to draw two marker lines around the full circumference of the pipe to indicate the depth of insertion.	 
4	The outside of the cut pipe and the inside of the socket to be joined and the joint ring must be thoroughly cleaned. The joint ring should be inspected to ensure it is not deformed or damaged.	
5	Thoroughly apply the lubricant evenly along the	

	circumference of the rubber ring at the socket Apply lubricant to the full circumference of the pipe being inserted, from the edge of the cut pipe to the marker lines. Especially be sure to completely coat the chamfered part.	
6	Use a ratchet clamp to perform the insertion. Loosely fit the chamfered part of the pipe to be inserted into the rubber ring at the socket, and then use an insertion machine, etc. to insert the pipe up to marker line. The incoming cut pipe must be aligned and entered carefully into the socket until it makes contact with the joint ring.	
7	After insertion, use the check gauge to confirm that the joint ring is positioned correctly. If it is not correctly inserted, promptly pull out the pipe and re-perform the work.	
8	Execute every jointing work by filling necessary items in a check sheet. The example of check sheet is shown below.	

date, year (   )

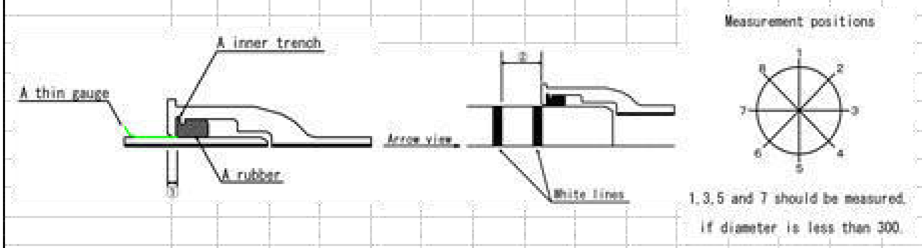
Push fit joint check sheet

Construction name (   )

Observation point   (   )

Diameter, Pipe materials (   )

Plumber (   )



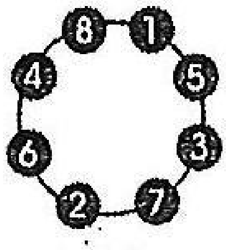
No. of pipe								
A rough sketch								

No. of joint								
Clean the inside of socket and spigot								
Spread lubricant								
Confirm the inner trench of the soket								
① Distance from the edge of socket to the rubber	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
② Distance from the edge of socket to the white line	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
check results								

※ Used by Nagoya water works

3.2 Flange joint

Preparation			
Item	Flange joint	1	
	DI pipe	2	
	Torque wrench	1	
	Bolts and nuts	8	
	Gasket	1	

Steps	Procedures
1	Clean flange faces, bolts, nuts and a gasket to prevent foreign matters
2	Tighten all bolts by hand and ensure that adjoining flanges and gasket are correctly aligned. Lightly tighten the bolts using a calibrated torque wrench in the correct sequence. (see the illustration). Tighten gradually by torque wrench and ensure all bolts reached specified torque.  8 Bolts
3	Visually confirm that flange faces are joined in parallel each other without gap and the gasket is precisely positioned
4	Execute every jointing work by filling necessary items in a check sheet. The example of check sheet is shown below.

date, year (   )

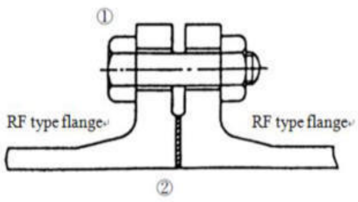
Flange joint check sheet

Construction name (   )

Observation point   (   )

Diameter, Pipe materials (   )

Plumber (   )



Product Name and Shape								
Product No.								
Diagram								

Joint No.								
Cleaning								
① Bolt	Quantity							
	Torque (N·m)							
② Position of gasket								
Determination								

Determination criteria	① Bolt fastening torque:	Based on the standard fastening torque in Table .
	② Position of gasket:	Parallel joining of flange faces without misalignment of gasket.

3.3 Under Pressure Tapping

Preparation			
Item	Tapping machine	1	
	DI pipe	1	

- Mark the tapping point on the DI pipe
- Conduct tapping and ferrule installation

3.4 Pressure test

Preparation			
Item	Water pressure test pump	1	
	HDPE pipe (Dia. 90mm)	1	

Steps	Procedures
1	Connect the high pressure hose with Water pressure test pump (Be careful to put rubber ring at the end of hose). Then, fill the water tank of pump with clear water, pull off the plug, fasten the pressure relief valve. Then, connect the other end of the high pressure hose to the test pipe.
2	Apply pressure up to the prescribed pressure level by Water pressure test pump (4bar, 1-2minutes) and observe the pressure gauge to check the pressure decrease or increase.
3	Visual check of leaks. If visible leaks found repair it.
4	After testing, loosen pressure relief valve, release the pressure and remove the high pressure hose.
5	Make sure there is no drop of water remaining in the machine, clear it for next use.
6	Record the pressure test. The example of pressure testing report is as below.

PRESURE TESTING REPORT

LAYING OF uPVC PIPES & SPECIALS

Contractor : SD&CC

Contract No :

Road/ Note : Dehiwala Maharagama

Date : 17/05/2017

Time : 10.30 p.m.

01. Location Data

Change From : 0+045 LHS

Change To : 0+170 LHS

Pipe Diameter : 160 mm

Type : uPVC

IL of Lowest Point :

Distance :

IL of Highest Point :

Class :

Elevation of Pressure Guage :

Couplings :

Fittings :

02. Working pressure (t= 24 hr)

Date : 17/05/2017

Time From : 10.30 p.m.

Pressure 6 Bar Temperature : ˚C

Date : 18/05/2017

Pressure 6 Bar Temperature : ˚C

Time To : 11.30 p.m.

03. Test Pressure (t= 2 hr)

Date : 18/05/2017

Time/ Pressure 11.30 p.m/ 9 bar

Time	Pressure (Bar)	Pressure Loss(Bar)	Temperature (˚C)
11.30 p.m.	9	–	
12.00 a.m.	9	–	
12.30 a.m	9	–	
1.00 a.m.	9	–	
1.30 a.m.	9	–	

Test Result : Passed : Passed Failed :

04. Filled Leakage Test $Qm = \frac{L \times D \times \sqrt{P}}{795,000}$

Test Duration	Additional Water Volume (L)	
	Actual	Allowable

Qm	=	Allowable leakage in litters per hour (1/hr)
L	=	Length of pipe tested in meters
D	=	Nominal diameter of the pipe in millimeters (mm)
P	=	Average test pressure during test in Kilopascals(kPa)
Test Result		
Passed : ✓		
Failed :		

Test Performed By ; [signature]

Name / Signature of Contractors

Witnessed By: [signature]

Name / Signature of Engineer

Training Guideline

3. Service Pipe Installation

a. HDPE Service Pipe Installation

Table of contents

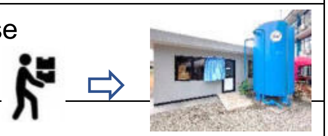
1 Outline

1.1 Purpose

Purpose of training	The purpose of this training is to provide a practical training on installation of HDPE service pipes. Also, it is important to share the knowledge of this training with not only the staff of NWSDB but also contractors.
Training Contents	➢ Socket fusion joint ➢ Thread joint ➢ Pressure test

1.2 Flow of training with time schedule

The total time is 2 hours and 15 minutes.

No.	Activity	Required time	Venue
1	Lecture	30 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Distribution pipe or Service pipe connection area)  
3	Preparation for practical training	10 min.	
	*Details are described in “3 Practice (Page 6)” *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse 		
4	Practical training	60 min	TY
	*Details are described in “3 Practice (Page 6)” ➢ Socket fusion joint ➢ Thread joint ➢ Pressure test		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse 
6	Move to lecture room	5 min.	Lecture room
7	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.

- Do not eat food in the TY.

2 Knowledge acquisition

2.1 Outline of HDPE

- Standard of HDPE pipes
    - ISO 21307: 2011 Plastics pipes and fittings, butt fusion jointing procedures for polyethylene (PE) pipes and fittings used in the construction of gas and water distribution systems.
- Handle with care not to make scratch
- Keep away from ultraviolet
- Use proper jointing tools or cutters which are dedicated to HDPE pipes
- Advantages and disadvantage of HDPE pipe

Advantage
· Excellent corrosion resistance, flexibility, cold and impact resistance · Almost all pipes used in current pipe new installations are PE pipe · Greater strength and can handle higher temperatures than other pipe materials · The life cycle and construction cost of PE pipe can be less than other metal pipes · Connection method by fusion welding forms leak-free joints that are as strong as, or stronger than, the pipe itself · PE pipe installations are cost-effective and have long-term cost advantages due to the pipe's physical properties, leak-free joint and reduced maintenance costs
Disadvantage
· Connection method by fusion welding requires a high skill · Vulnerable to external wounds and heat · Vulnerable to the penetration of chemicals from the outside, such as gasoline and solvent

- Marking of pipe

  Each pipe shall be legibly and indelibly marked at intervals not more than 3m with the followings:
    - Manufacturer's name or registered trademark
    - Material
    - Nominal outside diameter, wall thickness
    - Maximum allowable pressure at 30 degree Celsius, PNT
    - Batch number
    - Intended use (e.g. W/P)
    - Angle of bending of bends
    - Diameter of both ends in reducers and specials

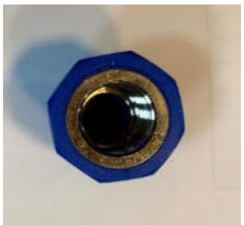
2.2 Jointing method

There are mainly two jointing method for HDPE distribution pipes: Socket fusion joint and Thread joint.

2.2.1 Socket fusion joint

Socket fusion joint	Details
 	Socket fusion joint connect HDPE pipe and socket by heat of socket fusion welding machine. This method is very common way to joint HDPE service pipe and the durability of this joint part is high.

2.2.2 Thread joint

Thread joint	Details
 	Male thread and female thread are used for thread joint. The thread has shape of screw and male thread and female thread can be connected very easily and swiftly.

2.3 Construction management

Followings are important points for construction management

- Material Inspection
- Pre inspection
- Post inspection
- Safety arrangement
- Supervision
- Backfilling
- Pressure Testing

3 Practice

3.1 Socket fusion joint

Preparation			
Item	Socket fusion welding machine	1	
	Socket	1	
	HDPE pipe	1	
	HDPE pipe cutter	1	

Steps	Procedures	
1	Check the pipe and socket whether they are damaged or not. Measure the depth of socket and mark the insertion length on the pipe surface.	
2	Chamfer the edge of pipe. The chamfer angle should be 30° and the width of chamfer should not exceed 2.0mm.	
3	Clean and dry the chamfered pipe and socket	
4	Push the end of the pipe and socket into socket fusion welding machine up to the marked insertion length. Be careful not to turn the pipe and socket while heating.	
5	Pull out the pipe and socket from the socket fusion welding machine after proper heating time, insert the pipe into socket evenly and swiftly and wait until they cool down.	

➢ The recommended technical parameter for socket fusion is as below (Thermal temperature is 260 degree Celsius).

Outer diameter(mm)	Heating time(s)	Maximum Transit Time(s)	Minimum Cooling Time(s)
20	5	4	2
25	7	4	2
32	8	6	4
40	12	6	4
50	18	6	4
63	24	8	6

3.2 Thread joint

Preparation				
Item	Male thread	1	
	Female thread	1	
	Seal tape	1	

Steps	Procedures
1	Wrap the male threaded end of the fitting with seal tape clockwise.
2	Screw the male thread which is wrapped with seal tape into a socket (female screw) clockwise.

3.3 Pressure test

Preparation			
Item	Water pressure test pump	1	
	Jointed HDPE pipe	1	

Steps	Procedures
1	Connect the high pressure hose with Water pressure test pump (Be careful to put rubber ring at the end of hose). Then, fill the water tank of pump with clear water, pull off the plug, fasten the pressure relief valve. Then, connect the other end of the high pressure hose to the test pipe.
2	Apply pressure up to the prescribed pressure level by Water pressure test pump (4bar, 1-2minutes) and observe the pressure gauge to check the pressure decrease or increase.
3	Visual check of leaks. If visible leaks found repair it.
4	After testing, loosen pressure relief valve, release the pressure and remove the high pressure hose.
5	Make sure there is no drop of water remaining in the machine, clear it for next use.
6	Record the pressure test. The example of pressure testing report is as below.

PRESURE TESTING REPORT
LAYING OF uPVC PIPES & SPECIALS

Contractor : SD&CC
Contract No :
Road/ Note : Dehiwala Maharagama

Date : 17/05/2017
Time : 10.30 p.m.

01. Location Data

Change From	: 0+045 LHS	Change To	:	0+170 LHS
Pipe Diameter	: 160 mm	Type	:	uPVC
IL of Lowest Point	:	Distance	:	
IL of Highest Point	:	Class	:	
Elevation of Pressure Guage	:			
Couplings	:			
Fittings	:			

02. Working pressure (t= 24 hr)

Date : 17/05/2017
Time From : 10.30 p.m. Pressure 6 Bar Temperature : .... °C
Date : 18/05/2017 Pressure 6 Bar Temperature : .... °C
Time To : 11.30 p.m.

03. Test Pressure (t= 2 hr)

Date : 18/05/2017
Time/ Pressure 11.30 p.m / 9 bar

Time	Pressure (Bar)	Pressure Loss(Bar)	Temperature (°C)
11.30 p.m.	9	–	
12.00 a.m.	9	–	
12.30 a.m	9	–	
1.00 a.m.	9	–	
1.30 a.m.	9	–	

Test Result : Passed : Passed Failed : ....

04. Filled Leakage Test $Qm = \frac{L \times D \times \sqrt{P}}{795,000}$

Test Duration	Additional Water Volume (L)	
	Actual	Allowable

Qm	=	Allowable leakage in litters per hour (1/hr)
L	=	Length of pipe tested in meters
D	=	Nominal diameter of the pipe in millimeters (mm)
P	=	Average test pressure during test in Kilopascals(kPa)
Test Result		
Passed : ✓		
Failed :		

Test Performed By ; [signature]
Name / Signature of Contractors

Witnessed By; [signature]
Name / Signature of Engineer

Training Guideline

3. Service Pipe Installation

b. PVC Service Pipe Installation

Table of contents

1 Outline
1.1 Purpose

Purpose of training	The purpose of this training is to provide a practical training on installation of PVC service pipes. Also, it is important to share the knowledge of this training with not only the staff of NWSDB but also contractors.
Training Contents	➢ Solvent cement joint ➢ Thread joint ➢ Pressure test

1.2 Flow of training with time schedule

The total time is 2 hours and 15 minutes.

No.	Activity	Required time	Venue
1	Lecture	30 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Distribution pipe or Service pipe connection area)  
3	Preparation for practical training	10 min.	
	*Details are described in “3 Practice (Page 6)” *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse 		
4	Practical training	60 min	TY
	*Details are described in “3 Practice (Page 6)” ➢ Solvent cement joint ➢ Thread joint ➢ Pressure test		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse 
6	Move to lecture room	5 min.	Lecture room
7	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.



- Do not eat food in the TY.



2 Knowledge acquisition

2.1 Outline of HDPE

- Standard of PVC pipes
    - SLS 147:2013 - Unplasticized poly (vinyl chloride) pipes for water supply and for buried and above ground drainage and sewerage under pressure
    - ISO 1452:2009 - Plastic piping systems for water supply and for buried and above ground drainage and sewerage under pressure—Unplasticized poly (vinyl chloride) (UPVC-U)
- Advantages and disadvantage of PVC pipe

Advantage
· Anti- corrosion (except for some solvent)
· High stiffness
· Low weight
· Cost effectiveness

Disadvantage
· Pressure resistance is not as good as DI pipes.
· Flexibility is not as good as HDPE pipes.
· Lifespan is more than 20 years but less than DI pipes.
· Vulnerable to external wounds and heat
· Low UV resistance
· Low toughness
· Lower strength than other pipes

- Marking of pipe

  Each pipe shall be legibly and indelibly marked at intervals not more than 3m with the followings:
    - Manufacturer's name or registered trademark
    - Material
    - Nominal outside diameter, wall thickness
    - Maximum allowable pressure at 30 degree Celsius, PNT
    - Batch number
    - Intended use (e.g. W/P)
    - Angle of bending of bends
    - Diameter of both ends in reducers and specials

2.2 Jointing method

There are mainly two jointing method for HDPE distribution pipes: Solvent cement joint and Thread joint.

2.2.1 Solvent cement joint

Solvent cement joint	Details
	Solvent cements for pipes and fittings are flammable, so there should be no smoking or other source of heat or flame in working or storage areas. Be sure to work only in a well-ventilated space and avoid unnecessary skin contact with all solvents.

2.2.2 Thread joint

Thread joint	Details
	Male thread and female thread are used for thread joint. The thread has shape of screw and male thread and female thread can be connected very easily and swiftly.

2.3 Construction management

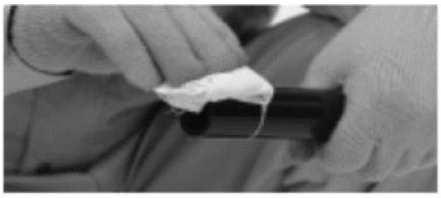
Followings are important points for construction management

- Material Inspection
- Pre inspection
- Post inspection
- Safety arrangement
- Supervision
- Backfilling
- Pressure Testing

3 Practice

3.1 Solvent cement joint

Preparation			
Item	Socket	1	
	PVC pipe	1	
	Pipe cutter	1	
	Adhesive	1	
	Chamfer	1	
	Marker	1	
	Dry cloth	1	

Steps	Procedures	
1	Check the pipe and socket whether they are damaged or not. Measure the depth of socket and mark the insertion length on the pipe surface. Draw a cut line and cut the pipe along the cut line at right angle to its longitudinal axis.	 
2	Chamfer the edge of pipe. The chamfer angle should be 30° and the width of chamfer should not exceed 2.0mm.	
3	Clean and dry the chamfered pipe and socket	
4	Apply adhesive evenly from the interior of the fitting to the cut pipe.	

5	After applying adhesives, insert the pipe straightly into the fitting until the gauge line and hold.	
6	Remove excess adhesive from the pipe immediately after jointing, and do not apply pressure to the jointed area.	

3.2 Thread joint

Preparation		
Item	Male thread	1
	Female thread	1
	Seal tape	1

Steps	Procedures
1	Wrap the male threaded end of the fitting with seal tape clockwise.
2	Screw the male thread which is wrapped with seal tape into a socket (female screw) clockwise.

3.3 Pressure test

Preparation		
Item	Water pressure test pump	1
	Jointed HDPE pipe	1

Steps	Procedures
1	Connect the high pressure hose with Water pressure test pump (Be careful to put rubber ring at the end of hose). Then, fill the water tank of pump with clear water, pull off the plug, fasten the pressure relief valve. Then, connect the other end of the high pressure hose to the test pipe.
2	Apply pressure up to the prescribed pressure level by Water pressure test pump (4bar, 1-2minutes) and observe the pressure gauge to check the pressure decrease or increase.
3	Visual check of leaks. If visible leaks found repair it.
4	After testing, loosen pressure relief valve, release the pressure and remove the high pressure hose.
5	Make sure there is no drop of water remaining in the machine, clear it for next use.
6	Record the pressure test. The example of pressure testing report is as below.

PRESURE TESTING REPORT

LAYING OF uPVC PIPES & SPECIALS

Contractor : SD & CC

Contract No :

Road/ Note : Dehiwala Maharagama

Date : 17/05/2017

Time : 10.30 p.m.

01. Location Data

Change From	:	0+045 LHS	Change To	:	0+170 LHS
Pipe Diameter	:	160 mm	Type	:	uPVC
IL of Lowest Point	:		Distance	:	
IL of Highest Point	:		Class	:	
Elevation of Pressure Guage	:				
Couplings	:				
Fittings	:				

02. Working pressure (t= 24 hr)

Date : 17/05/2017

Time From : 10.30 p.m. Pressure 6 Bar Temperature : .... °C

Date : 18/05/2017 Pressure 6 Bar Temperature : .... °C

Time To : 11.30 p.m.

03. Test Pressure (t= 2 hr)

Date : 18/05/2017

Time/ Pressure 11.30 p.m / 9 bar

Time	Pressure (Bar)	Pressure Loss(Bar)	Temperature (°C)
11.30 p.m.	9	–	
12.00 a.m.	9	–	
12.30 a.m.	9	–	
1.00 a.m.	9	–	
1.30 a.m.	9	–	

Test Result : Passed : Passed Failed : ....

04. Filled Leakage Test $Qm = \frac{L \times D \times \sqrt{P}}{795,000}$

Test Duration	Additional Water Volume (L)	
	Actual	Allowable

Qm	=	Allowable leakage in litters per hour (1/hr)
L	=	Length of pipe tested in meters
D	=	Nominal diameter of the pipe in millimeters (mm)
P	=	Average test pressure during test in Kilopascals(kPa)

Test Result

Passed : ✓

Failed : ....

Test Performed By ; [signature]

Name / Signature of Contractors

Witnessed By: [signature]

Name / Signature of Engineer

Training Guideline

4. Leak Repair

a. HDPE Distribution & Service Pipe Repair

Table of contents

1 Outline

1.1 Purpose

Purpose of training	Water leaks have a significant impact on water supply business. Water leaks from the distribution lines not only affect the revenue of the water utilities but also cause accidents on a road and its surrounding, so it should be repaired immediately when it is detected. Also, the amount of leakage from the service pipe is relatively small, however, it will be large amounts if the leakage is left for a long time. Therefore, service pipe leaks must be repaired as soon as they are detected. Pipe fitters typically gain their experience and skills through field works and training programs. This training aims to acquire theoretical knowledge and practical skills of HDPE pipe repair through a practical training.
Training Contents	➢ Leak repair of HDPE distribution pipe with repair clamp and coupling ➢ Leak repair of HDPE service pipe with repair clamp, socket fusion, compression joint and hack joint

1.2 Flow of training with time schedule

The total time is 3 hours and 40 minutes.

No.	Activity	Required time	Venue
1	Lecture	45 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Distribution pipe or Service pipe connection area)
3	Preparation for practical training	20 min.	 
	*Details are described in “3 Practice (Page 12)” *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse 		
4	Practical training	120 min. each	TY
	*Details are described in “3 Practice (Page 12)” <HDPE Distribution pipe> ➢ Leak repair of HDPE distribution pipe with repair clamp and coupling <HDPE Service pipe> ➢ Leak repair of HDPE service pipe with repair clamp, socket fusion, compression joint and hack joint		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse ⇨ 
6	Move to lecture room	5 min.	Lecture room
7	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.

- Do not eat food in the TY.

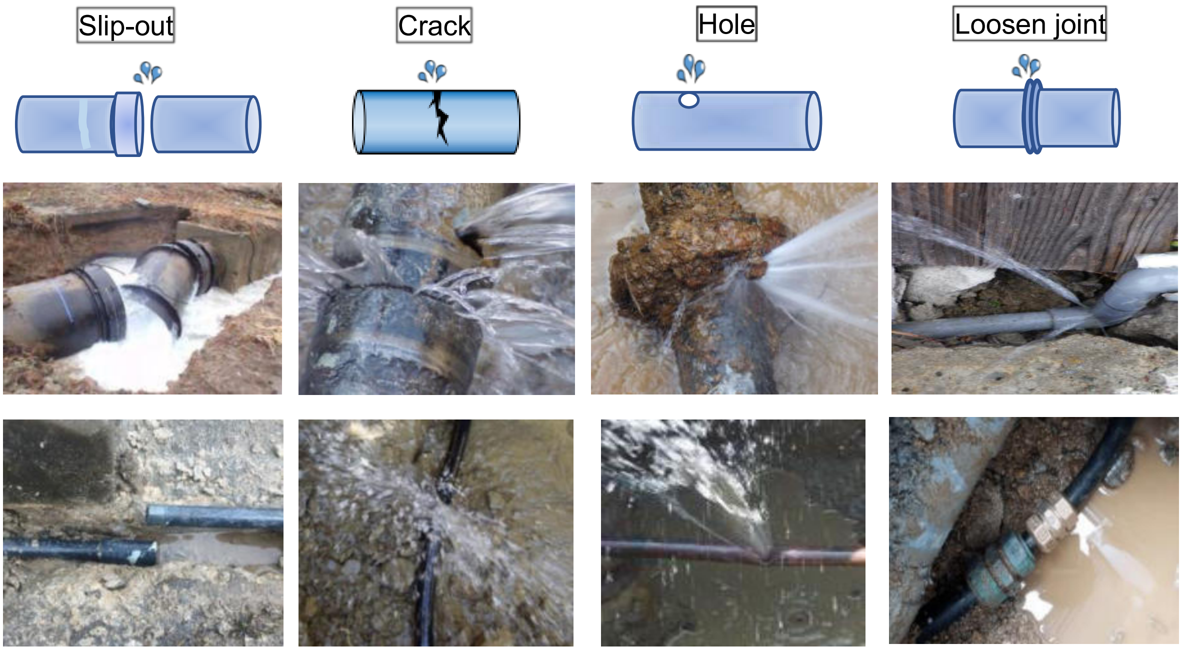
2 Knowledge acquisition

2.1 Characteristic of HDPE

Advantage
➢ Excellent corrosion resistance, flexibility, cold and impact resistance 
➢ Almost all pipes used in current pipe new installations are PE pipe
➢ Greater strength and can handle higher temperatures than other pipe materials
➢ The life cycle and construction cost of PE pipe can be less than other metal pipes
➢ Connection method by fusion welding forms leak-free joints that are as strong as, or stronger than, the pipe itself
➢ PE pipe installations are cost-effective and have long-term cost advantages due to the pipe's physical properties, leak-free joint and reduced maintenance costs
Disadvantage
➢ Connection method by fusion welding requires a high skill
➢ Vulnerable to external wounds and heat
➢ Vulnerable to the penetration of chemicals from the outside, such as gasoline and solvent

2.2 Type, cause and preventive measure of leakage

Type of leakage
Typical leak types are slip-out, cracks, holes and loosen joint etc.



Causes of pipe leaks are divided in two categories, internal factor and external factor. Occurrence of leakage can be reduced by preventive measures in consideration of the following factors. These preventive measures can also extend pipe life span that contribute to effective management of water supply utilities.

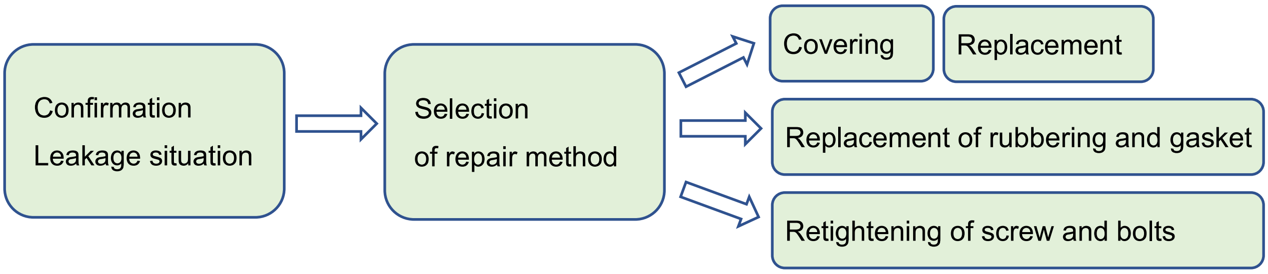
Cause and preventive measure	
Internal factors	Preventive measure
<u>Due to pipe and material</u> ➢ Improper materials and structures of pipes, fittings, and attached equipment ➢ Corrosion ➢ Aging of materials <u>Due to design and construction</u> ➢ Design error ➢ Improper installation of joints, etc. ➢ Improper backfill ➢ Insufficient anticorrosion method ➢ Potentiometric corrosion due to dissimilar metals <u>Due to cause in the pipes</u> ➢ Chronic high pressure, Water hammer ➢ Water quality (Internal corrosion) ➢ Stress due to change of water temperature (especially freezing)	➢ Select appropriate material (use of certified products, Inspect by own organization) ➢ Painting or covering by anticorrosion tape ➢ Vinyl sleeve protection ➢ Reinforcement of surrounding land ➢ Reinforcement of laying foundation ➢ Installation of laying base structure ➢ Improvement of joint work technology by training ➢ Pipe protection concrete ➢ Inside of pipe lining
External factors	Preventive measure
<u>Due to buried environment</u> ➢ Impact from traffic load ➢ Hollow around pipes due to leakage and poor construction. ➢ Ground subsidence due to excessive pumping of groundwater ➢ Soil contamination by a factory effluent ➢ Corrosive soil environment ➢ Salt damage (sea breeze, underground water level) ➢ Difference between design and actual condition <u>Thing caused by other construction or disaster</u> ➢ Damage by other works ➢ Changes in buried environment due to other construction ➢ Ground and road fluctuation due to earthquakes and other disasters ➢ Ground movement by rain, flood and terrain deformation, etc.	➢ Appropriate backfill (backfill material, construction method) ➢ Installation of anticorrosive device ➢ Reinforcement of surrounding land ➢ Reinforcement of laying foundation ➢ Installation of laying base structure ➢ Improvement of joint work technology by training ➢ Pipe protection concrete ➢ Installation of the indication tape, sheet ➢ Collecting pipeline information (as built drawings of distribution pipe and service pipe) ➢ Mapping system

2.3 Repair method

Followings should be considered for repair work:

- Pipe material
- Leaking condition (leak position, leak volume, damage condition, etc.)
- Space of repair work
- Time of suspension of water supply

Repair method shall be mainly divided in two type, ‘Covering’ and ‘Replacement’. And depending on pipe material and joint types, tightening and welding are also appropriate.



Note:

Although the method using adhesive tape is often introduced as the repair of the pipe, the water supply authority should, in principle, carry out permanent repairs. It should be used for only temporal repair.

2.3.1 Covering

The leakage part of distribution and service pipe is covered by repair clamp.

<table>
<tr><th colspan="2">Required parts and equipment</th></tr>
<tr><td>➢ HDPE Distribution & Service pipe
➢ Repair clamp</td><td>The main method is to cover the entire pipe with a repair clamp which has rubber plates divided into 2 or 3.
Repair clamp for HDPE pipes are mostly made of stainless steel.
 </td></tr>
<tr><th colspan="2">Procedures</th></tr>
<tr><td colspan="2">i. Check the diameter of the pipe, proper repair clamp size for each diameter must be used.
ii. Clean up the surface of the pipe
iii. Mark the size of the repair clamp on the pipe so that the damaged part will come to the center of the repair clamp.
iv. Set the repair clamp. Please be careful not to set the seam of repair clamp on the damaged part
v. Tighten all bolts with proper torque and following proper tightening sequence.
 </td></tr>
</table>

2.3.2 Replacement

The leakage part of pipe is replaced. A new pipe is connected to the original pipe with the coupling. For the repair of HDPE distribution pipe, coupling method is generally used. And for the repair of HDPE service pipe, socket fusion, compression joint and hack joint method are generally used.

(1) Coupling

Required parts and equipment	
➢ HDPE Distribution pipe ➢ Coupling ➢ Pipe cutter ➢ Chamfer ➢ Lubricant, brush, clean tissue	   

Procedures

i. Check the diameter of the pipe, proper coupling size for each diameter must be used

ii. Mark the size of cutting part including the damage. Check the deteriorated part also which may cause future leakage

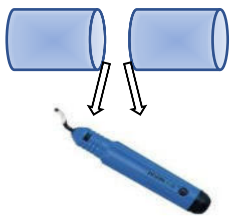
iii. Set the cutter on the pipe

iv. Tighten the cutter until the wheel blade touch on the surface of pipe

v. Spin and retighten the cutter and repeat this process until the pipe is cut

vi. After cutting, chamfer the edge of pipe with a deburring knife or chamfering device

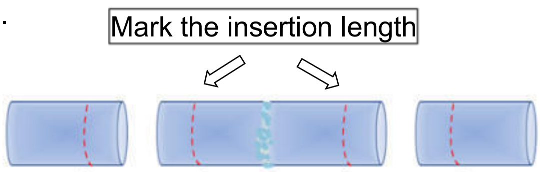
vii. Cut new pipe into suitable length. The length of the new pipe will be shorter than the length of removed pipe



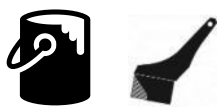
viii. Chamfer the edge of new pipe with a deburring knife or chamfering device

Note: Be sure to chamfer the cut surface of the pipe, otherwise the rubber ring will be damaged when inserting

ix. Mark the insertion length on the pipe surface so that the center of the coupling locates at the connecting point of original pipe and new pipe.



x. Apply lubricant to the inside of coupling and outside of pipe.



xi. Set couplings on the original pipe and insert new pipe into coupling

Note: If sliding work is hard, use a chain block

(2) Socket fusion

<table>
<tr><th colspan="2">Required parts and equipment</th></tr>
<tr><td>

- HDPE Service pipe
- Socket fusion machine
- Pipe cutter
- Chamfer
- Thread tape

</td><td>   </td></tr>
<tr><th colspan="2">Procedures</th></tr>
<tr><td colspan="2">

i. Cut off the damaged part of the original pipe

ii. Measure the length of removed pipe

iii. Cut a new pipe to the required length

iv. Chamfer the edge of original pipe and new pipe

v. Mark the insertion length on the surface of original pipe and new pipe so that the center of coupling locates at the connecting point of original pipe and new pipe.

vi. Activate the socket fusion machine

vii. Insert the coupling and original pipe to the fusion machine.

viii. After heating, insert the original pipe into coupling

ix. Do the same way for new pipe and coupling.

x. Deactivate the socket fusion machine

</td></tr>
</table>

(3) Compression joint

<table>
<tr><th colspan="2">Required parts and equipment</th></tr>
<tr><td>

- HDPE Service pipe
- Double compression joint coupling
- Pipe cutter
- Chamfer
- Thread tape

</td><td></td></tr>
<tr><th colspan="2">Procedures</th></tr>
<tr><td colspan="2">

i. Cut off the damaged part of the original pipe

ii. Measure the length of removed pipe
iii. Cut a new pipe to the required length
iv. Chamfer the edge of original pipe and new pipe
v. Mark the insertion length on the surface of original pipe and new pipe so that the center of coupling locates at the connecting point of original pipe and new pipe.
vi. Set the compression coupling to the original pipe and tighten screw with correct torque until the screw stops.
Note: Tightening with a pipe wrench will cause over torque and damage of thread.

vii. Do the same way for new pipe and coupling.

</td></tr>
</table>

(4) Hack joint

<table>
<tr><th colspan="2">Required parts and equipment</th></tr>
<tr><td>

- HDPE Service pipe
- Hack joint
- Hacker
- Pipe cutter
- Chamfer
- Thread tape

</td><td>   </td></tr>
<tr><th colspan="2">Procedures (Service pipe)</th></tr>
<tr><td colspan="2">

i. Cut off the damaged part of the original pipe

ii. Measure the length of removed pipe

iii. Cut a new pipe to the required length

iv. Chamfer the edge of original pipe and new pipe

v. Mark the insertion length on the surface of original pipe and new pipe so that the center of coupling locates at the connecting point of original pipe and new pipe.

vi. Insert original pipe and new pipe into hack joint

vii. Clamp hack joint with hacker

</td></tr>
</table>

3 Practice

Practical training is conducted for distribution pipe and service pipe as below.

- Distribution pipe:
  - Covering
  - Coupling
- Service pipe:
  - Covering
  - Socket fusion
  - Compression
  - Hack joint

3.1 Distribution pipe

Covering	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ HDPE Distribution pipe: 2 pcs. ➢ Repair clamp: 1 pcs. ➢ Tool set: 1set
Practical training	Follow the procedures written in “2.3.1 Covering (Page 7)”

Coupling	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ HDPE Distribution pipe: 2 pcs. ➢ Coupling: 1 pcs. ➢ Pipe cutter: 1pcs. ➢ Chamfer: 1pcs. ➢ Lubricant, brush, clean tissues: 1set ➢ Tool set: 1set
Practical training	➢ Follow the procedures written in “(1) Coupling (Page 8)”

3.2 Service pipe

Covering	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ HDPE Service pipe: 2 pcs. ➢ Repair clamp: 1 pcs. ➢ Tool set: 1set
Practical training	Follow the procedures written in “2.3.1 Covering (Page 7)”

Socket fusion	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ HDPE Service pipe: 2 pcs. ➢ Coupling: 1 pcs. ➢ Socket fusion machine: 1 set ➢ Pipe cutter: 1pcs. ➢ Chamfer: 1pcs. ➢ Thread tape: 1pcs. ➢ Tool set: 1set
Practical training	Follow the procedures written in “(2) Socket fusion (Page 9)”

Compression joint	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ HDPE Service pipe: 2 pcs. ➢ Double compression joint coupling: 1 pcs. ➢ Pipe cutter: 1pcs. ➢ Chamfer: 1pcs. ➢ Thread tape: 1pcs. ➢ Tool set: 1set
Practical training	Follow the procedures written in “(3) Compression joint (Page 10)”

Hack joint	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ HDPE Service pipe: 2 pcs. ➢ Hack joint & Hacker: 1 set ➢ Pipe cutter: 1pcs. ➢ Chamfer: 1pcs. ➢ Thread tape: 1pcs. ➢ Tool set: 1set
Practical training	Follow the procedures written in “(4) Hack joint (Page 11)”

4 Keep repair record

When water leakage is found at the site, it is necessary to keep a record. Based on the records, it is possible to understand the deterioration status of pipes, determine the necessary frequency of detailed inspections and the make a standard for renewal.

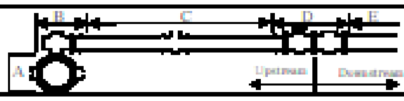
The repair record has to include following information.

- Leakage location: address, hose number, road name etc.
- Pipe information: pipe material, size, installed year, part of leakage
- Leakage information: type of damage, size of damage, leakage volume
- Repair work information: materials used for repairs, number of staff, time taken to complete the repair work, used machine, volume of excavation, road type
- Water outage information for repair work, such as affected area of water supply, operated valves, water volume for cleaning the pipe

The repair record sheet is shown below.

The Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center-Western South of NWSDB in Sri Lanka

Leak Repair Detail Sheet	office	National Water Supply & Drainage Board
	officer	
Reported date and time		
Reported by	☐Complain ☐Meter reader ☐Leak detection ☐Others	
Compainer's Name & Add.		
Attended date and time		

Leakage information								
Location	Adress							
	Meter No.							
	Consumer No.							
	☐Meter ☐Service pipe(Joint or pipe) ☐Ferrule ☐Distribution pipe							
								
Considerable cause	☐Deterioration ☐Traffic load ☐Poor construction ☐Others( )							
Pipe material	☐DI ☐PVC ☐PE ☐Others( )							
Pipe Dia.		Pipe depth						
Road surface	☐Asphalt ☐Concret ☐I.L.B ☐Others ( )							
Traffic density	☐Heavy ☐Midium ☐Light							
Leake repair	Yes		No		Leak volume		m3/h	
Repair information								
Material used								

Machinery Used		Location(Sketch)
(1)	Power Light (1.5.1)Hrs	
(2)	Night work (1.5.2)Hrs	
(3)	Water Pump(Dewatering)Hrs	
(4)	Others	

Measurment

BOQ Item No.	Description	Unit	L(m)	B(m)	D(m)	Qty

Comment

Contractor Officer

NWSDB Officer

Training Guideline

4. Leak Repair

b. PVC Distribution & Service Pipe Repair

Table of contents

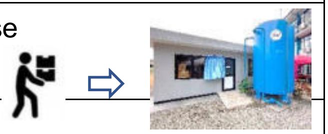
1 Outline

1.1 Purpose

Purpose of training	Water leaks have a significant impact on water supply business. Water leaks from the distribution lines not only affect the revenue of the water utilities but also cause accidents on a road and its surrounding, so it should be repaired immediately when it is detected. Also, the amount of leakage from the service pipe is relatively small, however, it will be large amounts if the leakage is left for a long time. Therefore, service pipe leaks must be repaired as soon as they are detected. Pipe fitters typically gain their experience and skills through field works and training programs. This training aims to acquire theoretical knowledge and practical skills of PVC pipe repair through a practical training.
Training Contents	➢ Leak repair of PVC distribution pipe with repair clamp and coupling ➢ Leak repair of PVC service pipe with repair clamp and coupling

1.2 Flow of training with time schedule

The total time is 3 hours and 40 minutes.

No.	Activity	Required time	Venue
1	Lecture	45 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Distribution pipe or Service pipe connection area)  
3	Preparation for practical training	20 min.	
	*Details are described in “3 Practice (Page 10)” *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse 		
4	Practical training	120 min. each	TY
	*Details are described in “3 Practice (Page 10)” <PVC Distribution pipe> ➢ Leak repair of PVC distribution pipe with repair clamp and coupling <PVC Service pipe> ➢ Leak repair of PVC service pipe with repair clamp and coupling		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse 
6	Move to lecture room	5 min.	Lecture room
7	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.

- Do not eat food in the TY.

2 Knowledge acquisition

2.1 Characteristic of PVC

Advantage

- Anti- corrosion (except for some solvent)
- High stiffness
- Low weight
- Cost effectiveness

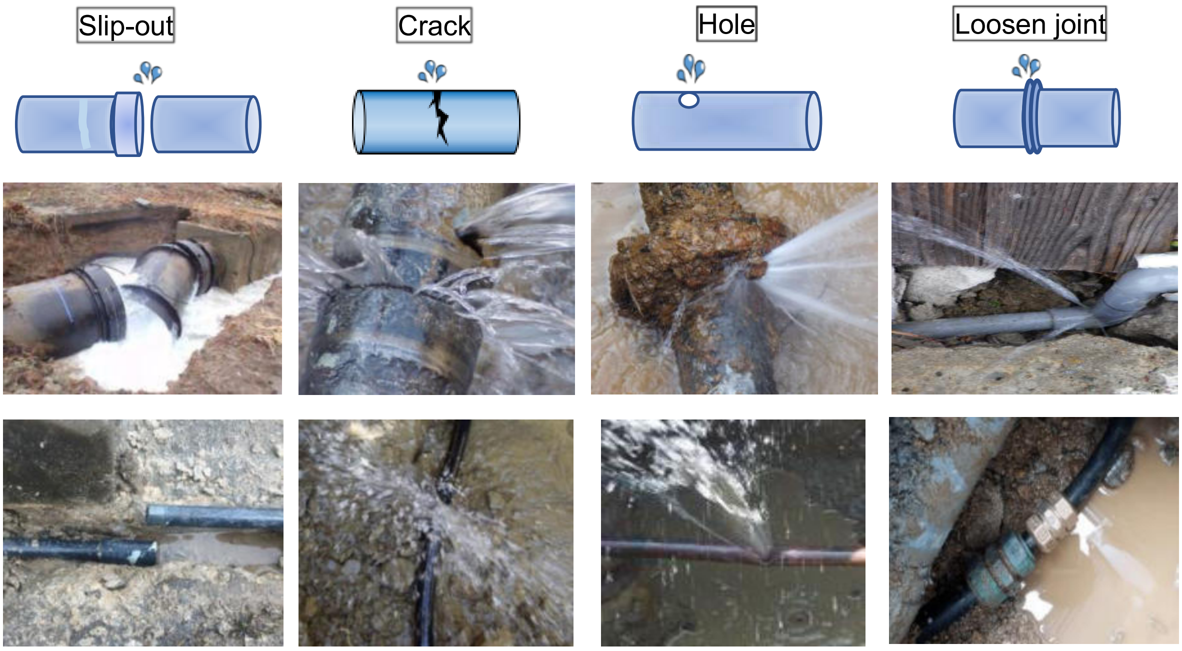
Disadvantage

- Pressure resistance is not as good as DI pipes.
- Flexibility is not as good as HDPE pipes.
- Lifespan is more than 20 years but less than DI pipes.
- Vulnerable to external wounds and heat
- Low UV resistance
- Low toughness
- Lower strength than other pipes

2.2 Type, cause and preventive measure of leakage

Type of leakage

Typical leak types are slip-out, cracks, holes and loosen joint etc.



Causes of pipe leaks are divided in two categories, internal factor and external factor. Occurrence of leakage can be reduced by preventive measures in consideration of the following factors. These preventive measures can also extend pipe life span that contribute to effective management of water supply utilities.

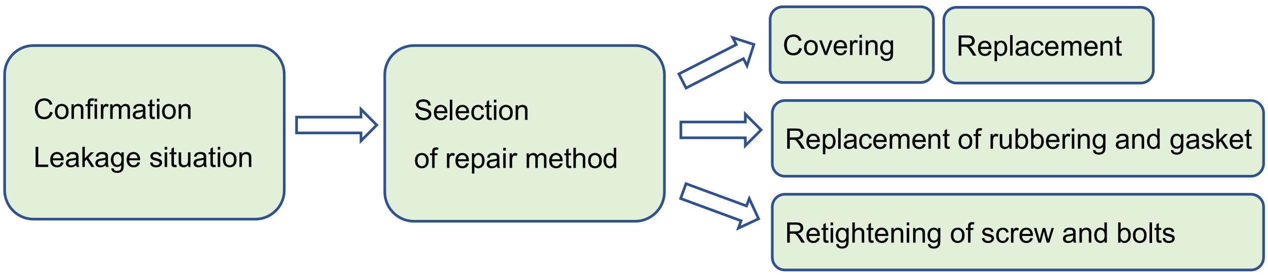
Cause and preventive measure	
Internal factors	Preventive measure
<u>Due to pipe and material</u> ➢ Improper materials and structures of pipes, fittings, and attached equipment ➢ Corrosion ➢ Aging of materials <u>Due to design and construction</u> ➢ Design error ➢ Improper installation of joints, etc. ➢ Improper backfill ➢ Insufficient anticorrosion method ➢ Potentiometric corrosion due to dissimilar metals <u>Due to cause in the pipes</u> ➢ Chronic high pressure, Water hammer ➢ Water quality (Internal corrosion) ➢ Stress due to change of water temperature (especially freezing)	➢ Select appropriate material (use of certified products, Inspect by own organization) ➢ Painting or covering by anticorrosion tape ➢ Vinyl sleeve protection ➢ Reinforcement of surrounding land ➢ Reinforcement of laying foundation ➢ Installation of laying base structure ➢ Improvement of joint work technology by training ➢ Pipe protection concrete ➢ Inside of pipe lining
External factors	Preventive measure
<u>Due to buried environment</u> ➢ Impact from traffic load ➢ Hollow around pipes due to leakage and poor construction. ➢ Ground subsidence due to excessive pumping of groundwater ➢ Soil contamination by a factory effluent ➢ Corrosive soil environment ➢ Salt damage (sea breeze, underground water level) ➢ Difference between design and actual condition <u>Thing caused by other construction or disaster</u> ➢ Damage by other works ➢ Changes in buried environment due to other construction ➢ Ground and road fluctuation due to earthquakes and other disasters ➢ Ground movement by rain, flood and terrain deformation, etc.	➢ Appropriate backfill (backfill material, construction method) ➢ Installation of anticorrosive device ➢ Reinforcement of surrounding land ➢ Reinforcement of laying foundation ➢ Installation of laying base structure ➢ Improvement of joint work technology by training ➢ Pipe protection concrete ➢ Installation of the indication tape, sheet ➢ Collecting pipeline information (as built drawings of distribution pipe and service pipe) ➢ Mapping system

2.3 Repair method

Followings should be considered for repair work:

- Pipe material
- Leaking condition (leak position, leak volume, damage condition, etc.)
- Space of repair work
- Time of suspension of water supply

Repair method shall be mainly divided in two type, ‘Covering’ and ‘Replacement’. And depending on pipe material and joint types, tightening and welding are also appropriate.

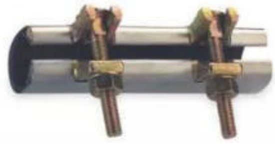


Note:

Although the method using adhesive tape is often introduced as the repair of the pipe, the water supply authority should, in principle, carry out permanent repairs. It should be used for only temporal repair.

2.3.1 Covering

The leakage part of distribution and service pipe is covered by repair clamp.

<table>
<tr><td colspan="2">Required parts and equipment</td></tr>
<tr><td>➢ PVC Distribution & Service pipe
➢ Repair clamp</td><td>The main method is to cover the entire pipe with a repair clamp which has rubber plates divided into 2 or 3.
Repair clamp for PVC pipes are mostly made of stainless steel.
 </td></tr>
<tr><td colspan="2">Procedures</td></tr>
<tr><td colspan="2">i. Check the diameter of the pipe, proper repair clamp size for each diameter must be used.
ii. Clean up the surface of the pipe
iii. Mark the size of the repair clamp on the pipe so that the damaged part will come to the center of the repair clamp.
iv. Set the repair clamp. Please be careful not to set the seam of repair clamp on the damaged part
v. Tighten all bolts with proper torque and following proper tightening sequence.
 </td></tr>
</table>

2.3.2 Replacement

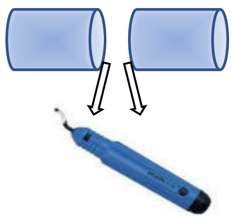
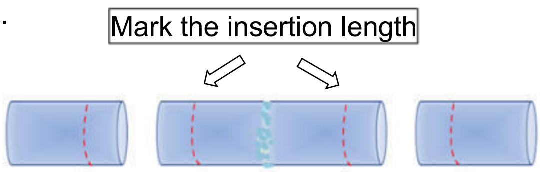
The leakage part of pipe is replaced. A new pipe is connected to the original pipe with the coupling. For the repair of PVC distribution pipe, coupling with lubricant is generally used. And for the repair of PVC service pipe, coupling with adhesive (solvent cement) is generally used.

(1) Coupling with lubricant

<table>
<tr><td colspan="2">Required parts and equipment</td></tr>
<tr><td>
➢ PVC Distribution pipe
➢ Coupling
➢ Pipe cutter
➢ Chamfer
➢ Lubricant, brush, clean tissue
</td><td>




</td></tr>
<tr><td colspan="2">Procedures</td></tr>
<tr><td colspan="2">
i. Check the diameter of the pipe, proper coupling size for each diameter must be used
ii. Mark the size of cutting part including the damage. Check the deteriorated part also which may cause future leakage

iii. Set the cutter on the pipe
iv. Tighten the cutter until the wheel blade touch on the surface of pipe
v. Spin and retighten the cutter and repeat this process until the pipe is cut
vi. After cutting, chamfer the edge of pipe with a deburring knife or chamfering device
vii. Cut new pipe into suitable length. The length of the new pipe will be shorter than the length of removed pipe

viii. Chamfer the edge of new pipe with a deburring knife or chamfering device
<u>Note</u>: Be sure to chamfer the cut surface of the pipe, otherwise the rubber ring will be damaged when inserting
ix. Mark the insertion length on the pipe surface so that the center of the coupling locates at the connecting point of original pipe and new pipe.


x. Apply lubricant to the inside of coupling and outside of pipe.



xi. Set couplings on the original pipe and insert new pipe into coupling
<u>Note</u>: If sliding work is hard, use a chain block
</td></tr>
</table>

(2) Coupling with adhesive

<table>
<tr><th colspan="2">Required parts and equipment</th></tr>
<tr><td>

- PVC Service pipe
- Adhesive (solvent cement)
- Coupling
- Pipe cutter
- Chamfer

</td><td>



</td></tr>
<tr><th colspan="2">Procedures</th></tr>
<tr><td colspan="2">

i. Cut off the damaged part of the original pipe

ii. Measure the length of removed pipe
iii. Cut a new pipe to the required length
iv. Chamfer the edge of original pipe and new pipe
v. Mark the insertion length on the surface of original pipe and new pipe so that the center of coupling locates at the connecting point of original pipe and new pipe.
vi. Apply adhesive to each joint part
Note: Be careful not to apply too much quantity of adhesive
vii. Insert the original pipe and new pipe into the Coupling.

</td></tr>
</table>

3 Practice

Practical training is conducted for distribution pipe and service pipe as below.

- Distribution pipe:
  - Covering
  - Coupling with lubricant
- Service pipe:
  - Covering
  - Coupling with adhesive

3.1 Distribution pipe

Covering	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ PVC Distribution pipe: 2 pcs. ➢ Repair clamp: 1 pcs. ➢ Tool set: 1set
Practical training	Follow the procedures written in “2.3.1 Covering (Page 7)”

Coupling	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ PVC Distribution pipe: 2 pcs. ➢ Coupling: 1 pcs. ➢ Pipe cutter: 1pcs. ➢ Chamfer: 1pcs. ➢ Lubricant, brush, clean tissues: 1set ➢ Tool set: 1set
Practical training	➢ Follow the procedures written in “(1) Coupling with lubricant (Page 8)”

3.2 Service pipe

Covering	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ PVC Service pipe: 2 pcs. ➢ Repair clamp: 1 pcs. ➢ Tool set: 1set
Practical training	Follow the procedures written in “2.3.1 Covering (Page 7)”

Coupling with adhesive	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ PVC Service pipe: 2 pcs. ➢ Adhesive: 1 pcs. ➢ Coupling: 1 pcs. ➢ Pipe cutter: 1pcs. ➢ Chamfer: 1pcs. ➢ Tool set: 1set
Practical training	Follow the procedures written in “(2) Coupling with adhesive (Page 9)”

4 Keep repair record

When water leakage is found at the site, it is necessary to keep a record. Based on the records, it is possible to understand the deterioration status of pipes, determine the necessary frequency of detailed inspections and the make a standard for renewal.

The repair record has to include following information.

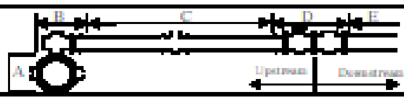
- Leakage location: address, hose number, road name etc.
- Pipe information: pipe material, size, installed year, part of leakage
- Leakage information: type of damage, size of damage, leakage volume
- Repair work information: materials used for repairs, number of staff, time taken to complete the repair work, used machine, volume of excavation, road type
- Water outage information for repair work, such as affected area of water supply, operated valves, water volume for cleaning the pipe

The repair record sheet is shown below.

The Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center-Western South of NWSDB in Sri Lanka

Leak Repair Detail Sheet	office	National Water Supply & Drainage Board
	officer	
Reported date and time		
Reported by	☐Complain ☐Meter reader ☐Leak detection ☐Others	
Compainer's Name & Add.		
Attended date and time		

Leakage information

Location	Adress	
	Meter No.	
	Consumer No.	
	☐Meter ☐Service pipe(Joint or pipe) ☐Ferrule ☐Distribution pipe	
		
Considerable cause	☐Deterioration ☐Traffic load ☐Poor construction ☐Others( )	
Pipe material	☐DI ☐PVC ☐PE ☐Others( )	
Pipe Dia.		Pipe depth
Road surface	☐Asphalt ☐Concret ☐I.L.B ☐Others ( )	
Traffic density	☐Heavy ☐Midium ☐Light	

Leake repair	Yes		No		Leak volume		m3/h

Repair information

Material used	

Machinery Used		Location(Sketch)
(1)	Power Light (1.5.1)Hrs	
(2)	Night work (1.5.2)Hrs	
(3)	Water Pump(Dewatering)Hrs	
(4)	Others	

Measurment

BOQ Item No.	Description	Unit	L(m)	B(m)	D(m)	Qty

Comment

Contractor Officer

NWSDB Officer

Training Guideline

4. Leak Repair

c. DI Distribution Pipe Repair

Table of contents

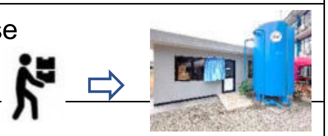
1 Outline

1.1 Purpose

Purpose of training	Water leaks have a significant impact on water supply business. Water leaks from the distribution lines not only affect the revenue of the water utilities but also cause accidents on a road and its surrounding, so it should be repaired immediately when it is detected. Pipe fitters typically gain their experience and skills through field works and training programs. This training aims to acquire theoretical knowledge and practical skills of DI pipe repair through a practical training.
Training Contents	➢ Leak repair of DI distribution pipe with repair clamp and coupling

1.2 Flow of training with time schedule

The total time is 3 hours and 40 minutes.

No.	Activity	Required time	Venue
1	Lecture	45 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Distribution pipe or Service pipe connection area)  
3	Preparation for practical training	20 min.	
	*Details are described in “3 Practice (Page 8)” *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse 		
4	Practical training	120 min. each	TY
	*Details are described in “3 Practice (Page 8)” <DI Distribution pipe> ➢ Leak repair of DI distribution pipe with repair clamp and coupling		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse 
6	Move to lecture room	5 min.	Lecture room
7	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.



- Do not eat food in the TY.



2 Knowledge acquisition

2.1 Characteristic of DI

Advantage

- ➢ High strength, high toughness
- ➢ It is resistant to corrosion and has high electric resistance, so it is not easily affected by electrolytic corrosion.
- ➢ Good workability

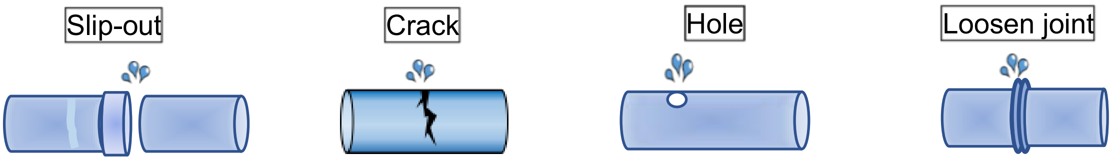
Disadvantage

- ➢ Relatively heavy weight
- ➢ If the soil is corrosive, external corrosion protection is required
- ➢ It is easy to corrode if the internal or external anticorrosion protection is damaged

2.2 Type, cause and preventive measure of leakage

Type of leakage

Typical leak types are slip-out, cracks, holes and loosen joint etc.



Causes of pipe leaks are divided in two categories, internal factor and external factor. Occurrence of leakage can be reduced by preventive measures in consideration of the following factors. These preventive measures can also extend pipe life span that contribute to effective management of water supply utilities.

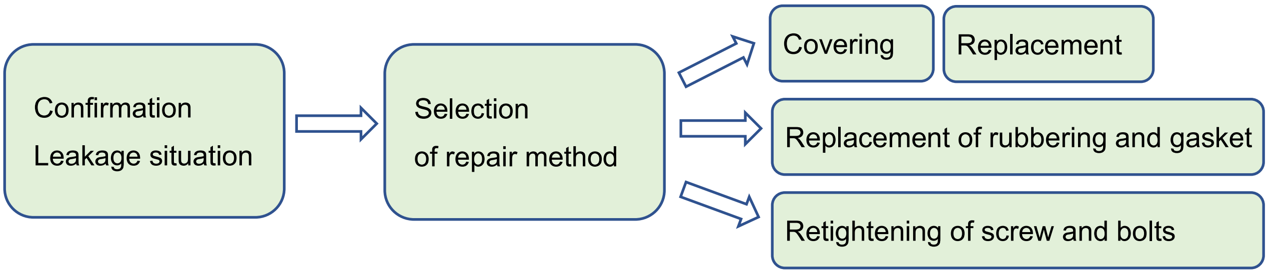
Cause and preventive measure	
Internal factors	Preventive measure
<u>Due to pipe and material</u> ➢ Improper materials and structures of pipes, fittings, and attached equipment ➢ Corrosion ➢ Aging of materials	➢ Select appropriate material (use of certified products, Inspect by own organization) ➢ Painting or covering by anticorrosion tape
<u>Due to design and construction</u> ➢ Design error ➢ Improper installation of joints, etc. ➢ Improper backfill ➢ Insufficient anticorrosion method ➢ Potentiometric corrosion due to dissimilar metals	➢ Reinforcement of surrounding land ➢ Reinforcement of laying foundation ➢ Installation of laying base structure ➢ Improvement of joint work technology by training ➢ Pipe protection concrete
<u>Due to cause in the pipes</u> ➢ Chronic high pressure, Water hammer ➢ Water quality (Internal corrosion) ➢ Stress due to change of water temperature (especially freezing)	➢ Inside of pipe lining
External factors	Preventive measure
<u>Due to buried environment</u> ➢ Impact from traffic load ➢ Hollow around pipes due to leakage and poor construction. ➢ Ground subsidence due to excessive pumping of groundwater ➢ Soil contamination by a factory effluent ➢ Corrosive soil environment ➢ Salt damage (sea breeze, underground water level) ➢ Difference between design and actual condition	➢ Appropriate backfill (backfill material, construction method) ➢ Installation of anticorrosive device ➢ Reinforcement of surrounding land ➢ Reinforcement of laying foundation ➢ Installation of laying base structure ➢ Improvement of joint work technology by training ➢ Pipe protection concrete
<u>Thing caused by other construction or disaster</u> ➢ Damage by other works ➢ Changes in buried environment due to other construction ➢ Ground and road fluctuation due to earthquakes and other disasters ➢ Ground movement by rain, flood and terrain deformation, etc.	➢ Installation of the indication tape, sheet ➢ Collecting pipeline information (as built drawings of distribution pipe and service pipe) ➢ Mapping system

2.3 Repair method

Followings should be considered for repair work:

- Pipe material
- Leaking condition (leak position, leak volume, damage condition, etc.)
- Space of repair work
- Time of suspension of water supply

Repair method shall be mainly divided in two type, ‘Covering’ and ‘Replacement’. And depending on pipe material and joint types, tightening and welding are also appropriate.



Note:

Although the method using adhesive tape is often introduced as the repair of the pipe, the water supply authority should, in principle, carry out permanent repairs. It should be used for only temporal repair.

2.3.1 Covering

The leakage part of distribution pipe is covered by repair clamp.

<table>
<tr><th colspan="2">Required parts and equipment</th></tr>
<tr><td>DI Distribution pipe
Repair clamp</td><td>The main method is to cover the entire pipe with a repair clamp which has rubber plates divided into 2 or 3.
 </td></tr>
<tr><th colspan="2">Procedures</th></tr>
<tr><td colspan="2">i. Check the diameter of the pipe, proper repair clamp size for each diameter must be used.
ii. Clean up the surface of the pipe
iii. Mark the size of the repair clamp on the pipe so that the damaged part will come to the center of the repair clamp.
iv. Set the repair clamp. Please be careful not to set the seam of repair clamp on the damaged part
v. Tighten all bolts with proper torque and following proper tightening sequence.
 </td></tr>
</table>

2.3.2 Replacement

The leakage part of pipe is replaced. A new pipe is connected to the original pipe with the coupling. For the repair of DI distribution pipe, coupling with lubricant is generally used.

(1) Coupling with lubricant

Required parts and equipment	
➢ DI Distribution pipe ➢ Coupling ➢ Pipe cutter ➢ Lubricant, brush, clean tissue	  

Procedures

i. Check the diameter of the pipe and proper coupling size.

ii. Mark the size of the cutting part including the damaged part. Check not only the part of water leaking but also around part of leaking.

iii. Cut the pipe with pipe cutter.

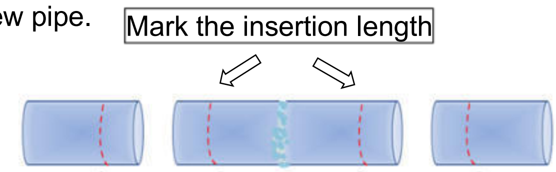
iv. After cutting, chamfer the edge of the pipe with a file or grinder.

v. Cut new pipe in suitable length. The length of the new pipe will be shorter than the length of the cut-off existing pipe.

vi. After cutting, chamfer the edge of the pipe with a chamfering device such as a file or grinder.

Note: Be sure to chamfer the cut surface of the pipe, otherwise the rubber ring will be damaged when inserting and a large force will be required for insertion.

vii. Mark the insertion length on the pipe surface so that the center of the coupling locates at the connecting point of the original pipe and the new pipe.



viii. Apply lubricant to the inside of the coupling and external of the pipe.

ix. Set couplings on the original pipe and insert new pipe into coupling

3 Practice

Practical training is conducted for distribution pipe as below.

- Distribution pipe:
  - Covering
  - Coupling with lubricant

3.1 Distribution pipe

Covering	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ DI Distribution pipe: 2 pcs. ➢ Repair clamp: 1 pcs. ➢ Tool set: 1set
Practical training	Follow the procedures written in “2.3.1 Covering (Page 6)”

Coupling	
Preparation	➢ Mark the leak point on the pipe
Necessary parts and equipment for each team	➢ DI Distribution pipe: 2 pcs. ➢ Coupling: 1 pcs. ➢ Pipe cutter: 1pcs. ➢ Chamfer: 1pcs. ➢ Lubricant, brush, clean tissues: 1set ➢ Tool set: 1set
Practical training	➢ Follow the procedures written in “(1) Coupling with lubricant (Page 7)”

4 Keep repair record

When water leakage is found at the site, it is necessary to keep a record. Based on the records, it is possible to understand the deterioration status of pipes, determine the necessary frequency of detailed inspections and the make a standard for renewal.

The repair record has to include following information.

- Leakage location: address, hose number, road name etc.
- Pipe information: pipe material, size, installed year, part of leakage
- Leakage information: type of damage, size of damage, leakage volume
- Repair work information: materials used for repairs, number of staff, time taken to complete the repair work, used machine, volume of excavation, road type
- Water outage information for repair work, such as affected area of water supply, operated valves, water volume for cleaning the pipe

The repair record sheet is shown below.

The Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center-Western South of NWSDB in Sri Lanka

Leak Repair Detail Sheet	office	National Water Supply & Drainage Board
	officer	
Reported date and time		
Reported by	☐Complain ☐Meter reader ☐Leak detection ☐Others	
Compainer's Name & Add.		
Attended date and time		

Leakage information

Location	Adress	
	Meter No.	
	Consumer No.	
	☐Meter ☐Service pipe(Joint or pipe) ☐Ferrule ☐Distribution pipe	
		
Considerable cause	☐Deterioration ☐Traffic load ☐Poor construction ☐Others( )	
Pipe material	☐DI ☐PVC ☐PE ☐Others( )	
Pipe Dia.		Pipe depth
Road surface	☐Asphalt ☐Concret ☐I.L.B ☐Others ( )	
Traffic density	☐Heavy ☐Midium ☐Light	

Leake repair	Yes		No		Leak volume		m3/h

Repair information

Material used	

Machinery Used		Location(Sketch)
(1)	Power Light (1.5.1)Hrs	
(2)	Night work (1.5.2)Hrs	
(3)	Water Pump(Dewatering)Hrs	
(4)	Others	

Measurment

BOQ Item No.	Description	Unit	L(m)	B(m)	D(m)	Qty

Comment

Contractor Officer

NWSDB Officer

Training Guideline

4. Leak Repair

d. Valve and Accessory

Table of contents

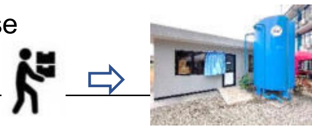
1 Outline

1.1 Purpose

Purpose of training	In order to maintain stable water supply, it is necessary to properly manage not only water pipes but also accessories such as valves and air valves, etc. and repair any water leaks as soon as possible. Accessories are more complicated structure than pipes, and it may not be simple to identify and repair leaks. In this program, we learn the structure of the accessories, locations where water leakage may occur, and learn how to repair them depending on the leak location.
Training Contents	➢ Leak repair of gate valve ➢ Leak repair of air valve ➢ Leak repair of fire hydrant

1.2 Flow of training with time schedule

The total time is 3 hours and 40 minutes.

No.	Activity	Required time	Venue
1	Lecture	45 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Distribution pipe or Service pipe connection area)  
3	Preparation for practical training	20 min.	
	*Details are described in “3 Practice (Page 13)” *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse 		
4	Practical training	120 min	TY
	*Details are described in “3 Practice (Page 13)” ➢ Leak repair of gate valve ➢ Leak repair of air valve ➢ Leak repair of fire hydrant		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse 
6	Move to lecture room	5 min.	Lecture room
7	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.



- Do not eat food in the TY.



2 Knowledge acquisition

2.1 Type of accessories

The accessories used for water supply distribution facilities are valves, fire hydrant, air valves, PRV (Pressure Reduce Valve), check valve, etc. This training program deals with gate valves, air valves and fire hydrants, which are the most frequently installed facilities.

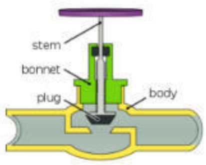
2.1.1 Valve

Valves are classified according to their function and structure.

- Shut-off valve: Gate valve, Butterfly valve, Grove valve, Ball valve, Score valve
- Control valve: PRV, Diaphragm valve, (Grove valve) , Check valve.
- Air valve

(1) Shut-off valve

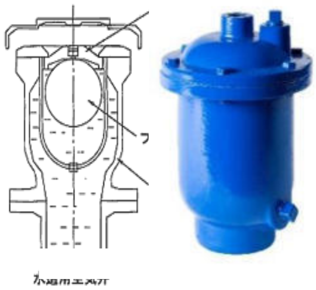
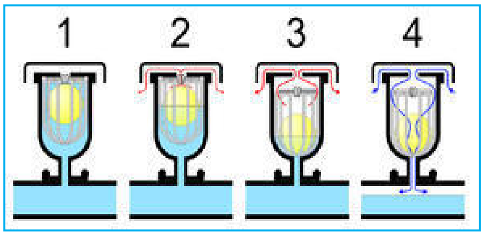
The shut-off valve normally passes and shuts off the water flow in the pipeline by fully opening and closing the valve body. This valve operates when shutdown is required such as pipe installation works, change of a water distribution area or a water distribution block and in an emergency by an accident.

Shut-off valve	
Gate valve  	The gate valve is a valve for separating the water pipe, and the type of soft seal gate valve is often used because of its water tightness and little loss. Gate valves have the advantage of low fluid resistance but should be fully open or fully closed because exposure to fluid at an intermediate opening may cause valve body vibration.
Butterfly valve 	In a short cylindrical valve box, a disc-shaped valve body rotates around a valve rod to open and close the flow path. Due to its structure, it was difficult to close the valve seat, but various high-performance models have been developed by adopting elastomers and plastics. Since the valve body is plate-shaped, water hammer and unbalanced torque are likely to occur, so be careful in operation.
Grove valve  	The valve box has a globe shape, the center lines of the inlet and outlet are in a straight line, and the fluid flow is S-shaped. When the direction of the flow changes, the passage expands and contracts rapidly, so the pressure loss occurs when. But the shutoff performance and ease of flow adjustment are excellent. Flow rate adjustment is performed by a component called a valve body.
Ball valve  	A spherical valve body with a hole in the valve box rotates around a valve rod to open and close the flow passage. Since the flow path is straight, the fluid resistance is small when fully opened.

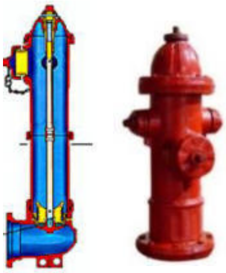
(2) Control valve

Control valve	
Pressure reduce valve 	Pressure Reduce Valve (PRV) protects pipes and other facilities from high water pressure, reduces water leak volume, and enables more comfortable water supply to the consumer. The operation of the PRV is performed by adjusting the opening area of the water path in the valve. The throttle opens when the secondary pressure increases and decreases. For that purpose, there is a diaphragm that moves by receiving the secondary pressure, and a mechanism that pushes back the pressure by providing a spring. PRV reduces the water pressure and sustain high pressure exceeding the control range of the water pressure control valve to maintain an appropriate dynamic water pressure in the water distribution area.
Check valve  	Check valve protects pumps, meters and other equipment for water supply from accidents and water contamination caused by backflow. The back pressure of the fluid activates the valve body to prevent backflow.

(3) Air valve

Air valve	
Air valve  	The air valve is installed at a high position in the pipeline, such as pipes over a river or the water pipe bridge and has the function of automatically drawing in and discharging the air accumulated in the pipe. Since the air valve is susceptible to tilt, it is necessary to adopt a construction method that can eliminate tilts. Mechanism of air valve is as below.  1. Normal condition. 2. When a small amount of air is accumulated. 3. When a large amount of air is accumulated. 4. When a negative pressure is reached.

2.1.2 Fire hydrant and other equipment

Fire hydrant and other equipment	
Fire hydrant 	There are two types of fire hydrants: above ground and below ground. In the above-ground type, it is often branched from a distribution pipe and installed on a sidewalk. On the other hand, the underground type has a manhole on the roadway and is installed underground. Since there are accidents caused by vehicles in the above-ground type, a sluice valve should be installed in the middle of the distribution pipe and fire hydrant so that water can be stopped in the event of an accident and repaired. Fire hydrants shall be installed in distribution branch pipes, and the installation shall be in accordance with the following items. ➢ Consider the situation of buildings along the railway ➢ Install them at intervals of 100 to 200m. ➢ In principle, single-mouth hydrants are for water pipes with a diameter of 150 mm or more, and double-mouth hydrants are 300 mm in diameter
Water pressure gauge and an automatic water quality meter, etc. 	Water supply measuring equipment is also included in the accessories to ensure stable and safe water supply. Water pressure meters, residual chlorine meters, flow meters, etc. are devices that may leak water. Most of the water leakage of this kind of equipment is from the joint part.

2.2 Cause of leakage

Water leakage in valves and accessories mainly occurs due to deterioration of rubber packing and corrosion of parts as shown below.

Deterioration of gasket and packing

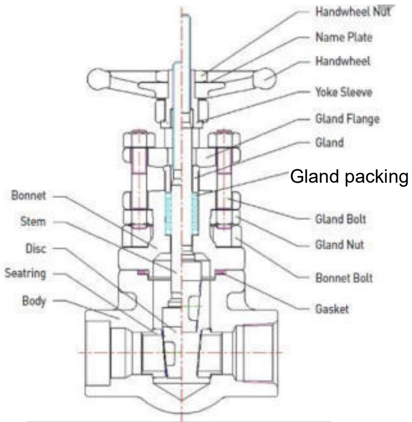
Loose bolt
Corrosion of parts

Crack of body by excessive external force

2.3 Type of leakage

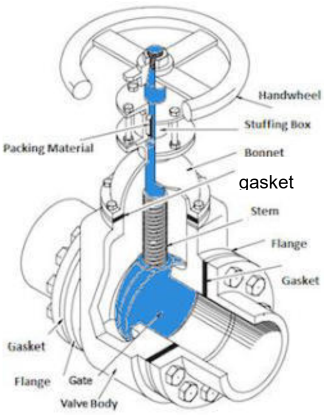
2.3.1 Valve

Valve	
Gland leak	Leakage from the gland packing occurs due to wear of the packing by valve operation and deterioration of the packing itself.
Gasket leak	Leakage from the gasket mounted between the valve body and the lid occurs when the packing aging.
Leak from valve body	Leakage from the valve body occurs due to cracks by corrosion.



Leak from gasket

Leak from grand packing



Leak from gasket

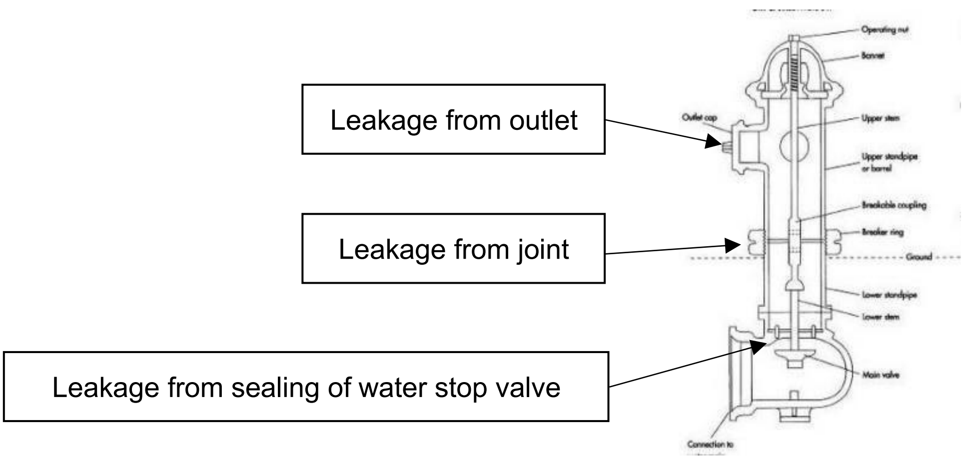
Crack

2.3.2 Air valve

Air valve	
Foreign matter in the valve	It occurs when foreign matter such as sand or debris is caught between float and valve box that have the function of stopping water.
Damage to main body and joints	Water leakage often occurs from damaged main body or joints.

2.3.3 Fire hydrant

Fire hydrant	
Outlet, joint, valve	Leakage from a fire hydrant can occur from outlet and joint. The packing at the joint of a ground-type fire hydrant deteriorates due to ultraviolet rays. Leakage occurs from the joint when the fire hydrant hose is connected.



2.4 Repair method

2.4.1 Valve

Leakage from gland packing

i. Retighten the ground bolts.

ii. If the leakage does not stop, replace the gland packing.

Leakage from gasket

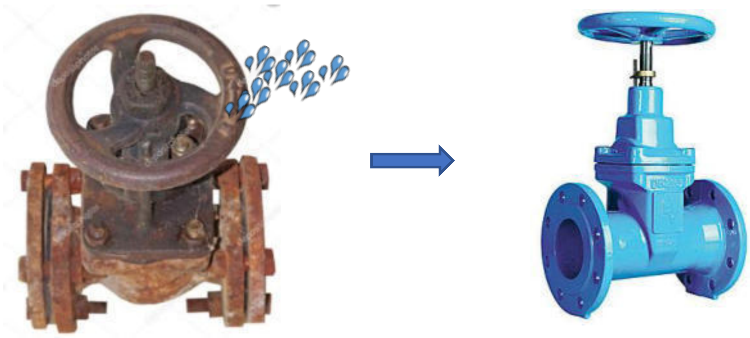
i. Retighten bolts.

ii. If the leakage does not stop, replace the gasket.

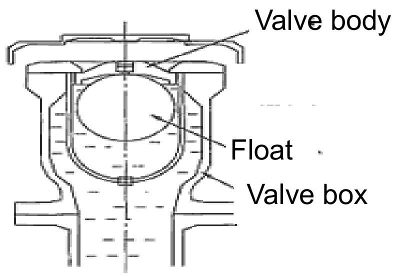
Note: When retightening the gasket, keep the valve in the middle or fully open state. Care must be taken when the valve is fully closed, since the seat will be damaged or the valve stem will bend, as a result, the valve itself becomes inoperable. Also, select the shape of the gasket that matches the flange.

Leakage from valve body

In such a case, it is desirable to replace the valve.

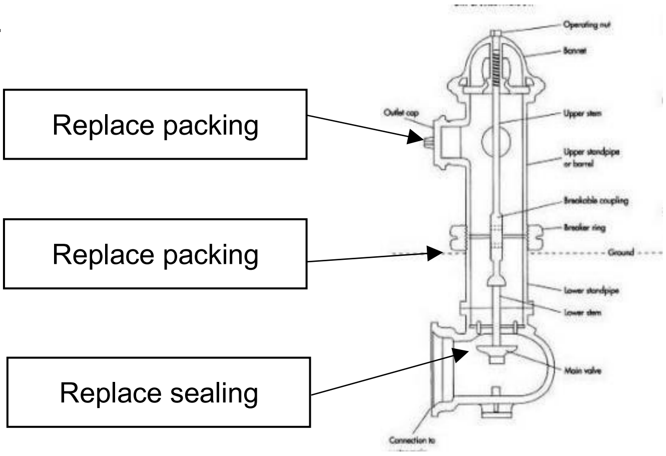


2.4.2 Air valve

Foreign matter is caught in the valve
Open the body that the float is in, then remove foreign matter such as sand or debris.  
Damage to main body and parts
Replace damaged parts or body completely. 
Leakage from the joint
Retighten the bolts. If leakage does not stop, replace the gasket.  Retighten the bolts or replace gasket

2.4.3 Fire hydrant

Leakage from fire hydrant
Replace a packing or sealing.



2.5 Maintenance of accessories

Maintenance of accessories tends to be neglected, but periodical inspection is necessary to maintain the integrity of the entire pipeline network. In this section, introduce a simple check method that should be performed on site. To carry out more detailed inspections, it is necessary to plan a detailed inspection schedule and select inspection items by an appropriate method.

➢ Simple check method

First, check the status of accessories from the appearance of the item body, etc.

And inspection results data must be recorded and stored. Main check points and simple measures of maintenance activities are as below:

Method	Detail	Measures of maintenance
Visual inspection	damage, corrosion, painting, external water leakage, opening indication, submersion	cleaning, descaling, retightening bolt, repainting, replace packing or gasket, lubricating, draining
Operation	open / closed state	
Hearing sound	water stopped (water flowing sound)	
Palpation	vibration	

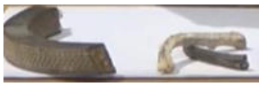
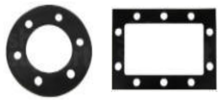
If any abnormal noise, vibration or leakage are observed while operating the valve (including air valve, fire hydrant), it is necessary to suspect defects of the valve. In such case, immediate repair is recommended.

3 Practice

3.1 Preparation

In addition to a tool set, prepare following equipment.

3.1.1 Gate valve

Status	Assuming water leakage from the gland and flange gasket.		
Item	Valve	1	  
	Grand packing suitable for valve size	1	
	Gasket suitable for valve size	1	
	Material fixing blocks / wood chips	1	

3.1.2 Air valve

Status	Assuming water leakage due to foreign matter clogging		
Item	25mm air valve or 75mm air valve	1	
	Cleaning cloth or paper	1	
	Material fixing blocks / wood chips	1	

3.1.3 Fire hydrant

Status	Assuming water leakage from operating nut		
Item	Fire hydrant	1	 
	Seating valve	1	
	Material fixing blocks / wood chips	1	

3.2 Procedures of training

The typical method to repair water leaks in valves and other accessories are retightening bolt, replacement of gasket or other parts.

3.2.1 Gate valve

(1) Leakage from valve joint gasket

Steps	Procedures	
1	Remove bolts and bonnet of valve gate.	
2	Replace a gasket	
3	Put back the bonnet and fix it with bolts and nuts.	

(2) Leakage from gland packing

Steps	Procedures	
1	Loosen gland bolts	 
2	Remove the gland flange	
3	Remove old gland packing	
4	Prepare suitable length of new gland packing for stem diameter Add a curve to fit the stem	
5	Install new packing	 
6	Fix bolts	 

3.2.2 Air valve

Steps	Procedures	
1	Remove bolts and nuts and then remove the bonnet	
2	Remove the bonnet	
3	Clean inside of the air valve. Remove foreign matter Carefully observe the float for scratches	 
4	Fix the bonnet with bolts and nuts	
5	Open the cock and check water leak	

3.2.3 Fire hydrant

Steps	Procedures	
1	Remove nuts and bolts from the joint at the base of the top bonnet	
2	Turn the operation nut to the direction of opening until the bonnet stops its upward movement	 
3	Insert seat wrench on the stem	
4	Remove all parts including main brass valve seat	
5	Remove lower valve plate from the stem by turning counterclockwise	
6	Seating valve or other parts can now be easily replaced as needed Reassemble valve and stem with new material	
7	Tighten lower valve plate clockwise.	
8	Apply appropriate food grade anti-seize to threads of bronze valve seat	
9	Re-insert valve mechanism with seat wrench into standpipe Tighten clockwise and check for leak around	

10	Turn operating nut to the direction of closing until top bonnet stops downward movement and is tight	
11	Replace four flange bolts and nuts.	
12	Turn on isolation valve, let the hydrant flow, and check to see if the hydrant is working properly	

4 Keep repair record

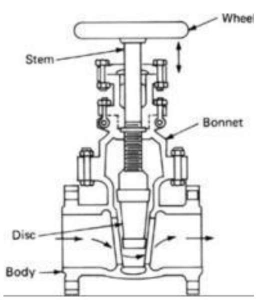
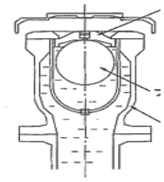
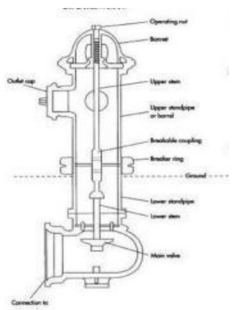
When there is a leak from an accessory at the site, it is necessary to keep a record as well as a pipeline leak. From the accumulated records, it is possible to understand the deterioration status of accessories and determine the necessary frequency of detailed inspections and the standard for renewal.

The repair record has to include following information.

- Name of accessory
- Cause of leakage (If not clear, assuming)
- Part of leakage
- Materials used for repairs
- Time taken to complete the repair
- Address, leakage volume, etc.
- Type of connected pipe
- Diameter
- Installed year
- Mapped the point of leaking

The repair record sheet is shown below.

Accessory Leakage Record Sheet

Office							
Officer							
Attended date and time							
Repair date & time							
Information provider of leak information	Reported date and time						
	Reported by	☐Complain ☐Meter reader ☐Leak detection ☐Others					
	Complainer's Name & Add.						
Leakage information							
Leak location	Address	Location(Map copy or Sketch)					
	Accessory	□Valve □Air valve □Fire hydrant □Meter □Other[ ]					
	Installation Location	□In the room □In the chamber □Outside of chamber □Above ground □Other[ ]					
	Part	□Flange Joint □Gland □Fire hydrant outlet □ Air outlet □ Body □Other [ ]					
	Considerable cause	□Deterioration: □Body, □Bolt & nuts, □ Gasket, □Packing □Clack □Things get caught inside □Others( )					
	Installation year		Manufacture				
	  						
Pipe information	Pipe material		Pipe Dia.		Pipe depth		
Road surface	Concrete, Asphalt, Bare ground, Turf, Grassland				Pipe Installation year		
Leak repair	Yes		No		Leak volume		m3/h
Repair information							
Material used							
No. of workers and Activity time							
Machinery used	Power Light: Hrs Water Pump(Dewatering): Hrs Excavation: m3 Others						
Comment or Photograph							

Contractor Officer

NWSDB Officer

Training Guideline

5. Measurement

a. Water Meter

Table of contents

1 Outline

1.1 Purpose

Purpose of training	➢ Understand meter reading, type of meters, meter accuracy & class, maintenance. ➢ Measure the accuracy of customer meters with the test meter kit (reference meter) and learn how to do it easily on site.
Training contents	➢ Customer meter accuracy test

1.2 Flow of training with time schedule

The total time is 2 hours and 45 minutes.

No.	Activity	Required time	Venue
1	Lecture	45 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Distribution pipe or Service pipe connection area)  
3	Preparation for practical training	10 min.	
	*Details are described in “3 Practice (Page 16)” *Activate pump of TY *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse (Pressure logger, Ultrasonic Flow Meter, Meter test kit)  		
4	Practical training	50 min.	TY
	*Details are described in “3 Practice (Page 16)” 		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse 
6	Move to lecture room	5 min.	Lecture room
7	Data visualization	25 min.	Lecture room
	*Use PC		
8	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY.RP should order to participants wearing suitable item






- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.

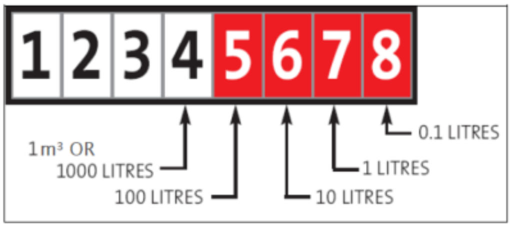


- Do not eat food in the TY.



2 Knowledge acquisition

2.1 Meter reading



The water meter shows several digits as shown in the right figure. This digit means 1234 m^3 and 567.8 liter, or 1234.5678 m^3. When the counter of 0.1 liters is moving between two numbers, it is counted as lower number.

Another water meter has pointers as shown in the right photo. m^3 is shown in the upper black digits and liter is shown in the lower red pointer. When the pointer is between two numbers, it is counted as lower number.

When the digit of counter reached maximum (e.g. 9999.999), it back to all zero (e.g. 0000.000), and sometimes it makes mistakes of calculation of consumption. As shown below, it is necessary to calculate on the assumption that it has one digit in the left side which is not shown on the display.

Previous reading:9989.123, Current reading:0002.234

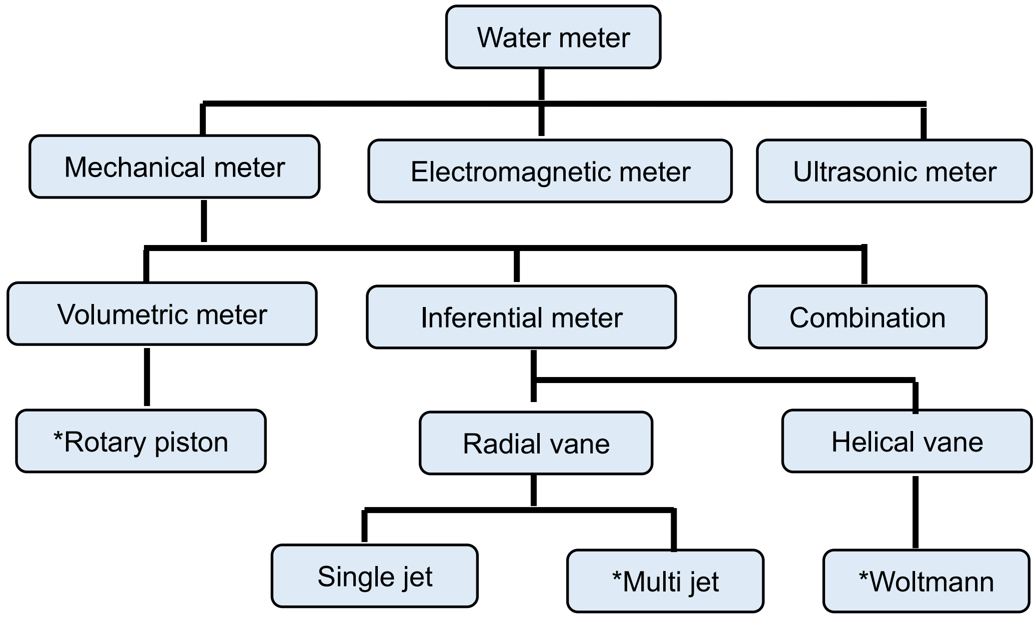
Consumption: <u>10002.234</u>-9989.123 = 13.111

2.2 Type of meter

In Sri Lanka, the type of meter is determined by NWSDB so it is necessary to select the proper meter based on the regulation of NWSDB.

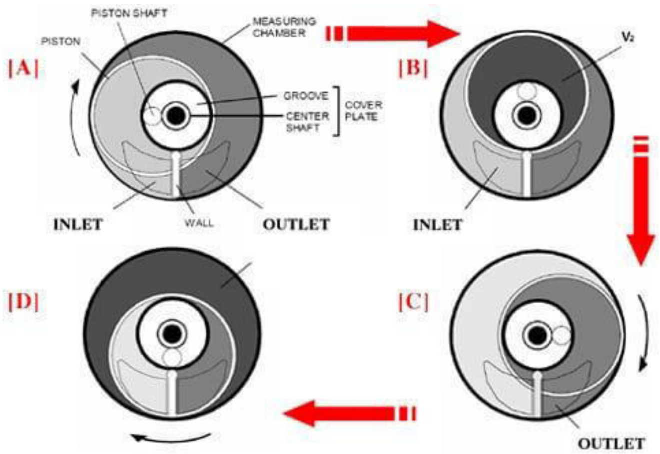
The type of water meter is classified as below.

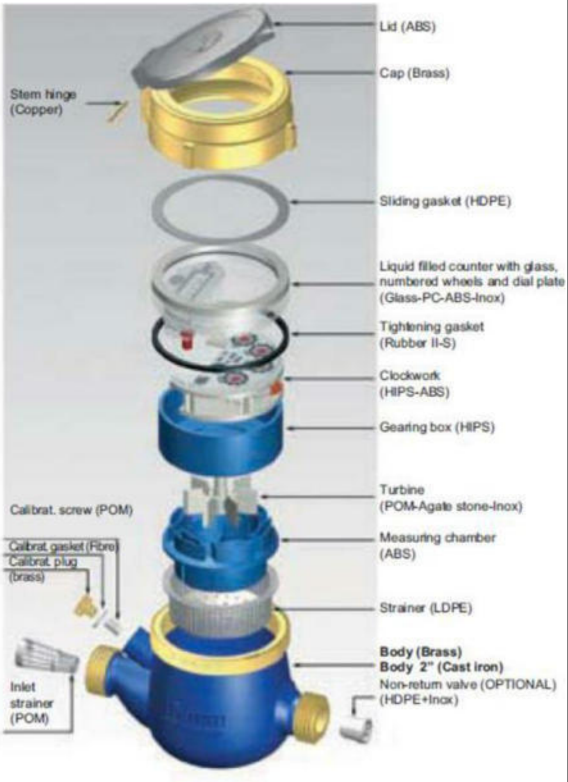
Type of meter



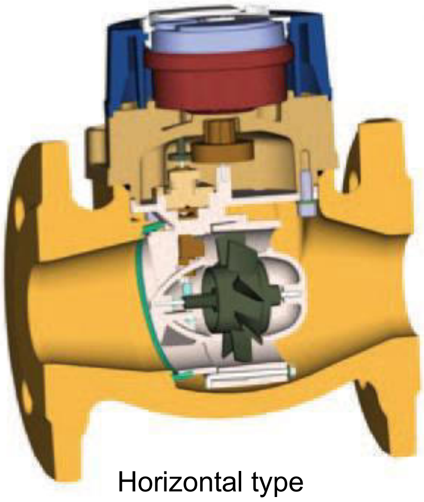
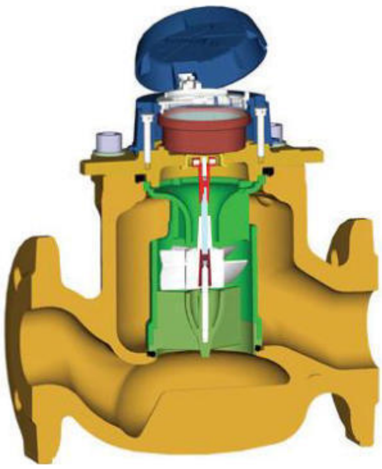
*The details are as given below

Mechanical meters i. Rotary piston meters	
Characteristics 	Rotary piston meters are popular for their combination of accuracy, long-life and moderate cost so they are widely used. Rotary piston meters come in many different shapes and sizes as shown in the left photos. Wet or dry dials are used. Sand or other suspended solids easily get stuck between the piston and chamber wall. Thus, it is important to be installed in the system with very good water quality and to install built-in strainer. <Mechanism> The rotor is basically a disc shape with an annular groove on its underside capable of holding and transporting flow from the chamber inlet to the outlet. Some fluid is also transported in a cavity formed between the rotor outside wall and the chamber wall. A centre ‘peg’ under the rotor is constrained to run in a circular groove in the body. A web (or plate) in the body is engaged with a slot in the rotor and this modifies the rotation to that of an oscillation as flow passes.

	
Application and Installation	Rotary piston meters are commonly used most domestic applications up to diameter 25mm. They are not sensitive to the wide flow velocity profile. <u>Rotary piston meters can be installed in any position with stable accuracy and placed close to bend or pump</u>. ➢ Applicable pipe diameter: 13mm – 40mm ➢ Suitable installation location: Place where the power is out and there is no cover to protect rainwater

<table>
<tr><th colspan="2">ii. Multi Jet meters</th></tr>
<tr><td>Characteristics
</td><td><Mechanism>


The multi jet meters are an inferential water meter. Their operation is similar to that of single jet meter, except that they use several jets to drive the impeller at multiple points. This means that the forces on the impeller are better balanced than in single jet meters, which reduces wear on the moving parts and provides greater durability. A cutaway view of a multi jet meter is shown in the left photo.
Multi jet meters normally use an internal bypass with a regulating screw to adjust the flow passing through the impeller. This allows the manufacturer to adjust the meter's error curve for achieving the best accuracy before sealing it for the prevention of meter tampering. A strainer is installed on the inlet side, which can be removed for cleaning.
➢ Advantages: No power required, Accurate at low flow rate
➢ Disadvantages: If a foreign substance gets in, accuracy falls, or the impeller will be damaged. Piping friction loss occurs. Not applicable to large diameter pipes.</td></tr>
<tr><td>Application and Installation</td><td>Multi jet meters are mainly used for domestic applications, and are normally more cost effective than single jet meters in diameters larger than 20 mm. The accuracy of multi jet meters is not affected much by changes of velocity profile.
➢ Applicable pipe diameter: 13mm – 40mm
➢ Suitable installation location: Place where the power is out and there is no cover to protect rainwater</td></tr>
</table>

iii. Woltman meters	
Characteristics 	<Mechanism> The Woltman meters are an inferential meter that uses an impeller with helical vanes. As water flows over the helical vanes, it rotates the impeller. Then, the rotation is transmitted to the dial via reduction gearing. There are two main types of Woltmann meters called Horizontal (WP) and Vertical (WS) Woltmann meters. Horizontal Woltmann meters have their inlets and outlets directly along the pipeline. The axle of the helical vane is parallel to the flow. Water flows directly through the meter with small loss caused by the meter body. The flow direction is changed 90 degrees after entering a vertical Woltmann meter, pass through the impeller and then turn back to the original direction as shown in the cross section of left Figure.  Horizontal type  Vertical type Woltmann meters are affected by flow distortions or changes in meter dimensions. Excessive sediment in the meter can cause severe error. All Woltmann meters have dry and sealed dials. ➢ Advantages: No power required, Highly accurate ➢ Disadvantages: If a foreign substance gets in, accuracy falls, or the impeller will be damaged. Piping friction loss occurs. Not applicable to large diameter pipes.
Application and Installation	Woltmann meters are widely used throughout the world. They are mainly used to measure the consumption volume of bulk users, or to determine the flow pattern in water distribution systems. Horizontal Woltmann meters can be installed in all directions without affecting the accuracy. The counter, however, should never be placed upside down. Vertical Woltmann meters must be installed horizontally with the display facing upwards.

	➢ Applicable pipe diameter: 40mm – 400mm ➢ Suitable installation location: Place where the power is out and there is no cover to protect rainwater

2.3 Metrology, Meter classes and other requirements

2.3.1 Definition of meter accuracy

The volume of water that passes through a water meter is called the actual volume, or Va. However, since no meter is 100% accurate, the meter will not register all the water passing through it but show a indicated volume (Vi), which is slightly lower or higher than the actual volume. The difference between the indicated volume and actual volume (Vi - Va) is called the meter error. When the error is expressed as a fraction (percentage) of the actual volume, it is called as the relative error.

[Relative error]: (Vi - Va) / Va x 100 (%)

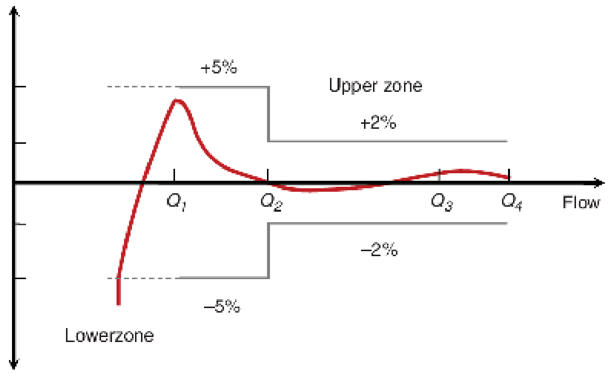
Where: Vi is the indicated volume. Va is the actual volume.

2.3.2 Meter error curve

Water meters are designed for a specific flow rate, which is called as the permanent flow rate or Q_3.The meter should be able to work at the permanent flow rate (or a lower flow rate) continuously for its design life without exceeding the permissible error.

Although a meter is designed for the permanent flow rate, the actual flow through a meter is not constant. Thus, water meters should not only be accurate at the permanent flow rate, but also be accurate over a wide range of flow rates.

It is useful to draw a graph of a meter's relative error. This curve is called the meter's error curve.



- Q1 – Minimum flow rate: [Sri Lanka 16l/h, D15mm]

  The lowest flow rate at which the meter is required to give indications within the maximum permissible error tolerance (± 5% error).
- Q2– Transitional flow rate: [Sr Lanka 25.6l/h, D15mm]

  The flow rate at which the maximum permissible error of the water changes in value from ± 5% error to ± 2% error.
- Q3 – Permanent flow rate: [Sri Lanka 1.6m³/h, D15mm]

  Permissible continuous load. Half the maximum flow rate (± 2% error).
- Q4 – Maximum flow rate (Overload Flow Rate): [Sri Lanka 2.0m³/h, D15mm]

  The highest flow rate at which the meter is required to operate in a satisfactory manner for a short period without deteriorating (± 2% error)

2.3.3 Conventional meter classes

Conventionally four classes of meters are defined and denoted by the letters A, B, C(V100) and D. The accuracy requirements are the same for all four classes, namely a maximum permissible error of ±5% in the lower flow zone and ±2% in the upper flow zone.

The differences between the classes lie in how high the transitional and minimum flow rates are allowed to be in relation to the permanent flow rate. Class A has the lowest performance and class D has the highest performance. Class C and D normally used for customer meter.

NWSDB regulates the quality of meters. Some of them are listed below.

<The regulation of meters by NWSDB>

[SPECIFICATION FOR VOLUMETRIC DISPLACEMENT TYPE WATER METERS AND SPARE PARTS] Materials Water meters may only be constructed of copper alloy. Woltmann meters are allowed to use other ferrous materials. Meter type All domestic water meters and spare parts to be supplied shall be of volumetric type with threaded end connections. Single or multi jet type meters class C accuracy will not be accepted for volumetric type meter. Seals and markings Meters must be sealed in the factory after assembly and verification so that it is impossible to tamper with the meter without visible damage to the meter or seal. The following markings should be added on the meter body: 01. Model number 02. Name or Trademark 03. Permanent Flow Rate 04. Size in DN 05. Pressure Loss in bars 06. Year of Manufacture 07. Serial Number 08. An arrow indicating the direction of flow 09. The letter “NWS&DB” of height not less than 5 mm 10. Measuring Range 11. Class of the meter (Instead of ‘C’ = V100) 12. Other Markings

2.4 Operation and maintenance

2.4.1 Introduction

It is important for operating water meter to keep a good operating condition and comply with the legal metrological requirements. Also It needs a carefully planned systematic meter management system.

2.4.2 Installation

Once a meter has been selected it has to be installed in the system. Correct installation is critical since it will affect the performance of the meter for its full-service life. Incorrect installation may lead to high under-registration losses and shorten the service life of a meter.

Before the meter is installed, the connecting pipe work must be thoroughly flushed to remove any dirt that may block the meter strainer or damage the meter. Regarding plumbing work, it is necessary to take care not to use too much adhesive. The solidified adhesive may clog the filter or be caught in the meter and cause a failure.

Meters installed outside of the private land are easier to access by meter readers.

A meter installation should comply fully with the following requirements:

- Correct direction of flow through the meter – an arrow on the meter indicates the correct flow direction.
- Correct orientation of the pipe work (e.g. horizontal or vertical).
- Securing minimum straight length of pipe upstream and downstream of the meter.
- Some meters require the installation of a separate strainer upstream of the meter.
- Isolating valves should be installed on both the upstream and downstream side of the meter.
- Electrical meters need protection against lightning and electrical surges.

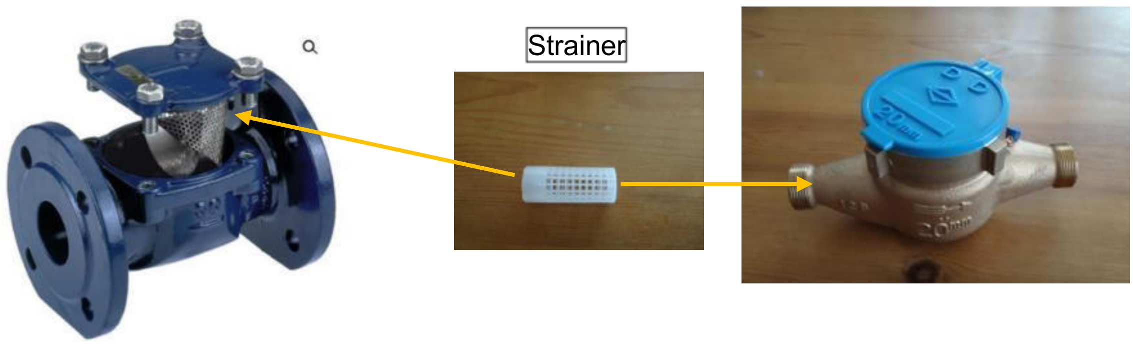
2.4.3 Maintenance

The proper maintenance of any metering device is essential to ensure the accuracy. Most meter manufacturers have a recommended maintenance and testing method in the operation manual.

The most common problems experienced with water meters in the field are as below:

- Suspended solids in the water cause stuck or damage of meter and meter strainer. These solids enter the system most often due to:
  - Large pipe bursts.
  - Inadequate flushing of pipes after installations or repairs.
  - High velocities in the network stir up sediments that was accumulated on the bottom of pipes.
  - Inadequate water treatment or malfunction of treatment plants.
  - Service complaints after meter replacement or maintenance caused by:
- Leakage from meter connections.
- Deposit of lime or metal oxides on the inside of meters due to high dissolved solid loads in the water.

A strainer should be installed upstream of the meter to protect the rotor from objects such as stones and pebbles. As for maintenance, the strainer needs to be cleaned regularly.



2.5 Meter accuracy test method

Like any mechanical device, water meters deteriorate with use. The starting flows and accuracy at low flows are the areas on the accuracy curve that tend to deteriorate most rapidly.

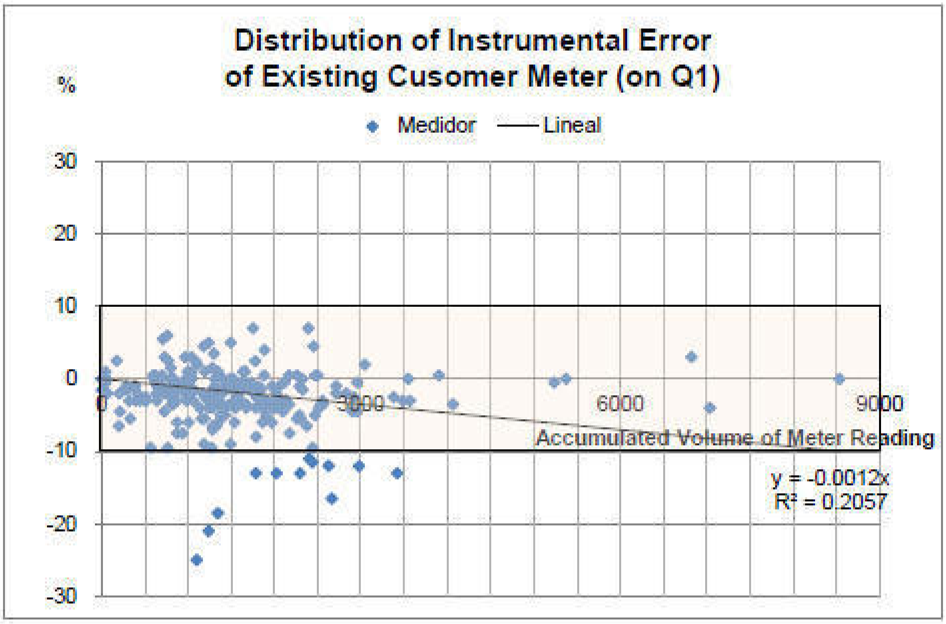
It is not possible to predict meter performance since there are so many factors that affect the way meters age, including water demand patterns, volume through the meter, water quality and environmental conditions.

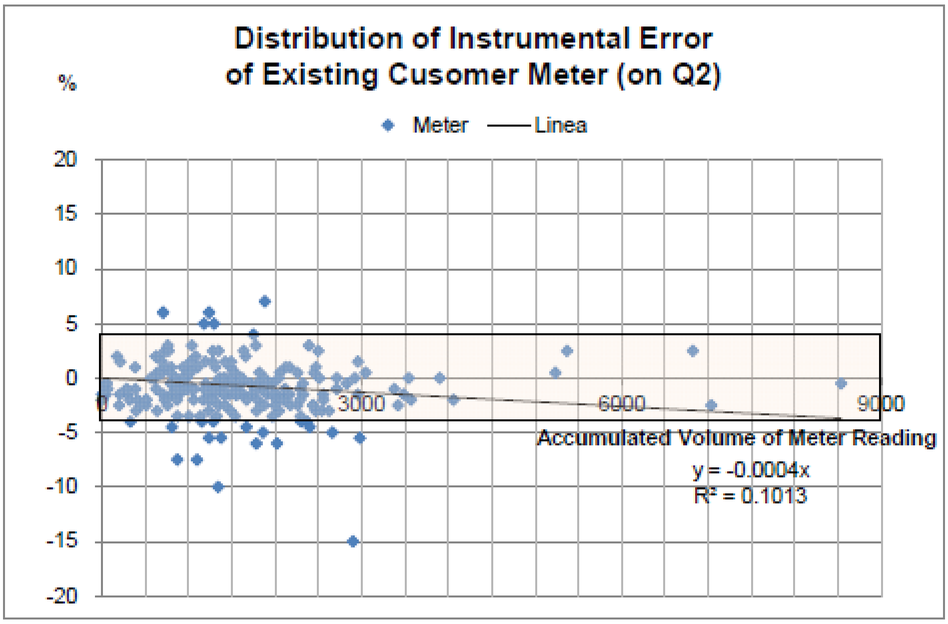
Test method	When testing meters, it is important to take the purpose of the test into consideration. If the accuracy of a meter needs to be verified for trade purposes, such as in response to a consumer complaint, the test methods must comply with metrology legislation and certification.   Various methods are available for testing the accuracy of water meters. The most precise method is that removing the meter from the field and test it on a laboratory test bench.
Large size meter	All large meters need to be tested regularly. Meters between 25mm and 100mm are tested every five years, and meters of 100 mm and larger are tested every year. 
Domestic and small size meter	Domestic and small water meters are tested every 10 years. However, it doesn't make sense to try to test all domestic and small meters due to the large numbers of meters in the system. The recommended approach to domestic and small meter testing is to classify the meters according to the factors such as meter model, size, age, volume measured and user type, and then select several group of meters to test.   In Japan, the law requires all meters to be replaced every eight years. Updating all meters after a certain period in this way leads to the most accurate measuring. It is preferable to perform an error test when the meter value is outlier before customer's complaint.

2.6 Meter reliability evaluation

Generally, the larger the cumulative value of the meter, the longer the years of use, so that it tends to be aged and malfunction. By plotting the cumulative water volume of the meter on the horizontal axis and the meter instrument error on the vertical axis, you can read the accumulated meter value of the meter and the tendency of the generator difference.

If there is a high correlation between the accumulated flow rate value and the occurrence of instrumental error, it is possible to determine when it is desirable to update the existing meter.





< Relation between cumulative water volume and instrumental error >

3 Practice
3.1 Outline
3.1.1 Meter accuracy test
This meter accuracy test using test meter provides certain level of accuracy in site but it isn't completely accurate. Therefore, it is necessary to note that this test is not authorized measurement but tentative measurement in site.

The purpose of the test is to check the meter accuracy as part of a meter replacement study and to obtain quick approximation as a customer service. This will satisfy the requirements for such purpose.

The error is shown in a percentage, and is equal to:

(V1 – V2) / V1 x 100%

Example of a meter accuracy calculation.

- The customer water meter has an initial reading of 123.456 m3.
- Flow water about 50 littler through the reference meter
- The customer meter reading is 123.602 m3.

Deference between the customer meter and the reference meter:

123.602 - 123.456 = 0.046 m3 = 46 little

Error ratio = error volume / actual volume = (50 – 46 = 4) / 50 = 0.08 = 8%

Accuracy rate exceed the permissible error rate of installed meter (5%).

3.1.2 Bulk meter installation
It is important to consider the order torque of bolting when installing bulk meter. The procedure of bulk meter installation in TY is shown as below.

3.2 Preparation
3.2.1 Meter accuracy test
<table>
<tr><td>Status</td><td colspan="3">Run the pump and let the water flow</td></tr>
<tr><td rowspan="4">Item</td><td>Portable meter test kit</td><td>1</td><td rowspan="4"></td></tr>
<tr><td>Hose and connection parts</td><td>3</td></tr>
<tr><td>Some of sample customer meters</td><td>1</td></tr>
<tr><td>Water stop cock</td><td>1</td></tr>
</table>

3.2.2 Bulk meter installation & accuracy test
<table>
<tr><td rowspan="5">Item</td><td>Bulk meter (Installed in TY)</td><td>1</td><td rowspan="5"></td></tr>
<tr><td>Torque wrench</td><td>1</td></tr>
<tr><td>Bolts and nuts</td><td>8</td></tr>
<tr><td>Gasket</td><td>2</td></tr>
<tr><td>Container with measurement scale</td><td>1</td></tr>
</table>

3.3 Operation

Operation of meter test kit is as below.

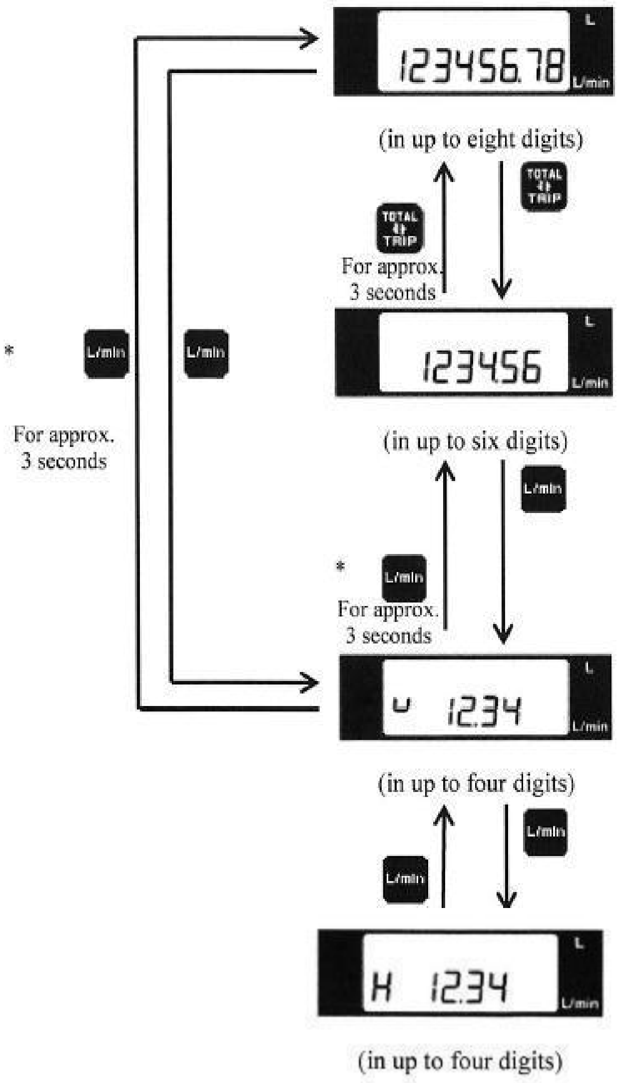
⚠ Do not hold TOTAL TRIP and L/min depressed for a long time simultaneously.

This operation transfers to the configuration mode (blinking display). If you change the configuration setting incorrectly, correct measurement will not be guaranteed.

Return to the measurement mode (solid display) by leaving the test meter for 10 seconds or longer without any operation or by pressing TOTAL TRIP .

⚠ Ensure that the display is not blinking.

Blinking display indicates that the test meter is in the configuration mode. If you change the configuration setting incorrectly, correct measurement will not be guaranteed. Return to the measurement mode (solid display) by leaving the test meter for 10 seconds or longer without any operation or by pressing TOTAL TRIP .



Accumulated flow amount display

Shows the accumulated flow amount.

Trip accumulated amount display

Shows the trip accumulated amount.

Pressing TOTAL TRIP resets the trip accumulated amount to zero.

Just transferring to the momentary flow rate display does not reset it to zero.

Momentary flow rate display

Shows the momentary flow rate.

* Pressing and holding L/min for approximately 3 seconds, the display returns to the state immediately before switching to the momentary flow rate display.

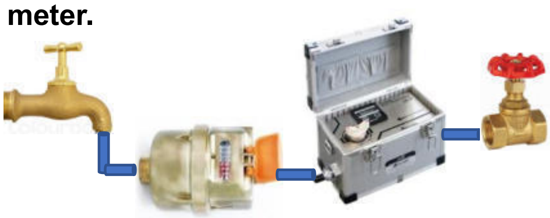
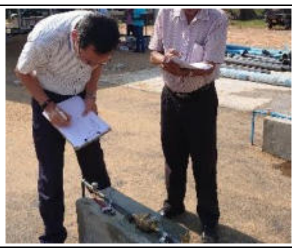
Momentary flow rate hold display

Holds the momentary flow rate value.

Measurement of the momentary flow rate, accumulated amount, and trip accumulated amount continues during the hold display.

3.4 Procedures of training

3.4.1 Meter accuracy test

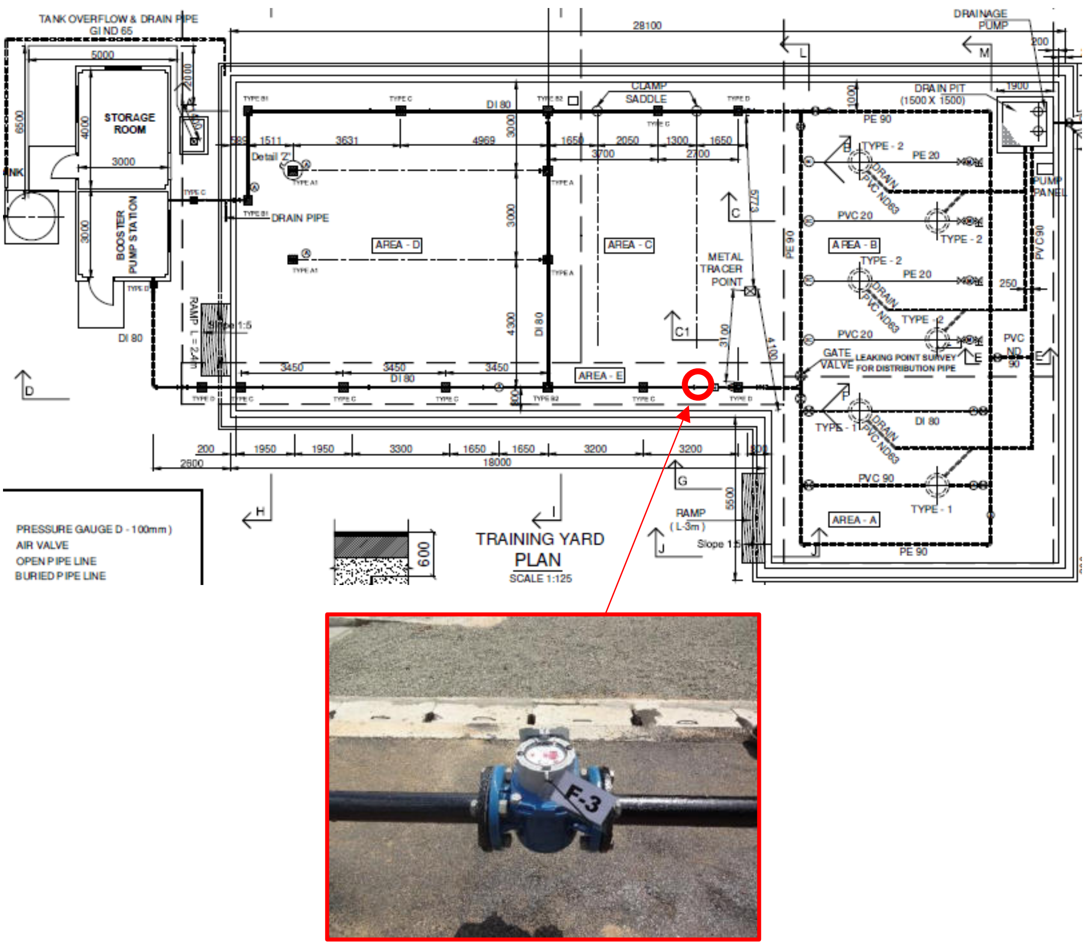
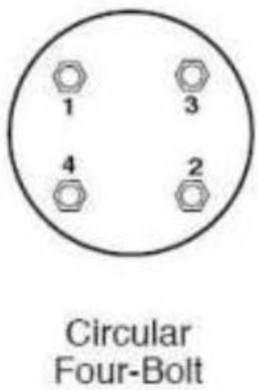
Steps	Measurment activities	
1	Activate pump and ready to run water.	
2	Connect water tap, sample customer meter and test meter kit with an appropriate water pipe or hose. Connect the water stop cock at the end. **Note: Water flow should be controlled on the downstream of meter.** 	 
3	Run the water to the pipe and wait until inside air is completely removed from pipe and hose **Note: Air in pipes and meters must be completely exhausted.**	
4	Close the cock at the end and read all meters and record.	
5	Open the cock at the end and flow volume should be measured more than 20L, valve open ratio should be kept more than half and keep the flow rate.	
6	When the specified amount of water has flowed, close the cock. Read meters and fill out the record sheet shown below. Calculate an accuracy rate. Accuracy % = [(Customer meter – Reference meter) / Reference meter] x 100	
7	Remove all meters and equipment	

3.5 Meter error test record sheet

Sample of Meter error test record sheet is as below.

DMA:	**Subzone:**	**Data**
AC/ID Number		
Customer name		
Address		
House No.		
Product Year		
Installed Year		
Passage Year		
Meter Diameter (mm)		
Meter Number		
Manufacturer		
Date of Test		
Customer's Meter (L)	Initial	
	Last	
	Flow Amount: A	
Test Meter (L)	Initial	
	Last	
	Flow Amount: B	
Difference Amount	B-A	

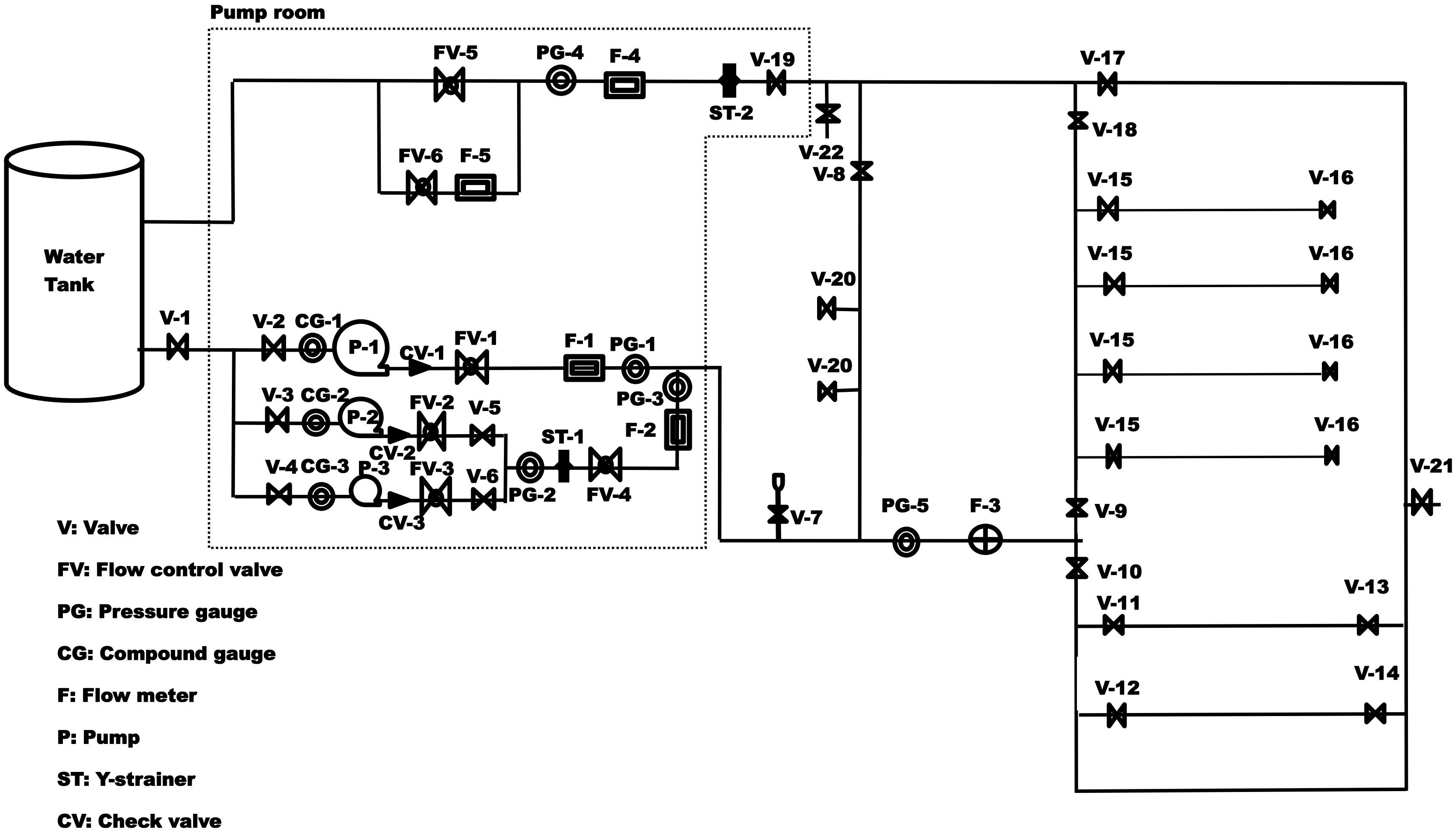
3.5.1 Bulk meter installation & accuracy test

<table>
<tr><th>Steps</th><th colspan="2">Details</th></tr>
<tr><td>1</td><td colspan="2">As the preparation of training, remove the bulk meter installed in the following plan of TY.

</td></tr>
<tr><td>2</td><td>Clean flange faces, bolts, nuts and a gasket</td><td></td></tr>
<tr><td>3</td><td>Place the water meter and flange between pipes. Tighten all bolts by hand evenly according to the cross bolt tightening pattern.</td><td>
</td></tr>
</table>

4	Using a torque wrench, torque to a maximum of 30% of the full torque according to the cross bolt tightening pattern. Then, torque to a maximum of 60% and full torque according to the cross bolt tightening pattern.	
5	Ensure the flanges and gasket are correctly aligned.	
6	Close the valve “V-19” to let the water flow to the “V-19”. (Refer the “Attachment: System Drawing”)	
7	Place a container under the “V-22”. (keep the valve “V-22” closed at this time)	
8	Activate the pump “P-3”, let the water flow to the “V-19” and wait until the air in the pipe is released through air valve.	
9	Confirm if there is water leakage around the bulk meter.	
10	Record the current number of the bulk meter.	

11	Slowly open the valve “V-22” to let the water flow through the bulk meter and discharge it into container.	
12	After a few moments, close the valve “V-22” and record the number of bulk meter. Then, stop the pump.	
13	Compare the volume of water measured by the bulk meter and discharged into container. If the volume of them is same, the bulk meter is accurate.	

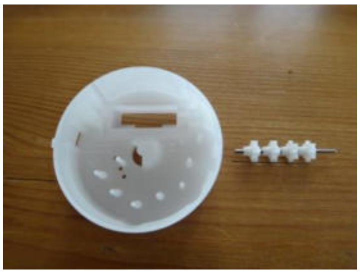
Attachment: System Drawing



Assembly/decomposition of 20mm Water meter

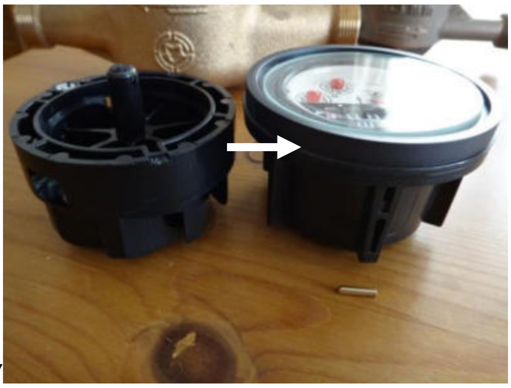
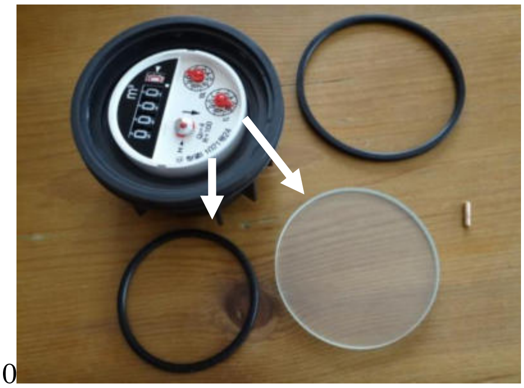
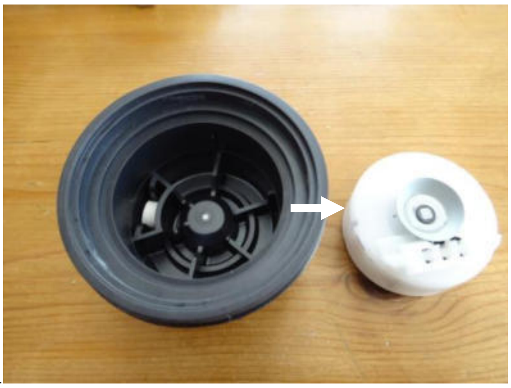
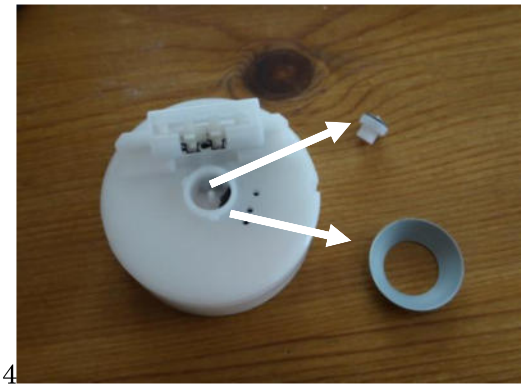
1. Parts list

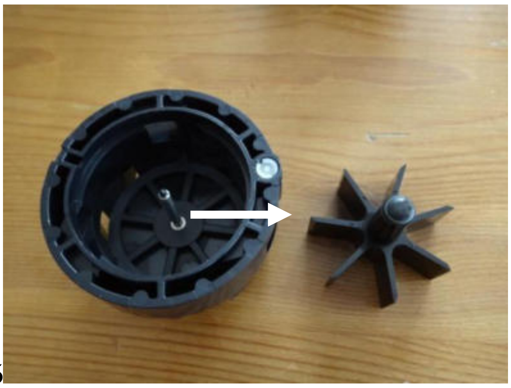
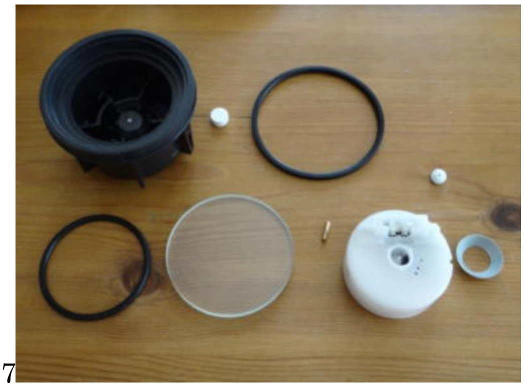
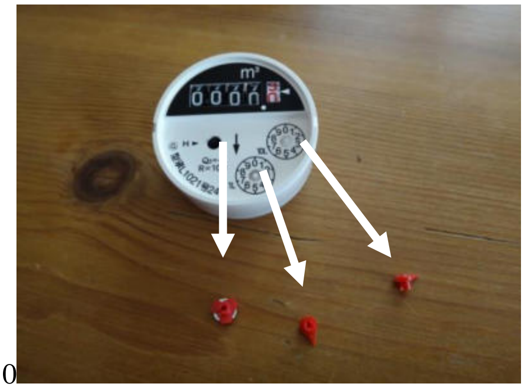
 Water meter	 Whole parts	 Strainer
 Lid	 Plastic ring	 Bottom case with impeller
 Bottom case/Impeller	 Rubber ring	 Rubber ring and glass lid
 Meter case & drying agent	 Drying agent	 Reverse side of meter

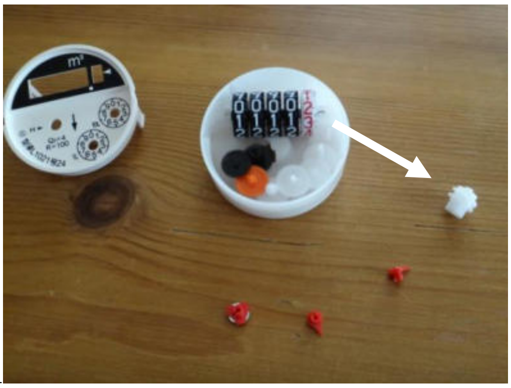
 Meter/Magnet ring /Small gear	 Magnet ring	 Small gear with magnet
 Water meter	 Inside the meter/lid	 Gears
 Indicater body	 Indicator body parts	 Indicator support
 Indicater support parts		

2. Decomposition of water meter

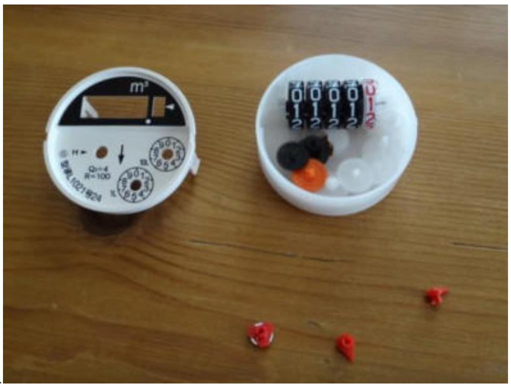
1 	2  Pull out strainer
3  Separate lid parts	4  Plastic ring
5  Meter units	6  Tiny iron bar for adjustment

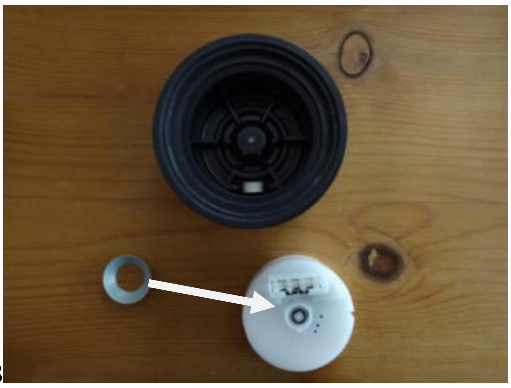
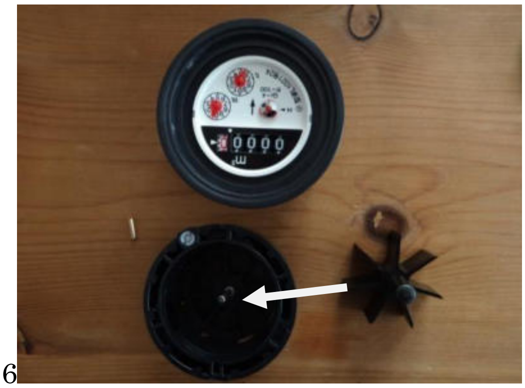
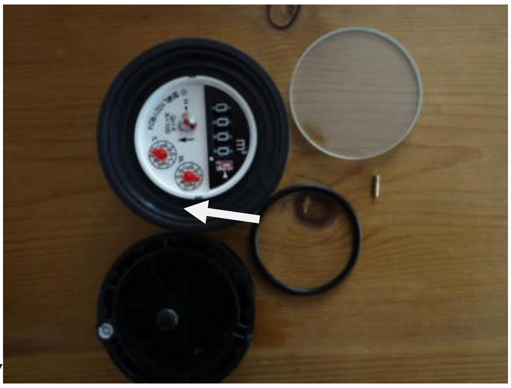
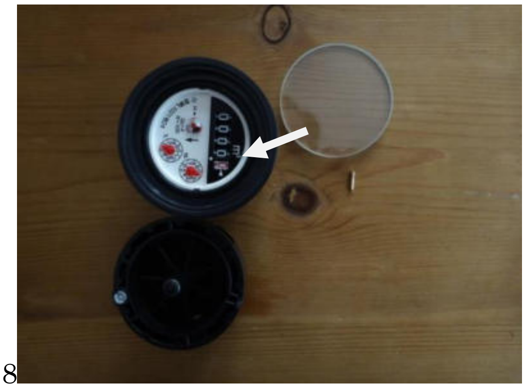
7  Meter bottom case/meter body	8  Meter units
9  Rubber ring	10  Glass lid/another rubber ring
11  Meter case/meter body	12  Surface of water meter
13 	14 

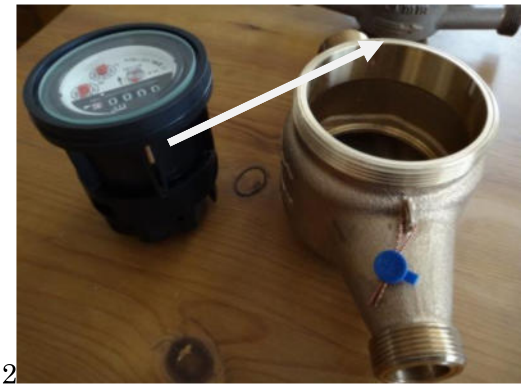
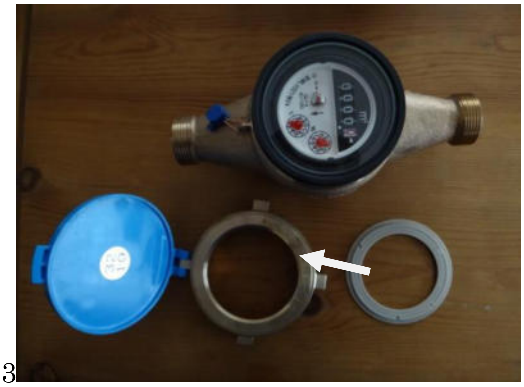
Rivers side of water meter	Magnet/small gear with magnet
15 	16 
Meter bottom case/Impellar	Meter case with drying agent
17 	18 
Meter units	Decomposition of water meter
To adjust figures as 00000	
19 	20 
Pilot/Indicator	Remove pilot/indicators

21  Remove the lid to push part of the hook	22  Inside
21  Remove the lead gear	22  Set the number to 00000

3. Assembly of water meter

After adjustment	
1  Put on the lead gear	2  Place the lid
3  Set the pilot/indicators	4  Adjust 1L/10L indicator not to move the figures pressing the pilot indicater
Assembly of meter units	
1  Drying agent	2  Small gear

3  Magnet	4  Meter unit
5  Assemble meter unit	6  Impellar
7  Rubber ring	8  Glass lid
9 	10 

Rubber ring	Assemble meter unit & lower case
11 	12 
Tiny iron bar	Assemble meter unit & iron case
13 	14 
Plastic ring	Upper case
16 	17 
Confirm moving pilot meter by blowing	Water meter

Training Guideline

5. Measurement

b. Flow Measurement

Table of contents

1 Outline

1.1 Purpose

Purpose of training	➢ Learn how to measure water flow through Ultrasonic Flow Meter (UFM) & Insert type Electromagnetic Flow Meter (IEMFM)). These two types of flow meters are not used for measuring the water consumption of the customer but are often used to measure the water flow temporarily when the meter is not installed as a balk meter.
Training contents	➢ Flow measurement by ‘Ultrasonic flow meter (UFM)’ and ‘Insert type electromagnetic flow meter (IEMFM)’, and visualization of data by PC.

1.2 Flow of training with time schedule

The total time is 2 hours and 45 minutes.

No.	Activity	Required time	Venue
1	Lecture	45 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Distribution pipe or Service pipe connection area)  
3	Preparation for practical training	10 min.	
	*Details are described in “3 Practice (Page 7)” *Activate pump of TY *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse (Pressure logger, Ultrasonic Flow Meter, Meter test kit)  		
4	Practical training	50 min.	TY
	*Details are described in “3 Practice (Page 7)” 		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse  
6	Move to lecture room	5 min.	Lecture room
7	Data visualization	25 min.	Lecture room
	*Use PC		
8	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY.RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.



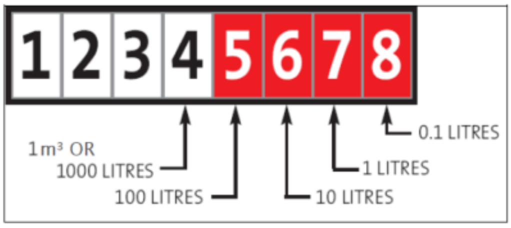
- Do not eat food in the TY.



2 Knowledge acquisition

2.1 Meter reading

The water meter shows several digits as shown in the right figure. This digit means 1234 m^3 and 567.8 liter, or 1234.5678 m^3. When the counter of 0.1 liters is moving between two numbers, it is counted as lower number.



Another water meter has pointers as shown in the right photo. m^3 is shown in the upper black digits and liter is shown in the lower red pointer. When the pointer is between two numbers, it is counted as lower number.

When the digit of counter reached maximum (e.g. 9999.999), it back to all zero (e.g. 0000.000), and sometimes it makes mistakes of calculation of consumption. As shown below, it is necessary to calculate on the assumption that it has one digit in the left side which is not shown on the display.

Previous reading:9989.123, Current reading:0002.234

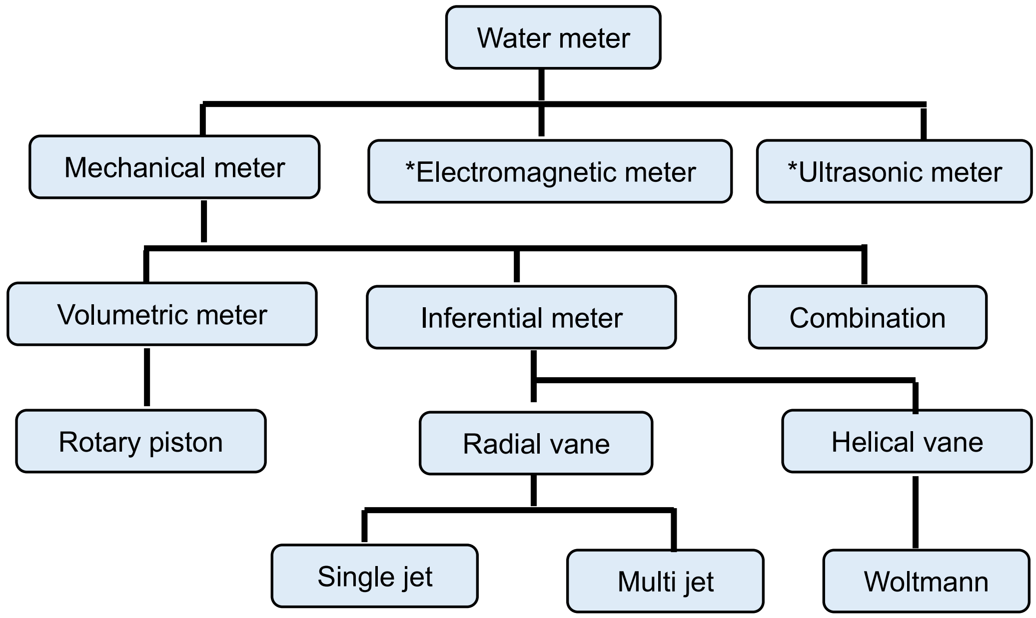
Consumption: <u>10002.234</u>-9989.123 = 13.111

2.2 Type of meter

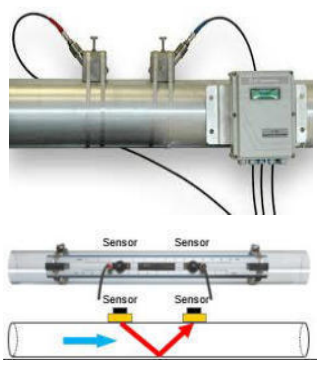
In Sri Lanka, the type of meter is determined by NWSDB so it is necessary to select the proper meter based on the regulation of NWSDB.

The type of water meter is classified as below.

Type of meter



*The details are as given below

i. Ultrasonic Flow Meters (UFM)	
Characteristics 	UFM has some good advantages such as no head loss by no moving parts and cheaper than electromagnetic flow meter for large pipes. On the other hand, it requires long straight section for installation. Turbulences and bubbles in liquid affects its accuracy. Thickness of pipe wall and lining are necessary for accurate measurement. ➢ Required length of straight pipe: Upstream 10D, Downstream 5D (Refer to the manufacturer manual for more details) ➢ Applicable pipe diameter: 13mm – Large diameter ➢ Advantages: Piping work is not necessary (ultrasonic transducers are installed on the surface of pipe), Applicable pipe diameter is wide, No head loss. ➢ Disadvantages: Air intrusion decreases accuracy.

ii. Electromagnetic meters	
Characteristics 	Electromagnetic meters have high accuracy from small to large flow rate, and they are not affected by liquid temperature, pressure, density, viscosity and corrosive liquid. They have no moving parts, so there is no head loss. Both-way, forward and reverse, measurement is possible. Electromagnetic meters for large diameter are more expensive than other meters. ➢ Applicable pipe diameter: 13mm – Large diameter (Battery type: up to 350mm) ➢ Advantages: High measurement accuracy, No head loss ➢ Disadvantages: Electromagnetic meters for large diameter are expensive Note: Sometimes lightning damages the flowmeter, so earthing/grounding is necessary

2.3 Maintenance

Maintenance of Ultrasonic flowmeter

The following items are important for maintenance.

- ➢ Appearance inspection and cleaning
- ➢ Indicator value check
- ➢ Detector installation status check
- ➢ Inundation status check of the flowmeter chamber

Meintenance of electromagnetic flow meter

The following items are important points for maintenance.

- ➢ Appearance inspection and cleaning
- ➢ Indicator value check
- ➢ Confirmation of water in the chamber to avoid submerging of the sensor

3 Practice

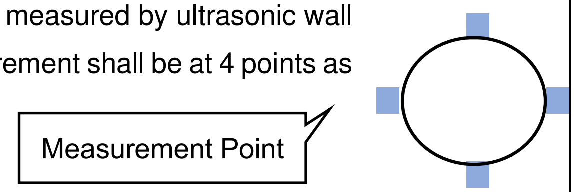
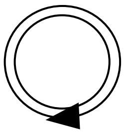
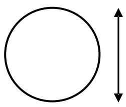
3.1 Ultrasonic Flow Meter (UFM)

The following points should be noted when using UFM. For details, refer to the device manual.

3.1.1 Preparation

Prepare accurate data in advance. Information of DI pipe installed in the TY are as follows:

- Pipe material: [Ductile Iron]
- Pipe diameter or Outer circumference of pipe: [Inner 80mm, Outer 98mm]
- Thickness of pipe wall (some models can be measured on the spot): [6 mm]
- Lining type of pipe inner surface: [Mortal, 4 mm]

Items	Requirement
Installation point	UFM Generally requires following straight pipe length on upstream and downstream of UFM Upstream: 10D Downstream: 5D 
Pipe Wall Thickness	The pipe wall thickness shall be measured by ultrasonic wall thickness gauge and the measurement shall be at 4 points as shown in the figure. 
Liquid	No air bubbles and solid content does not exceed 5%.
Pipe Condition	The pipe wall exterior should be free from dirt, paint or corrosion. For optimum measurement, the interior wall should also be free from deposits or corrosion.
Pipe Diameter	Input pipe diameter or Circumference It is better to input diameter based on circumference when the diameter of the pipe is not clear  Circumference D=L/3.14  Diameter
Pipe material & speed of sound	Materials shall be selected from Carbon Steel (3,200m/s), Ductile Iron, (3,000m/s) Cast Iron (2,500m/s) , Copper (2,270m/s), Stainless Steel (3,100 m/s) , PVC (2,280 m/s) , FRP (2,560 m/s), Acrylic (2,720 m/s) or User Defined (Input any value between 500 to 9,000m/s).
Sensor condition	Sound-path shall be selected from followings (1) V-path method, (2) Z-path method
Fluid condition	Choose (1) Types: Water, (2) Sound speed: 1,460 [m/s], (3) Density 1,000.0 [kg/m3], (4) Specific heat [J/kgK] The sound speed varies with temperatures. The sound speed of water shall be put as follows, 0°C : 1,402.74[m/s], 10°C : 1,447.60[m/s], 20°C:1482.66[m/s], 30°C:1482.66[m/s] 40°C:1529.18[m/s]
Flow unit	M3/h, For small flow rate L/s, Decimal point: ***.***

3.1.2 Measurement procedures

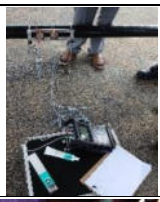
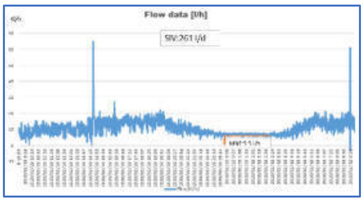
Refer the UFM manual [Appendix-1]

- Input pipe information to the handy device.
- Secure proper length for measurement
- Set transducers on the pipe
- Start logging then Stop logging
- Extract flow data to a Flash memory and transfer to the PC
- Analise obtained data and visualize data as graph

3.1.3 Preparation of materials & pre-assembling

<table>
<tr><td>Status</td><td colspan="3">Run the pump and let the water flow</td></tr>
<tr><td rowspan="4">Item</td><td>UFM</td><td>1</td><td rowspan="4"> </td></tr>
<tr><td>Lint free cloth</td><td>1</td></tr>
<tr><td>Flash memory</td><td>1</td></tr>
<tr><td>PC with ‘EXCEL’</td><td>1</td></tr>
</table>

3.1.4 Practice by trainee

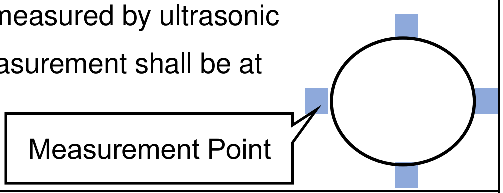
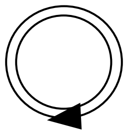
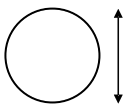
Steps	Procedures	
1	Set basic data (data acquisition interval, flow rate unit, etc.) ➢ Interval: 5 second ➢ Unit: litter/s	
2	Clean up the surface of the pipe. Measure the circumference of pipe. Prepare the information such as thickness of pipe wall, lining material and thickness of lining in advance.	
3	Input the information of pipe to the device such as pipe material, thickness of pipe wall, lining material, thickness of lining, etc. Then calculate the sensor distance.	
4	Confirm the distance of sensors. Apply lubricant to the sensors, install the sensor to the pipe. Note: The sensor should be installed on the side of the pipe to avoid the effects of air inside the pipe.	
5	Get data more than 5 minutes.	
6	Remove UFM and clean up sensors and pipe surface. Transfer data to the PC using 'Flash memory' and save measurement data as 'SIV' data. Move to the lecture room.	
7	At the lecture room, confirm the data by the 'Excel'.	
8	Visualize the measured data by 'Excel function' and save data as 'Excel' so as not to disappear a graph. *Details are described in the manual of Guideline.	

3.2 Insert type electromagnetic flow meter (ITEFM)

The insertion sensor must be installed correctly in relation to the liquid flow direction in the pipe. Ensure that the flow direction is known. The flow rate will be measured in the positive direction when the liquid in the pipe is flowing from – to the + direction as indicated on the tag plate of the sensor.

If the flow rate changed after the installation, the measured direction can be reversed by changing the sign of the Calibration coefficient (KA factor) in the sensor menu of the converter electronic.

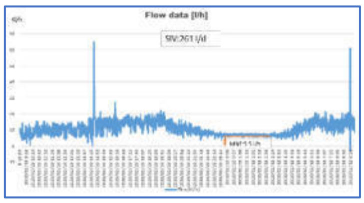
3.2.1 Preparation

Items	Requirement
Preparation of data	DI pipe installed in the TY are diameter 80mm.
Installation point	Although UFM requires straight pipe of 10D, 5D length upstream and downstream, longer straight pipe length might be better for ideal condition of measurement of ITEFM.
Pipe Wall Thickness	The pipe wall thickness shall be measured by ultrasonic wall thickness gauge and the measurement shall be at 4 points as shown in the figure. 
Liquid	No air bubbles and solid content does not exceed 5%.
Pipe Condition	The pipe wall exterior should be free from dirt, paint or corrosion. For optimum measurement, the interior wall should also be free from deposits or corrosion.
Pipe Diameter	Input pipe diameter or Circumference It is better to input diameter based on circumference when the diameter of the pipe is not clear  Circumference D=L/3.14  Diameter
Pipe material & speed of sound	Materials shall be selected from Carbon Steel (3,200m/s), Ductile Iron, (3,000m/s) Cast Iron (2,500m/s) , Copper (2,270m/s), Stainless Steel (3,100 m/s) , PVC (2,280 m/s) , FRP (2,560 m/s), Acrylic (2,720 m/s) or User Defined (Input any value between 500 to 9,000m/s).
Fluid condition	Choose (1) Types: Water, (2) Sound speed: 1,460 [m/s], (3) Density 1,000.0 [kg/m3], (4) Specific heat [J/kgK] The sound speed varies with temperatures. The sound speed of water shall be put as follows, 0°C：1,402.74[m/s], 10°C：1,447.60[m/s], 20°C:1482.66[m/s], 30°C:1482.66[m/s] 40°C:1529.18[m/s]
Flow unit	M3/h, For small flow rate L/s, Decimal point: ***.***

3.2.2 Preparation of materials & pre-assembling

Status	Run the pump and let the water flow		
Item	ITEFM	1	 
	Lint free cloth	1	
	Flash memory	1	
	PC with ‘EXCEL’	1	

3.2.3 Practice by trainee

Steps	Procedures	
1	Start the pump.	
2	Inset the electromagnetic flowmeter	
3	Measure water flow with the IFM	
4	Visualize the measured data by ‘Excel function’ and save data as ‘Excel’ so as not to disappear a graph. *Details are described in the manual.	

Appendix

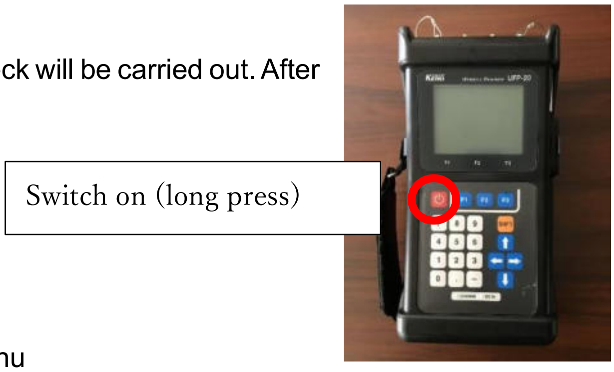
[Appendix-1]

UFM (Ultrasonic Flow Meter) Setting

I. Pre-setting

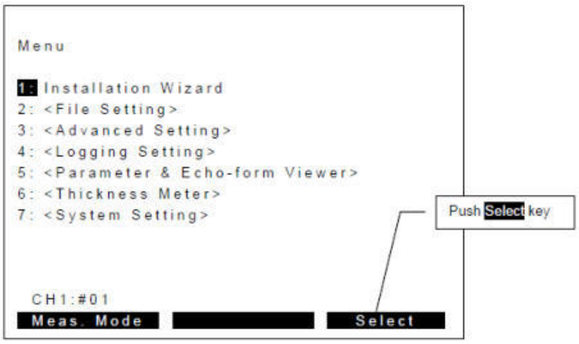
１. Unit setting

-Turn switch on. Then automatically Self Check will be carried out. After the Self Check, select “OK” <F3>



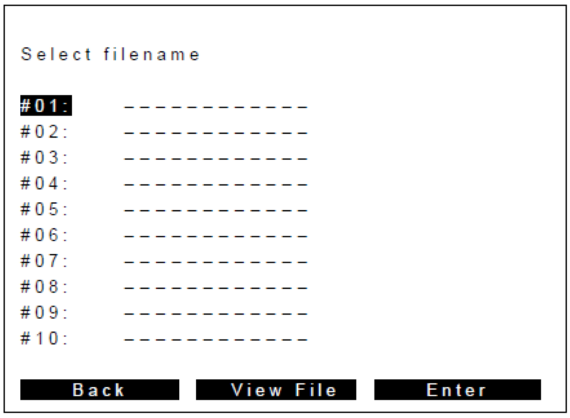
Select “Installation Wizard” on the basic menu

-Select “1: Installation Wizard” by direction ore numeric button. Then push “Select” key (F3 button).

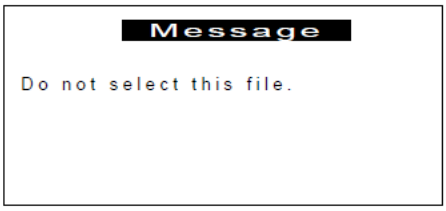


Select file position as “#No.”

-Please select Not-Used area by direction button, then push “Enter“ key (F3 button).



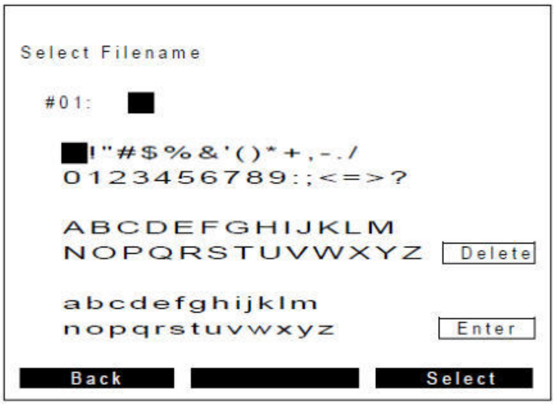
-Not-used area indicated as “--------” and you can not select this position. To remove site setting file, please refer to Chapter 2. When you select used area, you can see following indication.



File name input

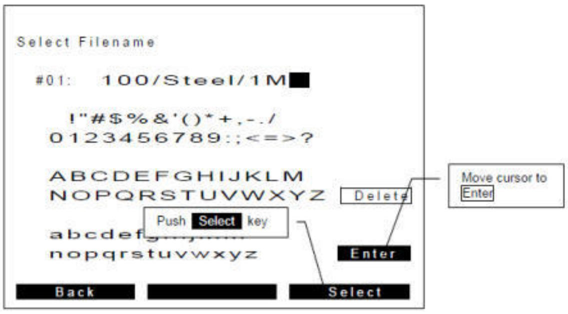
-Please input file name by direction button. Here for example, let’s input as “100/Steel/1M”.

-Move cursor to “1” (for example) by direction button. and push “Select” key (F3 button) to select character. You can see that “1” would set first position as below.



Finalizing file name

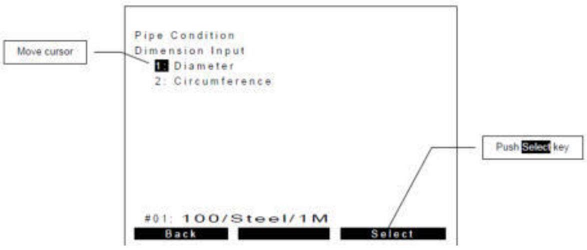
-By repeating procedure of 1-4, you can input “100/Carbon Steel/1M” as follows. After finalizing the file name, proceed next menu by move cursor “Enter” and push “Select” key (F3 button), otherwise [SHIFT] + F3 button makes the same step taken.



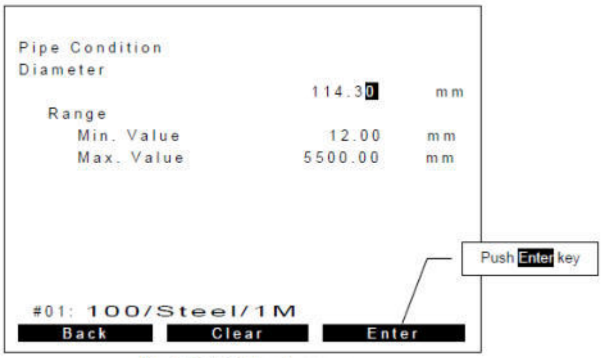
2. Install pipe information

Pipe size setting

-Input pipe diameter by diameter itself or circumference of pipe. You can select which way you want by direction or numeric button. Here for example, select “1: Diameter” by push “Select” key (F3 button). Note: diameter should be OUTER diameter.



-Input diameter by numeric button directly. Here for example, input 114.30mm as right. Then push “Enter” key (F3 button) to proceed to next step.



Pipe material

-Select material of the pipe from default choices or User Defined by direction or numeric button. Here for example, select “1: Carbon Steel”, then push “Select” key (F3 button) to proceed next step.
-After you select material, you will see predefined sound speed, normally just proceed to next. If you would like to select any un-listed materials, please select “User Defined” then enter actual sound speed of the material at the next extra menu.

Thickness of pipe
-Input pipe thickness by numeric button directly. Here for example, input “4.50mm”, then push “Enter” key (F3 button) to proceed to next step.

Lining material
-Select material of the lining from default choices or User Defined by direction or numeric button. Here for example, select “2: Epoxy”, then push “Select” key (F3 button) to proceed next step.

- After you select material, you will see predefined sound speed, normally just proceed to next. If you would like to select any un-listed materials, please select “User Defined” then enter actual sound speed of the material later at the next extra menu.

Thickness of lining
-Input lining thickness by numeric button directly. Here for example, input “1.00mm”, then push “Enter” key (F3 button) to proceed to next step.

Fluid Selection
-Select fluid from default choices or User Defined by direction or numeric button. Here for example, select “1: Water”, then push “Select” key (F3 button) to proceed next step.

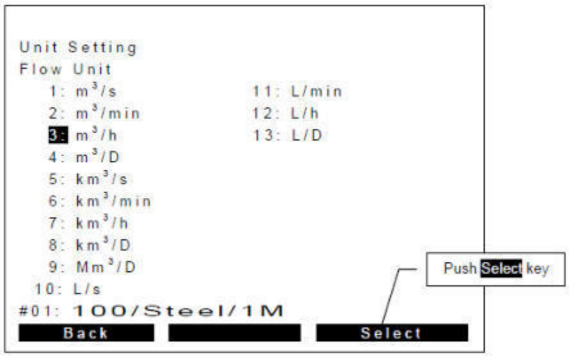
- After you select material, you will see predefined sound speed and viscosity, normally just proceed to next. If you would like to select any un-listed fluid, please select “User Defined” then enter actual sound speed of the fluid later at the next extra menu.

Transducer type
Select transducer type from default choices by direction or numeric button. Here for example, select “2: UP10AST”, then push “Select” key (F3 button) to proceed next step.

Sound-path selection
-Select sound-path method from default choices by direction or numeric button. Here for example, select “2: V-Path method”, then push “Select” key (F3 button) to proceed next step.

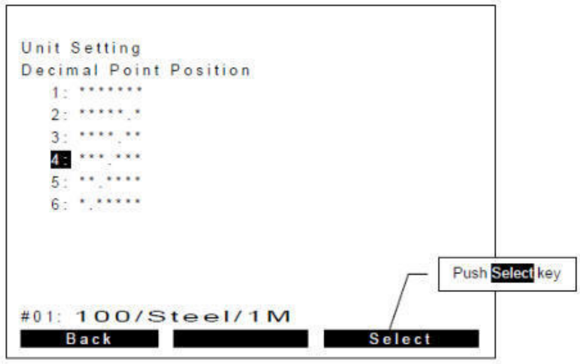
Flow rate unit setting

-Select flow rate unit from default choices by direction or numeric button. Here for example, select “3: m3/h”, then push “Select” key (F3 button) to proceed next step.



Decimal point position

Select decimal point position from default choices by direction or numeric button. Here for example, select “***.***”, then push “Select” key (F3 button) to proceed next step.

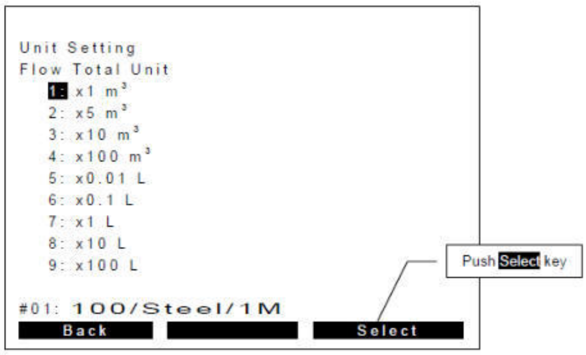


Totalizing unit setting

-Select totalizing unit from default choices by direction or numeric button.
Here for example, select “1: ×1m3”, then push “Select” key (F3 button) to proceed next step.

Store site data

-Finalize wizard by store all data on this menu. Select “2: Yes” by direction or numeric button. Then push “Select” key (F3 button) to proceed next step

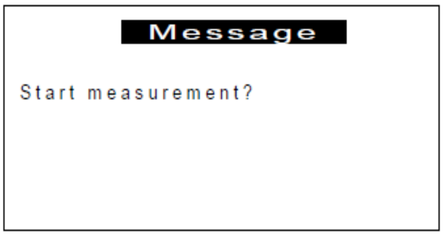


Store data

-Finalize wizard by store all data on this menu. Select “2: Yes” by direction or numeric button. Then push “Select” key (F3 button) to proceed next step.

When select “2: Yes”, following message will be shown.

After storing site setting data, following confirmation message shows up. Then push “Yes” (F3 button) to proceed next step. Otherwise when you select “No” button), return to initial basic menu.



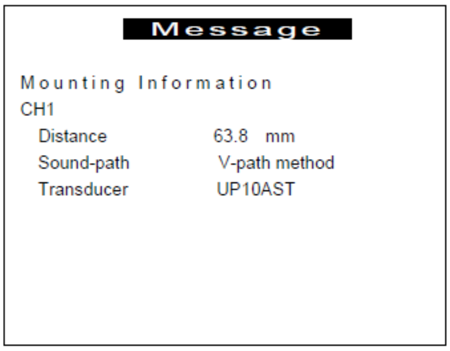
(F1

II. Transducers installation

1. Transducer distance

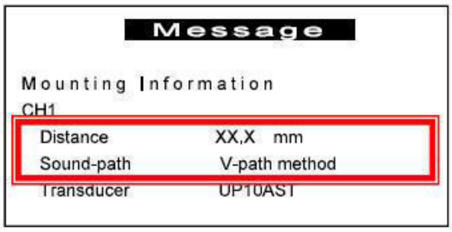
-The main unit calculates proper distance between transducers as following message. Then push “OK” (F3 button) to start measurement. Please set transducer mounting with indicated transducer distance in accordance with instruction on this example, distance of transducers is 63.8 mm.

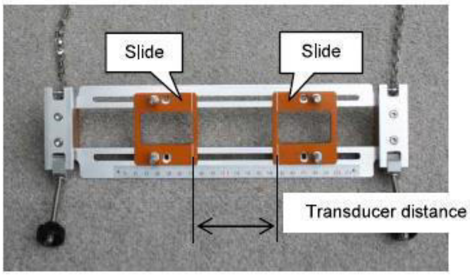
Then proceed with Transducer setting.



Transducer distance setting

-Set distance between transducers on mounting fixture in accordance with the main unit calculation.





2. Transducer mounting

Set mounting fixture onto the pipe

Wrap the mounting chain around the pipe and hook an endo link with the hook knob arrangement.

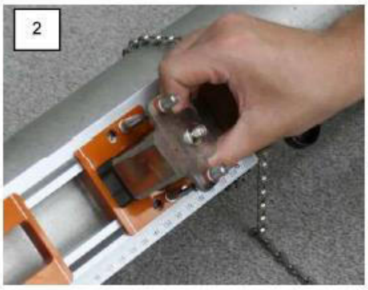
Tighten the chain at the other end of the fixture.

Add coupslant and set transducers to mounting fixture

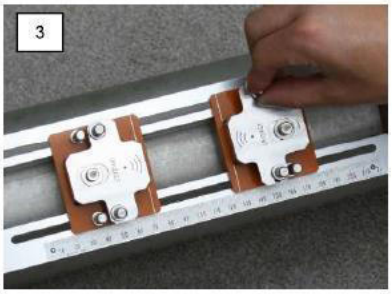
Add silicone grease as acoustic couplant onto surface of tranceducers.

Then set them into mounting fixture.

1. Add couplant onto surface of transducer as photo.



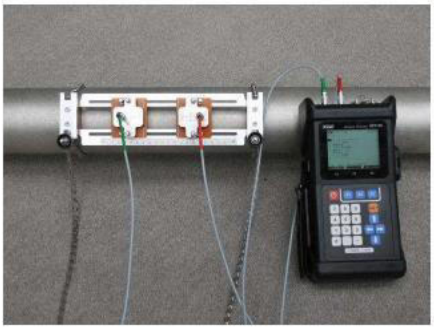
2. Set transducer to fixture.



3. Fix transducers by screw.

Set cables with the transducers and the main unit

Correct cables with the trancducers the main unit



Let's start measurement

Finished prepare to measurement. Push OK key to start measurement (mounting information menu)

<u>Measurement for over DN200mm pipe</u>

In case of measurement for over DN200mm, you need to use mounting fixture 1 and 2 for extension together as below. The distance of between fixtures is 100mm.

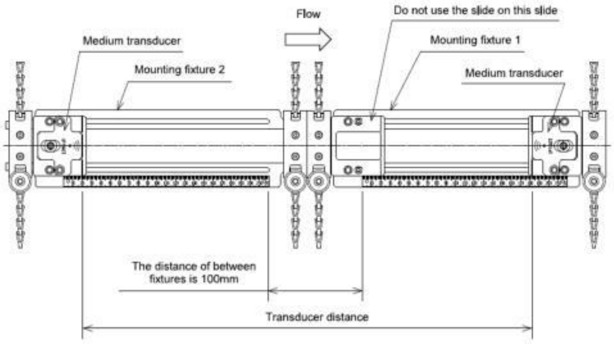


Fig. 1.2.9-15 Combine mounting fixture (over DN200mm)

III. Start and stop logging

1. Start logging

-Select "OK" <F3>

- Select "Log Start" <F1>, then start logging

   <u>- Confirm display "save" & " battery supply mark</u> <u>" if you use extra battery.</u>

[It happen many cases no save!!. Data doesn't record as file.]

2. Stop logging

- Select "Log Stop" <F1> when you want to stop logging.

3. Logged data download to USB memory

-When you stopped logging, select “MENU” <F3>.

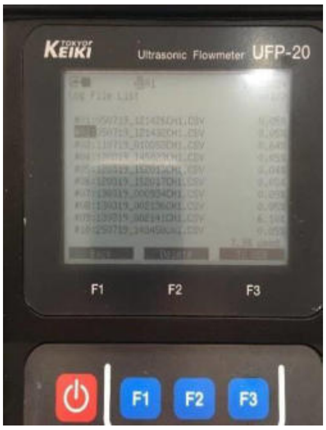
- Select “Logging Setting” from the menu list<F3>.

-Select “1 : Log File List”

The logging filename is defined automatically. [DDMMYY.csv]

-Connect USB memory to the unit.

-Choose a certain file, then select “To USB” <F3>.

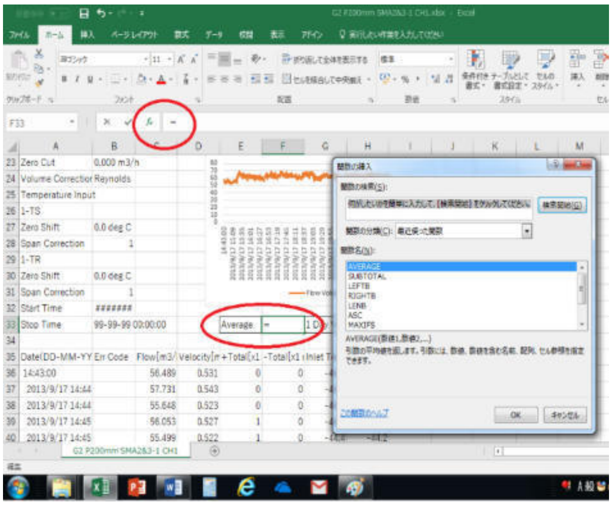


IV. Data saving and visualization

<u>1. Data Transfer to PC’ s “Excel”</u> [Without this procedure, after save the data, graph will disappear]

1. Insert USB
2. Find the Folder name like “ LOG170412_DIR” this folder include file such as [DDMMYY -oooooCH1.CSV]
3. Open Folder, the chose file [DDMMYY -oooooCH1.CSV]
4. Save this file by change the file extension from “csv” to “exe”. Chose “save as” then put your favorite file name. Then chose file style <u>“save as type” [::::exe],</u> and save place such as PC’s desktop or other data folder. Then return.

2. Calculation of average flow volume & 1-day consumption



Open needed file name file or [LOG YYMMDD]:

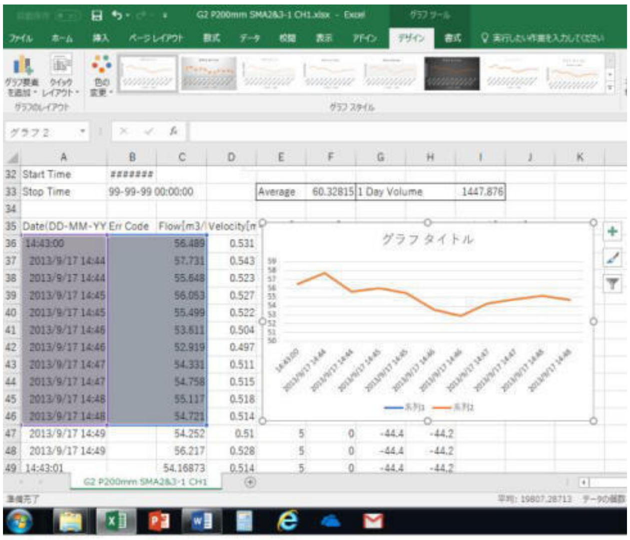
In case you don't save as Excel, open CSV file [DDMMYY -oooooCH1.CSV]

1. On the screen, wide column "A" to see all date ⇒ appear DD/MM/YY
2. Chose a cell to make "Average flow" cell
3. Click [fx], function of Excel : Find [AVERAGE]
4. Click [OK]
5. Click Upper arrow[↑]
6. Chose cells under "Flow [m3/h] column for adequate time: (24hs example; 14/2/2019 12:31~15/2/2019 12:30)
7. Enter

➢ Screen showing cells area click [OK] Average appear in the cell

8. Chose a cell to make "1 day volume" cell
9. Put in the cell: = 24*(multiple) and then click the cell of "Average flow". I day consumption appear

3. Make a Graph



1. Open file
2. @{`This procedure does not need depend on the Excel version}

➢ On the "A" column. Remove DD/MM/YY from the first sell of "Date (DD/MM/YY)" column at the point you want to start making graph.

3. Choose cells in the columns "A" of "Date (DD/MM/YY)", "Err Code" and "Flow(m3/h)" to the end of your favorite time.
4. Mostly 3.procesure made the cursor go to the end of data. To make Graph on top of the sheet, move the ruler of "up & down ruler" by the cursor go up to the most upper point.
5. Chose [Insert] on the upper side ruler, then chose kind of graph such as "Line" , then chose normal line chart.

➢

➢ @{ after this procedure, if you need to do understanding the Graph easily or for explanation to others}}

6. Edit the regent: Chose [Select data], Look “Legend entries”, Click “Series 1” and remove it. Then click “Series 2” and click “Edit”, find “Series name”. Put name such as {Water volume m3/h} as its graph showing.
7. Renew the Graph title: Click graph title (name is same as Series 2 at the moment), then out your favorite name such as { Panadra flow volume 20/04/2017}
8. Save: Save file just “save” or “as save” put new name.

- Don’t forget save as “Excel” file！！

End

Training Guideline

5. Measurement

c. Pressure Measurement

Table of contents

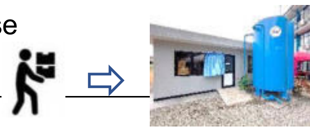
1 Outline

1.1 Purpose

Purpose of training	➢ Learn how to use water pressure logger
Training contents	➢ Pressure logging and visualization by PC.

1.2 Flow of training with time schedule

The total time is 2 hours and 45 minutes.

No.	Activity	Required time	Venue
1	Lecture	45 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Distribution pipe or Service pipe connection area)  
3	Preparation for practical training	10 min.	
	*Pressure logger *Activate pump of TY *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse (Pressure logger, Ultrasonic Flow Meter, Meter test kit)  		
4	Practical training	50 min.	TY
	*Details are described in “3 Practice (Page 4) 		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse 
6	Move to lecture room	5 min.	Lecture room
7	Data visualization	25 min.	Lecture room
	*Use PC		
8	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY.RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.

- Do not eat food in the TY.

2 Knowledge acquisition

2.1 Pressure measurement

2.1.1 Outline

When water flows through the pipeline, energy loss occurs due to friction or other resistance, and the pressure changes corresponding to the energy loss in the water pipe. The pressure occurs in the pipe water flowing is called dynamic water pressure. This phenomenon occurs when many people use water in the daytime. Also, when the water is not used at night, the water pressure increases. The pressure is called hydrostatic pressure. It is necessary to keep this water pressure fluctuation low when supplying water.

2.1.2 Pressure unit

NWSDB general pressure unit is “Bar” and sometimes “meters” is used as pressure 1bar≒10 meters, but actually 1bar = 10.197 meters.

Multiply by							
Convert from	Convert to						
	Pa (N/m^2)	bar	atmosphere	mm Hg	mm H_2O	m H_2O	kg/cm^2
Pa (N/m^2)	1	10^{-5}	$9.87\ 10^{-6}$	0.0075	0.1	10^{-4}	$1.02\ 10^{-5}$
bar	10^5	1	0.987	750	$1.0197\ 10^4$	10.197	1.0197
atmosphere	$1.01\ 10^5$	1.013	1	759.9	10332	10.332	1.03
mm Hg	133.3	$1.33\ 10^{-3}$	$1.32\ 10^{-3}$	1	13.3	0.013	$1.36\ 10^{-3}$
mm H_2O	10	0.000097	$9.87\ 10^{-5}$	0.075	1	0.001	$1.02\ 10^{-4}$
m H_2O	10^4	0.097	$9.87\ 10^{-2}$	75	1000	1	0.102
kg/cm^2	$9.8\ 10^4$	0.98	0.97	735	10000	10	1
pound square feet	47.8	$4.78\ 10^{-4}$	$4.72\ 10^{-4}$	0.36	4.78	$4.78\ 10^{-3}$	$4.88\ 10^{-4}$
pound square inches (psi)	6894.76	0.069	0.068	51.7	689.7	0.690	0.07
inches Hg	3377	0.0338	0.033	25.4	337.7	0.337	0.034
inches H_2O	248.8	$2.49\ 10^{-3}$	$2.46\ 10^{-3}$	1.87	25.4	0.0254	0.0025

2.1.3 Pressure gauge & logger

Pressure gauge is classified as mechanical pressure measuring instruments, and thus operate without any electrical power. The pressure display is indicated by a needle.

Pressure logger has a digital display to show current water pressure. To record pressure data, some steps are required before setting a logger.

3 Practice

3.1 Basic information

Atmospheric pressure affects water pressure, so it needs calibration before use. When a pressure logger is installed, the pressure should be checked with a calibrated pressure gauge. If there are leaks on the hydrant or tap coupling, pressure logging will be affected.

3.2 Procedures

i. Input the necessary information to the device through PC, such as start and stop time, recording interval, etc.
ii. Set the logger then start and stop from menu screen.
iii. Connect with PC by USB connecting cable.
iv. Analyze data and visualize data as graph.
v. Save data into PC.

LEO 5 Operation manual

LEO 5 is equipped with two touch keys.
A keypress is initiated by touching the «SELECT» or «ENTER» key field and activated by releasing it after at least 0.5 second (move your finger at least 1 cm away from the display).

Turn ON, Basic Menu

Turn ON: Touching the «SELECT» key turns on the display. «PRESS ENTER» appears on the device. Press «ENTER» to start the manometer and use «SELECT» to choose between different functions. To execute a selected command, press «ENTER» again. The device has the following main functions:
MENU: Provides access to the functions that are specified in the «MENU» and «SUB-MENU» section of these instructions.
RESET: The min./max. values are set to the actual pressure.
OFF: Turns the device off.
Note. If no keys are pressed for 10 seconds, the display switches back to the main screen.

USB Connection

The USB interface is used to load and communicate with the manometer. Remove the rubber protection on the back of the device to access the USB interface.

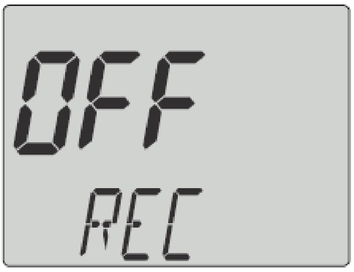
Note: The rubber also acts as an overpressure safety valve. It will fall off if the internal pressure exceeds a critical level.

Menu

Rec ON
Starts the Record process. Settings for measurement interval, start time, etc. are reconfigured via the computer software.

Rec OFF

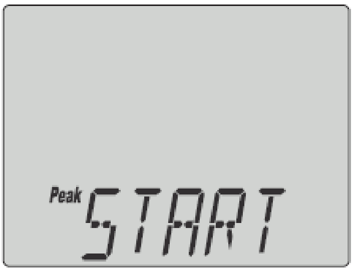
Ends an active record.

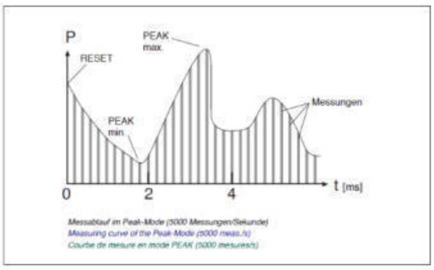


Peak START and OFF

PEAK OFF: Normal measuring mode with 2 measurements per second. PEAK ON: Fast measuring mode with 5,000 measurements per second.

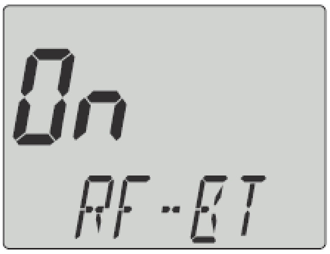
In Peak mode, the battery has a life of around 160 hours. The Record function is also available in Peak mode. The device records 5,000 measurements per second and calculates the minimum (PMin) and maximum (PMax) pressure values from those recorded. In addition, a pressure value (P1) and the temperature in the selected measuring interval (TOB1) are saved at most once per second.





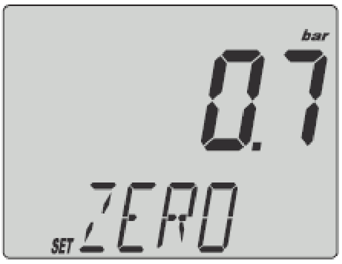
RF BT ON/OFF

Switch the LEO 5 Bluetooth module (optional) «ON» or «OFF» to communicate wirelessly. If turned «ON», one battery charge lasts for about 40 hours.



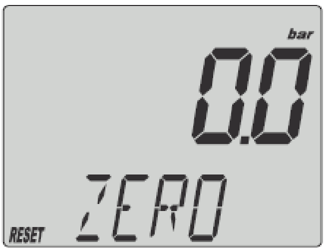
ZERO SET .

Sets a new zero reference point.



ZERO RESET

Sets the zero pressure point to its factory setting.



Submenu

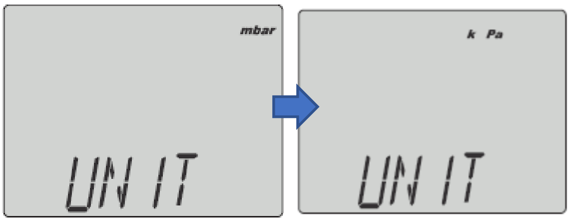
EXIT

Each sub-menu can be left by pressing «ENTER» while «EXIT» is displayed. The display will switch back to the main menu.

UNIT

Unit selection

[bar, mbar, hPa, kPa, MPa, PSI, kp/cm2, cmH2O, mH2O, inH2O, ftH2O, mmHg, inHg]



CONT

Continuous mode

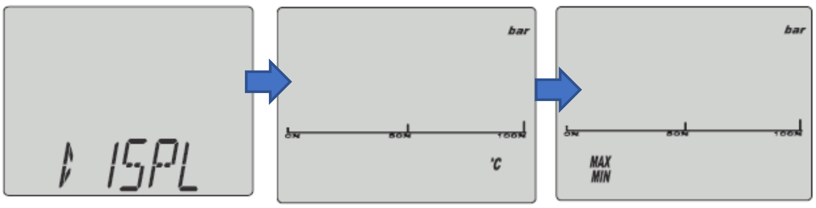
CONT ON: Deactivates the automatic turn-off function.

CONT OFF: Activates the automatic turn-off function (the device turns off 15 minutes after a key was last pressed).

DISPL

Main display selection

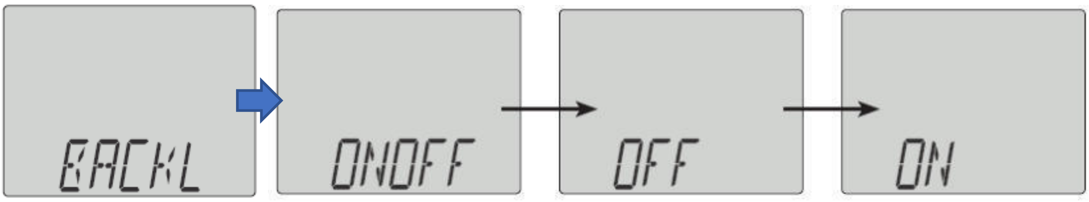
Switches between the temperature display and the min./max. pressure value display.



BACKL

Backlight setting

The backlight can be set to «ONOFF», «ON» or «OFF». «ONOFF» launches the automatic turn-off function, which activates the backlight when it is pressed and turns the backlight off 10 seconds after a key was last pressed.



RWSL

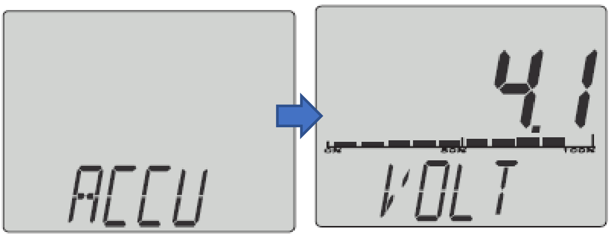
Resolution selection

Sets the measuring resolution to between 0 and 4 decimal places (full scale dependent).

ACCU

Accumulator information and charge status

Displays the accumulator voltage and charge level. 3.2 volts indicates an empty accumulator, 4.2 volts a fully charged one.



＊LEO 5 is powered by a rechargeable battery which can only be charged using an USB cable. The rechargeable battery is welded into the device. Only the manufacturer may replace the accumulator. Opening the device without authorization voids the warranty. To prevent total discharge, the manometer’s Peak, Record and Bluetooth functions must be deactivated when it is not in use and the accumulator must be recharged once a year. Batteries must never be disposed of in normal household waste. To prevent possible damage to the environment or to health due to uncontrolled waste disposal, this product must be separated from other waste and recycled correctly in order to ensure sustainable use of the raw materials.

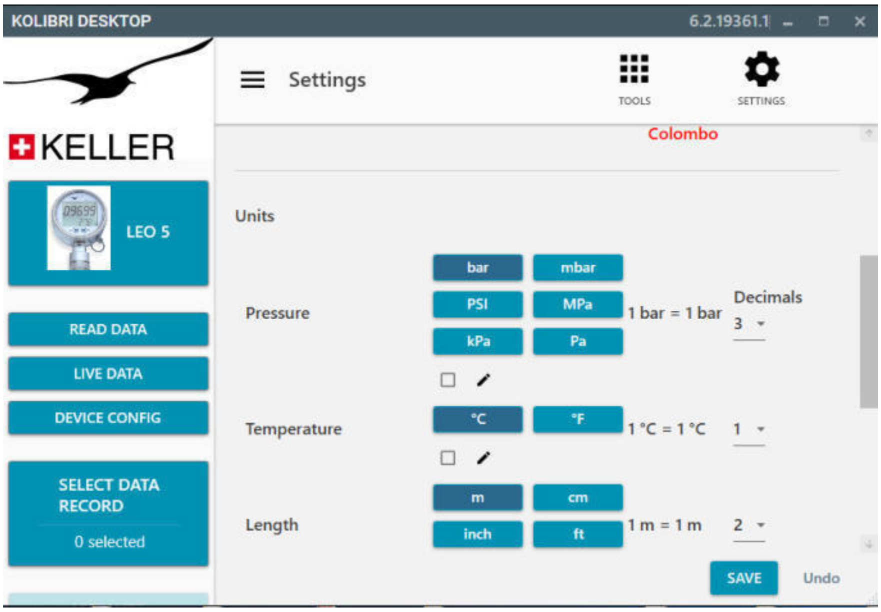
[LEO 5 Operation by PC]

Install KELLER

Install software of KELLER to a PC.

From C drive of PC, go into the [KELLER] them [KOLIBRI DESKTOP] install.

If USB connected next screen appear



[READ DATA]

You ca read stored data

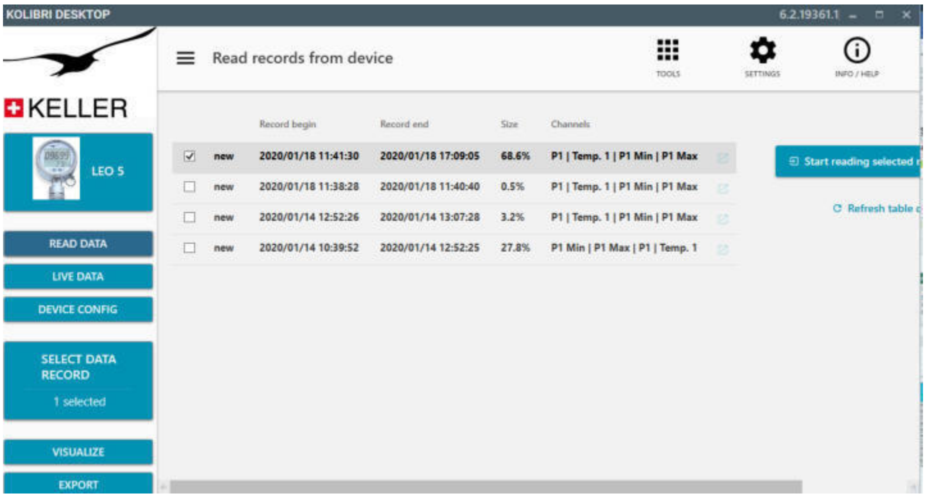
[LIVE DATA]

You can observe current data.

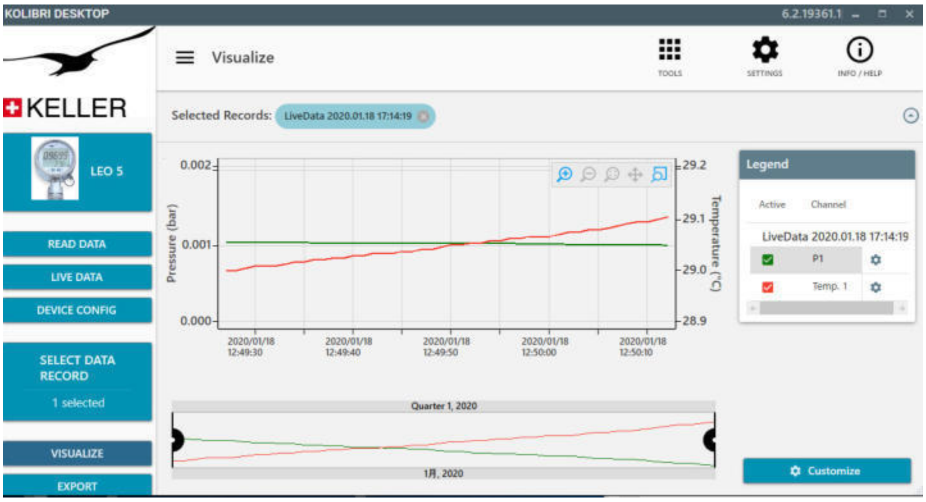
[Live data Recording] Change recording interval from 1 sec to 24hr

[Start recording] [Stop recording]

[SELECT DATA RECORD]

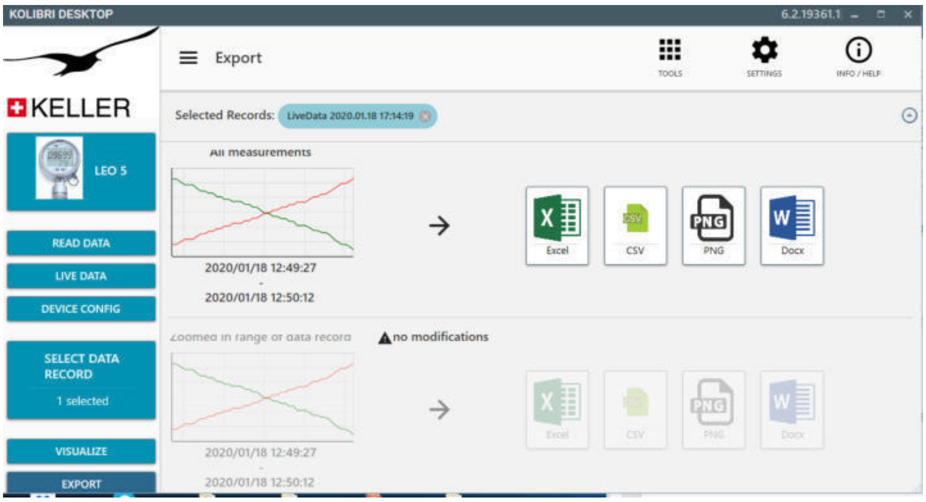


Wen you selected graph appear.



[VISUALISE]　when graph appeared [VISUALISE] color change dark

[EXPORT] Can save [Excel-Succesefully expor do] appear, The Excel data base appear



Training Guideline

6. DMA

DMA Creation & Step Test

Table of contents

1 Outline

1.1 Purpose

Purpose of training	It is necessary to grasp the water flow in the water distribution system to survey water leakage. However, water distribution pipes spread complicatedly, and it makes difficult to grasp water flow in a certain area of distribution system. Districted Metered Area (DMA) and step test can solve this problem by measuring inflow and outflow in districted area.
Training Contents	➢ How to find leakage by DMA and step test.

1.2 Flow of training with time schedule

The total time is 2 hours and 20 minutes.

No.	Activity	Required time	Venue
1	Lecture	45 min.	Lecture room
2	Move to TY	5 min.	TY & Warehouse (Leak survey area)
3	Preparation for practical training	10 min.	 
	*Ultrasonic flow meter *Insertion type electromagnetic flow meter *Pressure logger *Pipe locator *Metal detector *Acoustic listening stick *Electric leak detection *Activate pump of TY *Wear work clothes (Clothes, safety shoes, gloves, hard hat) *Bring necessary tools and equipment from warehouse 		     
4	Practical training	50 min.	TY
	*Details are described in “3Practice (Page 10)” ➢ How to find leakage by DMA and step test.		
5	Return tools & equipment and clean up	10 min.	TY & Warehouse  
6	Move to lecture room	5 min.	Lecture room
7	Data visualization	25 min.	Lecture room
	*Use PC		
8	Q & A & evaluation	15 min.	Lecture room
	*Use Evaluation sheet		

1.3 Safety notice

- All members must wear safety equipment in TY. RP should order to participants wearing suitable item

- Do not sit on the pipes or put your foot on.

- Do not touch the installed equipment unnecessarily.



- Do not eat food in the TY.



2 Knowledge acquisition

2.1 DMA creation

The technique of leakage monitoring requires the installation of flowmeters at strategic points throughout the distribution system to grasp water flowing into and out of a certain area. Such an area is called a DMA

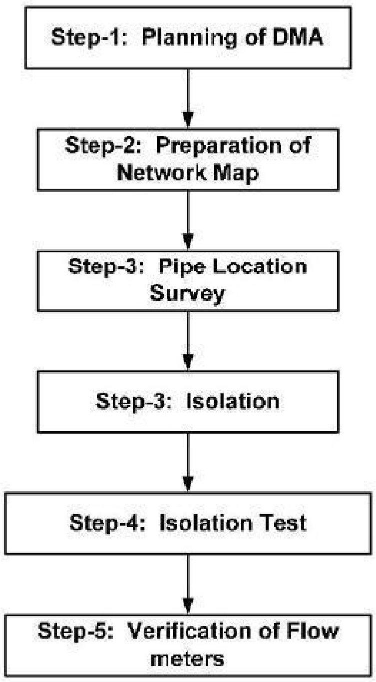
The DMA has two aims:

i. By dividing the distribution network into DMAs, night flows into each district can be regularly monitored and unreported bursts or leakage can be identified and located.
ii. By managing the pressure in each district, the network is operated at the optimum level of pressure.

Depending on the characteristics of the network, a DMA will be:

- Supplied via single or multiple feeds.
- Discrete area (i.e. with no flow into adjacent DMAs)
- Area which cascades into an adjacent DMA.

The procedures of establishment of DMA are as below.



2.1.1 Step-1 Planning of DMA

(1) Size of DMA

The number of connections should be generally established between 1,000 and 2,500. However, for the DMA with high NRW ratio, it’s better to subdivide them into sub-DMA of 1000 or fewer connection.

The distribution map is the main information source for considering size of DMA. The tips for confirming the distribution map are as below.

- Compare the distribution maps with GIS layer and AutoCAD layer and identify the difference.
- Identification of features and types of distribution system and their types (e.g. pipes, valves, washouts, ferrules, water meters etc.)
- Identification of facility structures of DMA (Towers, Reservoirs, Sumps and Storage tanks)
- Source of water flowing into and out of the DMA
- Difference between feeder line and distribution line
- Identification of natural and man-made boundaries, pipe dead ends of distribution system
- House connections and priority connections
- Identification of important parameters of DMA (ex- MNF/ Critical pressure etc.)

The tips for considering the boundary of DMA are as below.

- Importance of definition of DMA boundary
- Special features to be considered (Natural or man-made)
- Available number of connections within the DMA
- Type of connections and its characteristics of water usage
- Prediction of demands/demand categories

(2) Schedule

Schedule which includes periods of making schematic of the pipe network and route survey is necessary.

(3) Stuff allocation for DMA

(4) Selection of type of flow meter for measuring inflows and outflows

(5) Decision of measurement period

(6) Selection of DMA

The tips for DMA selection are as below.

- Ease of boundary isolation
- Number of family units
- Number of valves that must be closed to isolate the DMA
- Number of flow meters to measure the inflows and outflows
- Ground level variation within the DMA

2.1.2 Step-2 Preparation of pipe network map

The tips for the preparation of pipe network map are as below.

- Show the pipe route on the map based on the actual situation
- Indicate the diameter and materials of pipe
- Show the buried side of pipe in road
- Indicate house numbers
- Indicate the existing valves and caps
- Decide the points of flowmeters and valves for isolation

*Please refer to the appendix

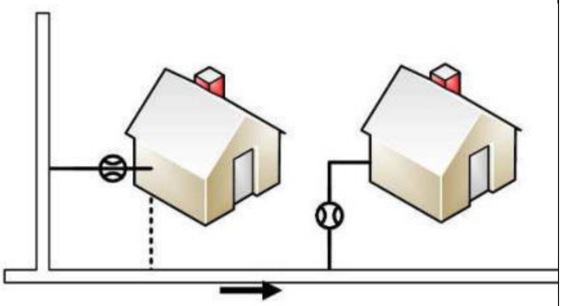
2.1.3 Step-3 Pipe location survey

i. Gather information about the existing pipe based on the repair records in witness of the contractors

ii. Survey by following equipment

➢ Pipe locator Pipe locator such as non-metallic pipe locator can be used for tracing the location of non-metallic pipe	
➢ Metal detector A metal detector is an electric instrument which detects the presence of metal objects buried underground. Metal detectors are useful for finding valves also.	

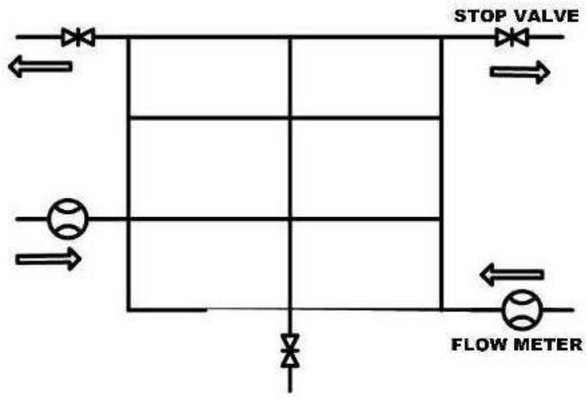
iii. Confirm the connection point of service pipe

➢ Confirm the connected point of service pipe between house and distribution pipe ➢ Check the operation and the function of water meters ➢ Check the leakage of water taps ➢ Check the materials of service pipe	

2.1.4 Step-4 Isolation

Install isolation valves and flow meters at inflow and outflow points of DMA. The tips for considering isolation are as below.

- Method of isolation-Connecting as a circle
- Importance of keeping one input point and one output point to a DMA
- Separation of Steps within the DMA
- Installation of boundary valves in necessary point
- Checkout of isolation by conducting PZT (Pressure Zero Test)



2.1.5 Step-5 Isolation test

Confirm all pipes in the boundary of DMA are either closed or metered by performing an isolation.

2.1.6 Step-6 Verification of flow meters

The calibration of all flow meters should be periodically conducted.

2.2 Step test

Step test is to divide DMA into sub-zone and to measure leakage volume in each sub-zone. The area where leakage occurs can be identified by this step test. The important points of step test are as below.

- Theory behind the step test
- How to divide steps within the DMA
- Time allocation per step
- Method of step test
- Efficient resource utilization
- Record the works (e.g. opening and closing valves)
- Specifications/Method statements

The procedures of step test are as below.

2.2.1 Step-1 Planning of sub-zone

Sub-zone should be considered when planning of DMA.

2.2.2 Step-2 System Input Volume (SIV) measurement

Consider the inlet point of all sub-zone by distribution map etc.

2.2.3 Step-3 Sub-zone creation

Consider how to organize sub-zone by distribution map etc. Install flow meter in the inlet point of all sub-zone for SIV measurement and valves for sub-zone creation.

2.2.4 Step-4 Drop test

Measure the pressure in sub-zone in order to confirm that the sub-zone was isolated correctly. The procedure of drop test is as below.

i. Tap the pipe in sub-zone and install pressure gauge

ii. Close the valves for sub-zone creation
iii. Confirm the pressure
iv. If the pressure decrease, sub-zone is isolated correctly since water is consumed by households or leaks. If the pressure doesn't change, other pipes is connected to the sub-zone and it means the sub-zone isn't isolated correctly.

2.2.5 Step-5 Flow meter installation

Install ultrasonic flow meter or insertion type electromagnetic flow meter in the inlet point of all sub-zone in order to measure the inflow (minimum night flow) of all sub-zone.

2.2.6 Step-6 Step test

Close the installed valves for sub-zone creation in the order of distance from the inlet point, from farthest to nearest, to prevent water hammer. Record the time when closing each valve. It is important to wait around 10 minutes after closing valve until water flow stabilize.

2.2.7 Step-6 Record flow data

Record flow data of installed meter in SIV, ultrasonic meter and insertion type magnetic flow meter during step test. After step test, open the valves from nearest one to farthest one to prevent water hammer.

2.2.8 Analyze recorded data & Visualization

Transfer the recorded data to PC, analyze and visualize it to grasp the area where the water leaks occur. It is important to consider the followings.

- Graphing methods
- Characteristics of each step in the graph
- Method of identification of leakage areas
- How to calculate MNF (Minimum Night Flow)
- Calculation procedure of other parameters (T factor/ LNF (Legitimated Night Flow) etc.
- Method of calculation of leakage volume using graph or Excel

3 Practice

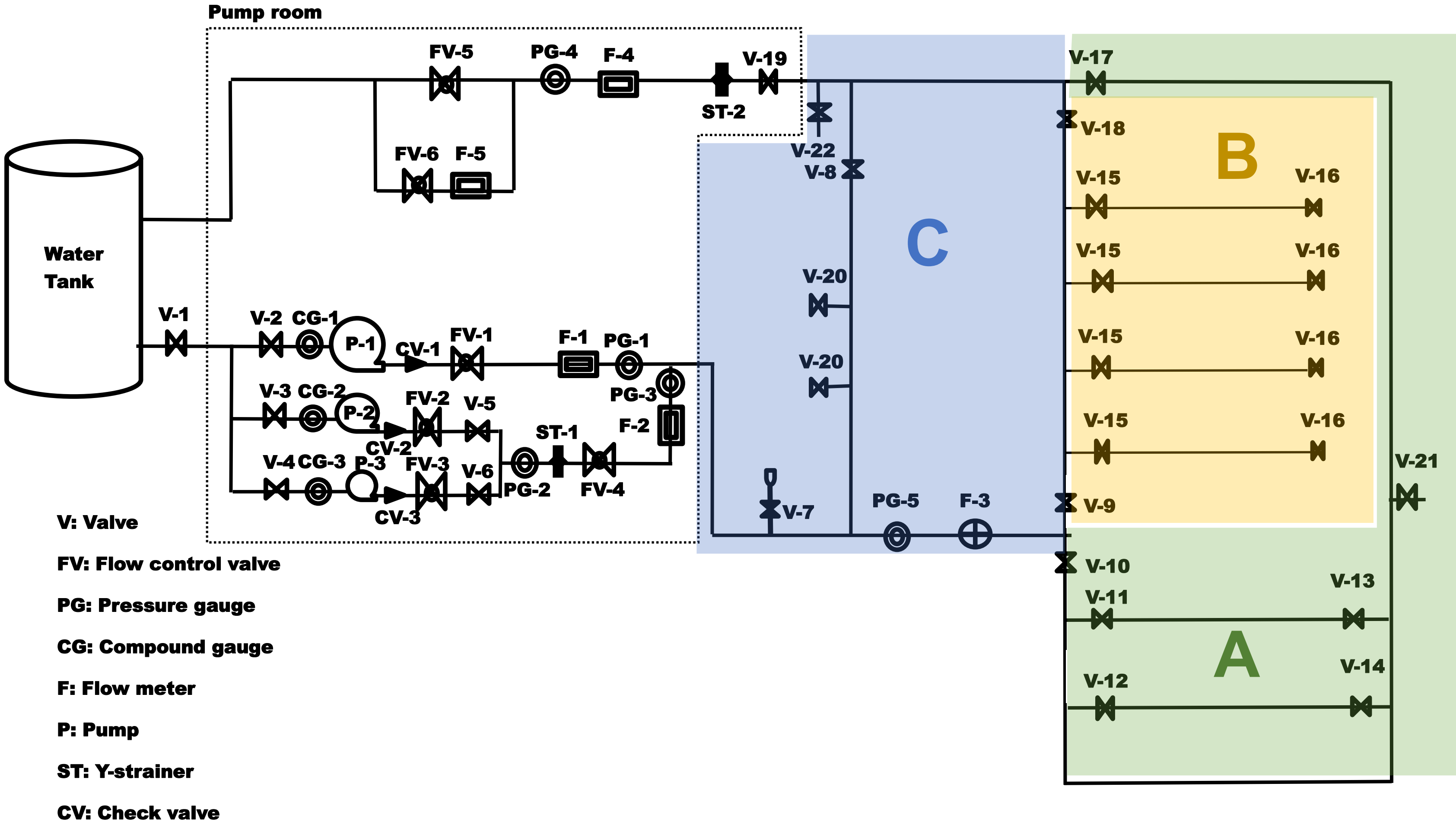
The procedures of practical training of DMA and step test are as below.

i. Consider SIV measurement point
ii. Consider how to create sub-zone in training yard
iii. Install pressure logger at faucet of leaked service pipe and conduct drop test
iv. Install the ultrasonic flow meter or insertion type magnetic flow meter in training yard
v. Measure whole area flow (ABC, *Please refer to the Appendix) and pressure by ultrasonic flow meter or insertion type flow meter and pressure logger
vi. Separate distribution pipe area (A, *Please refer to the Appendix)
vii. Measure whole area flow and pressure by ultrasonic flow meter or insertion type flow meter and pressure logger
viii. Separate service pipe area (B, *Please refer to the attachment)
ix. Measure whole area flow and pressure by ultrasonic flow meter or insertion type flow meter and pressure logger
x. Data extraction & visualization
xi. Identification of followings

- Identification of step which contribute most to the water leakage.
- Identification of leak point by using leak detection equipment.
- Identification of buried valves/iron particles using metal/valve locator.
- Identification of metallic and non-metallic pipes using pipeline tracer.



Appendix: Pipe system of training yard



Training Guideline

7. Data

How to use the data obtained from pilot activity

May 28th, 2021

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1 Outline of this training session

1.1 Background

National Water Supply and Drainage Board (NWSDB) was established in 1975 as a principal authority providing safe drinking water and facilitating the provision of sanitation in Sri Lanka, presently under the Ministry of Urban Development. NWSDB has been improving water supply facilities throughout the country for the realization of a stable water supply. Currently, although coverage of the water supply system of densely populated Colombo district has reached 94.5 %, that of the whole country is still 48.1 %. Therefore, NWSDB will continue to enhance water supply capacity and improve its service.

Enhancement of its capacity for leakage control as that of their daily O&M work directly leads to reduction of non-revenue water (NRW) and an improvement of business operation and finance.

The pilot activity was implemented through Japanese Cooperation Project named Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center Western-South, so that staff of NWSDB RSC W-S acquire the knowledge, technology, and skills necessary for leakage control through practical On-the-Job Training in the actual water distribution network.

1.2 Purpose of this training session

Table 1.2.1 Outling of Training Session

Items	Descriptions
Purpose of training	With daily water supply service, a huge and varied amount of data is generated. Many kinds of the data are related to the NRW as an indicator to measure the efficiency of the water supply management. As one of the methods to reduce NRW, there is a DMA method which create isolated area in water distribution system. This training aims to learn how to collect data from DMA and analyze them to get the information which contribute to the decrease of NRW. *This training program is conducted in the lecture room, so you don't need to use TY.
Training Contents	[First Session] 1. Basic knowledge about Non-Revenue Water (NRW) 2. Implementation Steps of Pilot Activities for Leakage Reduction 3. Implementation Procedure of Pilot Activity 4. Evaluation of DMA using indicator and making strategy for leakage

	reduction 5. Type of Evaluation Indicators 6. Data storage and update 7. Data collection of leakage repair 8. Sustainable Use of Created DMA 9. Accuracy Inspection of Customer Meter [Second Session] 10. Theory of Pulse Signal Measurement for Water Flow Monitoring 11. Practice of Pulse Signal Measurement using Test Kit

1.3 Flow of training with time schedule

The total time is 2 hours and 15 minutes.

Table 1.3.1 Time Schedule of Training Session

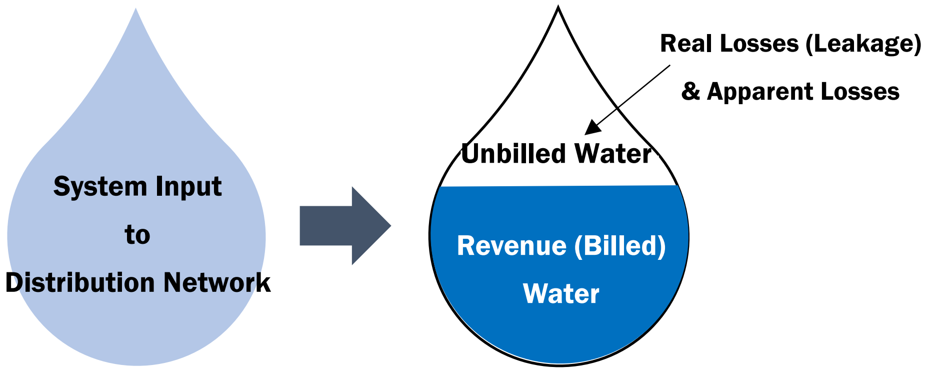
No.	Activity	Required time	Venue
1	Lecture (1st Session)	90 min.	Lecture room
2	Lecture (2nd Session) and Practice of pulse signal measurement	30 min	Lecture room
3	Q & A	15 min.	Lecture room

2 Strategy of Pilot Activity

2.1 Basic knowledge about Non-Revenue Water (NRW)

2.1.1 Definition of NRW

Non-Revenue Water (NRW) can be calculated based on the System Input Volume (SIV) and Revenue water as below.



$$\text{NRW (\%)} = \frac{\text{System Input Volume (m}^3\text{)} - \text{Revenue (Billed) Water (m}^3\text{)}}{\text{System Input Volume (m}^3\text{)}} \times 100$$

Figure 2.1.1 Definition of NRW

System Input Volume	"System Input" is the amount of water supplied to the user through pipelines and water tankers.
Billed Water	"Billed Water" is the amount of billable water authorized by the water utilities. This includes not only the amount of water based on meter reading results, but also the estimated amount of use. The measurement period for "Billed Water" must match the measurement period for "System Input".

2.1.2 Evaluation of NRW

The amount of leakage reduced by a series of activities is a very important indicator for measuring performance.

Leakage reduction is not only essential for effective use of water resources, but also has a major impact on improving the management of water utilities.

"Non-Revenue Water" is also one of the factors in evaluating water supply management, and one of the major causes of NRW is leakage.

2.1.3 Water Balance defined by International Water Association (IWA)

The first step in reducing NRW is to understand the whole picture of the water supply system, the person in charge of considering the measures is required to prepare a Water Balance table.

By creating this Water Balance, it will be possible to comprehensively understand the scale, causes, and required costs of NRW in an area.

The standard water balance table proposed by IWA is as follows.

Table 2.1.1 IWA Water balance table

<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>Metered consumption</td><td rowspan="2">Revenue water</td></tr>
<tr><td>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">Apparent losses

(Commercial losses)</td><td>Unauthorized consumption</td></tr>
<tr><td>Meter inaccuracies</td></tr>
<tr><td rowspan="3">Real losses

(Physical losses)</td><td>Leakage on transmissions or distribution mains</td></tr>
<tr><td>Leakage & Overflow at storage tanks</td></tr>
<tr><td>Leakage on service connection up to point of customer meter</td></tr>
</table>

Source: Performance Indicators / First Edition 2000, IWA

2.1.4 Unavoidable Annual Real Losses (UARL)

Real Losses cannot be eliminated totally. The lowest technically achievable annual volume of Real Losses for well-maintained and well-managed systems is known as Unavoidable Annual Real Losses (UARL). It is said that this value will be about 2 to 4% of the total amount of water distributed by any water utility, and it can be understood as the allowable amount of leakage.

Figure 2.1.2 shows the relation between Current Annual Real Losses (CARL) and UARL. Using the four methods of leakage management, Real Losses can be controlled, but cannot be reduced any further than the UARL

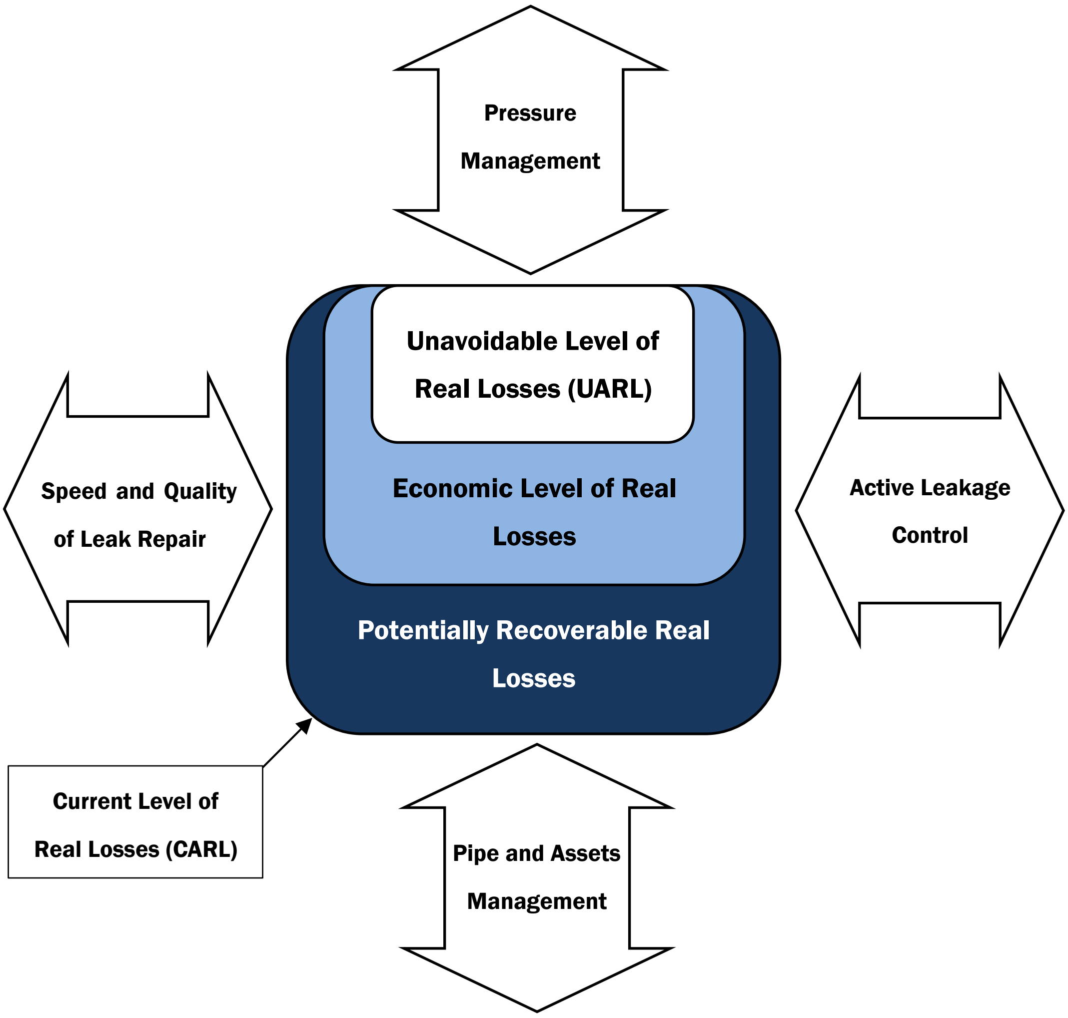


Figure 2.1.2 The four basic methods of managing Real Losses

UARL and CARL can be calculated with the following formula.

UARL (L/day) = (18×Lm + 0.8×Nc + 25×Lc) × P

Lm : Total length of distribution pipes (km)

Nc : House Connection Number

Lc : Total length of service connection pipes (km)

= Average length per connection (km/connection) × Ns. of connection

P : Average water supply pressure (m H_2O)

$$\text{CARL (L/day)} = \frac{\text{Annual Volume of Real Losses (m}^3\text{/year)} \times 1000}{\text{Number of Water Service Days}}$$

Figure 2.1.3 Equation of Current Annual Volume of Real Losses (CARL)

2.1.5 Infrastructure Leakage Index (ILI) and Target Value of Real Losses

ILI is a value recommended by IWA as an indicator of the vulnerability of distribution pipes. ILI is obtained by dividing the amount of water leakage (CARL). It can be an indicator to judge how appropriately the distribution network is maintained.

$$\text{Infrastructure Leakage Index (ILI)} = \frac{\text{Current Annual Volume of Real Losses (CARL)}}{\text{Unavoidable Annual Real Losses (UARL)}}$$

Figure 2.1.4 Equation of Infrastructure Leakage Index (ILI)

Basically, ILI can be applied in relatively large systems at the national, city, and zone levels. The conditions are as follows.

Number of connection	:	more than 3,000 (no limit for density)
Average water supply pressure	:	more than 25m as water head

In the case of an ideal water distribution network with no problems, ILI=1.0. However, it is a value that is practically impossible, ignoring cost-effectiveness, and it is not necessary to target this level.

If the current ILI and target value can be set in this way, the real losses to be targeted can be determined using the following matrix according to the ILI value and the average water supply pressure.

Table 2.1.2 Target value of real losses

Technical Performance Category		ILI	Physical Losses (L/connection/day) (when the system is pressured) at an average pressure of:				
			10m	20m	30m	40m	50m
Developed Countries	A	1 - 2		< 50	< 75	< 100	< 125
	B	2 - 4		50 – 100	75 – 150	100 – 200	125 – 250
	C	4 - 8		100 – 200	150 – 300	200 – 400	250 – 500
	D	> 8		> 200	> 300	> 400	> 500
Developing Countries	A	1 - 4	< 50	< 100	< 150	< 200	< 250
	B	4 - 8	50 – 100	100 – 200	150 – 300	200 – 400	250 – 500
	C	8 - 16	100 – 200	200 – 400	300 – 600	400 – 800	500 – 1000
	D	> 16	> 200	> 400	> 600	> 800	> 1000

Source: Roland Liemberger, IWA Leakage 2005 Conference

Category A Good. Further loss reduction may be uneconomic and careful analysis needed to identify cost-effective improvement.

Category B Potential for marked improvements. Consider pressure management, better active leakage control, and better maintenance.

Category C Poor. Tolerable only if water is plentiful and cheap, and even then, intensify NRW reduction efforts.

Category D Bad. The utility is using resources inefficiently and NRW reduction programmes are imperative.

2.2 Implementation Steps of Pilot Activities for Leakage Reduction

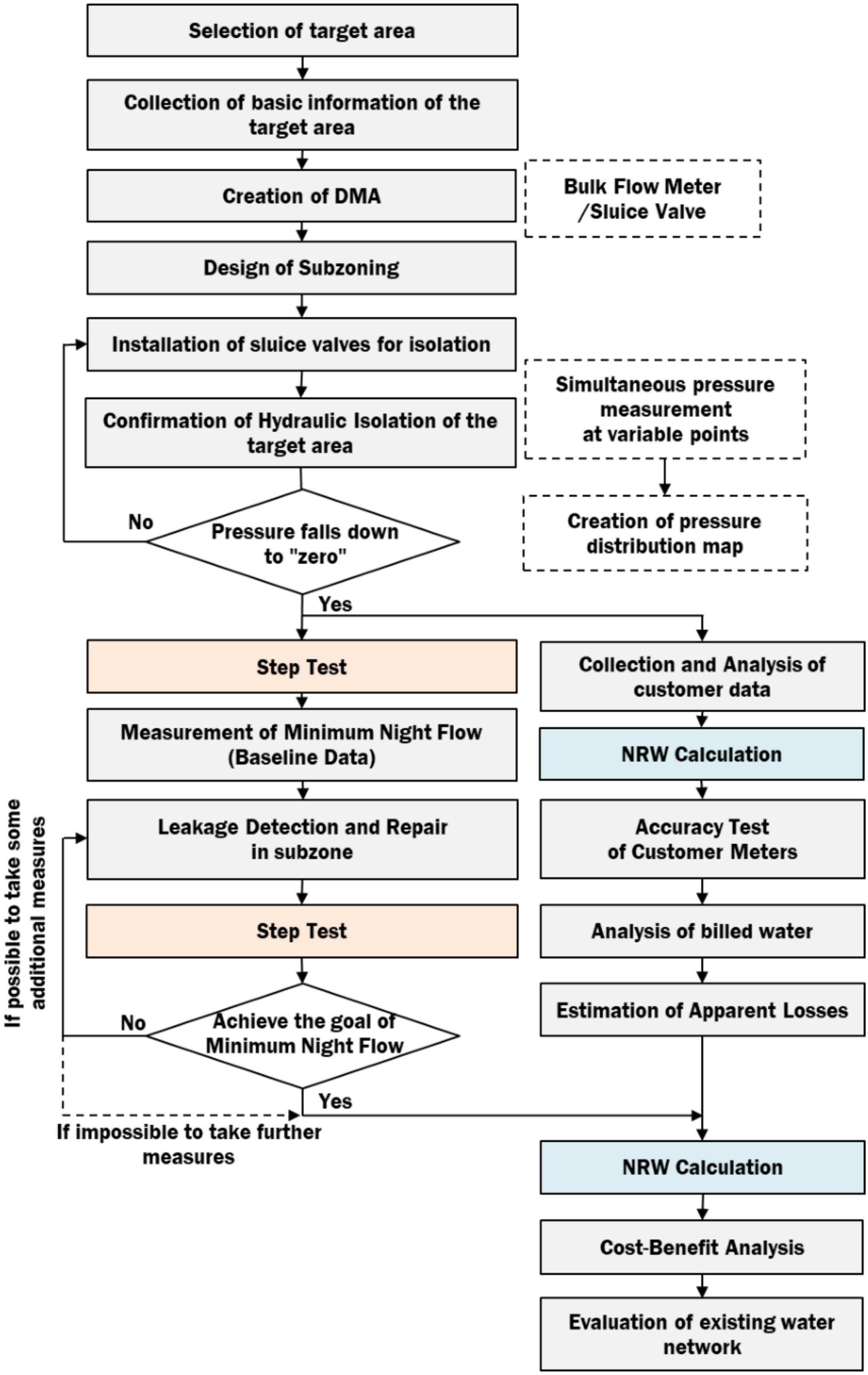


Figure 2.2.1 Implementation Steps of Pilot Activities

2.3 Implementation Procedure of Pilot Activity

2.3.1 Selection of Target Area

In implementing the leak reduction plan, candidate areas to be targeted for activities must be selected and identified. The method of DMA creation is only one of various methods of leak management.

Construction a DMA is not a cure-all to reduce leakage and is not required in all water distribution networks. Constructing a DMA, especially in an existing complex water network, requires considerable effort, materials and time.

In addition, effective activities cannot be carried out without understanding the utilization method after constructing the DMA and the procedure for reducing water leakage.

When applying the DMA method to an existing distribution network, it is of utmost importance to limit it to areas where NRW, water leakage is significant, or the risk of water leakage is high.

Major Factors to be considered
when selecting water supply scheme for DMA creation

- Non-Revenue Water
- Historical record of leakage occurrence and repair
- Age of pipe and pipe installation year
- Type of pipe (Asbestos Cement, Galvanized Iron, PVC, Polyethylene, Ductile)
- Water Supply Pressure
- Topographical condition and land use
- Variation in nodal elevation
- Water demand and number of customers
- Water quality
- Number of sources that feed water to the area

The first factor to be considered is NRW in the area under the jurisdiction of OICs.

It is important to grasp not only the NRW of the entire jurisdiction area but also the NRW in each zone and divide it into three ranks to identify the areas that require countermeasures. As a result, there may be cases where it is not desirable to apply the DMA method.

For example, in an area where pipes have been laid for more than 50 years and the amount of non-revenue water is 40% or more, the pipes should be completely renewed without considering the application of DMA method.

The following shows the basic flow for considering the application of the DMA method.

In this case, NRW is used as an indicator for selection, but it is also possible to use the number of annual leakages, annual repairs, or minimum water inflow rate of nighttime instead of NRW.

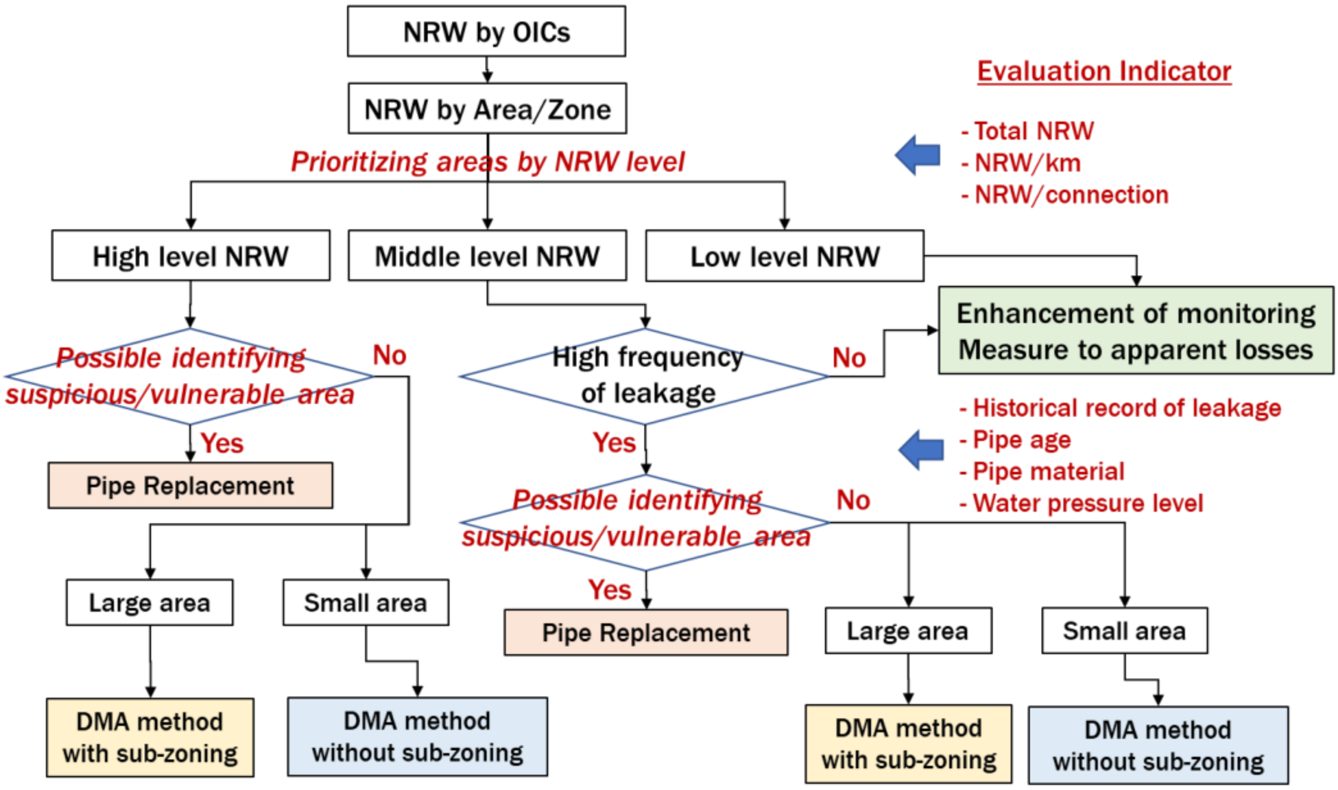


Figure 2.3.1 Basic flow for considering the application of DMA method

2.3.2 Measurement of Baseline Data

Once selected the target area for leakage reduction, the following information should be collected.

Table 2.3.1 Major data to be collected before commencement of activities

No	Items
1	Number of connections
2	Number of effective customer meter
3	Billing data during last 12 months
4	Meter reading data during last 12 months
5	Number of users by category
6	Distribution Network Drawing
7	Length of pipes by type of material
8	Length of pipes by diameter

While conducting the activity, check the consistency between the data base of billing status and the current water users, so that NRW and real losses can be calculated accurately after DMA creation.

Table 2.3.2 Customer data to be collected before commencement of activities

No	Items	No	Items
1	ID Code of region	13	Type of commercial activities
2	Region	14	Water source
3	Zone	15	Connection date
4	Registration number	16	Sewerage service
5	Customer number for billing	17	Status of meter box
6	Direction	18	Operating condition of meter
7	Type of connection	19	Manufacturer of meter
8	Water usage status	20	Nominal diameter of meter
9	Contact number	21	Serial number of meters
10	Customer name	22	Type of service pipe
11	Type of building	23	Diameter of service pipe
12	Economic status		

2.3.3 Creation of District Metered Area (DMA)

(1) Type of DMA

District Metered Area (DMA) means "Hydraulically isolated area where flow meter can control water inflow volume".

The DMA method is generally adopted to manage leakage reduction in the target area.

By measuring the inflow of water from one or more inlet pipes with flow meters and deducting the total consumption of water recorded by customer meters from inflow, the amount of water loss in DMA can be calculated.

There are three types of DMA as shown in the figure below.

Type 1: DMA with one inflow point

Type 2: DMA with two or more inflow points

Type 3: DMA that has inflow points and outflow points

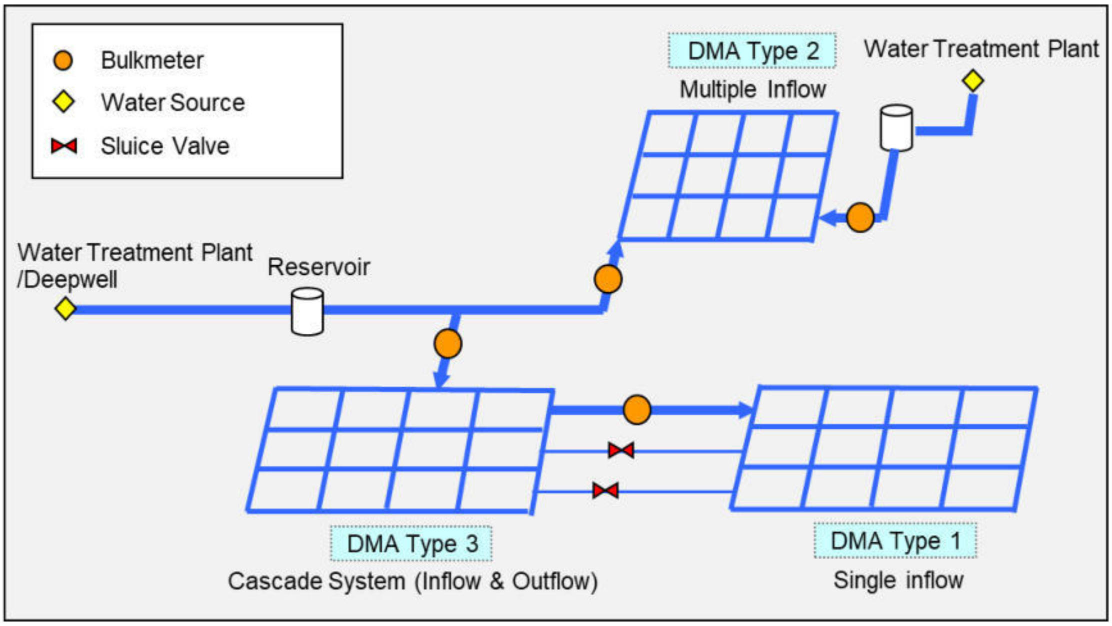


Figure 2.3.2 Type of DMA

(2) Definition of DMA

In this activity, DMA is defined as follows.

<u>Definition of DMA</u>

DMA is the smallest leak management area constructed in the distribution network.
It is used to estimate the amount of water loss occurring in the sector by making it hydraulically independent at night when water demand is low and measuring the Minimum Night Flow (MNF).

【Complementary conditions】

- Water communication between adjacent distribution networks is allowed, but valves must be installed in place to allow the distribution network to be independent (separate from surrounding distribution networks) when needed.
- Multi point Inflow is permitted.
- It is not an absolute requirement to install a flow meter at the inflow point, but it must be possible to install a portable flow measurement device and measure the inflow water amount at night.

<u>Scale of DMA</u>

DMA will be set in consideration of distribution network conditions, water demand, customer density, etc.
For efficient control of water leakage reduction activities, it is desirable that the number of water supply connections for one DMA is about 500 to 3,000.

The ideal DMA is a system that is always disconnected from the surrounding water distribution network 24 hours a day and allows you to compare the amount of water supplied to the sector with the amount of water consumed within a certain period.

In order to construct DMA with perfect condition, it is necessary to perform hydraulic calculation based on distribution pipe data, and to develop a pipe network that does not cause a significant shortage of water demand, which requires a great deal of cost and time.

(3) Purpose of creating DMA

The purpose of constructing a DMA is as follows.

- After limiting the boundary of distribution network from the surroundings at night, measure the Minimum Night Flow (MNF) to roughly understand the level of water leakage occurring in the area.
- Divide MNF by the number of customers existing in the area to calculate the Minimum Night Flow rate per connection (MNF/connection).
- Divide MNF by the pipeline extension in the area to calculate the Minimum Night Flow rate per km (MNF/km).
- Compare the MNF of different DMAs to identify areas with high levels of water leakage and NRW, and take efficient and effective water leakage reduction measures considering priority.
- It is recommended that the effect of the measures should be regularly confirmed in the DMA that has taken measures against water leakage, at least once a month.
- By installing a remote monitoring system in DMA, we can monitor daily inflow water volume and water pressure and respond to sudden leaks and water distribution network accidents.

(4) Information needed for DMA design

The following information needs to be confirmed when designing a DMA.

- Location, diameter and actual status of existing valves and its diameter
- Location and diameter of Inlet pipe of a target area
- Information of distribution pipes near the expected boundary
- In case of sub-zoning, detail of pipeline of its boundary
- Water supply pressure

(5) Design Criteria of DMA

Several factors should be taken into consideration when designing a DMA.

- Size
- Boundary

- Hydraulic modeling
- Number of flowmeters
- Variation of ground level

1) Size

DMA size is usually determined by the number of connections or the length of distribution pipeline within a DMA. In practical situation, smaller DMAs have several advantages compared to larger DMA as follows:

- Smaller leaks can be identified against the legitimate night use
- Survey time can be reduced
- Survey cost can be reduced

After all smaller DMA can be maintained in lower level of leakage. If a DMA is larger than 5,000 connections, it becomes difficult to identify occurrence of small bursts from night flow data, and it takes longer to locate it.

On the other hand, the constructing small DMAs will tend to cost since it requires larger number of DMAs divide out existing distribution network system.

In practice, the size of an individual DMA will vary, depending on how boundary can be set actually. Also, hydraulic conditions and economic factors, in general, are the significant key factors to determine the size of DMAs.

2) Boundary

Individual DMA has to be independent from other DMAs hydraulically, so that the DMA should be disconnected from the network except feeding points. Physical discontinuity points of the network can be traced as a boundary to avoid any repercussions to the existing service. Otherwise, the closing valve will be needed for making boundary. Normally, it is better to limit the number of closing valves. Hence, a boundary should be designed to cross as few mains as possible.

In any cases, influences should be checked whether decrease of water pressure and increase of travel time of water would be acceptable or not. Testing by hydraulic modelling is always useful for this matter. Or if possible, it can be tested by creating the situation in actual site on a trial basis.

3) Number of flow meter

Flow meter should be installed at feeding point. If a DMA have inlet and outlet, several flowmeters will be needed at respective points. Generally, the lesser number of meters is recommended from the viewpoints of accuracy of flow measuring and maintenance cost. If a DMA contains several flow meters, measuring flows into/out of the district could result in misleading leakage levels because of compounding errors in flow calculation.

Therefore, it is better to reduce the number of flow meter, limiting the number of feeding points in minimum.

4) Hydraulic analysis

As mentioned above, closure of valves and limiting of feeder points will influence the existing network system. Hydraulic analysis can simulate and show how the creation of DMA will influence the existing network. It must be simulated how much water pressure will drop, how long travel time of water will extend.

Furthermore, they should be simulated in adverse condition. Then, water pressure should be simulated in the condition of peak time when many people use water service. Travel time should be simulated in the condition of average time.

5) Ground level variation

Minimum variation in ground level across the DMA is recommended. Furthermore, it would be better to take into consideration High/Low pressure problems that certain areas may have, to that those can be managed by installing booster pumps, or pressure reducing valves into inlet points.

2.3.4 Example of DMA creation in Panadura Area

This clause shows the example of DMA creation as a pilot project.

(1) Selection of Target Area for DMA creation

Candidate areas for pilot projects are under the jurisdiction of RSC Western-South. Zone 1 was selected for the Panadura OIC, which has an old distribution network and a high frequency of water leaks.

Table 2.3.3 Selection of Pilot Area

Candidate Area	1	2	3
Manager office	Kaluthala	Dehiwala	Panadura-Horana
OIC	Payagala	Moratuwa	Panadura
Area name	Maggona	---	Zone 1
Number of connections	3,000	5,000	7,000
NRW ratio of OIC	Less than	Less than 10%	Less than 15%
Pipeline	Relatively new system	Relatively new system	Relatively old system (more than 40 years)
Frequency of leakage	Medium	Low	Medium (high risk (Old Pipe))
Accessibility between RSC and Project office	45km / 1 hour	0km / 3 min.	8km / 20 min.
Water supply hours	24 hours	24 hours	24 hours
			Selected

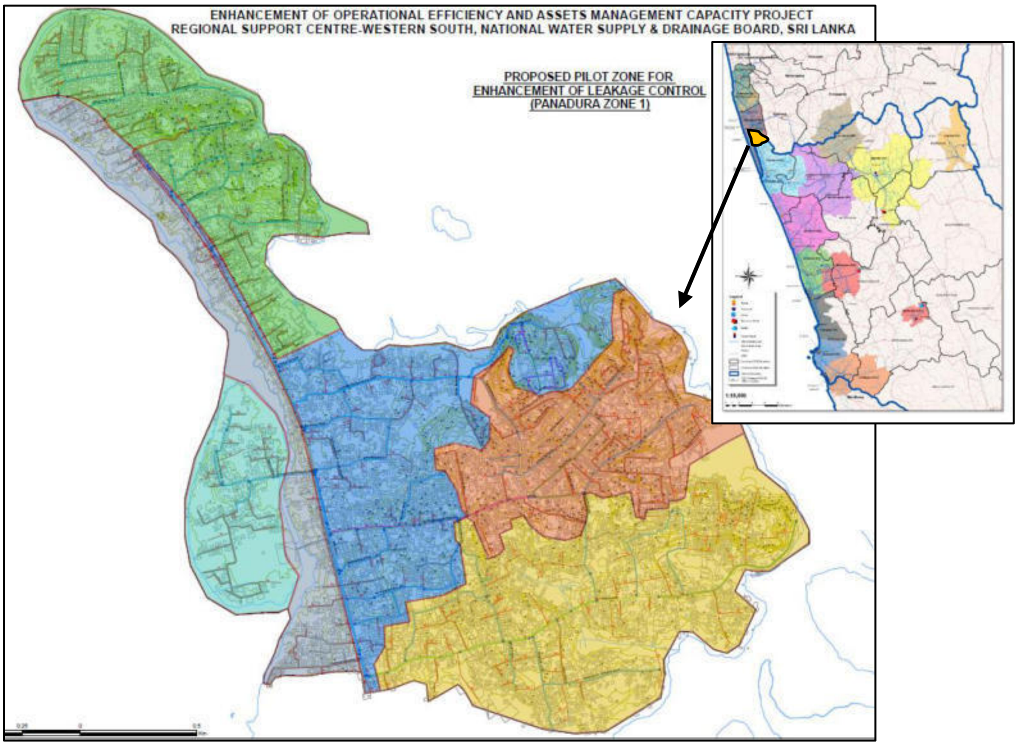


Figure 2.3.3 Location of Pilot Area (Zone 1)

(2) Baseline data of Pilot Area for DMA creation

The data collected before dividing the area into DMA is as follows:

Table 2.3.4 Pipeline information of Zone 1, OIC Panadura

Diameter Normal	Material	Pipe Length	Proportion
50mm	PVC	911 m	2.7%
63mm	PVC	3,012 m	8.8%
90mm	PVC	18,561 m	53.9%
110mm	PVC	2,528 m	7.4%
160mm	PVC	4,232 m	12.2%
225mm	PVC	1,056 m	3.1%
250mm	DI	886 m	2.6%
400mm	DI	705 m	2.1%
450mm	DI	311 m	0.9%
500mm	DI	1,942 m	5.6%
DN not specified		236 m	0.7%
Total		34,380 m	100.0%

Table 2.3.5 Connection per Category of Zone 1, OIC Panadura

Category	Connection	Proportion
Domestic	6,378	93.4%
Poverty house	117	1.7%
School	6	0.1%
Commercial facility	300	0.1%
Religious facility	10	0.2%
Government institution	12	0.1%
Other	5	100.0%
Total	6,828	
Population	63,952	person
Population/Household	9.85	person

To implement the leakage reduction activities efficiently and effectively, it is necessary to divide a large pilot area into small sections, considering geological condition, number of customers, location and condition of pipeline and valves.

(3) Preliminary Design of DMA creation

Based on the information collected in advance, the following ideas for division were created.

This preliminary plan was created based on the pipeline network drawing but there are various mistakes in the drawing information. Therefore, it is necessary to actually confirm the valve position at the site and repeatedly check the water pressure by closing the valve to determine the appropriate boundary line.

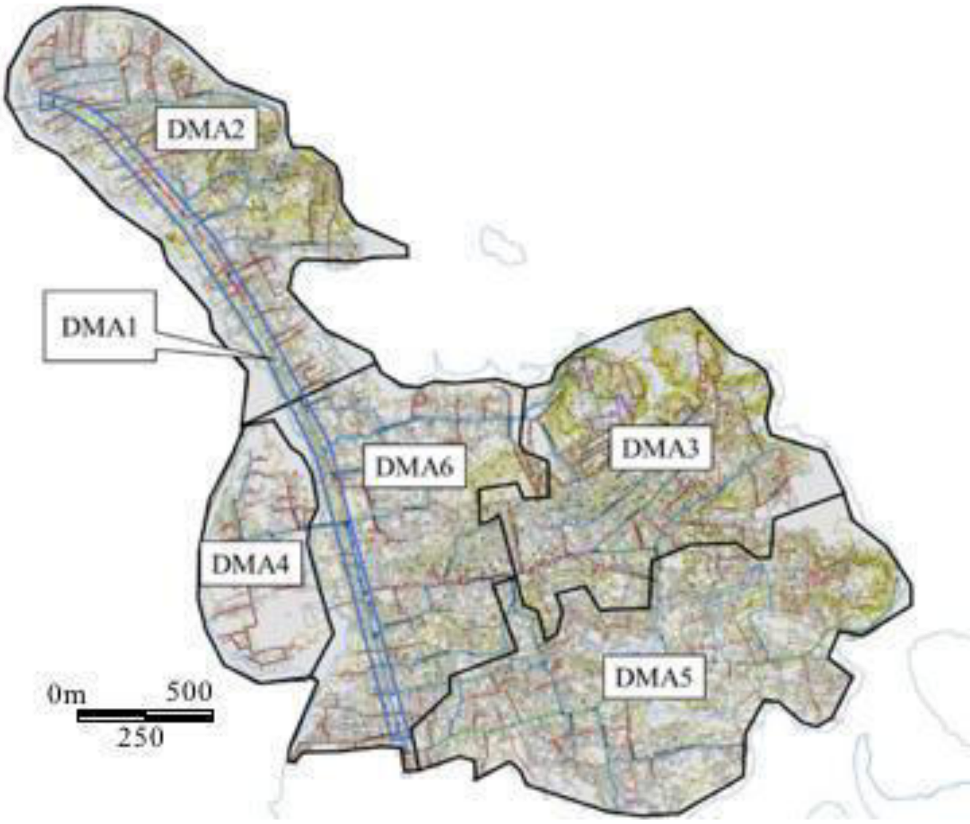


Figure 2.3.4　Original Design of DMA creation

【Necessary investigation at site】

- Close the existing valve to identify the range of the water supply area.
- If you have any doubts about existing drawings, consider the possibility of interconnection.
- Identify all the existing valves which can be operated without any defect.
- Identify the location of valves to be newly installed for appropriate isolation.
- If it is difficult to hydraulically isolate the target area, you can consider the branch line as an isolated section.

The draft boundary at the DMA design stage and the final boundary scheme are shown below.

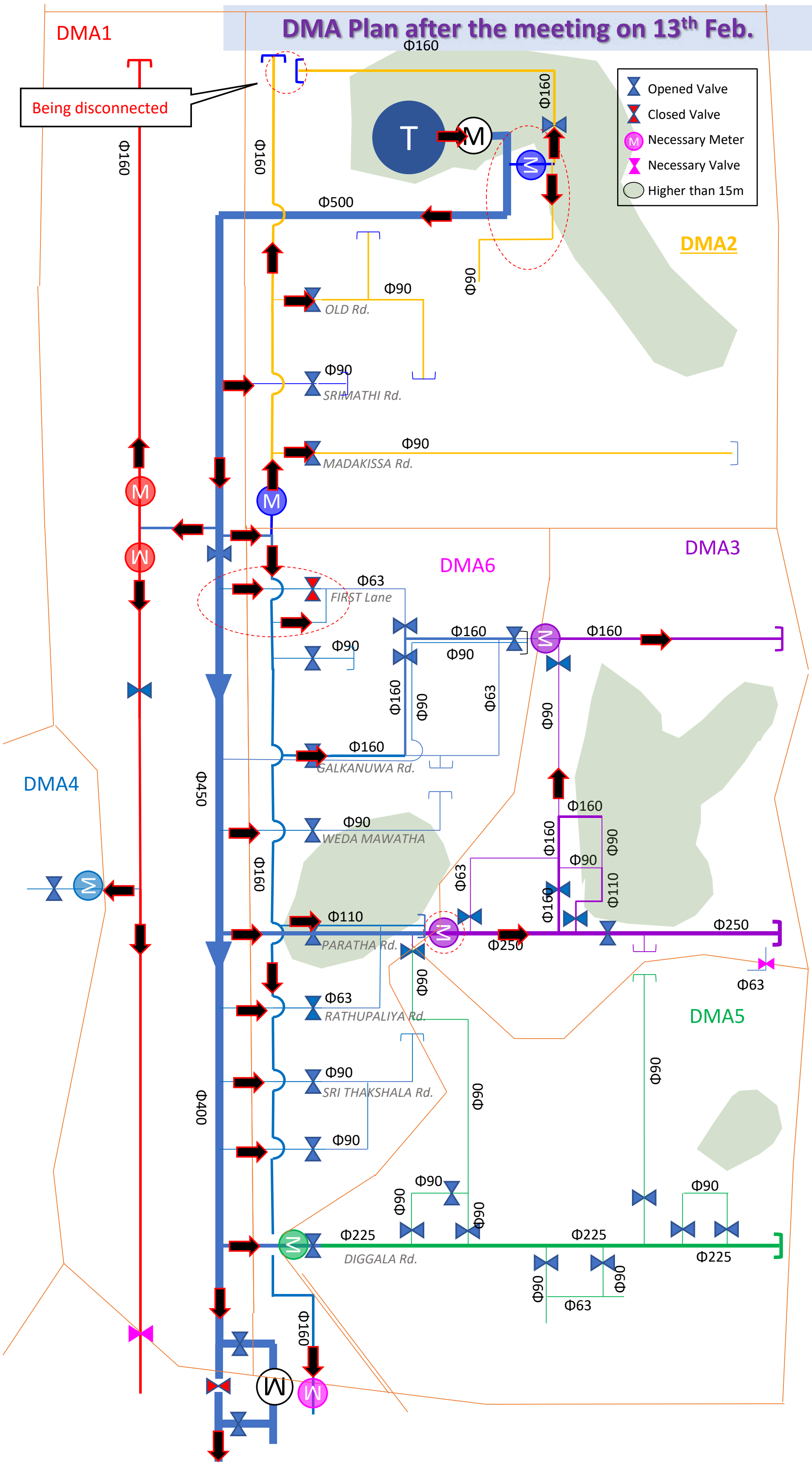


Figure 2.3.5 Original Design of DMA boundary

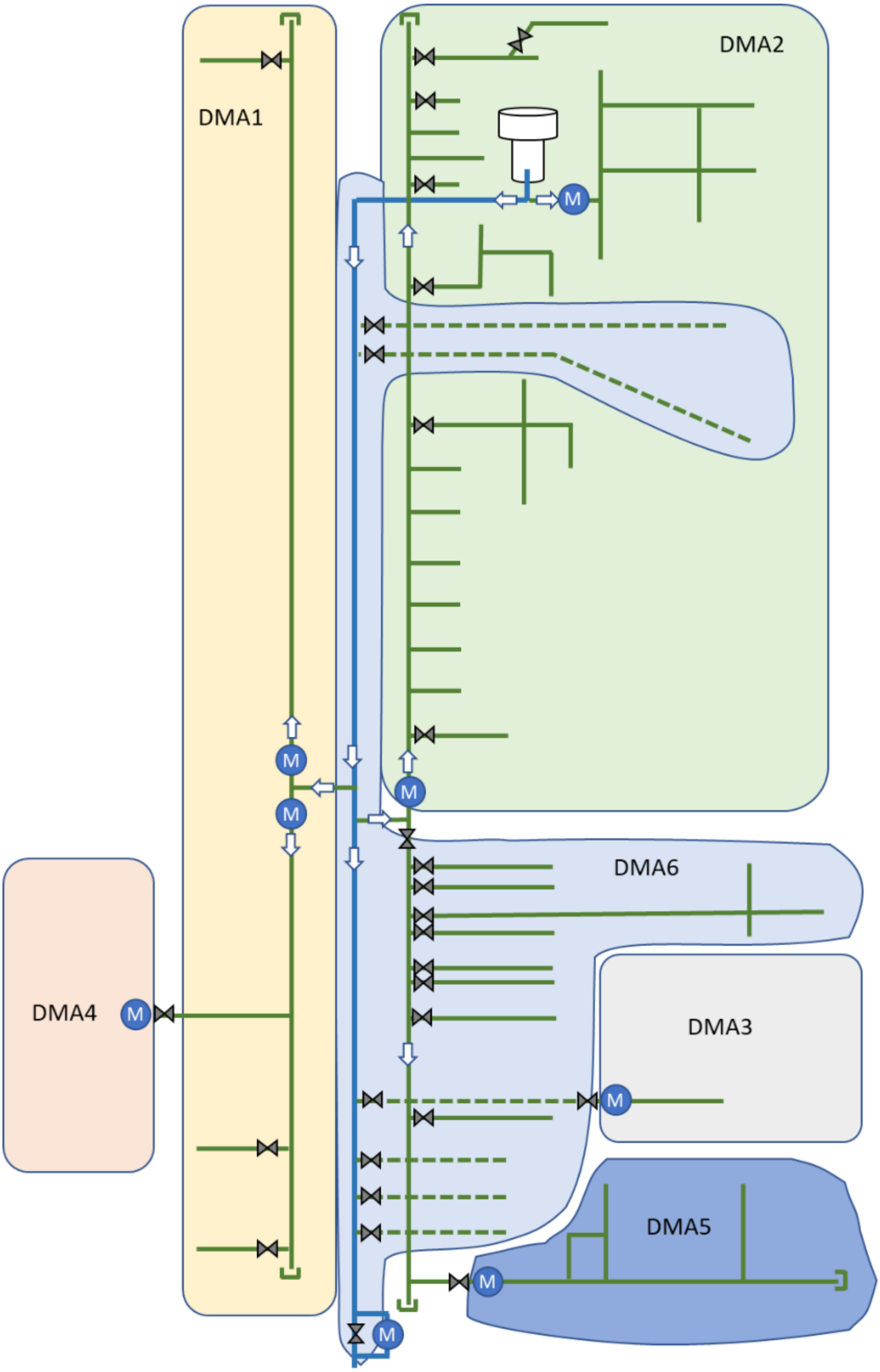


Figure 2.3.6 Final Design of DMA boundary

2.3.5 Monitoring of NRW in DMA

If the DMA is completely isolated from the surrounding water distribution network, the NRW per DMA can be calculated by comparing the amount of distributed water into the DMA with the amount of water used by customers.

(1) Collection of Billing Data

Once determined the boundarie of DMA, we should make a list of the customers that exist within it. The customer list can be obtained through the meter reading and billing departments.

However, the routes and areas that the meter reader is in charge of do not always coincide with the DMA boundaries. Therefore, one billing data list may include customers other than the target DMA.

In carrying out the DMA activity, it is important to extract and list the customers in the DMA based on the billing data, and it is desirable to confirm the following points.

- Identify users of large amount of water and historical billing data for the past 12 months
- Classify users per category, diameter of meter
- Identify the existence of abnormal water use from billing data

(2) Installation of Bulk Mater

To record water inflow of DMA, the bulk meters should be installed at feeding points.

For selecting the size of balk meter, required flow range (minimum and maximum) and head loss should be taken into account. The manual “Leakage Management and Control” compiled by WHO 2001 shows the following reference table for selection of meter size.

Table 2.3.6 Meter size and flow range (Turbine Meter Helix 4000 Kent)

Meter size (mm)	80	100	150	200
Maximum Flow (m^3/h)	200	250	600	1000
Recommended Continuous Flow (m^3/h)	120	180	450	700
Minimum Flow (m^3/h)	0.5	0.6	2	4

Table 2.3.7 Standard meter size by number of connections

Number of connections	Meter size (mm)
Less than 1000	80
1000 to 1500	100
More than 1500	150

(3) Meter reading interval for NRW monitoring

Even if the measurement is performed in a DMA, it is rare that the meter reading of the water meter is completed in one day, and the meter reading is usually performed over a plurality of days.

On the other hand, the bulk meter reading of the feeding point of a DMA is performed once a month, but it is impossible to completely match the interval of bulk meter reading with the reading cycle of customer meter.

For this reason, it is extremely difficult to accurately calculate monthly NRW. However, by advancing the NRW monitoring for several months, the error that the deviation of the meter reading date gives to the NRW rate can be reduced.

The points to note when measuring NRW in a DMA are as follows.

- Identify the representative date when the meter of the most customers is read based on the information in the customer list and billing data.
- On the specified day, read the bulk meter every month and calculate the Water Input Volume.

(4) Example of NRW monitoring

By continuing NRW monitoring, the effects of water leakage reduction activities can be confirmed.

An example of the results of water leakage reduction activities in DMA4 is shown below.

Table 2.3.8 Example of improvement of NRW in DMA4

	Average Input (m^3/day)	Average Billing (m^3/day)	NRW (%)
Before Activity (March 2019)	257.5	197.3	23.4
After Activity (August 2019)	223.2	202.2	9.4

2.3.6 Steps of Leakage Reduction Activity

The water leakage reduction activity using DMA is carried out according to the following flow:

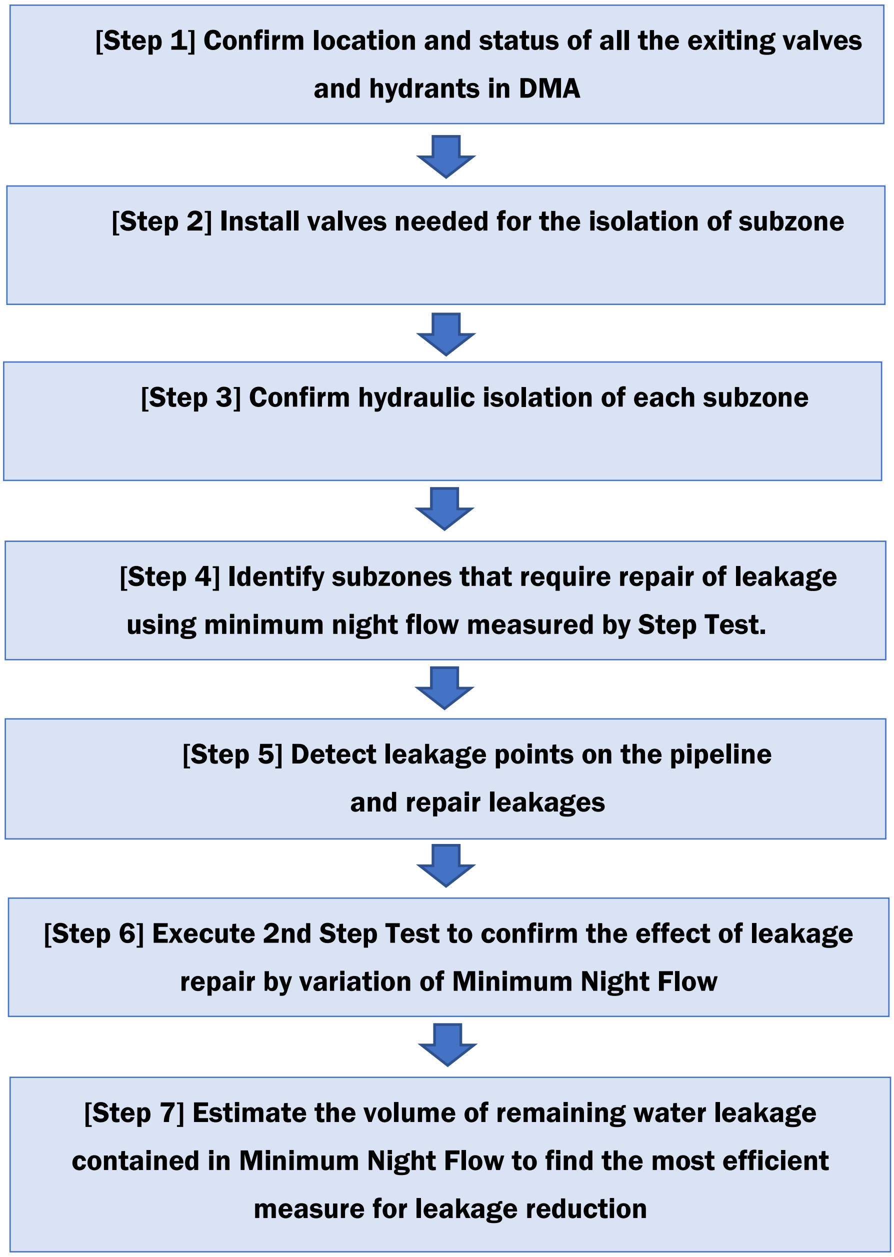


Figure 2.3.7 Steps of leakage reduction activities

2.3.7 Confirmation of Hydraulic Isolation of DMA

To proceed with the construction of the DMA, a field survey should be conducted based on the preliminary design created in advance. The distribution pipe, distribution status, the presence or absence of dead-end pipes, and the connection status with adjacent areas should be confirmed and should be reflected to updating work of pipeline network drawing.

After that, the changes from the preliminary design will be clarified and the boundaries for hydraulic independence will be set.

If the water pressure gauges are installed at multiple points in the area, the valves at the inflow points are closed, and the water supply pressure becomes zero after a certain period of time, it means that hydraulic independence has been achieved.:

	
Measurement of pressure at the water tap	Equipment of pressure measurement at a certain point of distribution pipe.

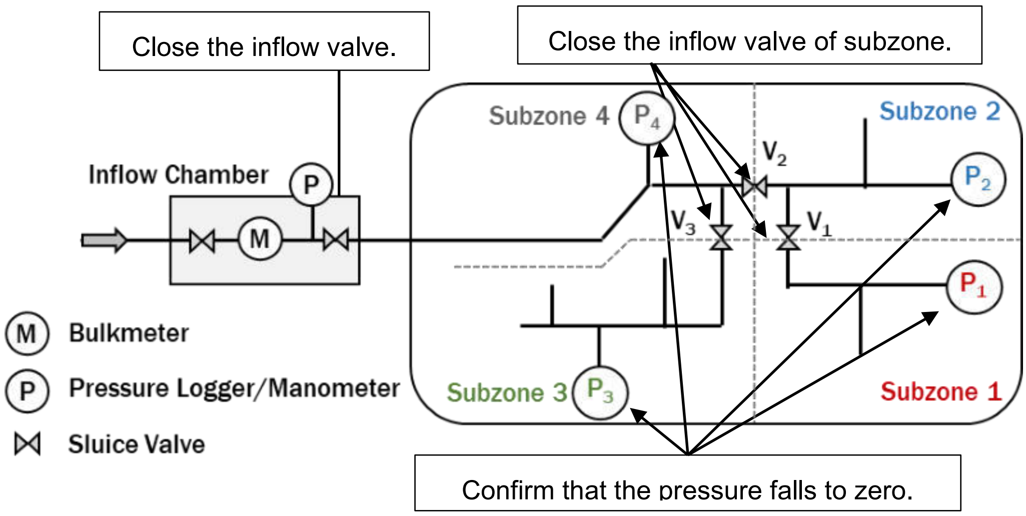


Figure 2.3.8 Image of pressure measurement in DMA

2.3.8 Measurement of Minimum Night Flow (MNF)

An ultrasonic flow meter and a water pressure data logger shall be installed at the target DMA inflow point, and the flow rate and water pressure will be measured for at least 24 hours. The MNF Measurement Method is a method of grasping the consumption water volume in the network at night when the water use on the user is small. This measured volume will be an approximate value of the leakage that has occurred in the network.

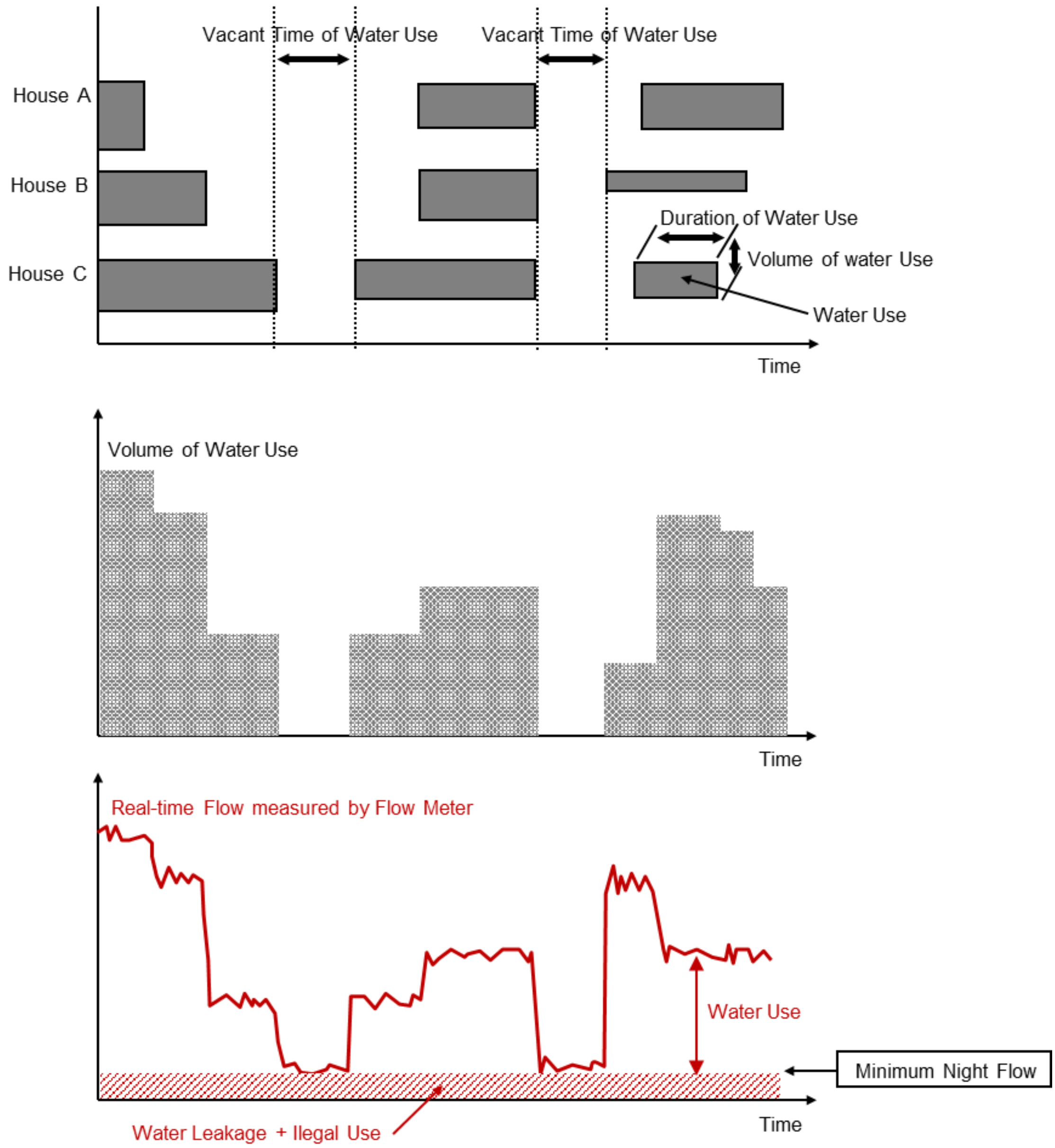


Figure 2.3.9 Minimum night flow and vacant time of water use

Although there is a certain amount of water used at night, it is considered that most of MNF is due to the amount of water leakage occurring in the sector, since the water demand of users is the smallest.

The measurement time period is from midnight to 6:00 in the early morning, and the core time of MNF analysis is generally between 1:00 and 4:00.

The MNF rate is often measured for the number of connections of about 500 to 1,000 according to the size of DMA. As an example, if the DMA can be divided into 5 sub-zones as follows, a sub-zone with a large potential leakage can be identified by performing a step test.

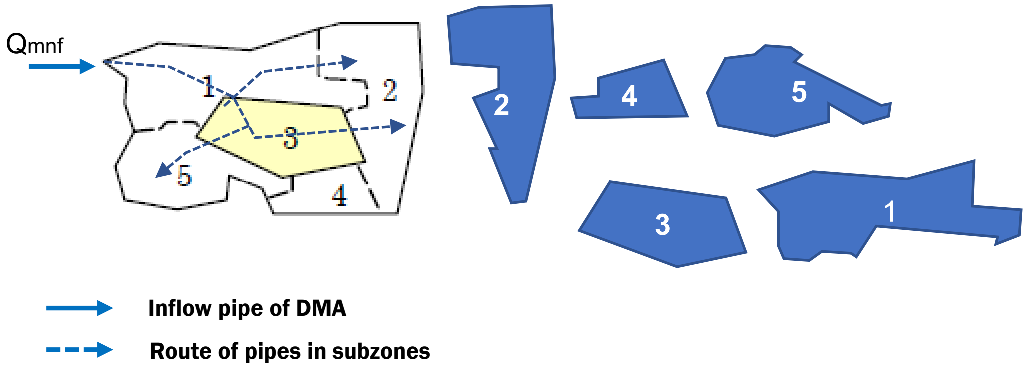


Figure 2.3.10 Image of DMA and sub-zoning

Depending on the conditions of the existing water pipe network, there are cases where there are multiple inflows and outflows, and the current pipeline layout is too complex to determine boundaries easily. If there is a branch-shaped branch pipe with a valve in the target area, it can be used as a sub-sector itself.

Here, a concrete example of how the subzones were constructed in the six DMAs is shown.

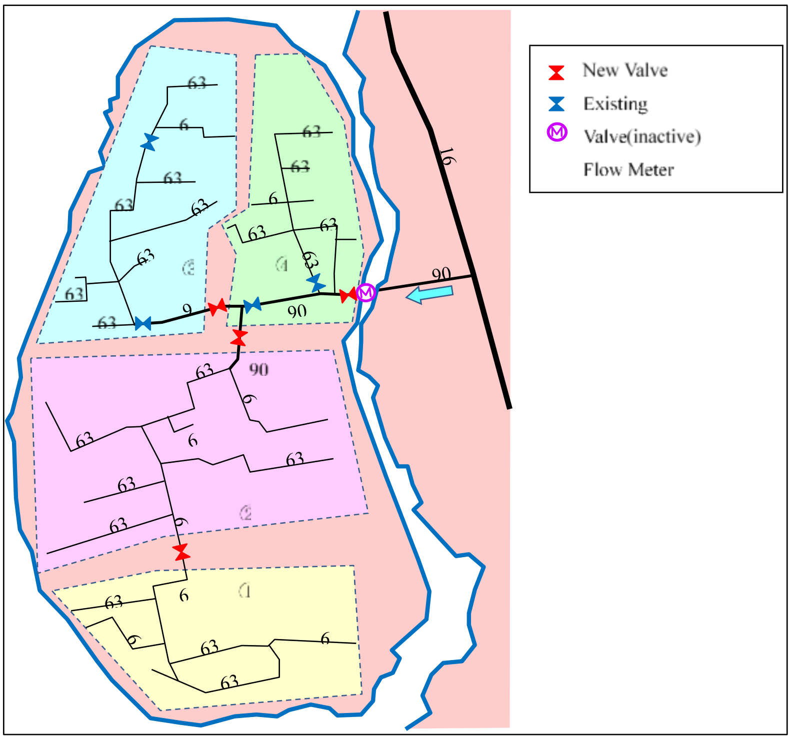


Figure 2.3.11 Example of sub-zoning of DMA 4

Table 2.3.9 Basic Information of subzone in DMA 4

Subzone No.	Number of connections	Extension of distribution pipes (km)
Subzone 1	47	1.3
Subzone 2	107	1.3
Subzone 3	89	1.2
Subzone 4	85	0.8
Total	328	4.6

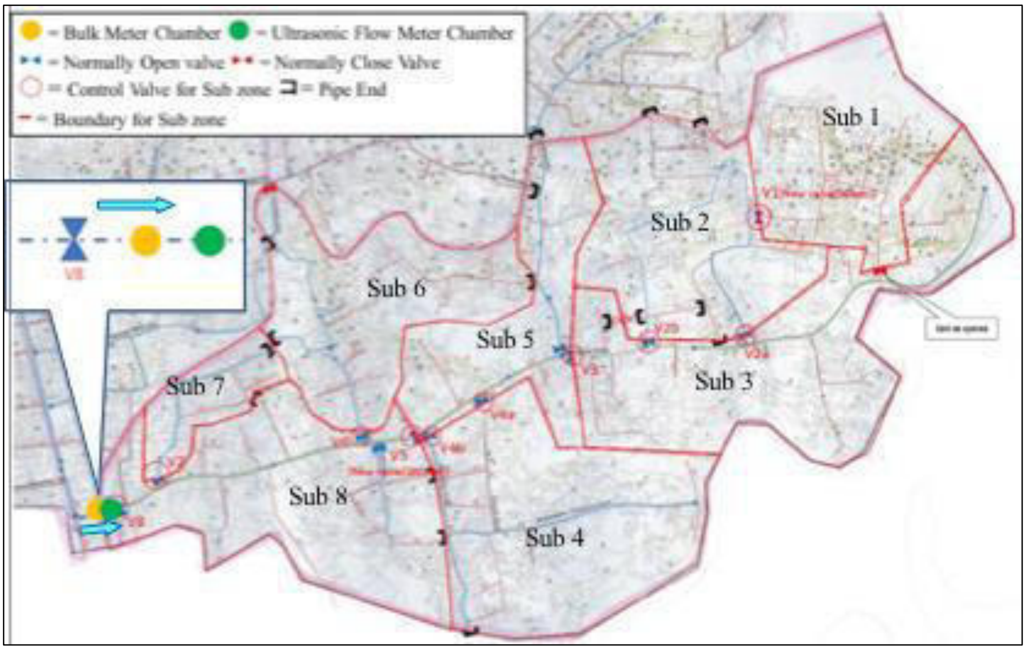


Figure 2.3.12 Example of sub-zoning of DMA 5

Table 2.3.10 Basic Information of subzone in DMA 5

Subzone No.	Number of connections	Extension of distribution pipes (km)
Subzone 1	159	1.9
Subzone 2	184	2.1
Subzone 3	721	2.5
Subzone 5		1.3
Subzone 4	299	1.7
Subzone 6	316	1.9
Subzone 7	197	1.0
Subzone 8	365	2.5
Total	2,241	14.9

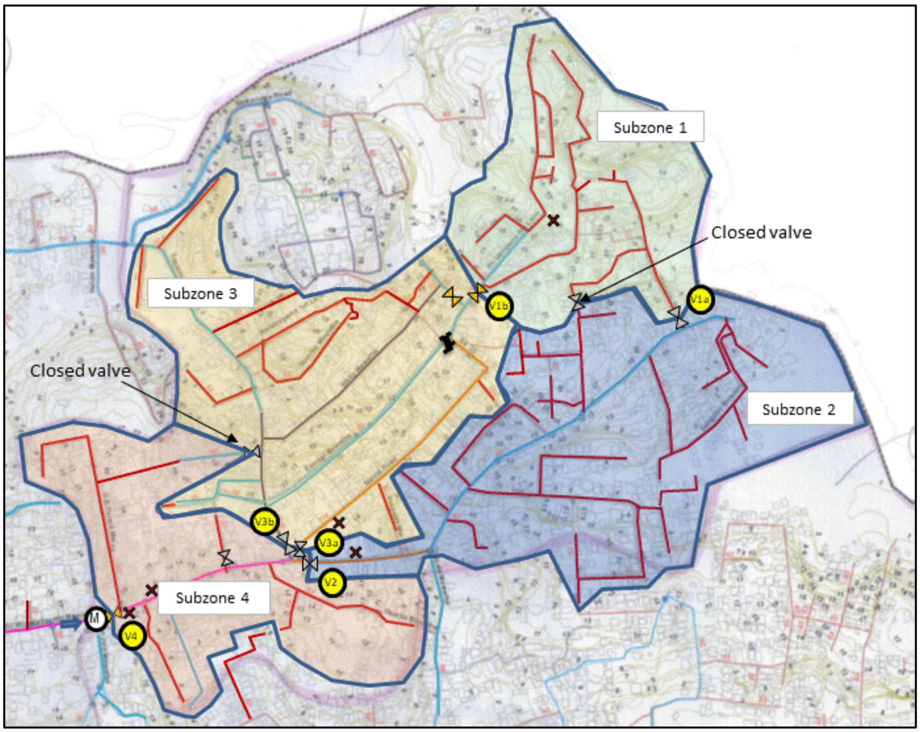


Figure 2.3.13 Example of sub-zoning of DMA 3

Table 2.3.11 Basic Information of subzone in DMA 3

Subzone No.	Number of connections	Extension of distribution pipes (km)
Subzone 1	657	2.2
Subzone 3		3.5
Subzone 2	250	3.7
Subzone 4	216	2.1
Total	1,123	11.5

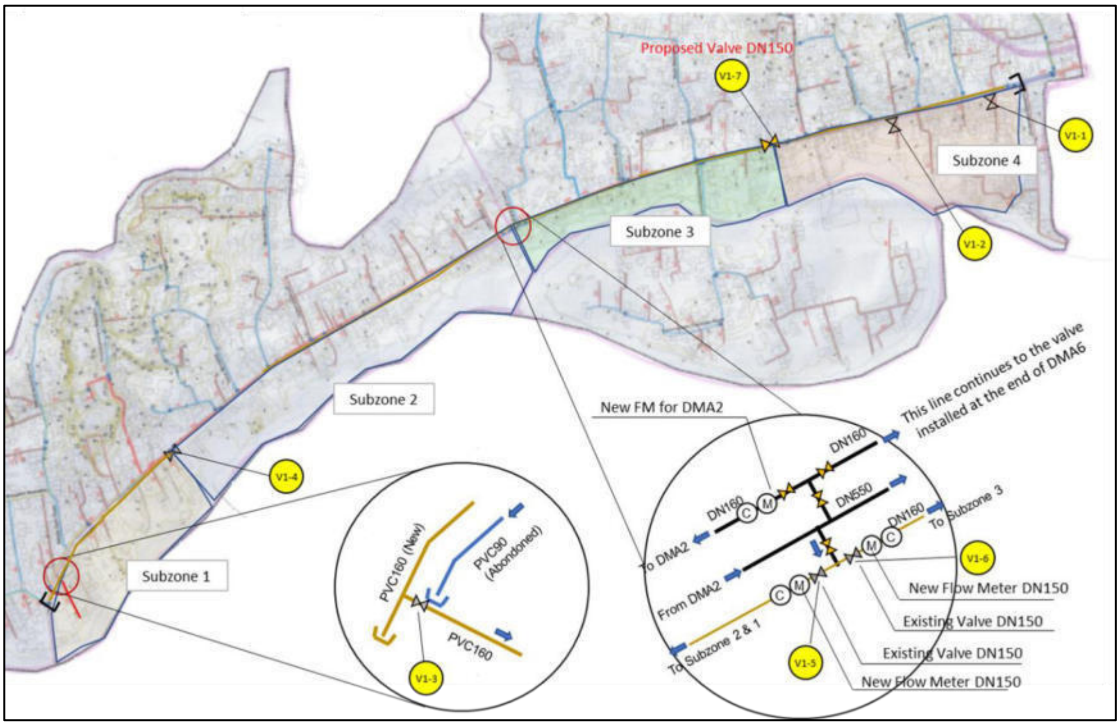


Figure 2.3.14　Example of sub-zoning of DMA 1

Table 2.3.12　Basic Information of subzone in DMA 1

Subzone ID.	Number of connections	Extension of distribution pipes (km)
Subzone 1a	-	0.25
Subzone 1b	-	1.81
Subzone 2	-	1.89
Subzone 3	-	0.71
Subzone 4a	-	0.54
Subzone 4b	-	0.08
Subzone 4c	-	1.34
Total	-	11.5

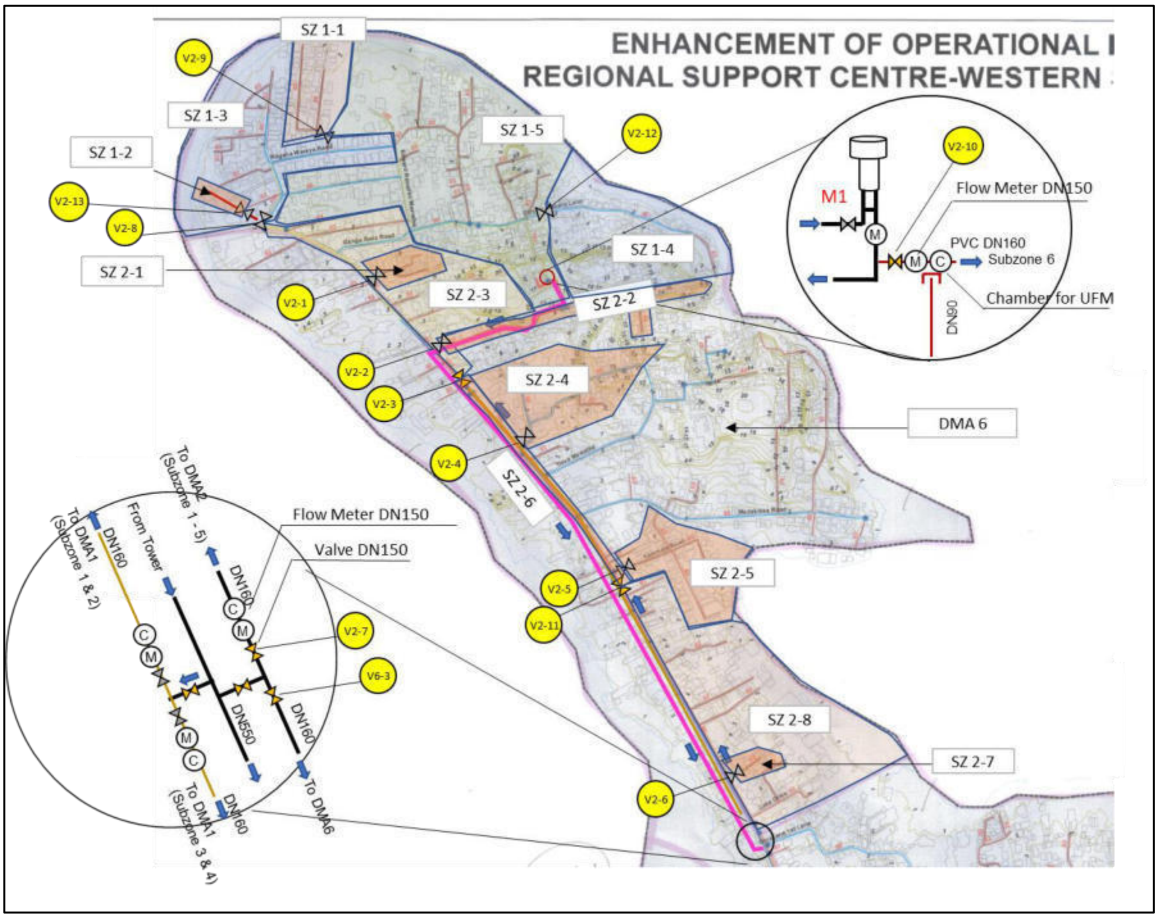


Figure 2.3.15 Example of sub-zoning of DMA 2

Table 2.3.13 Basic Information of subzone in DMA 2

Subzone ID.	Number of connections	Valve ID to isolate subzone	Extension of distribution pipes (km)
Subzone 1-1	-	V2-9	0.360
Subzone 1-2	-	V2-13	0.116
Subzone 1-3		V2-8	1.036
Subzone 1-4	-	V2-12	0.425
Subzone 1-5		V2-10	2.069
Subzone 2-1	-	V2-1	0.270
Subzone 2-2		V2-3	0.955
Subzone 2-3		V2-3	0.973
Subzone 2-4	-	V2-4	1.104
Subzone 2-5	-	V2-5	0.585
Subzone 2-6	-	V2-11	0.782
Subzone 2-7	-	V2-6	0.184
Subzone 2-8	-	V2-7	1.185
Total	-		10.044

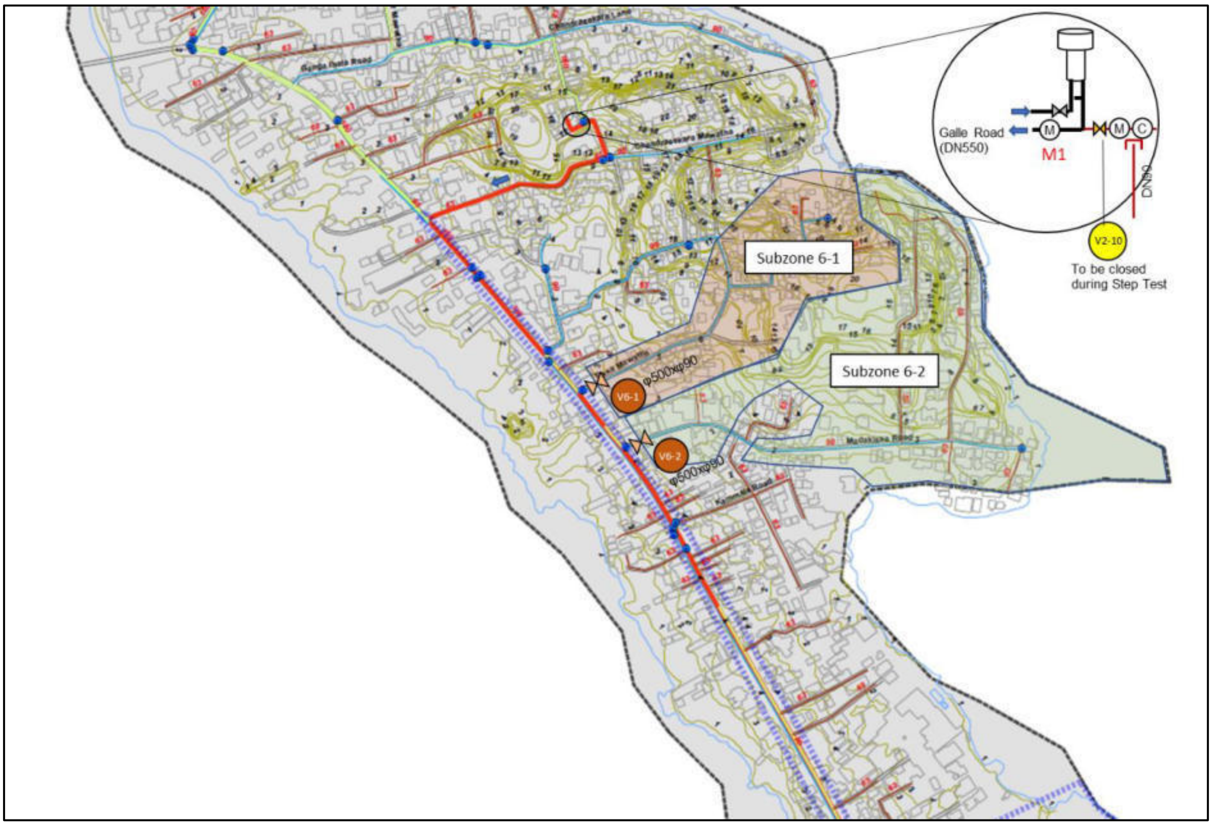


Figure 2.3.16   Example of sub-zoning of DMA 6 (1 of 3)

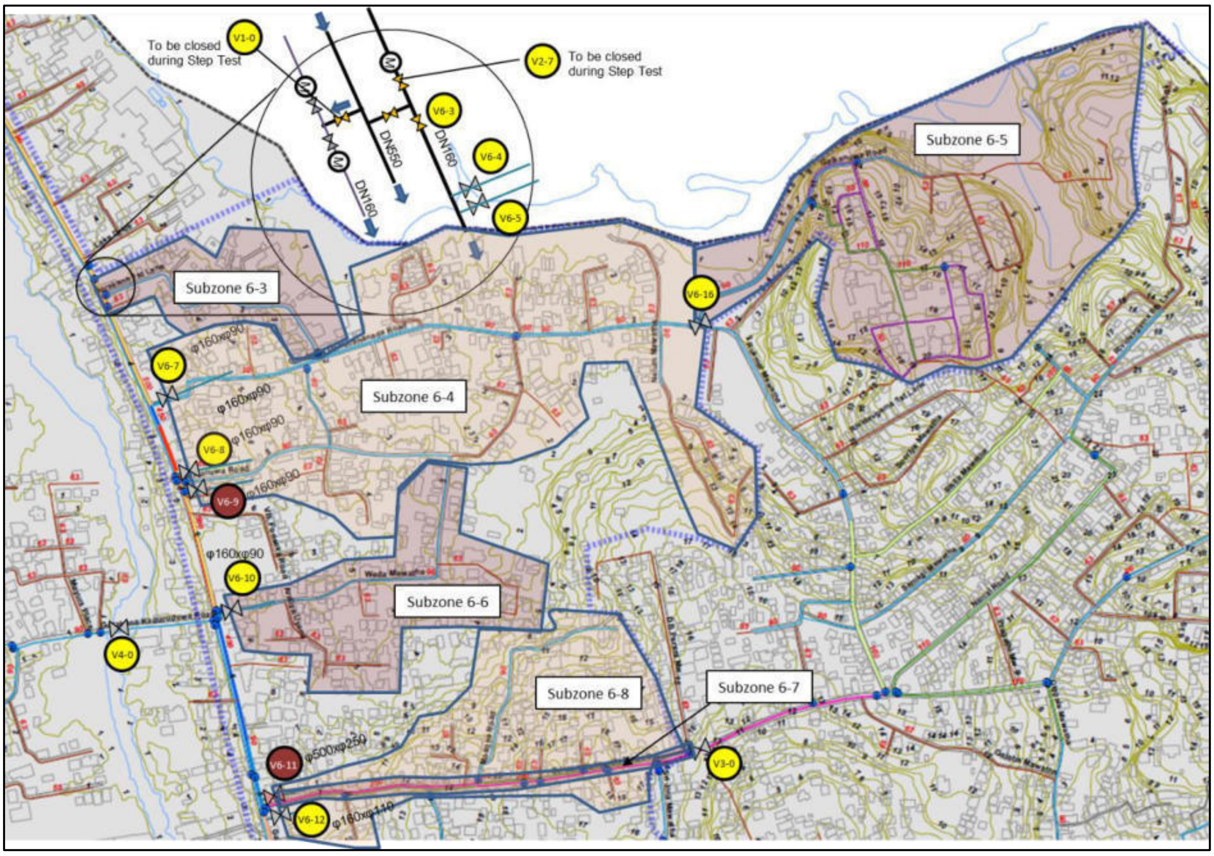


Figure 2.3.17   Example of sub-zoning of DMA 6 (2 of 3)

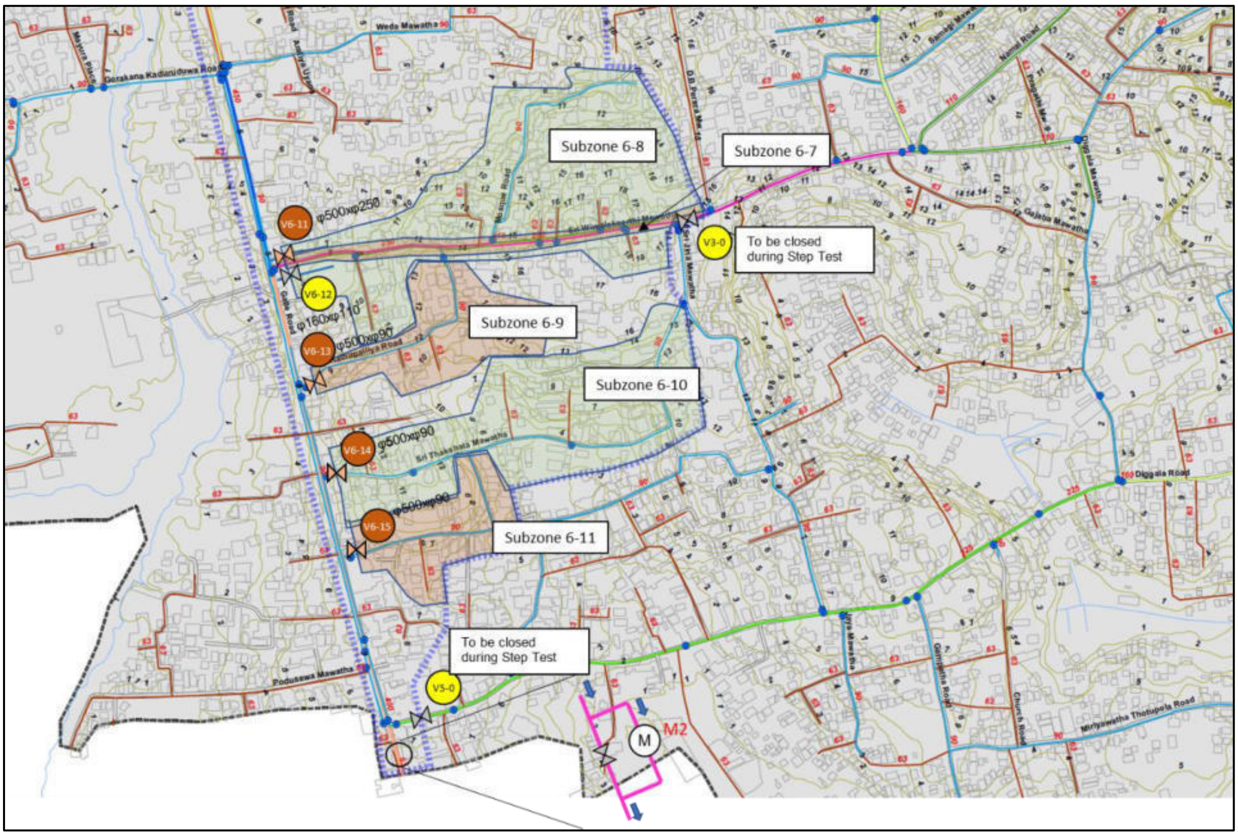


Figure 2.3.18 Example of sub-zoning of DMA 6 (3 of 3)

Table 2.3.14 Basic Information of subzone in DMA 6

Subzone ID.	Number of connections	Valve ID to isolate subzone	Extension of distribution pipes (km)
Subzone 6-1	-	V6-1	0.818
Subzone 6-2	-	V6-2	1.717
Subzone 6-3	-	V6-4	0.444
		V6-5	0.521
Subzone 6-4	-	V6-7	1.228
		V6-8	0.617
		V6-9	1.102
Subzone 6-5	-	V6-16	2.305
Subzone 6-6	-	V6-10	1.024
Subzone 6-7	-	V6-11	0.620
Subzone 6-8	-	V6-12	1.343
Subzone 6-9	-	V6-13	0.835
Subzone 6-10	-	V6-14	0.884
Subzone 6-11	-	V6-15	0.468
Remaining areas	-	V6-3	1.475
Total	-		15.401

2.3.9 Understanding the Mechanism of Ultrasonic Flow Meter (UFM)

(1) Characteristics of Ultrasonic Waves

An UFM is a flowmeter that obtains an output proportional to the flow rate of a pipe by utilizing the phenomenon that the speed at which ultrasonic waves propagate in a liquid changes according to the flow velocity of the fluid.

The characteristics of ultrasonic waves are that they have a slower propagation speed and a shorter wavelength than radio waves.

Propagation velocity of Radio Waves: approx. 300,000 km/second in air

Propagation velocity of Ultrasonic Waves: approx. 340 m/second in air

When the distance of an object is extremely large, such as a broadcasting tower with a distance of several tens of kilometers or the distance of a celestial body, the propagation speed of radio waves becomes practical and is used for radar and communication.

However, at a short distance in the pipe, the arrival time of radio waves is extremely short, and it is extremely difficult to detect the difference in propagation time.

For this reason, ultrasonic waves with a slow propagation time are practical for flowmeters.

The "sound heard by the human ear" is said to be in the range of about 20Hz (bass) to 20,000Hz (treble). Sounds outside that range, that is, low sounds below about 20 Hz and high sounds above about 20,000 Hz, are called "ultrasonic waves".

"Sound" including ultrasonic waves propagates in a gas, liquid, solid, etc. as a medium, and does not propagate in a vacuum.

In addition, the ease of transmission differs depending on the object. For example, the propagation efficiency tends to increase in the order of gas < liquid < solid, and the speed tends to increase in this order. The speed of sound in the air is about 340 m / second, but in water it is about 1,500 m / second.

(2) Advantages and disadvantages of ultrasonic flowmeter

【Advantage】

- Not affected by liquid temperature, pressure and viscosity.
- As long as it is a liquid through which ultrasonic waves pass, it does not matter whether it is conductive or not.
- Low pressure head loss

- One flow meter can measure a wide range of flow rates.
- In the case of the clamp-on type that can be set on the outside of the pipe, pipe cutting work is not required.
- Since the structure is symmetrical upstream and downstream, it is possible to measure the flow in the opposite direction.
- The response speed is fast and it can follow the pulsatile flow.

【Disadvantage】

- If air bubbles, foreign substances, etc. are mixed in the liquid, an error will occur.
- Rust and deterioration of the inner surface of the pipe affect the measurement accuracy.
- Straight sections are required in the upstream and downstream parts.
- Clamp-on type measurement accuracy is about 2 to 3% of full scale.

(3) Measurement principle of ultrasonic flowmeter

The type of ultrasonic flowmeter currently on the market is mainly the " Transit Time" type.

【Transit Time Method】

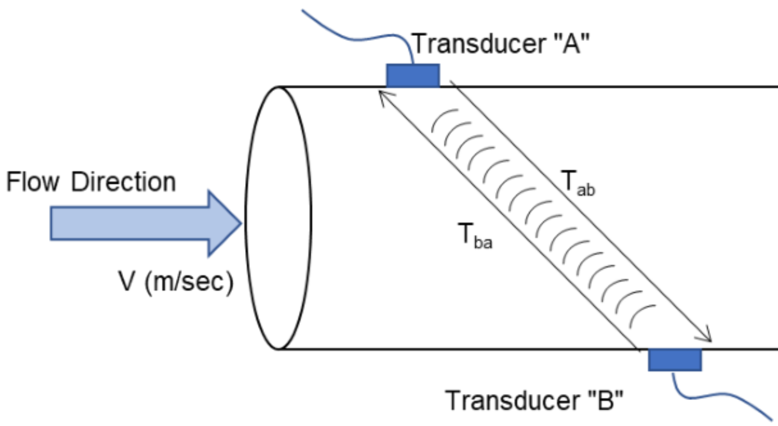


Figure 2.3.19 Principle of UFM

Several transducers (ultrasonic sensors) are placed in a pipe at a predetermined position to alternately transmit and receive ultrasonic waves.

When there is no flow, the time for ultrasonic waves to propagate from upstream A to downstream B (T_{ab}) is equal to the time for ultrasonic waves to propagate from B to A (T_{ba}).

When there is a flow in the tube, the ultrasonic waves transmitted from A to B are in the forward direction of the flow, so they propagate faster than when there is no flow. On the contrary, when it travels from B to A, it opposes the flow, so the propagation time is slower than when there is no flow.

The ultrasonic flowmeter detects such a difference in propagation time and calculates the flow velocity of the fluid by the principle formula. The calculated value is the average flow velocity, and the flow rate is calculated by multiplying this by the cross-sectional area in the pipe.

【Calculation Formla】

V: Flow velocity of liquid

T_{ab}: Transit time of ultrasonic waves from upstream to downstream

T_{ba}: Transit time of ultrasonic waves from downstream to upstream

L: Transit Distance

C: Velocity of sound in liquid

θ: Angle between the flow direction and the propagation direction of ultrasonic waves

With above-mentioned factors, we can get the following formula:

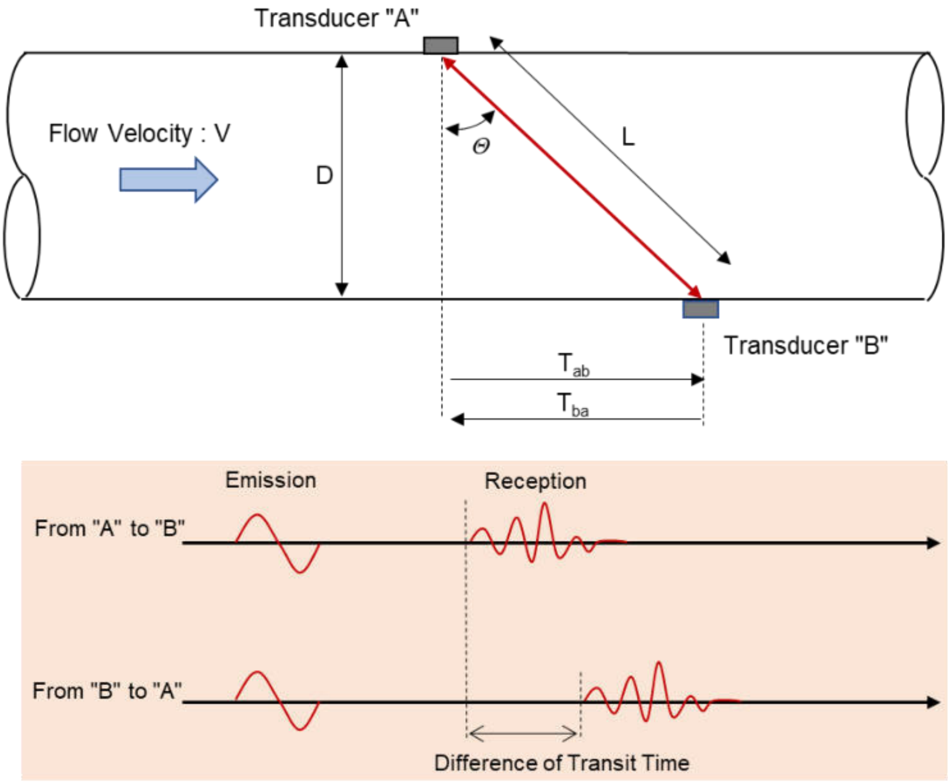
$$T_{ab} = L/(C + V \cdot \cos\theta) \text{ and } T_{ba} = L/(C - V \cdot \cos\theta)$$

From these two formula, we can get “V” value as follows:

$$V = (L / 2 \cdot \cos\theta) \cdot (1/T_{ab} - 1/T_{ba})$$

When we set Q as flow volume, and D as diameter, we can get a following formula:

$$Q = (\pi \cdot D^2/4) \cdot V$$



Transit time from "A" to "B" : $T_{ab} = L / (C + V \cos\Theta)$
Transit time from "B" to "A" : $T_{ba} = L / (C - V \cos\Theta)$

Figure 2.3.20 Calculation of velocity with difference of transit times (ΔT)

It should be noted that the above-mentioned calculation formula is a simplification and is not strictly correct.

The flow velocity V for converting to the flow rate must be the average flow velocity of the entire pipe cross section.

However, the flow velocity measured by the ultrasonic flowmeter is the average flow velocity on the path through which the ultrasonic waves propagate (called the line average flow velocity), not the average flow velocity of the surface.

Therefore there is an error between “Line Average Flow Velocity” and “Surface Average Flow Velocity”.

In an actual flow meter, the detected flow velocity value is corrected to the surface average flow velocity by the "flow rate correction coefficient", and then the flow velocity is calculated by multiplying the cross-sectional area.

(4) How to install the transducers

【V Method】

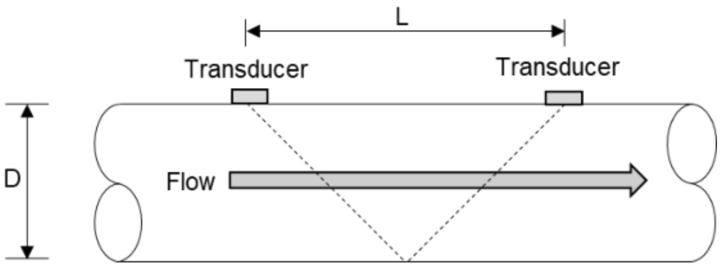


Figure 2.3.21 Setting of transducers in V method

This is the most basic and simple installation method, and is called the reflect mode.

Since the transducer (sensor) can be fixed to one guide rail and attached to the pipe, it is easy to set the distance between the sensors accurately.

If the resin pipe (PVC or PE), large-diameter pipe, or inner surface is treated with mortar lining, the V method may not be able to receive the signal well.

Normally, the V method is selected, but in the following cases, the Z method, etc. is applied.

- When the installation space is small
- When the turbidity of the liquid is high
- When the received wave signal is weak
- When the scale is thickly attached to the inner surface of the pipe

【Z Method】

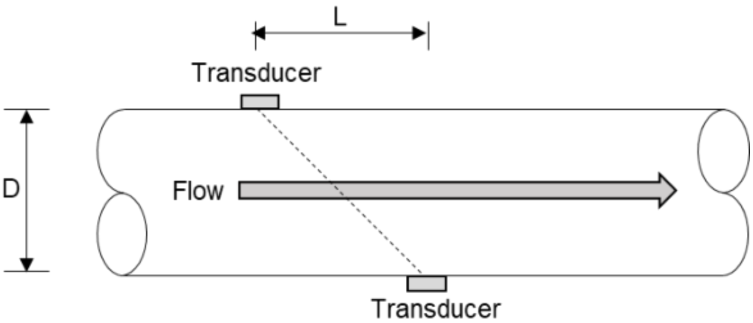


Figure 2.3.22 Setting of transducers in Z method

The Z method is known as direct mode.

Since the propagation path of ultrasonic waves can be shortened, it can be applied to flow rate measurement under fluid or pipe conditions where ultrasonic wave propagation conditions are not good.

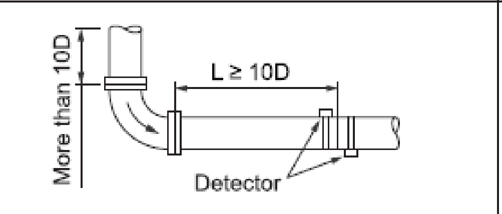
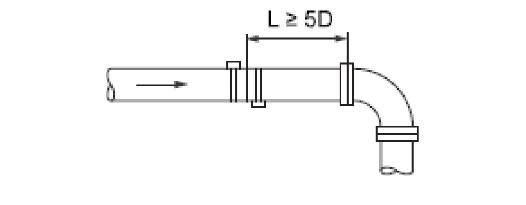
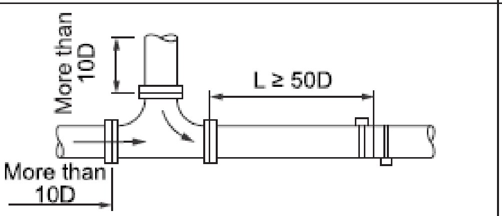
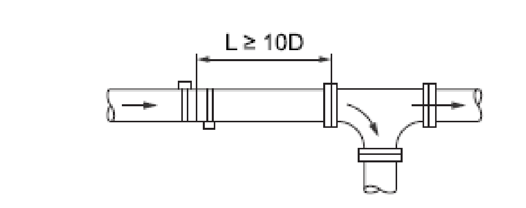
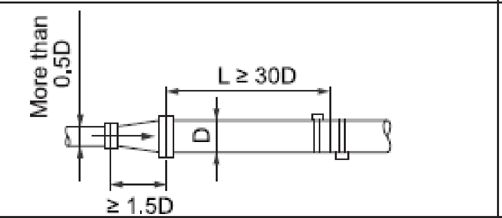
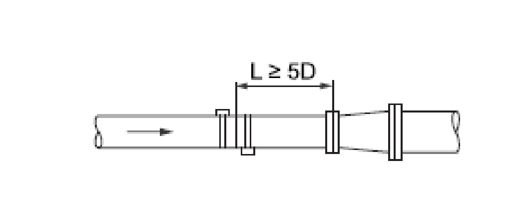
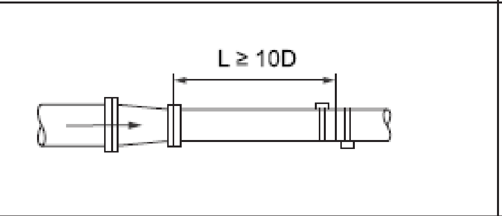
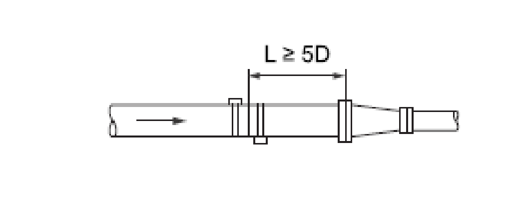
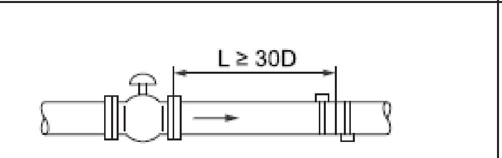
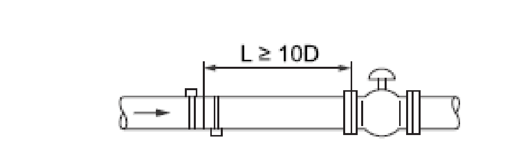
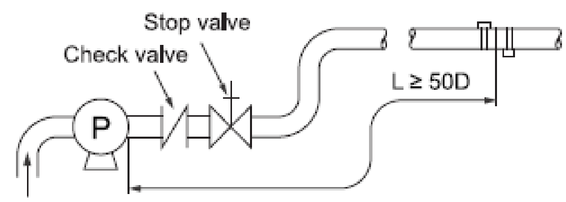
Since synthetic resins such as PVC or PE are less likely to propagate ultrasonic waves than metal pipes, it is recommended to use the Z method if the material of the tube to be measured is synthetic resin.

In addition, since the required straight section of the Z method is half that of the V method, the Z method is used even when there is no installation space.

(5) Recommended Condition of Transducer Setting

The transducers of the ultrasonic flowmeter cannot measure accurately unless it is fixed in an appropriate position.

Table 2.3.15　Recommended Distance for Detector Setting

Classification	For upstream side	For downstream side
90° bend		
Tee		
Diffuser		
Reducer		
Valves	 Flow control valve exists on upstream side.	 Flow control valve exists on downstream side.
Pump		

The piping must completely be filled with fluid when it flows.

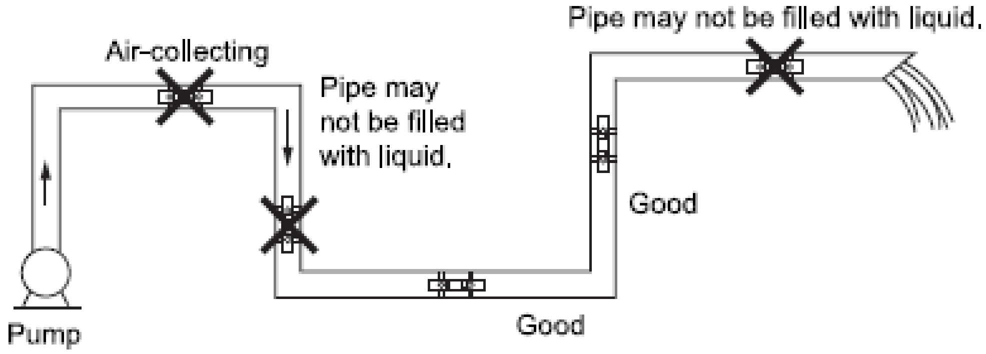


Figure 2.3.23 Ideal Location of Transducer (1)

For a horizontal pipe, mount the detector within ±45° of the horizontal plane.

For a vertical pipe, the detector can be mounted at any position on the outer circumference.

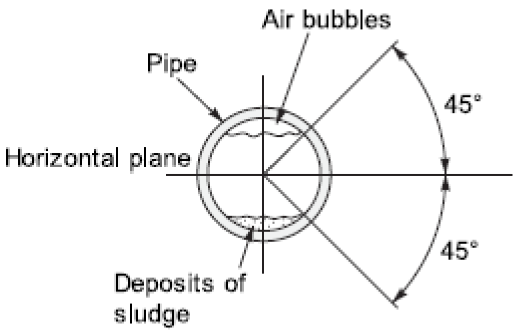


Figure 2.3.24 Ideal Location of Transducer (2)

Avoid mounting the detector near a deformation, flange or welded part on the pipe.

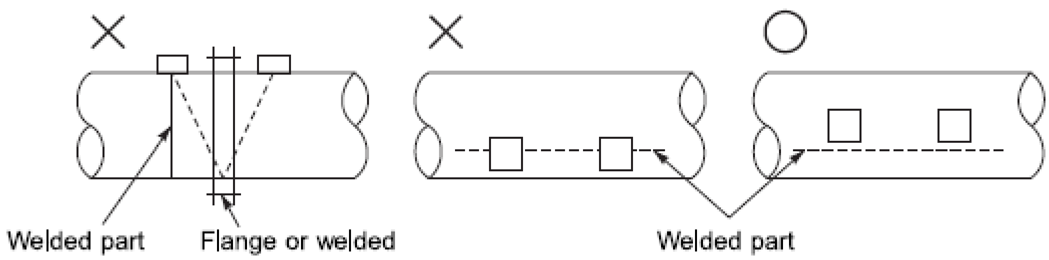


Figure 2.3.25 Ideal Location of Transducer (23

(6) Understanding Accuracy of UFM

All flow meters have an error in the equipment itself and it also applies to the ultrasonic flowmeter. Since the transducer is installed by a human, the position and accuracy of its installation greatly affect the error.

1) Influence of flow velocity

Since the ultrasonic flowmeter measures the flow velocity in principle, the guaranteed accuracy differs depending on the flow velocity of the flowing water.

Normally, if the flow velocity is 2 m / second or more, the measurement accuracy is very stable, but it should be noted that the slower the flow velocity, the larger the error.

Table 2.3.16 Guaranteed accuracy of ultrasonic flowmeter

Diameter	Range of velocity	Accuracy
13mm ～ 90mm	1 m/sec or more	+/-2.5% of reading value
	Less than 1 m/sec	+/-0.02 m/sec (*1)
100mm ～ 250mm	1 m/sec or more	+/-1.5% of reading value
	Less than 1 m/sec	+/-0.015 m/sec
300mm ～ 5000mm	1 m/sec or more	+/-1.0% of reading value
	Less than 1 m/sec	+/-0.01 m/sec

Source: Instruction Manual of UFP 20, Tokyo Keiki

【Example of accuracy calculation(*1)】

In case of Pipe of DN 50mm

Accuracy is ±0.02 m/sec under 0.9 m/sec of velocity

$$\pm 0.02 = 0.9 \text{ m/sec} \times E/100$$

$$E = \pm 0.02 \times 100/0.9 = \pm 2.2\ (\%)$$

Accuracy is ±0.02 m/sec under 0.5 m/sec of velocity

$$\pm 0.02 = 0.5 \text{ m/sec} \times E/100$$

$$E = \pm 0.02 \times 100/0.5 = \pm 4.0\ (\%)$$

2) Influence of error of diameter

It the diameter of the pipe to be input is not correct. It affects the measuring result. As a rough calculation, if the difference of diameter is 1%, the reading flow rate will have about 3% of error after conversion of flow rate.

Table 2.3.17 Comparison of area value under difference diameter

	Inner Diameter		
	99mm (Area: 0.007694m^2)	100mm (Area: 0.007850m^2)	101mm Area: 0.008008m^2)
V=0.5m/sec	0.003847 m^3/sec	0.003925 m^3/sec	0.004004 m^3/sec

The following example shows the flow rate error when the inner diameter values differ by 1 mm.

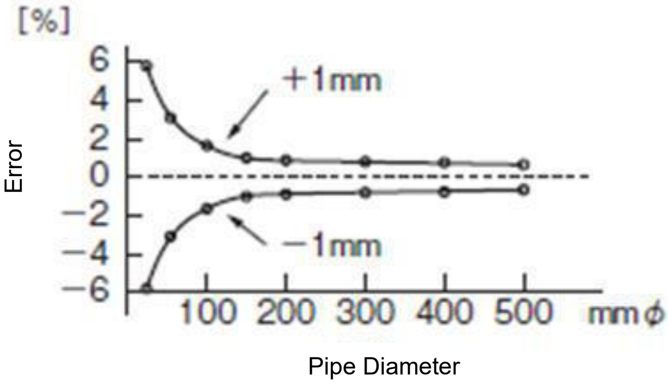


Figure 2.3.26 Influence of 1 mm of difference of inner diameter on flow rate error

3) Influence of transducer mounting interval

As a rough calculation, an error of +/- 1mm of distance between two transducers will result in a flow rate error of less than 1%.

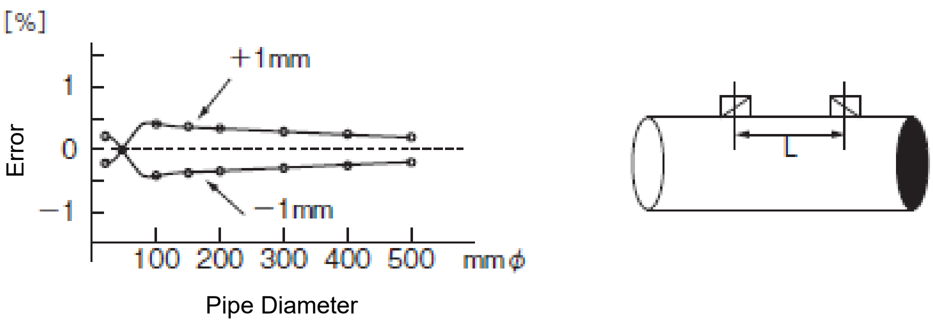


Figure 2.3.27 Influence of 1 mm of difference of transducer spacing on flow rate error

(7) Comparison with the measured value of the bulk meter

Thermometers and pressure gauges are easy to calibrate on-site, but flowmeters are difficult to calibrate. When using an ultrasonic flowmeter to check the accuracy of other flowmeters, the following points must be carefully considered.

- Consider each other's errors in the flowmeters.

  Estimate the calibration error by paying attention to the accuracy notation (FS%, RS%) of each flow meter.

- Collect and consider systematic data if there are differences

  Instead of comparing with the flow rate of only one point, write the measurement data in multiple flow rate ranges on a graph and evaluate it.

- Check the piping system thoroughly.

  Even if you think that the piping system is the same, the evaluation may be wrong if it flows in or out from a branch pipe in the middle.

- It is difficult to compare two flow meters

  Normally, if there is a difference between the measured values of the two flow meters, it is difficult to determine which is correct on site. It is necessary to confirm the standard criteria such as the water flow capacity of the pump and the change in the tank water level for which the capacity is known.

2.3.10 Procedure of Step Test

The work of grasping how the amount of water distribution in the DMA is distributed and estimating the degree of deterioration of the pipeline that produces many leaks is called “Step Test”.

The step test has the effect of running out of water in the entire DMA, so it must be performed during the time when water use is the least.

Generally, the core time of measurement is from 1:00 to 4:00 midnight, and the time before and after is also used for measurement depending on the actual conditions of water use in the area.

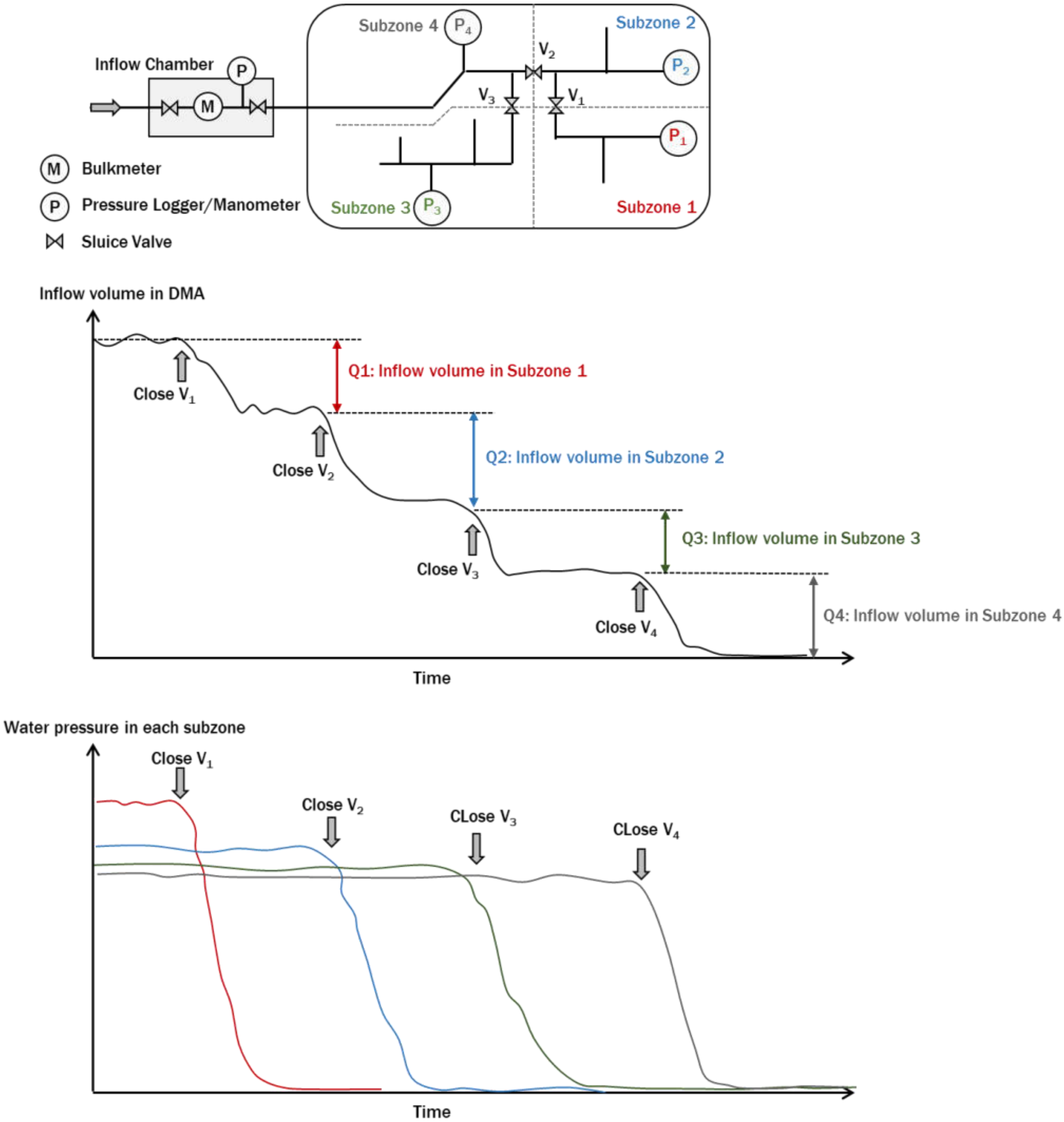


Figure 2.3.28 Image of Step Test procedure

In MNF measurement and Step Test, flow rate fluctuations must be recorded at minimum 10-second intervals, so a flow meter with the following functions is required, such as "Ultrasonic Flowmeter" or "Electromagnetic Flowmeter equipped with pulse emitter device".

- Flow rate can be measured at intervals of at least 10 seconds.
- Being capable of logging instantaneous flow rate and cumulative flow rate.
- Being capable of measuring in the low flow rate band.

In the case of an ultrasonic flow meter, the accuracy may be greatly reduced at a minute flow rate of 0.3 m/sec or less.

A general bulk flow meter with impeller cannot measure an instantaneous flow rate, and has a slow response speed to a flow rate fluctuation, so that it is impossible to determine a vacant time of water use. Therefore, this type of flow meter is used for long-term monitoring of water distribution and for analysis of daily or monthly fluctuation of inflow rate.

In the step test, an ultrasonic flow meter is installed in the inflow chamber, and the valve operation of each sub-sector is performed while monitoring the MNF rate. It is necessary to record the valve operating time and the measuring time required for the judgment.

In addition, the unit of flow rate should be unified so that the analysis will not be confused even if the measurer is different.

Secure a connection for water pressure measurement on the inflow pipe, and record the water pressure at the time of testing with a data logger.

The timing of closing the subzones must be carefully considered in advance, but the measurement time of one subzone should be maintained for 10 minutes or more.

One or more water pressure data loggers should be installed in each subzone to record water pressure fluctuations during the step test.

The sub-sector where the water pressure does not reach zero after the valve is closed indicates that hydraulic independence is incomplete.

【Example of recorded flow data in DMA 5】

During the Step Test, water inflow volume should be measured by Ultrasonic Flowmeter.

The following table is a part of recorded data which can be downloaded directly through USB memory stick.

Date(DD-MM-YY) Time	Flow[L/min]	Velocity[m/s]
2019/9/19 0:16	412.76	0.2
2019/9/19 0:16	415.46	0.201
2019/9/19 0:16	421.12	0.204
2019/9/19 0:16	425.89	0.206
2019/9/19 0:17	438.97	0.212
2019/9/19 0:17	460.39	0.223
2019/9/19 0:17	476.09	0.23
2019/9/19 0:17	484.85	0.235
2019/9/19 0:17	489.04	0.237
2019/9/19 0:17	485.87	0.235
2019/9/19 0:17	480.44	0.233
2019/9/19 0:17	471.83	0.228
2019/9/19 0:17	469.81	0.227

The original data of UFM is CSV data, so converting it into Excel Data, we can identify the minimum inflow volume in accordance with valve operation schedule, and plot the data on graph, as shown below:

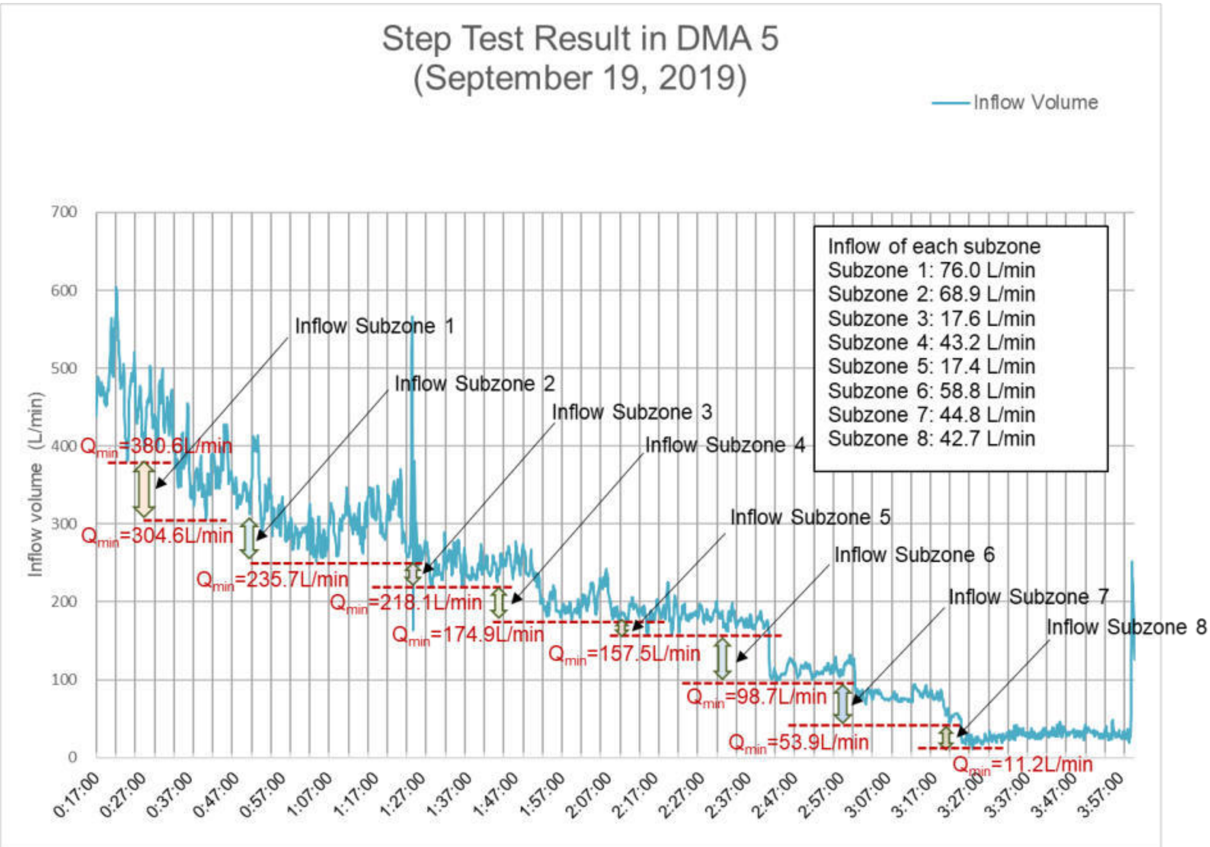


Figure 2.3.29 Component of MNF

2.3.11 Calculation of amount of leaked water

The MNF rate measured in DMA includes the amount of water used at night and the amount of illegal water used in addition to water leakage.

Especially when each household has a water storage tank and water is continuously stored at night, MNF contains a considerable amount of water used, it is necessary to notify residents in advance or secure closure of meter valves.

The component of the amount of water contained in the MNF is shown below.

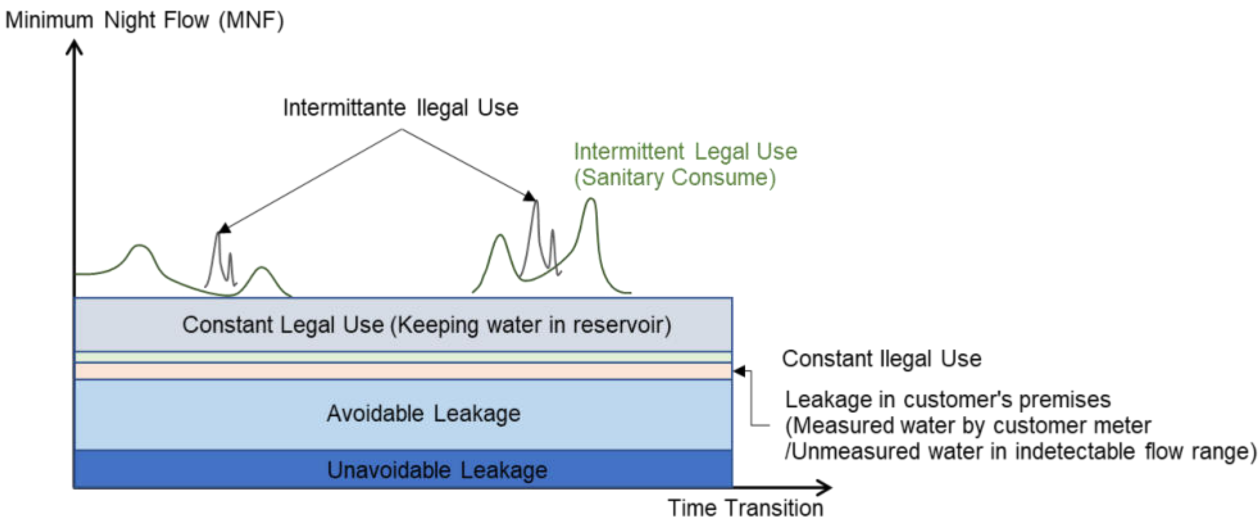


Figure 2.3.30 Component of MNF

The value of MNF will be gradually lowered by the leak detection and repair.

The reduced amount of water leakage can be calculated by performing MNF measurement and step test again when all the measures for water leakage have been completed.

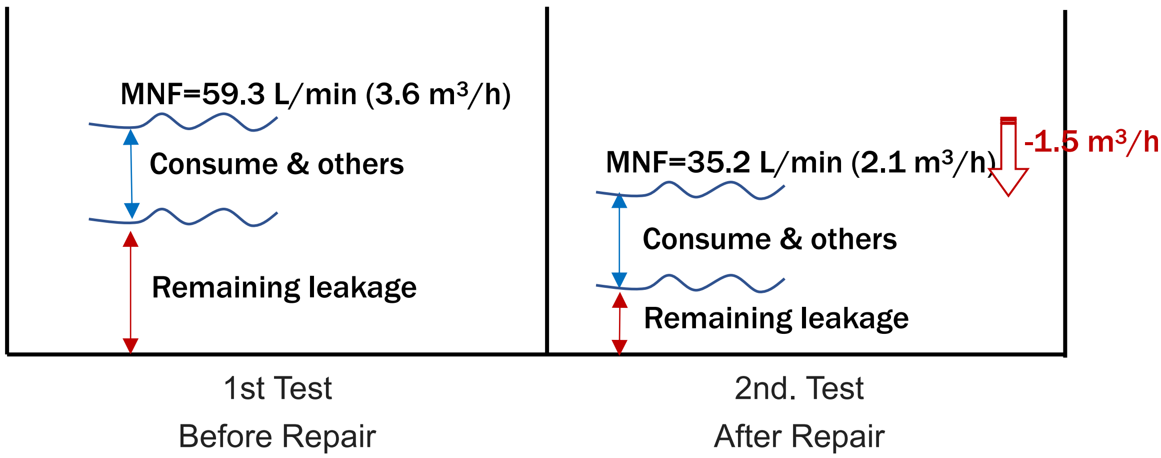


Figure 2.3.31 Monitoring of Minimum Night Flow

2.3.12 Measurement of Water Supply Pressure

(1) Purpose of Pressure Measurement

Water pressure is an important factor to consider the potential area of leakage or proper water supply etc. The examples which can be evaluated by water pressure are as below.

- Area of high water pressure and high risk of leakage
- Area of where the water pressure is less than 10 bar during daytime
- Area of water pressure fluctuation between daytime and nighttime is large

It is necessary to measure water pressure at multiple points to evaluate whole target area. The example of multiple measurement of water pressure and the visualization of water pressure in target area are shown below.

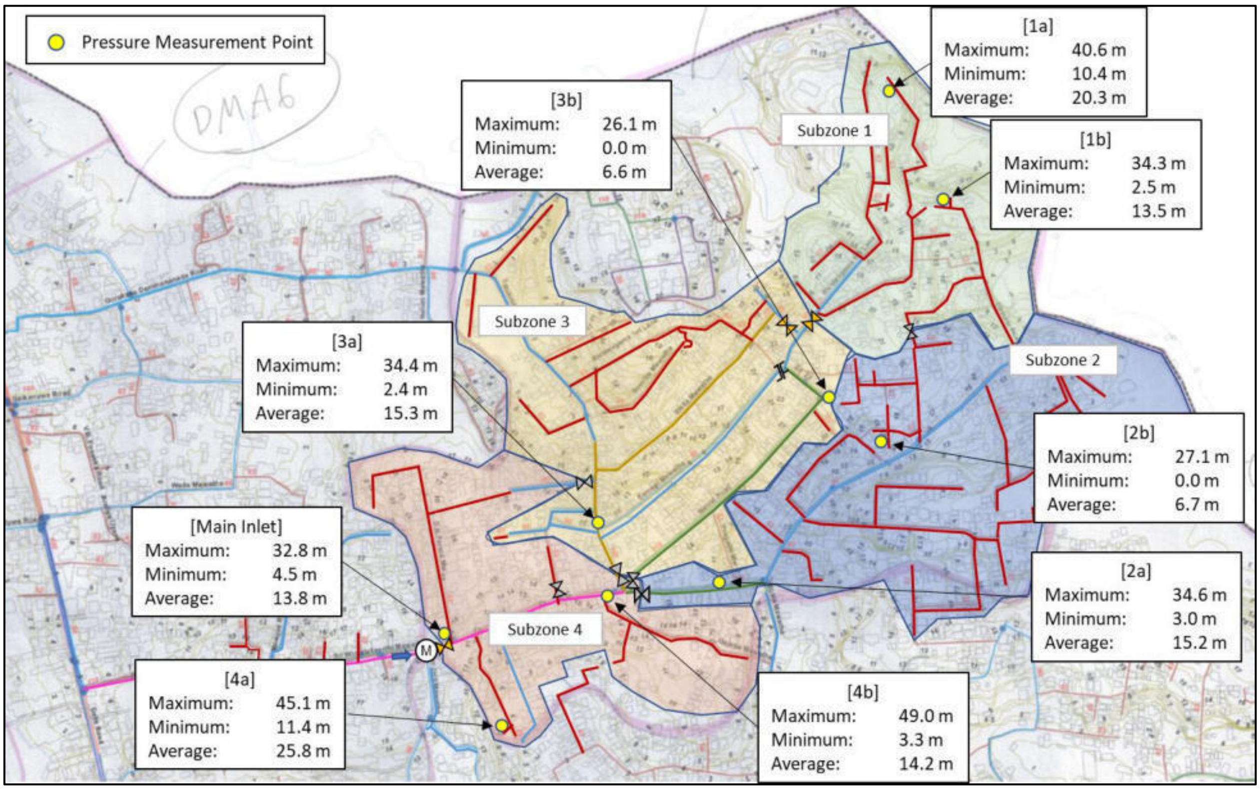


Figure 2.3.32 Multiple measurement of water pressure

Figure 2.3.33 Visualization of water pressure

The pressure distribution map allows us to understand the following situation:

- Where is the water pressure during the daytime less than 10 bar?
- Which route has a high maximum water pressure and a high risk of water leakage?
- Where is the area where the water pressure is low even though the pipe diameter is sufficient?
- Where is the area where the water pressure fluctuation during daytime and nighttime is large and the water supply demand is large?

(2) Use of Pressure Datalogger

A port for pressure measurement should be provided in the DMA inflow pipe using a tapping saddle and a ball valve (incorporation valve).

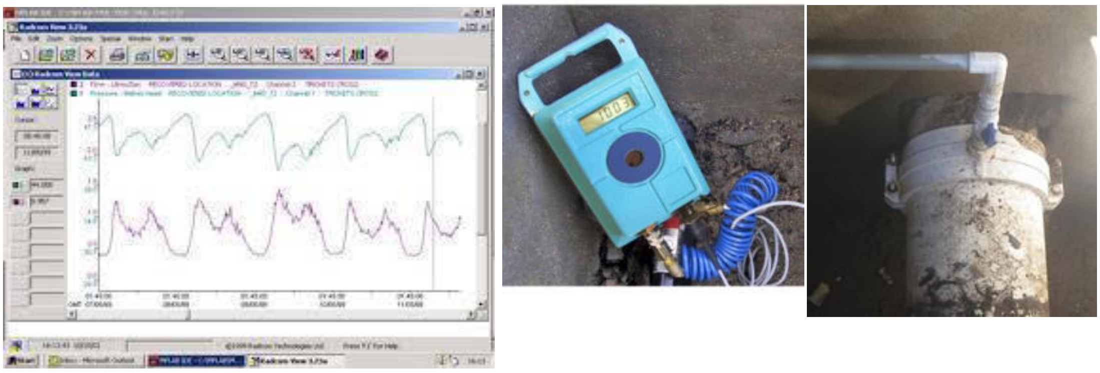


Figure 2.3.34 Installation of pressure data logger

(2) Log Sampling Interval

Since the water pressure fluctuates according to changes in the amount of water in the distribution network, it is necessary to set an appropriate interval according to the purpose of measurement.

Table 2.3.18 Recommended interval for each purpose

Logging Interval	Purpose
1 second	Suitable for observing instantaneous water pressure fluctuations. Especially analysis of water pressure fluctuations and water hammer pressure in pump water pipes, etc. There is also a high-precision Logger that can record in 1/100 second.
10 seconds	Suitable for detailed analysis of water supply pressure in DMA. It is also possible to estimate the household use hours and usage patterns from water pressure fluctuations, and it will be the basic data for considering the renewal of the pipe network.
1 minute	Suitable for monitoring water pressure fluctuations in the distribution network. If there is a large fluctuation in units of 1 min, shorten the interval and measure again.

Using the measured water pressure data, the water pressure fluctuation for each time zone is summarized as follows.

This is the key data used to estimate the actual amount of leak reduction.

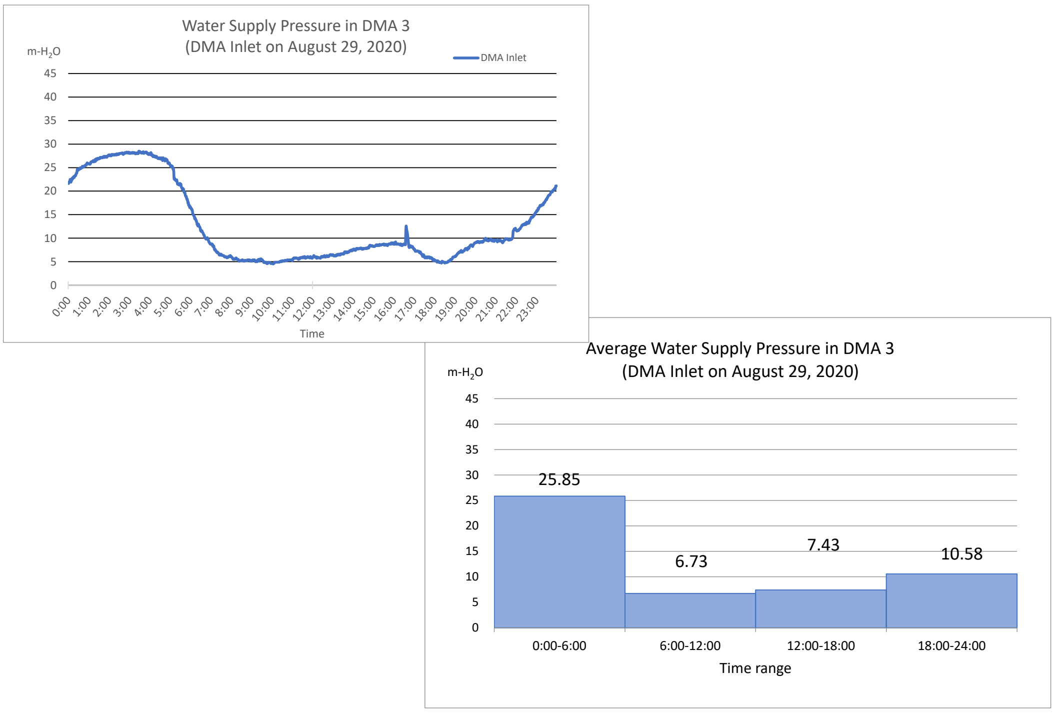


Figure 2.3.35 Water fluctuation pattern

2.3.13 Relation between pressure and leakage volume

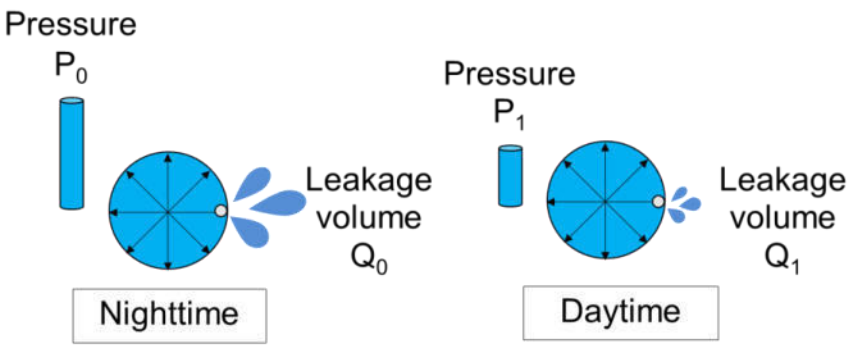
In the above-mentioned example, MNF has decreased by 1.5 m^3/h after leak detection/repair work, and if the amount of water used does not fluctuate, it can be considered as the reduced amount of leak.

However, this amount of water is the value at midnight when the water pressure is the highest, so in order to convert it into the average amount of water per day, it is necessary to take into account the fluctuations in water pressure during the day and correct it.

The relation between pressure and leakage volume is shown as follows. The coefficient N depends on the size and shape of the leak hole and the material of the pipe.

Leak from small orifice： N=0.5

Leak from crack of pipe or flange joint： N=1.15



$$Q_1 / Q_0 = (P_1/P_0)^N$$

Figure 2.3.36 Relation between leak volume and pressure

Here, assuming that the average water pressure of DMA is changing as follows, the daily average value of the leakage reduction amount is calculated as follows.

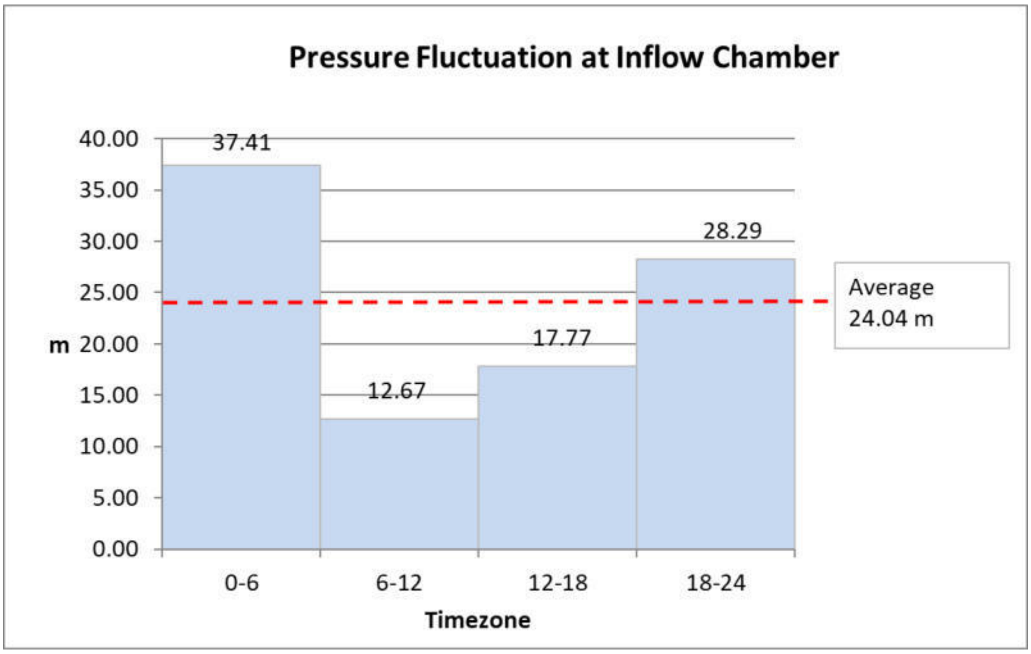


Figure 2.3.37 Relation between leak volume and pressure

Table 2.3.19 Calculation of prevented water leak

Item	Time Range				Average
	0:00-6:00	6:00-12:00	12:00-18:00	18:00-24:00	
Pressure (m)	37.41	12.67	17.77	28.29	24.04
Ratio (P_x/P_o)	1.00	0.339	0.475	0.756	
$(P_x/P_0)^{0.5}$	1.00	0.582	0.689	0.869	
Water Volume (m^3/h)	1.50	0.87	1.03	1.30	1.18

$Q_x = (P_x/P_0)^{0.5} \times Q_0$

Q_0: Water flow at a reference time range

P_0: Pressure at a reference time range

P_x: Pressure at a target time range

Calculating in the above example,

Prevented leakage at midnight： 1.50 m^3/h (at pressure of 37.41m H_2O)

Average volume of prevented leakage： 1.18 m^3/h (at pressure 24.04m H_2O)

2.4 Type of Evaluation Indicators

2.4.1 Necessary basic data

In this section, we will learn what kind of indicators can be created and what kind of evaluation can be made by analyzing the flow rate measured in DMA.

Table 2.4.1 Type of Basic Data (1 of 3)

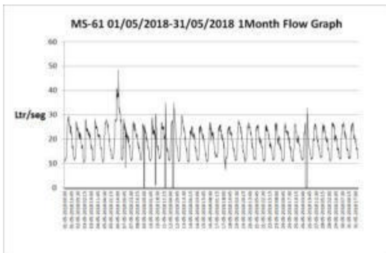
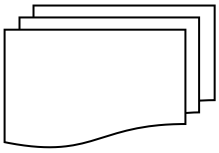
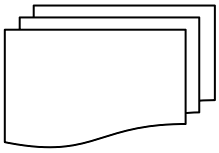
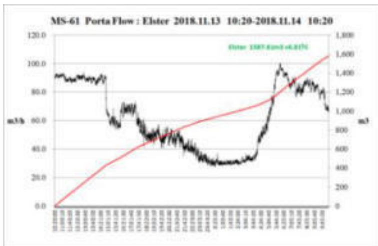
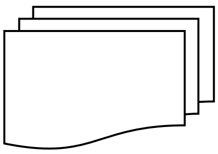
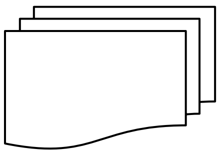
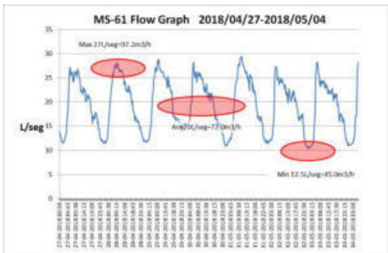
Type of data	Data and Graph	Analytical Parameters
Measurement of inflow in a month	 Variation of inflow in a month	･Maximum inflow ･Minimum inflow ･Average inflow  NRW (%) 
From the monthly flow rate data, the maximum inflow per hour, the average inflow per hour, and the minimum night inflow can be obtained. In addition, if the billed amount of water is known from the amount of water used measured in the same period, the amount of Non-Revenue Water can be calculated. At this time, let's compare these water flow rate with the Minimum Night Flow, assuming that about 60% of the Non-Revenue Water amount is due to physical loss (Leakage).		

Table 2.4.2 Type of Basic Data (2 of 3)

Type of data	Data and Graph	Analytical Parameters
Variation of inflow in a day	 Variation of inflow in a day	･Maximum inflow ･Minimum inflow ･Average inflow  NRW (%) 
From the daily flow rate data, the maximum inflow per hour, the average inflow per hour, and the minimum night inflow can be obtained.		

Type of data	Data and Graph	Analytical Parameters
Generally, the Minimum Night Flow contains a large amount of physical loss (Leakage), and this value may be recognized as an approximate value of the amount of water leakage. However, since this Minimum Night Flow is a measured value during the time when the water pressure is high at night, a correction calculation using the average daily water pressure is required. A simple calculation shows that when the water pressure is 35m as water head at night and 25m as water head on average, it is: √25 / 35 = 0.84, and the value obtained by multiplying the Minimum Night Flow rate at night by 0.84 corresponds to the amount of average daily water leakage.		

Table 2.4.3 Type of Basic Data (3 of 3)

Type of data	Data and Graph	Analytical Parameters
Minimum Night Flow (MNF)	 Variation of MNF	Indicator 2: **L/con/day** Indicator 3: **L/km/min**
MNF is measured to estimate the amount of physical losses in a hydraulically isolated area. Depending on the conditions, in most cases, the measurement of MNF is performed using a method called a Step Test, and the MNF of each stage is recorded while temporarily separating the subsectors. As a result, MNF rate occurring in each subsector can be grasped, and you can identify the subsector where the large amount of water losses occurs using the above-mentioned Indicator 2 and 3.		

2.4.2 Types of indicators and how to use them

The method proposed by IWA is well known as an index for evaluating Non-Revenue Water.
The indicators proposed by IWA are used for comparing the vulnerability of different DMAs and used as performance indicators for comparison of efficiency between different water supply utilities.
On the other hand, the pipeline network of each water supply utilities has its own characteristics. In order to evaluate its vulnerability, aging status and risk of leakage, it is desirable to adopt an index that is easier to use while being based on the IWA index. .
Here, we show how to use the evaluation index using the measured values obtained at the DMA level, based on the value of Non-Revenue Water.

The water distribution network is evaluated by ranking with multiple indicators.

It consists of 5 indicators related to water volume measurement data and 2 indicators required as complementary data.

- Principal indicators No. 1 to No. 5 are useful for diagnosing pipes and pipeline networks.
- Complementary indicators No.6 and No.7 are used when it is necessary to rectify the principal indicator.
- Complementary indicator No. 8 is effective for confirming the evaluation of activities.

Principal Indicators

PI No. 1
NRW (%)

PI No.2
NRW (L/day/con)

PI No.3
NRW (L/min/km) **MNF (L/min/km)**

PI No.4
$\frac{\textbf{NRW}}{\textbf{UARL}}$ $\frac{\textbf{MNF}}{\textbf{UARL}}$

PI No.5
UARL

Complementary Indicators

CI No.6
Pressure value

CI No.7
Meter Error

CI No.8
Residual Leakage

Table 2.4.4 Type of Indicator

Type	Descriptions
PI No. 1 **NRW** **(%)**	Indicator No. 1 is the ratio of Non-Revenue Water. When comparing the NRW ratio in DMA basis, the length of pipes, the number of connections (customers) or the customer density per km and differences of the amount of water usage per connection may affect the evaluation result of the pipeline network Even if two DMAs show the same NRW ratio, the evaluation result of the pipe network differs depending on the conditions.
PI No.2 **NRW** **(L/day/con)**	Indicator No. 2 is the total amount of NRW converted into the amount of water per customer and per day. Strictly speaking, it is calculated by the number of service branches from the water main, so in the case of apartments and condominiums, it is not necessary to consider the total number of users. This indicator is highly linked to physical loss on service pipe. If there is little water leakage in the distribution main, this index can be used to evaluate the amount of water lost. 【Calculation Formula】 NRW per month / 30 days / Number of connections The index L/con/day defined by IWA is originally an index calculated using the amount of physical loss. Here, as one method of estimating the vulnerability of the pipeline network, the total amount of NRW is expressed by L/con/day.
PI No.3 **NRW** **(L/min/km)** or **MNF** **(L/mim/km)**	Indicator No. 3 is the total amount of NRW converted to the amount of water per 1 km of distribution pipe. This indicator is highly linked to physical loss on service pipe as same as Indicator No.2 If there are more water leaks in the distribution pipe than in the water service pipe, this index can be used to evaluate the amount of water losses. 【Calculation Formula】 NRW per month / 30 days / 24 hours / Length of pipes If data on the Minimum Night Flow (MNF) is available, it is easier to determine the degree of deterioration of the pipe network.

Type	Descriptions
PI No.4 $\frac{\textbf{NRW}}{\textbf{UARL}}$ or PI No.4 $\frac{\textbf{MNF}}{\textbf{UARL}}$	The index on which Indicator No. 4 is based is called the ILI (Infrastructural Leakage Index) and is known as the index recommended by IWA. ILI = [Current Annual Real Losses (CARL)] / Unavoidable Annual Real Losses (UARL)] CARL: Current Physical Losses UARL: The amount of water leakage that cannot be reduced any more. If this value is large, the problem of water leakage in the distribution pipe network is remarkable, and it indicates that the degree of deterioration is progressing. Since a detailed investigation is required to accurately grasp the amount of physical loss, an index in which CARL is replaced with the amount of NRW is adopted here only for the purpose of comparing the degree of deterioration of the distribution network. If data on the Minimum Night Flow (MNF) is available, it is easier to determine the degree of deterioration of the pipe network by calculating "MNF / UARL" using Minimum Night Flow instead of NRW. In order to calculate the ILI recommended by IWA, it is necessary to accurately grasp the amount of physical loss (leakage volume). The following method is used to calculate the amount of physical loss in the analysis of water balance. 1) Assuming that a few percent of the Billed Metered Water Volume corresponds to the apparent losses, the physical losses is calculated subtracting the apparent losses from the total water losses. 2) Precisely analyze the Minimum Night Flow rate to determine the true amount of physical loss. Although the accuracy of 2) is higher than that of 1), it is required to accurately grasp the true amount of water usage which is included in the Minimum Night Flow. If you have a wealth of pilot project data, you can set a value such as 60% or 70% of the Minimum Night Flow as the volume of physical loss.
PI No.5 **UARL**	UARL is the amount of water that cannot be reduced any more, and is a theoretical value obtained by a calculation formula. However, if cost-effectiveness is ignored, it is not impossible to actually reduce it to zero. The unit is L/day or L/min.

2.5 Case Study from Activities in DMA 5

2.5.1 Location of DMA 5

Using DMA 5 in the OIC Panadura area as a case study, the concept and usage of indicators are shown below.

The number of house connection of DMA5 is 2,241, and the length of the water pipe is about 14.9km.

The features of DMA 5 are as follows.

- There is only one inflow pipe to the area.
- Since there are many existing valves in the area, it is easy to set the DMA boundary.
- There are multiple types of road pavement.
- There is a difference in elevation, and it is necessary to select an appropriate leak detection method according to the water pressure condition for each subzone.
- The number of house connection of DMA5 is 2,241 in total.
- The length of the distribution pipe is about 14.9km.

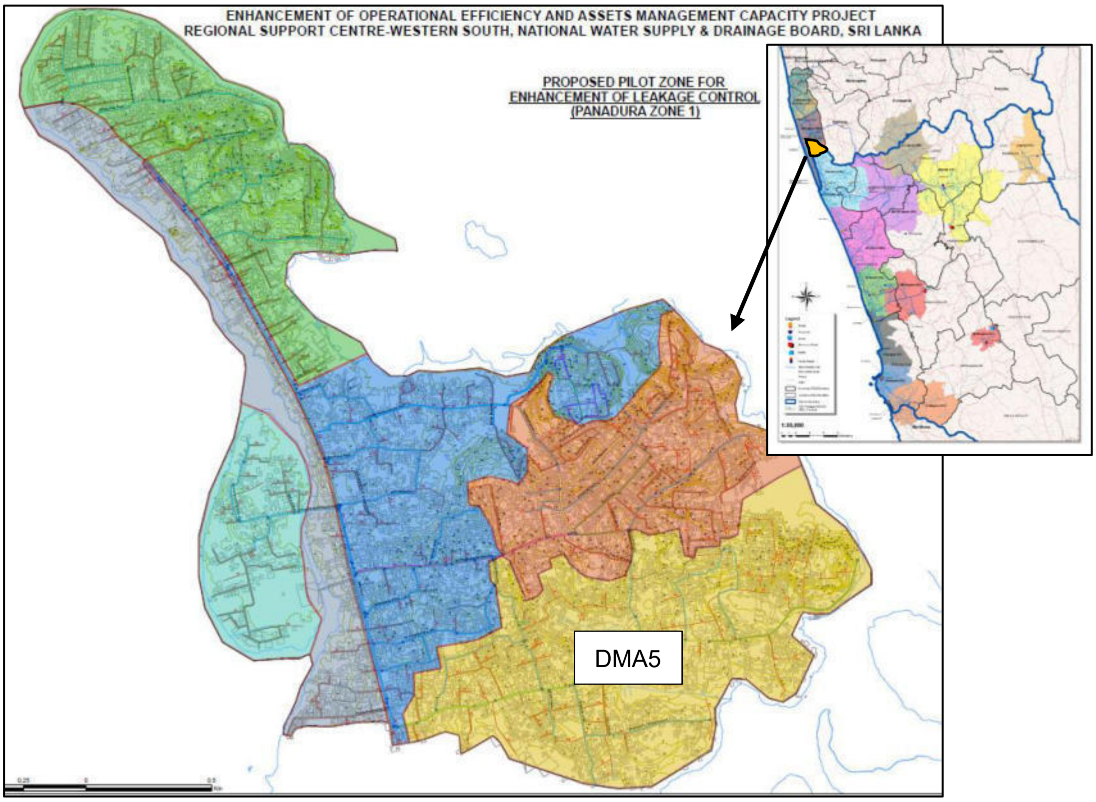


Figure 2.5.1 Location of DMA 5

2.5.2 Sub-zoning Plan of DMA 5

The inside of this DMA 5 is divided into eight subsectors, and each subsector can be made hydraulically independent by operating the sluice valve.

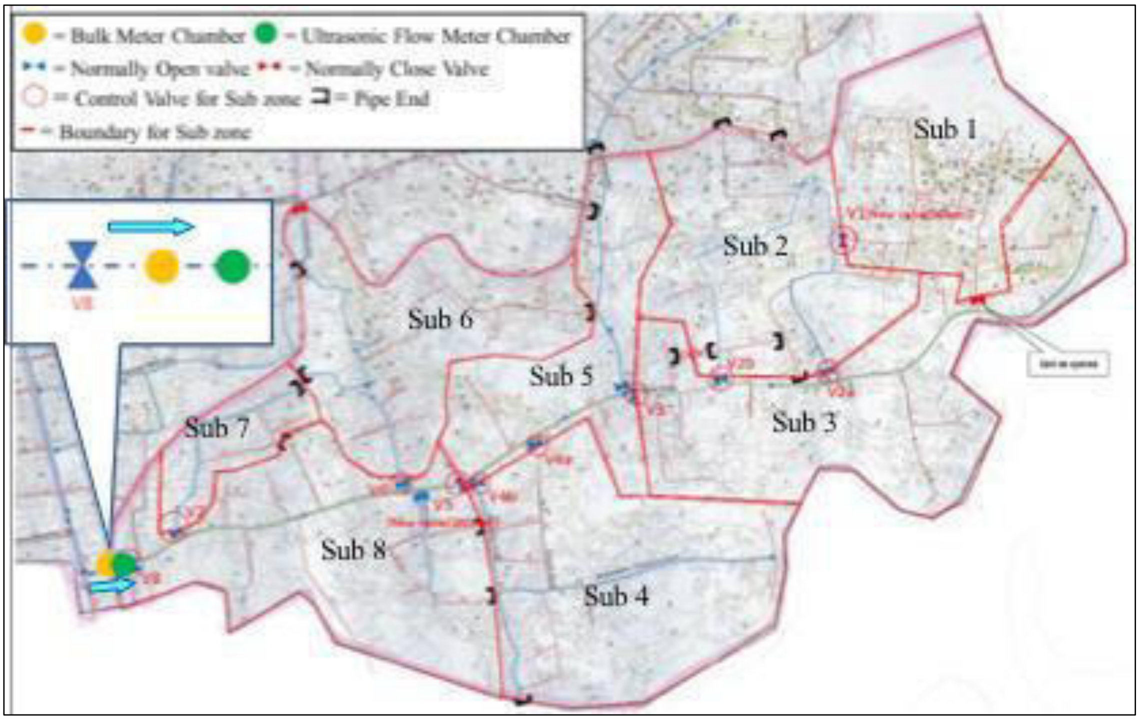


Figure 2.5.2 Sub-zoning Plan of DMA 5

Table 2.5.1 Basic Information of Subzones

Subzone No.	Number of connections	Extension of distribution pipes (km)	General situation
1	159	1.9	Quiet residential area, good survey environment. The difference of ground elevation is large.
2	184	2.1	Quiet residential area, good survey environment. The difference of ground elevation is large.
3	721	2.5	Divided into noisy areas facing avenue and quiet residential areas Attention should be paid to noise on traffic road.
5		1.3	Divided into noisy areas facing avenue and quiet residential areas Attention should be paid to noise on traffic road.
4	299	1.7	Quiet residential area, good survey environment. The difference of elevation in the area is small, but it becomes lower as it goes to the end of the pipeline.
6	316	1.9	Quiet residential area, good survey environment. The difference of ground elevation is large.
7	197	1.0	Quiet residential area, good survey environment. There are some small factories, etc. The elevation at the valve V7 point is low and gradually increases toward the end of the pipe.
8	365	2.5	This area is facing the main road. There are many shops, and noise continues to occur during the day. The difference of elevation is small
Total	2,241	14.9	-

2.5.3 Result of Step Test

Based on the results of the Step Test and the MNF measurement, set the baseline data before starting water leakage reduction measures. The example is shown as below.

Table 2.5.2 Result of 1st Step Test

Subzone	Time	Flow		Average value of drop-down (L/min)	Length of pipe (km)	Average volume of drop-down / km (L/min･km)
		L/min	m^3/h			
MNF (Base Line)	**:** am	380.64	22.84			
Step 1 (Sub 1)	**:** am	304.60	18.28	76.04	1.9	40.0
Step 2 (Sub 2)	**:** am	235.70	14.14	68.90	2.1	32.8
Step 3 (Sub 3)	**:** am	218.13	13.09	17.57	2.5	7.0
Step 4 (Sub 4)	**:** am	174.93	10.50	43.20	1.7	25.4
Step 5 (Sub 5)	**:** am	157.51	9.45	17.42	1.3	13.4
Step 6 (Sub 6)	**:** am	98.70	5.92	58.81	1.9	31.0
Step 7 (Sub 7)	**:** am	53.95	3.24	44.75	1.0	44.8
Step 8 (Sub 8)	**:** am	0.00	0.00	53.95	2.5	21.6
					14.9	

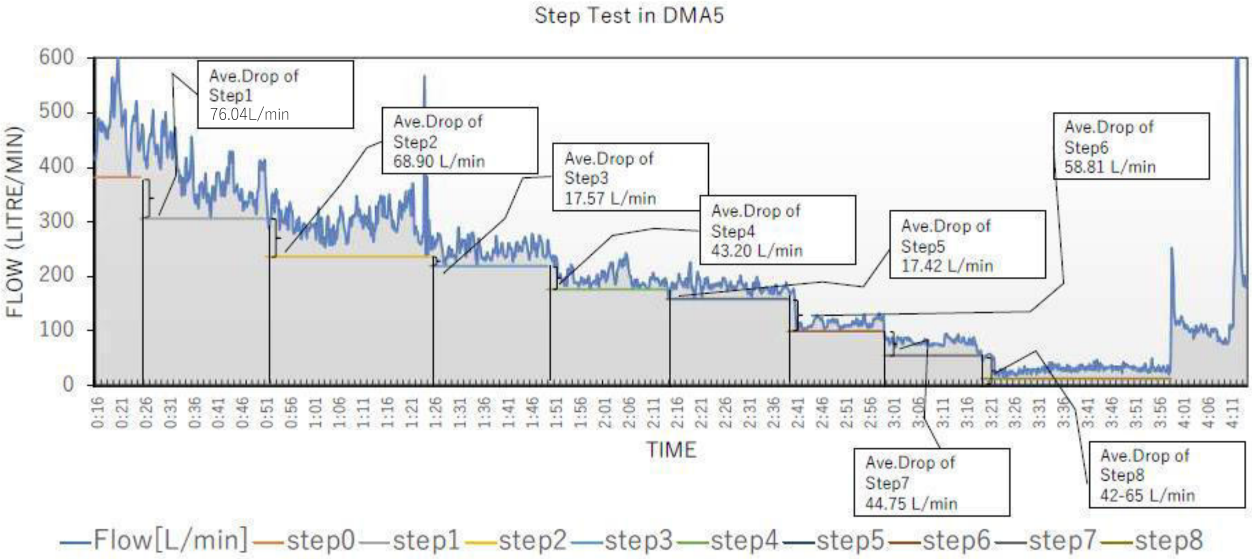


Figure 2.5.3 Original Water Flow Record in 1st Step Test

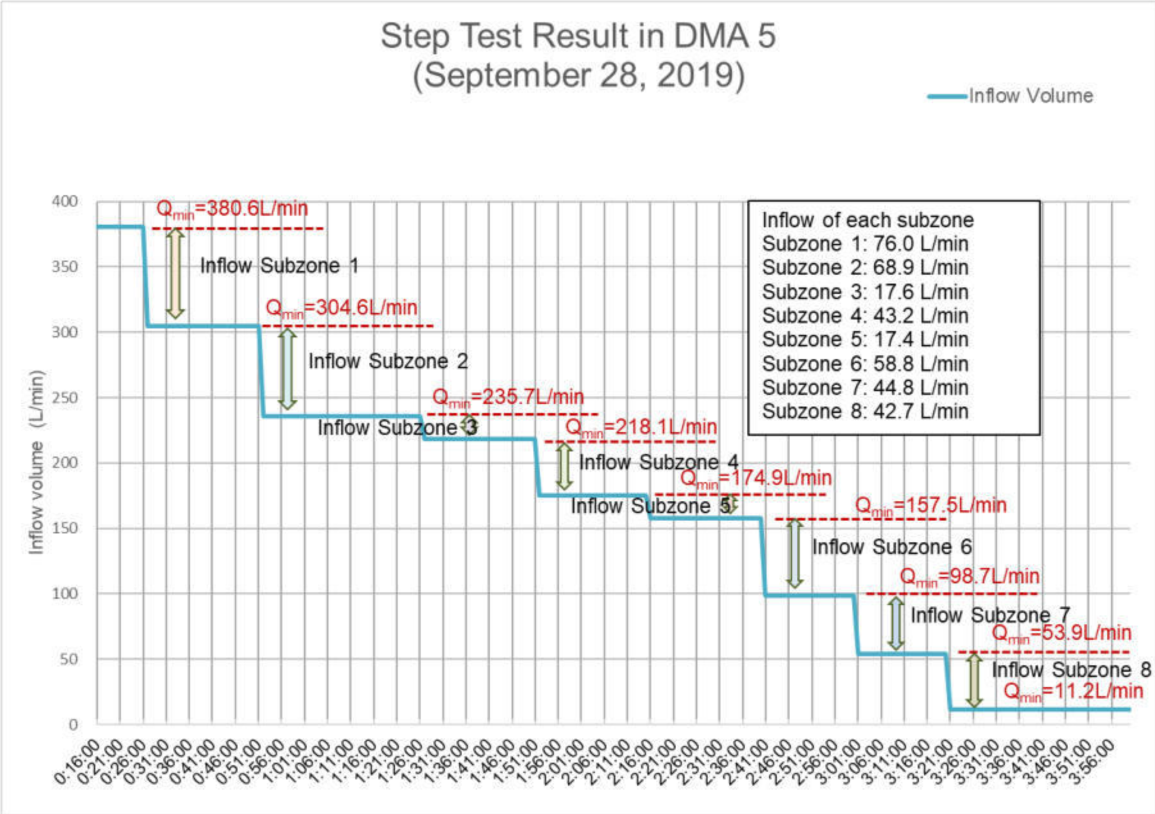


Figure 2.5.4 Summarized Record of 1st Step Test

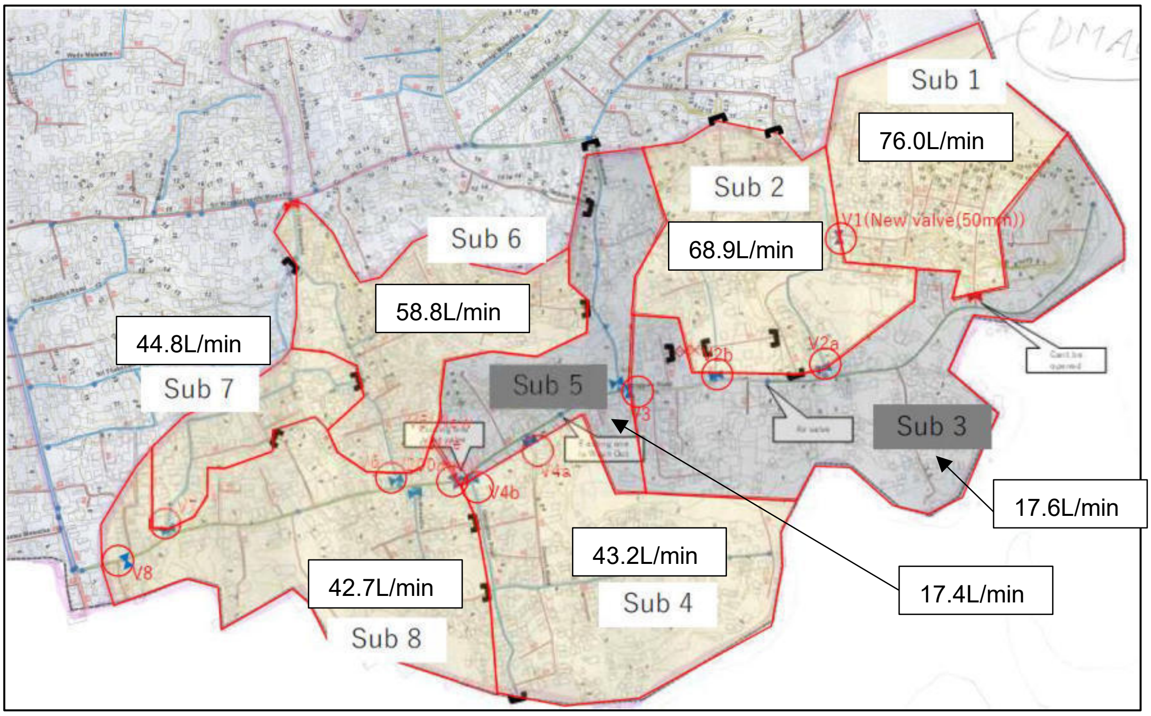


Figure 2.5.5 Result of 1st Step Test

From this change of inflow rate, the amount of water flowing into each subzone can be grasped. However, in order to estimate the status of subzones and the existence of water leaks, it is necessary to evaluate using the following indicators.

2.5.4 Evaluation of distribution network on subzone basis

(1) Evaluation using Minimum Night Flow (MNF) per pipeline length

- Minimum Night Flow in entire DMA5: 380.6 L/min
- Pipeline length: 14.9 km
- MNF/pipeline length: 25.5 L/min・km

This value [25.5 L/min・km] can be used as a criteria of indicator.

Table 2.5.3 Evaluation using MNF and Pipeline Length

Zone ID	MNF (L/min)	Pipeline Length (km)	Evaluation Index (L/min･km)	Prioritization (Risk)
Subzone 1	76.0	1.9	40.00	High
Subzone 2	68.9	2.1	32.81	Middle
Subzone 3	17.6	2.5	7.04	Extremely Low
Subzone 4	43.2	1.7	25.41	Middle
Subzone 5	17.4	1.3	13.38	Low
Subzone 6	58.8	1.9	30.95	Middle
Subzone 7	44.8	1	44.80	High
Subzone 8	42.7	2.5	17.08	Extremely Low

Table 2.5.4 Example of criteria

MNF per pipeline length (L/min・km)	Risk Level
<10	Extremely Low
10≦e<25	Low
25≦e<40	Middle
40≦e	High

(2) Evaluation using Minimum Night Flow (MNF) and UARL

- Minimum Night Flow in entire DMA5: 380.6 L/min
- Unavoidable Annual Real Losses (UARL): 55,723 L/day = 38.7 L/min

UARL (L/day) = (18 x Lm + 0.8 x Nc + 25 x Lc) x P

Lm: Length of Distribution Pipe (km): 14.9

Nc: Number of Connection:	2,241
Average service pipe length:	3m per connection
Lc: Average service pipe length x Nc	6.723km (3 x 2,241)
P: Average pressure (m):	25

➢ MNF/UARL: 9.8

This value [9.8] can be used as a base of criteria.

Table 2.5.5 Evaluation using MNF and UARL

Zone ID	MNF (L/min)	Pipe Length		Allocation of UARL (38.7 x a%)	MNF /UARL	Prioritization (Risk)
		(km)	(%)			
Subzone 1	76.0	1.9	12.8	4.9	15.5	High
Subzone 2	68.9	2.1	14.1	5.5	12.5	High
Subzone 3	17.6	2.5	16.8	6.5	2.7	Low
Subzone 4	43.2	1.7	11.4	4.4	9.8	Middle
Subzone 5	17.4	1.3	8.7	3.4	5.1	Low
Subzone 6	58.8	1.9	12.7	4.9	12.0	High
Subzone 7	44.8	1	6.7	2.6	17.2	High
Subzone 8	42.7	2.5	16.8	6.5	8.3	Middle

Table 2.5.6 Example of criteria

MNF / UARL	Risk Level
≦6	Low
6<e≦10	Middle
10<e	High

2.6 Data storage and update

2.6.1 Necessary basic data

The necessary basic data related to water supply system is shown below. It is important to collect the basic data as much as possible to consider proper NRW and measures.

Table 2.6.1 Necessary basic data of water supply system

No	Item
1	Number of connections
2	Number of effective customer meter
3	Date of meter installation
4	Serial number of meters
5	Nominal diameter of meters
6	Manufacturer of meters
7	Diameter and material of service connection pipe
8	Billing data during last 12 months
9	Meter reading data during last 12 months
10	Number of users by category
11	Distribution Network Drawing
12	Extension of pipes by type of material
13	Extension of pipes by diameter

2.6.2 Data storage and update

Existing mapping system, which NWSDB are currently has, is useful to store and update data. It should be managed based on the daily O&M works of water supply system. The ideal steps for data storage and update are shown below:

i. Step 1

Each OIC stores daily data on water leak repair and pipe laying work as paper documents. So, the staff of each OIC digitizes paper documents as described below. The software used for digitization is Google Earth Pro (GEP).

- Record leakage repair on the map as below (Figure 2.6.1)
- Connect the information of pipe, valve position, laying year and the construction document number etc. to the map record as attribution

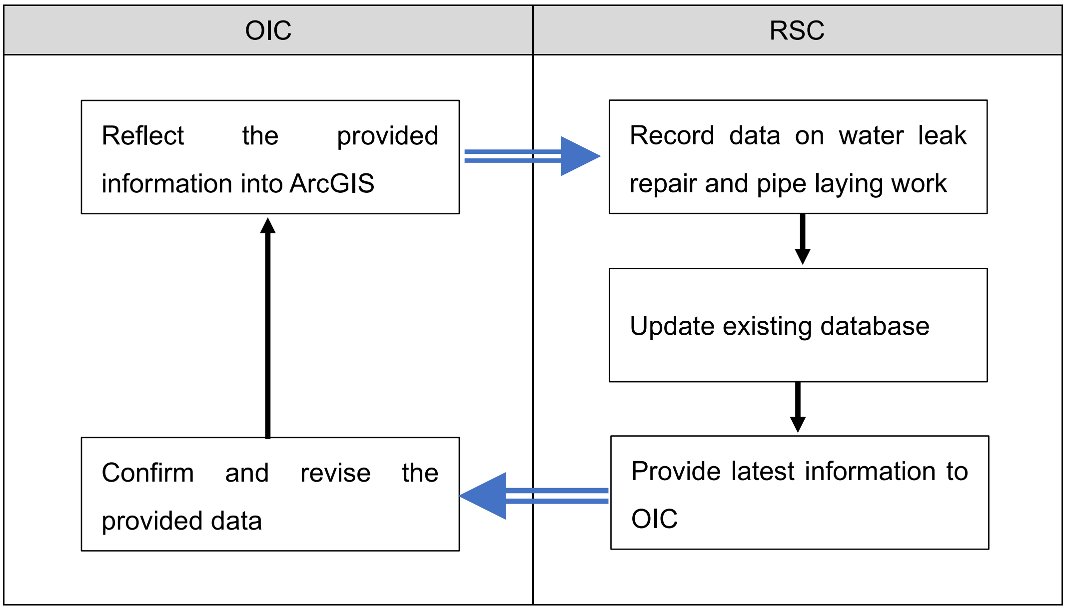
Figure 2.6.1 Record of leakage repair on the map

ii. Step 2

The staff of each OIC sends the digital data created in Step 1 to Planning & Design section of Western South office (P&D-WS) by e-mail every month.

iii. Step 3

P&D-WS staff will reflect the data of Step 2 to ArcGIS every month. If installed year information is missing, P&D-WS staff estimates the year of installation and enters the data into ArcGIS.



2.7 Data collection of leakage repair

2.7.1 Purpose of collection of leakage repair data

Water leakage from the pipe is a main factor to evaluate pipe deterioration. Accumulated leakage data is inevitable for asset management that suggest us the timing of pipe replace. Information that should be kept on the leakage repair record sheet is as shown below. A model leakage repair record sheet is shown in Appendix.

- Address of leak point and actual point
- Date of repair work and
- Date when water leakage was first confirmed
- Pipe material, diameter, part of leaking point on the pipe(strait, bend, joint, saddle, etc.)
- Rode surface form (asphalt, concrete gravel, etc.)
- Leak volume
- Required material for repairing
- Required time, number of staff, type of equipment and machine

2.7.2 Asset management

Leakage repair works data are required for Asset Management System (AMS). Since the occurrence of water leakage is an indicator of deterioration of pipelines, it is possible to know which pipeline has a large number of faults by collecting leakage records. Even if the water authority tries to keep the pipeline soundly, the cost of keeping it will increase due to frequent leaks. These pipelines must be given a higher priority of renewal, and renewing can maintain stable water supply.

Table 2.7.1 Leakage Repair Record Sheet

<table>
<tr><td colspan="9">The Project for Enhancement of Operational Efficiency and Asset Management Capacity of Regional Support Center-Western South of NWSDB in Sri Lanka</td></tr>
<tr><td rowspan="3">Leak Repair Detail Sheet</td><td colspan="8">National Water Supply & Drainage Board</td></tr>
<tr><td>Office</td><td colspan="7"></td></tr>
<tr><td>Officer</td><td colspan="7"></td></tr>
<tr><td>Work day</td><td>Day</td><td colspan="3"></td><td>Time</td><td colspan="3"></td></tr>
<tr><td>Attendance day</td><td>Day</td><td colspan="7"></td></tr>
<tr><td>Work reason</td><td>Complain</td><td>Meter reader</td><td>Leak detection</td><td colspan="5">Other</td></tr>
<tr><td>Compainer's name & add</td><td colspan="8"></td></tr>
<tr><td rowspan="4">Leakage location</td><td>Adress</td><td colspan="7"></td></tr>
<tr><td>Meter No.</td><td colspan="7"></td></tr>
<tr><td>Consumer No.</td><td colspan="7"></td></tr>
<tr><td>Coordinate</td><td colspan="7"></td></tr>
<tr><td>Type of Leak</td><td>Meter</td><td colspan="2">Connection pipe(Joint , pipe)</td><td colspan="2">Ferrule</td><td colspan="3">Distribution pipe</td></tr>
<tr><td>Cause of Leak</td><td colspan="8"></td></tr>
<tr><td>Nature of repair</td><td colspan="8">Diameter & Material</td></tr>
<tr><td>Leake repair</td><td>Yes</td><td></td><td>No</td><td></td><td>Leak volume</td><td colspan="2"></td><td>M3/h</td></tr>
<tr><td>Material of use</td><td colspan="8"></td></tr>
<tr><td colspan="3">Machinery Used</td><td colspan="6">Location(Sketch)</td></tr>
<tr><td colspan="3">(1) Power Light (1.5.1)Hrs</td><td colspan="6" rowspan="8"></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">(2) Night work (1.5.2)Hrs</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">(3) Water Pump(Dewatering)Hrs</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">(4) Others</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="9">Measurment</td></tr>
<tr><td>BOQ Item No.</td><td colspan="3">Description</td><td>Unit</td><td>L(m)</td><td>B(m)</td><td>D(m)</td><td>Qty</td></tr>
<tr><td></td><td colspan="3"></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td colspan="9">Comment</td></tr>
</table>

Contractor Officer NWSDB Officer

2.8 Sustainable Use of Created DMA

2.8.1 Setting the target level of leakage management

Water pipes deteriorate over time due to various factors such as deterioration, corrosion, and traffic load, and this deterioration causes water leakage.

Also, unless the deteriorated pipeline is completely renewed, a new leak will occur soon after the repair.

This phenomenon is called "Leakage Recurrence"

There are only two methods to reduce the amount of residual water leakage.

- Continue water leakage prevention work at a pace that exceeds the amount of water leakage recurrence.

  ・Increase the amount of water leakage prevention work. (Investment of human resources)

  ・Improve water leak detection technology. (Training and accumulation of experience)

  ・Adopt efficient leak detection and repair technology. (New technology)

- Erasure of restoration itself by renewing dilapidated pipelines

  ・Use a pipe that does not easily leak water. (Change of material)

  ・Shorten the length of the pipe to make an efficient piping route. (Improved efficiency)

  ・Adopt appropriate piping technology. (New technology)

2.8.2 Monitoring of Leakage Recurrence Speed

It is estimated that the recurrence of water leakage appears in the pattern shown in the schematic image below.

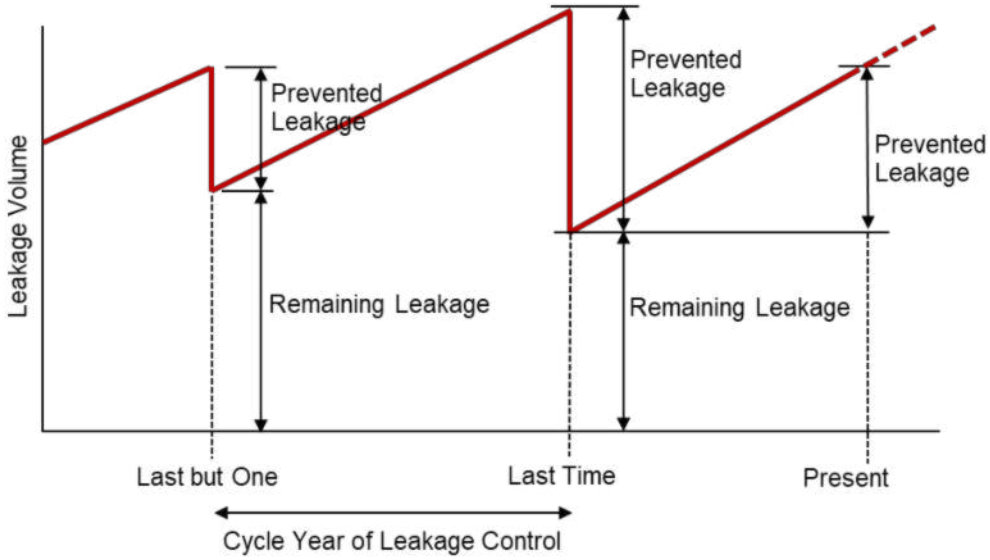


Figure 2.8.1 Image of Leakage Recurrence

Practically, the costs and human resources available to prevent water leakage are limited. For this reason, it is necessary to set the criteria for determining the allowable amount of water leakage and pipeline renewal while considering the amount of water that has been prevented, the amount of residual water, and the cost spent for prevention activities.

To this end, it is necessary to investigate how quickly the reduced water leakage will recur, and it is recommended to monitor the water inflow to the DMA and MNF monthly.

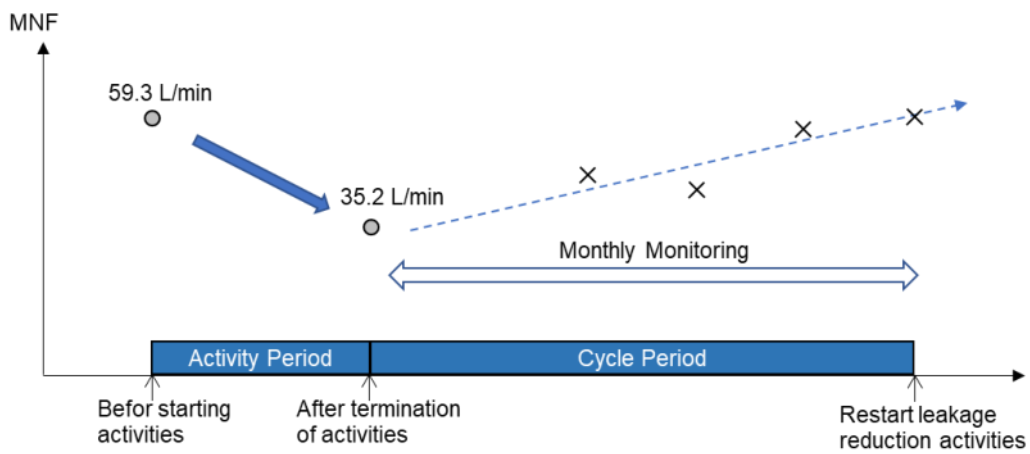


Figure 2.8.2 Monitoring for Leakage Control

2.9 Accuracy Inspection of Customer Meter

2.9.1 Survey Plan and Equipment Preparation

First, the target area and the number of cases, the number of investigators, and the approximate survey period should be decided. For equipment, a portable electronic test meter and standard tank (20 liters) will be prepared.

Figure 2.9.1 Example of a test meter and a standard tank

2.9.2 Type of inspection method

There are two methods for on-site meter inspection, but this guideline describes a simple method.

It should be noted that all water meters have a permissible error, so a predetermined error will occur even when inspected with an electronic test meter.

In order to perform meter inspection with higher accuracy, it is recommended to prepare a standard tank whose volume is accurately measured with officially appropriate method in advance, instead of using a potable reservoir, and compare the amount of water accumulated in the reference tank with the meter reading.

【Simple method using a test meter】

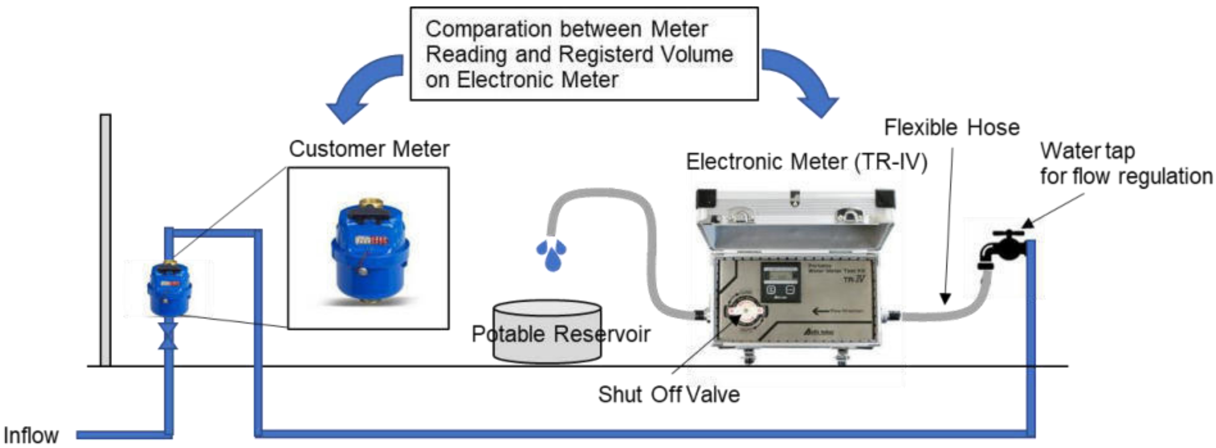


Figure 2.9.2 Method of Inspection with Test Meter

The permissible error of the water meter is determined by the flow rate range. Therefore, it is necessary to adjust the amount of water for each flow rate range for inspection, and an electronic test meter is used to set this flow rate.

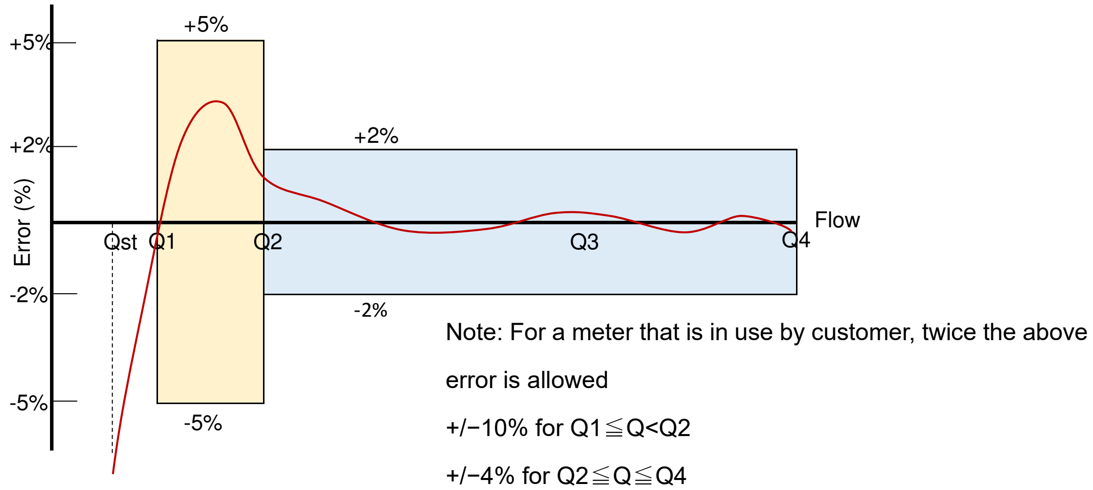


Figure 2.9.3 Calculation Formula of Metering Error

The meter body inside the test meter has the following specifications.

Aichitokei-Denki Electronic Meter: Model EDS-20 (DN20)

Minimum Flow Rate (Q_1): 0.040 m^3/h (0.67 L/min)

Transitional Flow Rate (Q_2): 0.064 m^3/h (1.07 L/min)

Maximum Flow Rate (Q_3): 4 m^3/h (66.67 L/min)

Overload Flow Rate (Q_4): 5 m^3/h (83.33 L/min)

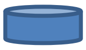
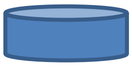
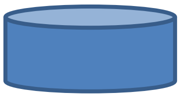
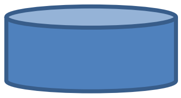
The error table of the instrument difference of the test meter shows the error at three points: large flow rate (1,000 L/h), medium flow rate (200 L/h), and small flow rate (100 L/h), in the factry pre-shipment inspection. Refer to the test result certificate in the meter box.

Table 2.9.1 Instrumental Error of Test Meter

Model: TR-IV Serial No.	Instrumental error by flow rate		
	1000L/h (16.67L/min)	200L/h (3.33L/min)	100L/h (1.67L/min)
118	-1.4 %	+1.5 %	+0.5 %

When confirming the accuracy of the meter in use, it is desirable to perform a test in the following multiple flow rate ranges, make corrections using errors close to the flow rate bands, and perform a comprehensive evaluation.

Table 2.9.2　Example of meter test pattern

	Step 1 Starting Flow Q_{st}	Step 2 Between Q_1 & $1.1{*}Q_1$	Step 3 Between Q_2 & $1.1{*}Q_2$	Step 4 Approx. Q_3	Step 5 Between $0.9{*}Q_3$ & Q_3
Image					
Flow rate	3L/h～10L/h	27～33 L/h	108～132 L/h	Approx.600L/h	1350～1500 L/h
	0.05～ 1.66L/min	0.45～0.55L /min	1.8～2.2 L /min	Approx.10 L /min	22.5～25 L /min
Total Test Volume		5L 	10L 	20L 	20L 

2.9.3 Test Procedure

(1) Preparation of the Test Meter

1a. Remove the air from the meter so that the meter is filled with water.

1b. Secure a higher place than the main body in the middle of the outlet hose so that air does not enter the hose when water is stopped.

1c. Close the test meter valve and check that there is no water leakage from the piping or hose joint.

1d. Switch the LCD counter display to "Instantaneous Flow Rate Mode".

In instantaneous flow mode, a U is displayed to the left of the number. 4-digit display, unit is L/min

1e. Fully open the Shut Off Valve of the test meter body and adjust it so that it is within the flow rate range of the inspection target while changing the opening of the Water Tap.

1f. After adjusting the flow rate to the specified range, fully close the Shut Off Valve on the test meter body.

1g. Use of water from other taps in the residential area is prohibited during the inspection.

(2) Test procedure

Since the counter display was set to ”Instantaneous Flow Rate Mode” during flow rate adjustment in the preparation stage, change the display mode to “Trip Mode” or “Cumulation Mode” before starting the test.

- The display of the counter changes when the L/min button is pressed for about 3 seconds.
- Press the Total/Trip button to display zero reset in Trip Mode.

2a. Record the reading on the water meter before starting the test.

2b. Determine the amount of test water for each flow rate band. (Small flow: 10 Lts, Medium flow: 10 Lts, Large flow: 20 Lts).

2c. Set the counter of the test meter to “Cumulation Mode” and reset to zero

2d. Simultaneously with the start of the test, open the valve of the test meter body and start passing water.

2e. While checking the display on the test meter, close the valve on the test meter main body at the moment when the predetermined amount of test water is reached to stop water flow.

2f. Record the amount of water passing through with a test meter.

2g. Check the instrumental error (%) in the flow rate range indicated in the test meter instrumental error report.。

2h. Check the reading on the water meter and record the amount of water measured within the above time.

2i. Calculate the instrumental error of the water meter by the following formula.

$$\text{Error (\%)} = \frac{\text{Water Volume measured by Customer Meter} - \text{Water Volume registered by Test Meter}}{\text{Water Volume registered by Test Meter}} \times 100$$

$$+ \text{ Instrumental Error of Test Meter}$$

Figure 2.9.4 Calculation Formula of Metering Error

2.9.4 Aggregate meter accuracy inspection results

The test results are recorded in the table below.

Table 2.9.3 Format of test record

Meter ID					
Step	1	2	3	4	5
Target test flow rate	Starting Flow	30 L/h (0.5 L/min)	120 L/h (2.0 L/min)	600 L/h (10 L/min)	100%
Total test volume	Variable	5 L	10 L	20 L	20 L
Initial reading of customer meter					
Final reading of customer meter					
Registered volume of customer meter “A” (L)					
Registered volume of Electrical Test Meter “B” (L)					
Test time (min)					
Test flow rate of TR-IV (L/min)					
Difference of volume between A & B (“A”-“B”)					
Error ((A-B)-B)*100 (%)					

2.9.5 Meter reliability evaluation

Generally, the larger the cumulative cumulative value of the meter, the longer the years of use, so that it tends to be aged and malfunction. By plotting the cumulative water volume of the meter on the horizontal axis and the meter instrument error on the vertical axis, you can read the accumulated meter value of the meter and the tendency of the generator difference.

If there is a high correlation between the accumulated flow rate value and the occurrence of instrumental error, it is possible to determine when it is desirable to update the existing meter.

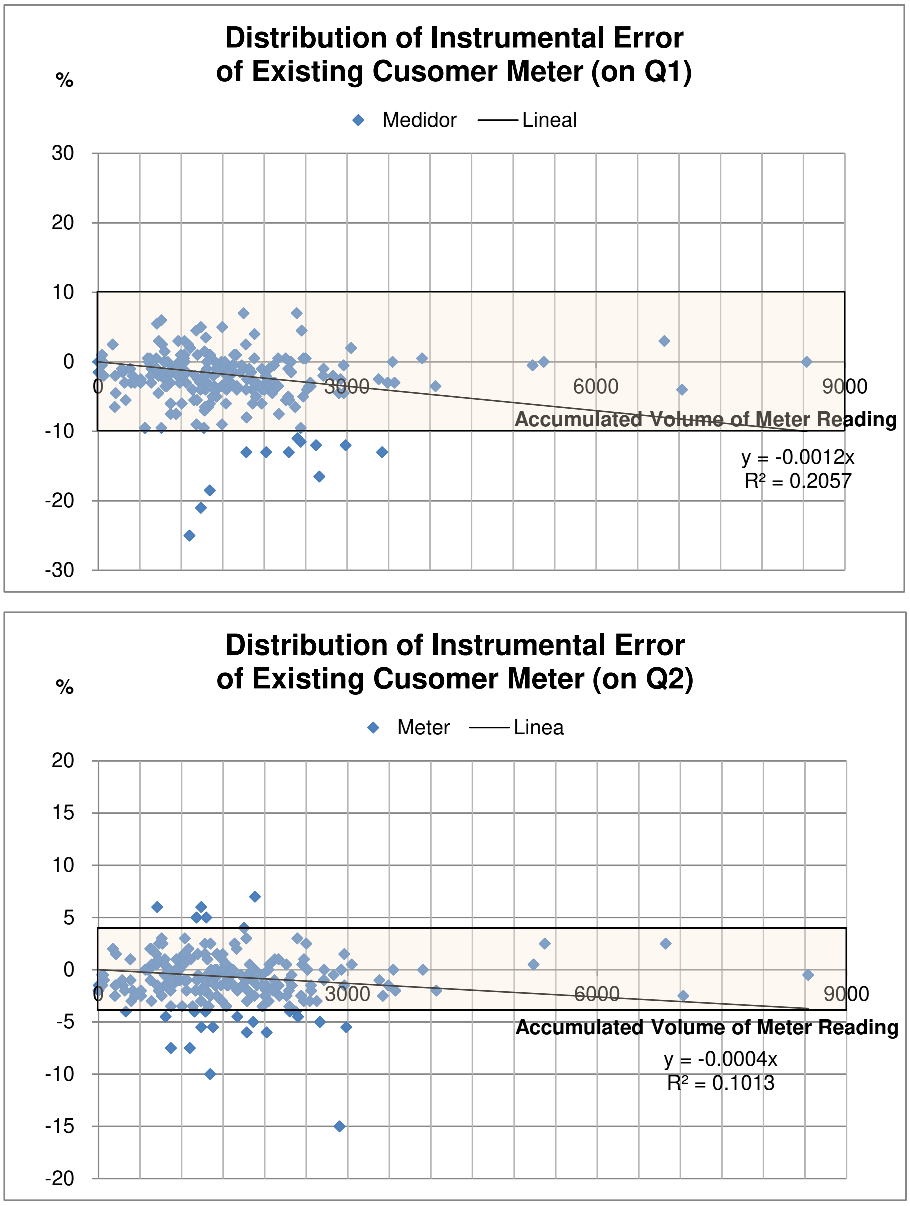


Figure 2.9.5　Relation between cumulative reading value and instrumental error

2.9.6 Estimation of apparent losses

If all test results are plotted on a graph, it can be shown as follows.

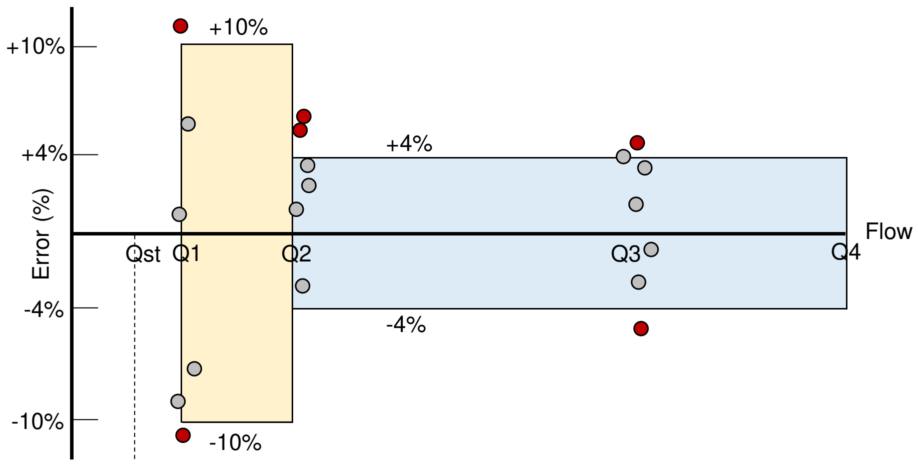


Figure 2.9.6 Distribution of instrumental error of customer meter

The error of the existing meter differs depending on each flow rate band.

For households that use water in a large flow rate, the error near Q_3 has a large effect on the amount of billed water. On the other hand, for low-income households who often use water in a small flow rate, the error near Q_1 to Q_2 greatly affects the billed water.

As mentioned above, since the measurement error occurs depending on the band and frequency of the actual water consumption of the household, it is necessary to investigate the water consumption band of the household in order to estimate the influence of the meter error on the billed water amount.

Therefore, when calculating the apparent loss of water due to meter error using a simple method, use an error in the vicinity of Q2 (100 to 120 L/h), which is the band, for the typical amount of water usage flow band.

Once the monthly NRW is calculated, the ratio of apparent loss and actual loss can be estimated by the following formula.

By comparing the calculated actual water loss and the MNF rate, it becomes possible to grasp the amount of water leakage remaining more accurately in the DMA.

$$\text{Apparent Losses (L/min)} = \frac{\text{Billed Water (m}^3\text{/month)} \times \text{Error (\%)} / 100}{\text{Billing Interval (days)} \times 24 \times 60 \times 1000}$$

$$\text{Real Losses (L/min)} = \text{Non-Revenue Water (L/min)} - \text{Apparent Losses (L/min)}$$

Figure 2.9.7 Calculation Formula of Apparent Losses

2.9.7 Determination of sample size

When considering the sample size under the following conditions, the statistical size is as shown in the table below.

- Allowable error: 5%
- Confidence level: 95%

Table 2.9.4 Table of sample size

Total number of customer meter in DMA	Sample size (Number of meter)	Percentage against total number of meters
250	152	60.8%
300	169	56.3%
400	196	49.0%
500	220	44.0%
800	260	32.5%
1,000	280	28.0%
2,000	325	16.3%
3,000	345	11.5%
5,000	360	7.2%
10,000	370	3.7%
25,000	380	1.5%
50,000	385	0.8%
> 100,000	385	< 0.4%

2.9.8 Example of Simple Test of Customer Meter

As mentioned earlier, the tolerance of the meter depends on the flow band, so when checking the accuracy of the meter, it is necessary to test in multiple flow ranges, such as Q1, Q2 and Q3.

However, in some cases, a test is also conducted to show the correctness of the billed water amount in the field in response to the customer's complaint.

The following are the test results conducted on 16 meters in DMA4. This test was performed in only one flow rate between Q1 and Q2.

The average error rate was + 0.077%, which was found to be within the permissible range of error (+/- 5% for the Q1 to Q2 bands).

Table 2.9.5 Test Result of Customer Meter of DMA 4

No.	Date	DMA	Sub zone	Acount No.	House No.	Customer meter			Test meter			Error ratio
						Initial	Last	Flow amount a	Initial	Last	Flow amount b	(a-b)/b
1	18/03/2019	4	4		6/23	0,688,511.9	0,688,613.9	102.0	0.00	101.20	101.2	0.79%
2	18/03/2019	4	4	259/13	8/44	2,241,375.7	2,241,476.0	100.3	0.00	101.08	101.1	-0.77%
3	18/03/2019	4	4	303/13	8/14 A	0,989,634.2	0,989,736.2	102.0	0.00	100.80	100.8	1.19%
4	18/03/2019	4	4	333/13	8/43/1	0,357,423.1	0,357,525.6	102.5	0.00	100.95	101.0	1.54%
5	18/03/2019	4	3	160/11 2	30/5	4,357,020.7	4,357,119.8	99.1	0.00	100.30	100.3	-1.20%
6	18/03/2019	4	3	164/17 2	30/6	1,784,718.7	1,784,817.9	99.2	0.00	100.39	100.4	-1.19%
7	18/03/2019	4	3	183/14	30/12 B	4,174,959.8	4,175,058.2	98.4	0.00	100.33	100.3	-1.92%
8	18/03/2019	4	3	190/15	30/19	5,786,842.5	5,786,937.7	95.2	0.00	100.42	100.42	-5.20%
9	19/03/2019	4	2	015/8	15 A Thilaka Rd.	0,621,929.0	0,622,033.7	104.7	0.00	101.20	101.20	3.46%
10	19/03/2019	4	2	37/2	27/4 Thilaka Rd.	0,442,162.3	0,442,265.4	103.1	0.00	101.23	101.23	1.85%
11	19/03/2019	4	2	115/17	16/44 Thilaka Rd.	1,711,424.9	1,711,527.6	102.7	0.00	101.36	101.36	1.32%
12	19/03/2019	4	2	48/19	29 A Thilaka Rd.	1,233,416.1	1,233,518.6	102.5	0.00	102.14	102.14	0.35%
13	19/03/2019	4	1	79/11	34 B Thilaka Rd.	1,238,782.4	1,238,885.7	103.3	0.00	101.36	101.36	1.91%
14	19/03/2019	4	1	83/15	38/13 Thilaka Rd.	1,100,699.8	1,100,798.4	98.6	0.00	101.08	101.08	-2.45%
15	19/03/2019	4	1	87/11	40/5 Thilaka Rd.	0,048,859.8	0,048,961.4	101.6	0.00	100.92	100.92	0.67%
16	19/03/2019	4	1	315/15	40/27 Thilaka Rd.	0,941,237.2	0,941,339.1	101.9	0.00	101.20	101.20	0.69%

3 Practice of Pulse Signal Measurement

3.1 Importance of Long-term Monitoring of Water Flow

Water pipes deteriorate over time due to various factors such as deterioration, corrosion, and traffic load, and this deterioration causes water leakage.

Also, unless the deteriorated pipeline is completely renewed, a new leak will occur soon after the repair.

This phenomenon is called "Leakage Recurrence"

There are only two methods to reduce the amount of residual water leakage.

- Continue water leakage prevention work at a pace that exceeds the amount of water leakage recurrence.

  ・Increase the amount of water leakage prevention work. (Investment of human resources)

  ・Improve water leak detection technology. (Training and accumulation of experience)

  ・Adopt efficient leak detection and repair technology. (New technology)

- Erasure of restoration itself by renewing dilapidated pipelines

  ・Use a pipe that does not easily leak water. (Change of material)

  ・Shorten the length of the pipe to make an efficient piping route. (Improved efficiency)

  ・Adopt appropriate piping technology. (New technology)

It is estimated that the recurrence of water leakage appears in the pattern shown in the schematic image below.

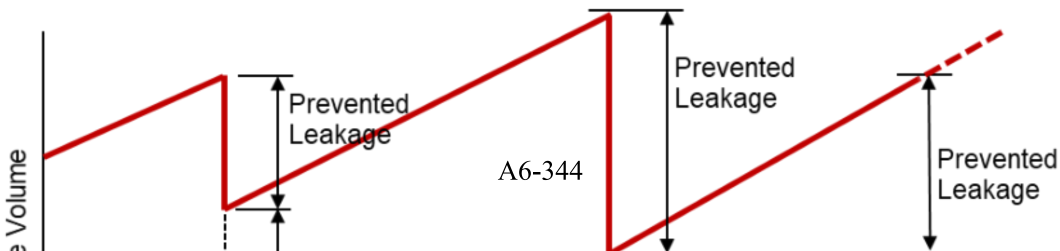


Figure 3.1.1 Image of Leakage Recurrence

Practically, the costs and human resources available to prevent water leakage are limited. For this reason, it is necessary to set the criteria for determining the allowable amount of water leakage and pipeline renewal while considering the amount of water that has been prevented, the amount of residual water, and the cost spent for prevention activities.

To this end, it is necessary to investigate how quickly the reduced water leakage will be recured, and it is recommended to monitor the water inflow to the DMA and MNF monthly. One way to efficiently carry out this monitoring is to build a remote communication system.

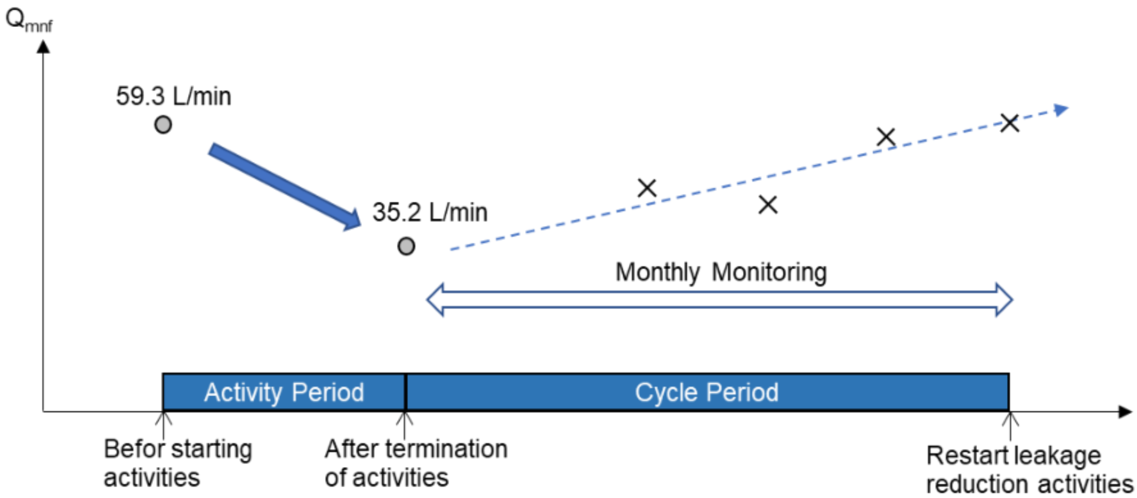


Figure 3.1.2 Monitoring of Minimum Night Flow

3.2 Mechanism of Remote Monitoring System

In DMA 5 the remote monitoring system was installed on site as mentioned below:

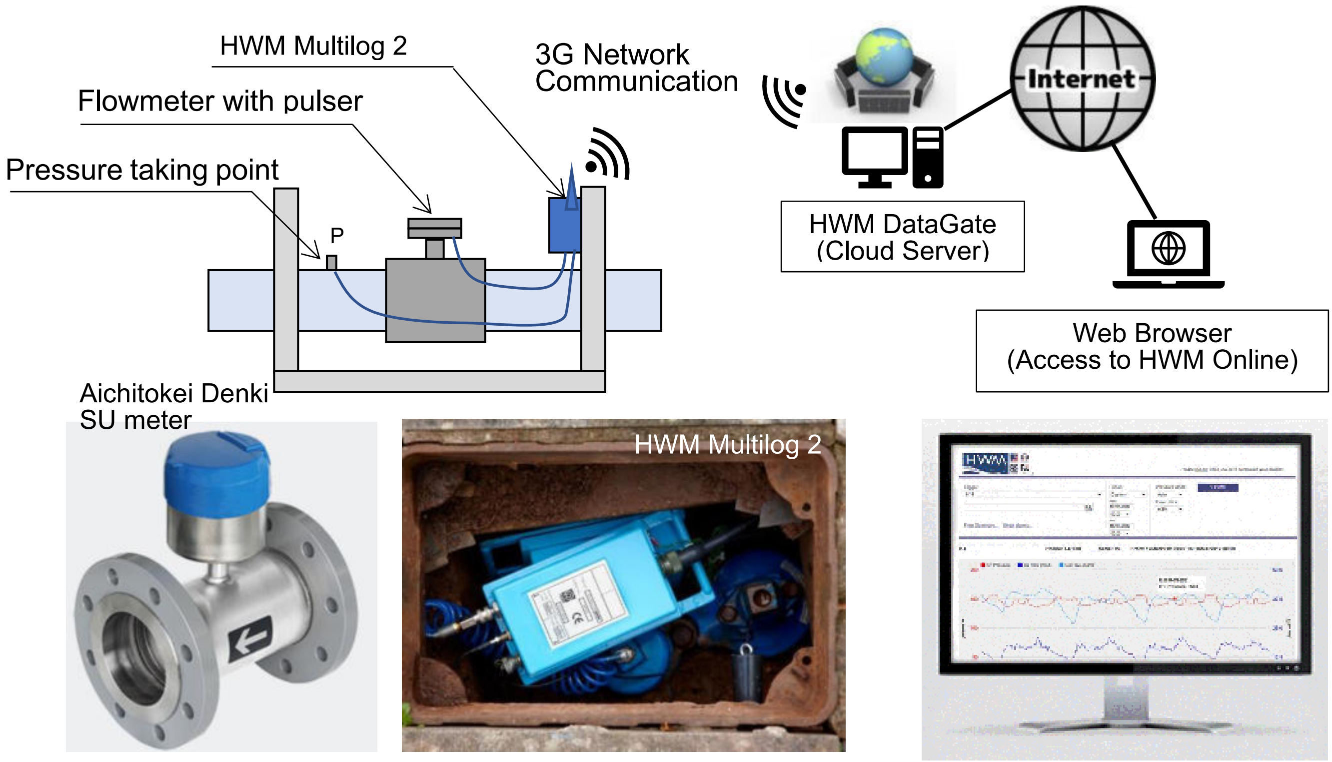


Figure 3.2.1　Image of Remote Monitoring System

Table 3.2.1　Necessary basic data of water supply system

No	User's responsibility	HWM's service
1	Installation of 3G Modem Datalogger	Data saving in Cloud Server
2	Preparation of Data SIM card	Data sharing by HWM Online
3	3G Modem Configuration	Maintenance of Cloud Server
4	3G Network Fee	Security measures against illegal access
5	Mobile tablet or PC	Provision of access key
6	Internet Access from PC	
7	DataGate Hosting fee	
8	Flowmeter with pulse signal output	
9	Connection cable for digital signal	
10	Pressure taking point on pipe	
11	Pressure taking cable with quick coupler	
12	External battery (if necessary)	

The monitoring system introduced on a trial basis this time is a service provided by a data logger manufacturer (Halma Water Management). The user can easily check the measurement data anywhere on the earth simply by preparing a SIM card using the mobile phone communication network and paying the service usage fee.

Data can be viewed in graphical or table format from any internet enabled device using web viewer HWM Online or seamlessly integrated into a third-party corporate system.

On receipt of an alarm DataGate can send automatic alerts to multiple users to enable action to be taken promptly. The system will even store data from loggers it does not recognize, and then add this information to the logger's history when it is registered on the system.

Multiple accounts can be set up and configured to ensure that users only see data from the specific loggers they require.

Figure 3.2.2 Monitoring Screen on Web Browser

3.3 Use of Pulse Signal

Pulse signals are used in various measurement sites such as automobile speed, water flow rate, and electricity usage.

However, even if we look only at the pulse signal, we do not know the specific value.

Since a pulse signal is a digital signal converted from mechanical changes such as velocity and flow rate, it becomes valuable only by analyzing the data.

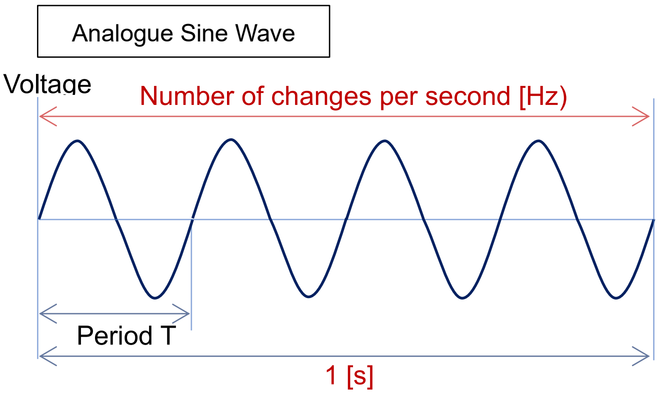
3.3.1 Basic Calculation Method of Pulse Signal

In the case of flowmeter, a preset pulse signal is output according to the rotation speed of the impeller or its passed water volume detected by internal electrical device. Therefore, the flow that has passed can be measured by counting the pulse signals generated within a certain period of time.

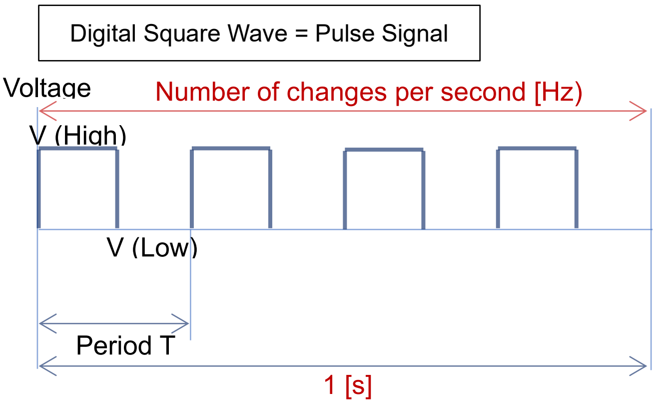
(1) Frequency of Pulse Signal

"Frequency" indicates the number of vibrations generated per second, that is, how many times the pulse signal is output. The time required for a pulse signal to make one round trip is called "Period".

"Frequency" and "Period" have a reciprocal relationship, and once one is known, the other value can be calculated.



$$\text{Frequency } f\ [\text{Hz}] = \frac{1}{\text{Period } T\ [\text{s}]}$$



$$\text{Frequency } f\ [\text{Hz}] = \frac{1}{\text{Period } T\ [\text{s}]}$$

Figure 3.3.1 Monitoring Screen on Web Browser

(2) Example of electronic water meter

When measuring with a flow meter that emits one pulse when 10 L of water passes, if the data logger counts 10 pulses per minute, the passing flow rate can be calculated as 10 L x 10 pulses = 100 L/min.

There are several pulse signal output methods. The following explanation is an example of mechanism using the simplest open drain method.

An NPN transistor is built inside the flowmeter.

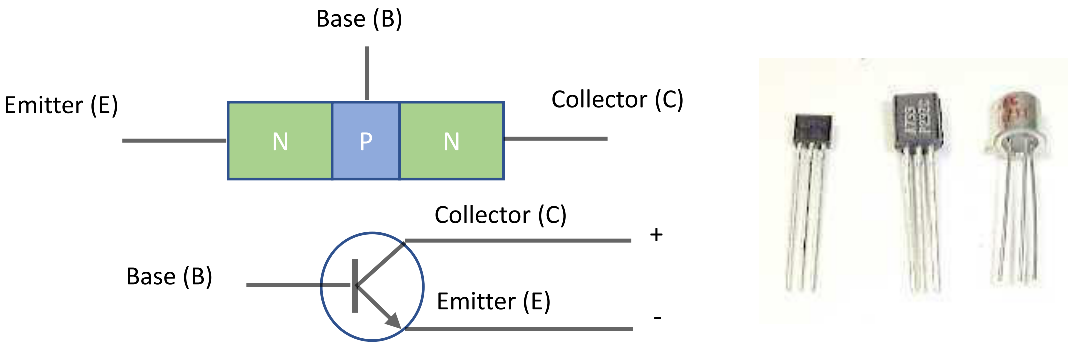


Figure 3.3.2 Mechanism of Transistor

A collector voltage (C), a base voltage (B), and an emitter voltage (E) are generated in the three electrodes of the transistor and play the role of a switch.

VB < VE	No current flows from B to E. The resistance between C and E is ∞Ω. → This means “Switch off state”.
VB > VE	Current flows from B to E. The resistance between C and E is 0 (zero) Ω. → This means “Switch on state”.

For example, design so that the base voltage (VB) is momentarily loaded when the flow meter counts 10 L, and a state of VB> VE is created. Then, every time the passing flow rate reaches 10 L, the resistance between C and E becomes 0 Ω, and a state in which current flows is created.

In this state, a current flow between C and E for a very short time, and the voltage becomes 0 V (LOW).

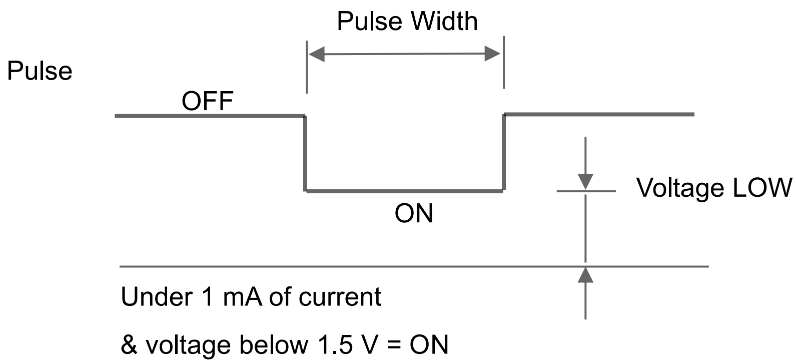


Figure 3.3.3　Relation between Pulse and Electrical Voltage

When receiving a pulse signal from the flow meter at the counter, the signal is counted at the moment when the voltage changes from HIGH to LOW.

When one pulse signal is generated, the resistance between C and E returns to the state of ∞Ω until the next 10L is reached.

Until then, no current flows, so the voltage between C and E reaches the maximum value (HIGH). As long as this OFF state continues, no pulse signal is generated.

(3) Sampling Rate

The sampling cycle at which the pulse is measured is called the "sampling rate", and the unit is [S/sec] (Sample per second). As the sampling rate becomes faster, the sampling cycle becomes narrower, so the faster the sampling cycle, the more accurate the waveform can be reproduced.

On the other hand, when the sampling rate is low, there arises a problem that a pulse having a short cycle cannot be detected and the pulse width cannot be measured.

That is, the measurement accuracy of the pulse width depends on the sampling rate, and it is important to set the sampling rate suitable for the frequency and characteristics of the original pulse signal.

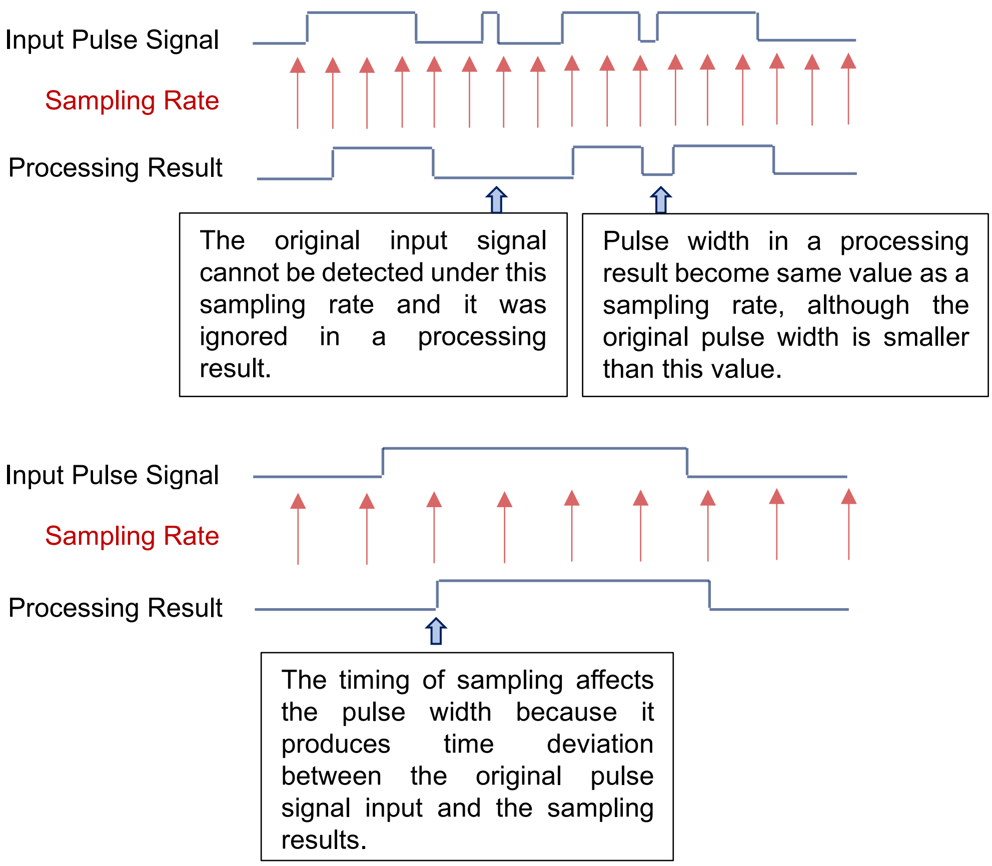
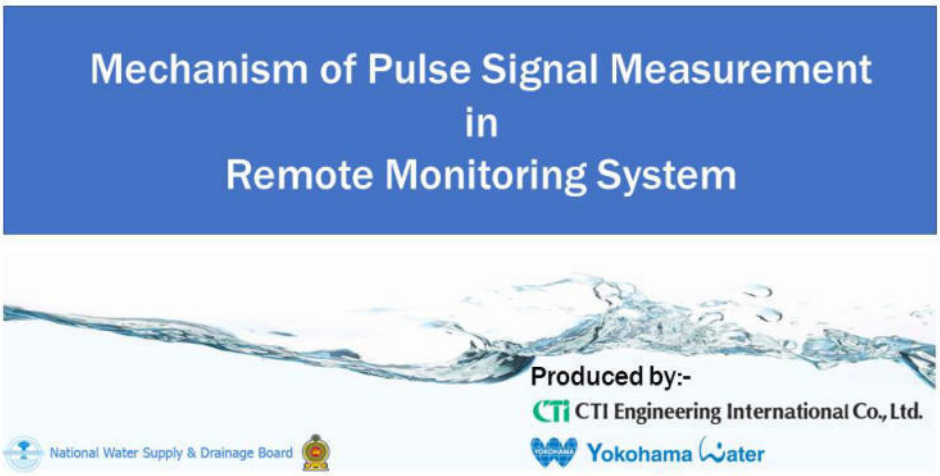


Figure 3.3.4 Importance of Selection of Appropriate Sampling Rate

3.3.2 Test Kit for Pulse Measurement Practice

The process of recording the pulse output from the flow meter with a data logger will be explained using the following system so that you can understand it in the indoor training.

Video Lecture



(1) Contents of the test kit

A. Electronic turbine flow meter

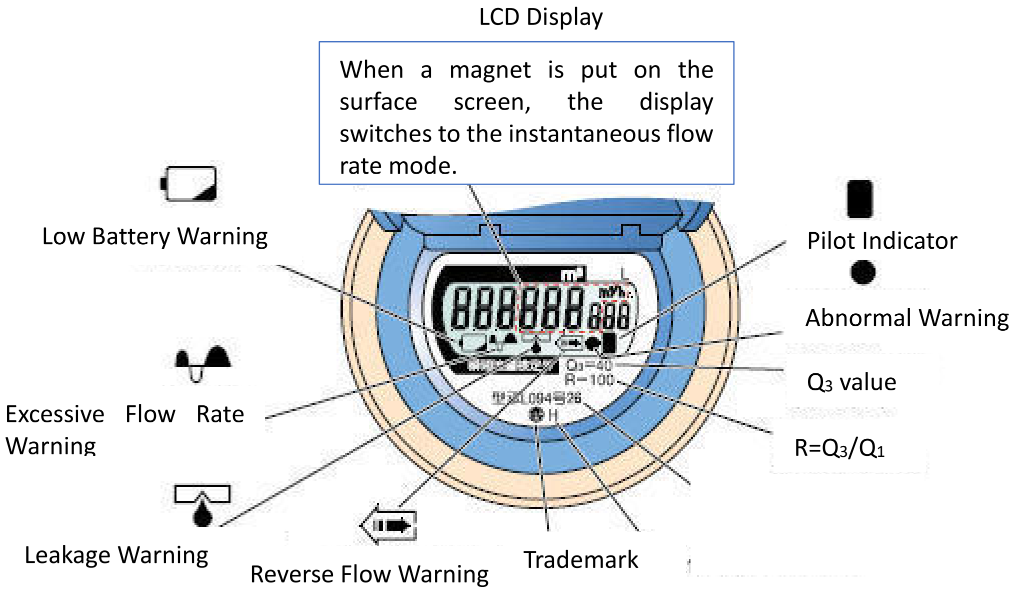
Nominal Diameter: 13mm Type: Single jet turbine flow meter

Manufacturer: Aichitokei Denki EDS13Q

Specifications:

Q_1:	0.025 m^3/h (0.42 L/min)
Q_2:	0.040 m^3/h (0.67 L/min)
Q_3:	2.5 m^3/h (41.67 L/min)
R (Q_3/Q_1)	100
Pulse rate:	1 L/P (Open Drain Pulse)

Using the electric air pump of this test kit the impeller rotates at a speed equivalent to a flow rate of about 1.5 m^3/h.



B. Electric Air Pump

This pump is used supply air power to rotate the impeller of a water meter.

The internal battery (4000mAh) Can be charged with a USB cable.

Since the air volume is too large in the default state, it is desirable to cover half of the outlet with tape.

C. Wireless Pulse Logger

The pulse signal output from the water meter can be recorded and displayed as a graph on a tablet or PC using a dedicated application.

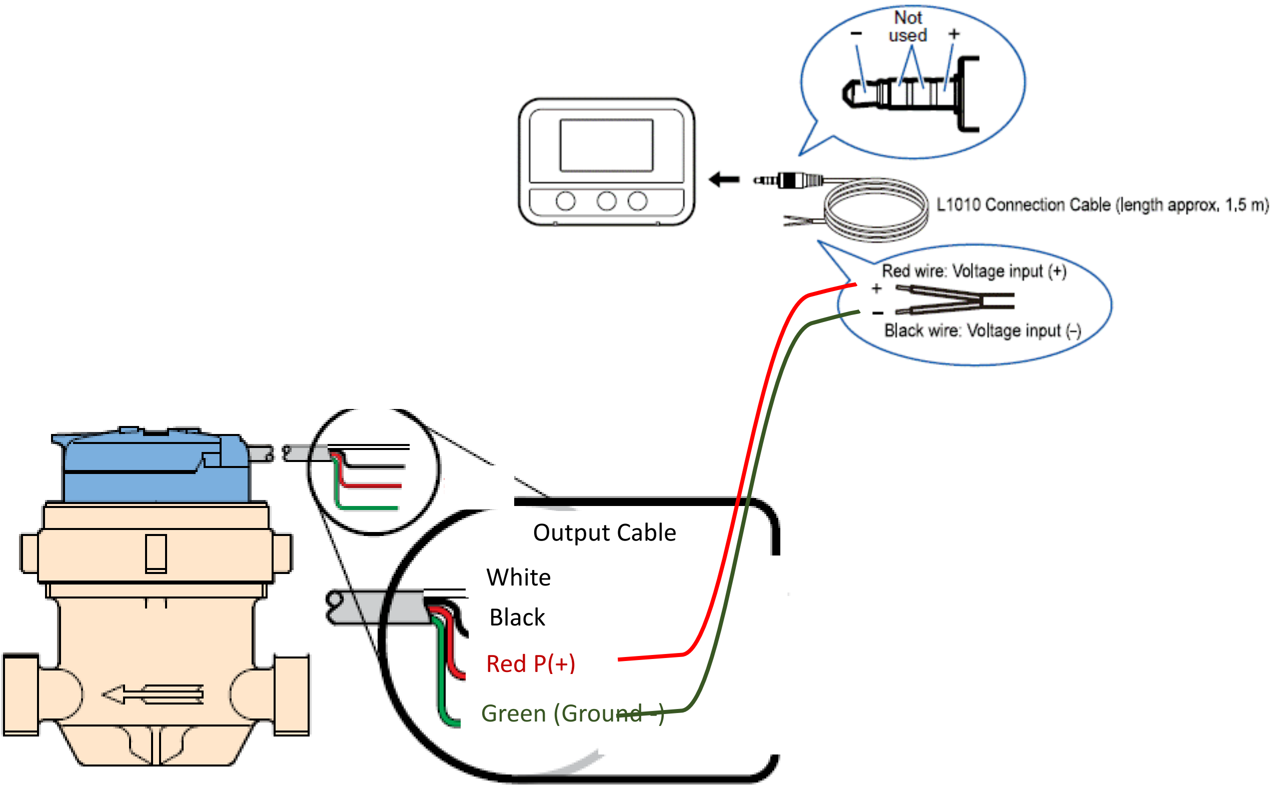
The battery life varies depending on the recording interval. In case of the free run function, the battery life is the same as for 1 second regardless of the ¥recording interval setting. (when recording interval setting is more than 2 seconds.)

Mode	Recording interval			
	0.1 sec.	1 sec.	10 sec.	1 min.
Real-time measurement Bluetooth ON	Approx. 5 days	Approx. 7 days	Approx. 10 days	Approx. 10 days
Manual data collection Bluetooth ON	Approx. 14 days	Approx. 14 days	Approx. 14 days	Approx. 14 days
Manual data collection Bluetooth OFF	Approx. 1.5 months	Approx. 2 months	Approx. 2 months	Approx. 2 months

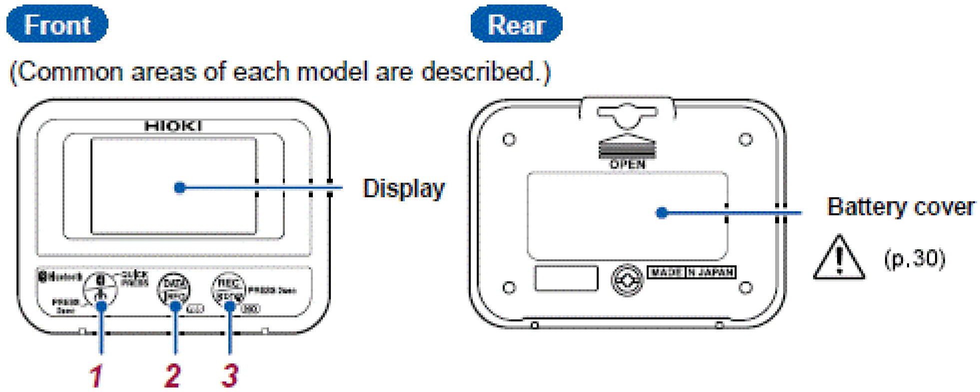
(2) Pulse measurement using a test kit

❶ Connect the pulse logger and electronic water meter

Connect the connection cable to the LR8512 connection terminal.



❷ Configure the pulse logger LR8512

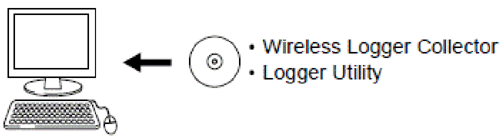


Operation keys	Press briefly	Hold down (for at least 2 seconds)
1 Power 	Bluetooth ON/OFF	Power ON/OFF
2 Display 	Display change YES (During operation verification)	-
3 Measurement 	NO (During operation verification)	Measurement start/stop as manual mode

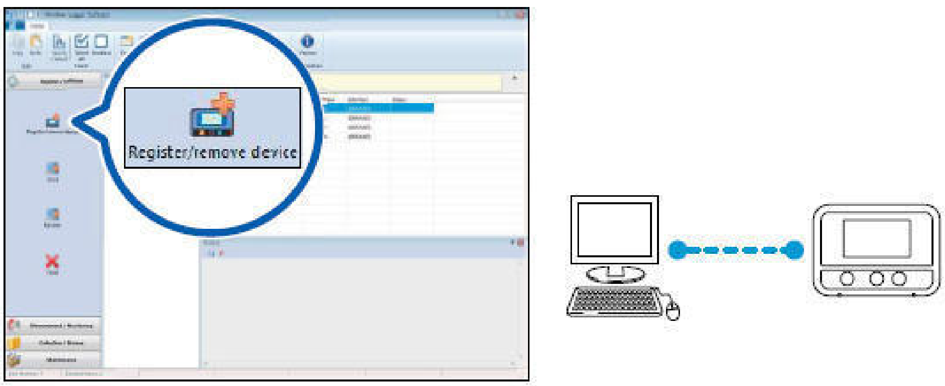
Note: To save the battery life, select OFF in Bluetooth mode if you do not need frequent communication.

Measurement Workflow

1 Install the software on the Windows® PC.



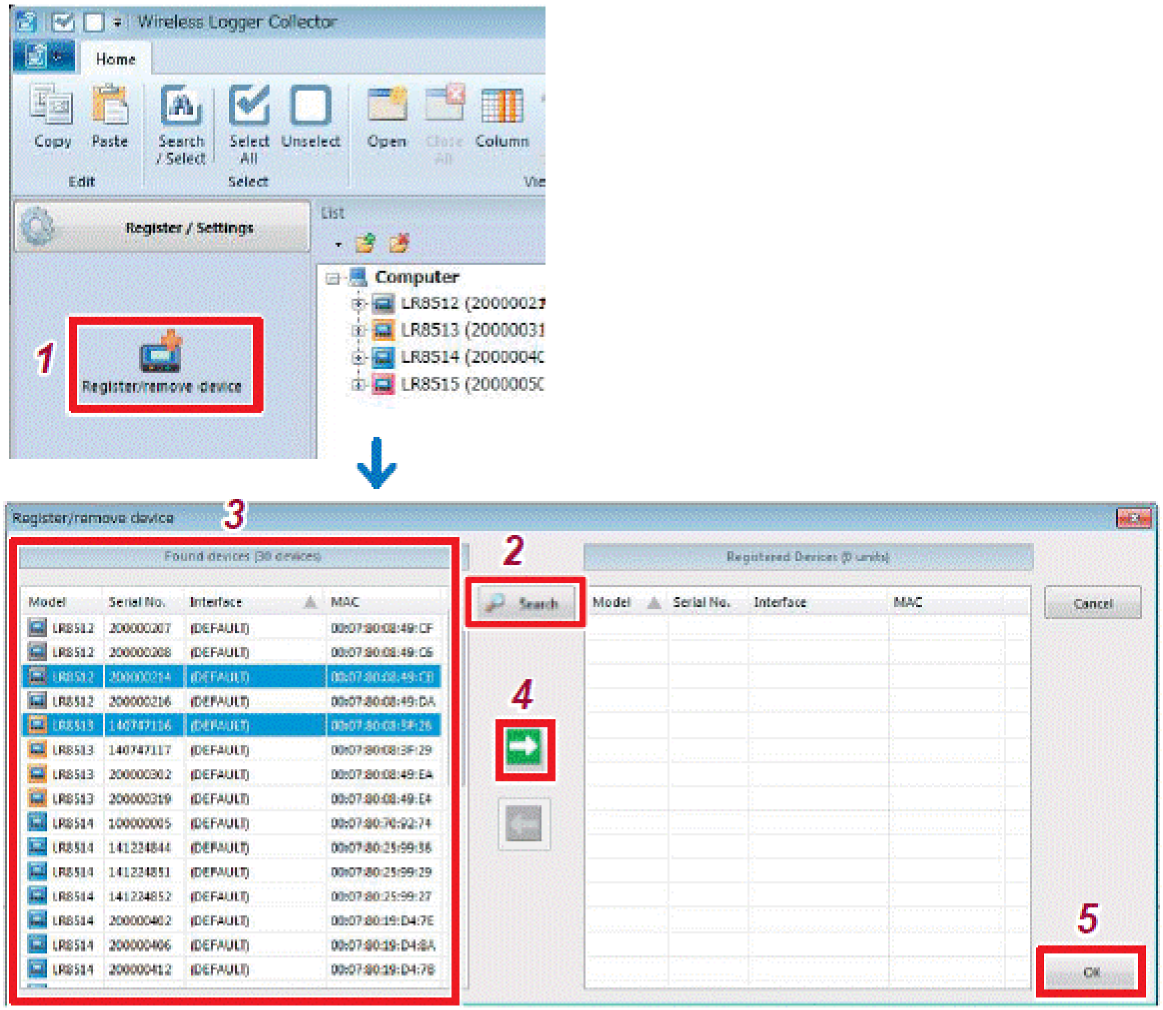
2 Register the instrument in Wireless Logger Collector.



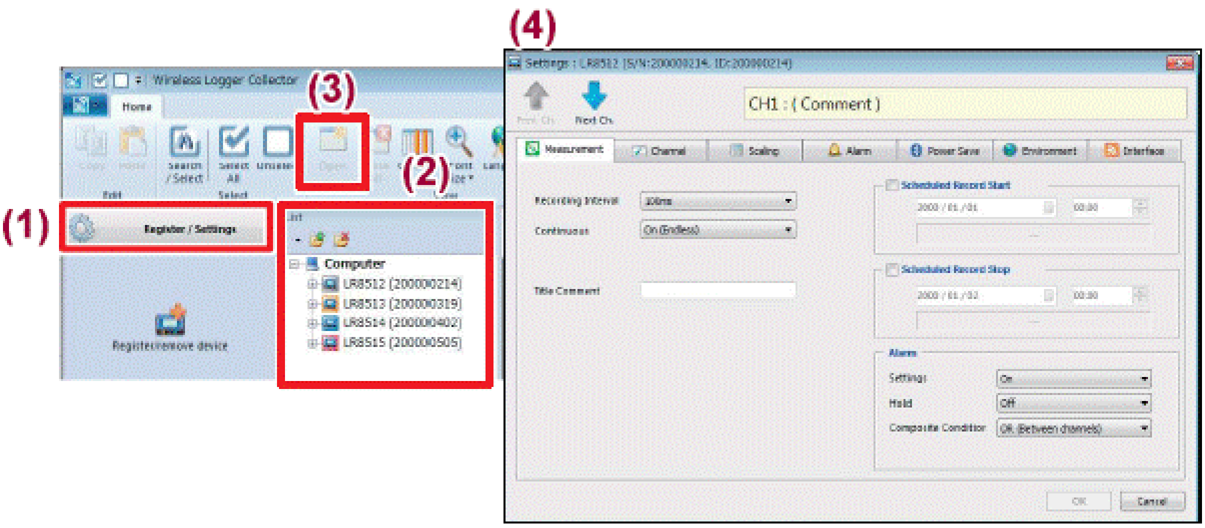
When no wireless logger is found

- When the symbol in the screen is off, press the power key to turn ON the Bluetooth function.
- When the symbol in the screen is off, a wireless connection is not established. Place the instrument closer to the PC or remove any obstacle and then search for the logger again.

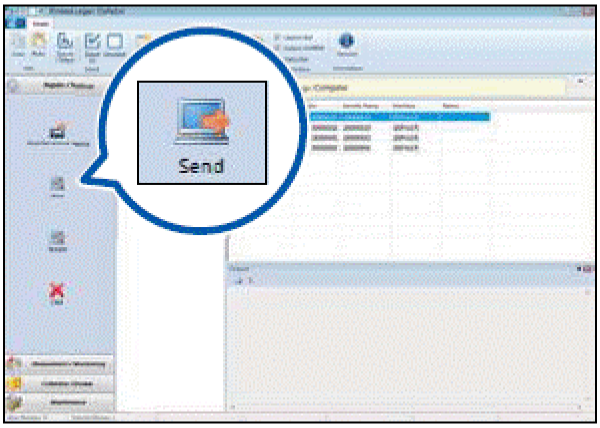
Registration



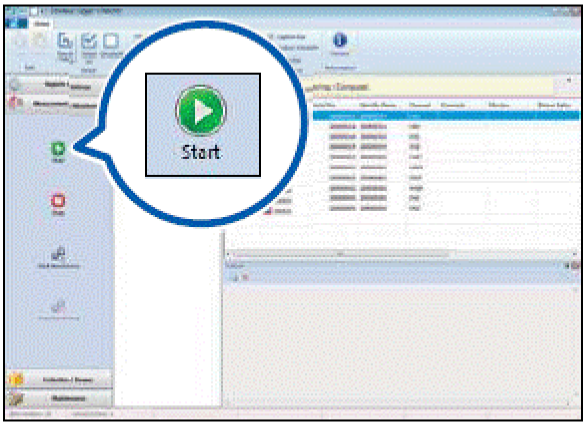
3 Set the measurement conditions in Wireless Logger Collector.



4 Send the measurement conditions to the instrument.

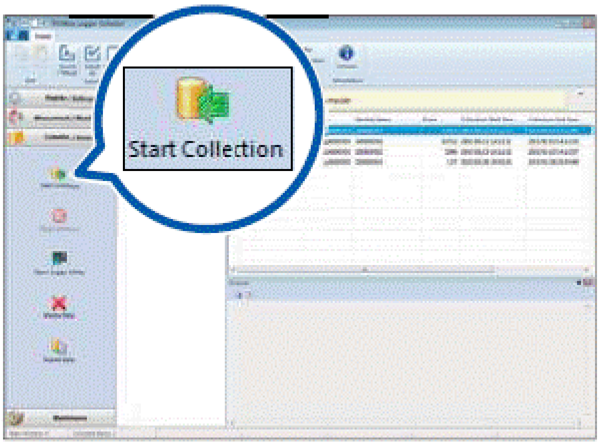


5 Start measurement.



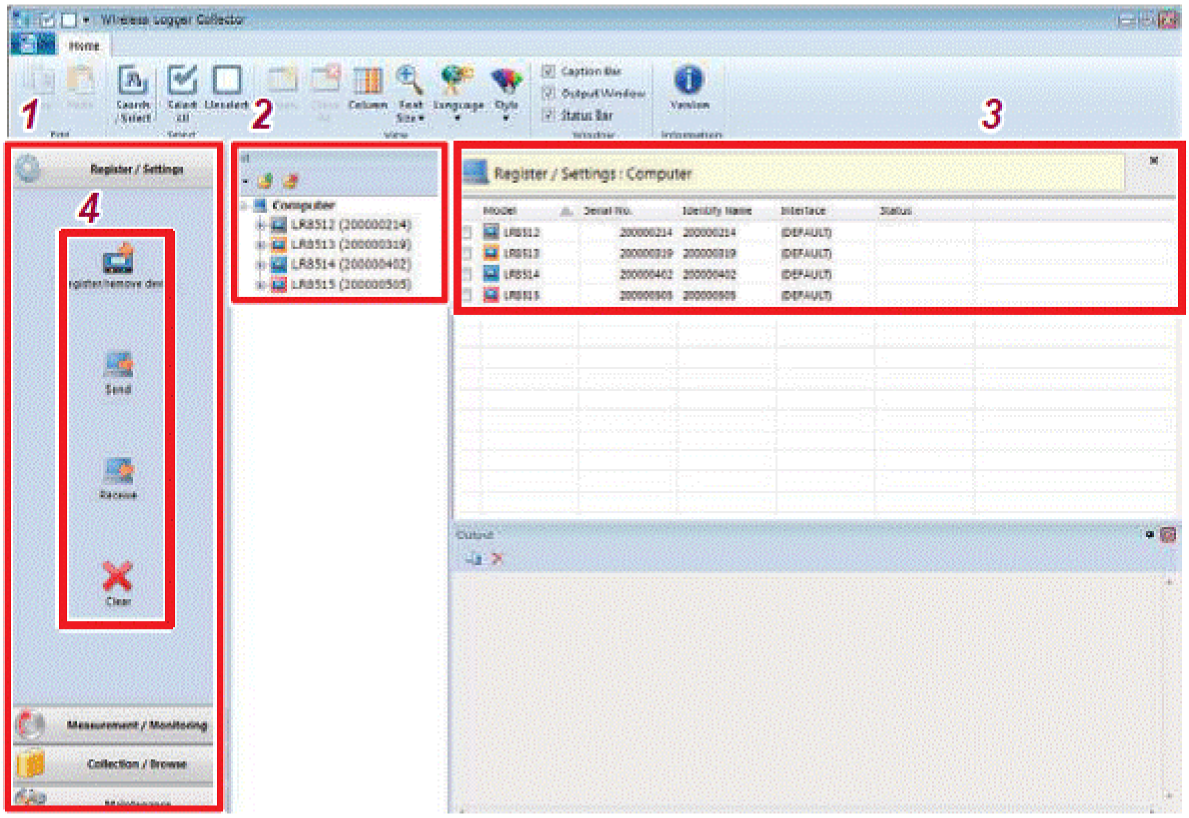
You can also start measurement by holding down this button.

6 Collect measurement data using Wireless Logger Collector



Basic Operation Procedure

[Operation flow]



1 Select one of the following categories from the Navigation bar.

[Register/Settings]

[Measurement/Monitoring]

[Collection/Browse]

[Maintenance]

2 Select a group and wireless logger from the wireless logger list.

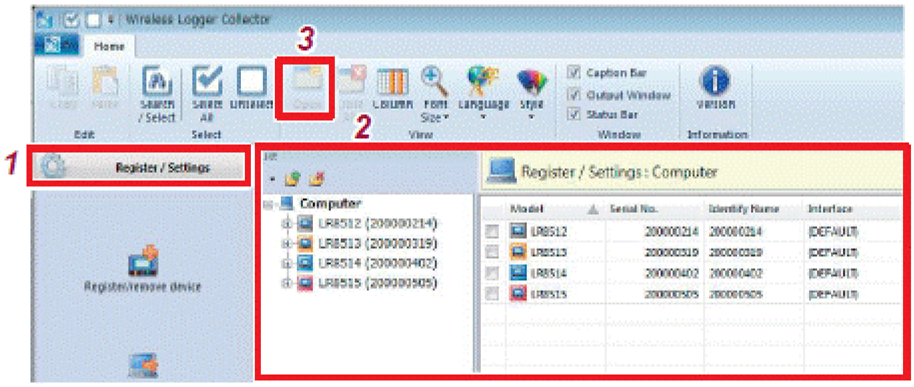
3 Select the item to be displayed from the wireless logger/channel/file list.

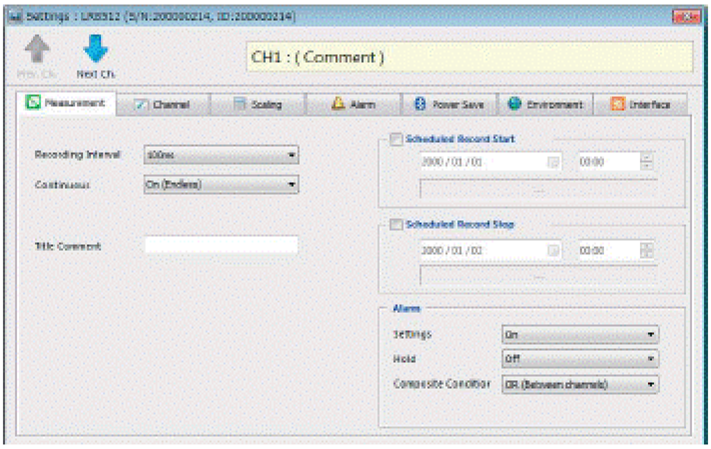
4 Press the operation button of the Navigation bar.

Or right-click the item in the list and select the operation from the displayed menu.

Setting Measurement Conditions

Set the measurement conditions for wireless loggers.





1 Select [Register/Settings] from the Navigation bar.

2 Select the target wireless logger.

3 Click [Open] on the Ribbon bar. → The settings dialog box is displayed.

[Recording Interval]

Allows you to set the interval to import data.

Setting options:

0.1 sec., 0.2 sec., 0.5 sec., 1 sec., 2 sec., 5 sec., 10 sec., 20 sec., 30 sec., 1 min., 2 min., 5 min., 10 min., 20 min., 30 min., 1 hour

In this trial system with EDS13Q, the air pump blows between 1 and 2 m^3/h of air into the meter, so the meter will emit about 20 pulses per minute.

Therefore, in this trial work with HIOKI LR8512, select “1 min”.

[Continuous Recording]

Allows you to set a processing method when the memory is full.

Setting options:

Off (One-time):	Stops recording when the memory is full.
On (Endless):	Overwrites old data when the memory is full.

In this trial work with HIOKI LR8512, select “On (Endless)”.

[Title Comment]

Allows you to set the title comment. (Up to 40 single-byte characters)

The characters entered are converted to the following symbols.

^2	^{2} (Superscript)
^3	^{3} (Superscript)
~u	µ
~c	°
~e	ε

In this trial work with HIOKI LR8512, input “Trial” as a title comment.

[Scheduled Record Start]

Measurement can be started at the specified time.

If the current time has passed the preset time, measurement is not started.

Setting options:

☑	OFF (The preset start function is disabled.)
□	Starts recording at the preset time.

The instrument enters the recording start standby state at the same time as the Scheduled Record Start ON setting is sent. Measurement start by signal communications cannot be accepted in this state.

In this trial work with HIOKI LR8512, select “OFF”, because we use manual operation mode.

[Scheduled Record Stop]

Measurement can be stopped at the specified time.

If the current time has passed the preset time, measurement is not stopped.

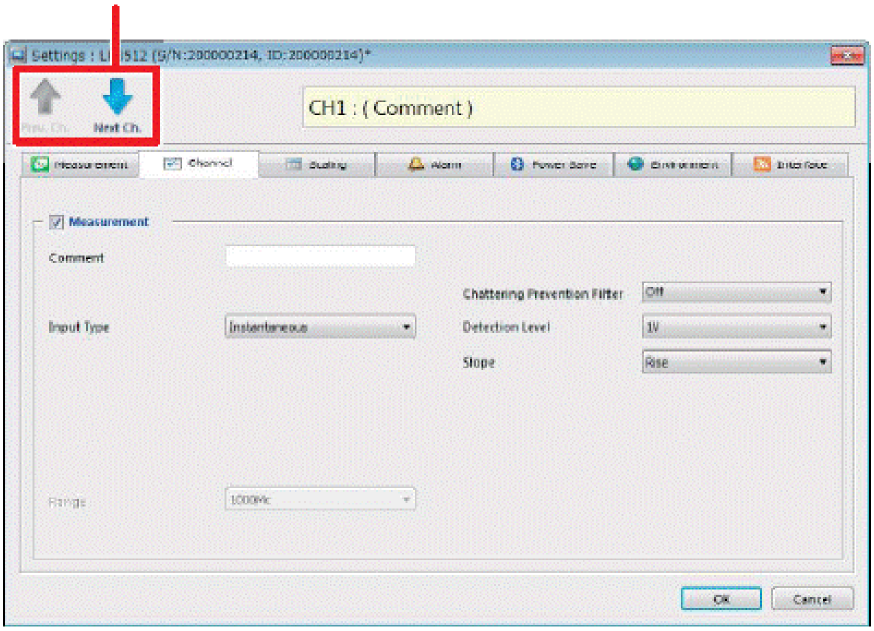
Setting options:

☑	OFF (The preset start function is disabled.)
□	Stops recording at the preset time.

In this trial work with HIOKI LR8512, select “OFF”, because we use manual operation mode.

Setting the channel

The channel to be set is switched.



In this trial work with HIOKI LR8512, no need setting for CH2 and delete the check from CH2 measurement.

[Measurement]

Allows you to set measurement to ON/OFF.

Setting options:

□	Does not perform measurement
☑	Performs measurement

After updating the firmware of Wireless Logger Collector, this selection mode will not appear.

[Comment]

Allows you to set the channel comment. (Up to 40 single-byte characters)

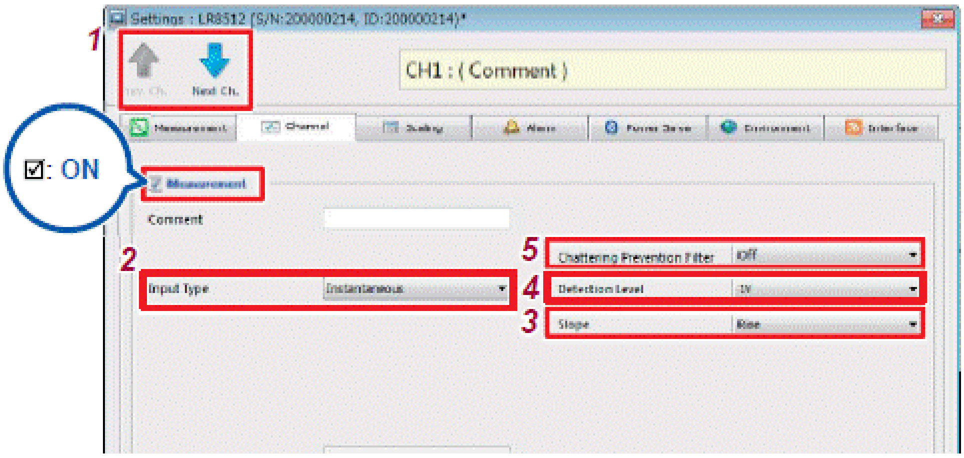
The characters entered are converted to the following symbols.

^2	^{2} (Superscript)
^3	^{3} (Superscript)
~u	µ
~c	°
~e	ε

In this trial work with HIOKI LR8512, remain this part blank

Making setting for integrated measurement

The number of integrated pulse output from the integrated power meter or flow meter is measured.

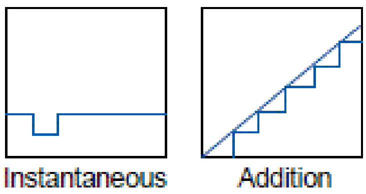


1 Select the channel to be set and check the Measurement checkbox [☑] (ON).

2 Select the input type.

Setting options:

Instantaneous	Measures the number of pulses input to the instrument within the recording interval. The number of pulses is reset for each recording interval.
Add	Measures the number of integrated pulses after measurement starts.



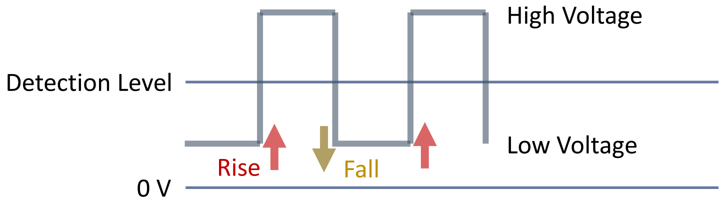
In this trial work with HIOKI LR8512, select “Instantaneous” mode.

3 Select the measurement reference (slope).

Setting options:

Rise	Integrates the number of times the pulse changes from LOW to HIGH.
Fall	Integrates the number of times the pulse changes from HIGH to LOW.

In this trial work with HIOKI LR8512, select “Fall” mode.



4 Select the HIGH/LOW reference value (detection level)

Setting options:

1 V	Determines 1.0 V or higher to be HIGH, 0 V to 0.5 V to be LOW.
4 V	Determines 4.0 V or higher to be HIGH, 0 V to 1.5 V to be LOW.

In this trial work with HIOKI LR8512, select “4V” mode.

5 Select the chattering prevention filter setting.

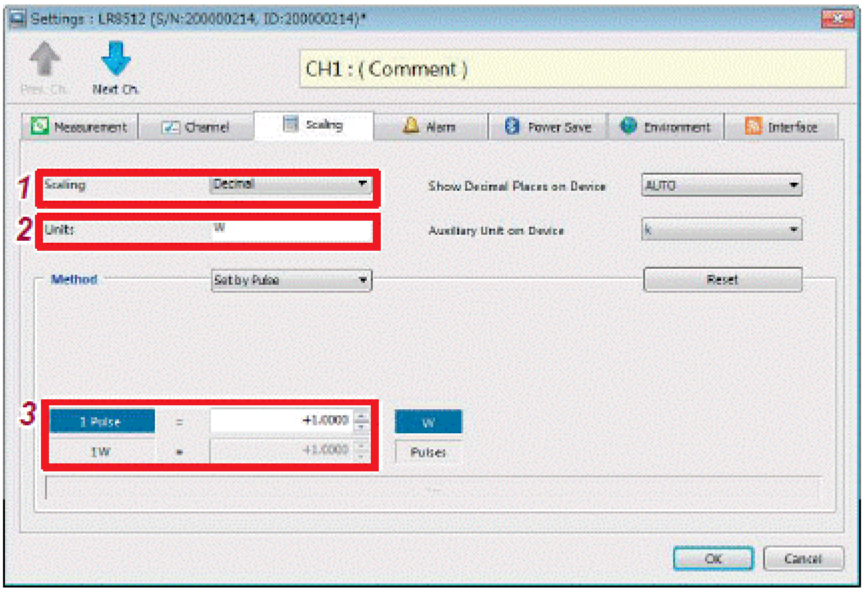
Setting options:

OFF	Turns OFF the chattering prevention filter.
ON	Turns ON the chattering prevention filter. For mechanical contact (relay) output signals, a count error due to chattering can be prevented.

In this trial work with HIOKI LR8512, select “OFF” mode.

Setting scaling for integrated measurement

The number of integrated pulses can be converted to a physical quantity for the object to be measured.
For a pulse output instrument, the physical quantity per pulse or the number of pulses per basic unit (example: 1 kWh, 1 L, 1 m^3) is defined.



1 Select the display format of the scaling value.

Setting options:

OFF	No scaling
Decimal	Displays the converted value as a decimal number
Exponential	Displays the converted value as an index number. Wireless logger display is in a decimal number only.

In this trial work, select “Decimal” mode.

2 Set the unit to be converted (up to 7 single-byte characters)

The characters entered are converted to the following symbols.

^2	^{2} (Superscript)
^3	^{3} (Superscript)
~u	µ
~c	°
~e	ε

3 Set the physical quantity per pulse or the number of pulses per basic unit

The electronic flow meter (EDS13Q) emits pulse signal per 1 L of water flow, so in this trial work the scale setting shall be the followings:

Scaling: Select “Decimal” option.

Unit: Input “L” from keyboard.

1 pulse = +1.000 L

Setting the displayed digit under decimal point

The measurement value is displayed with the decimal point fixed to the specified digit.

Setting options:

AUTO	Displays a 4-digit value (0,000 to ±9,999). The decimal point position is changes as needed.
0 Digit / 1 Digit 2 Digit / 3 Digit	The decimal point is fixed to the specified digit.

In this trial work, select “AUTO” mode.

Setting the auxiliary unit

The value obtained when the measurement value is multiplied by the constant shown in the following table is displayed in the wireless logger screen. (The measurement value is not affected.)

Setting options:

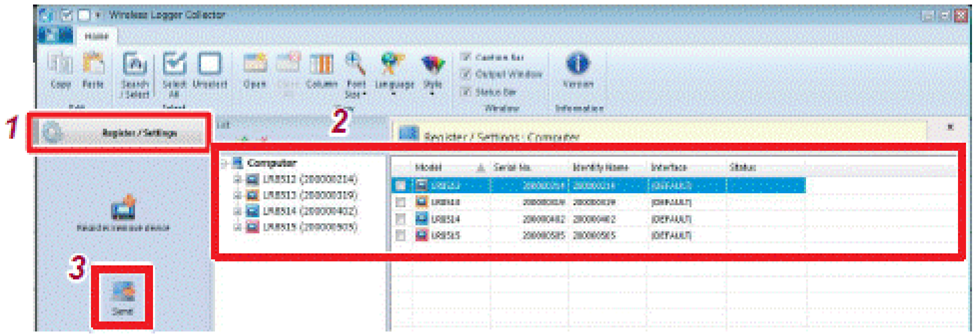
μ (micro)	$\times 10^{6}$
m (milli)	$\times 10^{3}$
-	$\times 1$
k (kilo)	$\times 10^{-3}$
M (mega)	$\times 10^{-6}$

Reset

The conversion parameter (conversion ratio, offset, input, output) is restored to the default setting.

Sending the settings

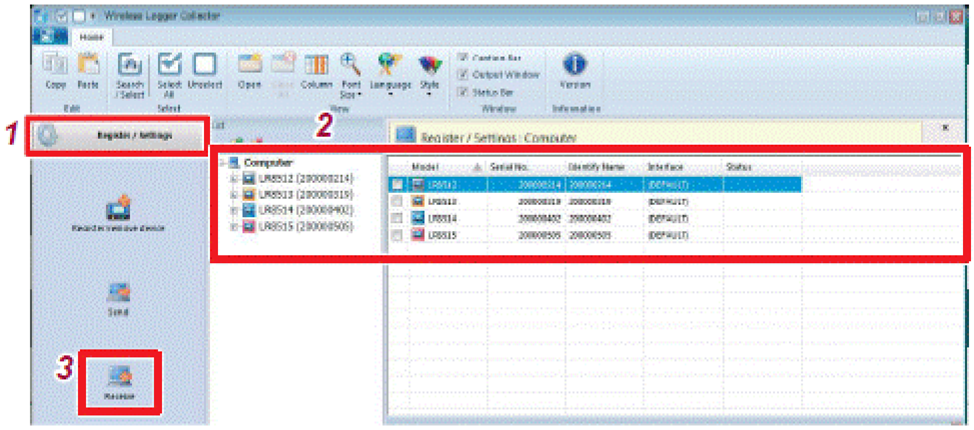
The setting conditions edited in Wireless Logger Collector are sent to and set for wireless loggers using wireless communications.



1 Select [Register/Settings] from the Navigation bar.
2 Select the target wireless logger.
3 Press [Send].

Receiving the settings

To confirm the current setting of logger, you can proceed to the following steps using wireless communications.

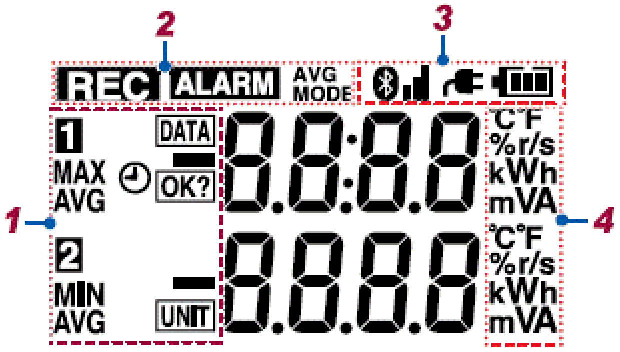


1 Select [Register/Settings] from the Navigation bar.
2 Select the target wireless logger.
3 Press [Receive].

> When the settings are received, the settings of the corresponding unit are all overwritten. The settings cannot be restored once they are overwritten.

Detail of Display

Display



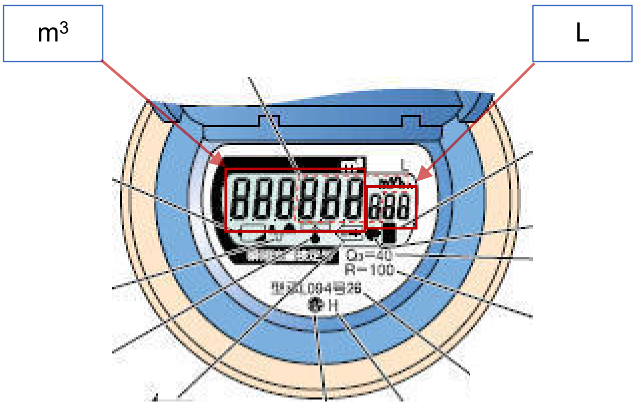
Display		Description
1	1 2	Channel (CH) Blinking: During monitoring
	MAX MIN AVG	Maximum value Minimum value Average value
	DATA	Data number
	UNIT	Unit number
		Date and time
	OK?	Operation verification
2	REC	Measurement Lit: Performing measurement Blinking: Waiting for a measurement start to be preset
	ALARM	Alarm Lit: The current measurement value is outside the range. Blinking: There was a value that was outside the range but the current value is in the range. (Alarm hold)

Display		Description
2	AVG MODE	Lit: Average recording mode Blinking: Maximum recording mode (LR8513 Wireless Clamp Logger only)
3		Lit: Bluetooth ON Blinking: Bluetooth OFF (The power saving function is enabled.) Off: Bluetooth OFF
		Bluetooth connection status (3 levels) (Signal strength 1: Weak to 3: Strong) Blinking: Security lock Off: Bluetooth not connected
		Operating with the AC adapter
		Battery indicator display (p. 31)
4		Displays the unit of measurement values.

- While the Bluetooth is being connected (the antenna symbol () is lit), it cannot be turned off.
- The power cannot be turned off during measurement.
- During real-time measurement using the LR8410 Wireless Logging Station, the measurement cannot be stopped with key operation on the instrument.

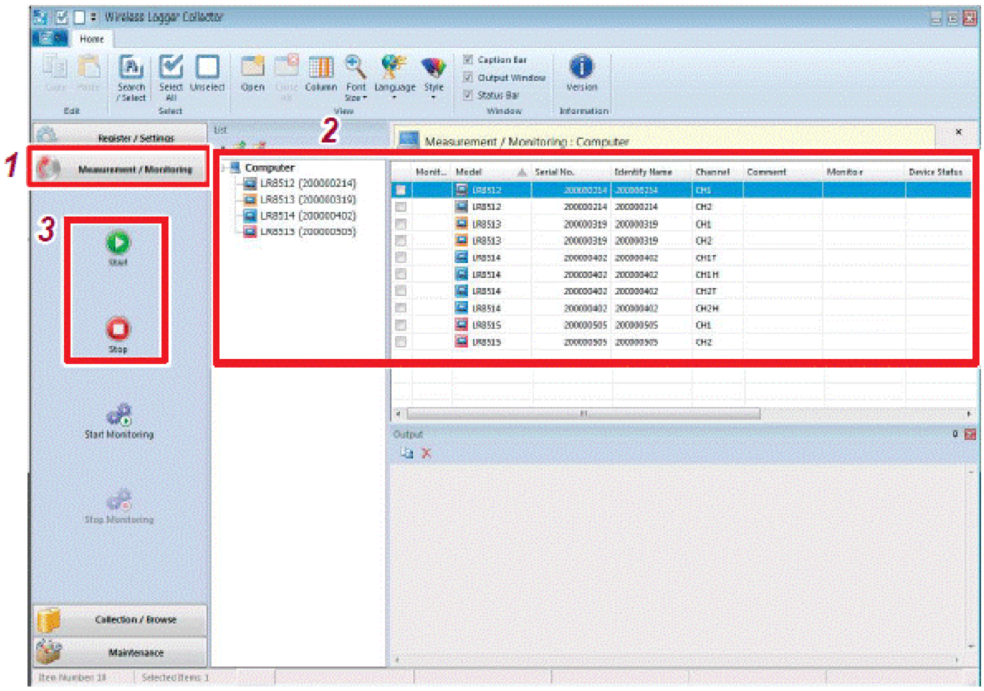
❸ Check the displayed value of the electronic turbine flow meter

Before starting the test, check and record the readings on the electronic turbine flow meter.



❹ Start recording of pulse logger

In this trial work, you start measurement by manual mode.

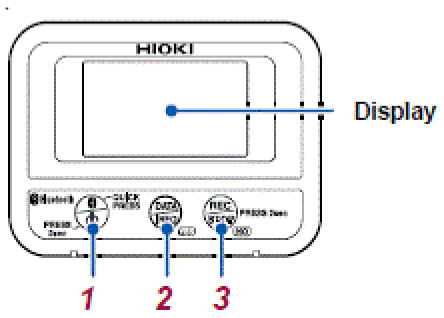


1 Select [Measurement/Monitoring] from the Navigation bar.

2 Select the target wireless logger.

3 Press [Start].

This start/step can also be controlled by manual mode as follows:



Hold down the button 1 for 2 seconds to start up the pulse logger.
Next, hold down the button 3 “REC/STOP” at least 2 seconds, and REC sign will appear on the display. Then Wireless logger measurement is started.

❺ Start the electric air pump and wait for 3 minutes.

Press the ON / OFF button of the electric air pump to send air into the flow meter.

Wait for about 3 minutes while checking that the value displayed on the meter is increasing.

❻ Stop the electric air pump

After about 3 minutes, press the ON / OFF button of the electric pump to stop.

❼ Stop recording of pulse logger

Select Stop in the same way as you started.
or
Hold down the button 3 “REC/STOP” at least 2 seconds, and REC sign will disappear on the display. Then Wireless logger measurement is stopped.

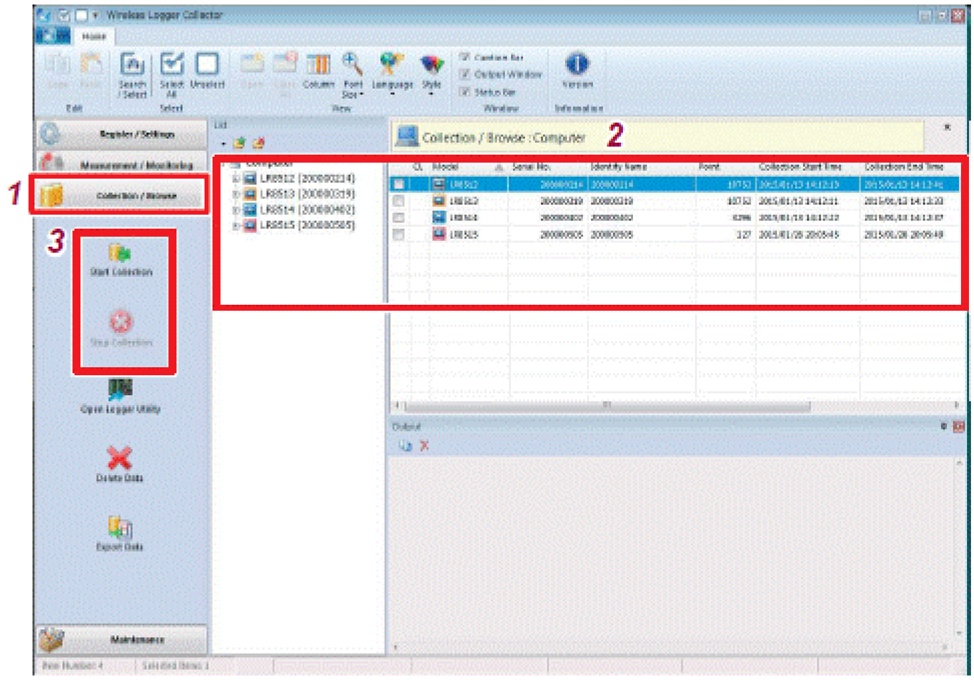
❽ Check the displayed value of the electronic water meter and calculate the passing flow rate

Before starting pump :	A (L)
After stopping pump :	B (L)
Passing flow :	B - A (L)

❾ Download recorded data of the pulse logger

Collecting Measurement Data

Measurement data is collected from wireless loggers. Measurement data can be collected even while wireless loggers are being measured. Measurement data is periodically collected until the data collection is stopped once the collection interval is set.



1 Select [Collection/Browse] from the Navigation bar.
2 Select the target wireless logger.
3 Press [Start Collection].

You can select the one of the following two ways to check the downloaded pulse data:

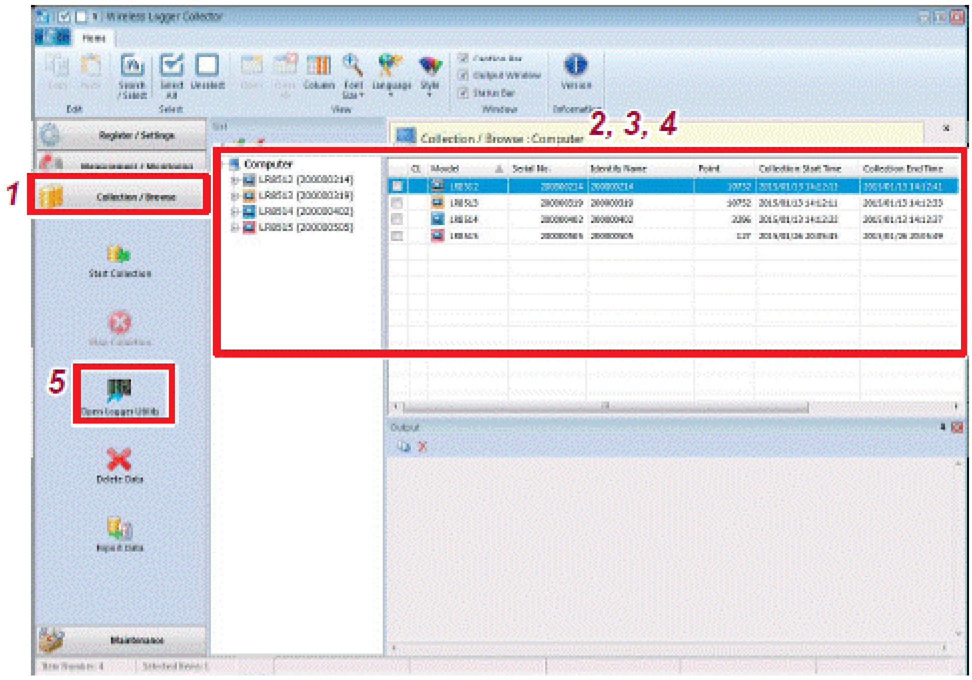
- Display with Logger Utility software
- Export data in csv format → Confirm it with MS Excel

[Logger Utility Software]

Logger Utility Software is for analyzing signal waveforms such as current, voltage, and temperature, and is not normally used for pulse loggers.

However, with this software, it is possible to check the data without downloading the data recorded in the pulse logger.

Collected measurement data can be displayed in a waveform using the Logger Utility.



1 Select [Collection/Browse] from the Navigation bar.
2 Select the target wireless logger.
3 Double-click the target wireless logger in the list using the mouse.
4 Select the measurement data to be browsed from the list.
5 Press [Open Logger Utility].

⑩ Calculate the flow rate from the recorded value of the pulse logger and compare it with the actual passing flow rate.

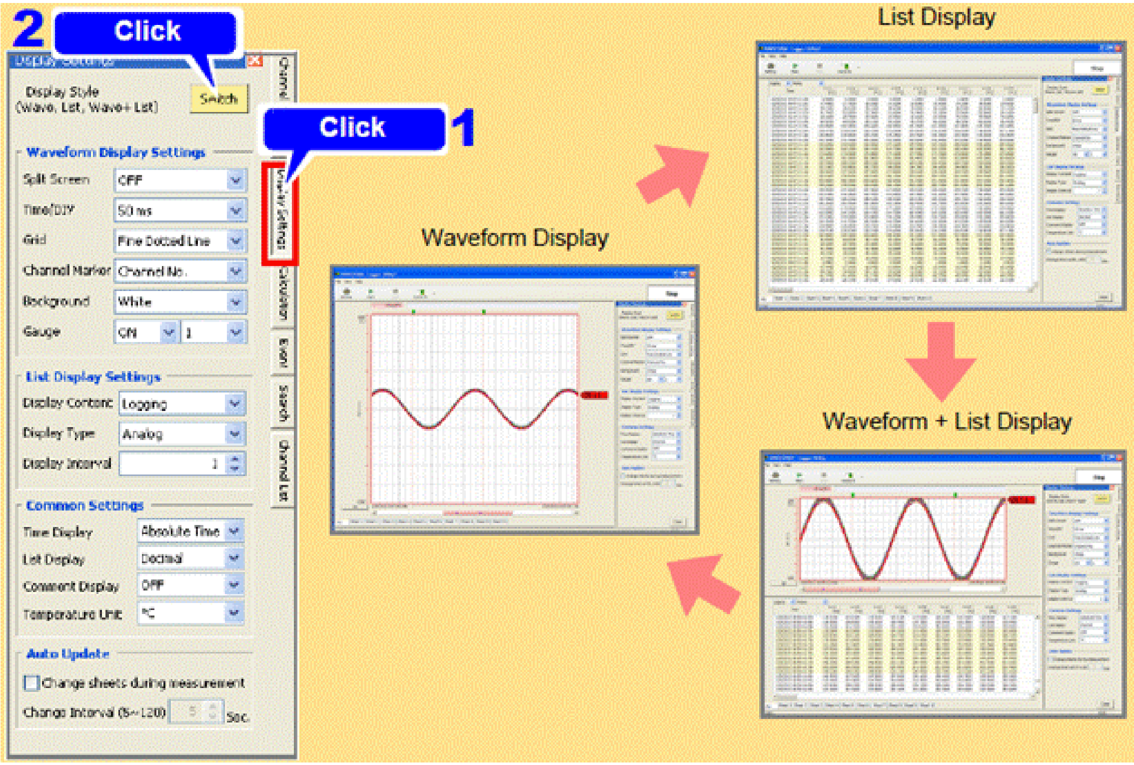
When the Logger Utility starts, the following screen is displayed.

You can switch the measurement data display method of the main screen among waveform display, list display and waveform plus list display.

1 Click the [Display Setting] tab on the right side of the main screen to open the setting window.
2 Each click of the [Switch] button switches the display of the main screen.

Selectable items:

List Display	Displays waveforms data as numerical values. It is also possible to display calculation results.
Wave Display	Displays measured waveforms.
Wave + List display	display both the waveform display and list display in one screen.



In this trial test, the waveform is not displayed because it only counts the pulses generated every minute.

⓫ Example of trial test

No	Action and record	Photos
1	Meter reading before starting the test Meter reading: 0000 m^3 566.5 L	
2	Start recording of data logger → Start the electric air pump → Stop the electric air pump, after 3 minutes → Wait until the meter counter stops → Stop recording of data logger	
3	Meter reading after stopping the test 0000 m^3 644.5 L	
4	If you attach a magnet to the top of the meter during the test, the instantaneous flow rate will be displayed. Instantaneous flow : 1.56 m^3/h	
5	Passed flow: 644.5 - 566.5 = 78.0 L	

No	Action and record	Photos
6	Recorded data in the pulse logger: Initial 1 minute = 24 L Next 1 minute = 25 L last 1 minute = 24 L Total = 73 L Error = (78-73)/78*100 = 6.4 % (Note 1)	Time | 1-1-1 [L] '20-10-02 19:24:54s | 0.0000 '20-10-02 19:25:54s | 24.0000 '20-10-02 19:26:54s | 25.0000 '20-10-02 19:27:54s | 24.0000
7	Calculate the instantaneous flow rate from the value of the pulse logger: 25 L/min → 1.5 m^3/h It matches the recorded value of the water meter.	

Note 1: The longer you record the data, the smaller the data error is.

National Water Supply & Drainage Board

Agencia de Cooperación Internacional del Japón

Supporting Document for TOT No.7

Basic Knowledge of Remote Monitoring System and Technical Guideline

April 2021

Contents

Chapter 1 Mechanism of pulse measurement

1.1 What is Pulse Signal?

Pulse Signal = Wave of Electrical Signal

The frequency of AC power supplied in Sri Lanka is 50Hz.

This value is the frequency of an electrical signal repeated per unit time, and "Hz" means the frequency per second. A wave of an electrical signal having a certain width generated in an extremely short time like this signal is called a "Pulse Signal", and the signal is classified as a square wave.

Classification indicator of pulse signal

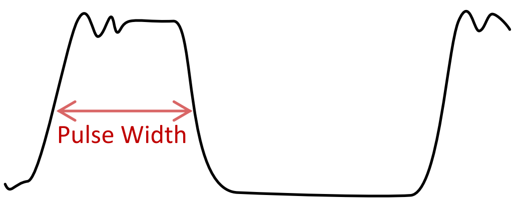
There are various types of pulse signals, which are classified according to their characteristics, and the characteristics of the signal are expressed using the following indexes.

❶ Indicator by number of times

A pulse that occurs only once when an event occurs is called an "On-shot Pulse", and a pulse that occurs continuously and repeatedly is called a "Continuous Pulse". An On-shot Pulse is used to detect when an object passes a single point, and a Continuous Pulse is used to measure the number of revolutions of a motor.

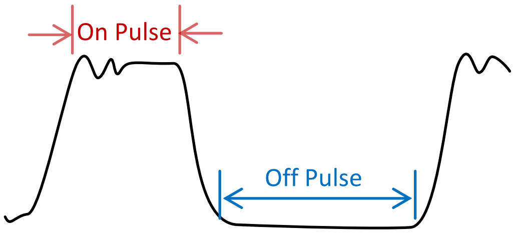
❷ Indicator by duration (width)

The time interval between the half point of the rising curve and the half point of the falling curve is called the pulse width.
There are various pulse widths, from a very small pulse width of 0.1 μsec to a very large pulse width of a few seconds.



❸ Indicator by interval

This is an indicator of the time interval at which repeated pulses are turned on and off.
The pulse width (mentioned in ❷) indicates the on-time of the pulse, whereas it indicates the off-time.
Since optical communication requires a very high bit rate, it is necessary to shorten the interval between output pulse signals and pack many pulses in a short time.



❹ Indicator by regularity

It is classified according to whether the pulses occur with a certain regularity or completely irregularly.
The serial communication signal is a representative of regular pulses, and the signal that detects the movement of a person is a representative of irregular pulses.

Applications for pulse signals

There are two uses for pulse signals:

- ➢ To measure using the input signal → Theme of this guideline
- ➢ To control an object outputting a signal

A basic application of measurement is to detect the rotation speed of a motor using a rotary encoder or the like, and display or analyze the rotation speed from a pulse signal. Typical systems that control drive using pulses include stepping motors (pulse motors) and servomotors.

In order to control these systems, an operation called "modulation" of electrical signals is indispensable. A method of transmitting and generating an electrical signal by changing a pulse is called pulse modulation.

★Pulse Width Modulation (PWM)

A method of controlling by changing the pulse width while keeping the pulse height (amplitude) constant.

★Pulse Amplitude Modulation (PAM)

A method of controlling by changing the pulse amplitude. In a pulse amplitude modulation inverter used in an air conditioner, the amplitude of the pulse voltage is changed by controlling the voltage of the rectifying unit.

1.2 Pulse Signal and Rotation Speed

A pulse that grasps and controls the rotation of the motor

There are two uses for pulse signals, which what is common to all of the above utilization methods is the element of "rotation".

❶ To measure using the input signal → Theme of this guideline

In the case of an impeller type water meter, a preset pulse signal is output according to the rotation speed of the impeller. Therefore, the flow that has passed can be measured by counting the pulse signals generated within a certain period of time.

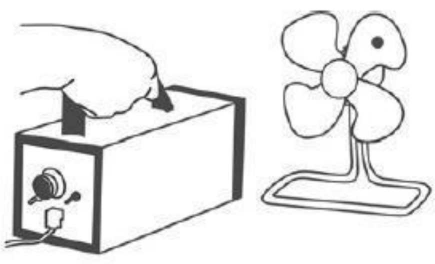
❷ To control an object outputting a signal

By outputting pulses, it is possible to control systems such as motors and inverters.

Measurement of rotation speed using pulses

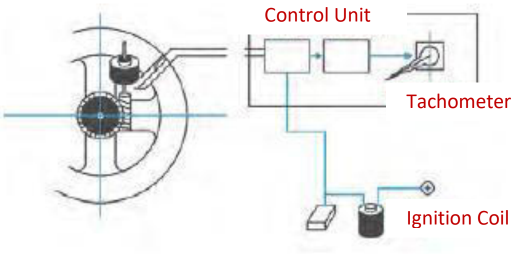
★Measurement with stroboscope

A device that repeatedly emits light that lights up instantaneously at regular intervals is called a stroboscope.
The figure shown on the right is a simple system of which a certain rotating wing is irradiated with light at equal time intervals using a stroboscope. When the blinking cycle of the light and the rotating cycle match, the wing rotating at high speed appears to be stationary. A stroboscope is a method of grasping a high-speed rotation speed by utilizing this phenomenon and is used for measuring the rotation speed of an engine or a motor and inspecting the presence or absence of damage to a rotating body.



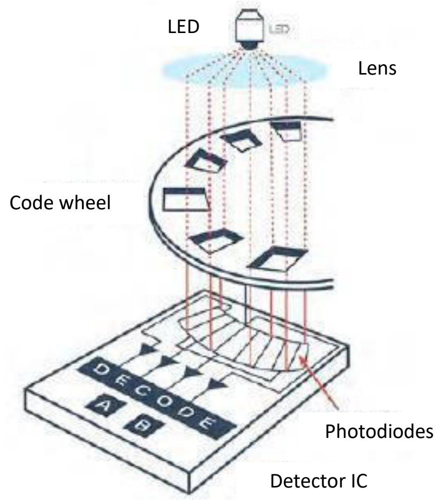
★Measurement with a tachometer

Tachometers that measure the number of revolutions of engines and motors can be classified into mechanical tachometers that read the rotation mechanically and electric tachometers that read the rotation electrically. Currently, many automobiles use electric tachometers.



★Measurement with optical equipment

Infrared light from a light emitting diode is applied to a rotating disk with fine slits and holes.
By passing the light that has passed through the slit or hole through the photodiode, the mechanical rotational displacement can be converted into a pulse signal and the number of revolutions can be obtained.
This similar technique is used when performing pre-shipment verification at water meter factories.



1.3 Mechanism of pulse measurement

Know the frequency and period from the output pulse signal

Pulse signals are used in various measurement sites such as automobile speed, water flow rate, and electricity usage.

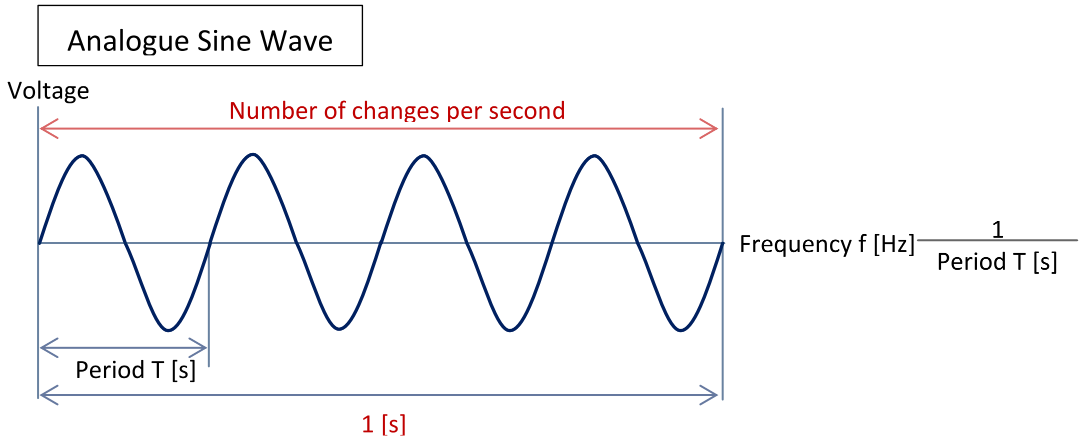
However, even if we look only at the pulse signal, we do not know the specific value.

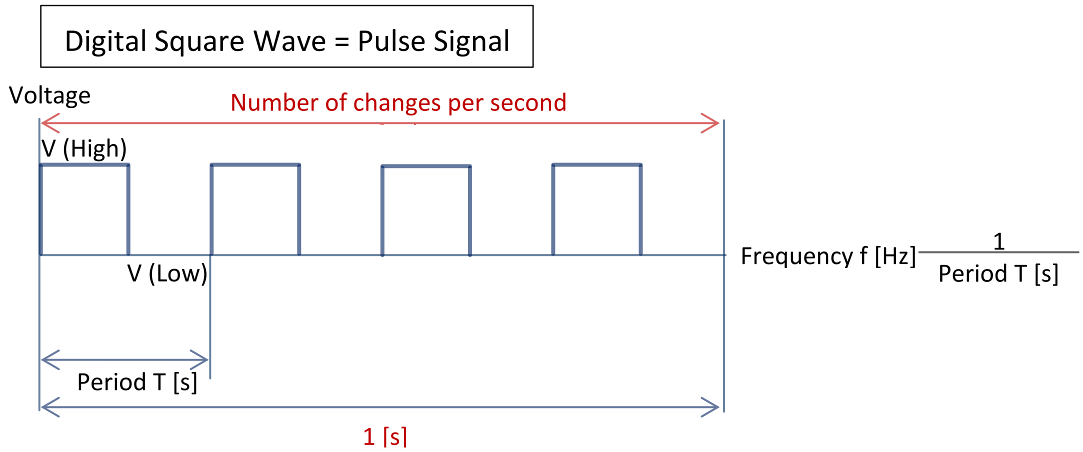
Since a pulse signal is a digital signal converted from mechanical changes such as velocity and flow rate, it becomes valuable only by analyzing the data.

Basic calculation method of pulse

"Frequency" indicates the number of vibrations generated per second, that is, how many times the pulse signal is output. The time required for a pulse signal to make one round trip is called "Period".

"Frequency" and "Period" have a reciprocal relationship, and once one is known, the other value can be calculated.



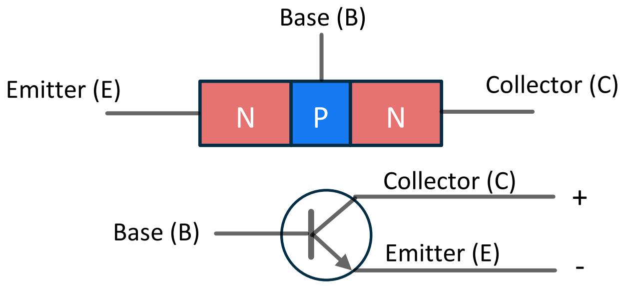


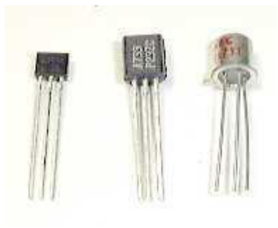
Example of electronic water meter

When measuring with a flow meter that emits one pulse when 10 L of water passes, if the data logger counts 10 pulses per minute, the passing flow rate can be calculated as 10 L x 10 pulses = 100 L/min.

There are several pulse signal output methods. The following explanation is an example of mechanism using the simplest open drain method.

An NPN transistor is built inside the flowmeter.



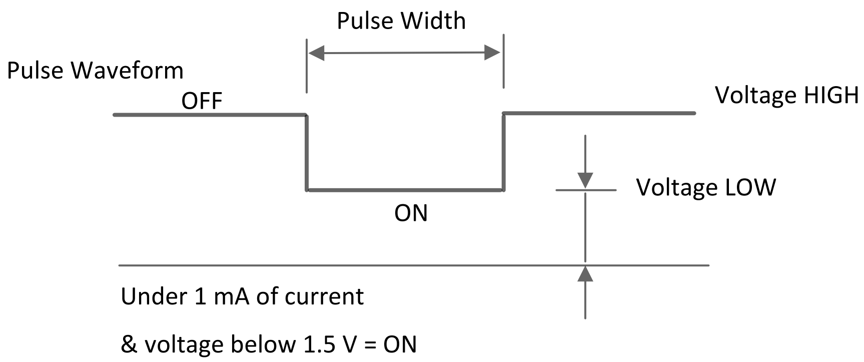


A collector voltage (C), a base voltage (B), and an emitter voltage (E) are generated in the three electrodes of the transistor and play the role of a switch.

VB < VE	No current flows from B to E. The resistance between C and E is ∞Ω. → This means "Switch off state".
VB > VE	Current flows from B to E. The resistance between C and E is 0 (zero) Ω. → This means "Switch on state".

For example, design so that the base voltage (VB) is momentarily loaded when the flow meter counts 10 L, and a state of VB> VE is created. Then, every time the passing flow rate reaches 10 L, the resistance between C and E becomes 0 Ω, and a state in which current flows is created.

In this state, a current flow between C and E for a very short time, and the voltage becomes 0 V (LOW).



When receiving a pulse signal from the flow meter at the counter, the signal is counted at the moment when the voltage changes from HIGH to LOW.
When one pulse signal is generated, the resistance between C and E returns to the state of ∞Ω until the next 10L is reached.
Until then, no current flows, so the voltage between C and E reaches the maximum value (HIGH). As long as this OFF state continues, no pulse signal is generated.

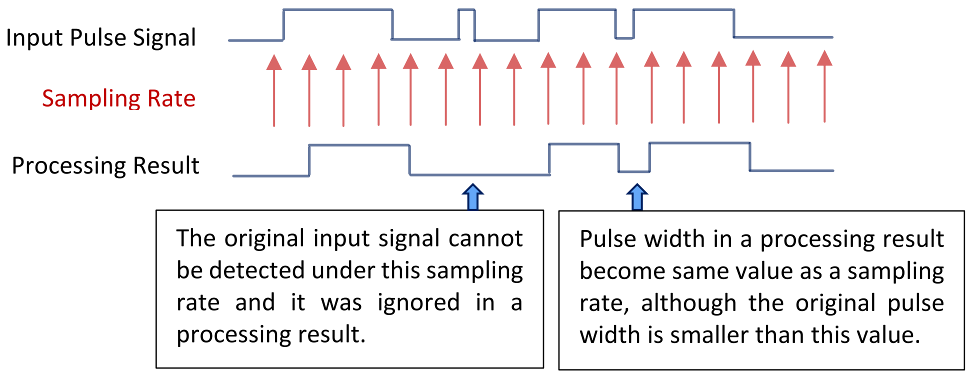
Set value in pulse measurement

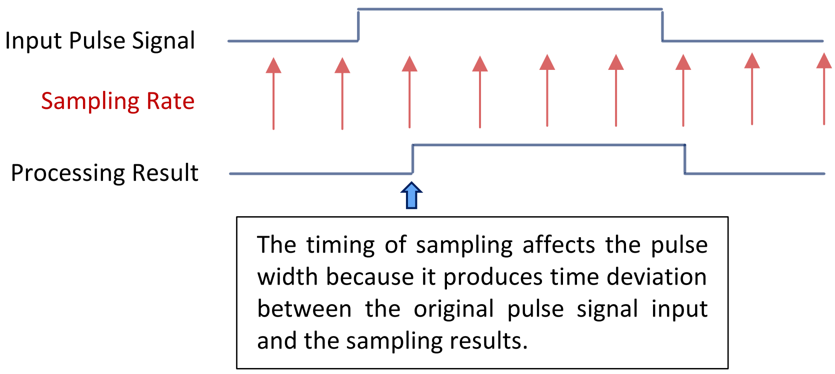
★Sampling Rate

The sampling cycle at which the pulse is measured is called the "sampling rate", and the unit is [S/sec] (Sample per second). As the sampling rate becomes faster, the sampling cycle becomes narrower, so the faster the sampling cycle, the more accurate the waveform can be reproduced.

On the other hand, when the sampling rate is low, there arises a problem that a pulse having a short cycle cannot be detected and the pulse width cannot be measured.

That is, the measurement accuracy of the pulse width depends on the sampling rate, and it is important to set the sampling rate suitable for the frequency and characteristics of the original pulse signal.





★Pulse rate

In the case of a flowmeter with a pulse output function, various pulse rates can be selected according to the application, but in principle, it must be specified when ordering the product.

【Example of the Electromagnetic Flowmeter Honeywell Q4000】

Output device	Option	Output 1	Output 2
Pulser	Standard	10 L/P	100 L/P
	High speed	1 L/P	10 L/P
Remote Display (Small size)	Standard	10 L/P	100 L/P
	High speed	1 L/P	100 L/P
Remote Display (Large size)	Standard	100 L/P	1000 L/P
	High speed	10 L/P	1000 L/P

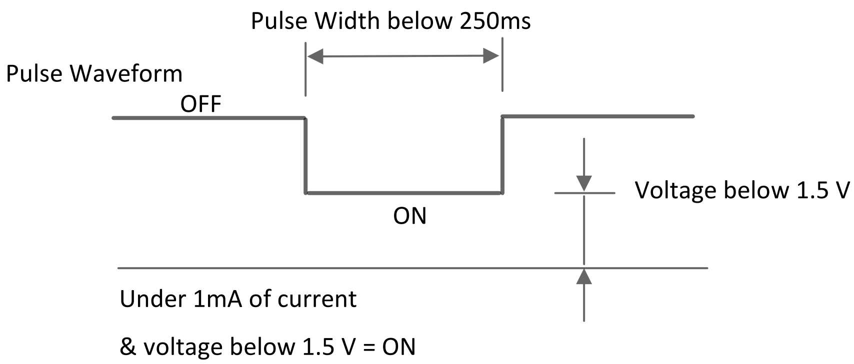
The flowmeter offers three types of pulse output devices, each with a choice of Standard or High-speed versions.

The Pulser is a device that is attached directly to the flow meter, and the Remote Display is selected when it is necessary to check the flow rate at a remote location (for example, outside the chamber).

Whichever option you choose, you can extract signals from the two channels at different pulse rates.

【Example of the electronic turbine flowmeter Aichitokei Denki EDS13Q】

Pulse Rate	Standard/Optional	Procured by JET
1 L/P	Optional	✔
10 L/P	Standard	
100 L/P	Optional	
1 m3/P	Optional	
10 m3/P	Optional	



Chapter 2 Mechanism of the remote monitoring system

2.1 System utilizing cloud server

In recent years, the term IoT has rapidly become widespread, but in order to monitor the flow meters and water pressure gauges installed in the distribution network, users need to secure communication lines, maintain servers, and also required appropriate knowledge and human resources.

In particular, the server that stores the huge amount of data measured every day needs to be operated 24 hours a day, security measures are required to prevent illegal access from the outside, and daily maintenance costs are a heavy burden for water service provider.

The monitoring system introduced on a trial basis this time is a service provided by a data logger manufacturer (Halma Water Management). The user can easily check the measurement data anywhere on the earth simply by preparing a SIM card using the mobile phone communication network and paying the service usage fee.

HWM Online™ and HWM DataGate™

[HWM DataGate™]

HWM DataGate™ is the WWM secure data warehouse and id the data storage system behind the HWM Online™ viewing platform. DataGate™ stores the data messages from the logger and the information required for displaying all the logger details on HWM Online™.

When you orderd your logger(s) with your HWM account manager, you will have been supplied with a Username and Password to the HWM systems. You can use DataGate™ to view your logger information and add additional information such as a mieningful site name, GPS location details, useful notes about the site, etc.

[HWM Online™]

HWM Online™ is a web viewing and management package for viewing the data for your fleet of loggers.

HWM Online™ uses the data stored in the DataGate™ data warehouse to display charts for the data recorded by the loggers and other useful information like the location of the loggers.

If you have HWM Online™ as part of your package, you will use the same username and password that was provide to you by your HWM account manager.

Benefits of Applications

Data can be viewed in graphical or table format from any internet enabled device using web viewer HWM Online or seamlessly integrated into a third-party corporate system.

On receipt of an alarm DataGate can send automatic alerts to multiple users to enable action to be taken promptly. The system will even store data from loggers it does not recognize, and then add this information to the logger's history when it is registered on the system.

Multiple accounts can be set up and configured to ensure that users only see data from the specific loggers they require.

Special Attention

The DataGate service for remote monitoring system introduced by the JICA Project will be valid until the end of December 2021 according to the private contract between CTII and the distributor (Optima Ingenieria S.A).

The NWSDB needs to NWSDB needs to follow the procedure below.

- Contact the person in charge of HWM.

  Ing. Paul Harrison

  PHarrison@hwm-water.com Tel: (+44) 0 1633 489479

- What to be informed to HWM

  1. Serial Number of Multilog 2 donated by CTII

     Device 1: 0008265

     Device 2: 0008273

  2. Change of owner of Multilog 2

     Previous owner: CTI Engineering International

     New owner: NWSDB RSC W-S

- Contract and Payment with HWM for DataGate Hosting fee

  5 years hosting fee per logger will be £80 approx. (LKR 22,000).

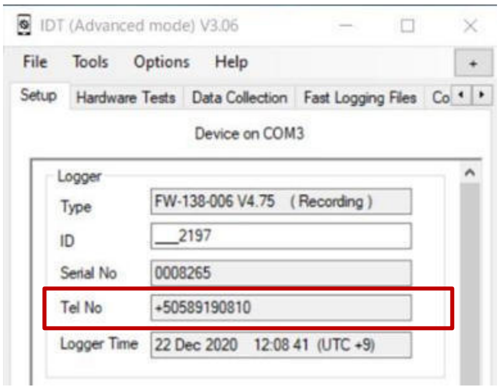
- Change of logger setting according to instruction by HWM

  1. Tel Number of Logger

Previous data: (+505) 8919 0810 (for Serial No.8265)

(+505) 83321428 (for Serial No.8273)

New data: to be instructed by HWM



2. Data Destination

Previous data:

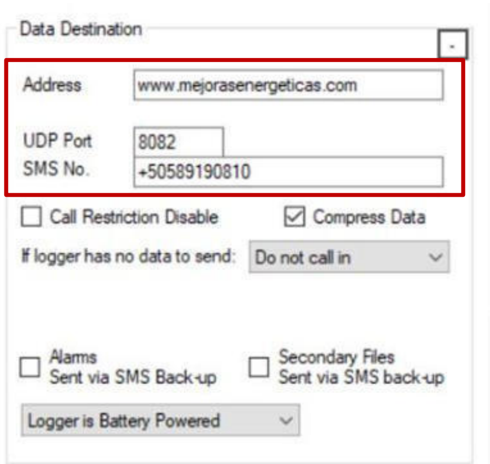
Address: www.mejorasenergeticas.com

UDP Port: 8082

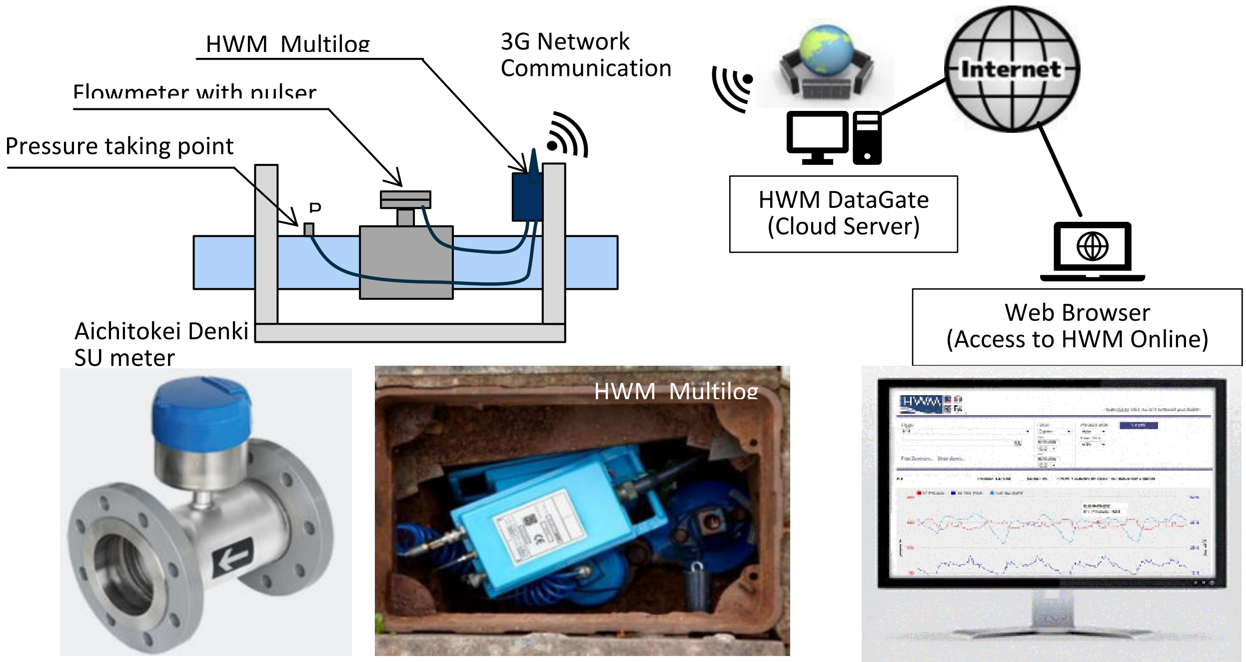
SMS No. (+505) 8919 0810 (for Serial No.8265)

(+505) 83321428 (for Serial No.8273)

New data: to be instructed by HWM



2.2 Component of the monitoring systemin DMA 3 & DMA 5



Equipment and responsibility:

User's responsibility	HWM's service
1. Installation of HWM Multilog 2	1. Data saving in Cloud Server
2. Preparation of Data SIM card	2. Data sharing by HWM Online
3. 3G Modem Configuration	3. Maintenance of Cloud Server
4. 3G Network Fee	4. Security measures against illegal access
5. Mobile tablet or PC	5. Provision of access key
6. Internet Access	
7. DataGate Hosting fee	
8. Flowmeter with pulse output	
9. Connection cable for digital signal	
10. Pressure taking point on pipe	
11. Pressure taking cable with quick coupler	
12. External battery (if necessary)	

[Bulk Meter for DMA 5]

Aichitokei Denki SU200-KF-C

Meter for DMA 5

Flow Performance to ISO 4064, OIML R49/2006						
Meter Size (mm)				125	150	200
Max. Flowrate		Q_4 [±2%]	(m^3/h)	313	500	788
Permanent Flowrate		Q_3 [±2%]	(m^3/h)	250	400	630
Transitional Flowrate		Q_2 [±2%]	(m^3/h)	1	1.6	2.52
Min. Flowrate		Q_1 [±5%]	(m^3/h)	0.625	1	1.58
Measuring Range Q_3/Q_1 (R)				400		
Low Flow Cut (m^3/h)				0.5	0.8	1.26
Pressure Loss at Permanent Flowrate (Q_3) (MPa)				0.063 or less		
Maximum Permissible Working Pressure (MPa)				1.0		
Measurable Fluid	Applicable Working Fluid Temperature (℃)			+0.1 to +30		
	Fluid Conductivity (μ S/cm)			50 or more		
Ambient Temperature (℃)				-10 to +55		
Waterproof				IP68		
Registration	Integrating Flow	Max. Registration (m^3)		999999.999	9999999.999	
		Smallest Scale Unit (L)		1		
	Others			Instantaneous Flowrate (m^3/h) No-Water Warning Low-Battery Alarm		
Power Supply				Built-in Lithium Battery Estimated Battery Life: 10 years at 30℃ ambient temperature (including storage time)		
Weight (Meter with 10m cable and Remote Display) (kg)				Approx. 18.8	Approx. 24.8	Approx. 32.8
Weight (Meter with 30m cable and Remote Display) (kg)				Approx. 19.8	Approx. 25.8	Approx. 33.8
Piping Connection				Flange Connection Method		

[Bulk Meter for DMA 3]

Aichitokei Denki SU250-KF-C

Meter for DMA 3

<table>
<tr><th colspan="5">Flow Performance to ISO 4064, OIML R49/2006</th></tr>
<tr><td colspan="3">Meter Size (mm)</td><td>250</td><td>300</td></tr>
<tr><td colspan="3">Max. Flowrate Q_4 [±2%] (m^3/h)</td><td colspan="2">1250</td></tr>
<tr><td colspan="3">Permanent Flowrate Q_3 [±2%] (m^3/h)</td><td colspan="2">1000</td></tr>
<tr><td colspan="3">Transitional Flowrate Q_2 [±2%] (m^3/h)</td><td colspan="2">4</td></tr>
<tr><td colspan="3">Min. Flowrate Q_1 [±5%] (m^3/h)</td><td colspan="2">2.5</td></tr>
<tr><td colspan="3">Measuring Range Q_3/Q_1 (R)</td><td colspan="2">400</td></tr>
<tr><td colspan="3">Low Flow Cut (m^3/h)</td><td colspan="2">2</td></tr>
<tr><td colspan="3">Pressure Loss at Permanent Flowrate (Q_3) (MPa)</td><td colspan="2">0.063 or less</td></tr>
<tr><td colspan="3">Maximum Permissible Working Pressure (MPa)</td><td colspan="2">1.0</td></tr>
<tr><td rowspan="2">Measurable Fluid</td><td colspan="2">Applicable Working Fluid Temperature (℃)</td><td colspan="2">+0.1 to +30</td></tr>
<tr><td colspan="2">Fluid Conductivity (μ S/cm)</td><td colspan="2">50 or more</td></tr>
<tr><td colspan="3">Ambient Temperature (℃)</td><td colspan="2">-10 to +55</td></tr>
<tr><td colspan="3">Waterproof</td><td colspan="2">IP68</td></tr>
<tr><td rowspan="3">Registration</td><td rowspan="2">Integrating Flow</td><td>Max. Registration (m^3)</td><td colspan="2">9999999.99</td></tr>
<tr><td>Smallest Scale Unit (L)</td><td colspan="2">10</td></tr>
<tr><td colspan="2">Others</td><td colspan="2">Instantaneous Flowrate (m^3/h)
No-Water Warning
Low-Battery Alarm</td></tr>
<tr><td colspan="3">Power Supply</td><td colspan="2">Built-in Lithium Battery
Estimated Battery Life: 10 years at 30℃ ambient temperature (including storage time)</td></tr>
<tr><td colspan="3">Weight (Meter with 10m cable and Remote Display) (kg)</td><td>Approx. 54.8</td><td>Approx. 70.8</td></tr>
<tr><td colspan="3">Weight (Meter with 30m cable and Remote Display) (kg)</td><td>Approx. 55.8</td><td>Approx. 71.8</td></tr>
<tr><td colspan="3">Piping Connection</td><td colspan="2">Flange Connection Method</td></tr>
</table>

[Specifications of Pulse Transmitter]

Transmitter (to SR-4DPAM)	MX35-2
Input	Receives the optical code from SU
Output	Outputs "SS" electronic statement to SR-4DPAM
Signal Cable	2-Wire (black & white)
	Polyvinyl Chloride Insulated Flexible Cords (VCTF)
	Finished Outside Diameter: ϕ 6mm
	Nominal Section Area: 0.75mm^2
	Maximum Conductor Resistance: 25.1 Ω/km (at 20℃)
	Color of Sheath: Grey
	10m/30m
Maximum Transmission Distance Between MX35-2 And SR-4DP	50m
Color	Blue
Weight (including 10m cable)	Approx. 530g
Weight (including 30m cable)	Approx. 1500g

Meter Size (mm)			150	200	250	300
Remote Display			SR-4DPAM			
Aichi Reference No.			SR-4DPAM-B			
Input			Receives "SS format electronic statement signal from MX35-2			
Output	Pulse	Output Form	Normally open			
		Pulse on Time	300ms			
		Number of Contact	2			
		Pulse Weight (CH1 and CH2) (L)	100/1000/ 10000	(100)*/1000/10000 * For Meter Size 200mm, 250mm and 300mm, the flow-rate must not exceed 600m^3/h when the pulse weight is 100L/pulse.		
		Kind of Pulse	Option0 Forward Net (Forward Pulse – Reverse Pulse) for CH1 and CH2 Option1 CH1: Forward Pulse CH2: Reverse Pulse Option2 CH1: D. Flag (Direction Flag) CH2: Forward Pulse + Reverse Pulse			
		Maximum Load Current	10mA			
		Maximum Load Voltage	24V			
		Interval to Update Pulse	1.8sec			
		Maximum Transmission Distance	200m (When the cable with 0.01 μ F/100m or less is used.)			
Color of Case			Beige			
Weight			Approx. 320g			

Pulse Weight of Bulk Meter in DMA 3 & DMA5
- Ch1: 100L/p
- Ch2: 1m^3/P

[In case of Honeywell Q4000 (similar model of flow meter)]

Honeywell Q4000

FLOW PERFORMANCE TO CEN PR14154, ISO4064, OIML R49 (LOW FLOW OPTION)

PIPE SIZE (mm)	50	65	80	100	125	150	200
MINIMUM FLOW Q1 (m³/h)	0.10	0.16	0.25	0.40	0.63	1.0	1.6
TRANSITIONAL FLOW Q2 (m³/h)	0.16	0.26	0.40	0.64	1.0	1.6	2.6
PERMANENT FLOW Q3 (m³/h)	40	63	100	160	250	400	630
MAXIMUM FLOW Q4 (m³/h)	50	79	125	200	313	500	788
MAXIMUM REGISTRATION (m³)	999999.999					9999999.99	
METER WEIGHT	4.5	5.0	5.5	6.5	7.5	9.5	15
PRESSURE LOSS AT Q3 (bar)	Less than 0.3 bar						

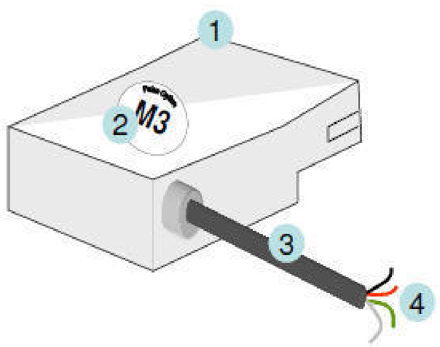
FLOW PERFORMANCE TO CEN PR14154, ISO4064, OIML R49 (HIGH FLOW OPTION)

PIPE SIZE (mm)	50	65	80	100	125	150	200
MINIMUM FLOW Q1 (m³/h)	0.16	0.25	0.40	0.63	1.0	1.6	2.5
TRANSITIONAL FLOW Q2 (m³/h)	0.26	0.40	0.64	1.0	1.6	2.6	4.0
PERMANENT FLOW Q3 (m³/h)	63	100	160	250	400	630	1000
MAXIMUM FLOW Q4 (m³/h)	79	125	200	313	500	788	1250
MAXIMUM REGISTRATION (m³)	999999.999				9999999.99		
METER WEIGHT	4.5	5.0	6.0	7.5	9.5	15	20
PRESSURE LOSS AT Q3 (bar)	Less than 0.1 bar						

OTHER DATA	
BATTERY LIFE	Fitted lithium batteries provide 10 years continuous life at 30ºC ambient temperature.
SAMPLING RATE	0.5 seconds fixed
WATER CONDUCTIVITY	50μS/cm or more

PULSE OPTIONS (LITRES PER PULSE)	OPTION	OUTPUT 1	OUTPUT 2	OUTPUT 3	OUTPUT 4
PULSER	Standard	10 litres Fwd-Rev	100 litres Fwd-Rev	Alarm	Common
	High speed	1 litre Fwd-Rev*	10 litres Fwd-Rev	Alarm	Common
	* Pulse weight changes to 10 litres automatically when fitted to larger meter sizes (with 7 digit meter display). Fwd-Rev: forward pulses only net of any reverse flow using reverse compensation method. Alarm output: meter battery low, pulser battery low, tamper, empty pipe, pulse setting changed.				
REMOTE DISPLAY - SMALL SIZES (6 FIG DISPLAY)	Standard	10 litres Fwd-Rev	100 litres Fwd-Rev		
	High speed	1 litre Fwd-Rev	100 litres Fwd-Rev		
REMOTE DISPLAY - LARGE SIZES (7 FIG DISPLAY)	Standard	100 litres Fwd-Rev	1000 litres Fwd-Rev		
	High speed	10 litres Fwd-Rev	1000 litres Fwd-Rev		
	Additional pulse output options featuring advanced forward and reverse flow monitoring suitable for data logging and AMR applications are available. For full technical details and any further information please contact your Elster Sales representative.				

Q4000 Pulse Output Unit



Pulse features

1. The Q4000 pulser is a fully sealed, IP68 unit suitable for installation in flooded environments.
2. Pulse Option label denotes the pulse configuration of the unit (see table below)
3. Robust communication cable in standard 10m length. 30m version is also available
4. 4-wire outputs:
   - Red - Pulse Channel 1
   - White - Pulse Channel 2
   - Black - Alarm output*
   - Green - Common

***Alarm**

The alarm output channel can provide an output signal to indicate:

- Meter Low Battery
- Pulser Low Battery
- Measurement stopped/ No water
- Tamper (pulser removed from meter)
- Pulse Option setting changed

Multilog 2

Multi-channel Data Logger

Input Options

Digital	Uni- or bi-directional pulse Up to 64 pulses per second
Analogue	Internal Pressure Transducer. External pressure. 4-20mA (optional). 0-20 bar / 0-200 meters head / 0-300psig, 0.1% repeatability / please note that the logger is calibrated to 10 bar as standard. (20 bar calibration must be specified at time of order if required) Leak noise, 0-10V, 0-1V, temperature or 4-20 mA variants
Serial Input	Proprietary serial interface for SonicSens 2 ultrasonic level monitors and third party devices like Serial Meters using Modbus, SDI12 and RS232

Communication

Local	Hi-speed USB for connection to hand held devices, Windows tablets, laptop or desktop PC
Internal Cellular Modem	Cellular modem supporting 2G/3G/ NBIoT/LTE-M (Cat-1) with SMS backup where available - contact HWM for available options GPRS/3G/4G NBIoT can send data down to every 15 mins, with appropriate battery pack
Accelerated dial-in	Dial-in rate is increased if alarm situation is triggered. Logger can accelerate dial-in at alarm level for multiple applications - including SonicSens, Flow, Pressure and other alarmed sensors.

Features

Frequency	Variable logger sample rate from 1s to 24hrs (this may affect battery life and communication costs)
Logger/Site ID	7 alphanumeric characters. Readable factory set serial number in firmware
Dimensions	257H x 129W x 77D (mm) 10.1" x 5" x 3"
Construction	Die-cast aluminium enclosure, powder-coat spray painted
Weight	1.6kg (3.5lb)
Operating Temp.	-20 to +60ºC (-5 to +140ºF)
Ingress Protection	IP68 submersible
Power	Typical 5 years (depending on settings and signal condition). External power connection for battery box and third party devices.
Memory	Standard recording: 2 million readings (optional up to 64 million readings and expandable HC SD card)
Fast Logging (secondary channel)	Secondary, fast channel supports sampling up to 25 Hz and record average. minimum, maximum, standard deviation or time interval between pulses (for data smoothing)
Pulse Interval Timing	Count and Event logging modes independent for both channels. Pulse Interval Timing helps to smooth readings (e.g. leakage) in low flows by counting the time between each pulse (event mode). This is available in addition to totalling the pulses (count mode)
Alarms	Multiple alarm options including Rate of Change, Profile, Minimum Night Flow and Threshold. 16 alarms per logger. Can be programmed to auto dial up to 8 telephone numbers on alarm. Over 16 alarms per logger depending on channel configuration

2.3 Configuration of HWM Multilog 2

Unpacking

Confirm that you have the following parts required to install the equipment.

- Multilog 2 data logger
- Software Installation Tool (IDT) from www.hwmglobal.com or CD-ROM
- External 3G Antenna
- USB programing cable
- Connection cable (Digital for pulse signal & Analog for pressure)
- External battery and appropriate cable

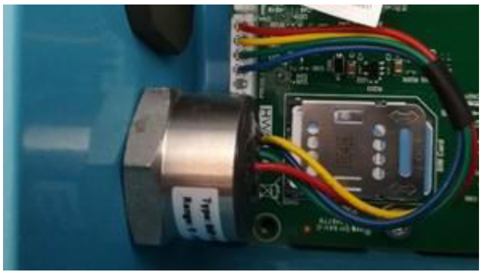
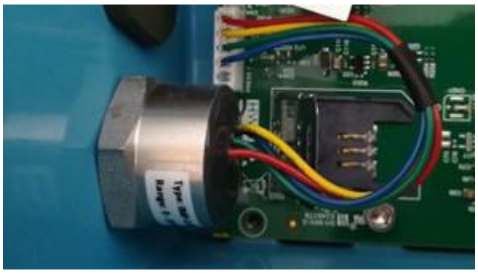
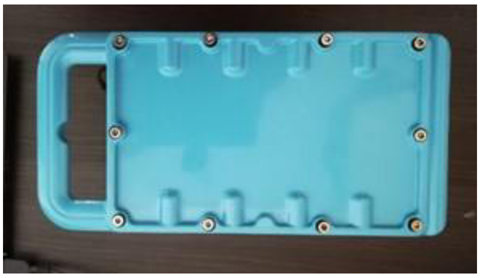
Before proceeding to site for physical installation, take the time to configure your logger in an office environment. Most settings can be configured before visiting site and this will save time at the point of install.

The user needs to have:

- A valid HWM-watar.com account with username & password.
- A valid HWM DataGate™ account with username & password.
- A PC with Windows 10 installed.
  Minimum requirements are
  1 GHz processor, 512Mb RAM, 2GB Disk Space
- A USB programming cable for connection to the logger.
- A description and reference number for the installation site.
- The SIM card installed into the logger and a good 3G signal on site for the chosen network (Roaming SIMs are also available).

Setting SIM card in Multilog 2

First, prepare a SIM card (standard size) that enables Internet communication over a 3G network.

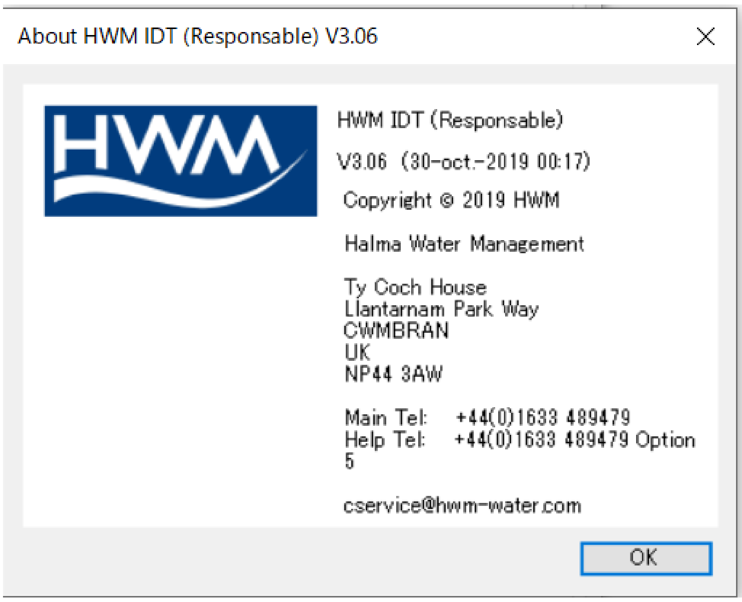
1. Remove the hexagon bolts on the back side.	4. Insert SIM card
	
2. Remove the back cover carefully.	5. Replace the SIM card slot cover
	
3. Pull up the SIM card slot cover.	6. Align the packing rubber and close the cover with hexagon bolts.
	

Installation and site hardware Diagnostics Tool (IDT)

The program IDT for setting the data logger can be downloaded from the following site.

https://www.hwmglobal.com/help-and-downloads/

This guideline is based on the following programs and may differ from the latest updated version of the program.

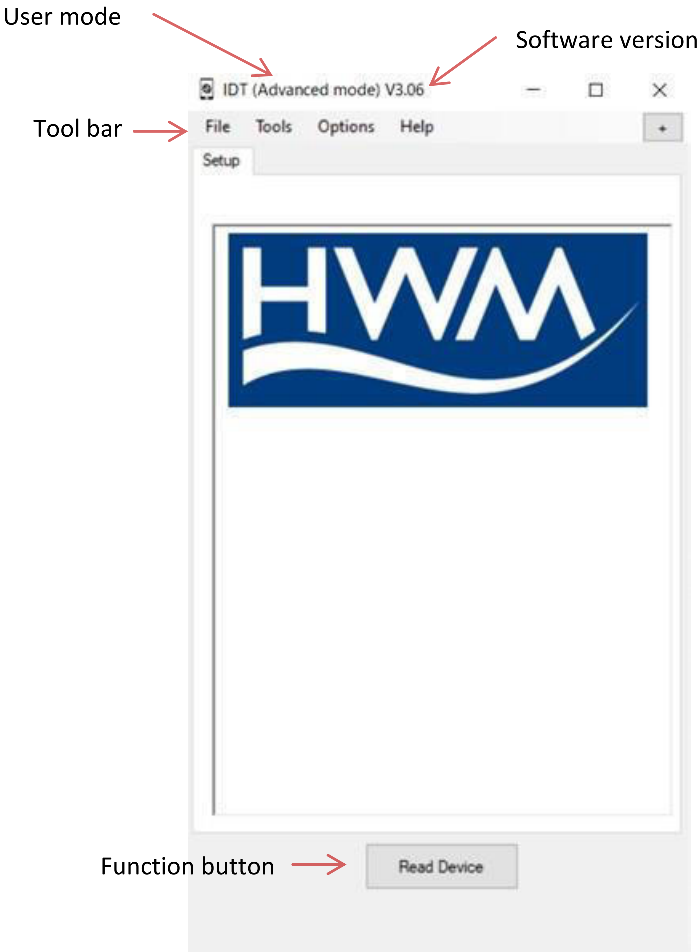


Once you have installed the IDT, connect the USB cable to your PC, then to the 10-pin connector on your logger.
The first time you connect your USB to a new USB port, Windows will configure the driver, wait until this process is completed before proceeding.

Reading the logger

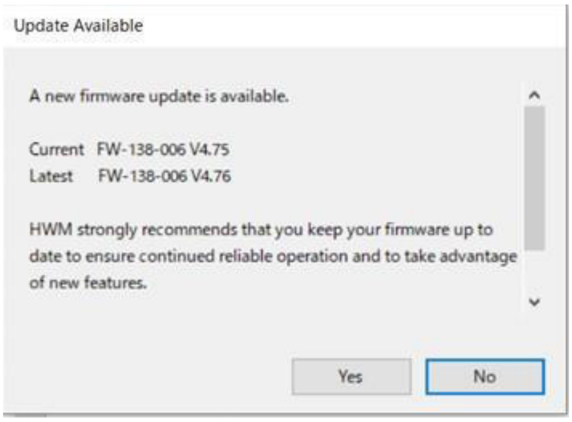
1 Run the IDT program.

2 The main window will appear of which the main items are: -

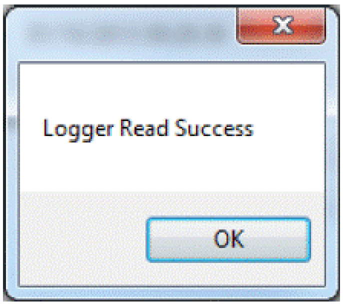


3 Now click the [Read Device] button to load the current logger settings into the setup window

4 The IDT will now download the current setting s form the logger.
At this point the IDT will check to see if there is a more up-to-date version of the logger firmware on the PC, if so, you will see the message “Update Available”. Click [Yes] to update the logger, the process will take approximately 2 minutes, however the logger will be restarted so you may wish to transfer any logged data first.
Now select [No].



5 Once all the settings have been loaded you will see this message. Click [OK] to start configuring your logger.



Configuring the logger

1 You will now see the main setup menu (expanded for illustration purposes). The menu is structured in sections for easy setup and changes content depending on software mode:

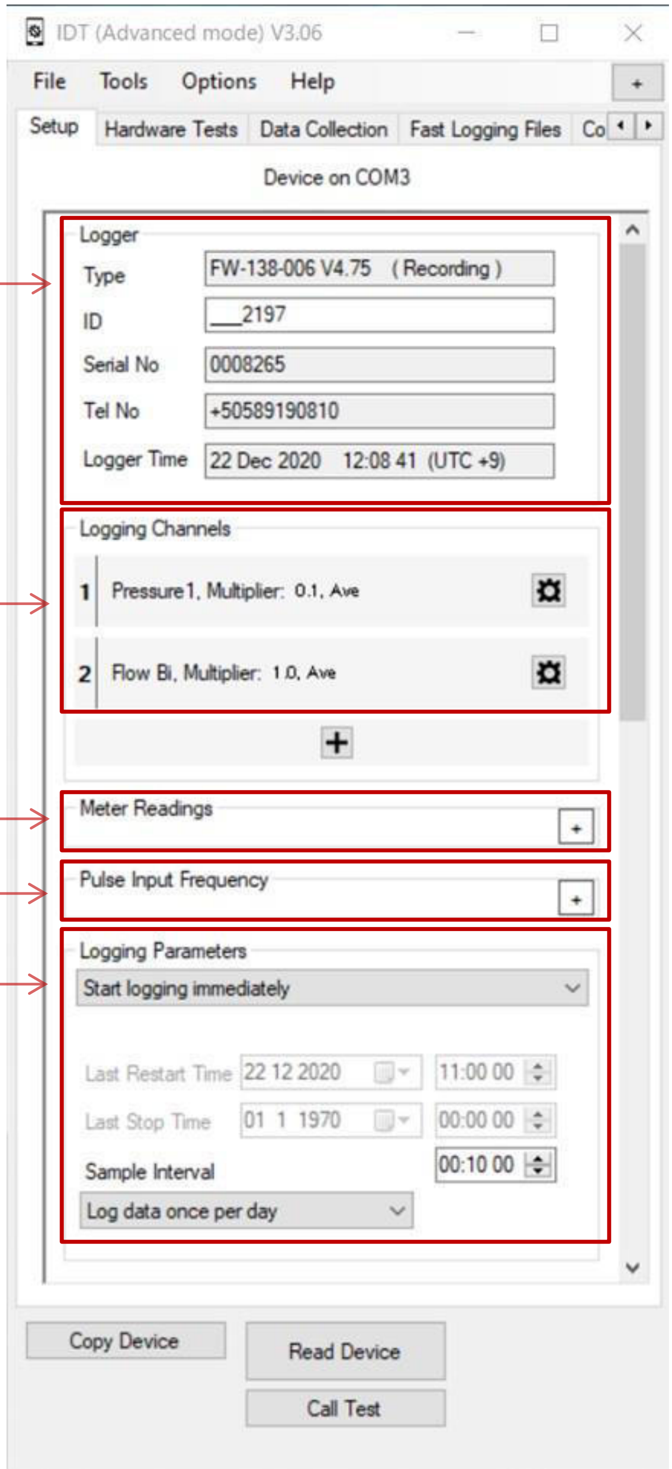
i) Logger details including ID and SIM card phone number. This data should be indicated by the HWM Online™ or DataGate™ service provider.

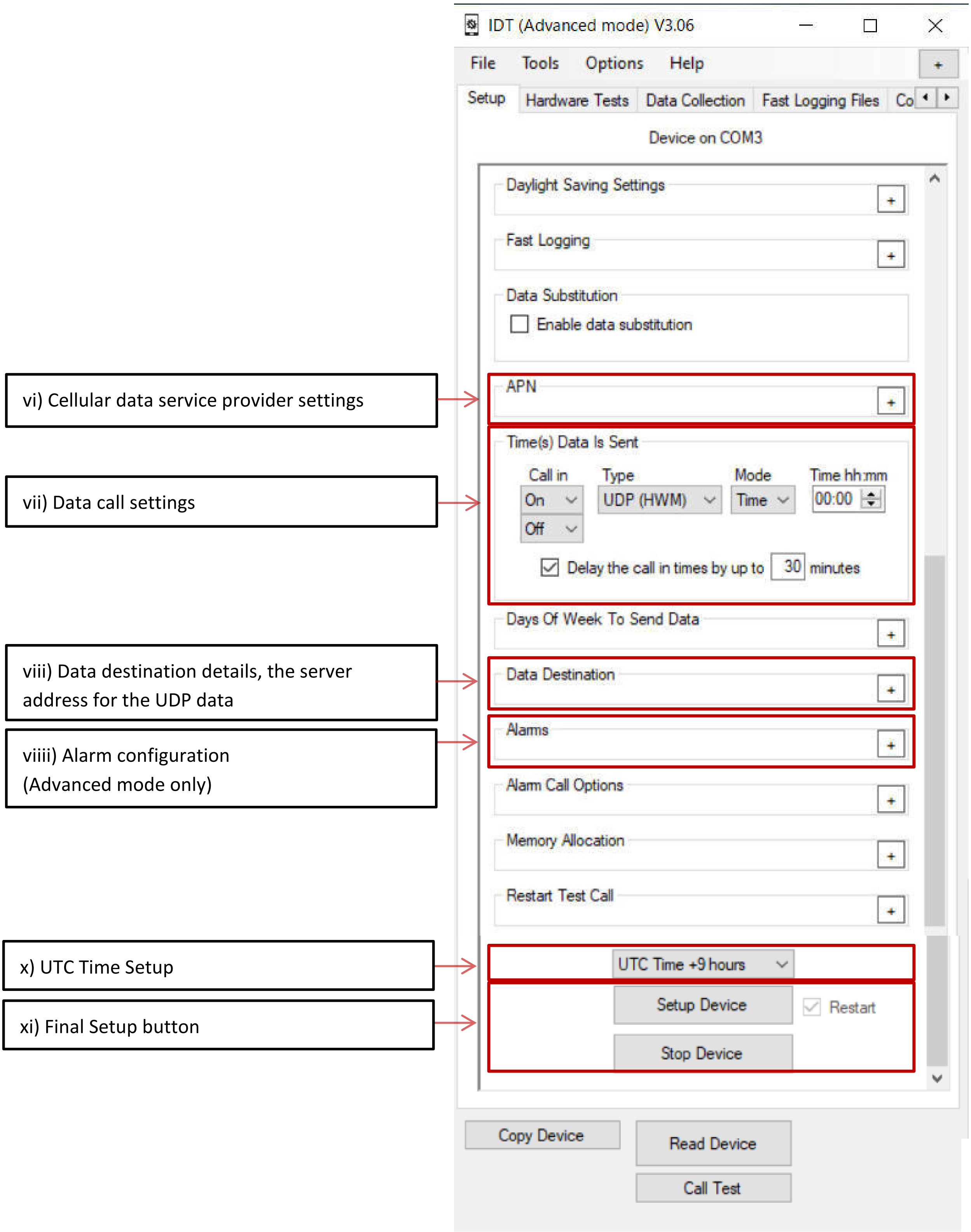
ii) Logger channel configuration including calibration factors.

iii) Logger recorded meter readings

iv) Pulse Sampling rate (0.5Hz – 128Hz)

v) Logger start time and data capture interval (days or times of measurement period)




vi) Cellular data service provider settings
vii) Data call settings
viii) Data destination details, the server address for the UDP data
viiii) Alarm configuration (Advanced mode only)
x) UTC Time Setup
xi) Final Setup button
IDT (Advanced mode) V3.06
File
Tools
Options
Help
Setup
Hardware Tests
Data Collection
Fast Logging Files
Co
Device on COM3
Daylight Saving Settings
Fast Logging
Data Substitution
Enable data substitution
APN
Time(s) Data Is Sent
Call in
Type
Mode
Time hh:mm
On
UDP (HWM)
Time
00:00
Off
Delay the call in times by up to 30 minutes
Days Of Week To Send Data
Data Destination
Alarms
Alarm Call Options
Memory Allocation
Restart Test Call
UTC Time +9 hours
Setup Device
Restart
Stop Device
Copy Device
Read Device
Call Test

2 Now you can enter the configuration you require for each section.

[Logger]

Enter the site ID that you wish for the logger. e.g., Postal/ZIP code up to 7 alpha-numeric characters and the telephone number associated with the SIM card.

In the trial test by CTII, the HWM Online^{TM} Service is provided by the official distributor of HWM, Mejorasenergeticas, so all the data were indicated by this company.

Setting information:

Type	FW-138-006 V4.75
ID	___2197
Serial No	0008265 (as indicated on the surface of Mutilog 2)
Tel No.	+50589190810

Type	FW-138-006 V4.75
ID	___2198
Serial No	0008273 (as indicated on the surface of Mutilog 2)
Tel No.	+50583321428

This tele-communication service of HWM Online^{TM} is valid from December 2020 to December 2021.

When NWSDB manages these datalogger by itself after termination of JICA Project, ID & Tel No should be modified in accordance with the instruction provided by the local distributor of HWM.

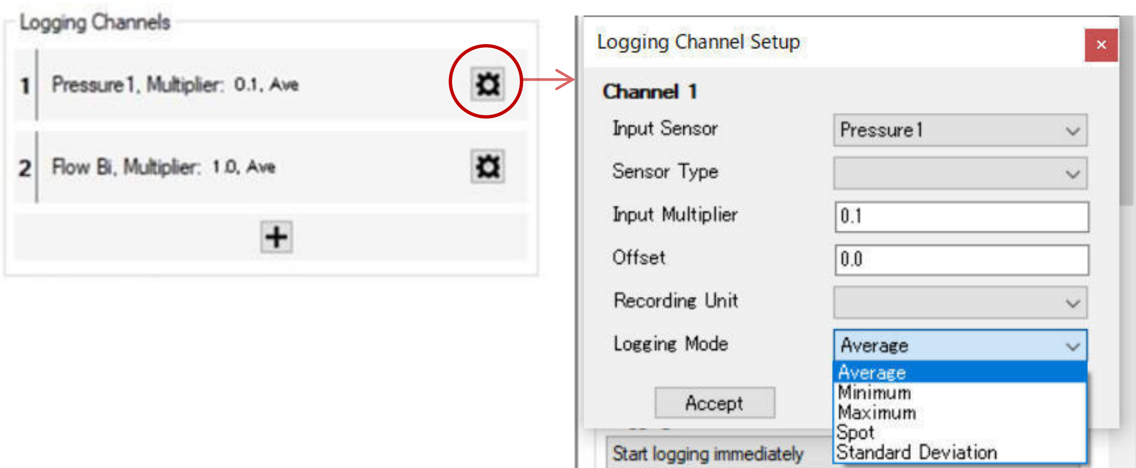
To use this On-ling service, NESDB needs to conclude a contract directly with HWM or with a local distributor and pay an annual fee.

[Logging Channels]

The datalogger procured by CTII has 2 channels.

<Channel 1>

Channel 1 is an analogue input from pressure sensor

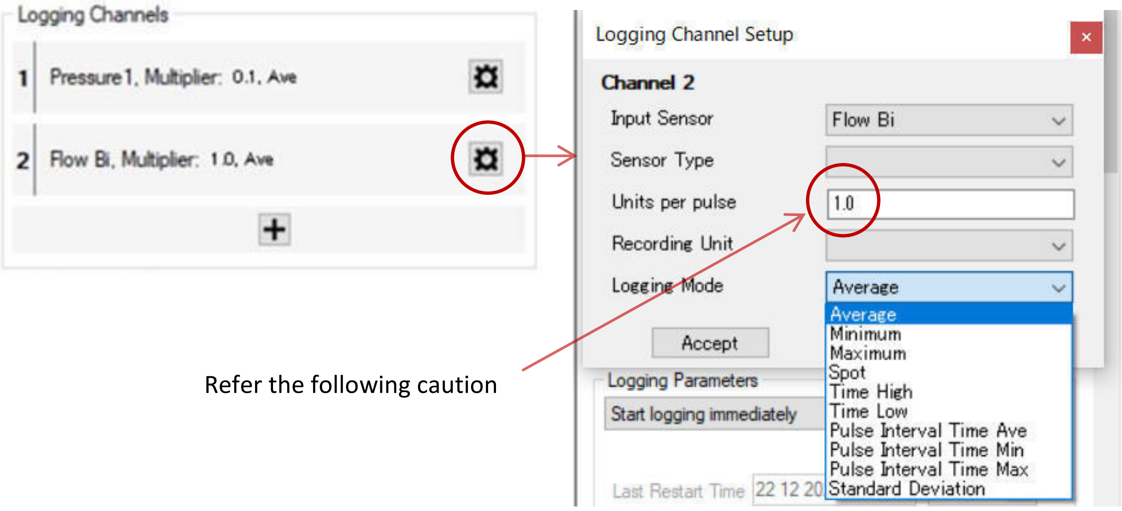


By the default configuration (0.1 for input multiplier), the pressure sensor will detect the pressure value and indicate on the graph with water head unit (m-H_2O).

You can select the logging mode from pull-down menu. If you select Average, the logger calculates an average value during log interval.

<Channel 2>

Channel 2 is a digital input from pulser of flow meter



The digital input will detect the pulse signal generated by the pulser installed on the flow meter.

When the pulse rate of flow meter is “100 Litter per Pulse”, you can enter “100” in the box of “Units per pulse”, so that the logger can send the Web Server the converted value as “Litter “.

You can select the logging mode from pull down menu.

<u>Caution</u>

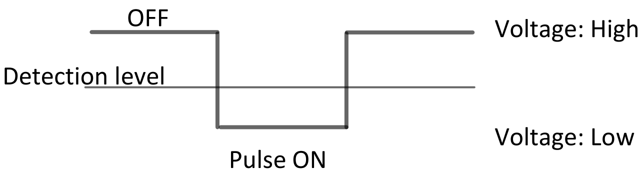
If the water meter does not have “Flow Direction Line” that can be connected with Multilog 2, you may add “-” (minus) just before the unit per pulse.

If the type of the pulser of flowmeter corresponds “Fall mode” as illustrated below, the logger recognizes the falling voltage as contrary flow detection, and the graph shows the negative value of water flow. In this case you will need to select “Net Flow” in the dialog box of Pulse Input Frequency as shown the next page.

Fall mode

Integrates the number of times

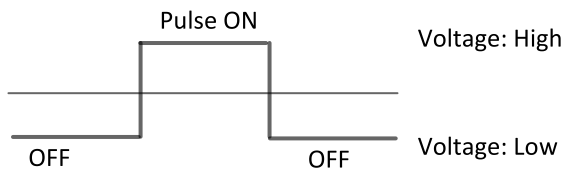
the pulse changes from HIGH to LOW.



Rise mode

Integrates the number of times

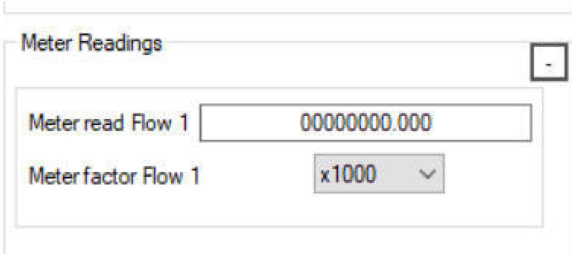
the pulse changes from LOW to HIGH.



[Meter Reading]

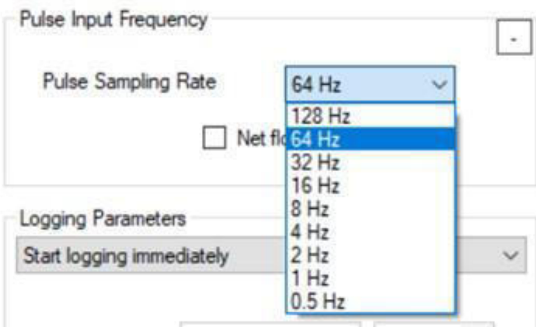
If your wish the meter reading to be sent through to HWM Online, enter the current value in the box(s). This needs to be configured on site as the timing is important, however it can be corrected later via HWM Online.

This parameter is ignorable in this project.



[Pulse Input Frequency]

This parameter is ignorable in this project.

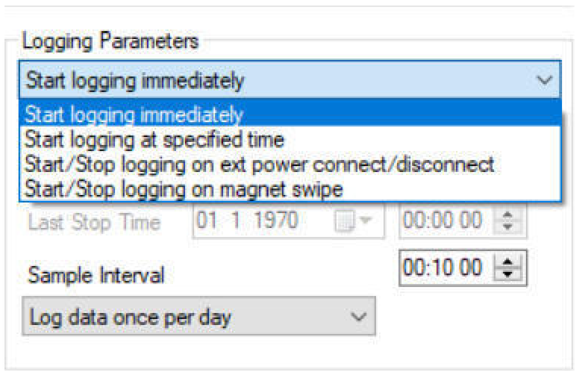


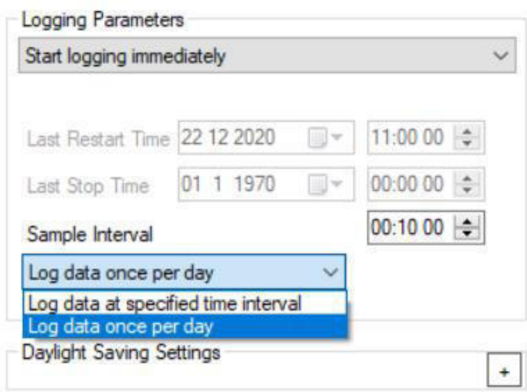
[Logging Parameters]

Accept the default start time or enter your own. Default start time is in the past so the logger will begin recording immediately. You can delay this start time by selecting one from the calendar or enter the time directly from your number keypad.

Set your sample interval and log interval in the time box (hour. minute. second).

If select 1 minutes as sample interval and 10 minutes as Log data at specified time interval, the logger detects pressure value every 1 minutes (as an average value or spot value), but the logger takes 10 data for 10 minutes and convert these data in the average value.





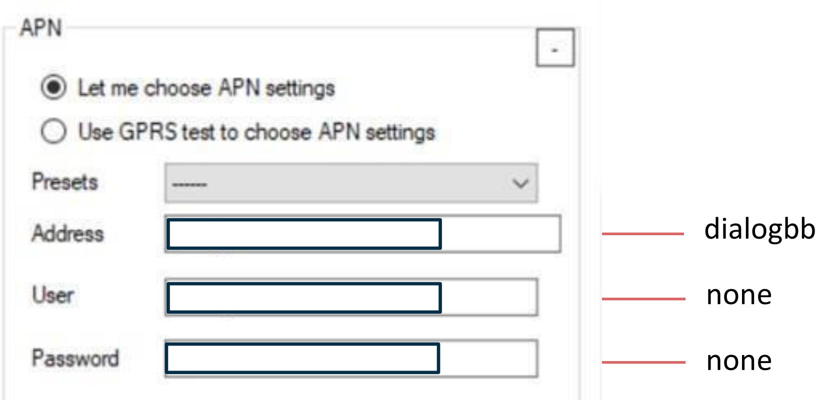
[Cellular data service provider settings]

If you have ordered a data pack from HWM you can leave this setting alone (as below) as your logger will have been preconfigured by HWM.

If you have ordered your data service & SIM card, then you will need to separately configure your service.

HWM recommends that you allow the 3G/GPRS test utility to search for these settings automatically, however if you wish to enter them manually, click the button beside “Let me choose APN settings”. Alternatively select your network from the drop-down list of presets.

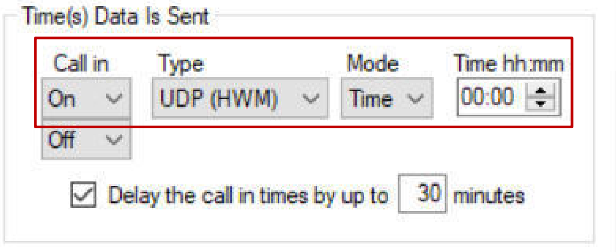
For the trial test in Japan, the data provided by the cellular network provider is as shown below.



[Time(s) Data sent]

Here you specify the Call Out requirement for the logger. There are 2 modes available, SMS (Short Message Service) and UDP (User Datagram Protocol).

SMS is a one-way unacknowledged data transfer service using the common text messaging service.



UDP is a true 2 way confirmed data transfer process via the internet over a 3G/GPRS connection.

Both have advantages, however HWM recommends UDP here ever possible as this offers the most secure method of data transfer.

Switch on the Call in by selecting "On" in the Address selector, then choose UDP or SMS from the Type selector.

As the standard setting it is recommendable to set 1 to 3 times per day (e.g., 00:00, 08:00 & 16:00). If you need to record data more frequently the external battery is required.

[Data Destination]

There will usually have been entered at the factory and should not be adjusted, however if you have your own data server, then you can enter either the telephone number for your receiving modem, or the UDP address & port no for where the logger is to send its data.

This will be applicable in the future, when NWSDB provide its own data server for remote monitoring.

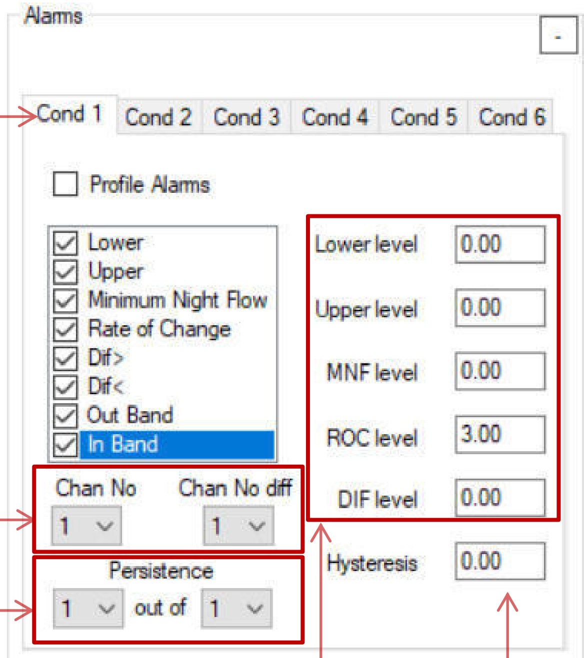
In this trial test, CTII contracted with the foreign company named "Mejorasenergeticas S.A.", so these data were provided by this company exclusively for the JICA Project.

If the owner of the equipment is changed from CTII to NWSDB and NWSDB desire to continue monitoring flow and pressure in DMAs, NWSDB should apply to HWM for a change of ownership and a contract to use the new HWM Online™ or DataGate™ to be provided with a new data server address, UDP port and SMS No etc.

[Alarms]

The Multilog 2 has a comprehensive alarm system that you can configure to send out Alarm messages when certain defined conditions are breached. (e.g., Sudden flow change by leakage, or accidents)

There are 6 possible different alarm conditions that can be configured, select each one from the tabs.



Choose the main alarm channel and then the difference channel if making a comparison.

Set your persistence or trigger point, e.g., 3 occurrences out of 5 incidents triggers the alarm.

Enter the alarm threshold

Enter the alarm hysteresis

Choose your type of alarm from the list: -
Lower or Upper Limit breach
Minimum Night Flow (MNF) not met
Rate of Change (ROC) faster than x per minute
Difference (Dif) between channels greater or less than limit
Either in or Out of Band set by Upper & Lower levels.

Note on Hysteresis:
When an alarm is triggered, if the value is set to zero, then immediately the threshold is re-crossed then another clear message will be sent. If there is a period when the alarm threshold is borderline, this can result in numerous messages for the same event. By specifying a value in the Hysteresis box, you can provide a window that allows the threshold to be repeatedly crossed without sending repeated messages.
(e.g., with an Upper limit of 5 and a Hysteresis of 1, the alarm will trigger at 5, but the clear message will not be sent until the value drops to below 4.

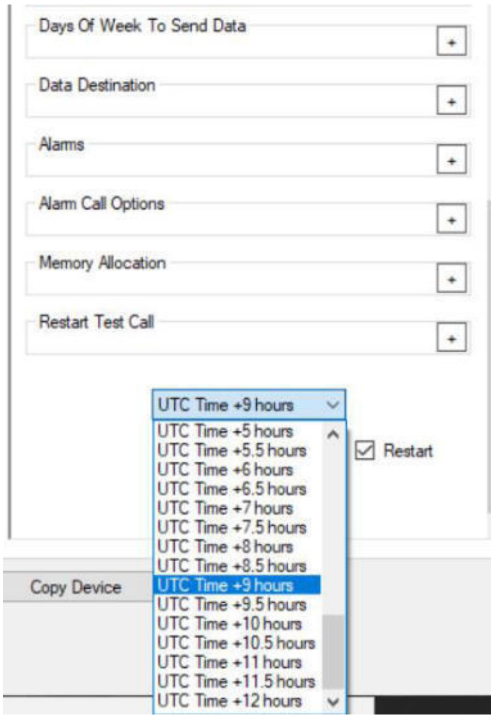
Lower:	Alarm triggered when level passes down through the specified limit.
Upper:	Alarm triggered when level passes up through the specified limit (for State alarm enter zero)
MNF:	Alarm triggered if minimum night flow is greater than specified level
ROC:	Alarm triggered if rate of change is greater than specified level
Dif>:	Alarm triggered if difference between 2 channels is greater than specified level
Dif<:	Alarm triggered if difference between 2 channels is less than specified level
Out Band:	Alarm triggered if value is less than lower level or greater than upper level
In Band:	Alarm triggered if value is greater than lower level and less than upper level

[UTC Time] (Coordinated Universal Time)

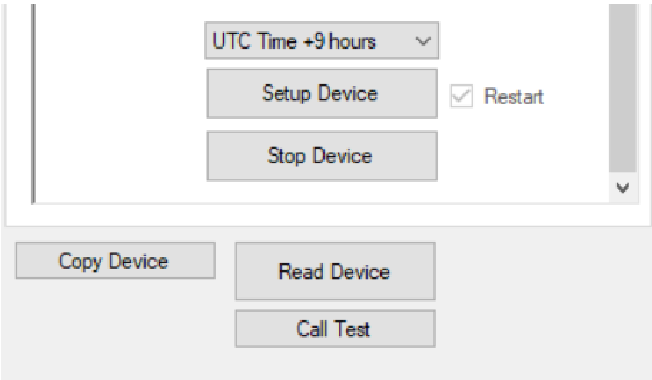
Final steps - By default the logger is set to UTC (Coordinated Universal Time, equivalent to GMT), however you can choose either an offset from this time, or for the logger to use your PC time.

<Japan> UTC + 9.0 hours

<Sri Lanka> UTC + 5.5 hours



When you are happy with all the settings click [Setup Device] button.



Data Communications Confirmation

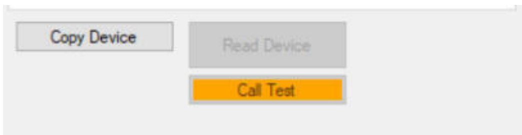
It is important to confirm that your logger is communicating with the data server before you leave site (or to be confident, your office), so you should undertake a 3G/GPRS test before you leave the logger in the field.

1 Connect an appropriate External 3G/GPRS antenna to the FME socket on the logger. The location on the socket can vary depending on the configuration of logger ordered, but the picture below illustrates a typical connection.

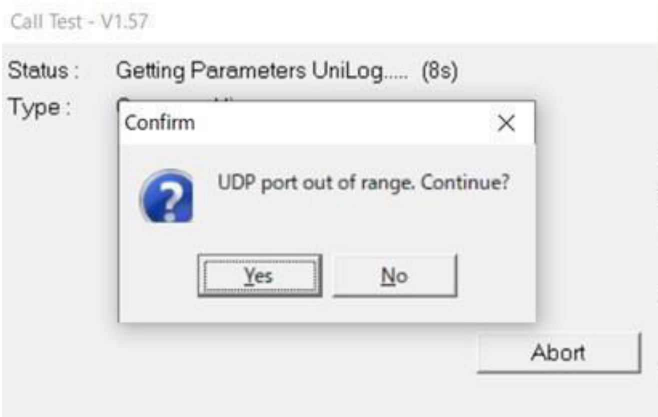
Note:
If this is the final Antenna connection, ensure that the connector is tightened with spanner or pliers to prevent water ingress to the antenna plug as this will reduce performance. do not over tighten.

2 Run the IDT and read your logger as shown above mentioned chapter.

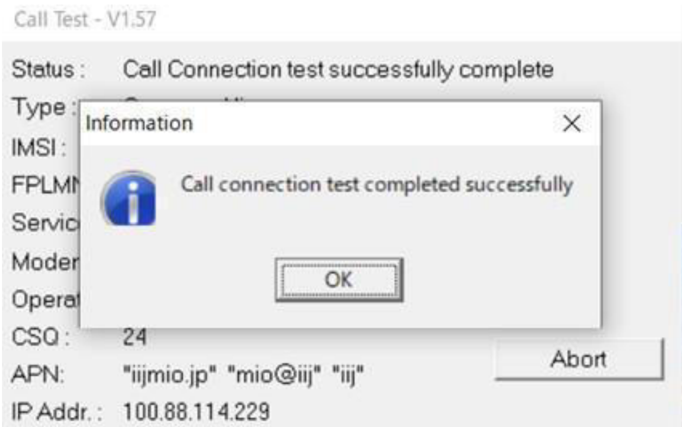
3. Now click the [Call Test] function button.



4 The Call Test program will now automatically execute a communications check with the data server of HWM Online™ or DataGate™ and deposit a test message that can be checked later on.
The test will take a few minutes and will confirm that the communication is successful.


Call Test - V1.57
Status : Getting Parameters UniLog..... (8s)
Type :
Confirm
UDP port out of range. Continue?
Yes
No
Abort


Call Test - V1.57
Status : Sending UDP data ... (75s)
Type : Command line
IMSI : 440030011046996
FPLMN : Cleared
Service: 3G
Modem : HE910-GL
Operator : "IIJ",2
CSQ : 24
APN: "iijmio.jp" "mio@iij" "iij"
IP Addr. : 100.88.114.229
Abort


Call Test - V1.57
Status : Call Connection test successfully complete
Type :
IMSI :
Information
Call connection test completed successfully
OK
CSQ : 24
APN: "iijmio.jp" "mio@iij" "iij"
IP Addr. : 100.88.114.229
Abort

Troubleshooting a Call Test failure

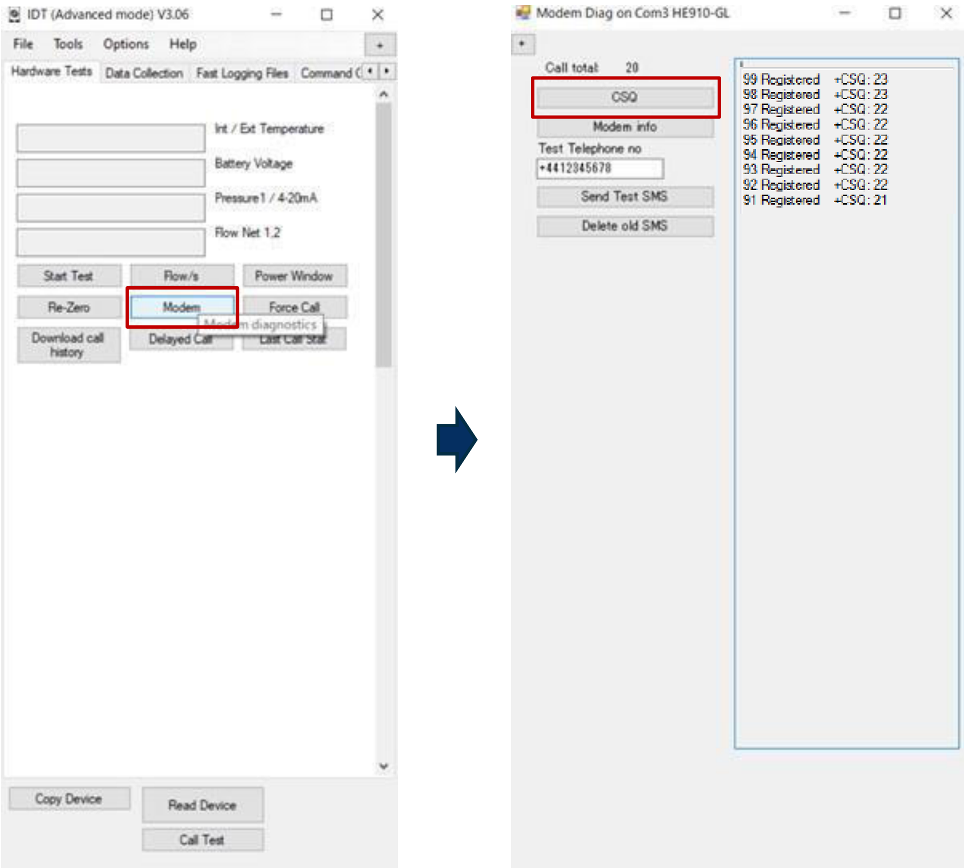
There are a number of reasons why a Call test may fail,

The following points should be checked before calling HWM support for assistance: -

Possible Problem	Solution
Network Busy due to excessive traffic. Commonly occurs around schools.	Retry the test after a few minutes.
3G/GPRS signal not available at your location. Not all Cell masts carry 3G/GPRS traffic.	The logger will call into the data warehouse once per day using an SMS message; relocate the logger if more frequent communications is required.
Network signal not strong enough. You need a CSQ (reported by the 3G/GPRS test) of at least 8 for reliable communications.	Relocate the antenna if possible or try alternative antenna configurations. Ensure antennas are vertically orientated where possible. See Antenna placement notes section.
APN settings incorrect.	The3G/GPRS tester knows about a large number of cellular networks and will try as many settings as possible and correct any error automatically. If there is still a failure, then you need to check with your network operator that you have the correct settings for your SIM.

Confirmation of Current Signal Strength

The [Modem] button on the [Hardware Tests] tab allows some more advanced diagnostics to be performed on the modem.
When you face Call Test failure, it is recommendable to check the actual signal strength.
[CSQ] button: Current Signal Quality



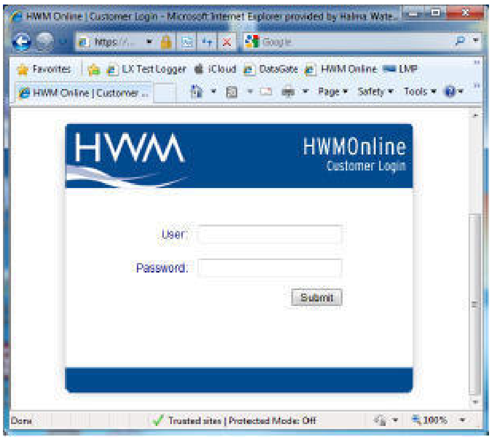
Cellular Network Signal Strength (as measured by CSQ Test)

0-7	Insufficient, the device may be able to register with network but will not be able to send or receive data reliably.
7-14	Marginal, depending upon the ambient conditions data transmission may be possible, important to select the correct antenna and install it in the most suitable location.
14-21	Adequate, Data transmission should be reliable.
21+	Ideal, Strong signal strength data transmission will be reliable.

Access HWM Online and check the transferred data

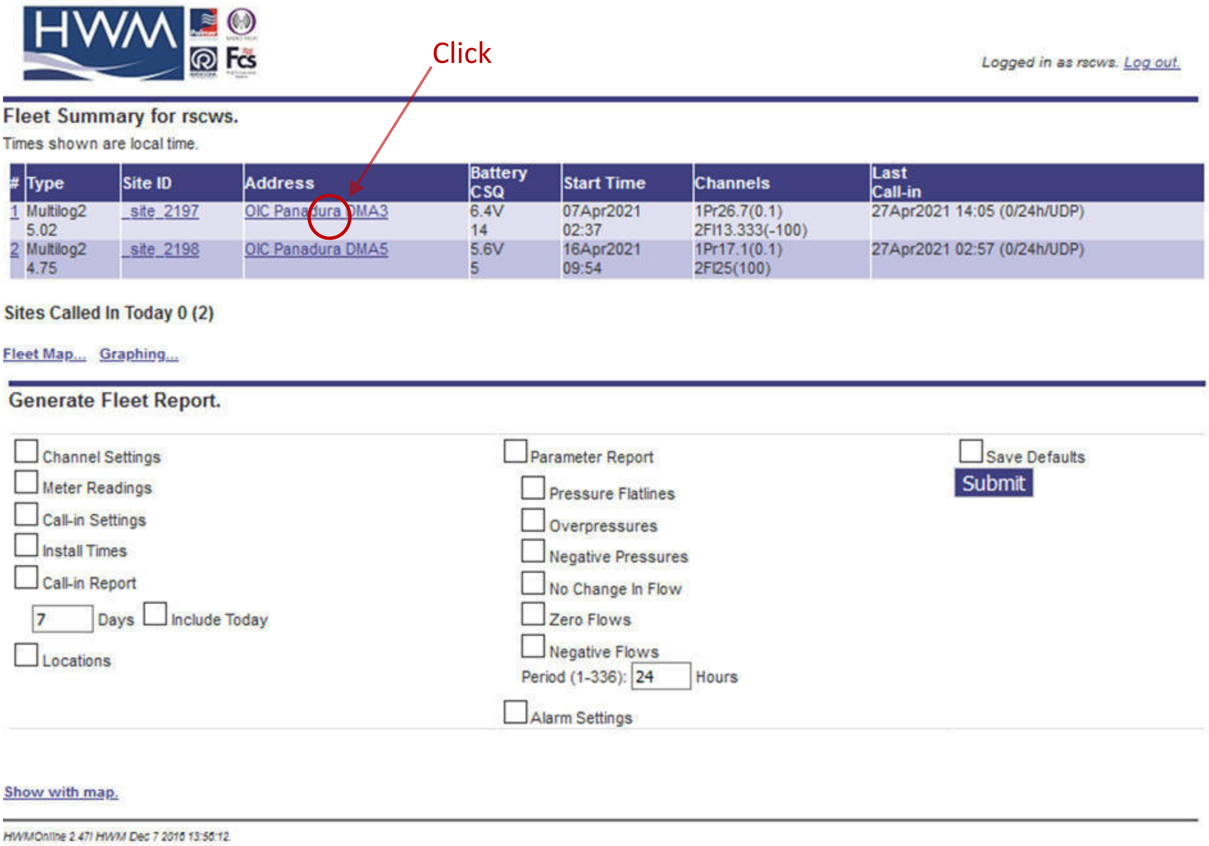
Since the data transmission setting is set to 3 times a day, access to HWM Online after a certain period of time has passed.

1. Open a new web browser window and navigate to
http://mejorasenergeticas.com:2225/hwmonline/
user: rscws
password: rscws-jica



This address of HWM Online service is valid only for the JICA project and the log-in permissions will end in December 2021.
If the data transmission is completed successfully, you can see the following page.

2. Once logged in successfully, you will see the main window below:



3. Chose the logger you wish to view and click. HWMOnline^{TM} will then retrieve your data from DataGate^{TM} and display it on the page.

4. The page below shows a typical result of a site query:

添付資料７：成果３キャパシティアセスメントシート

Name: ______________________________ Date: ______________

Responsible Training: ______________________________

Organization: ______________________ Position and working place: ______________________

Please answer the following questions to evaluate the improved capacity through the actual training in Training Yard.

Personal records and General Questions	**ANSWER**					
CHECK ITEM	**ANSWER**					**REMARKS**
Training program planning	A=Excellent	B	C=Moderate	D	E=Poor	
Capability of planning of training purpose and outline	☐	☐	☐	☐	☐	
Understanding of Training details	☐	☐	☐	☐	☐	
Understanding of training time table	☐	☐	☐	☐	☐	
Understanding of procedure for evaluation of training outcome	☐	☐	☐	☐	☐	
Ability to create training materials such as TG and text	A=Excellent	B	C=Moderate	D	E=Poor	
Expertise knowledge	☐	☐	☐	☐	☐	
Capability of creating lecture material	☐	☐	☐	☐	☐	
Capability of creating presentation material [PowerPoint, video, etc.]	☐	☐	☐	☐	☐	
Capability of creating easily understandable document	☐	☐	☐	☐	☐	
Ability to talk	A=Excellent	B	C=Moderate	D	E=Poor	
Teaching manner	☐	☐	☐	☐	☐	
Explanation skill [speed, loudness of voice, eye contact]	☐	☐	☐	☐	☐	
Explanation skill [communication with participants]	☐	☐	☐	☐	☐	
Explanation skill [document & prepared materials]	☐	☐	☐	☐	☐	
English level	☐	☐	☐	☐	☐	
Capability of Practical work	A=Excellent	B	C=Moderate	D	E=Poor	
Expertise knowledge	☐	☐	☐	☐	☐	
Capability of operation of general tools	☐	☐	☐	☐	☐	
Capability of operation of technical equipment	☐	☐	☐	☐	☐	
Capability of conducting proper method	☐	☐	☐	☐	☐	
Comments:						