Technical Guidelines
for
Water Meter (Management)
in Kenya

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Foreword

Water meters constitute a significant input in the normal operations of water utilities. The meter bridges the gap between the demand for water (consumers) and the supply of the service (water utility). It is the sole determinant of the volume supplied to the consumer. To the utilities, it is the sole determinant of the bill should be levied against the consumed volume. The challenge of Non-Revenue Water (commonly referred to as Unaccounted for Water) emanates in part from inaccurate meters that do not register the actual volumes supplied to an area (to establish a water balance), to the consumer (for proper billing) and –subsequently- the efficient/effective management of available (often scarce) water resources.

It is for this reason that the Water Services Providers Association (WASPA), as the umbrella body of water utilities, resolved to ameliorate the existing meter management procedures for the Kenyan market. Through an intensive consultative process, the initiative sought to identify and build on existing meter management practices, establish the underlying challenges and -subsequently- and establish these technical guidelines for water meter management - informed by international standards and leading practices of Kenyan water utilities.

We envision that with the established water meter guidelines, suppliers will be challenged to deliver high quality products to the market. In turn, utilities will be better equipped to procure the high quality meters they require. More so, the guidelines will assist them in making effective use of them - by providing guidelines for the selection (sizing), installation, calibration, servicing and replacement within the context of a wider asset management agenda. The guidelines are meant to form the basis upon which the Kenya Water Service Providers (WSPs) can develop and customize their utility specific meter management policies and procedures.

It is important to bear in mind that the guidelines are important to all stakeholders, particularly the Water Service Providers. The Kenyan government through technical departments in the Ministry of Water and Irrigation, Weights and Measures as well as the Kenya Bureau of Standards have attested and contributed enormously to this final product. This should serve as a quality assurance to the consumers and the general public as to the specific intent to improve the reliability of water meters in use moving forward.

The Water Services Providers Association is committed to quality and will continue providing support towards these and other noble initiatives aimed at increasing the effectiveness and efficiency of water, sewerage and sanitation service delivery in Kenya.

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Chairman

Water Services Providers Association

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- Water Services Regulatory Board

Abbreviations

DMA - District Metered Area

IWA - International Water Association

KEBS - Kenya Bureau of Standards

KENAS - Kenya National Accreditation Service

KEWI - Kenya Water Institute

MPE - Maximum Permissible Error

NRW - Non Revenue Water

PE - Public Entity

PPOA - Public Procurement Oversight Authority

Specs - Specifications

TOR - Terms of Reference

UFM - Ultrasonic Flow Meter

WASPA - Water Services Providers Association

WASREB - Water Services Regulatory Board

WSP - Water Service Provider

1 Introduction

Non-Revenue Water (NRW), being one of the main performance indicators for water utilities, has been only reduced marginally from *47 %* in 2008/2009 to *44 %* in 2011/12. At this pace, the national target of *30 %* set in the National Water Services Strategy (NWSS 2007-2015) will not be achieved [1]. "Despite the positive trend, NRW levels remain unacceptably high despite the increase in sector investment over the years. The total amount of money lost in 2012/13 has been estimated at a staggering *KSh 11.4 billion*" [2].

While good progress has been made with regard to access to safe and clean drinking water, sanitation and sewerage in Kenya, the goal of reducing NRW to *30 %* is still lagging behind.

Reducing NRW to the sector benchmark of *20 %* should be the number one priority for Water Service Providers (WSPs) to decrease drinking water wastage, increase revenue, extend coverage, and ultimately ensure a more efficient provision of water to consumers. The diagram (see Figure 1) below highlights meter inaccuracies as one of two key components of apparent (commercial) losses in the International Water Association's (IWA) water/NRW balance.

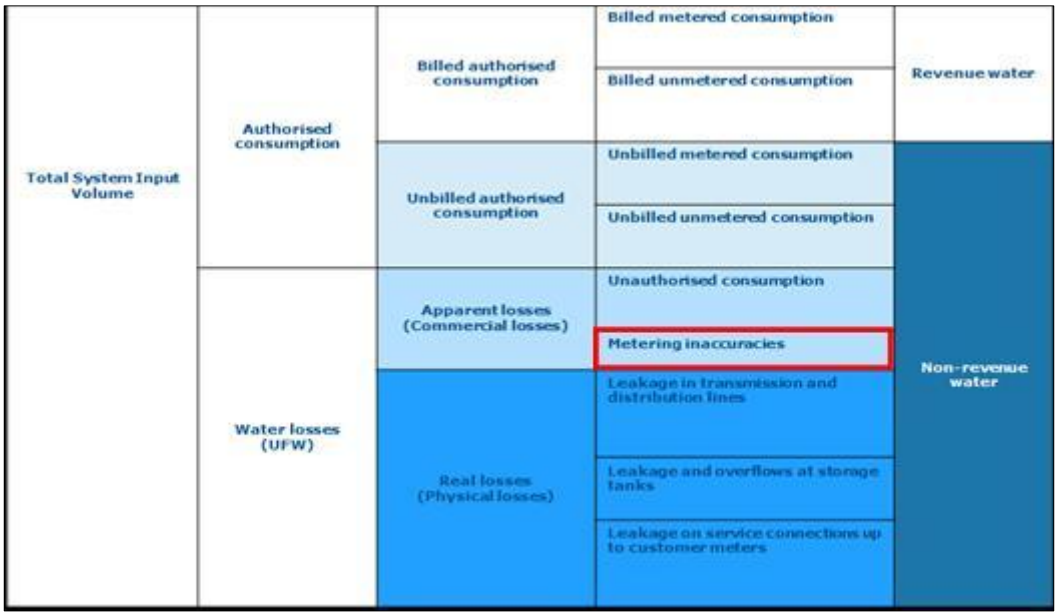

Figure 1: IWA's water/NRW balance (IWA NRW balance calculation model)

Reliable metering forms the backbone of a sound NRW management strategy/plan. It is the basis, after all, for water balance calculations at a utility level (to establish the baseline), at District Metered Area (DMA) level (subdivision in zones to prioritize geographic areas of focus) and at customer level (where a consumer should be charged on the basis of what they actually consume). The recently completed benchmarking exercise[1] underlines the need for WSPs to

[1] Revealing that: a) more than *5%* of all meters run static for 9 (*33%*) out of 27 WSPs at any given time, b) only 3 WSPs test more than *5%* of their meters annually, and c) 11 WSPs replacing more than *10%* of the meters they did test (for more details see Annex A).

prioritize their meter management agenda. In response, this Technical Guideline for Water Meter (Management) in Kenya intended for WSPs has been developed.

The Guideline is in line with the National Water Service Strategy (2007-2015), p. 18 [3], which states that, the "missing standardization of water equipment has resulted in a multiplicity of technologies which is not only a disincentive for private sector involvement but also a reason for lengthening break down times".

The Technical Guideline comprises recommendations for the procurement process, the selection of water meters, the establishment of technical specifications, and the installation, management and maintenance of water meters.

The Guideline is based on a thorough investigation of the current situation through questionnaires (filled in by *25%* of WASPA's member WSPs), interviews with stakeholders, and reviews of relevant documents and best available practices in the local and international market. The Guideline is envisaged to support and guide the WSPs through each step with regard to procurement, installation and maintenance of large and small diameter meters in the provision of water services.

To ensure that the Guideline is –increasingly- used in practice, it has been developed with contributions from the Kenya Water Institute (KEWI), enabling the Guideline to be used as a vital ingredient in KEWI's popular 'Meter Reading' course[2].

We recommend a regular update (every two years) of this Guideline based on emerging evidence from the field i.e. changes in types of water meters used and/or common practices with regard to procurement, selection, installation and maintenance of water meters. Updating of the Guideline should automatically result in vocational training of water utility personnel.

2 Recommendations for a Generic Procurement Process

As each WSP has established its own procurement process based on their specific requirements and experience, recommendations for further improvements are given instead of suggesting a 'one fits all solution'. These recommendations are based on the Kenyan Public Procurement and Disposal Act (2005), its subsidiary legislation entitled Public Procurement and Disposal Regulations (2006), and the ISO standard 10845-1:2010 – Construction Procurement – Processes, methods and procedures, which aims at establishing a procurement process being fair, equitable, transparent, competitive and cost effective.

The Public Procurement and Disposal Act and its subsidiary legislation, provide a legal framework for regulating public procurement. To ease its implementation, a Public Procurement and Disposal General Manual and a User Guide have been established. Both, the Act and Regulation apply to "Procurement by a Public Entity (PE)" which incorporates the procurement of water meters by WSPs. WSPs are classified as "Class B" PEs. PEs must carry out their procurement and disposal activities in accordance with the Public Procurement Oversight Authority (PPOA), the Regulations, Standard Tendering Documents (available on www.ppoa.go.ke), Manuals and any directions of the PPOA [4].

[2] Labeled as an 'operator course' on the website; a (separate) course focusing on plumbers and supervisory staff will need to cover all aspects of meter management.

This includes the basic procurement process, consisting of 17 steps and to be followed by all PEs, shown in Table 1. The main roles and responsibilities are taken over by the user department, accounting officer, tender committee, procurement unit, and evaluation committee.

Table 1: Roles and responsibilities in the procurement cycle [4]

	Steps	Roles & Responsibilities
Step 1	Procurement Plan & Budget	User Department, Procurement Unit & Boards/Councils
Step 2	Procurement Requisition Filled with clear Specs/TOR	User Department
Step 3	Confirmation of Availability of Funds	Accounting Officer
Step 4	Review of Specifications/TOR, Procurement Method, Evaluation Criteria, Potential Supply Market	User Department & Procurement Unit
Step 5	Procurement Method Approval	Tender Committee
Step 6	Preparation of Tendering Documents	Procurement Unit
Step 7	Approval of Tendering Documents	Tender Committee
Step 8	Advertisement & Invitation for Tender	Procurement Unit
Step 9	Receipt & Opening of Tenders	Tender Opening Committee
Step 10	Evaluation of Tenders (testing of provided samples)	Evaluation Committee and Testing facility (KEBS or Ministry of East Africa Affairs, Commerce and Tourism)
Step 11	Review of Evaluation Report (Approval or Rejection)	Tender Committee
Step 12	Award of Contract	Tender Committee
Step 13	Communicate Award	Accounting Officer
Step 14	Review	PPARB (optional)
Step 15	Sign Contract	Accounting Officer
Step 16	Contract Monitoring	User Department & Procurement Unit
Step 17	Contract Performance Evaluation	User Department & Procurement Unit

For those steps associated with shortcomings identified during our investigations, recommendations are given in 2.1 to 2.6. More detailed information on each of the steps and the main roles & responsibilities can be found in the “User Guide to The Public Procurement and Disposal Act, 2005” [4].

2.1 Step 1: Procurement Plan and Budget

As the first step, a procurement plan and budget should be established by the general management, namely the User Department, Procurement Unit & Boards/Councils, of the WSP [4]. The procurement plan is the overall framework directing the procurement process within a WSP. It should state that procurement of water meters is not only in the responsibility of the procurement department, but that also the technical department, favourably representatives of the water meter management team (see Chapter 6.2), should be strongly involved. Hence, the technical department should play an important part in the technical evaluation of the tender document (see Chapter 2.5). Furthermore, representatives of the technical department should choose and visually inspect a random batch of water meters to be tested prior to accepting the consignment (see Chapter 2.6).

Additionally, it is recommended that the procurement plan emphasizes the following points:

- 2-3% (of the ordered number) spare meters applicable as 'meter repair kits' should be ordered additionally.
- Furthermore, 2-3% (of all kinds of water meters already installed) spare meters applicable as 'meter repair kits' should be ordered. This requires separate tenders as different suppliers offer different products.
- Additionally, frequently used spare parts such as strainers and valves should be procured in stock.
- Each product should be tendered out separately. This applies to different kinds of products such as water meters and pipes but also to different types and models of water meters.
- It is recommended for WSPs to procure water meters once per year in bulk. Delivery and payment should take place on actual demand. Procurement once per year facilitates following a thorough procurement process. Furthermore, bulk purchases might be more cost efficient.

2.2 Step 2: Procurement Requisition Filled with clear Specs/TOR

Step 2, the Procurement Requisition Filled with clear Specs/TOR, is the preparation of procurement documents. Its most important part, the establishment of technical specifications, is elaborated on in detail in Chapter 4.

2.3 Step 4: Procurement Method

Within Step 4, a Procurement Method has to be chosen. There are seven different methods of procurement. Several factors such as the estimated value of goods and the urgency of the requirement determine which method to use. As the most frequently used methods identified in Kenya are either Open Tendering or Request for Quotations, these are explained in detail.

Open Tendering applies to both local and international tenders and is the preferred method of procurement. With regard to water meters (goods) and WSPs (Class B PE), the thresholds for national and international open tenders are comprised in Table 2.

Table 2: Thresholds for procurement of goods [4]

	Class B Procuring Entity	
	Maximum Expenditure (KSh)	**Minimum Expenditure (KSh)**
International Open Tenders	Determined by funds allocated in the budget	No minimum
National Open Tenders	Determined by funds allocated in the budget	4,000,000

Request for Quotations, an alternative method of procurement other than Open Tendering, can be used for the purchase of water meters by WSPs if:

- The procurement is for goods which are readily available and for which there is an established market; and
- The estimated value of the goods being procured is less than or equal to *1,000,000 KSh.*

2.4 Step 8: Advertisement & Invitation for Tender

Additional to the Procurement Method, a procurement procedure should be established when advertising and inviting for tenders. Based on our findings, we recommend the “Proposal procedure using the two-envelope system”. Tenderers should submit technical and financial proposals in two envelopes. The financial proposal is only opened should the technical proposal be found to be acceptable by the technical evaluation team only [5].

2.5 Step 10: Evaluation of Tenders

This is the process by which the best evaluated tender is selected for award of contract by the Evaluation Committee. One option is to appoint two separate committees, a Technical Evaluation Committee and a Financial Evaluation Committee whereas the Technical Evaluation Committee takes over the technical evaluation of the tender. Another option is to appoint Evaluation Committee members who possess sufficient competencies in technical requirements of water meters or to co-opt water meter experts for the specific evaluation of water meter tenders. In both cases, the vote of the technical representatives might either be the ones deciding on the sufficiency of technical aspects or, taking over an advisory role, they inform the other members on the most important factors to consider. The technical evaluation shall be done within 30 days after the opening of the tenders and the financial evaluation shall be done within 5 days after completion of the technical evaluation [4].

A preliminary evaluation is undertaken soon after opening the tenders to ascertain that the tender has been submitted in the correct format, has been signed by the authorized person, and that the correct number of copies, validity and any required samples have been provided. Any tender that does not meet the requirements is rejected [4].

For tenders that pass the preliminary evaluation, a technical evaluation is conducted which precedes the financial one. If the tender does not meet the technical requirements, it is not responsive and does not proceed to the financial evaluation [4]. It is recommended that at least two representatives evaluate each proposal independently and that a 2 stage approach is followed:

I. Primary technical evaluation criteria should at minimum incorporate the following, but a more detailed evaluation applying the form in Annex B is recommended. All tenders which do not meet the minimum quality requirements shall be rejected. This can be based on a ranking of all tenders applying a scale ranging from 1 to 5, with 5 indicating the best and 1 the worst quality.

a) Sufficiency of certificates as stated in technical requirements (see Chapter 4.1)
b) Correct type, class, sizing, and material as stated in technical requirements (see Chapter 4.2)

Based on this primary technical evaluation, the acceptable manufacturers should be shortlisted.

II. After short listing the most suitable tender offers, the short listed manufacturers should provide a sample of two meters to be tested regarding accuracy and pressure during the evaluation stage of the tender. **This needs to be clearly specified, up-front, in the tender documents.** The two meters should be tested by either, the Kenyan Bureau

of Standards, the Ministry of East Africa Affairs, Commerce and Tourism[3] (Department of Weights and Measures) or another accredited testing facility in Kenya (see Annex C). The costs for these meters and the testing have to be taken over by the manufacturer. In case one of the two meters fails the test, the specific tender shall be rejected.

The subsequent financial evaluation should also be based on a ranking applying a scale from 1 to 5. 5 indicates the best, the lowest price, and 1 the highest price. It is important that the chosen scale is identical to the one applied during the technical evaluation.

If the tender has not been rejected during the technical evaluation, the total tender evaluation points for each tender can be calculated. Subsequently, tenders can be ranked from the highest number to the lowest. The tenderer with the highest number of tender evaluation points should be recommended for the award of the contract, unless there are compelling and justifiable reasons not to do so [5].

If financial tenders appear to be abnormally low, those tenders may be rejected on the grounds that these present an unacceptable commercial risk. However, before doing so, the WSP shall request, in writing, details of the constituent elements of the tender which it considers critical [5].

2.6 Inspection and Acceptance of the Goods

Before authorizing payments, a random batch of 5% in every 100 meters should be selected by a representative of the WSP's technical department. Primarily, the person in charge should check whether the 5% randomly selected meters comply with the corresponding technical specifications through visual inspection. If they comply, the meters shall be tested by either the Kenyan Bureau of Standards, the Ministry of East Africa Affairs, Commerce and Tourism [4] (Department of Weights and Measures) or another accredited testing facility in Kenya (see Annex C).

A batch can be considered as failed if one or more meters do not comply with the established technical specifications or have failed the test by an accredited facility. Under these circumstances, the specific 100 meters have to be rejected. The costs for testing should be taken over by the manufacturer. Furthermore, the manufacturer has also to bear the costs for replacement if rejected.

3 Selection of Water Meters

3.1 Introduction to Water Meters

Since there are four main types of water meters used in Kenya, namely displacement, velocity, ultrasonic, and electromagnetic meters, only these are described in more detail in Table 3 overleaf.

Three different types of multijet meters are available on the market, dry dial, wet dial, and semi dry dial water meters [6]:

[3] As soon as sufficient capacity is established.

[4] As soon as sufficient capacity is established.

- The dry dial water meter has a reading mechanism hermetically separated from the water flow chamber. In this case the transmission to the reading mechanism gears takes place via magnetic coupling between the turbine and the reading mechanism itself.
- The wet dial water meters has the reading mechanism completely immersed in the water and the transmission is direct from the turbine to the gears of the mechanism itself. Hence, suspended particles within the water can block the reading mechanism and the probability of water related problems such as algae growth is higher.
- The semi dry dial water meter has the reading mechanism completely immersed in the water but the dial is partially separated from it remaining dry and the rollers are protected in a sealed capsule. The transmission from the turbine to the gears of the reading mechanism is direct.

Meters can be upgraded through incorporating a device onto the existing meter to make it 'smart enabled', allowing automatic meter reading. The device, a data communication module, can be data loggers that record pulses emitted from the meter. Collecting pulses from water meters can be done by connecting the input cable from a data logger into the pulse-output terminals on compatible meters, or using an optimal pickup on electric meters that do not have pulse terminals.

Communicating with smart meters can be done using almost any kind of communication protocol, but is predominantly using the GSM/GPRS mobile phone network. At the utility, a suitable information technology software has to compile and analyze the smart meter network information and integrate it into the utility applications, such as billing.[5]

[5] http://www.smsmetering.co.uk/smart-meters-overview/.

Table 3: Description of Water Meters used in Kenya

Meter Type	Description	Applicable under the following conditions
Displacement Meter	Displacement water meters rely on the water to physically displace the moving measuring element in direct proportion to the amount of water that passes through the meter. The piston or disk moves a magnet that drives the register. There are two main types of displacement meters: nutating disc and oscillating piston (rotary piston) [6].	○ Displacement water meters are suitable for low to medium water flow rates with diameters typically ranging from 13 to 50 mm [6]. They tend to be more accurate than velocity meters at low flow rates. ○ Due to its inner structure, displacement meters are sensitive to turbid water. Hence, an external strainer needs to be installed upstream when metering water with considerable amount of suspended particles [7]. The additional external strainer and the often in-built sieve/strainer have to be regularly cleaned. ○ In case of high possibility for meter air flow, displacement meters have shown to be less sensitive.
Velocity Meter	A velocity meter measures the velocity of the flow through a meter of a known internal capacity. In order to determine the actual consumption, the speed of flow is converted into flow volume. Two main types of velocity meters are used in Kenya: singlejet meter and multijet meters. ○ Singlejet meters incorporate a single tangential jet. ○ In a multijet meter, a tangential opening in the chamber directs the water flow across a multi-vaned rotor. The output speed of the rotor is proportional to the quantity of water passing through the measuring chamber. The meter works mechanically much like a singlejet meter except that the flow at the rotor is directed equally from several points, not just one; this minimizes uneven wear on the rotor and its shaft.	○ The singlejet meter is applicable for small flow rates (diameters typically range from 15 to 50 mm) [6]. ○ The multijet water meter is suitable for small and medium flow rates (diameters typically range from 15 to 150 mm) [6]. ○ When metering water with considerable amount of suspended particles, velocity meters tend to be less prone to clogging compared to displacement meters. This results in less additional effort for servicing. If the specific turbidity level is very high, an additional external strainer should be installed as well. Both, the external strainer and the often in-built sieve/strainer have to be cleaned regularly.
Ultrasonic Meter	Ultrasonic Flow Meters (UFMs) use sound waves to determine the velocity of a fluid flowing in a pipe[6].	○ Since no moving parts are incorporated, waste water and water with larger concentrations of suspended particles can be metered accurately.

[6] http://www.flowmeters.com/ultrasonic-for-corrosives.

Meter Type	Description	Applicable under the following conditions
		○ UFMs are mainly used for measurement of bulk flows (diameters typically range from 15 to 1,800 mm) and commonly used as 'clamp-on' meters to calibrate large diameter velocity meters. UFMs are typically supplied with a transducer that can be used in a range from 75 to 1,800 mm. By procuring a second transducer (smaller), the UFM can be used in a range of 15 to 75 mm [6].
Electro-magnetic Meter	An electromagnetic meter measures the flow rate of water by its electromagnetic properties instead of measuring it mechanically. The installation configuration should be such, that the transmission main is filled with water at all times (e.g. through installed non return valves).	○ Since no moving parts are incorporated, waste water and water even with high amount of suspended particles can be metered accurately. ○ Electromagnetic water meters are more sensitive to low flows. ○ Its usual diameter ranges from 2 to 1,800mm [6].

3.2 Recommendations for Selection

Since volumetric and velocity meters are most commonly used in Kenya, this section focuses on these two types of consumer water meters only. Subject to changing preferences in the sector and/or technological developments, we recommend a regular update of this section.

3.2.1 General Considerations

Of most importance is to only purchase new water meters. No reused or recycled meters as well as spare parts shall be bought. Furthermore, it is recommended to focus on easily disassembled/reassembled meters.

Additionally, in the standard ISO 4064-5:2014, it is stated that the type, metrological characteristics, and sizes of water meters should be determined according to the operating conditions of the installation and the environmental class(es) demanded. The following aspects are of particular relevance [7]:

- the available supply pressure. As the recommended pressure of 3 bars is not achieved everywhere, the specific prevailing pressure should be considered;
- the physical and chemical characteristics of the water, including water temperature and water quality;
- the acceptable pressure loss across the meter;
- the expected flow rates Q1 and Q3 of the meter shall be compatible with the expected flow rate conditions of the installations, including the water flow direction(s);
- the suitability of the meter type for the intended mechanical, climatic, electrical, and hydraulic conditions, including ambient relative humidity, vibrations, electrostatic discharges, continuous magnetic field, and electromagnetic disturbances;
- the available space and pipe work to install the meter and fittings;
- the possibility of deposition of substances from solution within the meter;

3.2.2 Type

Although it is stated in literature (see Chapter 3.2.1), that the selection of water meters should be based on several characteristics, we recommend for the sake of practicality to focus on the specific water quality and estimated flow rate to begin with.

The flow rate can be estimated based on the water demand measured in the past, or in case of new connections, the expected consumption. The expected consumption Q can be calculated with $Q=n*q$, with n the number of expected users and q the average amount of water consumed per capita and day in Kenya (assumption: $q=100$ *l/day* if connected to a water supply network). For large diameter consumer meters (big consumers including industries, institutions and hotels) this may require the WSP to measure the varying flow rates using a clamp-on UFM.

The water quality (i.e. suspended particles) depends on the water treatment efficiency (turbidity levels of the treated water), the continuity and velocity of supply (affecting the sedimentation process), the presence of wash outs (in case lines are flushed following repairs), the height of water meter installation, the location in the network (end-of pipe or not) and the pipe material/age/quality. In order to increase the reliability of this assumption, water quality samples may be taken and analyzed for suspended particles concentration.

For lower flow rates it is recommended to use displacement (rotating piston) meters, as velocity meters tend to be less accurate at lower flow rates. Furthermore, velocity meters have shown

to be more sensitive to meter air flow. This in turn is related to the continuity of supply and the presence of air release valves.

Nevertheless, if the metered water has a high turbidity level, velocity meters may be recommended, as experience shows that displacement meters clog more easily. In case displacement meters are preferred by the WSP, an additional external strainer should be installed before the meter (complementing the often in-built sieve/strainer). Both, displacement meters and additional external strainers have to be regularly cleaned and maintained depending on the water quality (see Chapter 7). In case velocity meters are chosen and additional external strainers are installed, both, meter and external strainer should be cleaned regularly as well. As velocity meters are less sensitive to clogging compared to displacement meters, the cleaning frequency is less considering the same water quality. Nevertheless, cleaning is of importance as a clogged external strainer upstream leads to a lower water flow rate (particularly when pressure levels are low). This in turn may influence the metering accuracy as velocity meters tend to be less accurate at lower flow rates.

When choosing the most suitable type, one must outweigh from case to case the additional effort for servicing displacement meters with the higher tendency of velocity meters to be more inaccurate.

3.2.3 Class

Based on ISO 4064:2005 and OMIL R49:2003, water meters can be divided into four classes: A, B, C and D. Each one sets a range of flow rates within which the meter must maintain its accuracy. A is the narrowest, D is the widest. Each meter can be considered perfect in the range of flow rates for which it has been designed.[7] However, in the latest standards, ISO 4064:2014 and OIML R49:2013, a new system based on the Reynard series has been established. The so called precision class of a water meter, R, is determined by the ratio between its permanent flow (Q3) and its minimum flow rate (Q1).

In general, the relationship between the previous Class A, B, C, and D is as indicated in Table 4. However, a definitive relationship one-for-one between meters classified under the earlier class system and those classified under the later standards is not possible.

As all the interviewed WSPs apply Class C water meters and water meter experts recommend Class B&C under prevailing circumstances, Class B&C is recommended for Kenya.

Table 4: Classes of Water Meters[8]

Class	New Classification	Description
Class A&B	R160	Applicability: narrow range of flow rates (e.g. irrigation).
Class C	R200	Most popular since it can cover conventional flow rate ranges.
Class D	R250	Applicability: wide range of flow rates

[7] http://kwlog.com/index.asp?LG=GB&P=Metrology.

[8] http://kwlog.com/index.asp?LG=GB&P=Metrology.

3.2.4 Sizing

Regarding the sizing of water meters for domestic consumers, it is recommended that meter diameter and the pipe diameter at which the meter will be installed should be of the same size [8]. In Kenya, the recommended meter size shall be of DN *15 mm*, length *165 mm* preferred (*115* or *134 mm* alternative) and DN *20 mm*[9], length *190 mm* preferred (*165 mm* alternative). For larger (than domestic consumer) diameter meters, however, the service connection should be sized to coincide with the consumption level: at a given pressure and demand (m^3), after all, the flow will increase (improving the accuracy of the meter) when reducing the diameter of the service connection line. During off-peak rates, the flow should fall within the specified flow range by the manufacturer.

3.2.5 Material of Water Meters

Regarding the material and construction of water meters, the following requirements shall be followed [7]. Additionally, the buyer (WSP) needs to ensure that the selected meter meets the Kenyan laws and regulations regarding material requirements with certificates as documentary evidence:

The material used shall be of adequate strength and durability. In particular,

- The material used shall not be adversely affected by water temperature variations within the working temperature range. In Kenya, water meters have to endure a water temperature of *50 ºC*, which results in a required meter temperature class of T50. Hence, it is recommended to use (co-)polymer or another material with similar attributes, rather than plastic. It is not recommended to use brass, as it would induce stealing. Nevertheless, this suggestion does not include the use of brass threads.
- All parts of a water meter in contact with the water flowing through it shall be manufactured from materials which are conventionally known to be non-toxic, non-contaminating, and biologically inert. Attention is drawn to national regulations.
- The material used shall be resistant to internal and external corrosion or which are protected by a suitable surface treatment.
- A water meter indicating device shall be protected by a transparent window. A cover of a suitable type may also be provided as additional protection.
- Where there is a risk of condensation forming on the underside of the window of a water meter indicating device, the water meter shall incorporate devices for prevention or elimination of condensation.
- A water meter shall be of such design, composition, and construction that it does not facilitate the perpetration of fraud.
- A water meter shall be fitted with a metrologically controlled display.
- A water meter may be fitted with an adjustment device.

4 Technical Specifications of Tender Document

Technical specifications of a tender document for the procurement of water meters should incorporate the following information. A template including the most relevant information can be found in Annex B.

[9] ¾ inch

4.1 Certificates

The manufacturer of the meters must hold the Quality System Certificate for the standard ISO 9001.

Additionally, the specific model purchased, shall be either certified according to EN ISO 4064 or OIML R49. Hence, a type approval certificate has to be provided. If tested according to OIML R49, the report has to be issued by one of the accredited institutions listed in Annex D (subject to changes). Although issued by different institutions, the main content of OIML certificates is the same (see Annex E for the usual content of an OIML certificate of conformity for comparison).

The Department of Weights & Measures, Ministry of East Africa Affairs, Commerce and Tourism, is establishing new rules and regulations for meters, to be known as "Water Meter Regulations", in the Weights and Measures Act, Chapter 513, which should be followed as soon as it becomes effective[10]. According to the anticipated "Water Meter Regulations", a sample of each model of any meter imported will be given to Weights and Measures for testing (at the department and randomly in the field in every county) and filing.

The supplier should provide additionally the specific manufacturer's authorization for selling its product and the relevant certificate issued by KEBS[11].

A calibration certificate provided by the supplier, that does not indicate an accredited institution, is not sufficient.

It is important to ensure that the specific model purchased is the one which had been certified.

4.2 Statement of Type, Class, Sizing, and Material of Water Meter

The selected criteria type, class, size and material as described in Chapter 3.2 should be stated in the technical specifications of the tender document.

4.3 Additional Technical Specifications

In ISO 4064 it is stated that "before undergoing type evaluation tests, each type of water meter submitted shall be examined to verify that it meets the requirements with respect to the design of the indicating device, the marking of the meter and the application of protection devices" (see Annex F for more details). The following tests are mandatory for the test program for type evaluation:

- Static pressure
- Error (of indication)
- Absence of flow[12]
- Water temperature
- Overload water temperature
- Water pressure
- Reverse flow

[10] Publication is planned in 2015

[11] KEBS recognizes calibration certificates from the following institutions: Nyeri Water; TUV SUD NEL; FCRI India

[12] This test is only required for electronic water meters or water meters with electronic devices

- Pressure loss
- Flow disturbance
- Magnetic field testing[13]

Hence, only the following technical specifications should be incorporated additionally:

- In-built sieves/strainers shall be incorporated in consumer flow meters.
- A water meter shall include protection devices which can be sealed so as to prevent, both before and after correct installation of the water meter, dismantling or modification of the meter, its adjustment device or its correction device, without damaging these devices. One of the methods frequently applied in Kenya, is sealing by a corrosive resistant wire inserted through *2.5 mm* diameter holes in the halves of the body, and secured by a circular sheet metal seal impressed by a device which provides a unique imprint on the seal[14].
- Threaded meters shall be supplied complete with a set of connectors that are made of copper alloy or equivalent material resistant to corrosion, rust and damage due to shock or vibration. The connectors shall be threaded to the correct male size, comprising cap nuts, linings and fibber sealing washers. The meter linings shall have adequate provisions to safeguard against tampering[15].
- The meter shall be delivered calibrated.
- In addition to the inscription requirement in ISO 4064-1 (see Annex F, Marks and Inscriptions), the nominal diameter is required to be marked on the meter. As the recommended temperature class, T50, differs from T30, it should be indicated additionally. Furthermore, the abbreviation of the specific WSP shall be engraved to reduce the chance of theft.
- The ISO standard regulates that the working pressure should be up to *1,000 kPa*; however, under Kenyan circumstances, a working pressure of *1,600 kPa* is recommended[16]. This should be indicated on the meter as well.
- A water meter shall be designated as accuracy class 2. This requires the Maximum Permissible Error (MPE) to be *±2 %* (for temperatures from *0.1 °C* to *30 °C* and *±3 %* for temperatures greater than *30 °C*) for the upper flow rate zone. As the temperature in Kenya is greater than *30 °C*, a MPE of *±3 %* is acceptable. The MPE for the lower flow rate zone shall be *±5 %*.

4.4 Additional Non-Technical Specifications

Spare *parts/aft*er sales service:

- Availability of spare parts has to be proven. The manufacturer should provide a complete list of available spare parts (in English), their specific costs (at the time of purchase) and delivery time. The manufacturer should guarantee the supply of spare parts for at least two years after the expiry of warranty[17].

[13] For all meters with electronic components and mechanical meters equipped with a magnetic coupling in the drive to the readout or any other mechanism which may be affected by the external application of a magnetic field.

[14] Malindi Water Technical Specifications.

[15] Kericho Water and Vitens Technical Specifications.

[16] Kericho Water, Nyeri Water and Vitens Technical Specifications.

[17] Malindi Water Technical Specifications.

- The name, address, and contact details of the local agent responsible for providing spare parts and maintenance shall be indicated[18].

Maintenance manuals: Maintenance manuals (in English) shall be provided[19].
Warranty: The minimum warranty period shall be two years.

5 Installation of Water Meters

5.1 Associated Fittings

Additional to the quality meter purchased, the following fittings and instructions should be applied and followed additionally, in order to ensure the correct functioning of water meters.

- Use gaskets that properly match the diameter of meters. Instrumental errors may occur when gaskets are projecting inwards [1].
- Threaded meters shall be installed using meter liners/connectors [8].
- A stopcock or valve, preferably with the direction of the valve operation indicated, should be installed upstream and downstream of the meter [7].
- In case of high probability of tampering of the downstream stopcock valve, a non-return valve shall be installed instead.
- If, under specific installation conditions, the accuracy of flow measurement is likely to be affected by suspended particles in the water, the meter may be installed with an additional external strainer. The strainer shall be placed before the stopcock valve in the pipe work upstream [7].
- For correct operation, a water meter shall be installed such that it is completely filled with water under normal conditions. If there is a risk of air entering the meter, as it is the case when water supply is rationed, an upstream air release valve shall be installed between the upstream stopcock valve and the meter itself [7].
- The difference in height between the lowest draw-off point of water after the meter and the water flow meter shall be not less than 10 times the diameter of the respective pipe.

The above mentioned points are summarized in Figure 2 overleaf.

[18] Malindi Water Technical Specifications.

[19] Malindi Water Technical Specifications.

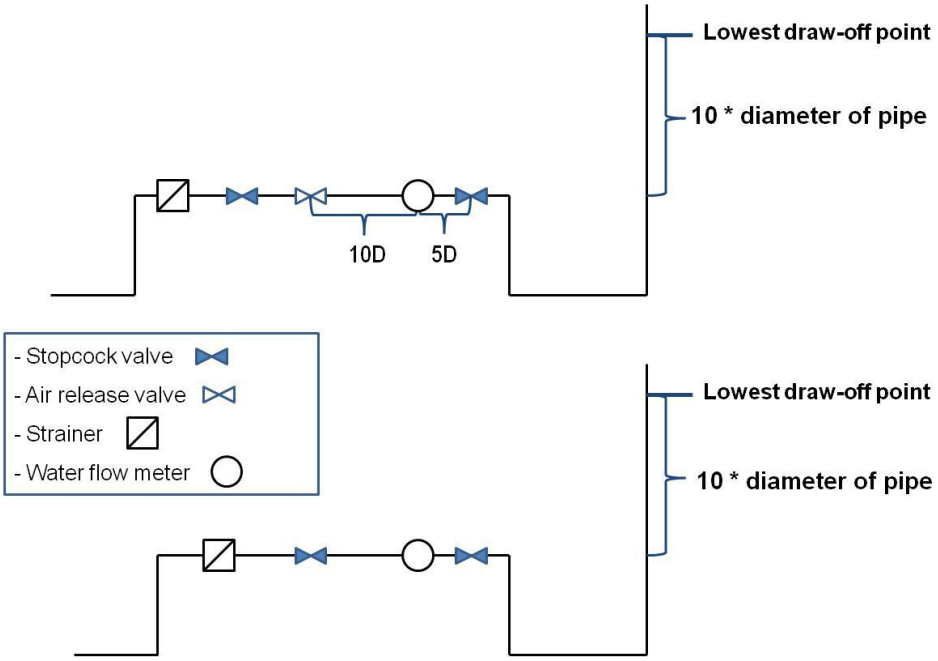

Figure 2: Correct installation of associated fittings

5.2 Installation Instructions

5.2.1 General Recommendations

Installation of water meters shall be carried out professionally according to the installation instructions provided by the specific manufacturer. Additionally, the following recommendations should be followed [1], [7]:

- Install meters horizontally at the designated location, with the arrow (typically shown on the lower case) facing towards the direction of the flow of meter. The meter shall be installed in a 90° angle to the meter flow and with the indication device facing upwards (see Figure 3).

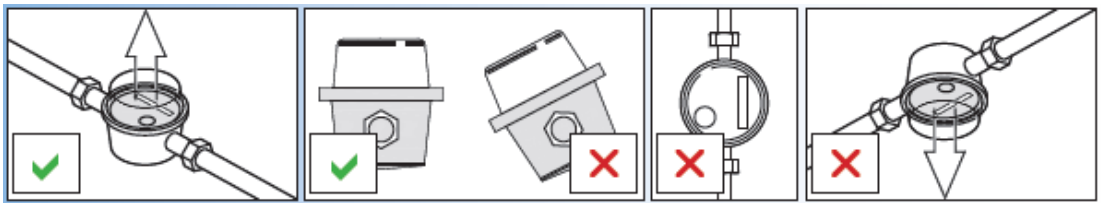

Figure 3: Comparison of correct and wrong installation of water meters [9]

Figure 4: Left: velocity meters installed incorrectly (vertically); right: displacement (rotating-piston) which can be installed vertically, but preferably not.

Figure 5: Velocity meter installed horizontally (correct) but too close to the up- and downward bend

- Provide a straight pipe length equivalent to 10 times[20] the diameter of the meter upstream and 5 times the diameter of the pipe downstream (10D/5D rule-of-thumb). This is indicated in Figure 2.
- Water meters shall be easily accessible for reading, for installation, for maintenance, for removal and for in situ dismantling of the mechanism if required.
- Measures shall be employed to avoid contamination, especially when the meter is installed in a pit, by mounting the water meter and the fittings at a sufficient height above the floor. If necessary, the pit shall be provided with a sump or drain for water removal.
- The meter shall be protected from the risk of damage by shock or vibration, from extremes of temperature, of water or ambient air, and due to external environmental corrosion.
- The meter shall not be subjected to undue stresses caused by pipes and fittings. If necessary, it shall be mounted on a plinth or bracket.
- Unfavourable hydraulic conditions, e.g. cavitation, surging and water hammer, should be avoided.

[20] More if the feeder line has a larger diameter than the service connection on which the meter is being installed.

- Meters should be installed inside meter casings to reduce the chance of theft and meter tampering. The casings should be lockable and can be made out of concrete or metal. Several WSPs such as Kericho and Naivasha, having experience with the design and construction of casings, can be contacted for further information.
- Meters should be installed in such a way, that each consumer unit can be billed individually (based on Article 41 1 (d), Constitution of Kenya[21]).

5.2.2 Step-by-Step Installation

Furthermore, the step-by-step guideline established by KEWI (General Water Meter Installation Conditions) is provided in Annex G.

5.2.3 Recommendations for Installation to Eliminate Disturbances

The circumstances leading to flow disturbances, which can have significant impact on the accuracy of the flow meter, are complex and too numerous to detail in this Guideline. However, potential causes should be generally eliminated prior to the implementation of remedial devices such as flow straightening devices. A guideline how to eliminate disturbances for new installations is given in Annex H [7].

5.3 First Operation of New or Repaired/Serviced Water Meters

The following points shall be considered before water meters are used the first time [7].

- Before installation, the water mains shall be flushed. Care shall be taken to prevent the ingress of debris into the water meter or supply lines.
- After installation, water shall be let into the mains slowly and with trapped air bled so that the trapped air does not cause the water meter to over speed, causing damage.

6 Management of Water Meters

6.1 Meter Registry

A meter registry provides complete information of each meter. It is recommended to establish the meter registry within the billing system. This in turn can be integrated in or linked with a Geographic Information System[22] for spatial analysis purposes. Billing software is generally more robust and less sensitive to manipulation. A simplified option is the establishment of the meter registry in a separate Excel file (see WASPA meter registry.xlsx[23]).

We recommend the inclusion of the following meter attributes:

- GPS coordinates
- (Administrative) zone code
- DMA code
- Account number
- Closest installed meter for a more efficient water meter reading route
- Serial number
- Brand

[21] Constitution of Kenya 2010, Article 43 1 (d) indicates that ‘every person has the right to clean and safe water in adequate quantities’

[22] Training for GIS offered by WASPA.

[23] Available from WASPA upon request.

- Length (in mm)
- Type: volumetric polymer; volumetric brass; velocity polymer; velocity brass
- Diameter
- Functional principle: volumetric; dry runner; semidry runner, wet runner
- Metrological class
- Meter material: brass; composite
- Manufacturing date
- Meter chamber: none; locked good condition; unlocked good condition; damaged
- Installation location: plot boundary; inside plot; inside building
- Installation mode: horizontal above ground; horizontal underground; vertical
- First installation date (can be used to establish the age of the meter in combination with the manufacturing data (which may not be known))
- Last installation (or servicing) date: (can be used to estimate the age of the meter (or when it was last tested/serviced/calibrated) if the first installation date is unknown)
- Operational status: functional; non-functional; damaged (but functional); testing request
- Seal status: (original WSP) seal in-tact; (original WSP) seal broken; no seal
- Visibility: visible (above ground); partially underground; invisible (underground)
- Visible defects
- Remarks

It is recommended to establish the meter registry as part of a door-to-door survey, which serves additionally to identify illegal connections and validate consumer data. An applicable template is shown in Table 9 in Annex I. This has been agreed upon by GIS Task Group members (with representatives from 10+ WSPs) and supported by the NRW Task Group in WASPA's Peer to Peer Benchmarking and Collective Learning Program.

Meter data should be entered into the system at the time the meter is purchased or first installed or whenever any testing or repair work is performed on the meter. These data can be entered directly into the system by the person receiving or repairing/testing the meter. Nevertheless, it is recommended to choose one person responsible for updating the registry. Furthermore, meter data should be regularly analyzed by a data analyst being part of the water meter management team as described in 6.2.

6.2 Training of Water Meter Management Team

It is recommended to establish a water meter management team within a utility. This can range from 2-3 people (including staff responsible for maintenance) up to 10-20 people depending on the capacity of the utility. This team will manage all required activities addressing all aspects of meter management: meter selection/sizing, procurement, installation, maintenance and replacement. As a starting point, the team should consist of one or more:

- **Supervisors:** responsible for customizing this Guideline to the WSP-specific context and overseeing the implementation of a meter management strategy.
- **Meter testing specialists**: a staff member who has been trained in using portable meter testing equipment for in-situ testing of small and large diameter meters. In the case of larger WSPs, this person would implement or coordinate the meter testing/servicing/calibration activities (with a meter test bench) in an established meter workshop.
- **Meter installation/servicing technicians**: one or more (subject to the number of meters) staff members responsible for new installations, (regular) meter servicing and replacement.

- **Data analysts**: a staff member who monitors the meter performance trends (i.e. monthly static meters), analyses the attributes of replaced (faulty) meters and refines the meter management (including replacement) strategy in consultation with the supervisor.

Figure 6: Water meter workshop

The team should be trained sufficiently in meter management (in house by the supervisors), data analysis and meter calibration[24] and re-trained regularly through vocational training to keep abreast with technological advancements. A list of potential training courses is available from training institutions, such as KEWI. Meter (testing equipment) manufacturers/suppliers can offer specialised/customized training courses as well.

7 Maintenance of Water Meters

Water meter performance tends to deteriorate over time, increasingly resulting in inaccurate readings. Furthermore, meters may be clogged, tampered or damaged (as a result of tampering or wear and tear). To ensure meter accuracy, the utility should establish a meter maintenance program. Maintenance of meters includes cleaning, testing, calibration and, if required, replacement of meters [9].

7.1 Maintenance Schedule

The duration within which water meters can retain their accuracy standards depends on many factors including, the quality of water, flow rate and the meter 'mileage' (registered volume).

We recommend following primarily a simplified, preliminary maintenance schedule for newly installed meters which have been chosen and installed according to this Guideline. After its successful implementation and the establishment of a thorough meter registry (see Chapter 6.1), a more detailed meter maintenance and/or replacement program can be considered. The basic idea is to group all installed water meters according to factors influencing their accuracy (e.g. age, water quality, flow rate). This data can be either taken from the established meter registry or a "door-to-door survey". For each group a representative batch (e.g. 10%) is chosen and regularly cleaned and tested based on a preliminary schedule. Based on this experience, a specific maintenance schedule for each group is customized. The more data are used to

[24] Internally or externally, subject to the available skills in house.

establish these groups, the more accurate a schedule can be established. However, this requires more effort in establishing the schedule and documentation of data taken.

The preliminary maintenance schedule could be based on the type of water meter chosen and quality and quantity of water being metered. Both, quantity and quality of water should be already identified during the selection of the most suitable type of water meter (see Chapter 3.2). Exemplary, the following eight groups may be established:

1) **Displacement meter**: good water quality; low consumption (one household)
2) **Displacement meter**: good water quality; high consumption (more than one household)
3) **Displacement meter**: medium to bad water quality; low consumption (one household)
4) **Displacement meter**: medium to bad water quality; high consumption (more than one household)
5) **Velocity meter**: good water quality; low consumption (one household)
6) **Velocity meter**: good water quality; high consumption (more than one household)
7) **Velocity meter**: medium to bad water quality; low consumption (one household)
8) **Velocity meter**: medium to bad water quality; high consumption (more than one household)

For each group, a representative batch (e.g. 10%) should be chosen. The meters chosen should be maintained more often in the beginning to develop a meaningful maintenance schedule. As a starting point, consider: a) cleaning displacement meters every 3 months, b) cleaning velocity meters every 6 months, and c) testing and calibrating all meters e.g. once at least every 2 years. Based on the experience during the preliminary schedule, a detailed maintenance schedule customized to each group can be established.

A fixed replacement schedule is not recommended. If during cleaning, testing and calibration the meter is considered to be not operational, it should be replaced.

In case of complaints from customer, accuracy should be checked independent of the established maintenance schedule. In this case, either an additional meter can be installed in series or an on-site, portable clamp-on meter can be used as described in Chapter 7.3.

Additionally, for water meters which have already been installed for many years, the following approach can be applied:

1) Select a representative batch of meters (e.g. 10%), half of which displacement meters, half of which velocity meters, that are more than 7 years old (if existing) and assess whether they meet the accuracy standards[25]. If they do, test meters that are more than 10 years old. If not, proceed with step 2).
2) Test meters that are 7 years old. If they meet the accuracy standards, the life span of meters is 7 years or more. If they don't, proceed with step 3).
3) Test meters that are 5 years old. If they meet the accuracy standards, the lifespan of meters is 5 years or more. etc.

[25] Meter error falls within the allowable limits of + 2 % in the higher flow rate range and + 5 % in the lower flow rate range. Without a lab-based meter test bench (enabling accuracy assessments for different flow rates), WSPs should test meters under in-field (single flow rate) conditions using one of the methods presented in Chapter 7.3.

4) Moving away from a sample, test ALL meters that are older than the estimated lifespan of the type-specific meter.

The meter testing/servicing/calibration procedures should be clearly documented in a meter management policy/strategy that is enforced by the team supervisor(s).

Figure 7: Servicing of water meters

7.2 Maintenance Procedure

Detailing the specific maintenance procedures would exceed the frame of this Guideline, as every type and brand has its own maintenance procedure. Hence, for more detailed information, the provided maintenance manual from the manufacturer should be consulted. However, the following generic procedure is given:

1) Close water supply
2) Removal of installed meter
3) Exterior cleaning
4) Breaking of seal
5) Dismantling of meter into its basic components of the shell or case, usually an upper and a lower part, the register, and the measuring chamber
6) Cleaning: sand- or bead-blasting; wire brushing; hand scrubbing
7) Checking of threads on the inlet and outlet spuds of the casing
8) Replacement of broken components
9) Reassembly of water meter
10) Calibration/accuracy testing: it should be demonstrated that the meter error falls within the allowable limits of *±2 %* in the higher flow rate range and ±5 % in the lower flow rate range. In the absence of a KENAS accredited lab-based meter test bench (enabling accuracy assessments for different flow rates), WSPs should test meters under in-field (single flow rate) conditions using one of the methods presented in Chapter 7.3.
11) Recalibration according to manufacturers' specifications
12) Re-sealing
13) Re-installation according to 5.2.2
14) Re-operation according to 5.3

7.3 Maintenance Equipment

For testing of water meters on-site (single flow rate), portable clamp-on UFMs (for larger diameter meters) or meter testing kits (for smaller diameter meters) can be hired from WASPA.

Figure 8: left: serial metering with precision meter upstream; right: serial metering with pressure and flow measurement upstream

Furthermore, the very simple 'bucket and stop watch method' can be applied as a first indication of meter accuracy (see Figure 9). A 'calibrated' bucket should be used indicating the amount of water it can be filled with. Another on-site method is the 'calibrated meter in series method'. The advantage of the former over the latter is that the portable kits are equipped with pressure gauges.

Figure 9: Simple testing with bucket and stop watch[26]

For more accurate testing and calibration of meters to evaluate the reliability of water meters under all operating conditions, water test benches are recommended. A list of accredited testing facilities is attached in Annex C (subject to changes). So far, only KEBS and Nyeri Water and Sewerage Company Ltd have KENAS accredited meter test benches. Several WSPs including Nairobi, Murang'a, Embu, Mombasa and Nakuru (before the end of 2015) as well as KEWI have meter test benches not yet accredited[27] (in some cases available for hire). Other WSPs may want to consider co-investing in/sharing a meter test bench in the future. It

[26] Vitens

[27] It is recommended for WSPs having meter test benches, to get accredited by KENAS (Kenya National Accreditation Service) based on ISO 17025. This is an opportunity for WSPs to increase revenue and to contribute to the reduction of water losses through metering inaccuracies in Kenya.

is important to note that meter test benches owned by WSPs, should be used by sufficiently trained staff to ensure that the established maintenance schedule and procedure is followed.

7.4 Disposal of Water Meters

According to the Public Procurement and Disposal Act [4], a PE must ensure that the Act, the Regulations and any directions of the Authority are complied with in respect to each disposal. This includes the appointment of a disposal committee, which can recommend the following disposal methods:

- Transfer to another PE or part of a PE, with or without financial adjustment;
- Sale by public order;
- Sale by public auction;
- Destruction, dumping or burying; or
- Trade-in.

To ensure that the aforementioned methods do not lead to illegal selling of recycled/reused meters and spare parts, WASPA could inform its members on the most cost efficient method and reliable companies based on a thorough study. On the long term, WASPA could establish its own shredding business with selling (shredded) scrap metal as a feasible business model.

References

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[6] American Water Works Association , Water Meters — Selctiong, Installation, Testing, and Maintenance, Denver: American Water Works Association , 2012.

[7] International Standard Organization, “ISO 4064 Water Meters for Cold Potable Water and Hot Water,” International Standard Organization, Geneva, 2014.

[8] Kenya Water Institute, “General Water Meter Installation Conditions,” Kenya Water Institute, Nairobi.

[9] Georgia Envrionmental Protection Division Watershed Protection Branch, “Water meter calibration, repair, and replacement program,” Georgia Envrionmental Protection Division (EPD), Atlanta, 2007.

Annex A: WASPA Meter Management Survey Findings

As is highlighted in the introduction, Chapter 1, this Guideline incorporates the findings of a meter management survey that was conducted by WASPA with bfz-SWAP, VEI and KEWI support. The questionnaire was disseminated to all 55+ member WSPs. We would like to appreciate the following 12 WSPs for directly contributing to the Guideline by submitting their questionnaires: Oloolaiser, Olkalou, Kisumu, Tililbei, Karuri, Garissa, Murang'a, Kikuyu, Kericho, Nairobi, Mombasa, Naivasha. The bullets below summarize the findings[28]:

Meter Management Strategy/Policy

- 10 of 12 WSPs do not allow consumers to procure their own meters - in line with (inter)national best practices.
- 5 out of 12 WSPs have a meter management policy/strategy in place in line with (inter)national best practices. Out of these 5 WSPs, only 1 WSP has not appointed/trained specialized staff member to (supervise the) implementation of the policy/strategy (despite possessing an underutilized meter test bench).
- On a scale from 1 (policy/strategy not implemented at all) to 5 (implemented to the letter), 3 WSPs award themselves a score of 2 or less and 2 WSPs a score of 4. The first three low-scoring WSPs (and those that did not submit) may stand to benefit from the latter two.
- The longest period for which a WSP water policy/strategy has been in place is 4 years.

Meter Procurement

- 4 WSPs calibrate newly procured meters before settling payments with the supplier, 3 internally and 1 externally.
- 2 WSPs indicate that they have rejected deliveries based on test results - in line with (inter)national best practices. 2 did not respond, the rest (8 WSPs) have not rejected any batches. Note: only WSPs with meter test bench have rejected deliveries!

Meter Registration

- 7 out of 12 WSPs have implemented a door-to-door survey to establish/update the meter registry - in line with (inter)national best practices. Those that have not are encouraged to do so!
- Respondents collect a varying number of meter attributes in the agreed upon (GIS) data model: zone, account number, meter serial number, brand, size, type, material, meter chamber, installation mode, installation location, first installation date, last installation (servicing) date, functional status, visibility, defaults/leakages, sealed, remarks (see Annex I).
- 6 out of 12 WSPs have incorporated the meter registry in the billing system - in line with (inter)national best practices. None of the WSPs are using the same billing software.

[28] More detailed information is available from WASPA on request.

Meter Specifications

- With the exception of 3 WSPs (mostly velocity meters), most WSPs are using rotating-piston meters. 2 WSPs are using a combination. Five WSPs, however, expressed a preference for velocity meters.

Meter Sizing and Selection

- In sizing/selection of meters, only 1 WSP suggests they do not explicitly take the diameter of the service connection line into account. 2 WSPs make reference to the 'anticipated consumption', 1 WSP to 'the size of the service line', 2 WSPs 'one size smaller than the service line', 1WSP to the 'expected maximum consumption'. Only 1 WSP appears to correctly base the sizing on the actual flow pattern of the (new) consumer.

Meter Installation

- 9 out of 12 WSPs indicate that they have documented (new) meter installation standards e.g. the 10D/5D rule (see footnote 18) while only 5 out of 12 WSPs have a meter management policy/strategy in place. This points to a limited focus on meter installation alone by some WSPs.

Meter Testing and Servicing

- WSPs are currently using varying types/sources of equipment[29] in testing small diameter meters:
  - Portable meter testing kit: 6 WSPs
  - Bucket and stop watch: 6 WSPs
  - Meter in series: 4 WSPs
  - None (no testing): 1 WSP.
- WSPs are currently using varying types/sources of equipment in testing large diameter meters:
  - Clamp-on UFM: 6 WSPs
  - None: 6 WSPs
- Surprisingly, 8 out 12 WSPs indicate that they are pro-actively testing consumer meters based on monitored consumption trends.

Meter Replacement

- 8 out of 12 WSPs indicate that all faulty meters are replaced when they are dysfunctional for 2-3 months in a row. 3 WSPs directly replace dysfunctional meters (if stocks permit)
- 3 out of 12 WSPs indicate that meters are refurbished and re-used. The rest discard them (5 WSPs) or lock them up in their stores (3 WSPs). Only one WSP indicates that they are 'disposed of as per regulations' to ensure that they cannot potentially find their way to the illegal market with due consequences for your/other WSPs.
- Only 4 out 12 WSPs have established the life span of their (type-specific) meters. This underlines the importance of establishing a meter registry to assess the correlation between meter life span/performance, meter attributes, water quality etc.
- 5 out of 12 WSPs indicate that they set aside a yearly budget for meter replacements. Only two WSPs linked this budget to a number of replaced meters. 2 WSPs are currently

[29] Note: some are using a combination of two due to address capacity constraints.

focusing on achieving a 100% metering ratio. 3 further WSPs indicate that they have no equipment and/or capacity to test a large numbers of meters.

Meter Reading

- WSPs who are billing more than 25% of their customers based on estimates (due to underperforming meter readers or gate-locked premises) need to address this -likely-source of commercial losses.
- With the exception of 3 WSPs, all WSPs rotate their meter readers to secure the reliability of meter readings. 6 out of 12 WSPs also conduct monthly/quarterly spot checks by the zonal manager, NRW team or meter reader supervisor (1 WSP - 10% sample; 1 WSP > $15m^3$ consumption; 1 WSP erroneous data).

Meter Tampering

- 8 out of 12 WSPs highlight meter reversal as the most common form of meter tampering, followed by damage to velocity meter impellers (3 out of 12 WSPs).
- 10 out of 12 WSPs seal their meters, and score the effectiveness of the measure at 3 on a scale from 1 (not effective) to 5 (very effective). We recommend the use of utility-specific seals (e.g. WSP initials) that are less prone to be forged without in-house equipment.
- 10 out of 12 WSPs fine consumers for meter tampering - KES 10-15,000 (5 WSPs), KES 5,000 (4 WSPs), KES 3,000 (1 WSP).
- Measures taken to reduce meter tampering include patrols, random spot checks (2 WSPs), relocation of meters to visible/accessible locations (1 WSP), double deposits (1 WSP), and lockable meter boxes (1 WSP).

Meter Personnel

- Only 4 out of 12 WSPs indicate they have not hired/appointed any (dedicated) 'meter management' staff.
- Most WSPs have 2-5 full-time staff engaged in 'meter management'. Those with more than 10 (2 WSPs) probably included meter readers.
- Most of these staff members are KEWI (diploma/certificate course) graduates with: a) experience levels varying from 2 to 5 years, and b) 3 out of 8 WSPs making reference to supplementary KEWI short courses.

Annex B: Template for Technical Specifications/Evaluation

Table 5: Template for Technical Specifications of Tender Document

Technical Requirement	Description	Evaluation (Requirement fulfilled - Yes/No)
Required Certificates	- ISO 9001 certified	
	- Type approval certificate (either according to EN ISO 4064 from 2005 or 2014, or OIML R49 from 2003 or 2013)	
	- Manufacturer's authorization	
	- KEBS certificate	
Type of Water Meter	(to be added)	
Class of Water Meter	(to be added)	
Sizing of Water Meter	(to be added)	
Material Requirements	(to be added)	
Additional Technical Requirements	In-built sieves/strainers shall be incorporated in consumer flow meters.	
	A water meter shall include protection devices which can be sealed so as to prevent, both before and after correct installation of the water meter, dismantling or modification of the meter, its adjustment device or its correction device, without damaging these devices. One of the methods frequently applied in Kenya, is sealing by a corrosive resistant wire inserted through 2.5 mm diameter holes in the halves of the body, and secured by a circular sheet metal seal impressed by a device which provides a unique imprint on the seal.	
	Threaded meters shall be supplied complete with a set of connectors that are made of copper alloy or equivalent material resistant to corrosion, rust and damage due to shock or vibration. The connectors shall be threaded to the correct male size, comprising cap nuts, linings and fibber sealing washers. The meter linings shall have adequate provisions to safeguard against tampering.	
	The meter shall be delivered calibrated.	
	In addition to the inscription requirement in ISO 4064-1 (see Annex F, Marks and Inscriptions), the nominal diameter is required to be marked on the meter. As the recommended temperature class, T50, differs from T30, it should be indicated additionally. Furthermore, the abbreviation of the specific WSP shall be engraved to reduce the chance of theft.	
	The ISO standard regulates that the working pressure should be up to *1,000 kPa*; however, under Kenyan circumstances, a	

Technical Requirement	Description	Evaluation (Requirement fulfilled - Yes/No)
	working pressure of *1,600 kPa* is recommended[30]. This should be indicated on the meter as well.	
	A water meter shall be designated as accuracy class 2. This requires the Maximum Permissible Error (MPE) to be *±2 %* (for temperatures from *0.1 °C* to *30 °C* and *±3 %* for temperatures greater than *30 °C*) for the upper flow rate zone. As the temperature in Kenya is greater than *30 °C*, a MPE of *±3 %* is acceptable. The MPE for the lower flow rate zone shall be *±5 %*.	
Additional Non-Technical Requirements	**Spare parts/after sales service**: Availability of spare parts has to be proven. The manufacturer should provide a complete list of available spare parts (in English), their specific costs (at the time of purchase) and delivery time. The manufacturer should guarantee the supply of spare parts for at least two years after the expiry of warranty.	
	Spare parts/after sales service: The name, address, and contact details of the local agent responsible for providing spare parts and maintenance shall be indicated.	
	Maintenance manuals: Maintenance manuals (in English) shall be provided.	
	Warranty: The minimum warranty period shall be two years.	

[30] Kericho Water, Nyeri Water and Vitens Technical Specifications

Annex C: List of Accredited Testing Facilities in Kenya

Table 6: List of Accredited Testing Facilities in Kenya

Testing Facility	Address; Contact person
Kenya Bureau of Standard (KEBS)	KEBS Centre, Popo Road, Off Mombasa Rd P.O. Box 54974 – 00200 Nairobi Tel: +254 (20) 6948000 PVoC: +254 724255242 Fax: +254 (20) 6948575 Email:info@kebs.org Contact: Eng. Samuel Okello Eng. Boniface Juma
Nyeri Water Company	Nyeri Water & Sewarage Company Ltd, Nyewasco HQ, Opposite Nyeri Town Health Centre, Nyeri. Tel: 061-2032684//061-2034127// 061-2034548 //061-2034622// 0733-826914 Fax: 061-2032734 Email: info@nyewasco.co.ke; kagwijoe@gmail.com Contact: Eng. Joseph Muchiri

Annex D: Accredited OIML Institutions

Table 7: List of OIML Issuing Authorities (https://www.oiml.org/en/certificates/certissuingauth_view)

Code	Acronym	Name	Country
AT1	BEV	Bundesamt für Eich- und Vermessungswesen	Austria
AU1	NMI	National Measurement Institute	Australia
BE1		SPF Economie, PME, Classes Moyennes et Energie	Belgium
BG1	SAMTS	State Agency for Metrology and Technical Surveillance	Bulgaria
BR1	INMETRO	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial	Brazil
CH1	METAS	Federal Institute of Metrology METAS	Switzerland
CN1	AQSIQ	General Administration of Quality Supervision, Inspection and Quarantine of P. R.	P.R. CHINA
CZ1	CMI	Czech Metrology Institute	Czech Republic
DE1	PTB	Physikalisch-Technische Bundesanstalt	Germany
DK1		Danish Safety Technology Authority	Denmark
DK2		FORCE Certification A/S	Denmark
DK3	DELTA	Dansk Elektronik, Lys & Akustik	Denmark
ES1	CEM	Centro Español de Metrología	Spain
FI1		Inspecta Oy	Finland
FR1		Ministère de l'Economie, des Finances et de l'Industrie	France
FR2	LNE	Laboratoire National de Métrologie et d'Essais	France
GB1	NMO	NMO Certification Services	United Kingdom
GB2	NPL	National Physical Laboratory	United Kingdom
HU1	MKEH	Hungarian Trade Licensing Office	Hungary
IT1		Ministero dello sviluppo economico - Direzione generale mercato, concorrenza, co	Italy
JP1	NMIJ / AIS	National Metrology Institute of Japan / National Institute of Advanced Industria	Japan
KR1	KATS	Korean Agency for Technology and Standards	Korea
NL1		NMi Certin B.V.	Netherlands
NL2		KIWA Nederlands B.V.	Netherlands
NO1	Justervese	Norwegian Metrology Service	Norway
NZ1	MAPSS Well	Measurement and Product Safety Service	New Zealand
PL1		Central Office of Measures (GUM)	Poland
RO1	B.R.M.L.	Romanian Bureau of Legal Metrology	Romania
RU1	VNIIMS	All-Russian Scientific Research Institute for Metrological Service	Russian Federation
SE1		SP Technical Research Institute of Sweden	Sweden
SI1	MIRS	Metrology Institute of the Republic of Slovenia	Slovenia
SK1		Slovak Legal Metrology	Slovakia
US1		NCWM, Inc.	United States
VN1	STAMEQ	STAMEQ - Directorate for Standards and Quality	Vietnam

Annex E: Content of OIML Certificate of Conformity

OIML CERTIFICATE OF CONFORMITY

OIML Certificate Nº….

Issuing authority- this shall be one of the issuing authorities listed in Annex B

Name:

Address:

Person responsible:

Applicant

Name:

Address:

Manufacturer of the certified type (can be stated that the manufacturer is the applicant)

Name:

Address:

Identification of certified type: NAME OF SPECIFIC TYPE

Further characteristics[31]:

- Minimum flow rate Q1 (m3/h)
- Transitional flow rate Q2 (m3/h)
- Permanent flow rate Q3 (m3/h)
- Overload flow rate Q4 (m3/h)
- Q2/ Q1
- Q3/ Q1
- Nominal diameter (mm)
- Length (mm)
- Connection type
- Accuracy class
- Maximum admissible pressure (bar)
- Min/max admissible temperature (ºC)
- Temperature class
- Indicating range (m3)
- Verification scale interval (m3)
- Orientation
- Environmental class
- Power supply (type; Umax; Umin; frequency)
- Flow conditioner
- Electromagnetic environment
- Minimum straight length of inlet/outlet pipe (mm)

[31] the specific sequence applied might be different to the one followed here; this is an exhaustive list and not all of the specifications have to be indicated on the certificate

Annex F: Design of the Indicating Device, the Marking of the Meter and the Application of Protection Devices

ISO 4064-1: 6.6 Marks and inscriptions

6.6.1 A place shall be provided for affixing the verification mark(s) (see OIML V 1:2013, 3.04), which shall be visible without dismantling the water meter after it has been place on the market or put into use.

6.6.2 A water meter shall be clearly and indelibly market with the following information, either grouped or distributed, on the casing, the indicating device dial, an identification plate or the meter cover, if it is not detachable. These markings shall be visible without dismantling the water meter after the instrument has been placed on the market or put into use.

a. Unit of measurement.
b. Accuracy class, where it differs from accuracy class 2.
c. Numerical value of Q_3 and the ratio Q_3/Q_1: if the meter measures reverse flow and the values of Q_3 and the ratio Q_3/Q_1 are different in the two directions, both value of Q_3 and Q_3/Q_1 shall be inscribed; the direction of flow to which each pair of values refers shall be clear. The ratio Q_3/Q_1 may be expressed as R, e.g. “R160”. If the meter has different value of Q_3/Q_1 in horizontal and vertical positions, both values of Q_3/Q_1 shall be inscribed, and the orientation to which each value refers shall be clear.
d. Type approval sign according to national regulations.
e. Name of trademark of the manufacturer.
f. Year of manufacture, the last two digits of the year of manufacture, or the month and year of manufacture.
g. Serial number (as near as possible to the indicating device).
h. Direction of flow, by means of an arrow (shown on both sides of the body or on one side only provided the direction of flow arrow is easily visible under all circumstances).
i. Maximum admissible pressure (MAP) if it exceeds 1 MPa (10 bar) or 0.6 MPa (6 bar) for DN ≥ 500.
j. Letter V or H, if the meter can only be operated in the vertical or horizontal position.
k. The temperature class as specified in 4.2.4 where it differs from T30.
l. The pressure loss class where it differs from Δp 63.
m. The installation sensitivity class where it differs from U0/D0.

(……..)

ISO 4064-1: 6.7 Indicating device

6.7.1 General requirements

6.7.1.1 Function

The indicating device of a water meter shall provide an easily read, reliable, and unambiguous visual indication of the indicated volume. A combination meter may have two indicating devices, the sum of which provides the indicated volume.

The indicating device shall include visual means for testing and calibration.

The indicating device may include additional elements for testing and calibration by other methods, e.g. for automatic testing and calibration.

6.7.1.2 Unit of measurement, symbol, and its placement

The indicated volume of water shall be expressed in cubic meters. The symbol m^3 shall appear on the dial or immediately adjacent to the numbered display.

If units of measurement outside the SI are required or allowed by a country's national regulations, these units of measurement shall be considered acceptable for indications in that country. In international trade, the officially agreed equivalents between these units of measurement and those of the SI shall be used.

6.7.1.3 Indicating range

The indicating device shall be able to record the indicated volume in cubic meters given in Table 8 without passing through zero.

Table 8: Indicating range of water meter

Q_3	Indicating range (minimum values)
m^3/h	m^3
$Q_3 \leq 6.3$	9 999
$6.3 < Q_3 \leq 63$	99 999
$63 < Q_3 \leq 630$	999 999
$630 < Q_3 \leq 6{,}300$	9 999 999

6.7.1.4 Colour coding for indicating devices

The color black should be used to indicate the cubic meter and its multiples. The color red should be used to indicate sub-multiples of a cubic meter. These colors shall be applied to either pointers, indexes, numbers, wheels, discs, dials or the aperture frames. Other means of indicating the cubic meter, its multiples and its sub-multiples may be used for a water meter provided there is no ambiguity in distinguishing between the primary indication and alternative displays, e.g. sub-multiples for verification and testing.

6.7.2 Types of indicating device

(…….)

ISO 4064-1: 6.8 Protection devices

6.8.1 General

A water meter shall include protection devices which can be sealed so as to prevent, both before and after correct installation of the water meter, dismantling or modification of the meter, its adjustment device or its correction device, without damaging these devices. In the case of combination meters, this requirement applies to both meters.

The display of the total quantity supplied or the displays from which the total quantity supplied can be derived shall not be resettable while the meter is in service to a single customer.

6.8.2 Electronic sealing devices

(……)

Annex G: General Water Meter Installation Conditions by KEWI

For a water meter to register water passing through it accurately the following conditions has to be observed.

i. After tapping a connection from a pipeline flush the laid pipes thoroughly before installing up a meter

ii. Test the meter before installing it

iii. Install a meter in a way that the flow of water flows in full bore in the meter

iv. Install meter to the pipeline ensuring that the arrow on the meter body coincides with the direction of water flow

v. Meter diameter and the pipe diameter that the meter will be installed should be of the same diameter

vi. Threaded meters must be installed using their meter liners/ connectors but not direct to a pipe fitting

vii. Locations which are subjected to severe shocks or hammer should be avoided

viii. For consumer meter installations, use a stop cock and where gate valve is used incorporate a non return valve to protect the meter from reversing when rationing or empting the pipeline. This is because all meters are not manufactured with in-build non retune valves

ix. Where water is not free from debris strainer should be installed upstream of the meter to protect it at all times

x. Avoid coupling a meter direct to sluice valve, Provide a straight pipe length equivalent to 10 times the diameter of the meter up and down stream to the meter

xi. Meter should not operate with a free discharge, there should always be some downstream resistance

xii. Flanged meter when making a gasket to couple it to a flange make sure internal diameter is precise to the meter internal diameter

xiii. Install a meter above the ground level to avoid it from being buried

xiv. Protect the meter by covering it from direct rays

Annex H: Recommendations for Installation to Eliminate Disturbances

The following factors serve as a guideline for new installations [7]:

- Velocity-profile distortion can easily be eliminated by careful application of installation procedures. This is particularly true in the case of “coning” down, abrupt section reduction and the incorrect installation of joint washers or gaskets. Upstream and downstream valves shall be of a type which does not cause any disturbances to the water flow while in the open position.
- Meters shall be installed in accordance with the upstream and downstream sensitivity classes, as given at type approval. The longer the pipe the better it is, particularly on the upstream side of the water meter.
- Wherever possible, a device that creates a flow profile disturbance, such as a check valve, orifice or pressure regulator, should be installed downstream of the meter.
- Water feed line connection to a main line in which a meter is installed shall not create swirl (see Figure 10).

Key
1 feed line
2 main line

Figure 10: Water feed line connection to main line [7]

- Two or more bends in different planes shall be:
  - either installed downstream of the water meter;
  - or moved as far as possible from the water if located upstream;
  - and separated as far as possible from each other.
- A compatible flow straightening device may be used upstream of the water meter to reduce the straight lengths of pipe, as long as this does not conflict with the meter manufacturer’s instructions.
- Adaptors shall not be used on cartridge meters and their related connection interfaces. Converters, which are not adaptors in the context of a cartridge meter system, can be used.

Annex I: Template for Meter Registry

Table 9: Template for Meter Registry[32]

										Condition						
Zone	Account No	Meter Serial No	Brand	Size	Type	Material	First Installation Date	Meter Chamber	Last Installation (Servicing) Date	Functional Status	Visibility	Defaults/ Leakages	Sealed	Installation Mode	Location	Remarks
					Volumetric Velocity	Brass Polymer		None Ok-locked Ok-unlocked Damaged		Functional Non-functional	Yes No		Yes No	Horizontal Vertical	On plot boundary Inside plot	

[32] Source: Vitens Evides International.