Handbook

on

Non-Revenue Water Management in Kenya

Final Draft

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APPENDICES

ABBREVIATIONS

DMA	-	District Metered Area
DN	-	Diameter Nominal – internal diameter of a pipe or fitting
DZ	-	Distribution Zone
GS/GI	-	Galvanized Steel or Iron
GIS	-	Geographical Information System
HDPE or PE	-	High-density polyethylene or polyethylene
hr	-	hour
ISO	-	International Standards Organization
JICA	-	Japan International Cooperation Agency
KS	-	Kenya Standard
MD	-	Managing Director
MPa	-	Megapascal
m3	-	Cubic meter
NRW	-	Non-Revenue Water
PN	-	Pressure Nominal (in bars) - pressure that a pipe is designed to safely withstand
TM	-	Technical Manager
uPVC	-	unplasticized polyvinyl chloride
uPVC-D/E	-	unplasticized polyvinyl chloride class D or E
WSP	-	Water Services Provider
WSPs	-	Water Services Providers

INTRODUCTION

CHAPTER 1

SENSITIZATION IN NON-REVENUE WATER MANAGEMENT

(Target Group: All Water Services Provider's Staff)

1.1 Introduction

The Non-Revenue Water phenomenon traverses the whole Water Service Provider (WSP) to such an extent that each and every staff member has a role to play in its prevention and reduction. If the headache of managing NRW were to be removed as an activity in a water supply, it would be noted that the overall workload would be greatly reduced.

1.2 Managing Director

The Managing Director (MD) bears the overall responsibility of all the WSP's activities, including NRW management. This responsibility includes formulating policy, planning, organizing, staffing, training, directing, controlling and leadership.

In reduction of NRW, the MD must take full responsibility and always facilitate the staff to enable them undertake the necessary intervention measures.

It is therefore imperative that he/she understands NRW issues in order to be the leader rather than the hindrance of NRW reduction and low-level sustenance.

The MD must especially ensure that:

- staff and customers are sensitized on NRW issues
- All the staff including NRW Unit staff are adequately trained on water loss prevention and reduction in their areas of operation
- NRW reduction is prioritized and allocated with adequate resources
- NRW reduction indicators are monitored, evaluated and continuously improved
- Every staff member recognizes and plays their NRW reduction role
- NRW reduction activities are well coordinated.
- External stakeholders (County Government, MPs, etc) are sensitized to make formulate and gazette policies and laws aimed at reducing NRW.

1.3 Technical Manager

Most NRW reduction processes, including several under commercial department are technical in nature and therefore require technical guidance. The WSP looks up to the Technical Manager (TM) to lead the way in all technical matters.

It is therefore imperative that the TM is well trained in NRW matters including practical experience in techniques and equipment handling. This ensures the WSP has a reliable technical capacity.

The NRW Unit is most often under the technical department. Even though the NRW Unit is the one carrying the day-to-day NRW activities, the TM should be fully in charge of and drive the process including ensuring adequate and prompt facilitation of materials, equipment, transport, etc.

He/she should ensure specifications for all materials and services are prepared or revised well in advance before procurement and filed for easy retrieval.

Monthly materials usage and restocking levels should also be prepared or revised before the budgeting process. This revision provides the opportunity to raise NRW issues with the management and make the appropriate arrangements for NRW intervention measures during the coming financial year.

1.4 Commercial Manager

Staff under commercial department often assume that NRW reduction is the responsibility of the technical department. This belief or attitude may cause blame game between the technical and commercial departments' staff when the NRW ratio rises or remains high. The commercial manager must debunk this belief and take up his/her rightful place in NRW reduction effort. Meter and billing related water loss (e.g. meter reading errors, unread meters, stopped/inaccurate meters, leaking connections, illegal water use, inaccurate billing data entry, billing adjustment errors, unbilled customers, failure to report leaks/bursts, unregistered customers, customers without address or with wrong address, disconnected customers consuming water, meter tampering, etc.) account for high NRW ratio in many WSPs.

Similarly like the TM, specifications for all materials and services; and monthly materials usage and restocking levels should be prepared or revised well in advance before the budgeting process and procurement commencement. This revision again provides the opportunity to raise NRW issues with the management and make the appropriate arrangements for NRW intervention measures during the coming financial year.

1.5 Procurement staff

Often, implementation of NRW and other activities delay or fail due to late or no procurement of related goods and services. Successful and timely procurement is a precursor to good coordination of activities and processes. The manager should:

- Request for specifications of all materials and services from departments and file well in advance before the annual tender/quotation documents preparation.
- Coordinate timely preparation of procurement plans, annual tenders, stocks re-order levels, etc.
- Place if possible, all goods and services in annual tenders to reduce procurement workload of quotation preparation.
- Maintain several suppliers for each item to enable quick change in case of supply delay.
- Initiate set-up (in consultation with the line managers) and maintain standing tender/quotation evaluation committees. Such committees include pipes and fittings, water treatment chemicals, water meters, building materials and general works, electromechanical works and materials, insurance, evaluation committee, etc. This ensures only competent staff are involved in evaluation and therefore quality is assured.
- Similarly, set-up and maintain various inspection and acceptance committees.

1.6 Stores staff

Efficient management of the stores is critical for NRW reduction. The stores staff should always be watchful to ensure no stock-out situations occur by:

- Timely documenting and orderly storage of materials in stores for easy retrieval.
- Regular revision of monthly usage cycle, restocking levels and timely reports on likely stock-outs.

Most WSPs have installed Enterprises Resource Planning software (ERP) for efficient stocks monitoring.

Storage of materials must always be in accordance with the manufacturers' specifications. This is especially important for unplasticized polyvinyl chloride (uPVC) and PE pipe which must be stored in flat areas and covered against sunlight. Stacking must not exceed specified height to avoid damage.

1.7 NRW Unit staff

The role of NRW Unit is to:

- collect, analyze and interpret NRW data
- Proactive leak detection by various methods and equipment/tools
- recommending on NRW reduction measures to be taken
- Coordinate timely meter replacement, servicing and testing
- Prepare monthly NRW reports

This team should understand the opportunities for water loss in other sections and activities of the WSP. It should therefore be staffed with competent and well trained personnel on NRW reduction strategies.

1.8 Water Production Staff

Large water losses often occur in treatment facilities through leaking valves, overflowing reservoirs due to poor maintenance. Lack of plumbers responsible for the water treatment area is the main cause. The in-charge should always seek the TM's intervention to ensure leakages are repaired promptly.

1.9 Design and Construction Staff

Designing and implementation of pipelines and other facilities should be carried out by qualified technical personnel. The reality is that many WSPs do not have a design section in their establishments. This leaves design work to unqualified staff thereby resulting in poor planning.

It is recommended that design sections be created in WSPs to handle routine minor design works and to be liaison in sophisticated design work by professionals.

1.10 Water Distribution Staff

They are responsible for all the repairs of pipe leaks/bursts and therefore must be well trained.

They should always strive to do repairs properly (desisting from jua kali repair methods and materials) and within the shortest time possible.

1.11 Water Connection and Meter Installation Staff

The key issues regarding staff in charge of connecting customers and installing meters are:

- Delay in installation of connections/meters
- Digging inadequate trench depths prone to pipe damage, and/or leaving uneven trench bottom prone to cause air entrapment service lines
- Inadequate backfilling prone to pipe damage
- Poor workmanship in jointing thereby leaving leaking pipes
- Poor positioning of service line and meter
- Improper recording of the connections and/or meters including drawing service line maps, capturing coordinates for Geographical Information System (GIS) mapping, errors in meter serial numbers, interchanging meters between customers, etc.
- Delay in submission or loss of documents for connections/meters installation, etc.

The staff should therefore be properly sensitized also needs to be very well coordinated to ensure they are

1.12 Meter Servicing and Testing Staff

Over time, customer meters become clogged by debris/silt depending on the quality of the water. This clogging gradually obstructs the moving parts of the meter thereby causing the meter to slow down or stop altogether. This results in revenue loss to the WSPs. Servicing of meters restores accuracy of measurement and extends their lifespan thereby postponing replacement to a later date.

Analysis of customer water consumption should be conducted on monthly basis to generate the list of customer meters for illegal use and leakage-in-premises investigation; or meter servicing and accuracy testing.

Meter accuracy testing before servicing helps to resolve some of the customer bill complaints.

Recently, some WSPs have installed a few non-serviceable meters which if inaccurate (due to clogging with silt, etc) can only be disposed. It is difficult to guarantee consistently good water quality everywhere in the water supply hence WSPs should consider carefully before installing such meters.

Accurate NRW ratio depends on accurate bulk meters. Bulk meter should therefore be serviced regularly. Annual servicing schedules (depending on water quality) should be prepared and implemented to ensure accurate measurement of water supplied.

1.13 Meter Reading Staff

It is expected the team must visit ALL the customer meters every month record:

- Accurate customer meter reading
- Any leaks noticed
- Any meter tampering, broken seal, etc
- Any other abnormality (e.g. buried meter, illegal consumption, stopped meter, etc.)

This performance of the team can assist to report substantial water leaks at the meter and some surface leaks on pipelines as they go about their work.

1.14 Disconnection/Reconnection and Meter Sealing Staff

Meter tampering increases water loss and hence should be prevented through meter sealing and monitoring. The method and scope of sealing should be carefully chosen to ensure its effectiveness.

The team must ensure that their activities do not leave leakages at the meter liners and should report such leakages for prompt repair if unable to by themselves.

1.15 Billing Staff

WSPs should ensure the billed volume generated by the billing system are correct (in some cases, for the lowest consumers category [say 0 to $6m^3$], all consumptions lower than $6m^3$ are rounded off to 6m3 resulting in a higher total consumption volume hence lowering the NRW ratio). This can be confirmed by comparing manually calculated total consumption with the system generated figure.

The billing staff should be good data encoders to prevent encoding.

1.16 Customer Care Staff

Customer care staff is the contact point between the WSP and customers. A comprehensive customer care system should be installed to manage customer reports which should include leaks reports from the public and staff.

Reports or incidents of leaks, etc should be shared with the relevant staff as soon as they are received for action and resolution.

A customer service charter should be formulated, disseminated to all staff and monitored for compliance and improvement.

Water utilities should incorporate sensitization activities for schools and communities within their service areas as an important part of their NRW reduction efforts. Sensitization activities, if correctly executed, help WSP in their daily operations such as voluntary reporting of water leakages and unauthorized water users to the WSP.

Sensitization activities can be categorized as short and long term.

In short term sensitization activities, the utility sensitizes the water users and other stakeholders to take instant actions such as reporting meter thefts or water conservation.

Long term sensitization activities aims to nurture water stewardship among water users and other stakeholders. An example is to educate children about water processing and the cost of producing and distributing safe and clean water to customers.

The goal of sensitization is to change the behavior of water users and stakeholders for the benefit of all.

The WSP should plan and conduct sensitization activities such as open days for the community. There, they inform about the role in enhancing the good performance and sustainability of the water services, and responding to the concerns of community needs. Public events such as agricultural show or World Water Day events (March 21st) are good venues for the utilities to sensitize the communities. The WSP can exhibit educational materials such as posters or demonstrate activities on related topics. Social medias are also important tools to communicate messages.

Engaging schools to enhance students' understanding of the water supply operations and the importance of water and sewerage play in public health have a long lasting impact. Inviting schools pupils for facility tours or visiting schools to give presentations by the utility staff require minimum resources.
The activities targeting pupils 5-7th grade is particularly appropriate as school curriculum in Kenya includes water treatment. It is important that the pupils are encouraged to share their experiences with their families and friends. This is meant to foster a more informed and responsible community.
The contents of sensitization activities for pupils can be as follows:

- Explanation of water treatment processes. Explaining where raw water is coming from and how clean and safe water is produced and distributed to the customers?
- Visiting facilities such as treatment plant, pump house, laboratory, etc which majority of pupils only read/learn about in the text book will leave a strong impression on them.
- Learning about the quality of water improves through comparing raw water and treated water and the role of chemicals.
- Giving them a quiz or chance to speak about what they learned from the visit.
- It is important to encourage pupils to discuss about their visits with their parents and families. The Utility can teach them about the importance of water conservation, prevention of unauthorized water use, and reporting of malpractices to their parents or families.

1.17 Mapping/GIS Staff

A comprehensive mapping of the water supply network is critical for NRW management.
In the past, GIS mapping software was too costly to most WSPs. Not anymore. Easy to use free GIS mapping software such as MAPinr and GPS Essentials; and field data collection tools such as kobo collect toolbox are downloadable from the internet. Digital GIS mapping is hence replacing paper maps thereby easing information update and sharing within the utility and with other related infrastructure agencies to facilitate communication.
No WSP therefore has any excuse to continue using paper maps and therefore should upgrade soonest.
Digital mapping should, where possible, be integrated with database systems such as billing system, customer care module, stores module, etc. This captures a vast array of information about the distribution network on one platform thereby easing work considerably.
The mapping staff should be upto the task of accurately and efficiently updating the maps. This will enable other staff to undertake their daily activities more efficiently and hence result in faster NRW reduction.

1.18 All Staff

All the staff have a responsibility to look out for and report any leaks/bursts, illegal water use, system vandalism, etc, immediately they notice or become aware for repair.

1.19 Customers

Reduction of NRW leads to better provision of better and more efficient services to the public. This can be accomplished by teaching the public to understand their role in managing NRW by reporting burst pipes, faulty valves, leaks, vandalism, illegal connections or other problems that may not occur in or around their neighborhood., Awareness programmes are therefore key and should be organized with targeted participants including a variety of stakeholders from the public, political leaders, community leaders, industrial and household consumers.

Such awareness programmes should be conducted with the help of suitable tools such as posters, fliers and SMSs to customers through by focusing on basic NRW concepts and how reduction of NRW helps ensure that communities receive better water supply and other services from WSPs.

It's prudent that after conducting awareness programmes in various communities the WSP staff work hard to maintain customer confidence in the WSP service. Maintenance of open communication is also key and WSPs should establish systems to efficiently receive, process and resolve complaints from consumers.

CHAPTER 2

WATER PIPES STANDARDS AND CONNECTION/REPAIR PROCEDURES

(Target Staff: Design, Procurement, Construction, Network Maintenance/Repair)

2.1 Introduction

The following passage in italic is an extract of Section 16.1 and 16.2 of the "Ministry of Water and Irrigation - Practice Manual for Water Supply Services in Kenya - October 2005".

a) General

Preferred Standards

- *Locally manufactured items shall be to Kenya Bureau of Standards (KS) Specification. Where a KS Specification is not published then the items should meet the requirements of the International Standards Organization (ISO). Where neither a Kenya Standard nor an ISO Specification are published then the locally manufactured item should be in accordance with the relevant British Standard Specification (BS) or other National Standards.*
- *Imported items should meet the requirements of the International Standards Organization (ISO). Where an ISO Specification is not published then the item should be in accordance with the requirements of the National Standards of the Country of origin (i.e. BS for British Manufacture, DIN for West German Manufacture etc.) with the proviso that*
    - *i) the Standards Specification lays down requirements not less than those required by the British Standards Institution*
    - *ii) the Standards Specification exists in official English translation*

New Standards

- *The list of KS, BS and ISO standards are expanded continuously and old standards are revised. It is therefore important that design engineers keep up to date with the development.*

Standards for Material used in Existing plants

- *For existing plants where other standards than KS were used originally, the same standards may be kept for the completion and extension work.*

b) Standards Relating to Water Supply

Standards valid in 2005

KS, BS and ISO Standards, which can be expected to have some application in water supplies, can be found in Appendix C.

The above extract is an indication of the great importance of specifying the Standard during procurement of materials. This ensures that the inspection and acceptance committee of the WSP has the criteria to receive conforming materials and reject non-conforming materials without ambiguity or confusion, which is common in WSPs.

2.2 Standards

2.2.1 Definition and Benefit of a Standard

A standard is a level of quality or achievement, especially a level that is thought to be acceptable.

The definition of a standard is something established as a rule, or basis of comparison. An example of standard is a guideline governing the thickness of 20mm diameter UPVC class E pipe, or the length of a pipe socket, etc.

In essence, a standard is an agreed way of doing something. It could be about making a product, managing a process, delivering a service or supplying materials; hence, standards can cover a huge range of activities undertaken by organizations and used by their customers.

The benefits of Standards are that consumers (eg. WSPs) can have confidence that their products are safe, reliable and of good quality.

2.2.2 Sources of Standards

Kenya Bureau of Standards (KEBS) develops and approves Kenya Standards in corroboration with relevant stakeholders in the various fields. Standards developed by KEBS are designated as KS.

KEBS also participates in development of international standards under International Standards Organization, ISO. Those standards resulting from such participation are designated as KS ISO. Standards approved in other countries such as British Standards (BS), German Standards, DIN etc are also applicable in Kenya where a Kenya Standard is not available.

WSPs can purchase standards online from KEBS website at reasonable prices (upto Kshs 20,000) depending on the standard.

2.2.3 Importance and Necessity of using Standards

In any society there are some people who want to make profit without providing commensurate value. The water sector in Kenya is not exempt especially with regards to pipe materials with cases of merchants supplying lower class than specified. WSPs rarely possess copies of material standards thereby forcing them to receive whatever is supplied without adequate inspection. This is dangerous especially for the inspection and acceptance committees who are at a risk of blame for poor materials.

WSPs should therefore identify, purchase and institutionalize use of available standards.

2.2.4 Testing of Materials

In a factory, ingredients are mixed in specified proportions and passed through the manufacturing process to produce, say pipes. It is normal procedure for samples to be taken at regular intervals (e.g. every 1 hour) and various tests conducted to confirm compliance with the standard and test certificates filed. As already stated in Section 2.2.3, some unscrupulous manufacturers increase the proportion of the cheaper ingredient to save on production cost thereby decreasing the quality of the final product. This enables them to give lower prices during tendering therefore winning most of the tenders. WSPs without proper inspection skills are therefore left exposed to poor materials despite their best effort to manage NRW.

WSPs should therefore:

a) send relevant staff on factory tours to sensitize them on the various tests and the parameters to check during inspection while referring to standards.
b) Include submission of test certificates as requirement during tendering
c) Institutionalize sample testing of materials before payment.

2.2.5 How to check whether pipes and fittings are as per the Specified Standard

Most WSPs in Kenya procure pipes and fittings without specifying the standard but only generally specifying the pressure rating (e.g. uPVC-E). Even where the standard is specified (which is very rare), they are rarely check for compliance during inspection and acceptance from the suppliers. This has often resulted in the materials being of lower class and/or very poor standard thereby contributing to serious leakages.

It is important to note that receiving pipe materials by simply referring to the colour coding (which is the common practice among WSPs) is grossly inadequate.
In addition to the above, WSPs rarely check for manufacturing defects when receiving materials.

The procedure below should be followed when inspecting pipes and fittings before acceptance:

a) Obtain a copy of the specified standard for procurement of the materials
b) Decide the proportion of the materials to be checked (say 5% if large quantity)
c) Inspect the sample materials for manufacturing or handling defects. The pipes/fittings should be smooth, even and symmetrical and without bubbles, cuts, slugs, holes, breaks, etc.
d) For each pipe, measure the outside (od) and internal (id) diameters of the non-socket non-chamfered part using vernier caliper (Figure 2.1 & 2.2) and compare with the standard.
e) Also measure the outside (od) and internal (id) diameters of the pipe socket
f) For fittings, measure the id and od of the socket part
g) Calculate wall thickness, t = (od-id)/2
h) For pipes, confirm that od and t are as per the standard
i) For fittings and pipe sockets, confirm that the **id** and **t** are as per the standard
j) Repeat the measurement for the 5% of the materials
k) If at least 95% of the materials comply, accept and receive the materials, otherwise reject all. Alternatively, check all the materials and reject those not complying. The WSP should come up with a policy on receiving of materials, goods ad services.

Figure 2.1: Measuring outside diameters of uPVC pipe with vernier caliper

Figure 2.2: Measuring inside diameters of uPVC repair coupling with vernier caliper

WSPs can device methods to confirm other parameters on site.

2.3 Working and Testing Pressure

- Working (or normal pressure) is the maximum pressure the pipe will be subjected to under normal operating situation in the field. This pressure should always include any likely water hammer pressure.
- Testing pressure is the maximum pressure the pipe should be subjected to during testing after installation in the field (Table 2.1).

Table 2.1 Testing Pressure for Water Pipe Materials

	Pipe Material	**Testing Pressure**
1	uPVC (Polyvinyl Chloride	1.5 x working pressure
2	High-density polyethylene (HDPE) or Polyethylene (PE)	1.2 x working pressure
3	GS/GI (Galvanized Steel/Iron)	Depends on material grade & pipe size
4	CI (Cast Iron)	Depends on material grade & pipe size
5	Epoxy coated/lined	Depends on manufacture recommendations
6	Concrete coated/lined	Depends on manufacture recommendations
7	PPR	1.5 x working pressure

2.4 Unplasticized Poly-Vinyl-Chloride (uPVC) Pipe Materials

2.4.1 General

PVC (Polyvinyl Chloride) is strong but lightweight plastic pipe. It is made softer and more flexible by addition of plasticizers. If no plasticizers are added, this makes it rigid, hard and strong, and it is called unplasticized polyvinyl chloride, uPVC.

2.4.2 uPVC Pipe Classification

uPVC pipes and fittings are classified by the maximum working pressure rating and identified by colour coding (Table 2.2) and in addition manufactured with electronic identification print on the pipes at every 2m (indicating manufacturer's name, date of manufacture, manufacture standard, pipe class).

Table 2.2: uPVC Pipes Pressure Rating and Colour Code

uPVC Class	Maximum Working Pressure			Colour Code
	(MPa)	(PN/bar)	(m head of water)	
B	0.6	6	60	Red
C	0.9	9	90	Blue
D	1.2	12	120	Green
E	1.5	15	150	Brown

2.4.3 How to Select uPVC Pipes and Fittings Standards

Table 2.3 indicates pipes with varying outside diameter and wall thickness.

Table 2.3**:** Dimensions of UPVC pressure pipes as per KS 06-149 Standard

NOMINAL OUTSIDE DIAMETER mm	OUTSIDE DIAMETER mm		WALL THICKNESS mm							
			CLASS A P = 0.60 MPa (6bar)		CLASS B P = 0.90 MPa (9bar)		CLASS C P = 1.2 MPa (12bar)		CLASS D P = 1.5 MPa (15bar)	
	min	max	min	max	min	max	min	max	min	max
* 20	20.0	20.3	-	-	-	-	1.40	1.80	1.40	1.80
25	25.0	25.3	-	-	-	-	1.40	1.80	1.60	2.00
* 32	32.0	32.0	-	-	1.40	1.80	1.70	2.10	2.10	2.60
40	40.0	40.3	-	-	1.60	2.00	2.10	2.60	2.60	3.10
50	50.0	50.3	1.40	1.80	2.00	2.40	2.60	3.10	3.20	3.80
* 63	63.0	63.3	1.70	2.10	2.50	3.00	3.30	3.90	4.10	4.80
75	75.0	75.3	2.00	2.40	3.00	3.50	3.90	4.50	4.80	5.50
* 90	90.0	90.3	2.40	2.90	3.60	4.20	4.70	5.40	5.80	6.60
* 110	110.0	110.4	3.00	3.50	4.40	5.10	5.80	6.40	7.10	8.00
125	125.0	125.4	3.40	4.00	5.00	5.70	6.50	7.40	8.00	9.00
140	140.0	140.4	3.80	4.40	5.50	6.30	7.30	8.30	9.00	10.30
* 160	160.0	160.5	4.30	5.00	6.30	7.20	8.30	9.40	10.30	11.60
200	200.0	200.6	4.80	5.50	7.10	8.00	9.40	10.60	11.60	13.00
* 225	225.0	225.7	5.40	6.20	8.00	9.00	10.50	11.80	13.00	14.50
250	250.0	250.8	6.00	6.80	8.90	10.00	11.70	13.10	14.40	16.00
* 280	280.0	280.9	6.70	7.60	9.90	11.10	13.10	14.70	16.20	18.10
* 315	315.0	316.0	7.60	8.60	11.20	12.60	14.70	16.40	18.20	20.20
355	355.0	356.1	8.50	9.60	12.60	14.10	16.60	18.50	20.50	22.80
400	400.0	401.2	9.60	10.80	14.20	15.90	18.70	20.80	23.10	25.70
450	450.0	451.4	10.80	12.10	16.00	17.80	21.00	23.30	26.00	28.80
500	500.0	501.7	12.00	13.40	17.70	19.70	23.40	26.00	28.90	32.00
* Preferred pipe sizes in Kenya										
Source: Ministry of Water and Irrigation - Design Manual for Water Supply in Kenya - October 2005".										

Figure 2.3: is an extract of ISO 4422: PART 2: 1996 Standard for uPVC Pipes.
The Standard is tight in both outside diameter and wall thickness of pipes allowing no slack. This helps to ensure tight joints and prevent leaks.

Nominal Outside Diameter	PN = 6 Bar	PN = 6.3 Bar	PN = 10 Bar	PN = 12.5 Bar	PN = 15 Bar
	Nominal wall thickness (mm)				
20	-	-	-	-	1.5
25	-	-	-	1.5	1.9
32	-	-	1.6	1.9	2.4
40	-	1.5	1.9	2.4	3
50	-	1.6	2.4	3	3.7
63	1.9	2	3	3.8	4.7
75	2.2	2.3	3.6	4.5	5.6
90	2.7	2.8	4.3	5.4	6.7

PN = Nominal Pressure

Figure 2.3 Extract of UPVC Pressure water pipes as per ISO 4422:Part2:1996 (International Standards)

Note:

1. Meru WSP managed to maintain relatively low NRW ratio (below 25%) by strict use of uPVC-E to ISO 4422: PART 2: 1996.
2. ISO 4422: PART 2: 1996 has already been replaced by KS ISO 1452-2:2009

2.4.4 uPVC Pipe Joints

2.4.4.1 General

Pipe jointing work is very important in leakage prevention. Those who supervise pipe work installation should not depend on the skills and experience of the workers but should themselves have adequate knowledge, experience and understanding of the principle of various types of joints.

WSPs are advised to set up standards for pipe jointing in liaison with the manufacturer.

Figure 2.4: Rubber ring couplings (dia≥63mm) and Bonding Joint Couplings (dia<63mm)

There are three types of joints for uPVC pipe system:

a) Bonding Joint (only used for pipes of diameter < 63mm in Meru WSP)
b) Rubber ring joints (used for pipes of diameter ≥ 63mm in Meru WSP)
c) Special Joints (Connecting Pipes of Different Materials)

Figure 2.4 shows couplings for rubber ring joint and bonding joint.

2.4.4.2 uPVC Pipe Taper Socket Bonding Joint

a) The Principle of Taper Socket Bonding Joint

This method uses a joint with a tapered end (Figure 2.5) and utilizes the swelling and elasticity of polyvinylchloride when combined with an adhesive.

i) As adhesive is applied to the pipe and socket, swelling approximately 0.1mm thick is produced on the surfaces. This facilitates insertion of the pipe. After the pipe is inserted to the point of stopper, the swollen layers bond to join the surfaces together. The diameter of the tapered socket is smaller than the diameter of the pipe thereby resulting in a squeezing counterforce on the pipe from the expanded socket. This counterforce also has the effect of tightening the joint.

ii) Before applying adhesive, the following procedure is necessary:
   - Measure the coupling length (Figure 2.5).
   - Temporarily and tightly insert the pipe into the socket and check to ensure the engagement length is 1/3 – 2/3 of coupling length

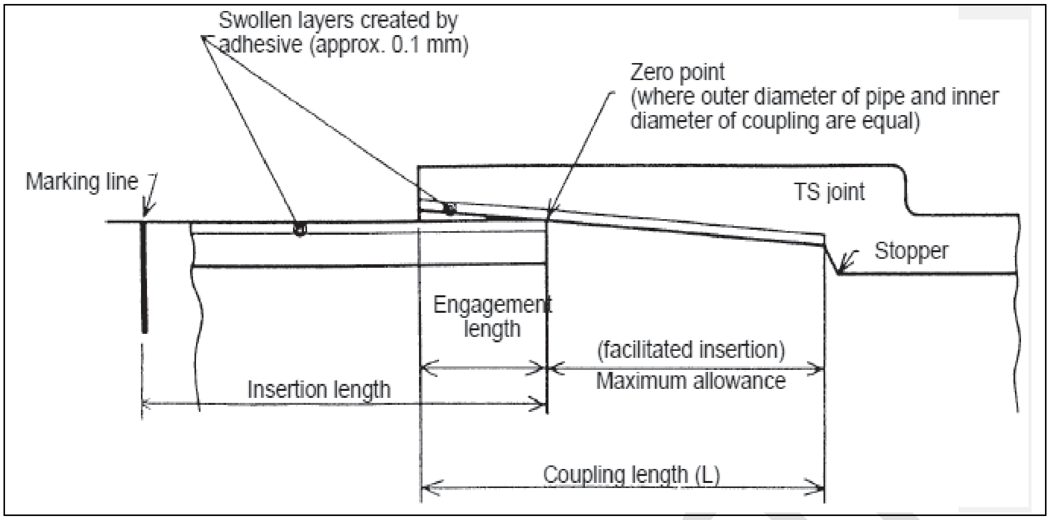


Figure 2.5 Detail of PVC bonding joint

iii) Quick-drying adhesive should be used as a rule. The pipe should be inserted as soon as the adhesive is applied, especially if it is under a hot sun where adhesive is likely to dry very quickly.
iv) It is wrong to assume that the more the adhesive is applied, the better the bonding. When too much adhesive is applied, the vapor weakens the pipe. Further, the adhesive disturbs water meters and also causes odour in the water.
v) To obtain strong adhesion, the surfaces to be joined should be clean and dry. Any oil sticking on the surfaces decreases the adhesive strength since the adhesive rejects oil and does not expand as in (i) above. The adhesive also rejects water, dust and other particles.
vi) In order to confirm that the pipe is inserted upto the stopper, the marking length of the insertion (or coupling length, L) before inserting is necessary.
vii) After inserting, it is necessary to hold the pipe and socket firmly together for a specified period of time to prevent the counterforce of the expanded socket from pushing the pipe out of the socket.

b) Procedure of Taper Socket Joint

i) Cut PVC pipes so that the end is straight
ii) Deburr (remove the rough edge left after cutting) the cut section by lightly chamfering (cutting away a right-angled edge or corner to make a symmetrical sloping edge)
iii) Clean the joint end and outer surface of the pipe spigot. Oil and water should be cleaned off completely
iv) Measure the joint coupling length (L) on the pipe from the pipe end and draw a marking line.

<u>Note:</u>

- For joints with a diameter between 20mm and 40mm, a marking line should be drawn at a point equal to the zero-point distance plus the adhesive length specified in the table below away from the pipe end. The zero point should be determined with the pipe lightly inserted in the joint as it depends on the dimensional tolerances of the outer diameter of the pipe and inner *diameter of the joint coupling.*

v) When the pipes are connected at a right angle using a joint such as elbow or bending coupling for a tap, indicate joining marks on the pipes and joint
vi) Apply PVC adhesive over the inner surface of the joint and outer surface of the pipe spigot. The adhesive layer must be thin and uniform.
vii) Do not apply PVC adhesive beyond the marking line on the pipe.
viii) If too much adhesive is applied, it may enter the pipe and cause disturbance to the water meters; and abnormal smell and taste.
ix) Rapidly insert the pipes straight into the joint. Hold them for a period of time not shorter than that shown below:

Table 2.4: Standard holding time for Taper Socket joints

Diameter (mm)	50 or less	63 or more
Standard holding time	30 sec. or more	60 sec. or more

x) If you release the pipe and socket before the specified holding time elapses, the pipe may eject out of the joint.
xi) Check and ensure that the pipe is inserted to the marking line.
xii) In case the insertion is improper, do not repeat the above steps using the same pipe surfaces and same joint. Cut off the pipe where adhesive has been applied and replace the joint with a new one.
xiii) Any adhesive forced out of the joint surfaces during insertion should be wiped off immediately.

b) Precautions for Prevention of Leakages

i) PVC pipes are susceptible to heat. Their structural strength decreases with rise in temperature. They are softened around 180°C.
ii) PVC pipes are susceptible to cold weather. In a cold area, they are easily broken by an external impact. They become brittle at -18°C.
iii) PVC pipes expand much with heat. They expand and contract more with temperature changes than steel pipes.
iv) PVC pipes are susceptible to solvents, especially antiseptics (creosote oil) and acetone. They are also affected by pipe adhesive.
v) PVC pipes are not suitable for use in temperatures exceeding 50°C or low temperatures. A straight PVC pipeline exposed to extreme temperatures should be supported with expansion joints at intervals of 30 to 40m.
vi) PVC pipes should be protected from direct sunlight. Do not stack them to a height over 1m. do not throw them, especially in cold weather.

2.4.4.3 uPVC Pipe Rubber Ring Socket joint

Experience in Meru WSP suggests that pipelines of 63mm diameter and above should be connected using rubber ring socket joints since they are easier to dismantle and reuse hence more convenient.

Rubber ring joints provide a water seal by compressing a rubber ring housed in the socket of a pipe (or fitting) when the spigot is passed into the socket. Correct jointing rings should always be supplied with the pipes or fittings.

Always follow manufacturer's jointing instructions including the recommended jointing lubricant. Other lubricants may not be suitable for drinking water contact and may affect the ring. Cooking fat can also be used as lubricant.

How to Joint Pipes/Fittings with Rubber Ring

a) Pipes may be jointed out of the trench but it is preferable that jointing be done in the trench to prevent possible "pulling apart" of the joint during pipe transfer to the trench.

b) Check that the spigot end has (been supplied with) a chamfer of approximately 12° to 15° to the pipe axis (Figure 2.6). For spigot end of pipe that is cut in the field chamfer must be made with a chamfering tool (or a body file ensuring sharp edge, which may cut the rubber ring is not left).

c) Deburr (remove sharp edges on the inside rim of) the pipe using a deburring tool (or round body file). Do not break or chip the inside edge (Figure 2.7).

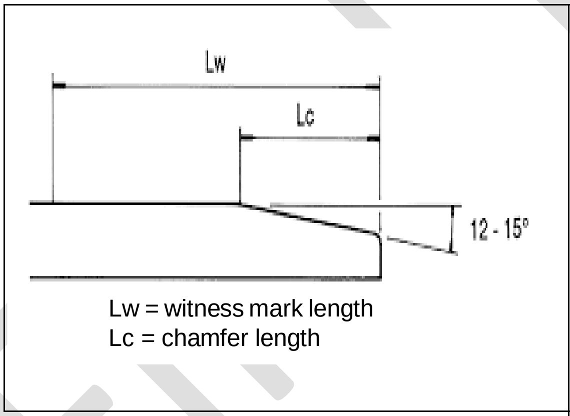


Figure 2.6: Unchamfered spigot

Figure 2.7: Unchamfered dimensions being deburred

d) Clean and dry the socket with a piece of cloth, especially the ring groove. Do not use rag with lubricant on it.

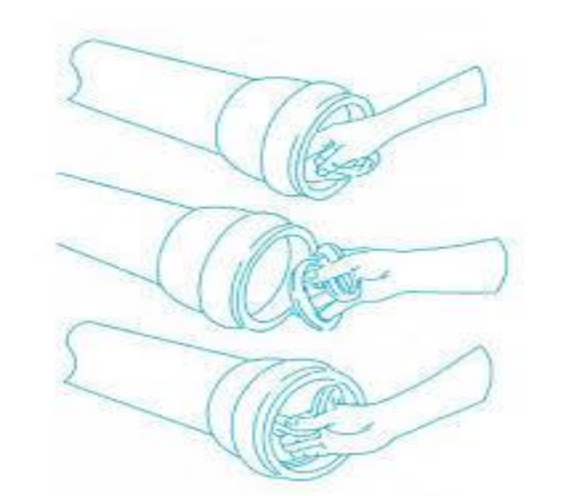


Figure 2.8: Inserting rubber ring into pipe socket

e) Clean and dry the rubber ring and insert it into the groove as per manufacturer's instructions (the fins of the rubber always go into the socket first) (Figure 2.8).

f) Run your finger around the lead-in angle (slight edge on inner ring surface which is the first part the spigot touches as it enters the socket) of the rubber ring to check that it is correctly seated, not twisted, and that it is evenly distributed around the ring groove.

g) Clean the spigot end of the pipe as far back as the witness mark

(Note: for spigot end of any pipe that is cut in the field, make the witness mark as per manufacturer's instructions (witness mark ensures the spigot leaves adequate compression gap to the socket end in case of earthquake or temperature movement) (Figure 2.9).

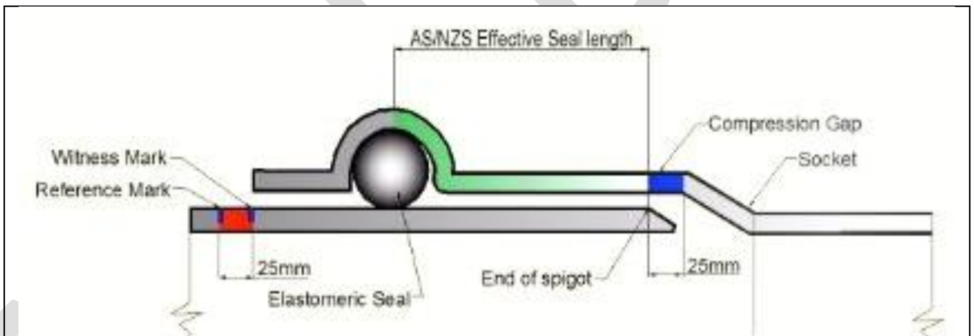


Figure 2.9: Witness mark on pipe spigot

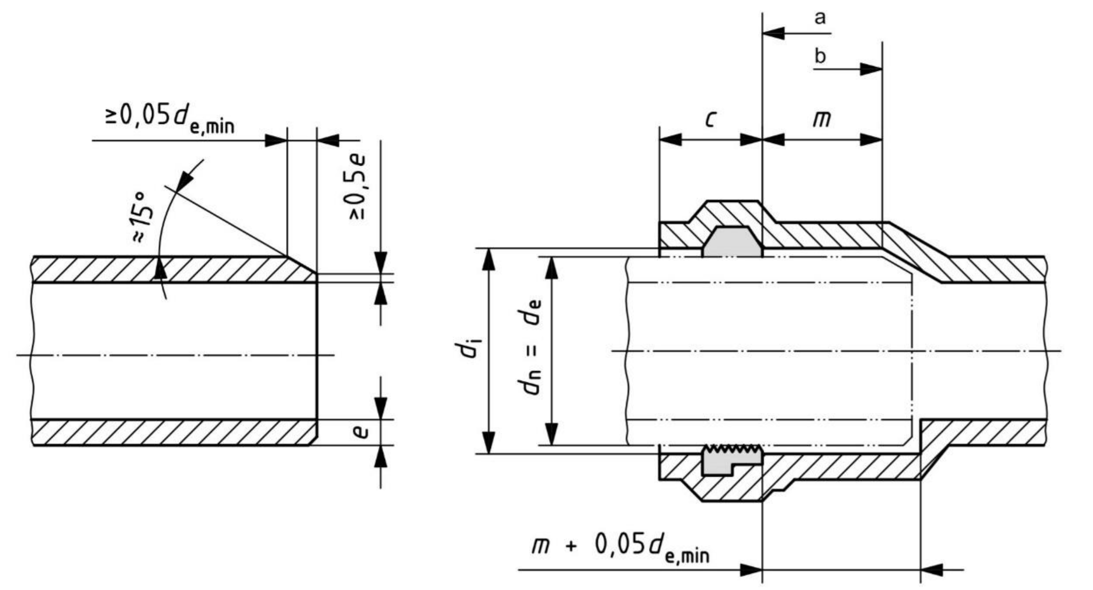


Figure 2.10: Dimensions of socket & spigot end for pipe with rubber ring

Table 2.5: Dimensions of Sockets for Solvent Cementing as per KS ISO 1452-2:2009(E)

Nominal inside diameter of socket, d_n	**Minimum mean inside diameter of socket, $d_{im,min}$**	**Minimum depth of engagement, m_{min}**	**Length of socket entrance & sealing area, c**
20	20.3	55	27
25	25.3	55	27
32	32.3	55	27
40	40.3	55	28
50	50.3	56	30
63	63.4	58	32
75	75.4	60	34
90	90.4	61	36
110	110.5	64	40
125	125.5	66	42
140	140.6	68	44
160	160.6	71	48
180	180.7	73	51
200	200.7	75	54
225	225.8	78	58
250	250.9	81	62
280	281.0	85	67
315	316.1	88	72
355	356.2	90	79
400	401.3	92	86
450	451.5	95	94
500	501.6	97	102

h) Apply jointing lubricant to the spigot end as far back as the witness mark and especially to the chamfered section.

Note: Keep the rubber ring and ring groove free of jointing lubricant until the joint is actually being made.

i) Align the spigot with the socket and apply a firm, even thrust to push the spigot into the socket. It is possible to joint 63mm to 150mm diameter pipes by hand.
j) For pipes larger than 150mm diameter, a bar & timber block lever (Figure 2.11) or a pipe puller (Figure 2.12) may be used. Insert the spigot upto the socket end or the witness mark (as per manufacturer's instructions).

Note:
- If excessive force is required to make a joint, it may mean that the rubber ring has been displaced.

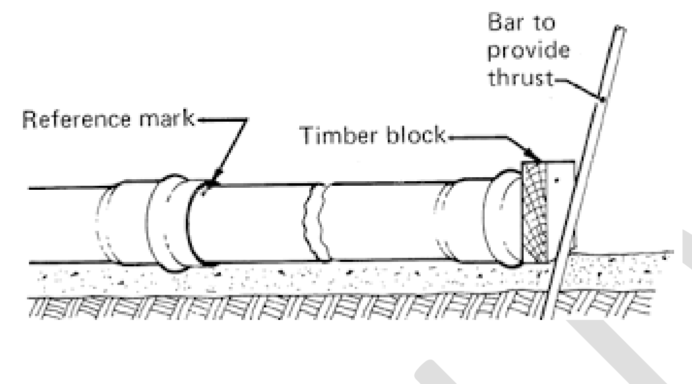


Figure 2.11: Bar & timber block lever


Figure 2.12: Pipe puller

k) Check whether the ring is properly placed (without dismantling the joint) by either:
   - Inserting a feeler gauge all round between the socket and pipe to check even placement, or
   - Shine a torch through the pipe. If there is anything protruding on the inside, the ring is not properly placed.
l) If a ring is not properly placed, dismantle the joint and repeat the procedure with a new rubber.
m) Brace or support the socket end of the line so that previously jointed pipes are prevented from sliding backwards.
n) Inspect each joint to ensure that the witness mark is just visible at the face of each socket.
o) With mechanical assistance, rubber ring joints can be recovered and remade years after the original joint was made.
p) New rubber rings should be used for recovered joints and care should be taken to ensure that there is no damage to pipe or socket.

2.4.4.4 Poor Pipe Repair Practices
Reduction of NRW in Kenya has been difficult in the past and even currently mainly due to poor repair practices like use of couplings made by heating pipes on fire. A fire-made coupling is repair coupling made from a piece of uPVC pipe by heating the pipe and inserting another unheated pipe into the heated end to make a socket.

Heating a pipe denature the pipe material thereby weakening it and destroying its elasticity. Further, the resulting socket is of no specific standard and loosely fits onto the pipe inserted thereby leaving a gap for leakage.
This practice was common in Meru WSP as shown in Figure 2.13 to 2.15 below. However, after staff training by KEWI and introduction of proper repair couplings and other repair materials, the practice was abandoned resulting in a substantial and sustained reduction in NRW.

Figure 2.13: Softening Pipe by Heating

Figure 2.14: Making Fire-made Coupling from Softened Pipes

Figure 2.15: Poor Repairs with Fire-made Couplings

Poor pipe repair practices are due to:

- lack of knowledge that heating plastic causes it to deteriorate thereby losing elasticity and strength which are very crucial in its performance

- lack of knowledge on the serious long term consequences of poor pipe repair practices on NRW
- lack of training on proper pipe repair practices
- failure by WSPs to prioritize procurement of proper pipe repair materials
- corrupt tendencies whereby staff pilfer repair materials
- lack of training on integrity and therefore lack of understanding on the future consequences of corruption
- lack of adequate and severe action on wayward staff

WSPs must decisively deal with these issues if they expect to make positive and sustainable impact of progressively and speedily bringing down their NRW to acceptable level. It is the high time that Kenya becomes the leader in NRW management.

2.5 PE Pipe Materials

2.5.1 General

HDPE is the material used for high pressure pipes. There are two qualities thus PE80 (most commonly named MDPE) and PE100 (which is the improved from PE80). PE100 is recommended since it offers additional long-term strength and performance over PE80 while allowing for thinner pipe walls for the same operating pressure.

2.5.2 PE Pipes Classification

PE pipes come in various colours depending on the purpose (Table 2.6) and pressure rating.

Table 2.6: Purpose Coding of PE Pipes

	Pipe Colour	**Purpose**	**Portable water Pipe**
1	Black	Industrial applications	
2	Blue, or black with blue stripes	Potable water	
3	Yellow, or black with yellow stripes	Gas conduits	

Pressure Coding

Further, PE pipes are coded depending on pressure class thus: PN4-Yellow, PN6-Red, PN10-Blue, PN16-Green. However, WSPs should always inspect the pipes to confirm the outside diameter and wall thickness using vernier caliper (Section 2.2.5).

PE pipes must have electronic prints every 2m indicating manufacturer's name, manufacturing date, standard and pipe class.

2.5.3 Connecting PE Pipes

2.5.3.1 Types of PE pipes joints

PE pipes can be connected using the following joints:

- Compression (quick-connection) joints
- Butt fusion joints
- Electrofusion sleeve joints

2.5.3.2 Compression (Quick-connection) Joint

A compression fitting is a type of coupling used to connect two pipes or a pipe to a fixture (or valve). A compression fitting has three components:

- Main body
- O-ring
- Wedge ring

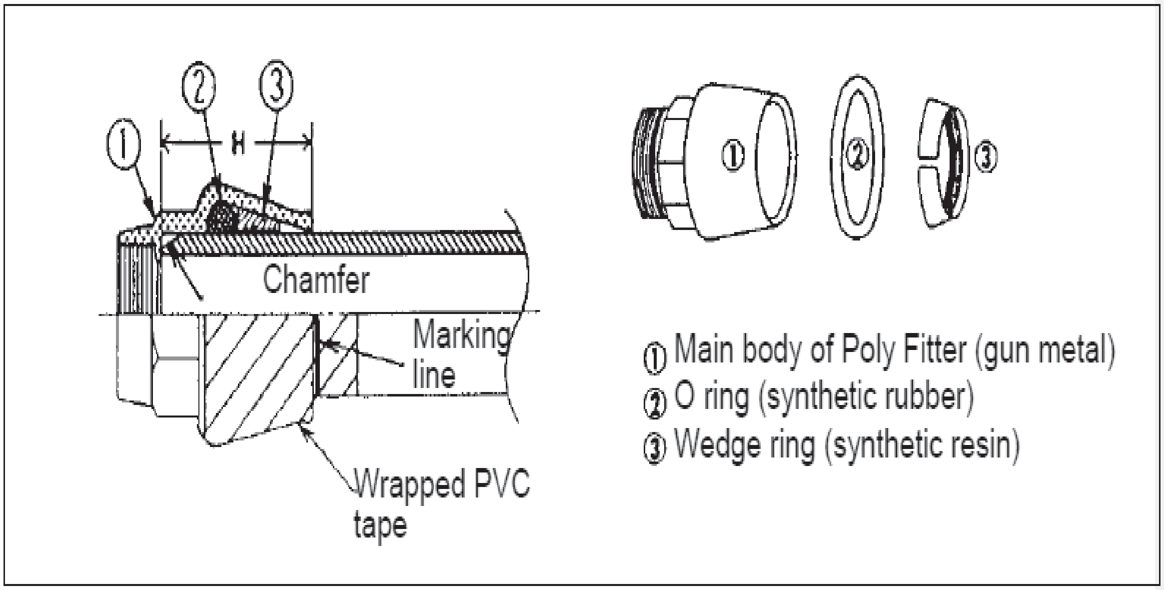


Figure 2.16: Quick-Connection Joint

As the nut is tightened, the compression ring is pressed into the seat, causing it to compress against the pipe and the compression nut thereby providing a watertight connection.

a) Assembling Compression Joint

i) Clean the pipe end and ensure it is free from burrs.
ii) Taper the pipe end down to ¾ of the pipe wall thickness. Remove cutting chips (since any remaining cutting chips may affect the water meters).

iii) Draw a marking line on the pipe to indicate the coupling or insertion length, H as per the manufacturer's specification (H is to ensure that the pipe is fully inserted).
iv) Check that the O-ring and wedge are:
- without damage.
- without twisting.
- installed correctly.

v) Insert the pipe spigot into the fitting socket.
vi) If the pipe has to be removed from the joint because of improper insertion, cut off the pipe by the length of the spigot and replace the O-ring and wedge ring with new ones.
  ii) When the coupling is disassembled for re-use, replace the O-ring and wedge ring with new ones.
  iii) After the pipe is connected, wrap the polyfitter with vinyl tape over more than ⅔ of its surface to prevent intrusion of sand and other foreign matter through any gap in the joint end.
  iv) When the pipe is to be bent, bending radius should be more than 20 times the diameter of the pipe (Figure 2.17).

Pipe Diameter (mm)	Minimum Bending Radius, R (cm)
20	54 or more
25	68 or more
40	96 or more

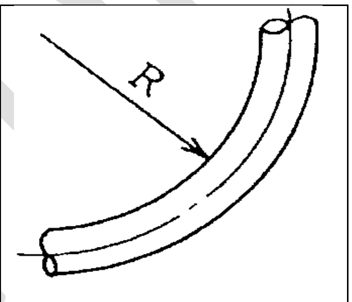


Figure 2.17: Minimum bending radius of PE pipes

b) Disassembling procedure for polyethylene pipes with Compression or Quick-Connection Joints

i) Fully insert the pipe into the main body of the socket to create a clearance between the main body and the wedge ring.
ii) Fully insert two dismantles (A) facing each other between the pipe and the wedge ring. Remove the pipe while firmly holding the main body.

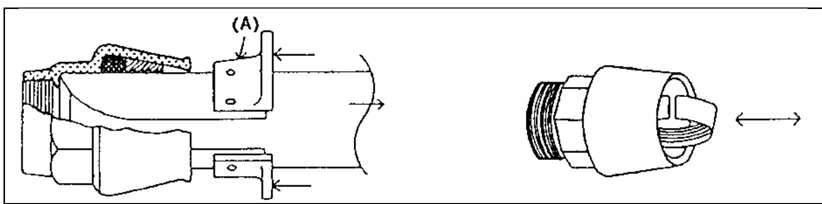


Figure 2.18: Disassembling Quick-Connection Joint

		
PE Compression Tee	PE Compression union/coupling	PE Compression Adaptor

Figure 2.19: PE Compression joint fittings

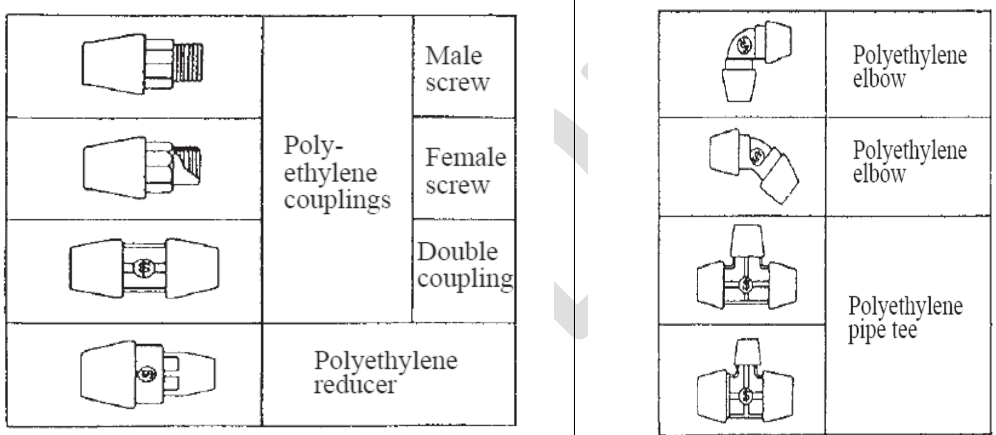


Figure 2.20: Types of Quick Connection/Compression Joints

c) Precautions for Prevention of Leakage

i) PE pipes have a lower tensile strength. Their strength is only about 1/5 of that of PVC pipes. Since they have soft surfaces, they tend to be easily damaged externally.

ii) They are combustible. Their strength decreases as the temperature rises. They soften around 90°C.

iii) They are susceptible to organic solvents and gasolines

iv) White coloured ones quickly age if exposed to direct sunlight for an extended period

v) Depending on the water quality, black coloured PE pipes react with chlorine to generate air bubbles. Very thin layers may peel off the inner surface after an extended period.

vi) It is preferable to store them indoors. When they are stored outdoors, they should be protected from direct sunlight and well ventilated. They should be stacked on a flat floor to a height not exceeding 1.5m regardless of whether they are in coils or not.

vii) Joints should be stored as packaged in an indoor location where they are not exposed to sunlight.

2.5.3.3 Butt fusion joints

Butt fusion means pipes are welded together end to end. PE pipes are butt fused using a properly sized butt fusion machine for the pipe size to be joined. The procedure is as follows:

i) Install and clamp the pipes in the butt fusion machine with pipe supports on both ends of the machine to support the pipes on the machine center line
ii) Align the pipe ends using the clamps on the fusion machine
iii) Face (or machine) the pipe ends to mechanical stops to ensure clean, parallel pipe ends for the heating process.
iv) Apply heat to prepared pipe ends and then push the pipe ends together with a pre-determined force to make a permanent butt fusion joint (a temperature-controlled heater is installed in the machine and the pipe ends are heated according to the butt fusion standard ASTM International F2620)
v) Once the heating criteria is met, the heater is removed and the pipe ends are brought together at the pre-determined force. This force is held on the joint for the time required by the standard. At this point, the pipe can be removed from the machine and visually inspected before putting down the pipeline

Note: Each butt fusion machine comes with the necessary manual detailing the procedure and specifications for butt fusion of pipes.

	
Figure 2.21: Butt welding Machine	Figure 2.22: Butt Weld Joint

2.5.3.4 Jointing PE Pipes by Electrofusion sleeve joints

Electrofusion welding uses the heat generated by an electric current flowing through a resistance to join pipes. Electric current is passed through resistive metal coils implanted in a fitting which is placed around the two ends of the pipes to be joined. The resistive heating of the coils melts small amounts of the pipes and the fitting, and upon solidification, a joint is formed. The procedure is as follows:

i) Wash pipe ends to create clean surfaces for joining
ii) Square pipe ends to facilitate optimal fit-up
iii) Clean area where coupler will be placed with isopropyl alcohol
iv) Mark the pipes slightly beyond half the length of the coupler, to indicate where scraping will take place in later steps
v) Mark the area to be scraped
vi) Scrape pipe in marked areas to remove surface layer, allowing clean pipe material to contact the coupler
vii) Examine scraped area thoroughly, making sure that fresh pipe material is exposed throughout the area
viii) Insert pipe ends into coupling to appropriate depth
ix) Secure coupler using clamp
x) Connect fitting to control box using electrical leads
xi) Apply fusion cycle
xii) Allow joint to be undisturbed for the entire prescribed cooling time

Note: Each electrofusion welding equipment comes with the necessary manual detailing the procedure and specifications for electrofusion of pipes.

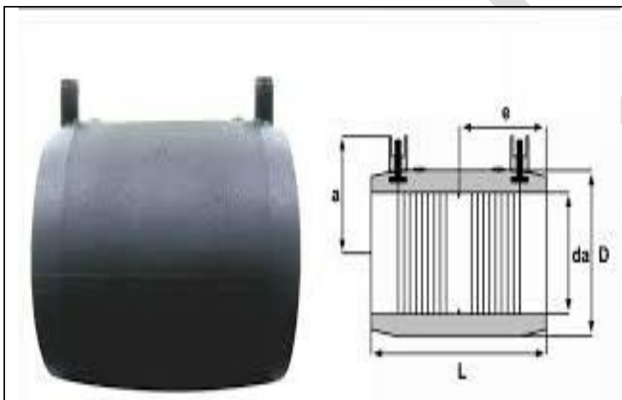


Figure 2.23: Electrofusion Sleeve Coupling

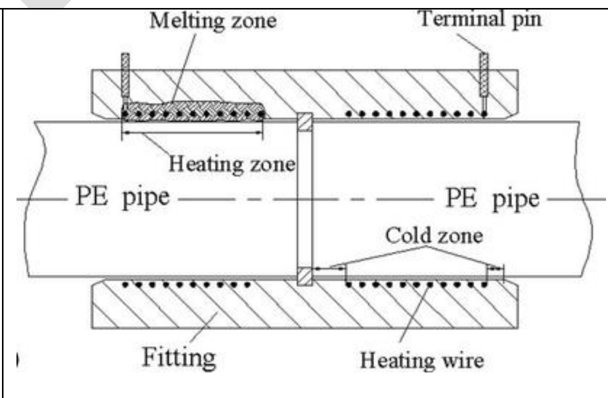


Figure 2.24: Electrofusion Sleeve Coupling Details

Figure 2.25: Electrofusion Welding in progress

Figure 2.26: Electrofusion Welded Joint

2.6 PPR Pipe Materials

Polypropylene Random (PPR) pipes are most reliable in plumbing inside the building due to their chemical features and fusion welding, which ensures perfect seal-tight joints.
PPR pipes are made to KS-ISO 15874 Standard.
In the water industry, PPR pipes are used in plumbing inside buildings such as residences, offices, etc. PPR pipes are not suitable where the pipe is exposed to sunlight due to deterioration.

Handheld tools are used to fuse PPR pipes of diameter 16 to 63mm. The tools come inside a case that contains the welder and a sheet that shows the welding parameters (diameter, pipe insertion depth, heating time, fusion time and time prior to testing).

Figure 2.27: Hand held PPR pipe fusion tools

Figure 2.28: Male & female fusion sockets (die pairs)


Figure 2.29: Heating PPR pipe & tee socket

The following is the procedure of making PPR fusion joint:

i) Mount the cold plate on the tool case as per the instruction sheet.

ii) Assemble (screw) the die pairs of the right diameter (corresponding to the pipe diameter to be joined) on the cold plate.

iii) Connect the welder to the power supply and switch power on (the cold plate and die pairs start heating).

iv) Wait for the sound signal that informs that the required temperature has been reached (see the user's manual of the welder).

v) Cut the pipe perpendicularly to its axis using the suitable pipe cutter.

vi) Mark the insertion length on the pipe.

<u>Note:</u> PPR Piping System mark a longitudinal sign (or line) on the external surfaces of the pipe and fitting as a reference to avoid turning the components to be welded while performing the welding procedure

vii) Place the ends to be welded close to each other to be able to begin the heating process of the material simultaneously

viii) After checking the surface temperature of the die pairs, insert the pipe inside the female die pair without rotating it and the fitting into the male die pair up to the sign previously marked for the heating time specified in the manual

<u>Note:</u> Do not heat up the parts to be welded twice.

ix) After the heating time, quickly remove the pipe and fitting from the die pairs and insert them one inside the other, within time the specified time, until you reach the insertion depth previously marked.

x) Hold the fused pipe pieces together and straight in line, not at an angle for 30 seconds.

<u>Note:</u>

(1) Be careful not to rotate the pipe into the fitting and carefully align the reference longitudinal signs

(2) PPR pipe heats very quickly and cools very quickly. Within 30 seconds, the pieces will have cooled enough to have fused into one piece of PPR pipe

xi) You can then put the fused pipe down and move on to your next task

Table 2.7 indicates the dimensions of PPR pipes as per KS-ISO 15874 Standard

Table 2.7: PPR Pipe Dimensions to KS-ISO 15874 Standard

PN 20 Pressure Rating	Pipe dia (mm)	20	25	32	40	50	63	75	90	110
	Wall thickness (mm)	3.4	4.2	5.4	6.7	8.3	10.5	12.5	15	18
PN 16 Pressure Rating	Pipe dia (mm)	20	25	32	40	50	63	75	90	110
	Wall thickness (mm)	2.8	3.5	4.4	5.5	6.9	8.6	10.3	12.3	15.1

Note: PPR pipes are manufactured with electronic identification print on the pipes (Indicating manufacturer's name, date of manufacture, manufacture standards, pipe class)

2.7 Galvanized Iron (GI) Pipes

2.7.1 General

GI pipes for domestic water supply mostly use threaded connections piping system. The pipes are normally supplied with threaded ends and one socket. Due to the many complex classification of GI pipes, a more simplified classification is normally adopted as in Figure 2.30 GI pipes sizes range from 0.5 to 6 inches in diameter.

Figure 2.30: GI Pipe Classification

Table 2.8: Galvanized and Black Steel Pipes as per KS 06-259 and BS 1387

Type, Class & Colour Mark	Normal Bore		Wall Thickness	Approx. Outside Diameter	Weight of Black Pipes Plain End	Weight of Black Pipe Threaded & Socketed	Weight of Galvanized Pipe Threaded & Socketed
	mm	in	mm	mm	Kg/m	Kg/m	Kg/m
LIGHT ‘A’ YELLOW	15	½”	2.00	21.3	0.95	0.96	1.04
	20	¾”	2.35	26.9	1.41	1.42	1.53
	25	1”	2.65	33.7	2.01	2.03	2.19
	32	1¼”	2.65	42.4	2.58	2.61	2.82
	40	1½”	2.90	48.3	3.25	3.29	3.55
	50	2”	2.90	60.3	4.11	4.18	4.51
	65	2½”	3.25	76.2	5.8	5.92	4.39
	80	3”	3.25	88.9	6.81	6.98	7.54
	100	4”	3.65	114.3	9.89	10.2	11.02
MEDIUM ‘B’ BLUE	15	½”	2.65	21.3	1.22	1.23	1.33
	20	¾”	2.65	26.9	1.58	1.59	1.72
	25	1”	0.33	33.7	2.44	2.46	2.66
	32	1¼”	3.25	42.4	3.14	3.17	3.42
	40	1½”	3.25	48.3	3.61	3.65	3.94
	50	2”	3.65	60.3	5.10	5.17	5.58
	65	2½”	3.65	76.2	6.51	6.63	7.16
	80	3”	4.05	88.9	8.47	8.64	9.33
	100	4”	4.50	114.3	12.10	12.40	13.39
	125	5”	4.85	139.7	16.2	16.7	18.04
	150	6”	4.85	165.1	19.2	19.8	21.38
HEAVY ‘C’ RED	15	½”	3.25	21.3	1.45	1.46	1.58
	20	¾”	3.25	26.9	1.9	1.91	2.06
	25	1”	4.05	33.7	2.97	2.99	3.23
	32	1¼”	4.05	42.4	4.43	4.47	4.83
	40	1½”	4.05	48.3	4.43	4.47	4.83
	50	2”	4.50	60.3	6.17	6.24	6.74
	65	2½”	4.50	76.2	7.9	8.02	8.66
	80	3”	4.85	88.9	10.1	10.3	11.12
	100	4”	5.40	114.3	14.4	14.7	15.88
	125	5”	5.40	139.7	17.8	18.3	19.76
	150	6”	5.40	165.1	21.2	21.8	23.54
200mm & 250mm Galvanized and Black Steel Pipes (Detailed specification on request							
	200	8”	5.20	219.1	27.71	28.56	30.84
	200	8”	6.00	219.1	31.82	32.57	35.18
	250	10”	6.00	267.0	39.09	40.01	43.23

<u>Note:</u> GI pipes are identified by colour code and in addition manufactured with electronic identification print on the pipes after every 2mtrs, (Indicating manufacturer’s name, date of manufacture, manufacture standards, pipe class)

2.7.2 GI Pipe Joints

Threaded GI to GI pipes is connected with threaded female coupling. PTF tape or hemp/boss white are used as sealant to prevent leakage.

Figure 2.31: Threading of pie with diestock

Figure 2.32: Threaded Joint

Care must be taken to ensure the thread length is adequate and the joint is watertight.

2.8 Jointing Different Pipe Materials (Special Pipe Joints)

Joints of different materials are called special joints. The following are special joints used in water supply:

2.8.1 Connecting Steel and PVC Pipes

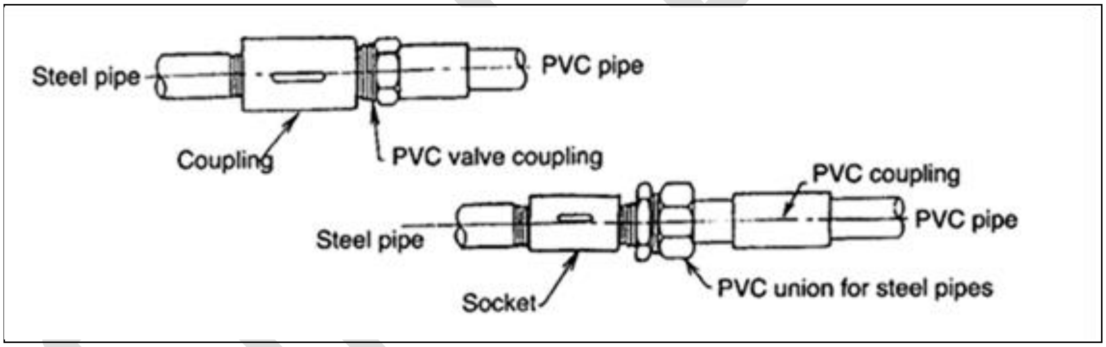


Figure 2.33: Connecting Steel pipe to PVC pipe using: (1) Steel coupling/PVC valve coupling; (2) Steel coupling/PVC union for steel pipes

2.8.2 Connecting Steel and PE Pipe

Figure 2.34: Stub end joint
(Connects flanged steel pipe and PE pipe)

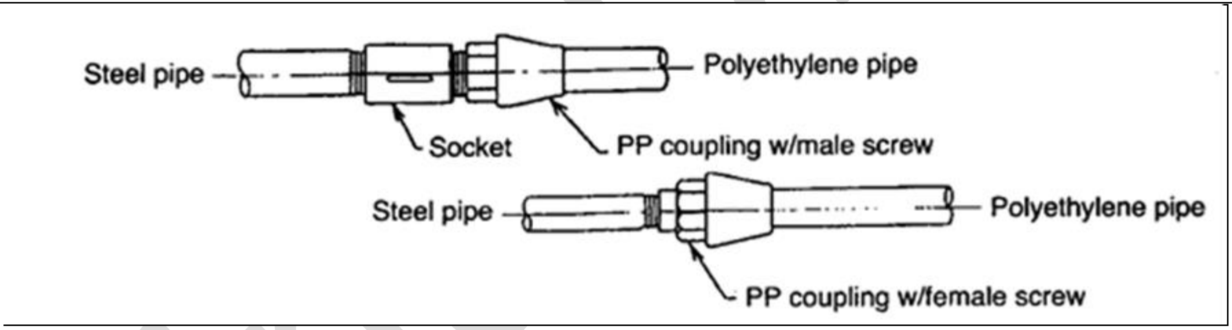


Figure 2.35: Connecting Steel Pipe to PE Pipe by (1) PE male coupling, (2) PE female coupling

2.8.3 Connecting uPVC and PE Pipes

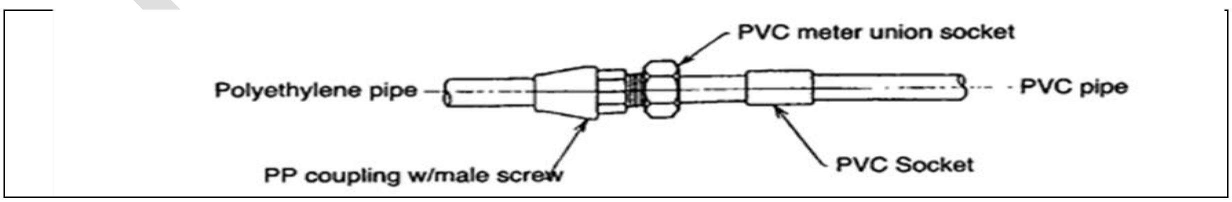


Figure 2.36: Connecting PE pipe to PVC pipe by PE male coupling/PVC union socket

2.8.4 Universal Joints

These are joints that can be used for any pipe materials

	
Figure 2.37: VJ/ Ranger Coupling	Figure 2.38: VJ Adaptor

	
Figure 2.39: VJ Dismantling joint	Figure 2.40: Pipe repair clamp

2.9 Comprehensive Specification of Materials for Procurement

Poor pipe and fittings materials are sometimes received from suppliers leading to NRW increase once used in the water supply. Below are some reasons for poor materials:

i) Poor project design
ii) Providing Poor and/or inadequate or no specifications of materials
iii) Failure to specify the materials standard
iv) Failure to provide the specifications to the inspection and acceptance committee members for use during inspection
v) Failure to understand implication of various standards to the project

vi) Failure to carry out adequate inspection of materials before accepting
vii) Having inexperienced or incompetent staff as members of inspection and acceptance committees for materials
viii) Failure to train inspection and acceptance committee members on how to do inspection
ix) Inspection and acceptance committee members being compromised by suppliers
x) Failure by managers to confirm quality of materials before approval for payment
xi) Failure to understand the implications of accepting poor quality materials
xii) Corruption

It is always prudent to ensure that materials specifications are adequately detailed to remove any ambiguity. This should include attaching brochures, or any materials that may assist in clarifying the requirements. Below is an extract of a bill of quantities for tendering in Meru WSP:

Table 2.9: Extract of comprehensively specified bill of quantities

S/Nr	Description	Unit	Quantity	Rate	Amount
1	PE100 Adaptor male 20mm dia PN16 to EN 12201-2 Standard	No	1		
2	PVC-U Bend 20mm dia x 90º PN15 to ISO 4422	No.	1		
3	PE100 Coupling 20 mm dia PN16 to EN 12201-2 Standard as per Annex-1 or equivalent	N0.	1		
4	PE100 Coupling 40 mm dia PN16 to EN 12201-2 Standard as per Annex-1 or equivalent	No.	1		
5	Float valve 4" dia PN10 cast iron as per Annex-6 or equivalent	No.	1		
6	PE100 Pipe 63 mm dia 100m long roll PN16 to EN 12201-2 Standard as per Annex-1 or equivalent	No.	1		
7	PVC-U Pipe 90mm dia PN15 to ISO 4422	No.	1		
8	PVC-U Saddle clamp 40x20mm (1 ¼’’ x ¾") dia PN15 as per **Annex-9** or equivalent	No.	1		
9	Sluice valve 80 mm (3") dia PN16 flanged to DIN 3352 part 4 / NF E 29-324 as per **Annex-10(a)** and specifications in **Annex-10(c)** or equivalent including Stem Cap Type 3 as per **Annex-10(d)**	No.	1		
10	Swivel ferrule 20mm (¾") dia as per **Annex-7** or equivalent	No.	1		
11	PVC-U Valve socket 50mm dia PN15 to ISO 4422	No.	1		

CHAPTER 3

HOW TO LAY WATER PIPELINES

(Target Staff: Design, Construction, Network Maintenance/Repair, NRW, Connection installation)

3.1 Introduction

A water supply starts developing weakness to leakage at design stage (if design is poor). Further weakness is introduced during implementation and finally during operation and maintenance.

It is therefore very important to ensure that quality control is exercised at every stage of the system.

This chapter specifies the steps to take during implementation to minimize leakage and hence NRW.

3.2 Trenching for Water Pipelines

a) Trenching excavation should be in such a manner as to minimise slips fall or disturbance to the sides and bottom of the excavation and therefore maintain the stability of all roads and other adjacent structures or works.

b) Trenches for pipes should be excavated to a sufficient depth to enable the pipe and the specified joints, bedding, haunching (side support) and surround to be accommodated. Unless otherwise stated, the width of the trench should be equal to the nominal diameter of the pipe plus 700 mm.

c) Any over-excavation beneath the pipe or bedding should be filled with well rammed selected general excavation material as per requirement specification of a qualified engineer. Any surplus excavated material not required for backfill should be dispose.

d) The sides of trenches should be adequately supported at all times or ensure that the side slopes of the excavation are sufficient for stability.

e) Where rock or boulders are present in the sides or base, the trench should be trimmed so that when the pipeline is laid, no projection of rock comes within 200mm of the outside of the pipe at any point.

3.3 Handling Pipes and Fittings

a) Before any pipes are delivered to site, all the staff handling the pipes (e.g. Stores staff, inspection and acceptance committee staff) should read and understand this section for handling pipes during transport, in store and during laying.

b) Always take into account any recommendations made by the pipe manufacturer in making arrangements for handling pipes.

c) Ensure all the materials (pipes, fittings, etc) are of good quality and quantity.

d) Pipes and fittings should only be transported on properly constructed or adapted vehicles with no pipes overhanging outside.

e) During transport and in store, pipes should not rest on narrow supports likely to cause damage to the pipe or its coating.
f) Pipes and fittings should not be subjected to rough handling at any time
g) Pipes should not be loaded or off-loaded from a vehicle by tipping or dropping; or be allowed to collide with one another
h) Any materials or pipes found defective or that have been dropped from a vehicle should immediately be rejected
i) Any pipes exceeding 200kg should be handled by means of a crane. Any WSP handling such heavy materials should acquire and maintain a suitable mobile crane for all loading, unloading, transferring between vehicles and lowering such pipes into the trench. The crane should be fitted with a sling of ample width. Wire rope slings or hooks at pipes ends should not be used for pipes or fittings of any diameter or mass.

3.4 Pipe Laying

a) Immediately before pipes are placed in any trench, the bottom should be cleared of all stones and other debris
b) Prior to placing in the trench, all pipes should be inspected for damage. Any end caps or discs placed on the pipes for protection during transit should not be removed until immediately before the pipes are jointed
c) Pipes should be laid in straight lines unless otherwise shown on the drawings
d) All lines should be cleaned after all installation work
e) When pipes are installed, all ends should be suitably plugged until final fixing of fixtures can be carried out. Pieces of cloth or stones should not be permitted inside
f) Construct:
    i) Concrete thrust blocks to support the pipe at bends and ends.
    ii) Concrete anchor blocks should be constructed at steep slope.
    iii) Concrete surrounds over pipeline across roads/rails

3.5 Pipeline Backfilling

a) Pipes should be firmly bedded throughout their length to the required alignment and level so that they are concentric at each joint.
b) All pipes should be suitably wedged, shored (prop) or restrained to prevent movement during testing and backfilling but such restraints should not be left in place permanently
c) Filling should begin with selected fill consisting of easily compacted material from which all stones larger than 25mm and all lumps of clay larger than 75mm have been removed
d) The selected fill should be deposited equally on each side of the pipe and carefully compacted in layers not more than 150mm thick. Care should be taken to ensure that no voids are left under the pipe.
e) The filling should be continued to a level of 300mm above the crown of the pipe

f) The remainder of the trench should be filled with excavated material and compacted in 150mm thick layers. The trench should be filled flush with the surrounding ground surface.
g) Where pipes have to bedded or surrounded with concrete, it should be in accordance with specifications from a qualified engineer
h) All pipes crossing driveways and roads should be surrounded with concrete for the entire length of crossing before trench backfilling

3.6 Pipeline Pressure Testing

a) Gauges used for pressure testing pipelines should be of the conventional circular type, not less than 200 mm diameter, calibrated in metres head water; or should have a digital indicator capable of reading increments of 0.1 m head.
b) Before any gauge is used, it should be checked for accuracy.
c) As the installation of the pipework proceeds, the various sections should be tested before they are built in, concealed, or finally connected. The sections should be about 300m long.
d) All the necessary records of the tests and results should be submitted for filing
e) All pipe systems should be hydraulically tested for 1 hour
f) The testing pressure should not be less than 1.5 times the design working pressure.
g) During the test, each branch and joint shall be examined carefully for leaks and any defects observed should be rectified and the section re-tested.
h) Before any length of main is charged with water, each pipe in that length should be covered to a depth sufficient to prevent uplift. The necessary backfilling should be such that each joint is left completely clear for inspection during testing unless it is practically impossible.
i) The pressure testing should be carried out as follows: -
    i) Before testing, valves should be checked and blanked off (or closed)
    ii) The sections of the mains should be filled with water and the air released.
    iii) After filling, the pipelines should be left under operating pressure for 24 hours so as to achieve as stable as possible for testing.
    iv) The pressure in the pipeline should then be raised steadily until the specified test pressure is reached in the lowest part of the section, and the pressure shall be maintained at this level, by pumping, if necessary, for a period of 1 hour.
    v) The pump shall then be disconnected, and no further water should be permitted to enter the pipeline for a further period of 1 hour.
    vi) At the end of 1 hour the original pressure should be restored by pumping and the loss measured by drawing off water from the supply line until the pressure as at the end of the test is again reached.
    vii) Calculate the water loss as flows:

$$\text{Water loss} = \frac{Q \times 24}{D_n \times L \times (P_L \times P_u)/2}$$

Where:

Q = water drawn from supply line over the 1-hour testing time (litres)
D_n = nominal pipe diameter (m)
L = length of pipeline being tested (km)
P_L = Pressure at lower end of pipeline (m)
P_u = Pressure at upper end of pipeline (m)
24 = 24 hour (means loss over 24-hour period)

The water loss should not be higher than the permissible loss.
The permissible loss is 2 litres per *metre nominal bore* per *kilometre length* per *metre head (calculated as the average head applied to the section)* per *24 hours*.

j) In addition to the test on separate sections, the whole pipeline shall be tested on completion to the same pressure and by the same procedures as that outline for individual sections.
k) On completion of a main, the whole length of the main shall be subjected to a final test under pressure with all valves along the length of the main fully open.
l) During pressure testing, air valves shall be isolated. Testing should not be permitted against closed line valves or washout valves.

3.7 Pipeline Disinfection

3.7.1 General

Disinfection of pipelines is not an NRW reduction factor. However, majority of WSPs in Kenya do not carry out this critical requirement thereby placing water consumers in grave danger. This handbook provides the right opportunity to sensitize WSPs on the need and procedure of pipeline disinfection.

When a pipeline is laid or upgraded, some contamination almost always gets into the pipes from the soil, mud and water in the trench, and from the feet or boots of the workers. It is important to kill any germs which may be in the pipeline before it supplies water to the community.
There are two forms of chlorine products suitable for making the disinfecting solution for pipelines. These are calcium hypochlorite (HTH) or sodium hypochlorite (liquid bleach). Normally, a 0.2% solution of chlorine should be made from either product.

3.7.2 Preparing chlorine solution for disinfecting pipelines

a) Safety for operators handling chlorine

- The operation and maintenance of equipment for dosing chlorine from cylinders should only be undertaken by trained and authorized personnel.

- Chlorine is a hazardous substance. In solution it is highly corrosive and splashes can cause burns and damage the eyes. When handling concentrated chlorine solutions, appropriate precautions should be taken. Ideally, gloves and protective eye glasses should be won. In the event of splashes and especially splashes to the eyes, it is important immediately to rinse thoroughly with water.
- All containers in which chlorine is stored should be labelled, identifying the contents, and with a hazard warning in a form which is readily understood locally.
- Storage sites for chlorine in any form should be secure against unauthorized access and especially against children.

b) Sodium Hypochlorite or liquid bleach

Liquid bleach is normally bought in bottles sachets. Check that the contents are sodium hypochlorite and water only. The normal concentration of chlorine in liquid bleach is 5%, but this may be lower if the bottle has been opened or stored for a long time.

Using Sodium Hypochlorite (liquid bleach) to make a chlorine solution

- Fill three plastic buckets with clean water up to 5cm from the top to allow for the bleach to be added. Most commercially available buckets hold 12.5 litres, but the quantity of water should be checked.
- Add enough liquid bleach to bucket to make up a 0.2% solution of chlorine as follows:

  Capacity of bucket of 12.5 litres water = 12,500 milliliters
  We need 0.2% or 0.2 grams of chlorine per 100 milliliters of water

  Therefore, $\frac{12500 \text{ ml} \times 0.2 \text{ g}}{100 \text{ ml}}$ = 25 g chlorine is needed per bucket

  Liquid bleach is assumed to contain 4% or 4 g of chlorine per 100 ml,

  Therefore, to make 25 g of chlorine we need $\frac{25 \text{ g} \times 100 \text{ ml}}{4 \text{ g}/_{100\text{ml}}}$ = 625 ml

  Hence 625ml of 4g/100ml liquid bleach must be added to each 12.5 litres of water to make 0.2% solution of chlorine.

- Mix the water and bleach well before use.

c) Calcium hypochlorite or High Test Hypochlorite (HTH)

Calcium hypochlorite comes as white granules. It is stronger than liquid bleach and does not lose strength so quickly. It comes in concentration ranging from 20 to 70% chlorine.

The best type of chlorine to use is HTH as it normally contains 50 to 70% chlorine. Always check with the supplier or on the side of the container to be sure of the percentage chlorine content.

Using calcium hypochlorite (HTH) 50% to make chlorine solution

- Fill three 12.5 litres plastic buckets with clean water to about 5cm from the top to allow for the hypochlorite to be added. Most commercially available buckets hold 12.5 litres, but the quantity of water should be checked.
- Add enough calcium hypochlorite to each bucket to make a 0.2% solution of chlorine as follows:

  Capacity of bucket of 12.5 litres water = 12,500 milliliters

  We need 0.2% or 0.2 grams of chlorine per 100 milliliters of water

  Therefore, $\frac{12500 \text{ ml} \times 0.2 \text{ g}}{100 \text{ ml}}$ = 25 g chlorine is needed per bucket

  If calcium hypochlorite contains 50% chlorine or 50g of chlorine per 100 g powder, then 25 g (amount of chlorine needed in a bucket) is contained in

  $\frac{25 \text{ g} \times 100 \text{ ml}}{50 \text{ g}/_{100\text{g}}}$ = 50 g of powder

  Hence 50 g of 50% HTH must be must be added to each 12.5 litres of water to make 0.2% solution of chlorine.

- Mix the water and bleach well and leave to dissolve for an hour. Some white sediments will sink to the bottom of the bucket. Only the clear liquid should be used to disinfect the pipeline and the sediment thrown away.

3.7.3 Disinfecting pipelines

When a pipeline is to be disinfected

- Close the pipeline with a plug or blank flange or valve at the lower end.
- Fill the pipeline with a 0.2% chlorine solution and leave it for at least 6 hours contact duration to kill any germs.
- Ensure customers DO NOT DRINK the chlorine water.
- Drain the disinfectant water flush the pipeline with treated water until residual chlorine of 0.2 to 0.8 mg/litre is reached (monitor the residual chlorine using a Lovibond comparator or electronic chlorine tester).
- Put the pipeline into operation.

3.8 Procedure of Installing Service Connections and Customer Meters

a) Application form for installation of service connections and customer meters

installation of a service connection normally begins with receipt of an application from a customer. the application form should be designed such that it is easy for customers to fill. it should also contain information that will assist the field staff to locate the customer premises such as mobile no., name of the next neighbour with a connection, nearest known landmark, etc. a sketch map should be attached to ease the locating.

b) Survey for installation of service connection

preparation for installation begins with a field visit to assess the site conditions and come up with a list and type of materials to be used, and labour requirements.
the connection is then installed once approved and resources allocated.

points to note:
all materials for connection installation including the meter should be procured by the WSP to ensure quality control. Situations where customers procure their own materials should be stopped.

c) Procedure for installation of service pipe

- i) excavate a trench from the distribution pipe to the customer connection point (customers may be allowed to excavation the trench for the service pipe but under competent supervision).
- ii) the trench should be at least 0.6m deep by 0.6m wide and straight (unless unavoidable); and follow the shortest route possible.
- iii) the trench bottom level should be even i.e. without ups and downs.
- iv) adequate working space should be provided around the distribution pipe (side-ways and underneath) where the tapping will be done.
- v) use good quality sand or soil for bedding. ensure no hard or sharp objects (stones, etc) that can damage the pipe.

d) Tapping and laying the service pipe

Water supplies in Kenya have a history of tapping using locally (jua kali) fabricated saddle clamps which are of no specific standard. Rubber from vehicle tyre tube is then used as the seal against leakage. Due to the poor quality of the resulting joint, leakage almost always occurs sooner than later.
Another tapping method has been to cut the distribution pipe and install a tee fitting. This really weakens the main pipe and is a cause of recurring leakages. The other problem is using gate valve for controlling water. Gate valves rust over time and eventually start leaking hence contributing to NRW.
These methods should be stopped if reduction of NRW is to bear fruits.
Materials for service pipes should be good quality (use good standards), without blemishes and of good class (PN10 and above depending on the local water pressures. Use PN16 saddle clamp (clamp) and ferrule).
Note: pipes weaken with time hence a good allowance should be provide.

e) Location of the meter

- i) Ensure that the meter will be located at points where meter reading, inspection, and maintenance can be easily performed.
- ii) Sites selected for the meter should be located in a dry area away from wastewater,

water logging, flooding, contaminated air or exhaust air.

iii) Meters should not be exposed to vandalism, theft or accidents. in Kenya, water meter installed above ground are more susceptible to theft. in such cases plastic body water meters are recommended.

iv) Meters should not be installed in areas with excessively high temperatures or where water pressures fluctuate excessively

v) Meters should not be located in areas where they are subjected to shocks or vibrations.

vi) Meters should be installed as close to the distribution pipeline as possible

vii) Factors to take into consideration when installing customer meters are the reliability of meter performance, ease of reading and ease of replacing and maintenance.

f) Tapping and laying the service pipe

the following procedure should be used when tapping:

Figure 3.1: Tapping with standardized saddle clamp and ferrule (tap)

source: Meru WSP

i) Ensure the exposed distribution pipe is clean all round (wash with water if possible)

ii) Tie thread tape PTF over the ferrule threads and fix the ferrule tap onto the saddle clamp

iii) In case of more than one service line, ensure adequate spacing is provided for maintenance

iv) Remove the ferrule tap and use a drill to bore a hole on the top side of the distribution pipe

v) Remove the drill and allow water to flow out for a few seconds to clean the cut hole ensuring the cut pipe piece comes out and does not fall into the pipe.

vi) Screw back the tap and close the water.

vii) Connect the service pipe to the ferrule and lay in the usual manner. Use only factory manufactured and standardized fittings such as socket couplings, socket bends/elbows, socket reducers, etc.

viii) Connect two horizontal GI pipe pieces, say 2.5ft long to the service pipe to ensure firm support of the meter. Only one pipe piece is necessary if meter is next to the distribution pipe

ix) Connect vertical GI pipe pieces to raise the meter to the required level (e.g. 0.5ft above the ground level or the level stipulated for the meter box) (connect a stop cork (called WSP stop cork) (not gate valve since it is often obstructed from closing by silt)

x) Connect the meter horizontally with the arrow on the lower case facing towards the direction of water flow. When meters are not installed perfectly horizontally, its sensitivity and durability are highly compromised.

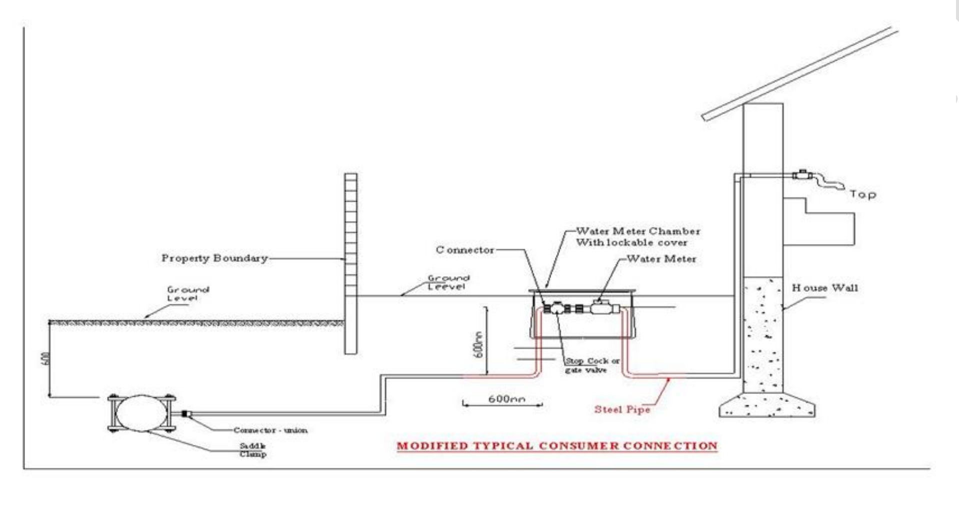


Figure 3.2: Customer Meter Installation with Meter Box

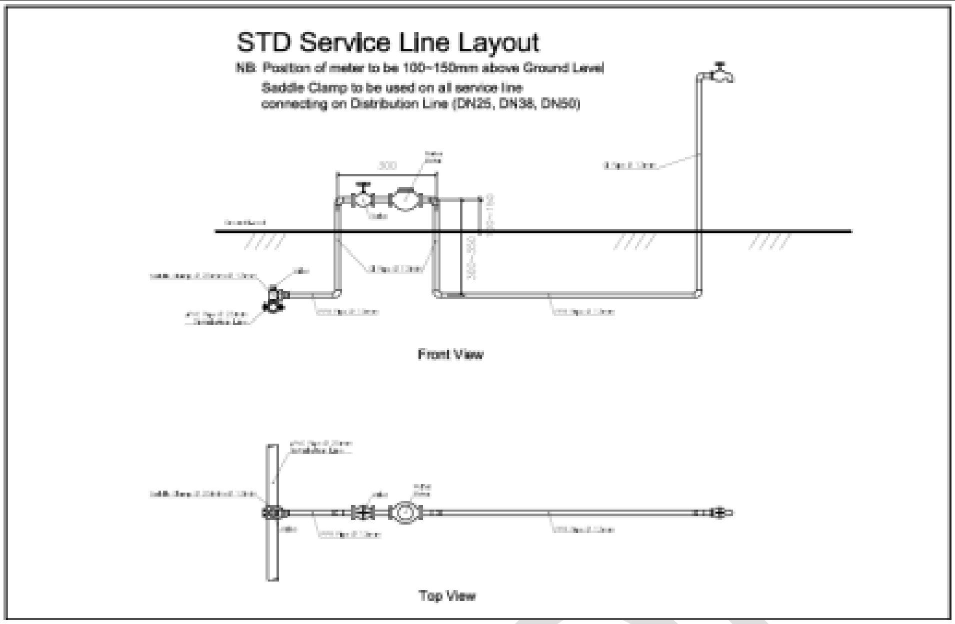


Figure 3.3: Customer Meter Installation without Meter Box

xi) It has been found advisable to install another stop cork immediately after the meter (called customer stop cork) to give the customer control of water without interfering with fittings between the saddle clamp and the meter.
xii) In case of more than one connection, provide adequate spacing between the pipes and also the meters for maintenance
xiii) No service pipe should cross over another service pipe
xiv) Connect the service pipe to the customer connection point
xv) Lightly backfill the trench leaving the joints exposed and allow connecting adhesive to dry
xvi) Close the WSP stop cork, customer stop cork, and all the taps and valves in the premises
xvii) Open the water at the ferrule and check for leakage at the joints between the saddle clamp and the WSP stop cork
xviii) Open the WSP stop cork slowly for the first time, in order to prevent water hammer.
xix) Open customer stop cork and ensure no leakage at the meter connections.
xx) Open the customer stop cork and check for leakage in the customer pipe system
xxi) Alternatively, carry out pressure testing of the system to see any leakage
xxii) Repair any leakage in the new service pipe and advise the customer to repair all leakages in his/her pipe system before commissioning the connection
xxiii) Complete backfilling and adequately compact the trench
xxiv) Draw a sketch map of the connection with measurements
xxv) Take GPS location of the saddle clamp and meter and record on the sketch map

Update the records on the relevant forms and take a picture of the installation

xxvi) Submit the connection records to the office

g) Backfilling

i) Use good quality sand or soil for backfilling. Ensure no hard or sharp objects (stones, etc.) that can damage the pipe.
ii) Water meter should be appropriately installed and there should be no obstruction to reading and replacement of meters.
iii) Install meter boxes ensuring that they are not buried in soil or mud

	
Photo 3.1: Installation of Customer Meters without meter box	Photo 3.2: Installation of Customer Meters in a meter box

3.9 Installation of Large Meters

Any pipe appurtenance such as sluice valves or pipe bends, cause turbulence in water flow. This turbulence can cause a meter installed nearby to record the flow inaccurately. To prevent such errors being introduced in flow measurement, all meters should be installed well away from any obstruction from appurtenances or bends, reducers and tees. The distance between the meter and any such obstruction is called the calming distance since it calms the water so that the flow is not turbulent as it passes through the meter.

The minimum recommended calming distance from the nearer end of the meter is 10D on the upstream and 5D on the downstream, where D is the pipe diameter.

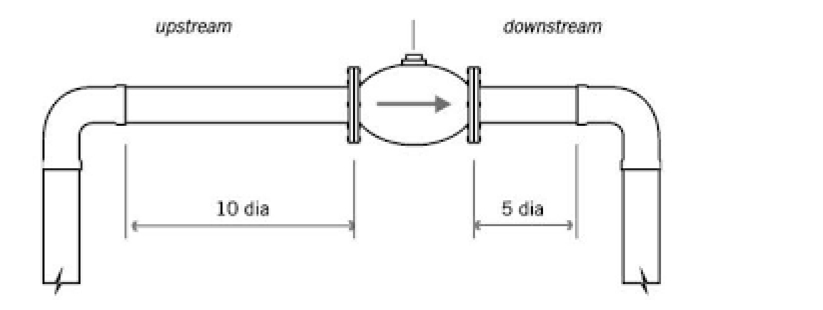


Figure 3.3 Calming sections for water meters

Small diameter meters come with meter liners that ensure compliance to this rule hence do not require further consideration. However, in some cases, such meters are installed directly without meter liners thereby introducing obstructions to the meter hence causing metering errors.

3.10 Meter Sizing

Undersized meters can cause huge NRW (especially when they are used for customers consuming large volumes of water) due to their under-registration of consumption. Hence, proper sizing (or resizing) of meters, especially for large and medium non-domestic customers, is quite important. The procedure of sizing customer meters is well documented in Volume 1: The Non-Revenue Water Guidelines in Kenya.

CHAPTER 4

MAINTENANCE OF WATER SUPPLY NETWORK

(Target Staff: Construction, Network Maintenance/Repair)

4.1 Institutionalizing Maintenance Schedules

Due to inadequate knowledge, most WSP staff in Kenya assume that water shortage that forces them into rationing is caused by inadequate water supply capacity in the face of a growing demand. They therefore, in most cases, advocate for new projects development to solve the problem. This problem can, to a large extent, be solved by ensuring that the water infrastructure is maintained at the level it was first constructed. However, due to aging, neglect, etc, it has over time fallen into disrepair and inefficiency.

Lack of properly functioning bulk meters to accurately monitor flow is an example. Failure to read them regularly enough (daily on minimum) to provide useful data for decision-making is another form of lack of maintenance. This lack of maintenance is widespread among other components of the water supply, including sluice valves, float valves, etc.

WSPs need to institutionalize comprehensive preventive activity schedules (Appendix-1) for all the water supply management components and not wait until breakdowns occur. Inclusion of maintenance for each component in the annual budget should also be institutionalization.

The most effective strategy to maintain appurtenances and equipment is to prepare and institutionalize maintenance schedules.

4.2 Maintaining Good Water Quality to Reduce NRW

a) How Water Quality Affects NRW

Does poor water quality contribute to increase in NRW? The answer is YES.

Poor water quality is most obvious when turbidity is high. High turbidity affects customer meters through clogging thereby causing lower meter indication than the actual consumption or even complete stoppage. This therefore increases commercial loss.

Experience in Kenya has shown that water turbidity should be kept below 2 NTU to ensure low level of water meter stoppage.

The following are the strategies to ensure low water turbidity:

b) Cleaning water supply intakes

Surface water intakes receive raw water which comes with tree trash, stones, sand, mud, etc. These require regularly cleaning to ensure free flow of water and to reduce dirt at the treatment plant which increases treatment chemicals requirement.

- Clean the reservoir and intake chambers by disludging the mud, removing trash from the trash racks and clearing the bush around the intake are necessary. The tools required are such as shovels, rakes, jembes, and slashers.

- Flush the intake pipe at the first and second wash out to ensure mud does not reach the intake.
- Paint any metallic parts of the intake once annually to ensure durability

NB: take care to prevent accidents such as drowning in deep intakes.

c) Flushing wash outs

- Flush wash outs along raw water mains depending on the season, i.e. more often in rainy season depending on the flow of the water in the pipelines.
- Flush wash outs along distribution lines at least twice per year and whenever a major burst is repaired.

d) Installing and regularly cleaning trash strainers

Most WSPs have had their bulk meters damaged by trash due to failure to install strainers before the meter especially on raw water mains. Appendix-2 is a sketch of a basket strainer that can easily be fabricated using locally available materials (such as steel pipe sections) and at a reasonable cost. The inner basket can be made from a steel sheet perforated with 5mm diameter holes such that its flow capacity before clogging is at least twice the maximum flow capacity of the pipe.
It is recommended that such strainers be installed on all raw water mains to protect the bulk meters against damage. A sluice valve should also be installed before the strainer for isolation during servicing.

This type of strainer is the easiest to clean as follows:

- Close the sluice valve before the strainer.
- Open the top cover of the strainer.
- Remove the strainer basket and clean the trash
- Return the basket
- Reassemble the top cover
- Open the sluice valve

e) Disludging sedimentation and flocculation basins

Sedimentation basins should be disludged regularly depending on the rainy/dry season to ensure efficient removal of turbidity from the water. The depth of disludge can be measured with a long broomstick which are available in treatment plants. Basins are normally in twos or more and hence can be cleaned in alternate days to maintain the supply.

Disludge as follows:

- Close the water inlet valve.
- Open the drain pipe for the sludge to drain away while stirring with long brooms.
- Scrub the walls and floor with a hose pipe until clean.
- Close the drain pipe and open the water inlet pipe.
- Start water treatment

f) Regular replacement of filter media

Often, the quality of filter media is left to deteriorate and this leads to poor water quality. The quality of the media should be monitored regularly and replenished or replaced at the right time.

g) Proper backwashing of filters

Staff should be trained on the backwashing process.

h) Regular cleaning of storage and break pressure tanks

A cleaning schedule should be prepared and followed to reduce clogging of meters by silt from tanks.

i) How to service air valves

- Isolate the air valve by closing the isolating valve between the valve and the pipe.
- Depressurize the valve by opening the depressurizing valve (refer to manufacturer's manual for procedure) and drain the water.
- Dismantle the top cover
- Clean the top cover to ensure no debris is settling inside the cover or obstructing the vent.
- Remove the float assembly and clean the top seal and any other moving parts to ensure free movement
- Reassemble the valve
- Close and tighten the depressurizing valve.
- Carefully open the isolating valve.

4.3 How to Maintain Valves and other Appurtenances

Management of a water supply is impossible without proper functioning control valves and other appurtenances. Evidence of poorly maintained appurtenances include leaking valves, overflows, airlocks, etc.

a) Appurtenances (sluice valves, etc) should be painted and/or greased regular (say annually) to prevent rust and deterioration.
b) Worn out parts (e.g. leaking gaskets and valve spindles) should be tightened or replaced
c) Tank level gauges should be greased for free operation

4.4 How to Formulate a Maintenance Schedule

a) Make a table list of all and every component in the water supply starting with the intake structures, raw water mainlines wash-outs, air valves, sluice valves, break pressure tanks, storage tanks, pressure reducing valves, pump sets, etc, including location (pipeline name), material, diameter and class (if possible).
b) Break down each component into its various parts.
c) List the type of maintenance required by each component, including cleaning, greasing, oiling, painting and spares.
d) List how often each component requires maintenance.
e) List how the maintenance period will be monitored for each component.

f) Prepare the specifications of the maintenance and spares required for each component
g) Make a bill of quantity of the estimated cost of maintaining each component
h) List the person responsible for the maintenance of each component
i) Prepare a maintenance schedule for each component.
j) Prepare a structured annual plan of expenditure for the financial year for each component.
k) Submit the annual plan of expenditure to the budget preparation coordinator
l) Justify the need to allocate budget during the budgeting process.
m) Implement the maintenance schedule.
n) Repeat the process every year without fail.

CHAPTER 5

HOW TO CARRY OUT LEAK DETECTION

(Target Staff: NRW Staff)

5.1 Procedure of Customer-to-Customer Leak Survey with Listening Stick

5.1.1 What is a Listening Stick

It consists of a steel rod/bar and a small circular vibration plate which is connected to the end of the bar at right angle. It is a kind of stethoscope without an electronic amplifier.

		
Figure 5.1: Listening Stick	Figure 5.2: Leak detection using Listening Stick	Figure 5.3: Leak detection using Listening Stick

5.1.2 Procedure of Customer-to-Customer Leak Survey with Listening Stick

Although it seems easy to use the equipment it requires some skills and lengthy training to detect small leaks and to distinguish the real leak noises from other similar noises.

To achieve the best result, the following procedure must be followed:

i) Gently hold the rubber part of the ear pad. Don’t hold the metal bar.

ii) Don’t press your ear against the ear pad as it will be harder to hear. Your ear should be slightly away from the pad.

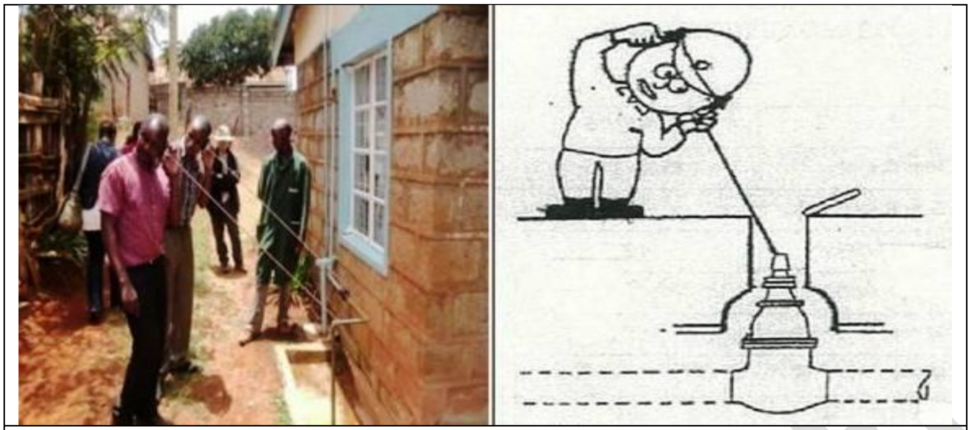


Figure 5.4: Leak detection using listening stick on pipe fittings

iii) Find the best condition for you to hear sounds by gently tapping the bar with your finger.
iv) Listen on the ear pad to hear the leak noises
v) Since most of the pipe facilities are buried, place the stick directly onto those elements with open boxes like taps, meters, valves, stand pipes, a pipe fitting, followed by placing worker's ear on the vibration plate set at the top of the bar. Listening Stick requires a lot of skill to distinguish the real leak noises from other similar noises.
vi) This method can only confirm the existence or non-existence of leakage near the listening stick but cannot locate the leak point.
vii) Where possible, the steel rod can be pushed through the soil along the top of the pipe (Figure 5.5) to come as close to the leak as possible. The louder the noise, the closer the leak. Therefore, the strength and changes of the sound is followed to locate leak.

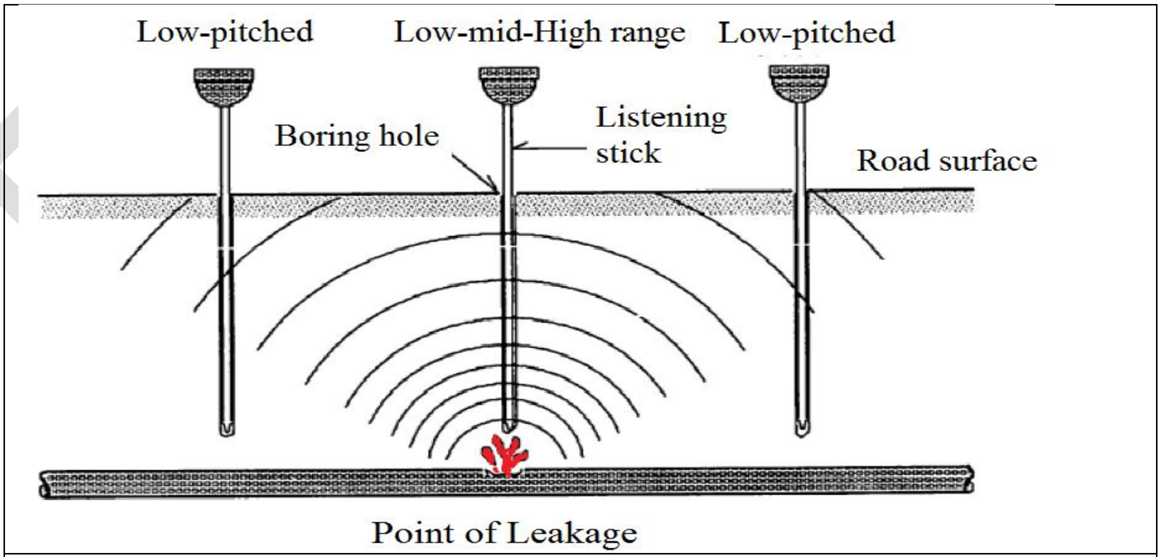


Figure 5.5: Leak detection using listening stick along pipeline

5.1.3 How to Differentiate Between Various Leak Sounds

In order to detect a leak, there is need to differentiate the various sounds coming through the ear pad. Table 5.1 shows some examples of leak and other sounds.

Table 5.1: Examples of leak and other sounds

SOUND	SITUATION ON SITE	TYPE OF LEAK
"hissssss"	If pipe has good water pressure	Small leak
"whoossssssh"	If pipe has good water pressure	Main break or big leak
Rapid "thumping" noises of water against soil in cavity or "clink, clink, clink" of small stones bouncing against pipe.	May be you are very close (4-6m) to a leak	Leak
Water splashing on the pipe	May be you are close to a leak or water is traveling along a pipe for long distance	May or may not be a leak
Pipe resonance noises (i.e. always very constant sound) as follows: "ummmm or ringingingingi"	There are power transformers or motors nearby	Not a leak
Pipe resonance noises as follows: "Click, click, click"	It may be a meter turning	Not a leak
Pipe resonance noises as follows: Intermittent and on/off again noises		Not a leak

5.1.4 Points to note in leak detection with listening stick

i) For most complete surveys, listen at every stop cork, meter, hydrant, valve, etc.
ii) For iron and steel pipelines, listen at hydrants or meters every 100 to 200m.
iii) For AC pipe, listen at hydrants and at a curb stop/stopcork/meter between them (max distance between points: 100m).
iv) For 20mm to 160mm PVC pipe, listen at maximum intervals of 150m.
v) For PVC pipe larger than 150mm, listen at maximum intervals of 100m
vi) When listening at curb stops/meter boxes, pick side of the street with shorter length services.
vii) Listen at hydrants, Valves, meters, curb stops, and other exposed sections / fittings.
viii) If there is no leak sounds, then no leak nearby.
ix) If there is no sounds at all, then no leak nearby.

5.1.5 Documentation of Detected Leaks

a) Manual Documentation

All leaks detected must be repaired, documented and mapped for further analysis and future reference.

Table 5.2 is a sample report as a guide.

Table 5.2: Sample Leakage Report

WATER LEAKAGE REPORT IN (WSP NAME):				**Report No:**
Date:	**Estate:**	**Road:**		**Pipeline:**
Method of Leak Survey (e.g. Listening Stick)	**Leakage on** (e.g. Service Connection, Main Pipe, Pipe Saddle or Ferrule, Pipe Fitting, Valve, Hydrant, Air Valve, Bulk Meter, Pump, etc.)	**Pipe DN (e.g. 63mm)**	**Pipe Material (e.g. PVC)**	**Estimated Leakage Rate (m3/hr)**
Block Map No.:	**Comments:**			
Sketch of Location:				
Report Issued by:	**Report approved by & date:**	**Repair Instruction to & date:**		**Work done by & date:**

b) Electronic Documentation

With advancement in technology, there are now free cloud-based software applications (e.g. kobocollect toolbox, input, etc) that can be downloaded from Play Store to smartphones and used to collect data from the field and automatically download it on to

GIS maps on a computer. These applications greatly ease work for staff and also ensure accurate and timely data collection and sharing with other staff.
WSPs that have not yet adopted this technology are therefore advised to adopt this data collection methods without further delay. Refer to *Volume 2 - Guidelines* for further information on this topic.

5.2 How to Detect Leakage Using Electronic Leak Detector

5.2.1 Introduction

Underground leaks are usually detected by a leak detector which can catch the leak noise generated at leak holes by the leaking water using a sensor placed on the ground surface/ (or pipe wall) near the leakage.
The volume and quality of leak noise vary depending on the soil properties, kind of pipe materials, pipe diameter, underground depth of pipes, magnitude of leakage, water pressure, distance between the leak point and the sensor of the detector, etc., especially, in case of clay soils or large pipe diameter
Leak detection work requires a lot of skills by virtue of heavy awareness of leak noises.

Electronic leak detector comprises the follows components:

i) Central Processing Unit (CPU) with monitor
ii) Head phones
iii) Transducer - vibration pick-up unit that is sensitive to sounds coming from the pipe system. If a sound is detected in the unit, it is transmitted to the CPU at a higher frequency. Since leaking water makes sound, the sound is used to detect leaks in pipes using electronic leak detector.
iv) Connecting cables
v) Carrying bag and strap

5.2.2 Operating Principle of Electronic Leak Detector

a) The leak detector catches the leak noise electronically.
b) The principle is that a vibration pick-up unit is placed on the ground to detect the vibration sound of a leakage that is transmitted underground.
c) This vibration energy is converted by the pick-up unit to electrical energy which is then amplified for indication by a meter or listening through a head phone.
d) A leak detector amplifies sound and filters (or cuts out the lower and higher) frequencies of vibration sounds. This enables the remaining sound to be listened to more clearly.
e) Different pipe materials have specific sound frequency (or filter) bands in which leak noise can be detected more clearly as shown in Table 5.3.

Table 5.3: Leak Detector Filter (Sound Frequency) Bands for Various Pipe Materials

Sound frequency (Hz)	**100**	**200**	**400**	**600**	**800**	**1200**
Cast Iron Distribution Pipe		←			→	
PVC Distribution Pipe	←			→		
PVC Service Pipe		←			→	
GI Service Pipe			←			→

Key: Filter Range (CIP: Cast Iron Pipe), (PVC: Polyvinyl chloride Pipe), (GI: Galvanized Steel Pipe)
Source: Fuji water leak detector (Operation Manual)

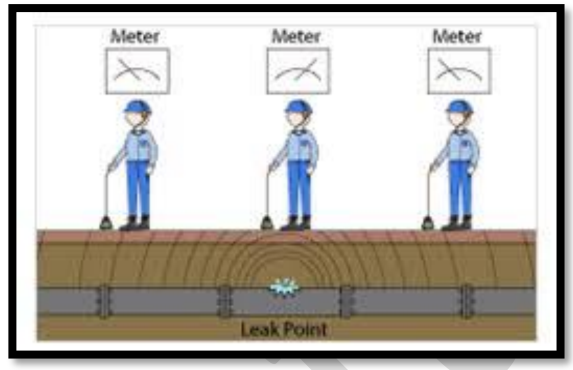
5.2.3 How to Detect Leakage using Electronic Leak Detector

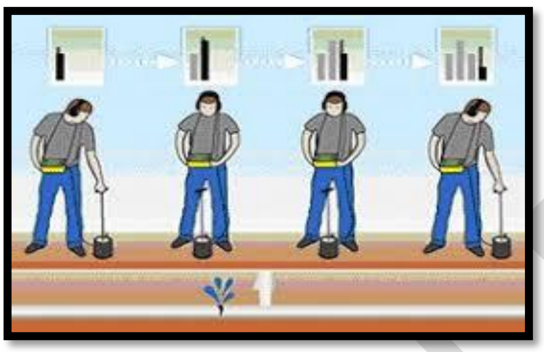
a) Ensure the equipment is fully charged
b) Decide the pipeline on which leak detection will be conducted
c) Move to the ground
d) Plug in the head phones and the transducer to the CPU and turn the volume to the lowest
e) Hang the CPU around your neck, wear the head phones and switch on the equipment
f) Adjust the volume to your comfort by gently tapping the transducer with the hand
g) Select the Filter (Sound Frequency) Bands to use based on the pipe material of the pipeline as per Table 5.3 above.
h) Place the transducer on the ground above the pipeline and listen for leak noise for a few moments while at the same time observing the meter
i) Shift the position of the transducer along the pipeline and repeat (h) above
j) The position where the meter indicates the highest noise is the location of the leak
k) Fill Table 5.2 and submit for repairs.

Figure 5.6 indicates the three types of display meters on a leak detector CPU.

The photos show the 3 types of display meter on Electronic Leak Detector CPU monitor and indicates a leakage as follows:

- Pointer - Indicates to the right
- Bar - Indicates tallest bar
- Digital – indicates highest number





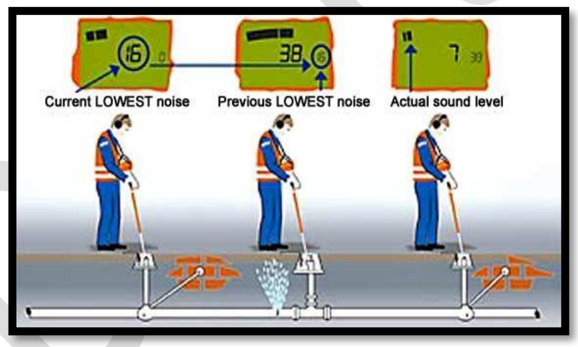


Figure 5.6: The Three Types of Meters on the CPU

5.3 How to Operate Ultrasonic Flow Meter for Flow Measurement

5.3.1 Introduction

Ultrasonic Flow Meter measures flow without interrupting the water supply. It is normally attached to the external surface of the pipe using its clamp-on features called sensors. The equipment does not interact with the water inside the pipe.

5.3.2 Functions/Uses of Ultrasonic Flow Meter

i) Flow measurement
ii) Bulk meter testing
iii) Leak detection

5.3.3 Components of Ultrasonic Flow Meter

i) MAIN UNIT – Portable Flow Meter
ii) Clamp-on Sensors (usually one or two pairs- one pair for small pipes, and one pair for large pipes (depending on pipe sizes to be measured)
iii) Sensor Mounting Accessories
iv) Coupling Component (gel or Vaseline)
v) Measuring Tape
vi) Operating Instructions manual (hand copy and CD)

vii) Downloading Cables and Software or USB port for data extraction

Figure 5.7: Ultrasonic Flow Meter and accessories

5.3.4 General Requirements for UFM Use

The following are required in order to use UFM:

a) Knowledge of existing pipe data (e.g. pipe location, material, lining) is crucial.
b) At the supply point of the pipe (i.e. starting point of the distribution zone (DZ) or district metered area (DMA) or pipe branch) select a straight part of the pipe with adequate length considering the 10D/ 5D rule (D = outside diameter).
c) Expose the area around the pipe and create a clear and adequate working space.
d) Clean the pipe off all dirt (the pipe may need to be washed with water) and wipe dry.
e) Measure the pipe dimensions (Circumference (C)) using the measuring tape.
f) For equipment requiring input of the Outside diameter use the formula Circumference = $\pi D^2/4$ to obtain the diameter.
g) Measure the pipe thickness using thickness gauge

5.3.5 How to Measure Flow in a Pipe Using Ultrasonic Flow Meter

a) Switch on the instrument - Main menu is displayed.

b) Check the battery level and ensure it is fully charged (if the battery is full, the unit is fully charged. Check the equipment manual on charging: - most equipment require charging for 8-12 hours to fully charge an empty battery).

c) From the Main Menu select the Installation Menu/Set-up Menu to enable you to update the site details as follows:

d)
   i) Select dimension units (usually millimeters - mm)
   ii) Select pipe features:
      - Material,
      - Size: - Circumference or Outside Diameter (O.D)
      - Presence/Absence of lining:

         -Lining Material
         -Lining thickness (if present)
      - Pipe wall thickness
   iii) Select the MEDIUM or FLUID in the pipe
      - In this case it is water.

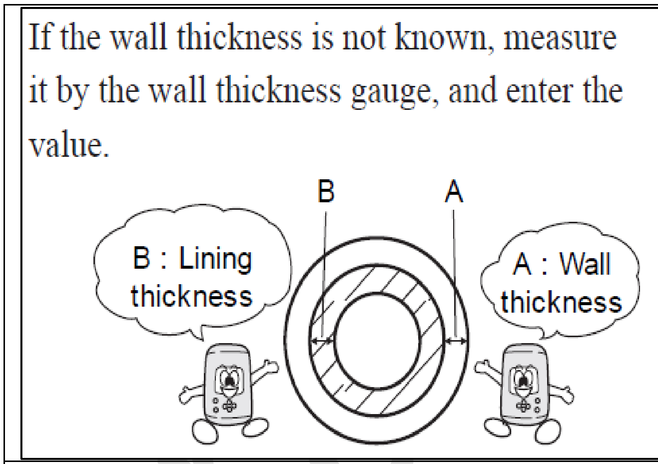


Figure 5.8: Lining and wall thickness of piping

e) <u>Select Sensor Mounting Mode Information</u>
Theoretically, sensors can be mounted in four different modes: slash (/), reflex (V), N, and W. Selection of a particular mode depends upon several factors such as pipe diameter, expected maximum velocity of water, type of sensors available, ease of working at site, and whether or not a mounting rack is available.
Reflex (V) is the most commonly used mounting mode.

	
Figure 5.9: UFM mounted on pipe	Figure 5.10: Sensor blocks
(Kindly refer to the specific equipment operational manual)	

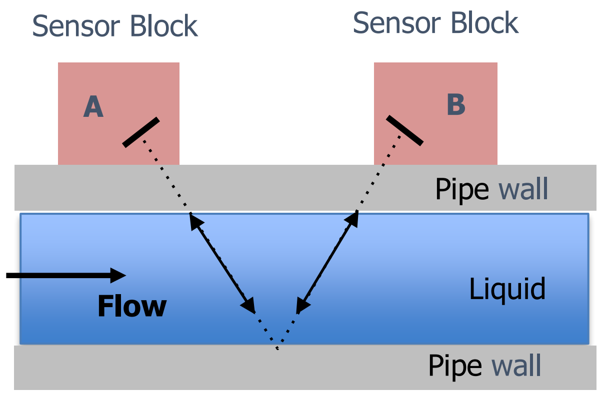


Figure 5.11: Clamped Sensors - Reflex Mode (top view)

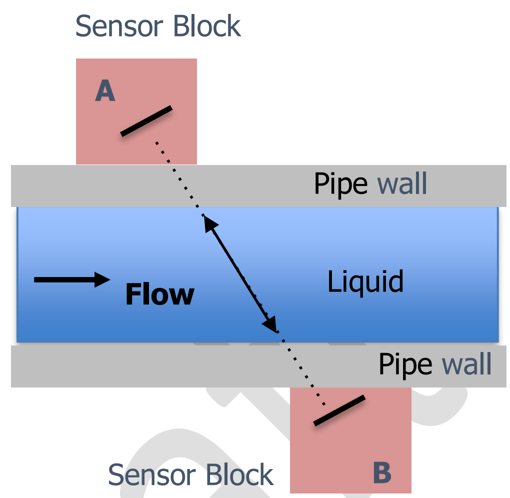


Figure 5.12: Clamped Sensors - Diagonal Mode (top view)

f) For a horizontal pipe:

Select a location where the transducers can be mounted on the **<u>side</u>** of the pipe (Figure 5.13) **<u>NOT</u>** top of pipe (Figure 5.14), so that the sound waves emitted by the transducers propagate horizontally in the pipe. In this way, the solid particles deposited on the bottom of the pipe and the gas pockets developing at the top will not influence the propagation of the signal.

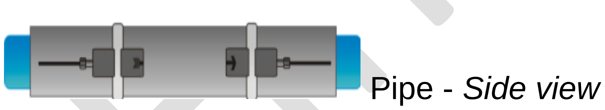


Figure 5.13: Sensors mounted on the side of pipe – **<u>Correct mounting</u>**

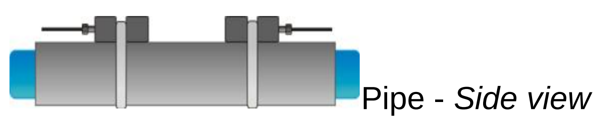


Figure 5.14: Sensors mounted on top of pipe – **<u>Wrong mounting</u>**

g) Clean the pipe off all dirt (may need to wash with water) and wipe dry.
h) Select the appropriate guide-rail, using the data entered, set the sensor separation distance on the measurement rail and clamp rail on pipe in the best position in a horizontal plane.
i) Apply couplant (or coupling gel) to both sensor-blocks and attach to the pipe using appropriate mounting hardware.

j) Slide the sensors into the rail and tighten thumbscrew fully compressing the coupling gel

k) Connect the sensor-blocks to the main unit of the Ultrasonic Flow Meter via provided cables observing the flow direction.
Check the connection signal; the signal strength depends on the model of the UFM. It is usually displayed as a percentage (%), graphical Display or wave form.

(e.g. for better accuracy, the signal strength should be above a certain range specified by the manufacturer. A signal strength of above 80% should be aimed for).

Figure 5.15: Side-mounted sensors on PVC pipe

l) Press enter to start flow measurement. (FLOW UNITS CAN BE CHANGED BY PRESSING APPROPRIATE KEYS e.g. m^3 or Litres and UNITS OF TIME e.g. Hr, Min or Sec.

m) The UFM will automatically record the flow in the pipe for the period of measurement and store in its memory.

n) Data Storage/Logging: This stores data for retrieval after the measurement period has elapsed.
<u>Note:</u> *Kindly refer to logging procedure on the specific equipment manual.*

o) Data Retrieval or Download or Transfer
To transfer the measured values to a computer, use the compatible software as follows:
   i) On the flow meter, go back to the main menu
   ii) Connect the UFM to the computer using the serial cable
   iii) On the computer, open the software
   iv) On the toolbar, start the data download or data transfer.
   v) NB: Some models allow data retrieval/download/transfer using an external data storage device e. g. USB flash/memory card (if USB slots are integrated on the UFM (Figure 5.16 below)).
   vi) The data can now be viewed on the computer and the necessary analysis conducted (Figure 5.17).

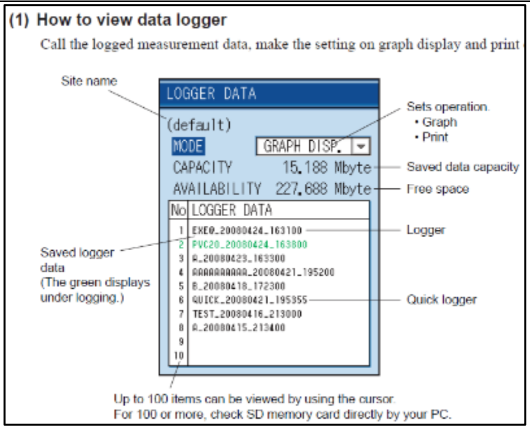


Figure 5.16: Data screen display

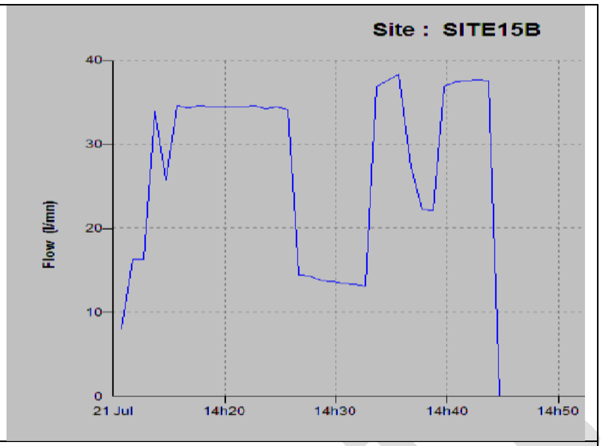


Figure 5.17: Data analysis

5.4 Minimum Night Flow Measurement

5.4.1 Introduction

Minimum Night Flow (MNF) is the lowest steady flowrate into a DMA/DZ during a 24 hours period. It is therefore a range of flows over a period of time and not one instantaneous flowrate. Figure 5.18 is a typical graph of 24 hours flow in a DZ. The lowest flow is 22 lts/hr and occurs between 02:30 am and 04:00 am.

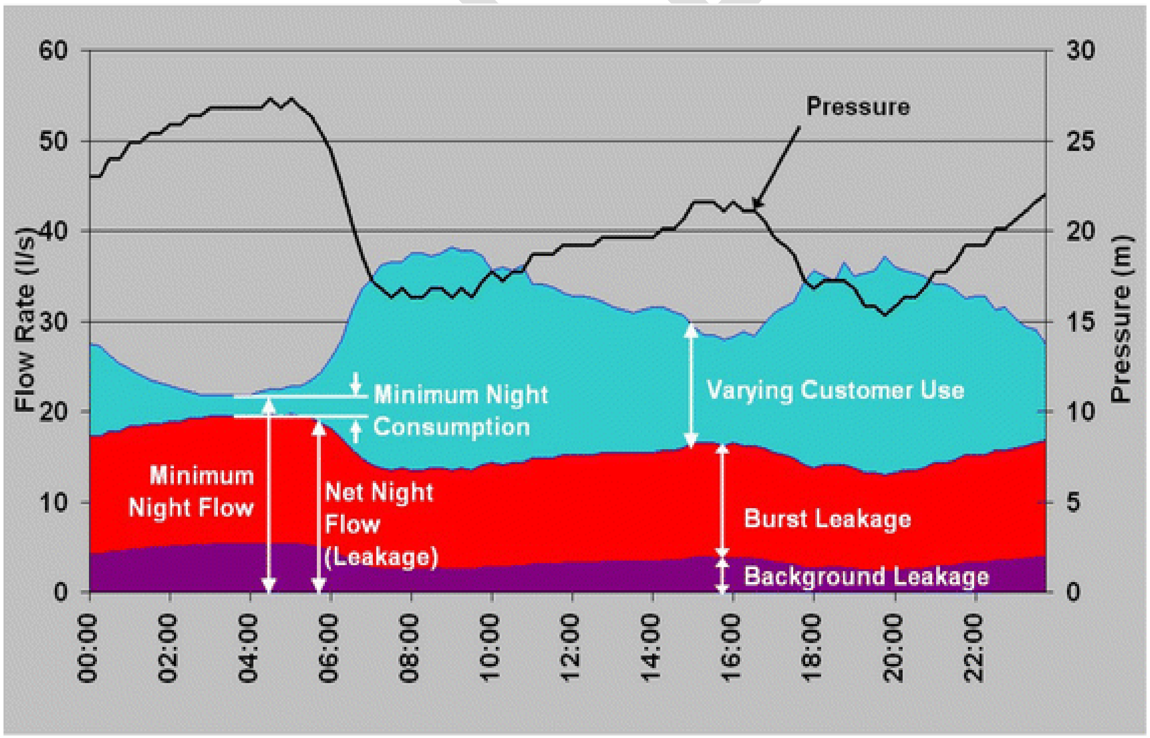


Figure 5.18: Typical Graph of 24 hrs Flow in a Water Supply

Figure 5.19 is a 24 hours graph of Kangaru DZ, Embu Water Co. The lowest steady flowrate was 190m^3/hr occurring between 00:00am and 06:00am.

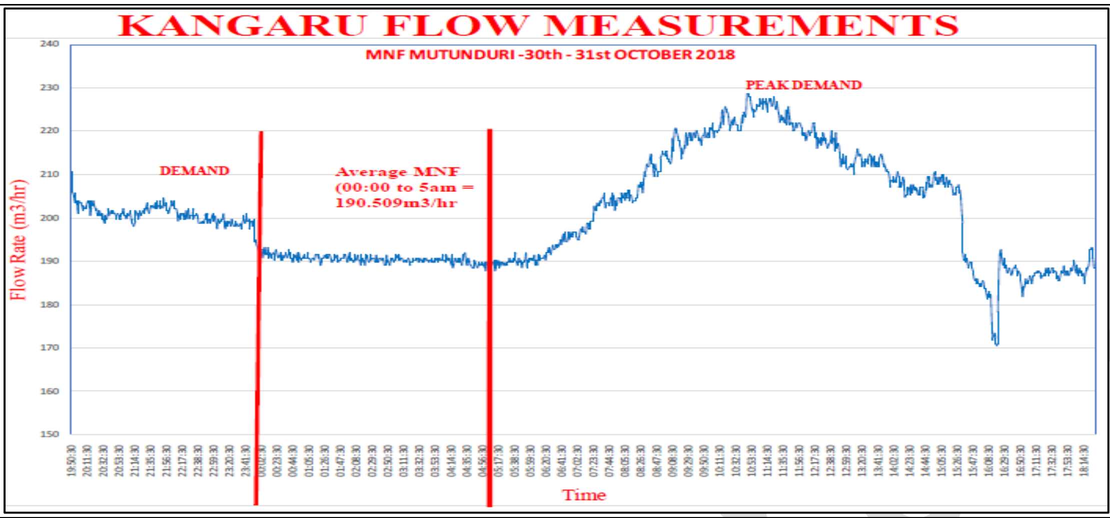


Figure 5.19: Graph of 24 hours Flow in Kangaru DZ, Embu Water Co., Kenya

The period of the lowest flow is unique for each distribution network and depends on the customers type and other factors. Table. 5.4 is a guideline on the recommended time of the night to conduct MNF measurement.

Table. 5.4: Recommended Time to Conduct MNF Measurement

	Customer Category	Time of MNF Measurement	
		Earliest Start Time	**Latest Stop Time**
1	Rural areas	11:00 pm	04:00 am
2	Peri-urban areas	00:00 am (midnight)	04:00 am
3	Urban areas	02:00 am	04:00 am

MNF comprises the following:

a) water being consumed by customers (flushing toilets, washing machines, night clubs, industries, hospitals, prisons) including filling and overflowing storage tanks at customers' premises.
b) illegal use
c) leakage and overflows from WSP tanks downstream of the measurement location.

MNF measures the total of (a) to (c) above. (a) is normally determined by manually reading customer meters for a sample of domestic customers and the flow estimated for all the customers in the DMA/DZ. For large customers, the meters can be read manually; or by automatic meters; or portable meters. This is done simultaneously with the MNF measurement. The total of (b) and (c) is the physical loss.

The purpose of measuring MNF is to determine and understand the level of physical losses occurring in a water supply network. Once this is determined, leak detection and repairs should commence and NRW monitored to achieve as low leakage level as possible.

Note:

a) If the supply system is intermittent make a provision to supply the area continuously for at least 24 hours. before starting to measure the MNF. The continuous supply may need to be extended to cover at least three nights without any interruption.
b) If the DMA has multiple inflow lines from other areas or outflow lines to other areas, each such lines should be metered. The readings from all the meters should then be aggregated and the minimum aggregated flow taken as the MNF.
c) It is recommended to measure water pressure in the pipeline simultaneously with the MNF measurement. The pressure gauge should be installed next to the UFM//bulk meter. The purpose of pressure measurement is to ensure that there is adequate pressure in the pipeline during the MNF measurement.

5.4.2 Relationship Between Water Flow Rate and Water Pressure in Pipelines

At around midnight people are in bed and water taps in houses are closed hence water consumption in a DMA becomes zero in general. However, there is a little flow in the distribution pipes at this time and this water volume is assumed to be leakages or water thefts, etc. This water comprises a little usage which are metered or not metered in houses and leaks.

Figure 5.20 shows an example of a service area composed of several DMAs. The red (●) circle in the figure shows the measurement point of MNF for DMA1. It is recommended to set a water pressure meter just downstream of the red circle. Figure 5.21 shows typical fluctuation records of water flowrate and its pressure over 24 hours. It shows the general relation between water flowrate and pressure and indicating that as the water flowrate reduces in the middle of the night the pressure rises. However, if there is some amount of water usage in other DMAs located upstream of the distribution main, the inlet water volume and its pressure at the red circle will be forced to reduce. In such a case, the minimum flow measured is an "apparent value" because it is affected by factors outside DMA1.

By simultaneously measuring water pressure and MNF, fluctuation of both flow rate and the pressure can be track as in Figure 5.21. If for example, a point such as the yellow vertical arrow where the flowrate is reducing while the pressure is gradually rising or remains steady, it can be said that the real MNF is measured.

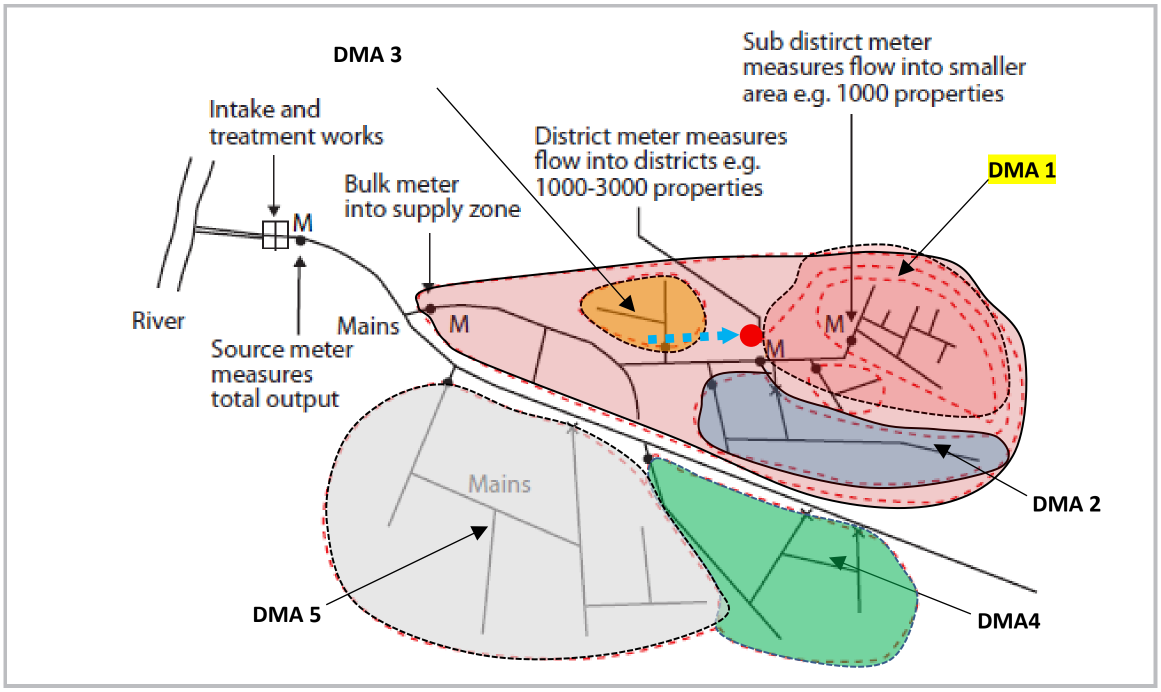


Figure 5.20: Model Plan of Water Service Area and Related Facilities

Source; "The Manager's Non-Revenue Water Handbook"

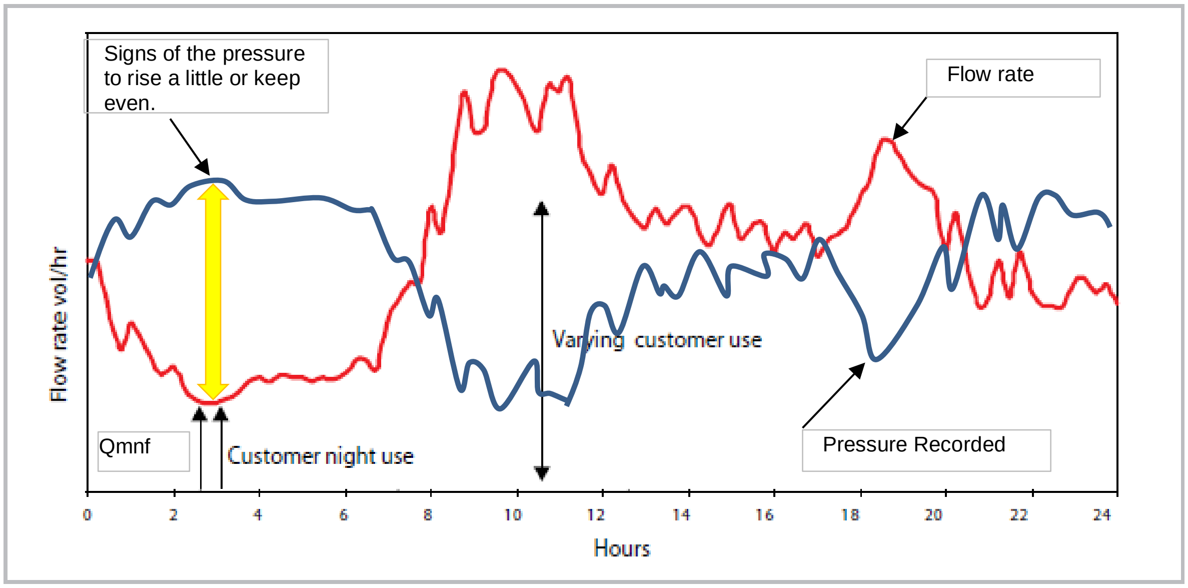


Figure 5.21: Relations between Flow Rate and Pressure in a Qmnf point

5.4.3 How to Measure Minimum Night Flow Using UFM

a) Identify the DZ/DMA/pipeline for Minimum Night Flow measurement.
b) If the DMA has other inflow lines from other areas or outflow lines to other areas, plan to measure flow in each line or closed them.
c) Determine the time of measurement based on Table 5.4 above.
d) Confirm that there is steady and adequate flow of water in the DZ/DMA/pipeline for the last say 2 to 3 days.
e) Plan and conduct flow measurement using UFM at the appointed time following the procedure in Section 5.3 above. Measure water pressure in the pipeline as MNF measurement progresses.
f) If possible, measure the water pressure at the UFM location (see Section 2.7 for procedure).
g) Monitor the supply tank(s) to ensure it is continuously full during the measurement period.
h) Downloaded the data.
i) Aggregate the data from all the measuring points.
j) Plotted a graph of the data
k) Interpret the data to determine the MNF.

5.4.4 Methods of Approximating Minimum Night Flow

Most WSPs may not have the financial capacity to procure UFM from their own resources. However, this should not be a hindrance to commence leak detection.
MNF can be approximated using any of the following methods:

- Recording bulk meter readings at 5- or 10-minutes intervals.
- Attaching data logger to a bulk meter – it stores the reading for a certain period.
- Attaching data logger and transmission gadget to a bulk meter – continuously transmits the readings to a computer.
- Automatic Meter Reading (AMR) gadget – continuously transmits the readings to the computer.

5.4.5 A Case Study of Minimum Night Flow Approximation

The NRW staff of Nakuru Town WSP has been conducting MNF measurement using a UFM. However, the UFM does not have the capacity to transfer data to a computer. They therefore have to manually read the data from the UFM and record in the computer.

Figure 5.22 and 5.23 are the graphs of meter readings from the two inlets lines into Kanyoni DMA in September 2018 indicating MNFs of 8.0 and 12.0 m^3/hr respectively. The readings were at 15 minutes intervals.

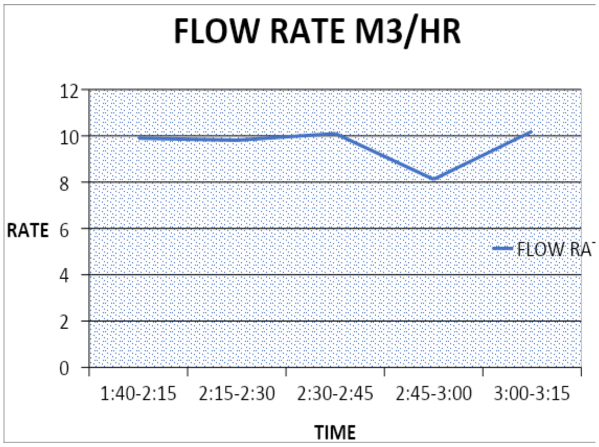


Figure 5.22: City Mission Line: MNF (Sep. 2018) = 8.0 m^3/hr

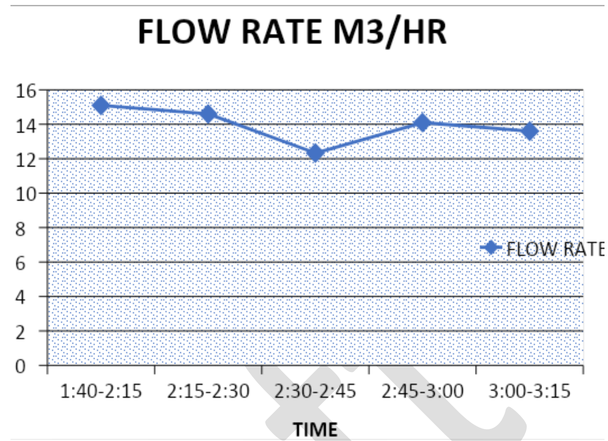


Figure 5.23: Scan Line: MNF Sep. 2018) = 12.0m^3/hr

The staff then conducted leak detection and repaired the leakages in Table 5.5 below.

Table 5.5: leakages detected and repaired in Kanyoni DMA, Nakuru Town WSP after the MNF measurement September 2018

	Location	Type of Leak Identified	No.
1.	Kanyoni estate	Leaks on meters liners	17
2.	Kanyoni estate	Leakage on 8" dia pipe	2
3.	Kanyoni estate	Leakage on 2" dia pipe	1
4.	Kanyoni estate	Leakage on 1.5" dia pipe	1
6.	Kabachia estate	Leakage from 12" dia sluice valve spindle	1
7.	Kabachia estate	Leakage from 12" pipe	1
8.	Shadrack Kimalel	Leakage from 12" dia sluice valve spindle	1

Figure 5.24 and 5.25 are the graphs of meter readings from the two inlets lines into Kanyoni DMA in December 2018 indicating MNFs of 2.7 and 3.9 m^3/hr respectively. The readings were at 15 minutes intervals.

The results indicate that leak detection is still possible even without a properly functional UFM.

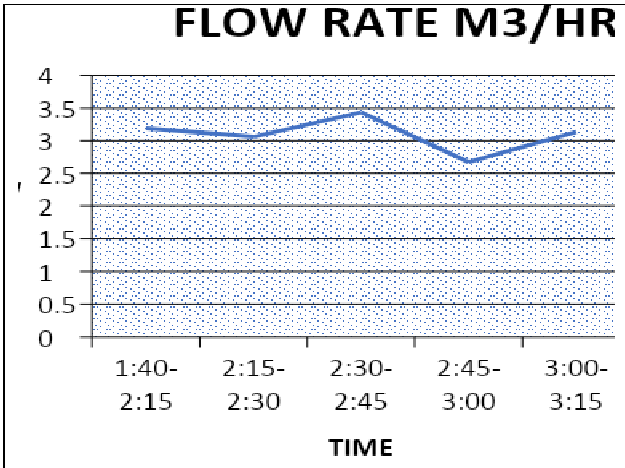
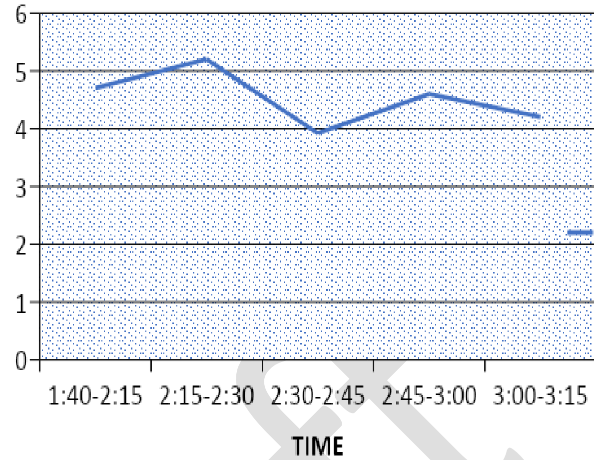
	

Figure 5.24: City Mission Line: MNF (Dec. 2018) = 2.7m^3/hr	Figure 5.25: Scan Line MNF (Dec. 2018) = 3.9m^3/hr

5.5 Procedure of Leak Detection Using Step Test Method

5.5.1 Introduction

Step test leak detection is a MNF measurement to determine water losses due to leakage from specific sections of a pipe network.

The test can be conducted by three methods:

a) continuous measurement using UFM
b) using an installed bulk meter
c) moving from one pipe section to another
d) at the supply point (starting point) of the DMA or DZ.

5.5.2 Procedure of Step Test Leak Detection by Continuous Measurement using UFM

a) Ensure that the DMA/DZ has only one inlet pipe (If more than one, a bulk meter should be installed on each and readings done for all at the same time).
b) Ensure that there are no pipe loops in the DMA/DZ. A Sluice Valve (SV) should be installed and closed to eliminate looping.
c) Ensure all the SVs in the DMA/DZ are open and the water supply is adequate and steady (not distorted by rationing or interruption).
d) Ensure you have a map or sketch of the DMA/DZ with all the SVs indicated and labelled.
e) Ensure all the SVs are easily accessible and are operating properly (can completely close the flow and are not leaking).
f) Flow measurements should be conducted between 00:00 am (midnight), and 04:00 am when most customers are asleep, hence any flow is likely to be leakage. Note:
   i) Some flow may be due to ongoing filling of some customers' tanks.
   ii) Some large customers like hospitals, industries and prisons operate 24 hours thereby causing flow.
g) Mount the UFM on the pipe at the starting point of the DMA/DZ (Section 5.3).

h) Start flow measurement and let the UFM continuously record for 10 to 15 minutes to ensure that flow is about constant. Do not stop the UFM.
i) Prioritize the pipe networks and close the furthest subzone as measurement continues. Record the time of closure and the subzone.
j) Continue the process until all subzones are closed with continuous measurement.
k) Stop and unmount the UFM.
l) Open all the valves for water to flow to customers at the end of the exercise.
m) Download the measurement data and draw a graph (Figure 5.26).
n) Calculate the differences between inflows of consecutive subzones.
o) Rank the pipe networks for leak detection with the smallest network which has high flow as the highest rank (where leak detection will be easiest to conduct); e.g. S/No. 2 is priority No. 1, etc.
p) Detect and repair as many leakages as possible within the shortest time possible (starting with priority No.1, then 2, etc.) while monitoring to confirm that the total DMA/Zonal daily flow is reducing.
q) If no more leakages are detected and further reduction of losses is still necessary, repeat the step test and again prioritize the networks as above.
r) If necessary and possible, conduct step test on those networks with high flow yet no more leaks are detected.
s) After achieving the desired low flow in the whole DZ/DMA, maintain this condition by patrolling (preferably with listening sticks) for visible or underground leaks and prompt repairs.
t) After repair of identified leaks a repeat step test can be conducted to detect the lines with relatively high flow for enhanced leak reduction.

Figure 5.26 is a graph of a step test by continuous measurement using UFM conducted in DZ 2 of Nakuru Town WSP on 26th February 2020.
The flow into each sub-zone is indicated as the difference between the step flows, e.g. subzone2 has the highest flow at 95 m3/hr.

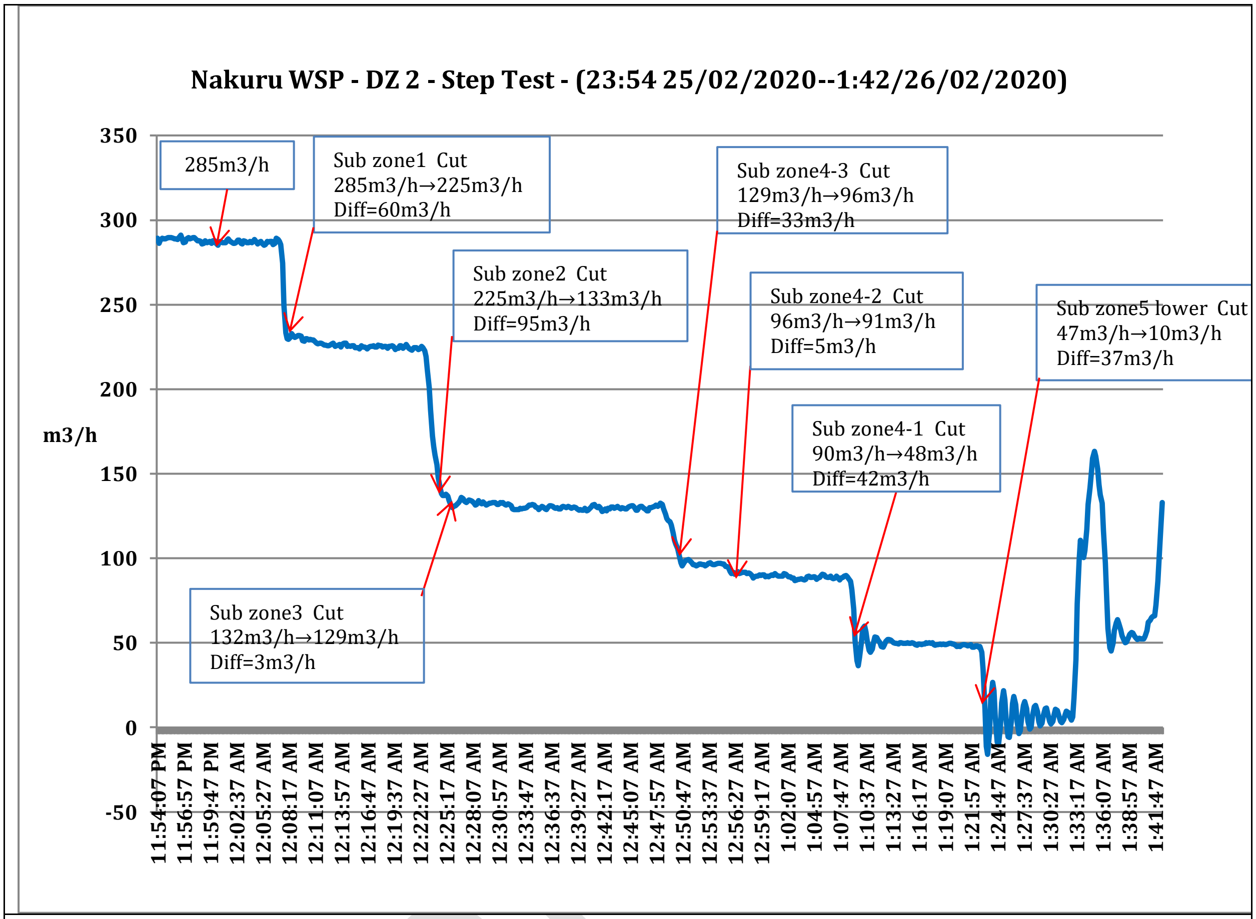


Figure 5.26: Step Test by continuous measurement using UFM (conducted in DZ 2 of Nakuru Town WSP - 26th February 2020)

5.5.3 Procedure of Step Test Leak Detection Using UFM (or Bulk Meter) without Continuous Measurement

Figure 5.27 is a map of DZ 2 in Meru WSP where a step test was conducted on 27th July 2019.

A transmission pipeline delivers water from the water treatment plant to the zonal tank (Tank ST-02) from where it is distributed to the customers. The yellow text boxes indicate sluice valves used to conduct the step test with data and analysis shown on Table 5.7. The pipelines are named either as (e.g.)

Table 5.6: Meaning of notations in Figure 5.27 and Table 5.7

	Notation (bold part)	**Meaning**
	J-02-02	J means pipeline dia≥ 90mm
	D2-02	D means dia = 63mm
	J-**02** & D**2**	means the pipelines are in DZ 2
	J-02-**02** & D2-**02**	means pipe No. 2 in the DZ
	J-02-02-**1** or D2-02-**1**	means tertiary pipes 40mm dia
	SV	means Sluice Valve

Pipelines J-02-01 and J-02-03 run on either side of the road although they seem as one pipe on the map.

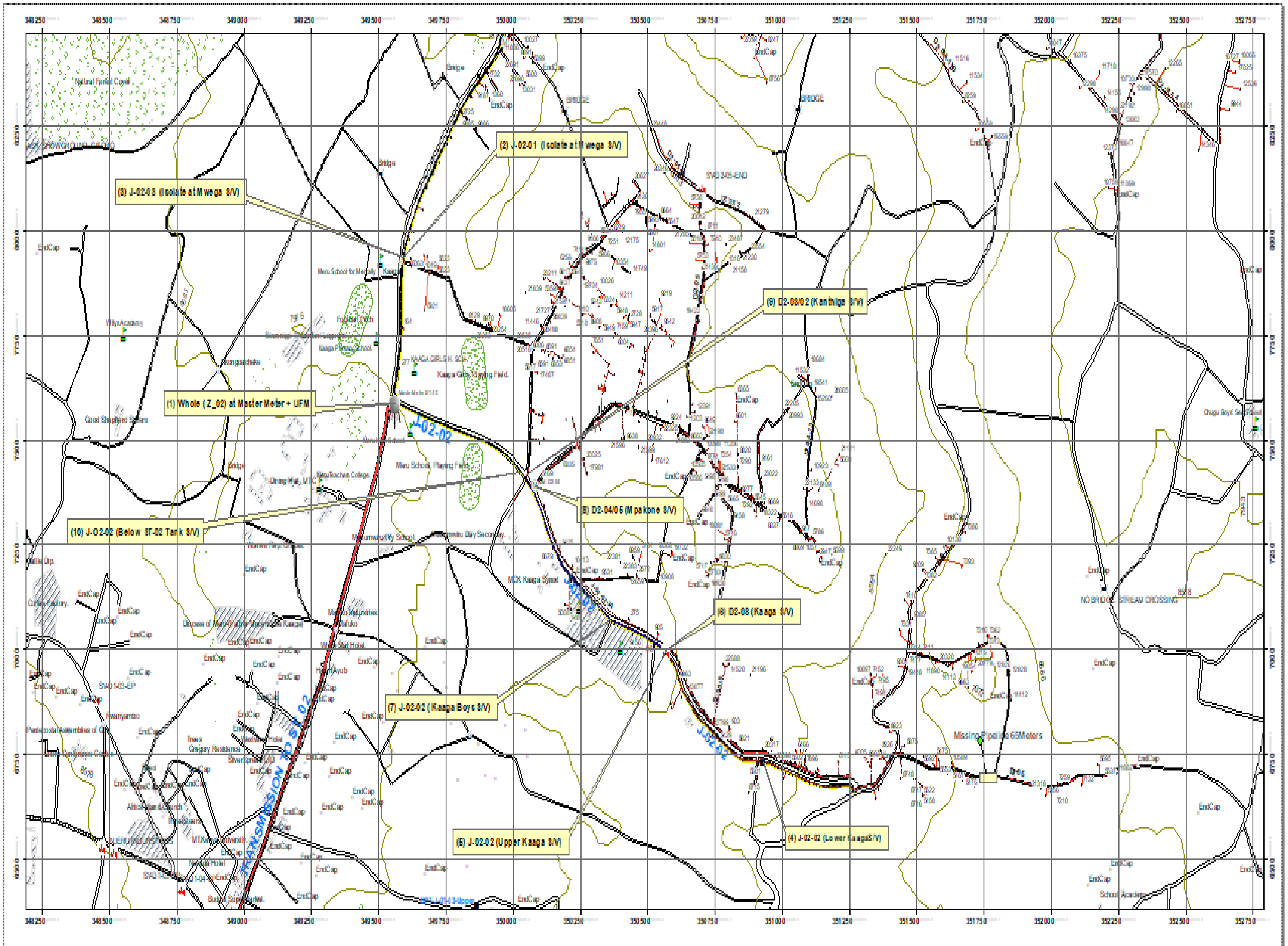


Figure 5.27: Map of DZ 2, Meru WSP Showing Sluice Valves Used for Step Test on 27th July 2019

Table 5.7: Data & Analysis of Step Test for DZ 2, Meru WSP, on 27th July 2019

a	b	c	d	e	f	g	h	i	j	k	l
S/ No.	**Pipeline Name**	**Pipeline Section Measured**		**Time of Measurement**		**Meter Reading**		**Flow in Unclosed Network**		**Flow in Closed Network**	**Priority for Leak Detection**
		From	**To**	**Starting**	**Stoppage**	**At Start**	**At stop**	**(= h - g) m^3/10min**	**(= i x 6) m^3/hr**	**(= upper – lower row) m^3/hr**	
1	Whole DZ 2	ST-02 Tank	Whole DZ	00:47 am	00:57 am	368475.95	368481.05	5.10	30.6	N/A	N/A
2	J-02-01	Mwega SV	End	01:02 am	01:12 am	368484.35	368485.93	1.58	9.48	21.12	1
3	J-02-03	Mwega SV	End	01:16 am	01:26 am	368486.51	368488.08	1.57	9.42	0.06	-
4	J-02-02	Lower Kaaga SV	End	01:29 am	01:39 am	368488.04	368489.60	1.56	9.36	0.06	-
5	J-02-02	Kaaga SV	Lower Kaaga SV	01:42 am	01:52 am	368490.00	368491.01	1.01	6.06	3.3	2
6	D2-08	Kaaga SV	End	01:55 am	02:05 am	368491.30	368492.20	0.9	5.4	0.66	7
7	J-02-02	Upper Kaaga SV	Kaaga SV	02:07 am	02:17 am	368492.44	368493.19	0.75	4.5	0.9	3
8	D2-04/05	Mpakone SV	End	02:21 am	02:31 am	368493.45	368493.89	0.44	2.64	1.86	4
9	D2-03/02	Kanthiga SV	End	02:35 am	02:45 am	368494.03	368494.20	0.17	1.02	1.62	6
10	J-O2-02 (Tank ST-02)	ST-02	Mid SV	02:50 am	03:00 am	368494.21	368494.22	0.01	0.06	0.96	5

Source: Meru WSP

The procedure was as follows:

a) Ensure that the DMA/DZ has only one inlet pipe (If more than one, a bulk meter should be installed on each and readings done for all at the same time).
b) Ensure that there are no pipe loops in the DMA/DZ. A Sluice Valve (SV) should be installed and closed to eliminate looping.
c) Ensure all the SVs in the DMA/DZ are open and the water supply is adequate and steady (not distorted by rationing or interruption).
d) Ensure you have a map or sketch of the DMA/DZ with all the SVs indicated and labelled (Figure 5.27 above).
e) Ensure all the SVs are easily accessible and are operating properly (can completely close the flow and are not leaking).
f) Flow measurements should be conducted between 00:00 am (midnight), and 04:00 am when most customers are asleep, hence any flow is likely to be leakage. Note:
    i) Some flow may be due to ongoing filling of some customers' tanks.
    ii) Some large customers like hospitals, industries and prisons operate 24 hours thereby causing flow.
g) Mount the UFM on the pipe at the starting point of the DMA/Zone (Section 5.3). If a UFM is unavailable, an installed accurate bulk meter may be used.
h) Record the starting meter reading and time (use Table 5.7).
i) Allow the water to flow for 10 minutes and record the reading and time again.
j) Prioritize the pipe networks and close the SVs starting with the furthest valve; and record the start and stop meter reading for each SV.
k) Continue the process until all SVs are closed and data obtained at each closure.
l) Open all the valves for water to flow to customers at the end of the exercise.
m) Calculate columns I to K.
n) Rank the pipe networks for leak detection with the smallest network which has high flow as highest rank (where leak detection will be easiest to conduct); e.g. S/No. 2 is priority No. 1, etc.
o) Detect and repair as many leakages as possible within the shortest time possible (starting with priority No.1, then 2, etc.) while monitoring to confirm that the total DMA/Zonal daily flow is reducing.
p) If no more leakages are detected and further reduction of losses is still necessary, repeat the step test and again prioritize the networks as above.
q) If necessary and possible, conduct step test on those networks with high flow yet no more leaks are detected.
r) After achieving the desired low flow in the whole DZ/DMA, maintain this condition by patrolling (preferably with listening sticks) for visible or underground leaks and prompt repairs.

5.5.4 *Step Test Leak Detection Method by Moving from One Pipe Section to Another Using UFM*

Refer to Figure 5.28 and Table 5.8 below for this sub-section.
This method is employed where the following conditions prevail:

i) The DMA/DZ has no bulk meter or the bulk meter is not accurate.
ii) High water flow is detected in a certain pipeline or a leakage is suspected but the leakage cannot be located by patrolling or listening stick or electronic leak detector.

The Step test can be conducted in two ways:

- At night from 00:00am (midnight) to 04:00am: - ideal method when it is necessary minimize interruption of supply to customers since they are asleep. The accuracy of measurement is higher since the flow is steadier.
- During day time: - this method is used in sparsely populated rural areas where overall consumption is expected to be low. Step test should be conducted when customers are expected to be out of the house (working). If possible, all the customer service pipelines should be closed at the stop-cork and the customers sensitized.

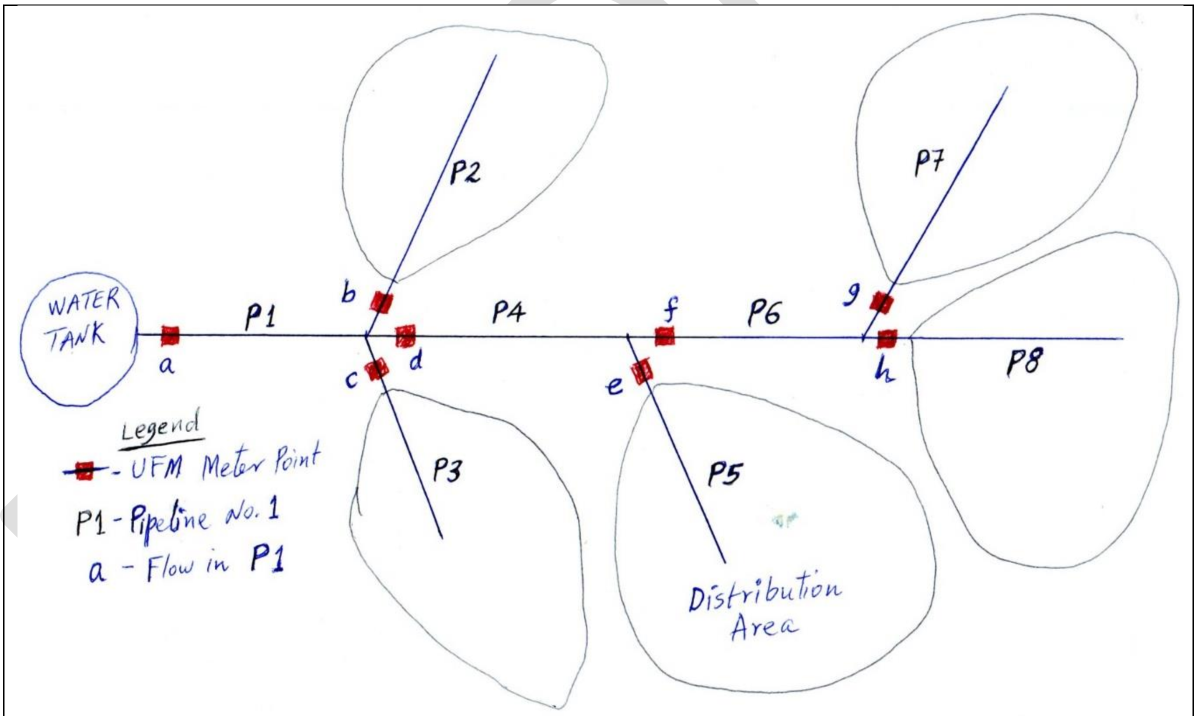


Figure 5.28: Sketch Illustrating Step Test by Moving from Pipe to Pipe Using UFM

Procedure

a) Locate the main distribution pipe into the DMA/DZ. If more than one main, each main should be considered separately (Figure 5.28).
b) Locate the main branches including their take-off points.
c) Ensure there is adequate, steady and continuous/uninterrupted flow into the DMA/DZ (it is not possible to conduct step test if water is inadequate or being rationed).

d) Excavate and expose the starting point of the main pipe and branches.
e) Measure flow (see Section 5.3 for procedure) in each pipe using UFM starting with the main pipe and then the branches.
f) Record the data in Table 5.8
g) Calculate Column H and the water losses within each pipe section (Column I).
h) Prioritize the pipelines for leak detection.
i) Conduct leak detection by patrolling, listening sticks and/or electronic leak detector.
j) Document the leaks detected in Table 5.2 (above) and submit for repair and mapping.
k) Monitor monthly NRW to confirm reduction.
l) Repeat the exercise to confirm and prioritize leak detection again to further reduce NRW.

Table 5.8: Results and Analysis of Step Test by Moving from Pipe to Pipe Using UFM

A	B	C	D	E	F	G	H	I	J
S/ No.	**Pipe Name**	**Time of Measurement (measure for 10 min)**		**Meter Reading**		**Flow through UFM**		**Water Loss in Pipeline**	**Priority for Leak Detection**
		Start time	**Stop time**	**At Start**	**At stop**	**(= F - E) m^3/10min**	**(= G x 6) m^3/hr**		
1	P1	0:00am	…….am	…….	…….	…….	…….	= a-b-c-d	…….
2	P2	…….am	…….am	…….	…….	…….	…….	= b	…….
3	P3	……am	……am	…….	…….	…….	…….	= c	…….
4	P4	…….am	…..am	…….	…….	…….	…….	= d - e - f	…….
5	P5	…….am	…….am	…….	…….	…….	…….	= e	…….
6	P6	…….am	…….am	…….	…….	…….	…….	= f - g - h	…….
7	P7	…….am	…….am	…….	…….	…….	…….	= g	…….
8	P8	…….am	…….am	…….	…….	…….	…….	= h	…….

5.5.5 How to Narrow Down on a Leak through Step Test Leak Detection Method Using UFM

This method assumes the following conditions that are common in Kenyan WSPs:

i) There is no bulk meter installed or it is inaccurate/unreliable.
ii) Sluice valves spacing is long or they do not function effectively

Under such conditions, it is difficult to locate some underground leakage by patrolling, listening stick or electronic leak detector.

In such cases, a step test can be conducted using a UFM to narrow down the search area.

The Step test can be conducted in two ways:

- At night from 00:00am (midnight) to 04:00am: - ideal method when it is necessary minimize interruption of supply to customers since they are asleep. The accuracy of measurement is higher since the flow is steadier.

- During the day time: - this method is used in sparsely populated rural areas where overall consumption is expected to be low. Step test should be conducted when customers are expected to be out of the house (working). If possible, all the customer service pipelines should be closed at the stop-cork and the customers sensitized.

Proceed as follows to narrow down on the leakage:

a) Select the pipeline, (AJ) where the location of a leak needs to be narrowed down (Figure 5.29)

Location Name	A	E	C	F	B	G	D	H	J
Pipeline									
Position	0	⅛	¼	⅜	½	⅝	¾	⅞	1
Priority	1st	4th	3rd	4th	2nd	4th	3rd	4th	

Figure 5.29: Narrowing Down on a Leak by Step Test Method

\- Leak location

b) Mark the pipe beginning - ‘A’, ½-way –‘B’, ¼-way – ‘C’ and ¾-way – ‘D’.
c) Excavate and expose the four points and prepare the area for leak detection using UFM as in Section 5.3.4 above.
d) Measure the flow at both ‘A’ and ‘B’ and record in Table 5.9.
e) For the purpose of this table, the pipe section between points ‘A’ and ‘B’ is (AB) while the water flowing between them is ab and so on,
f) If the difference aj – bj is high, then there probably is a leakage between ‘A’ and ‘B’.
g) To narrow down on the leak further, measure flow at ‘C’.
h) If flow aj – flow cj is low, then the leak is between ‘C’ and ‘B’

Figure 5.30: Flow Measurement Using UFM

i) If necessary, further narrowing can be done by measuring flow at ‘F’ and this will indicate that the water loss is between ‘C’ and ‘F’.
j) Depending on the length of the pipe section (CF), further subdivision of the pipe can be done and additional narrowing down conducted as above.
k) Once enough narrowing down has been attained, the leak can be located by patrolling or listening stick or electronic leak detector or even excavating along the section (CF).
l) Any leak along the pipe (AB) can therefore be located by this method using a UFM.
m) Record and analyze the data as per Table 5.9 below.

Table 5.9: Data and Analysis of Narrowing Down on a Leakage by Step Test Leak Detection on a Pipeline Using UFM

	Pipeline Name: ……………………….							**Date: …………….**	
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
S/ No.	**UFM Location on Pipe**	**Time of Measurement (measure for 10 min)**		**Meter Reading**		**Flow through UFM**		**Flow in Pipeline**	**Priority for Leak Detection**
		Start time	**Stop time**	**At Start**	**At stop**	**(= F - E) $m^3/10min$**	**(= G x 6) m^3/hr**		
1	‘A’ (0)	0:00am	…….am	…….	…….	…….	…….	(AJ) = aj	…….
2	‘B’ (1/2)	…….am	…….am	…….	…….	…….	…….	(BJ) = bj	…….
								(AB) =aj-bj	…….
3	‘C’ (1/4)	……am	……am	…….	…….	…….	…….	(CJ) = cj	…….
								(AC) = aj-cj	…….
								(CB) = cj-bj	…….
4	‘D’ (3/4)	…….am	…..am	…….	…….	…….	…….	(DJ) = dj	…….
								(BD) = bj-dj	…….
5	‘E’ (1/8)	…….am	…….am	…….	…….	…….	…….	(EJ) = ej	…….
								(AE) = aj-ej	…….
								(EC) = ej-cj	…….
6	‘F’ (3/8)	…….am	…….am	…….	…….	…….	…….	(FJ) = fj	…….
								(CF) = cj-fj	…….
								(FB) = fj-bj	…….
7	‘G’ (5/8)	…….am	…….am	…….	…….	…….	…….	(GJ) = gj	…….
								(BG) = bj-gj	…….
								(GD) = gj-dj	…….
8	‘H’ (7/8)	…….am	…….am	…….	…….	…….	…….	(HJ) = hj	…….
								(DH) = dj-hj	…….

5.6 Procedure of leak detection using leak noise correlator

5.6.1 Introduction

Leakages occurring in pressurized pipes continuously generate random leak noises, which travel in the pipe in both directions. A leak noise correlator equipment transforms the noise that is detected into an electric signal that is then displayed on the monitor of the correlator. It not only detects the existence of leakages, but also displays the location of the leak as a peak of the wave points.

For a comprehensive description of how to use a correlator, refer to the Leak Detection Technology and Implementation published by International Water Association (IWA) by downloading it from the following link:
https://library.oapen.org/bitstream/handle/20.500.12657/33035/578133.pdf?sequence=1&isAllowed=y

Below is a brief description on leak noise correlator equipment.
Leak noise correlation works by comparing the noise detected at two different points in the pipeline. Assuming consistent pipe material and diameter, the noise travels from the leak in both directions at a constant velocity, so that if the leak is not equidistant then these sensors will detect the same noise at different times. This difference in arrival times is measured by the correlation process.
The sound velocity depends on the pipe material, pipe diameter, and to a lesser extent, on the surrounding soil.

Figure 5.31: Leak noise correlator kit

A Leak Noise Correlator is a highly specialized leak detection equipment used to detect water leaks by electroacoustic means. The word “Electroacoustic” is any process involving the transfer of a signal from acoustic to electrical form.
A Leak Noise Correlator device is used in combination with various microphones/ Accessories.

5.6.2 Characteristics of leak noise correlator.

- It is costly
- It can be used to detect leaks over a distance of not more than 100m at a time; hence leak detection over the whole water supply takes a long time.
- For leak detection, the equipment sensors must be placed on sluice valves, hydrants or on the metallic pipe. For non-metallic pipes, a saddle clamp can be tied to the pipe to facilitate a place for the sensor.

- The spacing of the sensors must be 100m or less for the equipment to detect leakage.

It is therefore recommended that use of leak noise correlator should only be considered when the overall NRW ratio has been reduced to below 10% using other leak detection methods.

5.6.3 How a Leak Noise Correlator Works

- Sensors pick the leak sounds transmitted on the pipe walls.
- Leak sound will travel down the pipe wall away from the leak.
- Pre-Amplifiers/Transmitters amplify leak sounds and transmit them continuously to main processor (CPU).
- The CPU compares (Correlates) sound and displays correlation results.
- The CPU calculates the exact distance to the leak.
- These speeds of the noises transmitted are programmed into a software so that a mathematical formula is used to determine the time difference leak noise takes to reach two or more sensors from the point of the leak.
- Three inputs are generally needed to do the calculations which include the pipe material, pipe diameter, and the soundtrack (length) of pipe between the sensors.
- It can even find multiple leaks in the section between the sensors at the same time.
- A best practice is to verify the correlation by verifying the location with a ground microphone in case of errors in the data entered to do the leak noise correlation.

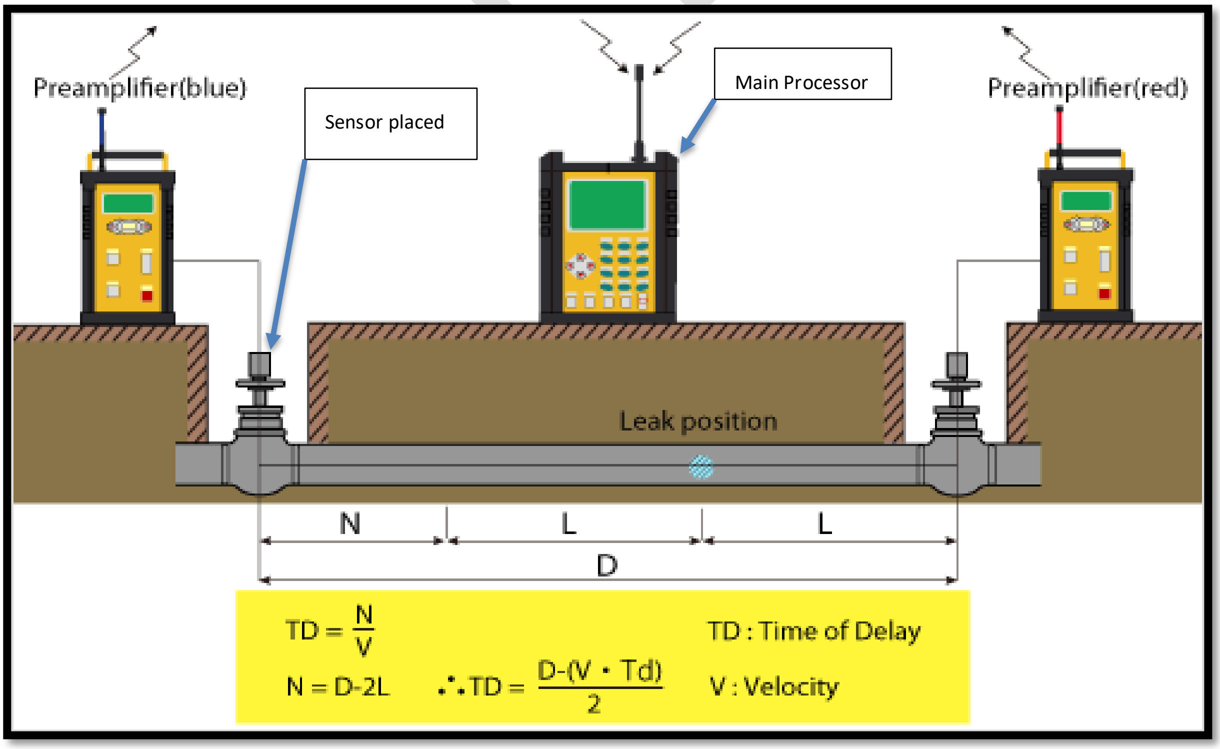


Figure 5.32: Using Leak Noise Correlator to Detect and Locate a Leak

5.6.4 Leak Noise Correlator Procedures & Mounting

- Mount the Blue and Red-amp transmitters (or Pre-amplifier) to the access points which are pipe fittings such as meters, valves, hydrants or on the pipe itself if it is metallic. Where metallic location is not available, it can be created by, say, tying a metallic clamp on the pipe.
- Switch the Main Processor and the Transmitters to ‘’ON’’ position.
- In PIPE DATA Input, select the pipe material, diameter, and length for every section of pipeline between the two sensors.
- Up to six pipe sections can be entered to the Main Processor (always in order from the “Blue” sensor to the “Red” sensor).
- The Main Processor Unit displays the correlation "picture" and the distances to the leak from the Red pre-amplifier transmitter and the Blue pre-amplifier transmitter.
- The Correlator samples the noise for a given period of time and stores the same in memory. This process is repeated severally over the period and added to the original information and averaging done.
- During correlation, any pipe branches located between the two sensors should be closed.

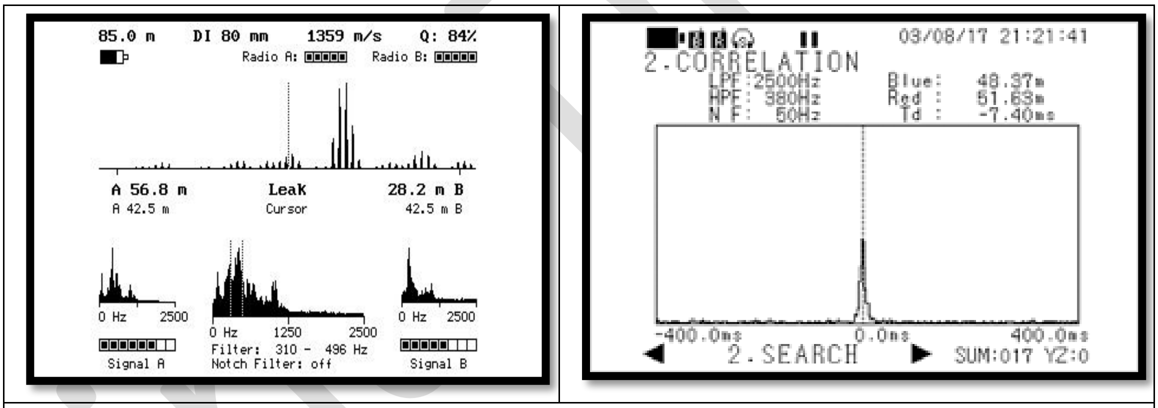


Figure 5.33: Two types of graphical representation of leak position from sources blue and red

Chart Interpretation

- Where the graphs are high it indicates leaks or branches take-off points from the line under investigation.
- The graph height indicates the magnitude of leakage.
- The charts also indicates the distances of leakage or take-off points from the blue and the red preamplifiers.

5.7 Advanced Analysis of Leak Detection Data

Advanced analysis of leakage data enables to identify the most effective priority sub-zone or pipeline on which to focus leak reduction intervention measures. Table 5.10A, B & C below are derived from leak detection data.

NRW can be defined (or measured) using the following five indicators:

No. 1	No.2-1	No.3-1	No.4-1	No.5
NRW (%)	**NRW (Ltr/con/da**	**NRW (Ltr/km/min**	**CAPL / MAAPL or UARL**	**MAAPL (UARL)**

(1) Indicator 1: NRW as a percentage, **%**
(2) Indicator 2: NRW as Leakage volume per connection per day (Ltr/con/day)
(3) Indicator 3: NRW as Leakage volume per km per minute (Ltr/km/min)
(4) Indicator 4: NRW as Current Annual Physical Losses (CAPL) / Unavoidable Annual Real Losses (UARL) = Infrastructure Leakage Index (ILI)
(5) Indicator 5: Minimum Achievable Annual Physical Loss (MAAPL) is the same as UARL in (4)

NRW in (2-1), (3-1) and (4-1) can also be replaced by Qmnf (Volume Minimum Night Flow) as below if Qmnf is considered as an approximation of the physical losses.

No. 1	No.2-2	No.3-2	No.4-2	No.5
NRW (%)	**Qmnf (L/con/day)**	**Qmnf (L/km/min)**	**Qmnf / MAAPL or UARL**	**MAAPL (UARL)**

Having defined the five indicators above, the following examples serve to describe how to apply the indicators in practice.

(I) Indicator 1: NRW as a percentage, %

In Table 5.10A, Column 9 indicates the NRW or Qmnf of each pipeline (Note: if a pipeline has a high Qmnf, the it will also have a high NRW%). The pipelines are then ranked based on the volume of leakage (highest Qmnf). Leak detection can then be conducted starting with pipeline Rank No. 1; then Rank No. 2, etc.

Table 5.10A prioritizes leak detection on the basis of the sub-zone with the highest flow rate.

Table 5.10A: Result of Step Test Measurement for DZ 8 Lower (Kambakia) –10th January 2020

	Column No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
slno.	**Pipeline No**	**pipeline route**		**Time to be measured**		**Meter Reading**		**Flow (3)**	**Flow (4)**	**Flow in Pipeline M^3/hr (5)**	**Rank**
		From	**To**	**Starting**	**Stoppage**	**At starting time**	**stoppage tim**	**(6)-(5) M^3/10min**	**(7)*6 M^3/hr**		
1	**WHOLE**	Origin	End	23:47 hrs	23:57 hrs	332259.35	332261.92	2.57	**15.42**		
2	**D8-04 (Rwanyambo)**	Origin	End	00:03 hrs	00:13 hrs	332262.65	332264.96	2.31	**13.86**	**1.56**	**No. 3**
3	**D8-04 (Stream)**	Origin	End	00:25 hrs	00:35 hrs	332265.95	332268.12	2.17	**13.02**	**0.84**	**o.k**
4	**D8-04A (WILLY'S)**	Origin	End	00:50 hrs	01:00 hrs	332270.08	332272.19	2.11	**12.66**	**0.36**	**o.k**
5	**D8-02 Lower (Kambakia)**	Origin	End	01:10 hrs	01:20 hrs	332272.95	332275.02	2.07	**12.42**	**0.24**	**o.k**
6	**D8-02 Upper (police)**	Origin	End	01:35 hrs	01:45 hrs	332275.95	332276.75	0.8	**4.8**	**7.62**	**NO. 1**
7	**J-08-02(v/ chamber)**	Origin	End	02:00 hrs	02:10 hrs	332277.23	332277.95	0.72	**4.32**	**0.48**	**o.k**
8	**D8-03 (Kenya-RE)**	Origin	End	02:20 hrs	02:30 hrs	332278.35	332278.38	0.03	**0.18**	**4.14**	**NO. 2**
9	**J-o8-02 (kenya-Re)**	Origin	End	02:45 hrs	02:55 hrs	332278.45	332278.46	0.01	**0.06**	**0.12**	**o.k**

(II) Indicator 2: NRW as Leakage volume per connection per day (Ltr/con/day)

In Table 5.10B(1), Column 9* are the values of Qmnf from Table 5.10A above. The values are subjected to further evaluation by converting to 24hour flow and dividing the flows by the number of connections on each pipeline to obtain Indicator2 in Ltr/con/day (Column No. 13). The pipelines are then ranked based on Table 5.10B(2) which is a World Bank's Physical Loss Target Matrix of a distribution system whose average water pressure is 50m (assumed average pressure in most WSPs in Kenya).

The pipelines with high Indicator2 (E is highest) value are the prioritized for leak detection.

Table 5.10B(1): Result of Step Test Measurement for DZ 8 Lower (Kambakia) on 10th Jan. 2020 (Note: 9* - Table starts with Column 9 of Table 5.10A)

	Column No.	[9]*	[11]	[12]	[13]	[14]**
	Indicator 2 (Ltr/con/day)					
s. no.	**Pipeline No.**	**Qmnf (m^3/h)**	**No. of Con.**	**Ltr/con/h**	**Ltr/con/day**	**Rank**
1	Whole	n/a	n/a	n/a	n/a	n/a
2	D8-04 (Rwanyambo)	1.56	217	7	173	B
3	D8-04 (Stream)	0.84	100	8	202	B
4	4-D8-04A (Willy's)	0.36	80	4	108	A
5	D8-02 Lower (Kambakia)	0.24	60	4	96	A
6	D8-02 Upper (Police)	7.62	325	23	563	D
7	J-08-02 (v/chamber)	0.48	2	240	5,760	**E**
8	D8-03 (Kenya-Re)	4.14	86	48	1,155	**E**
9	J-o8-02 (Kenya-Re)	0.12	0	#DIV/0!	#DIV/0!	D
		Total	870			
	Note: Column 14** - Ranking is based on Table 5.10B(2)					

Table 5.10B(2): Physical Loss Target Matrix (Indicator2 – Leakage Volume per Connection per Day) (*Source: World Bank Institute - see Table 5.11*)

Indicator2 (Ltr/con/day)	**Index**
＜125	**A**
125 to ＜250	**B**
250 to ＜500	**C**
500 to ＜1000	**D**
1000 & above	**E**

This index is used when there seems to be a lot of physical leakage in the service pipes.
Note: The true value CAPL cannot be known without direct measurement of flow. When it is judged that there is a lot of water leakage in the service pipe, a suitable survey method for measuring flow is formulated.

(III) Indicator3: NRW as Leakage volume per km per minute 9Ltr/km/min)

In Table 5.10C(1), Column 9* are the values of Qmnf from Table 5.10A above.

The values are subjected to further evaluation by converting the per hour to per minute flow and dividing the flows by the total length of each pipeline in km to obtain Indicator3 in Ltr/km/min (Column No. 16). The pipelines are then ranked based on Table 5.10C(2) which is the ILI recommended by the Japan International Cooperation Agency (JICA) NRW Project.
The pipelines with high Indicator3 (E is highest) (Ltr/km/min) are prioritized for leak detection.

Table 5.10C(1): Result of Step Test Measurement for DZ 8 Lower (Kambakia) on 10th Jan. 2020 (Note: 9* - Table starts with Column 9 of Table 5.10A)

	Column No.	[9]*	[15]	[16]	[17]
	Indicator 3 (Ltr/km/min)				
	Pipeline No.	**Qmnf (m3/h)**	**Length (km)**	**Ltr/km/min**	**Rank**
1	Whole	n/a	n/a	n/a	n/a
2	D8-04 (Rwanyambo)	1.56	0.104	250.0	E
3	D8-04 (Stream)	0.84	0.773	18.1	B
4	4-D8-04A (Willy's)	0.36	1.980	3.0	A
5	D8-02 Lower (Kambakia)	0.24	0.578	6.9	A
6	D8-02 Upper (Police)	7.62	1.065	119.2	E
7	J-08-02 (v/chamber)	0.48	0.404	19.8	B
8	D8-03 (Kenya-Re)	4.14	0.557	123.9	E
9	J-o8-02 (Kenya-Re)	0.12	0.350	5.7	A
		Total	5.811		

Table 5.10C(2): Physical Loss Target Matrix (Indicator3 – Leakage Volume per km per min.

Indicator3 (L/km/min)	**Index**
＜10	**A**
10 to ＜20	**B**
20 to ＜50	**C**
50 to ＜100	**D**
100 & above	**E**

This index is used when there is a lot of physical leakage in the water distribution pipes.

(IV) Indicator 4: NRW as Current Annual Physical Losses (CAPL) / Unavoidable Annual Real Losses (UARL) = Infrastructure Leakage Index (ILI)

Indicator 4: = Infrastructure Leakage Index (ILI)

$$= \frac{\text{Current Annual Physical Losses) (CAPL)}}{\text{Unavoidable Annual Real Losses (UARL)}}$$

Table 5.11: Physical Loss Target Matrix

Technical Performance Category		ILI	Physical Losses [litres/connection/day] (when the system is pressured) at an average pressure of:				
			10 m	20 m	30 m	40 m	50 m
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: World Bank Institute

Book Source: The Manager's Non-Revenue Water Handbook (A Guide to Understanding Water Loss)

In Table 5.11 above:

- Is the ***Infrastructure Leakage Index, ILI.***
- Is Indicator2 (***Ltr/con/day***) which shows the numerical value based on the average water pressure in the system. Table 5.10B(2) is modified to include <125 which is not in Table 5.11.

The value of ILI for each pipeline in Table 5.10A is calculated in Table 5.12 below.
(Note: The setting value of the indicator is different from ILI of Handbook).
Please See Sheet ILI Cal in ``Night flow 10.01.20 DZ 8 LOWER(JICA2020.07.01) rev.xlsx

Table 5.13, MAAPL (Ltr/day) =((18×Lm) + (0.8×Nc) + (25×Lp)) ×P
Where: -
Lm - Length of mains (km)
Nc - Number of service connections
Lp - Total Length of service pipe from property boundary to customer meter (km)
P - Average operating pressure in m (assumed 30m water head)
CAPL = k x Qmnf

Note: CAPL is obtained through direct flow measurement. However, measurement or calculation of CAPL is very difficult.
Therefore, CAPL value is normally estimated through common sense by multiplying Qmnf by a coefficient, k with value range 0.5 to 0.9 (Table 5.12).
This coefficient, k varies depending on:

- the setting, i.e. urban or rural setting.
- number of service pipes in the DZ.
- amount of wave amplitude on the Qmnf graph.

For example, CAPL in Meru WSP data tentatively calculated using 0.9xQmnf.

Table 5.12: A Guide to Coefficient k (estimated through common sense)

NRW%	Reference coefficient	Urban	Rural
20	0.6 to 0.8	0.6 to 0.7	0.7 to 0.8
30	0.7 to 0.85	0.7 to 0.8	0.75 to 0.85
40	0.75 to 0.9	0.75 to 0.85	0.8 to 0.9
50	0.8 to 0.9 or higher	0.8 to 0.9	> 0.9

Table 5.13: Infrastructure Leakage Index (ILI) Calculation for DZ 8

	Column No.	[11]	[18]	[19]	[20]	[21]	[22]	[9]	[23]	[24]
			Lm (Km)	Nc	Lp (1 tapping =30m): Km	P	MAAPL (Ltr/day)	Qmnf (m3/h)	CAPL (Qmnf*90%) Ltr/day	ILI
		No. of Connections	Length of mains	service connections	Total Length of service pipes	Pressure (mca)				
	Pipeline No.			=[11]	=[19]x30/1000		= (18x[18])+ (0.8 x [19])+ (25x[20])x[21]		= (9)x0.9x 24x1000	= (23)- (22)
1	**Whole**	**870**	**5.81**	**870**	**26.10**	**30**	**43,593**	**15.36**	**331,776**	**7.6**
2	D8-04(Rwanyambo)	217	0.10	217	6.51	30	10,147	1.56	33,696	3.3
3	D8-04 (STREAM)	100	0.77	100	3.00	30	5,067	0.84	18,144	3.6
4	4-D8-04A(WILLY'S)	80	1.98	80	2.40	30	4,789	0.36	7,776	1.6
5	D8-02 Lower (kambakia)	60	0.58	60	1.80	30	3,102	0.24	5,184	1.7
6	D8-02 Upper(police)	325	1.07	325	9.75	30	15,688	7.62	164,592	10.5
7	J-08-02(v/chamber)	2	0.40	2	0.06	30	311	0.48	10,368	33.3
8	D8-03 (Kenya-RE)	86	0.56	86	2.58	30	4,300	4.14	89,424	20.8
9	J-o8-02 (kenya-Re)	0	0.35	0	0.00	30	189	0.12	2,592	13.7

Table 5.14: Calculated ILI (from Table 5.13)

	Pipeline No.	ILI
1	**Whole**	**7.6**
2	D8-04 (Rwanyambo)	3.3
3	D8-04 (STREAM)	3.6
4	4-D8-04A (WILLY'S)	1.6
5	D8-02 Lower (Kambakia)	1.7
6	D8-02 Upper (police)	10.5
7	J-08-02 (v/chamber)	33.3
8	D8-03 (Kenya-RE)	20.8
9	J-o8-02 (Kenya-Re)	13.7

ILI Recommended by JICA NRW Project

LI=Indicator4 (CAPL/UARL	
1-4	**A**
4-8	**B**
8-16	**C**
16-20	**D**
＞20	**E**

ILI from Manager's Handbook

Technical Performance Category		ILI
Developed Countries	A	1 - 2
	B	2 - 4
	C	4 - 8
	D	> 8
Developing Countries	A	1 - 4
	B	4 - 8
	C	8 - 16
	D	> 16

Table 5.15: Recommended Priority Pipelines Using Recommended ILI Above

	Pipeline No.	**ILI**	**Prioritized Pipelines**
1	**Whole**	**7.6**	**B**
2	D8-04 (Rwanyambo)	3.3	A
3	D8-04 (STREAM)	3.6	A
4	4-D8-04A (WILLY'S)	1.6	A
5	D8-02 Lower (Kambakia)	1.7	A
6	D8-02 Upper (police)	10.5	C
7	J-08-02(v/ chamber)	33.3	E
8	D8-03 (Kenya-RE)	20.8	E
9	J-o8-02 (Kenya-Re)	13.7	C

JICA Project ILI

<u>**Note:**</u> E is the highest priority for leak detection

CHAPTER 6

MEASURING PRESSURE IN EXISTING PIPE NETWORK

(Target Staff: Design, Construction, Meter/Connection Installation)

6.1 Importance of Measuring Pressure in Existing Pipe Network

The rate of leakages increases with increase in pressure. It is therefore prudent to keep the pressure in pipelines low to reduce the amount of leakage.

The minimum allowable pressure at the customer point is 10m head. It is therefore not necessary to maintain higher than the minimum pressure, where possible, so that leakage remains low.

The purpose of measuring pressure in the network is to determine the pressure distribution (or pressure map) which can then be used to manage pressure thus:

- reduce pressure using pressure reducing valves or break pressure tank where pressure is unnecessarily high
- increase pressure using booster pumps where pressure is inadequate

This is normally best achieved by carefully considering the various options of combining booster pumps and PRVs/storage/break pressure tanks to come up with an energy-efficient network.

6.2 Procedure of Pressure Measurement using Pressure Gauge fitted with Min/Max Drag Pointer

1) *General*

A drag pointer is a red additional pointer with an arm that is pushed by the primary gauge pointer (black) upto when the pressure drops and the drag (or **max pointer)** remains at peak **pressure**, indicating **max pressure** achieved. This gauge can also function similarly as a min **pointer** on vacuum or compound ranges.

Figure 6.1: Red pointer pressure gauge

2) *Where to Install the Min/Max Drag Pointer Pressure Gauges*

a) A point at or near where the branch supplying a DZ starts.
b) Points at the end of a pipe network.
c) Peak points of a pipeline (where the minimum water pressure occurs).
d) Points at just in front and just behind a pressure reducing valve (to verify the reliability of pressure reducing valve).
e) Points where water hammer tends to start (e.g. Pump outlet pipe)
f) On a pipeline at 2 to 4 km intervals (for information on water leakage).

g) Around the customer meter.

3) How to Install a Pressure Gauge.

The following are required to enable installation of a pressure gauge:

- Pressure gauge,
- Fitting spanners,
- Thread tape or a rubber gasket
- Pressure tapping point.

Figure 6.2: Pressure gauges installed on pipes

Procedure

- Open the tapping point to release air if any
- Appy thread tape to the threads or fix the rubber gasket appropriately.
- Fix the gauge firmly screw the pressure gauge into the tapping point ensuring watertight seal (no leaks) for accurate readings.
- Open the facility tap and wait for a few seconds before reading.
- Live pressure can then be recorded.

Note: this method is best used to test static water pressure. If water is moving anywhere in the system, that may cause a false low reading.

4) How to Measure Maximum Pressure

a) Select the type of target pressure you want to measure (ie. Maximum, minimum or running pressure)
b) Select the type of location to install the pressure gauge from sub-section (2) above.
c) If the gauge is to be installed along the pipeline, prepared a pressure point in advance (install a branch connection (using saddle clamp or tee) with suitable adaptor for the pressure gauge inlet), while if it is along a customer line, the meter liner point would be most suitable.
d) Adjust the gauge to suit the type of pressure being measured:
   - To measure maximum pressure, adjust the drag (red) pointer **anti-clockwise** to lean against and above the black pointer and leave the gauge at that point

overnight. Record the maximum pressure achieved by checking the reading of the drag pointer.
- To measure the minimum pressure, adjust the red pointer clockwise to lean against and below the black pointer. Record the lowest pressure achieved by checking reading of the drag pointer.


Figure 6.3: Pressure gauge installed at customer metering point

Record the location coordinates with GPS.
- If around a customer meter, record the connection number and meter serial number.
- Record the initial or running pressure indicated by the black pointer immediately after installation.
- Leave the gauge overnight
- In the morning, record the pressure indicated by the red gauge (this is the maximum or minimum pressure in the pipeline at this location)
- You can opt to repeat the exercise in case of doubt or as a confirmation.

Table 6.1 is a conversion table for pressure units for reference.

Table 6.1: Pressure Units Conversion Table

1 bar = 0.987 Atm	1 KPa = 0.00987 Atm	1 psi = 0.068 Atm	1 Atm = 1.013 bar	1 m = 0.09804 bar
1 bar = 10 m	1 KPa = 0.01 bar	1 psi = 0.0689 bar	1 Atm = 101.3 KPa	1 m = 0.0968 Atm
1 bar = 14.504 psi	1 KPa = 0.14504 psi	1 psi = 6.8947 KPa	1 Atm = 14.696 psi	1 m = 9.804 KPa
1 bar = 100 KPa	1 KPa = 10 m	1 psi = 0.7032 m	1 Atm = 10.335 m	1 m = 1.45 psi

6.3 How to Measure Pressure Using Pressure Data Logger

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

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

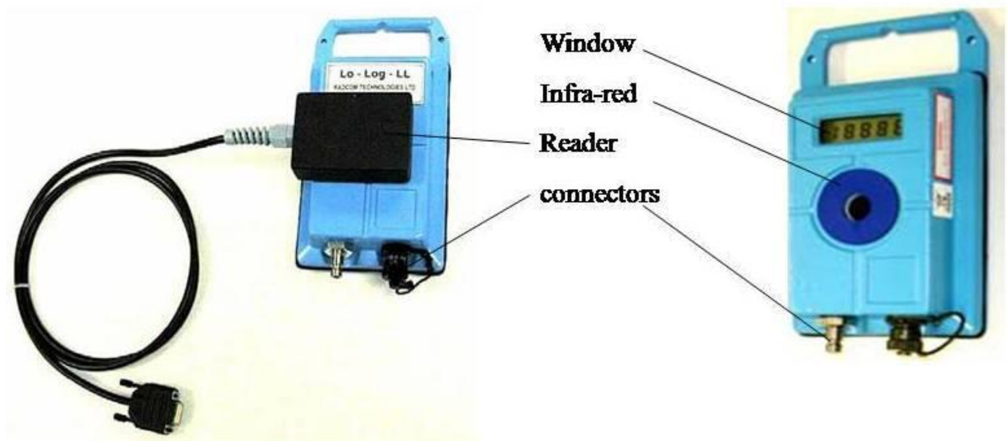


Figure 6.4: Pressure data loggers

Pressure loggers have programmable start and stop alarm times that make it possible to synchronize multiple water pressure data loggers to start at the same time, delay starting until a preset time, or limit the number of recordings during a day. They can also record water pressure data just about anywhere required as most of them are harsh weather resistant.

Applications

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

- DMA and General pressure Logging
- Water Demand Managements/Assessments
- Customer Metering Diagnostics
- Pressure mapping

Step 1: Software installation

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

Note: different loggers use different software the user should use the guidelines given to install software.

Step 2: Data Input (Set up)

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

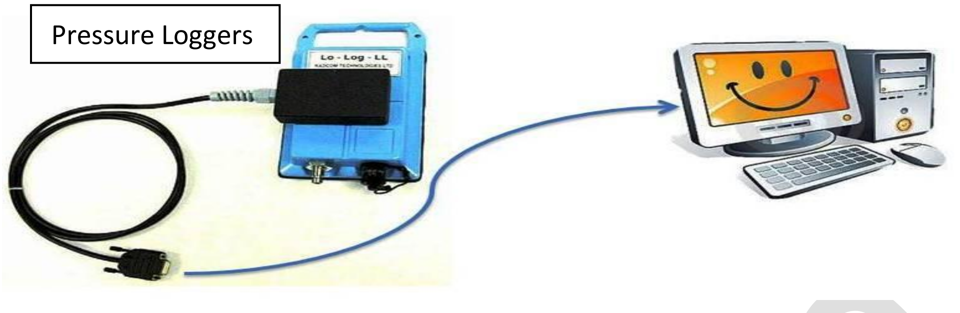


Figure 6.5: Data transfer from pressure logger to computer

Figure 6.6: Pressure Logger Installed on Pipe

Step3: How to Install Data Logger

Note: The logger is water resistant but it is advisable to install it in a chamber or box.

- Using the pressure flex tube, connect the logger to the pipe tapping point (Figure 6.6).
- Logging will start automatically as per set time.

Step 4: Downloading data

- Connect the data logger to a computer using infrared or wire cable and follow steps provided.
- The users can then interpret the data, develop graphs or covert to other formats.

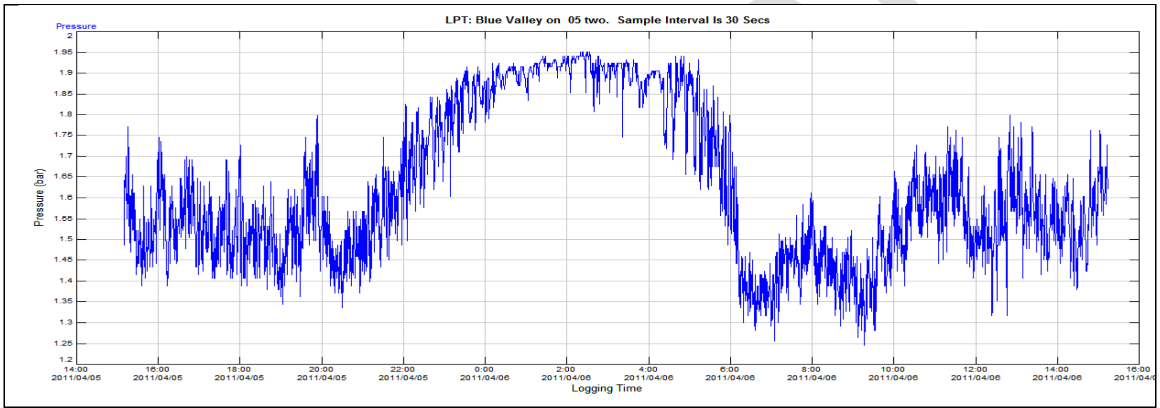


Figure 6.7: Pressure log graph

Maintenance

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

6.3.1 Self-Recording Water Pressure Measuring Instruments

This is a device that measures hydraulic pressure after connecting to a hydraulic fitting on a pipeline using a dedicated connecting fitting (coupling) and a water pressure sensor. (See Figure 6.8)

The recorder has a "pen" attached to an arm interlocking with a Bourdon tube that expands and contracts with change in pressure (there are both fixed and portable loggers). The recording paper can record for over 24 hours and uses a built-in clock (see Figure 6.8 to 6.10)

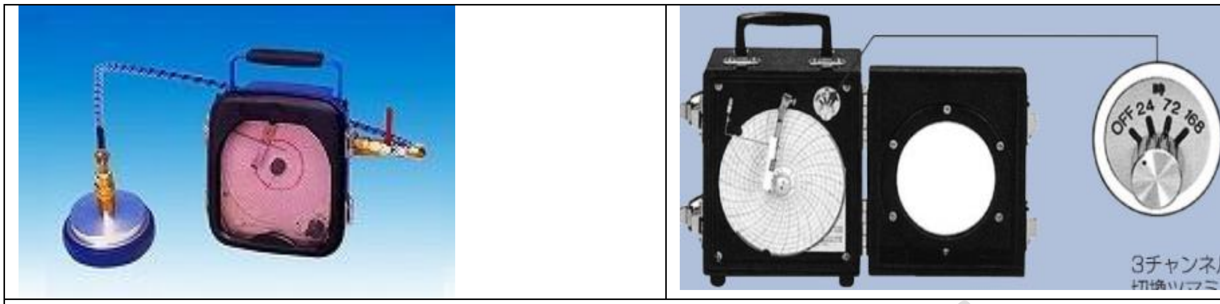


Figure 6.8: Self-recording water pressure measuring device models

Figure 6.9: Self-recording water pressure measuring device model

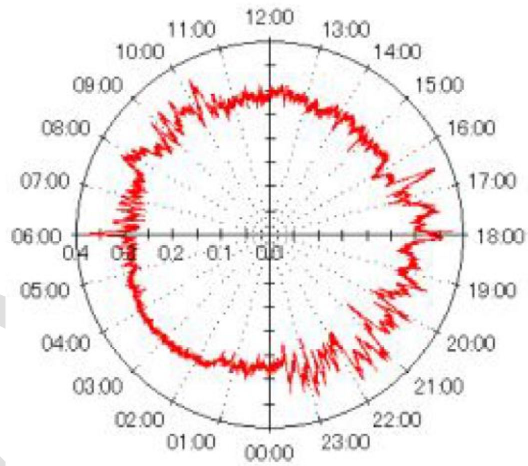


Figure 6.10: Water pressure recording paper

CHAPTER 7

PRESSURE TESTING OF PIPELINES

(Target Staff: Design, Construction, Meter/Connection Installation)

7.1 Importance of pressure testing of pipelines

Once a new pipeline is laid, its condition is unknown unless and until it is tested for pressure tightness. The practice of commissioning new pipelines without first subjecting to pressure tests (which is a common practice) is imprudent and leads to high NRW from the beginning. Pressure testing provides an opportunity to rectify any defects at the initial stage before heavy losses are incurred through water loss through leakage, revenue loss and leak detection costs later on.

Pressure testing of pipelines can also be conducted on an existing pipeline to determine its soundness. This is normally carried out in combination with leak detection to reveal any leakage points.

7.2 Procedure of Pressure Testing Pipelines Using Hand Pump

a) Select the pipeline on which to conduct the pressure test with handpump (e.g. newly installed connection, service line that has been replaced, connection with road crossing etc.).
b) Confirm that the gate valve or ferrule at the off-take point from the mainline is accessible and properly functional
c) Record the coordinates of the saddle or ferrule point using a GPS.
d) Confirm the pressure class of the pipe to be tested (pipe specifications) to ensure it will withstand the testing pressure (usually 1.5 times the expected maximum pressure at that point at night). If the pipe cannot withstand the testing pressure, replace it with the right pipe. Note: the testing pressure for all pipes is usually 1.5 times the rated pressure).
e) Confirm that the pipe is full of water at the time of the test.
f) check the condition of the trench in which the service line or connection has been installed. The pipeline should be half backfilled with the joints exposed so that any leakage will be visible.
g) Connect the pump on the far end from the ferrule ready for use and set the maximum pressure to be applied during test (usually 1.5 times the expected maximum pressures in that area at night).

Figure 7.1: Hand pump connected on different pipe materials ready for use

h) Close the gate valve or ferrule at the off-take point and pump water into the pipe column under test to the set pressure reading on the gauge. Remove air that might be in the column by opening the air valve on the pump.
i) After achieving the set pressure, wait for about 5 minutes to see if the pressure will sustain at the set level.
j) If the pressure drops, it indicates there is possibly a leakage in the pipe and therefore patrol the pipeline to locate it. If the pressure remains steady after 5 minutes, it means the pipeline has no leakage.

The test can be repeated for verification if need be and the results recorded for certification purpose.

7.3 Pressure Testing of Large Pipelines

Refer to Section 3.6 for detailed procedure.

CHAPTER 8

MANAGEMENT OF CUSTOMER AND BULK METERS

(Target Staff: NRW, Meter Servicing/Repair)

8.1 Meter Servicing and Accuracy Testing

8.1.1 Introduction

Meter Servicing refers to the opening up and cleaning of the internal parts of a meter from dirt and silt particles resulting from inadequately treated water or dirt infiltration (through leak holes) due to pipe shut downs. These sediments build up on the internal parts of meters, especially mechanical meters wearing out bearings thereby increasing friction between moving parts. This then causes the meter to slow down and thus under-register consumption. Utilities must sustain the turbidity of the treated water below 2 NTU and regularly monitor water quality in addition to servicing mechanical meters to minimize sediment levels and promote accurate meter measurements.

Wearing out of meter moving parts occur over time depending on the quality of the meter. Accuracy testing a range of meter brands and ages will determine which meters should be replaced.

8.1.2 Procedure of Customer Meter servicing

Meter servicing and repair is a very delicate exercise that should only be handled by trained and experienced staff.

Proceed as follows:

a) Identify the stopped meters while at the office from the meter stopped report from the billing system
b) Trace and confirm the meter locations
c) Move to the ground
d) Confirm the meters serial numbers and the current readings
e) Close the water supply by the stop cork
f) Remove the installed meter
g) Clean the external of the meter
h) Break or remove the seal
i) Dismantle the meter into its basic components of the shell/case, (upper and lower part for propeller meter; and side-by-side shells for volumetric meter), the register, and the measuring chamber. A vice is necessary to hold the meter.

   Note: Do not hit the meter with pipe wrench to make it easy to dismantle. It will get damaged and its accuracy deteriorated.

   Instead, use custom-made spanners as shown below while holding the meter using a pipe wrench:

Figure 8.1: Custom-made spanner for Propeller Type Meters

Figure 8.2: Custom-made spanner for Volumetric Type Meters

j) Confirm that the threads on the inlet and outlet of the meter are in good condition to avoid leakage.
k) Confirm that the threads if any) between the two casings are in good condition also
l) Cleaning internal plastic parts: use soft cloth and some soap. Never use wire brush or the meter will be permanently damaged. Replace worn out or broken parts.
m) Cleaning internal metallic parts: use soft brush and some soap. Never use wire brush or the meter will be permanently damaged. Replace worn out or broken parts.
n) Cleaning external surface: use wire brush or sand-blast or bead-blast and finish with *Sand Paper P80* and finish with *Sand Paper 0 (zero)*. Spray paint for a good finish.

o) Reassemble the meter (for volumetric meter, ensure the narrower side of the piston is placed on the upper side while the wider side is on the lower side or the meter will over-register)
p) Finally test the accuracy of the serviced meter. If accuracy is not within acceptable limits, try replacing the working chamber and retest.
q) If accuracy is still not acceptable, then discard the meter.

Figure 8.3: Debris trapped meter strainer

r) Re-sealing the meter
s) Re-install back the meter.

8.1.3 Procedure of Customer Meter Testing Using Calibrated Bucket

Meer testing is usually done immediately after meter servicing, on customer request or as a normal routine (based on consumption category prioritization) to determine accuracy. The target is to reduce commercial losses by increasing billed amount and hopefully the collection amount as well.
The test is usually done on-site and has an error margin of +/-5% (instead of the initial threshold of +/-2%) at flow rates above transitional flow rate (Qt or Q2).

Proceed as follows:
a) Identify the stopped meters or prioritized meters while at the office from the meter stopped report from the billing system or from the 'meter reading & billing analysis'.
b) Trace and confirm the meter locations
c) Move to the ground
d) Confirm the meter serial numbers and the current readings
e) Close the water at stop cork ensuring complete stop of flow (
f) Record the initial reading of the meter Including the litres (red digits)
g) Place the empty 10 (or 20) litres calibrated bucket at the tap to make sure it captures every drop

h) Fully open the tap to measure the maximum flow and stop the water when the bucket fills to the 10 (or 20) litres mark.
i) Record the final meter reading at the end of the test including the litres (red digits)
j) Calculate the meter error as follows as a percentage of the volume of the bucket

$$\text{meter error (\%)} = \frac{\text{(Final reading – Initial reading) x 100\%}}{\text{Volume of bucket (eg. 10 (or 20 litres))}}$$

As earlier indicated, the permissible error margin is ±5%.

k) Repeat the test with the tap half open (assumed medium flow)
l) Repeat the test with the tap adjusted to achieve a low flow rate which is assumed to be the minimum flow rate.
m) NB: For a meter to be deemed accurate it should be within the permissible error margin in all the three tests conducted with the different flow rates.
n) The test can be repeated for confirmation purposes if need be.

Figure 8.4: Testing a meter using calibrated bucket and a portable test meter

8.2 Procedure of Customer Meter testing Using Meter Test Bench

8.2.1 Components of a Meter Test bench

a) Water Meter Test Bench - 1 set (see Figure 8.5)
b) Recording paper - 1 set
c) Stopwatch - 1 set
d) Water meters to be tested - 6 to 10 pieces
e) Tool and materials: - pipe wrenches for opening/closing, thread tape PTF, etc

Figure 8.5: Water Meter Test Bench (EMBU WSP procured model)

8.2.2 Confirmation of water meter specification (ISO-Class)

The two specifications of water meters are illustrated in Figure 8.6. They are ISO 4064-1993 (Old Standard), and JIS B 857-2013 / ISO 4064-2005 (New Standard)

On the two meters, the specifications are shown inside the red circle thus:

- Old standard: Q_n:1.5m^3/h, Class C-H, PN16 bar, 40°C; while
- New standard: Q_3=2.5 (m^3/h), R=100

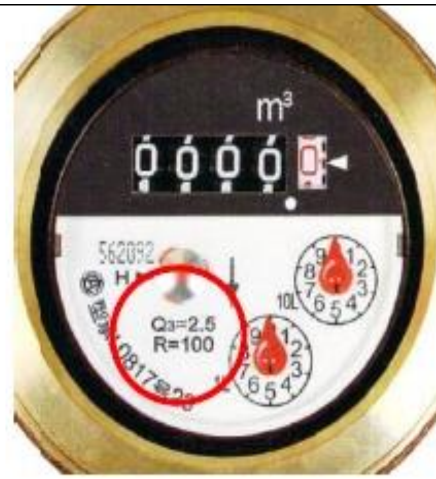
	
ISO 4064-1993 (Old Standard)	JIS B 857-2013 / ISO 4064-2005 (New Standard)
Type= Multi-jet dry-radial vane	Single-jet dry-radial vane
Class C-H (H=when installed horizontally)	R= Q_3/Q_1 =100
DN =15mm	DN=15mm
Q_n =1.5m³/hr	Q_3 = 2.5 m³/hr

Figure 8.6: Confirmation of water meter specification to be tested (ISO-Class)

For the old standard, Table 8.1 indicates the formulae to calculate Q_{min}, Q_t, and Q_{max}.

Table 8.1: Coefficients of small caliber meters (ISO 4064-1993) (Horizontally Installed)

Classes (ISO 4064-1993)	Meters of Q_n < 15m³/h (Small meters)
Class A	
Value of Q_{min}	0.04 x Q_n
Value of Q_t	0.1 x Q_n
Value of Q_{max}	2.0 x Q_n
Class B	
Value of Q_{min}	0.02 x Q_n
Value of Q_t	0.08 x Q_n
Value of Q_{max}	2.0 x Q_n
Class C	
Value of Q_{min}	0.01 x Q_n
Value of Q_t	0.015 x Q_n
Value of Q_{max}	2.0 x Q_n

Qn (m³/h)	DN (mm)
1.5	15
2.5	20

Values of Nominal Diameter (DN mm)

8.2.3 Conditions necessary to conduct meter testing with test bench

a) Temperature of water used: 20 ± 5 ℃
b) Water Quality:
   - The test water shall be tap water or equivalent water quality.
   - The water should not have objects (e.g. air bubbles, floating objects, etc.) that will adversely affect the meter operation.
c) Water pressure: A steady positive water pressure of at least 0.03 Mpa at the meter outlet should be ensured.
d) Ambient (weather) temperature range: 15 ℃ to 35 ℃
e) Range of peripheral relative humidity: 25 ° C to 75 ° C
f) Range of surrounding atmospheric pressure: 86 kPa to 75 kPa
g) The pressure loss of the water meter shall be within the operating conditions and shall not exceed 0.063 MPa (6.3 m = 0.63 kg/ cm^2) at rated maximum water flow.

8.2.4 Range of flow rate for meter testing

The accuracy of a meter is measurement at four flow rate points.

a) Rated minimum flow rate Q_{min}
b) Transitional flow rate Q_t
c) Nominal flow rate Q_n
d) Limiting flow rate Q_{max}

The four flow rates are obtained from Table 8.2 (as per ISO 4064-1993 Classification).

Table 8.2: Water meter classification to ISO 4064-1993 (flowrates in litres/hour)

Nominal dia, mm (inch)	**Q_n**	**Q_{max}**	**Class A**		**Class B**		**Class C**		**Class D**	
			Q_{min}	**Q_t**	**Q_{min}**	**Q_t**	**Q_{min}**	**Q_t**	**Q_{min}**	**Q_t**
15 (½") V	1,000	2,000	-	-	-	-	-	-	7.5	11.5
15 (½") H	1,500	3,000	60	150	30	120	15	22.5	11.25	17.25
20 (¾") H	2,500	5,000	100	250	50	200	25	37.5	18.75	28.75
25 (1") V	3,500	7,000	140	350	70	280	35	52.5	26.25	40.25
25 (1") H	6,000	12,000	240	600	120	480	60	90	-	-
32 (1¼) H	6,000	12,000	240	600	120	480	60	90	-	-
40 (1½) H	10,000	20,000	400	1000	200	800	100	150	-	-

Key

- V-Vertically installed (for volumetric meters only); H - Horizontally installed

In the latest standards (ISO 4064:2014 and OIML R49:2013), a new system based on the Reynard series has been established and the flowrates on Figure 8.7 are renamed as follows: $Q_{min} \rightarrow Q_1$, $Q_t \rightarrow Q_2$, $Q_n \rightarrow Q_3$, and $Q_{max} \rightarrow Q_4$. However, the values of Q_1 to Q_4 are not the same as Q_{min} to Q_{max} respectively.

The values of normal flow Q_3 and R ($R = Q_3/Q_1$) are written on the meter while the values of Q_2 and Q_4 are derived from the formulae:

$Q_2 = 1.6Q_1$

$Q_4 = 1.25Q_3$

8.2.5 Error specification for test flow rate (ISO-4064-2005)

At minimum 3 points calibration point, the test should be conducted in the following flow rate adjustment range (Figure 8.7).

a) First point = between Q_1 and $1.1Q_1$
b) Second point = between Q_2 and $1.1Q_2$
c) Third point = between $0.9Q_3$ and Q_3

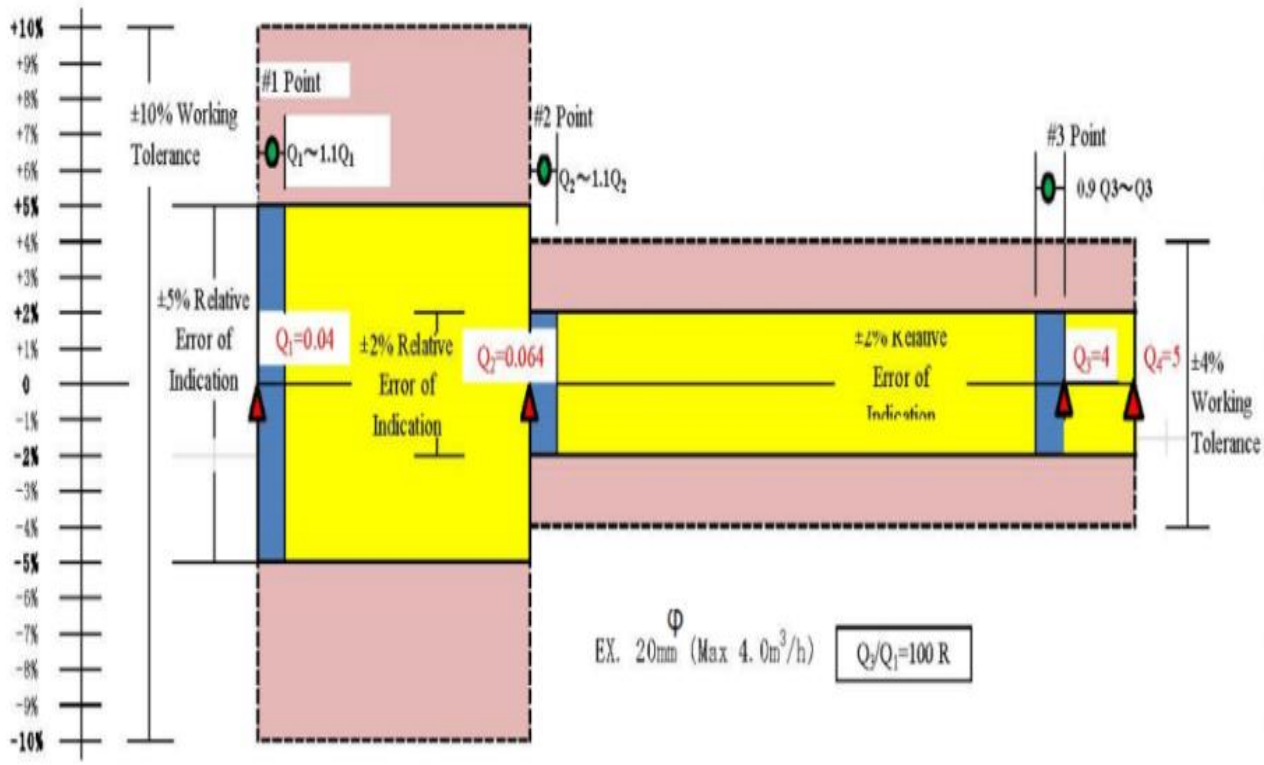


Figure 8.7: Concept of Detail Error Range of Test Flow

8.3 How to evaluate meter test result

8.3.1 Calculation method of equipment error ratio

Meter error indicates the ratio between the amount indicated by the meter and the actual amount of water.

$$\text{Relative Error of Indication (\%)} = \frac{I - Q}{Q} \times 100$$

I= Meter's Indication Q= Actual Volume

8.3.2 Acceptance criteria tolerance

The allowable range for judging acceptance or rejection of product inspection is shown in Table 8.3 and Figure 8.7.

a) It must be less than the test tolerance of each flow rate.
b) If only one flow rate exceeds the test tolerance, the test must be repeated three times, two times within the test tolerance, and the arithmetic mean of the three measurement results shall be within the test tolerance

Table 8.3: Example of Allowable Tolerance

JIS B 8570-2			
Test tolerance			Flow area
Rated minimum flow rate	Q_1 and above	±5%	Small flow rate range
Transitional flow rate	Below Q_2		
Nominal flow rate	Q_3 and above	±2% (Water temperature < 30 °C)	High flow rate range
Limiting flow rate (max.)	Below Q_4		

8.3.3 Data sheet

Table 8.4 is a sample of meter accuracy test measurement data sheet where all the parameters are set and regulated as recommended in the standard meter testing.
During On-Job Training different types of meters (old and new) were subjected to accuracy test on a test bench and the following the results obtained.

Table 8.4: Sample meter accuracy test measurement data sheet

Result of Joint OJT at EMBU

2017-June-22 @ EWASCO

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	Flow Rate: Qn (1500 l/h) Total flow vol = 200 lts					Comments ±4 % (in use)	Comments
							START	END	DIFRENCE		Error		
Volume used ; 200 lts=0.2 m3						0.2	R1 (m3)	R2 (m3)	R2-R1	%	100%		
1	Old	AC175298	PSM		15	3576.782	3576.782	3576.974	0.192	96%	-4%	Pass	
2	Customer	13081721	psm		15	2355.6125	2355.6125	2355.8089	0.1964	98%	-2%	Pass	
3	**New**	**15-05855**	**MJET**	**Kiambu WSP**	**15**	**0.4081**	**0.4081**	**0.6058**	**0.1977**	**99%**	**-1%**	**Pass**	**±2 % (New)**
4	Customer	7090712	psm		15	163.3051	163.3051	163.5014	0.1963	98%	-2%	Pass	
5	**New**	**15-05853**	**MJET**	**Kiambu WSP**	**15**	**0.3868**	**0.3868**	**0.5848**	**0.198**	**99%**	**-1%**	**Pass**	**±2 % (New)**
6	Above 1000	H570060	SJET		15	2779.702	2779.702	2779.891	0.189	94%	-6%	**Reject**	
7	Above 500	05-1059537	SJET		15	686.1175	686.1175	686.1175	0	0%	-100%	**Reject**	
8	In Service	8024018	psm		15	0.7072	0.7072	0.9016	0.1944	97%	-3%	Pass	

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	Flow Rate: Qt (120 l/h) Total flow vol= 50 lts					Comments ±10% (in use)	Comments
							START	END	DIFRENCE		Error		
Volume used: 50 lts= 0.05 m3						0.05	R2	R3	R3-R2	%	100%		
1	Old	AC175298	PSM		15	3576.974	3576.974	3576.975	0.001	2%	-98%	**Reject**	
2	Customer	13081721	psm		15	2355.8089	2355.8089	2355.8585	0.0496	99%	-1%	Pass	
3	**New**	**15-05855**	**MJET**	**Kiambu WSP**	**15**	**0.6058**	**0.6058**	**0.6562**	**0.0504**	**101%**	**1%**	**Pass**	**±5 % (New)**
4	Customer	7090712	psm		15	163.5014	163.5014	163.5525	0.0511	102%	2%	Pass	
5	**New**	**15-05853**	**MJET**	**Kiambu WSP**	**15**	**0.5848**	**0.5848**	**0.6355**	**0.0507**	**101%**	**1%**	**Pass**	**±5 % (New)**
6	Above 1000	H570060	SJET		15	2779.891	2779.891	2779.938	0.047	94%	-6%	Pass	
7	Above 500	05-1059537	SJET		15	686.1175	686.1175	686.11	-0.0075	??	??	**Reject**	
8	In Service	8024018	psm		15	0.9016	0.9016	0.9524	0.0508	102%	2%	Pass	

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	Flow Rate: Qmin (30 l/h) Total flow vol = 20 lts					Comments ±10% (in use)	Comments
							START	END	DIFRENCE		Error		
Volume used: 20 lts						0.02	R3	R4	R4-R3	%	100%		
1	Old	AC175298	PSM		15	3576.975	3576.975	3576.974	-0.001	??	??	**Reject**	
2	Customer	13081721	psm		15	2355.8585	2355.8585	2355.8585	0	0%	-100%	**Reject**	
3	**New**	**15-05855**	**MJET**	**Kiambu WSP**	15	**0.6562**	**0.6562**	**0.6756**	**0.0194**	**97%**	-3%	**Pass**	**±5% (New)**
4	Customer	7090712	psm		15	163.5525	163.5525	163.5716	0.0191	95%	-5%	Pass	
5	**New**	**15-05853**	**MJET**	**Kiambu WSP**	15	**0.6355**	**0.6355**	**0.6541**	**0.0186**	**93%**	-7%	Pass	**±5% (New)**
6	Above 1000	H570060	SJET		15	2779.938	2779.938	2779.958	0.02	100%	0%	Pass	
7	Above 500	05-1059537	SJET		15	686.11	686.11	686.11	0	0%	-100%	**Reject**	
8	In Service	8024018	psm		15	0.9524	0.9524	0.9718	0.0194	97%	-3%	Pass	

8.4 Procedure of Sealing Meters

8.4.1 General

Some customers do tamper with meters to reduce the volume of water going through the meter and therefore reduce the bill amount. Since tampering attracts penalties, customers devise various inconspicuous methods of tampering.
Some notorious customers even proceed to vandalize the meter so that it malfunctions to his advantage, or to stops its functioning altogether.

Meter Sealing refers to safeguarding or protecting a meter and the meter liners in such a way that any tampering with the meter and/or meter liners (especially the upstream liner) is easily detected with proof of the tampering being available as evidence.
This evidence can then be a basis to build a case against a customer and to come up with measures for compensation to the WSP.

Before sealing a customer meter, the water must be stopped. Four methods to close the water are:

a) Closing the stop cork upstream of the meter.
   This is not very effective due to often failure of stop corks to properly close, leaving a trickle of water.

b) Placing a plastic block washer between the meter and the upstream meter liner.
   This is the most popular method due to the ease and high efficiency of water closure. For large customer meters where block washers may not be available or practical, closure with water tight sluice gate or sluice valve is effective.

c) Closing water at the offtake point of the service line.
   This method is employed for customers who routinely tamper with meters. It can involve closing the water using a gate valve or ferrule (if using standard saddle clamp).

d) Uprooting the service line.
   This is an extreme method of closure for very notorious customers who reconnect even closures at offtakes. The WSP should consider carefully before employing this method of closure.

e) Automatic meter closure
   This is closure of water by remote method. It is only possible with smart meters since they can be remotely controlled from the office or pass-by.

8.4.2 Why Undertake Meter Sealing?

a) To secure a disconnection
b) To deter meter tampering during water supply service

c) Customer categorization (e.g. blue for large consumer or red for disconnected account, etc.).

8.4.3 Methods of Meter Sealing

There are two methods of sealing meters:

a) Using sealing wire, sealing lead and sealing pliers
This is the relatively cheap method.

b) Using serialized (or unserialized) plastic seals (these are still very new in the market)
The method is being preferred since it is:
- easy to clamp on the meter
- completely tamper-proof (once broken it cannot be reused hence the tamper evidence remains intact [and if serialized, the serial code can be traced])

8.4.4 Meter sealing Procedure Using Sealing Wire, Sealing Lead and Pliers

a) Insert the sealing wire through the holes on the meter liner that is upstream of the meter and then through the holes on the meter body and bring the two ends together.
b) Insert the sealing wire ends through the holes in the sealing lead.
c) Where a meter is being disconnected without taking it away, it is recommended to first close the stop cork/gate valve and then tightly tie the sealing wire around the handle of the stop cork/gate valve in such a way that it cannot be opened without breaking the wire, before passing both ends of the wire through the sealing lead. Confirm that the water is not flowing and the wire cannot be untied before the next step.
d) Press the sealing lead using a sealing pliers to ensure the sealing wire ends are firmly held and cannot become loose.
e) It is recommended that each sealing plier are engraves a unique number on sealing leads to identify the staff member who did the sealing.

Figure 8.8: Meter sealed by sealing wire and sealing lead

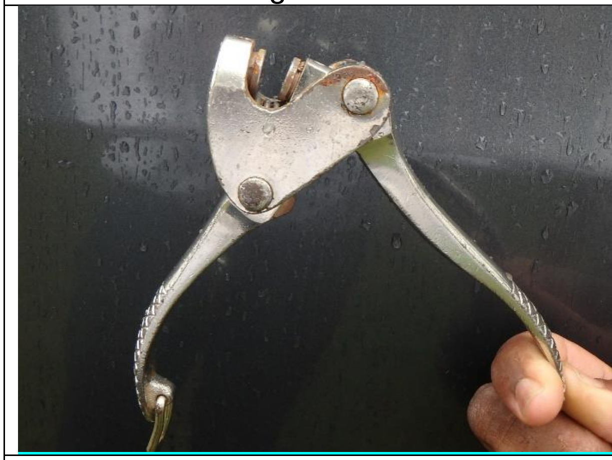


Figure 8.9: Sealing Pliers

Figure 8.10: Sealing lead stamped by Pliers No. MWS14

8.4.5 Meter Sealing Procedure Using Plastic Seals

A plastic seal comprises two halves of a rigid circular plastic band with flattened out ends (Figure 8.11). The flattened ends have either a hole or a knob. To seal a meter,

a) Place the two halves of the seal around the upstream union nut of the meter (one on top and the other underneath) with the hole of each half aligned to the knob of the other half.
b) Press the knobs against the holes and "snap" into the respective holes to clamp tightly onto the union.

Once clamped, they two halves cannot be separated without breaking. This ensures that the meter cannot be tampered with without leaving tamper evidence.

Note:

i) for more effective sealing, a second seal can be clamped on he downstream nut of the meter (Figure 8.12)
ii) the plastic seal can be engraved with a serial number for record purposes
iii) different color-coded plastic seals can be used to indicate different status of accounts, e.g.
  - disconnected account – e.g. red seal,
  - tamper suspect (under close monitoring) account – e.g. pink seal; or
  - certain consumer categories – e.g. large consumer – yellow.

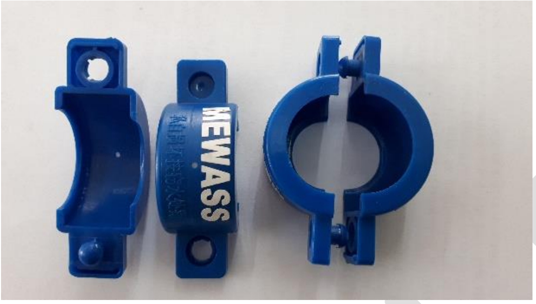


Figure 8.11: Plastic Seals	Figure 8.12: Meter Sealed Using Plastic Seals

8.5 Accuracy Testing of Bulk Meters

8.5.1 General

Testing of bulk meters for accuracy is an elaborate procedure only achievable by an accredited organization such as KEBS.

Fortunately, some WSPs such as Nyeri WSP is already accredited for meter testing and has been assisting WSPs in this regard.
Nevertheless, it is possible to conduct a rough check on the accuracy of a bulk meter using a UFM as below:

8.5.2 Rough Accuracy Testing of Bulk Meters

The procedure involves setting up the UFM on the same pipe and next to the bulk meter as detailed in Section 5.3. The flow through the pipe is then measured simultaneously using the UFM and the bulk meter. The two flows are then compared to determine the error level.

8.5.3 Testing Accuracy of Bulk Meters Using UFM

a) Introduction

Accuracy of bulk meters is important since the measured volumes are used to calculate the water balance. Their accuracy is usually tested using ultrasonic flow meter instead of installing a test meter in series thereby eliminating the need to cut the pipe.

b) Procedure of Bulk Meter Accuracy Testing

i) Ensure a timer (watch or stop watch) is available to time the bulk meter flow
ii) Ensure the bulk meter to be tested is easily accessible for reading
iii) Expose enough clear length of the pipe (away from pipe fittings) near the meter to accommodate the ultrasonic meter sensor spacing (from the manual)
iv) Mount the ultrasonic sensors on the pipe (at least 10 times pipe diameter from any fitting/bend/valve/etc.) and input the parameters required by the ultrasonic meter for logging (on start the ultrasonic meter) (refer to manual)
v) Start the ultrasonic meter. It will be logging the flow at the time intervals set and with the option of totalizing the flow volume
vi) Simultaneously note (and record) the bulk and ultrasonic meter readings and the time. Note the readings again after a time interval, say 1, 5, or 10 minutes. (full reading in litres should be taken)
vii) Compare the flow volume of the bulk meter to that of UFM (Note: the UFM can directly print the data or the logged data can be downloaded later depending on the model) (the difference should be within acceptable limits)

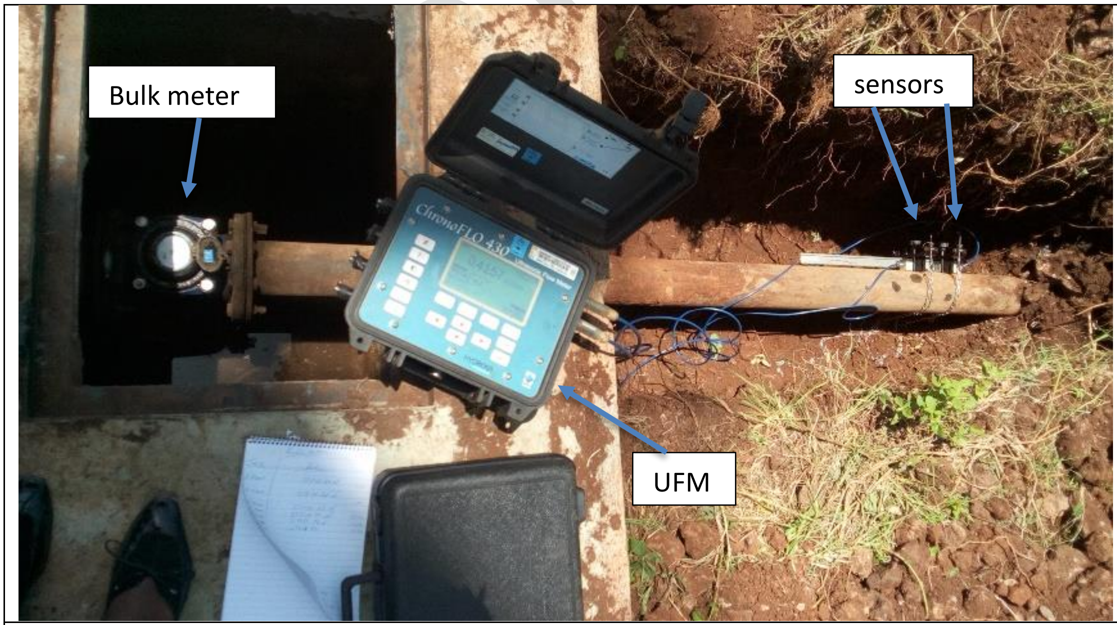


Figure 8.13: Bulk meter accuracy test using UFM

8.5.4 Accuracy Test of Zonal Bulk Meter with Air Intrusion

The zonal bulk meters installed at the outlets of distribution reservoirs are often affected by air intrusion especially under intermittent (rationing) water supply conditions. This air intrusion may cause significant over-estimation of flow (meaning that the meter reading may indicate higher flow than the actual flow). Air normally enters the bulk meter when the water level in the distribution reservoir is close to the bottom. When the trunk and branch distribution mains have no water they are full of air. If the air valves on the trunk and distribution mains are not working well, this air normally comes up backwards through the bulk meter when the trunk and branch distribution mains are getting filled. This air affects the accuracy of the bulk meters.

It is difficult to check the accuracy (with a potable UFM) of a bulk meter that is in a system with air intrusion because UFM (or electromagnetic flow meter) has the tendency to under-register (measure less) flow when there is air in the pipe. Furthermore,

- There may not be enough space to set the UFM in the bulk meter chamber ,or
- Exposing the pipe outside the meter chamber may be very difficult due to pipe size and/or depth.

Therefore, alternative methods to deal with air intrusion and/or check the accuracy of bulk meters with air intrusion are quite important. This is so especially when the affected zonal bulk meters are:

- Used for calculating the universal NRW ratio, and/or
- Used as the basis for paying for bulk supply.

The following are alternative methods of dealing with air intrusion or checking the accuracy of bulk meters with air intrusion:

a) Measuring the Water Level of Distribution Reservoir

If the reservoir does not have a water level gauge, a long fabricated ruler (or measuring tape attached to a straight bar) can be fixed to the side of a ladder into the reservoir from the access manhole on the roof. Thereafter,

- Close the inlet pipe to the reservoir,
- Measure the drawdown of the water level (volume of water discharged from the reservoir during a certain period, e.g. 30 mins
- Compare this with the flow measured by the bulk meter.

For accurate synchronization of the bulk meter readings and the water level measurements at the beginning and the end of a certain period, take a video of the bulk meter and the take using a Timestamp Camera (a free smartphone software). Of course ensure staff safety inside a reservoir.

b) Bulk Meter Relocation to a Depressed Part of the Trunk Distribution Main

If the accuracy of a bulk meter with air intrusion cannot be ascertained or is unacceptable, it may be relocated to the first depressed part of the trunk main (e.g. just

before the first washout) where the pipe will always be full of water. If the first depressed part is not possible, consider the second and then the third.
Trunk distribution mains are often metallic pipes of large diameter hence difficult to modify for the meter relocation. In such cases, a battery-powered insertion electromagnetic flow meter or a fixed installation clamp-on UFM may be a solution although these meters have a risk of stopping if their battery is not replaced on time.

c) Valve Control

If there is a gate valve or flow control valve just after (downstream of) the bulk meter with air intrusion, the valve may be closed to a certain degree when the reservoir water level is low (or when the trunk distribution main is not filled with water) so that water fills the section with the bulk meter without air coming in. However, this valve operation may be difficult to sustain manually and may make distribution of water difficult for some hours.

8.5.5 Use of Free Software as a substitute for potable UFM

A potable UFM is an effective equipment for NRW reduction. However, it is expensive compare to listening sticks that are the most cost-effective for NRW reduction. The following methods can be used as arrangements are made to procurement UFM.

- A “Timestamp Camera Free” can be installed on a smartphone (from Play Store) and used to take a video of the bulk meter dials and the reading vs time data used to calculate the flow rate of each time interval (e.g. every 30 seconds).
- A free software called GOM Player can be installed in a PC and a preferred video player play-back skip interval set to read the bulk meter. The data can then be used to analyse the change in flow rate over time. This technique can be used for minimum night flow measurement, step test and for checking the flow rate of bulk meter during high water demand hours to ascertain the adequacy of the meter size (by comparing measured flow rate to Qmax or Q4 of the bulk meter). The technique can also be used even after procuring a UFM, especially where it is difficult to install a potable UFM due to depth of buried pipe and/or inadequate space in the meter chamber.

  When conducting MNF measurement and step testing on a distribution network with many inlet and/or outlet bulk meters, videos of the bulk meters can be taken simultaneously with multiple smartphones instead of borrowing several potable UFMs.
  However, reading bulk meter dials as accurately as possible (between the lines) at a certain interval on video requires skills and patience. If a UFM does not have data logging function (or the software for data logging is not available at hand), a Timestamp Camera and GOM Player can be used to take a continuous video of the active screen of a UFM to manually create a flow rate change graph over time from the video.