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Vesi- ja ympäristötekniikan laitos

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Institute of Water and Environmental Engineering

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WATER METERING DEVELOPMENT IN DAR ES SALAAM, TANZANIA

by Jigabha Julius

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ABSTRACT

The study aimed at developing water metering in Dar es Salaam. The specific objectives included the assessment of the acceptability of water meters, identifying water metering problems, assessing the competence of developing countries to cope up with the fast development of the metering industry and establishing features of an appropriate water meter for developing countries. A literature review was conducted and a checklist of questions was used in an interview of both the customers and the water utility. In addition, a comparative field study on selected existing water meters and a prototype meter was carried out.

It was revealed that lack of cost recovery is the biggest problem. Water meters are used partly by selected consumers to establish defendable charges as an input to establish tariff structures. It is recommended that water meters should first be introduced to big consumers and later to small consumers if the capacity to manage them increases. Further, regular evaluations should be conducted to assess the water meter utilization, for improved water conservation and expanded service capacity.

The water authority has failed to recover a big amount of money from its debtors. Small consumers especially in areas with intermittent water supply do not like water meters, because they register air to a great extent.

Established programs of operation, maintenance, and replacement of meters are not followed. Poor water quality necessitates regular maintenance of meters. The study shows the extent of water quality effects on the meter performance.

The field study was limited to turbine meters existing in the distribution system. These were compared with prototype meters. Piston type water meters require better water quality compared to turbine meters. This feature has hastened their disappearance in the local systems leaving turbine meters in use.

Single-jet, dry dial turbine meters proved in principle to be the most suitable meter type for Dar es Salaam network, provided that they have adequate protection against external disturbance (vandalism, manipulation of readings etc.) and have adequately high counting threshold to avoid air registration.

1 INTRODUCTION

1.1 Background of water metering

Development of water metering in Dar es Salaam urban water supply is receiving much attention after being employed successfully in large scale programs for estimating consumer demand and analysis of water loss in distribution system. Through experience it has been evident that water meters can be constant sources of revenue loss through poor management of operation and maintenance. Water meters should perform efficiently if expected results of metering are to be obtained.

Van der Zwan (1988) pointed out that for correct estimation of water consumption in dwellings, domestic point or public stand post, water meters should be utilized. If water meters are properly utilized, the following is possible:

1) Detection of leakages in the water supply network upstream the water meters. This method enables comparison of total quantity of water supplied to the network by employing master meters with the consumption of individual water meters.

2) Detection of illegal connections, if leakage is controlled by the use of district meters.

3) Intervention and protection of wastage of water within consumer premises. This is possible if the consumer is aware that water actually consumed economically and wasted will be paid for.

4) Introduction of tariff systems based on the quantity of water supplied.

5) Utilization of saved water to enlarge the service area without necessarily increasing the production capacity.

Water metering in Tanzania is not a recently introduced policy. Like many other programs it has been practised according to previous approaches as inherited from English colonial masters. Despite long history and experience gained, the use of water metering in Tanzania is still mostly limited to urban water supplies. Among many reasons, these could be ranked to be the basic ones:

a) Majority of water supplies are managed by the government, ministry or departments. Decisions are made centrally and implemented at regional or district level. The implementation level lacks authority to control daily activities.

b) The policy has been that in rural areas individual connections have been discouraged (Katko 1989). Some governments favor the idea of providing free water to the rural community assuming that consumers cannot afford to pay for water services. Establishing and maintaining a metering system requires substantial foreign investment, which would otherwise overburden the already poor if they have to pay for water services.

c) Technologies used in most of the rural water schemes do not influence the use of water meters. For example it is not economical to use meters for rural water supply using hand pump technology.

In cities where water metering has a long history, the problems existing are still out of reach of many water utilities.

The following are the problems encountered:

1) intermittent water supply
2) lack of continuous metering and control of water supply networks
3) poor water quality
4) lack of trained manpower for operation and maintenance
5) dependence of importation of spare parts and replacement metres
6) lack of equipment and transport
7) lack of decision making and autonomy for setting local water charges
8) failure to collect revenue.

Bhattacharya (1982) outlined non-quantifiable auxiliary benefits which are not evaluated by developing countries, but are of great importance in determining the service level of a distribution system:

1) Meter reading helps to understand consumers' water use patterns. This is necessary to forecast future growth of water demand.

2) Meter reading at established or scheduled intervals serves as a reminder that water has a cost. The customer is compelled to use water more economically.

3) Reduction in use as a direct impact of metering may give rise to surplus capacity of an existing water supply system. Supply may be redistributed to increase the service level.

4) Data keeping may be enhanced by metering. Such data are daily per capital consumption, percentage of population served, per capita cost of water supply, etc.

1.2 Objectives of the study

To sustain a water metering system the following aspects are important:

1) appropriateness of the meters in use
2) management practices - operation and maintenance
3) attitude of the customers towards the use of water meters
4) political influences.

Importance of evaluation emerges to reflect how the system is behaving compared to established objectives. The primary objective of this study was to look into the performance of water meters in Dar es Salaam water supply distribution network, so that the results may be utilized by interest groups and users striving to balance capital outlays and revenues.

The study had the following specific objectives:

1) to assess the acceptability of water metering practices as a guide to establish undisputable charging units for supplied water

2) to define specific water metering problems associated with current development of water meter designs suiting industrialized countries

3) to assess the competence of developing countries to cope up with development trends of the water meter industry

4) to establish features necessary to develop an appropriate type of a water meter for developing countries.

To achieve the above objectives, the study covered the following:

a) Functional evaluation

This covered the performance evaluation of existing water meters. Review of the practices in sizing, selection, installation, replacement, operation and maintenance. Further, analysis to determine functional problems of water meters was conducted.

b) Assessment of management effects on metering practices

This covered:

1) planning and demand forecast
2) consumers knowledge, attitudes and practices
3) management practices.

c) Field study

1) defining operational problems, readability, reliability of data recording in direct meter reading system, detection of theft of water, etc.

2) suitability of the meter in local conditions, e.g. high temperatures, humidity, fluctuations in pressure levels, etc.

3) effects of water quality on water meter performance

4) effects on water supply status e.g. intermittent water supply and continuous water supply.

2 ASPECTS OF WATER METERING

2.1 Water meter types

Water meters are designed to provide, without the need for calculations or any manipulative skill, direct information regarding the quantity of water flowing through the pipeline. The volume of water can be indicated by pointers moving over dials, by counters or recorded automatically on a chart. Attachments for automatic remote transmission of readings may be provided.

Water meters can be categorized based on quantity (total flow or volume) and rate of flow. The quantity meters are those which indicate in units of volume the quantity of liquid that has passed through the pipe in the interval between two successive readings. The rate of flow meters indicate the discharge along the pipe in units of volume per time. The former category is the one used in the water distribution system.

Quantity meters are divided into two main groups: positive or displacement meters and inferential or turbine meters. One sub-group used is a combination of the two meters in parallel to form compound meters. It is also possible to categorize meters according to their use. Actually they fall almost under the same groups as may be seen later.

2.1.1 Positive or displacement meters

Positive meters are those in which the recording of the total flow is based on counting the number of times that measuring chambers of known volume are successively filled and emptied. Because of this phenomenon they are sometimes called volumetric meters.

Measuring chamber or set of chambers is the basic element of a positive meter. Several designs have been developed and used in the field of water supply. Such designs are disc meters (Figure 1) and oscillating piston meters (Figure 2). Close fit between the moving parts in the measuring chambers is the governing factor for accuracy of the meter. Of these parts, the cylinder (chamber) is the most desirable, because it enables some kind of seal or parking to be provided between piston or disc and the walls of the chamber. Modern displacement meters have capillary seals rather than packing seals to prevent slipping which might impair low flow accuracy (AWWA 1986 a).

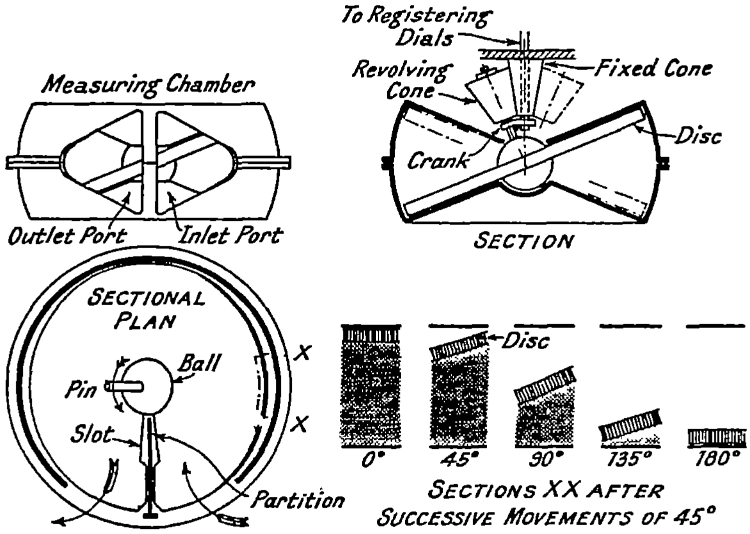

Figure 1. Disc meter (Kent Meters Limited 1988).

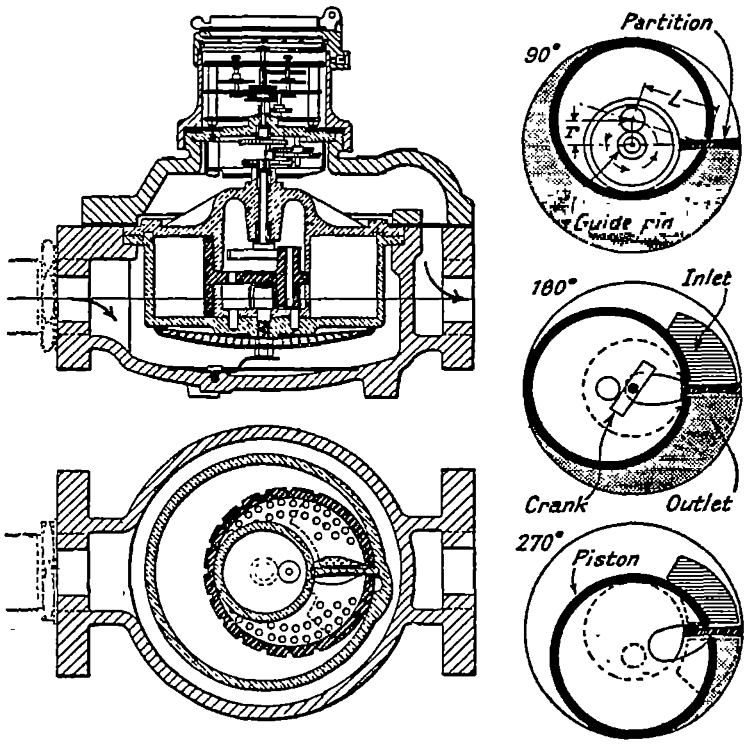

Figure 2. Oscillating piston meter (Kent Meters Limited 1988).

2.1.2 Inferential or turbine meters

Turbine meters are sometimes referred as propeller type meters. The measuring element is a rotor or propeller facing upstream (Figure 3), which is rotated by the velocity of water striking its angular blade. Based on its simple operation the inferential meter is regarded as a miniature hydraulic turbine working under no load. Especially in large sizes the propeller may be smaller in diameter comparing to the internal diameter of the pipe. This is intended for the main line services were flow rates do not change abruptly, as the propeller has a slight lag in starting and stopping.

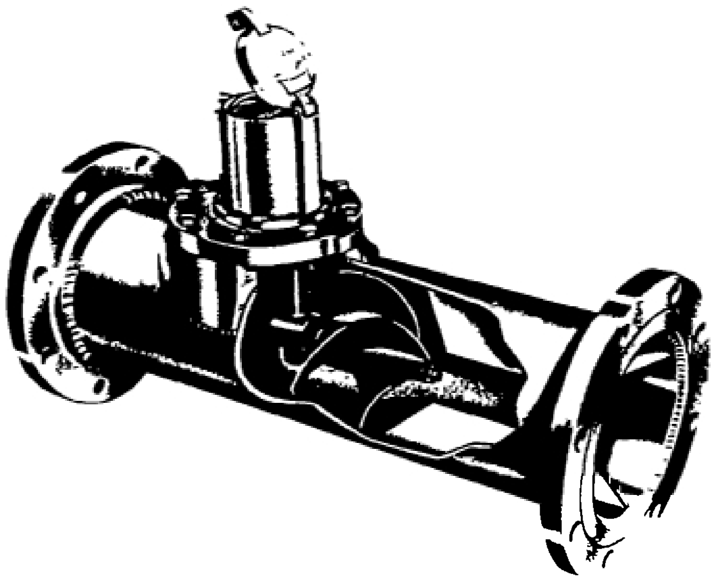

Figure 3. Propeller meter (AWWA 1986 a).

Various methods of transmitting motion from the propeller to the register unit have been developed, e.g. magnetic drive, gear train drive, etc. The magnetic drive eliminates the gear trains from the main casing and uses a magnetic unit to transfer the motion to the register. The main achievement in this design is that the register is sealed against air and moisture. The inclusion of the register with its high impact resistance lens reduces both fogging and breakage of the lens, and corrosion of the working parts. The conversional gear train transmission can be run dry or wet. This had been used to sub-divide the meter into wet or dry type. The wet type has its working parts submerged into the water to be measured. In case of turbid water this type of a meter can be easily clogged.

2.1.3 Compound meters

A compound meter includes a meter of large capacity placed in the main service line to register larger flows and a smaller by pass meter to measure small flows. Automatic valves are also included for diverting the small flows to the by-pass (Steel and McGhee 1979).

Compound meters are basically turbine meters meant for large flows to industries and commercial areas. The inability of these meters to detect small flows below 1/20 of their normal discharge can be remedied by using one small and one big meter in parallel (Figure 4). This arrangement necessitates the reading of two dials and the arithmetic addition of the two registrations gives the total quantity of water passed through the pipeline.

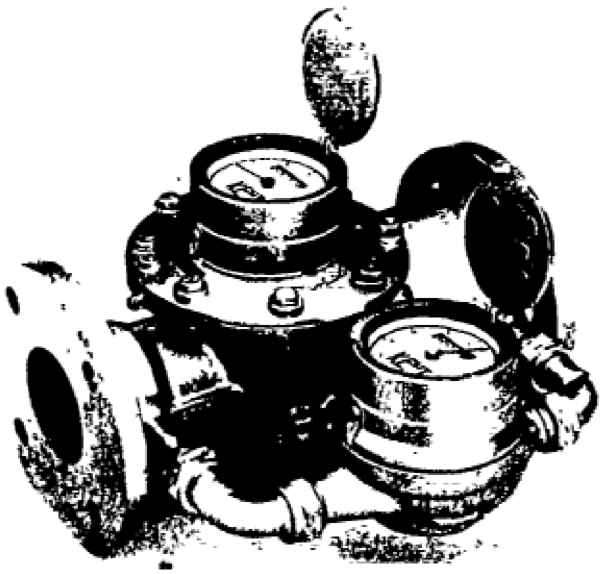

Figure 4. Compound meter (Smith-Vargo 1989).

2.2 Meter sizing, selection, installation and testing

The binding of the meter turbine, disc or piston usually renders high capacity meters placed in low use service line unserviceable. Such cases are common where over capacity meters are installed, either upon insistence of the customer as he/she wishes to ensure receipt of sufficient pressure and flow or due to over design. Failure of these meters to operate properly will result to increased non-revenue water and maintenance costs due to stopped meters. On the other hand, undersized meters will cause customer complaints, excessive wear on the meter, high maintenance costs and poor publicity of the water utility. Such incidence may be avoided by following established criteria for sizing, selection, installation and testing.

2.2.1 Meter sizing and selection

The selection of water meters involves both size and type of meter. The selection of meter size does not mean matching with the pipe size. The pipe is usually oversized to allow possible future increase in water demand or just to reduce pressure losses in a long pipe. According to AWWA (1986 b), the type of the meter is determined by the range of flow rates, plus allowable pressure losses and possibly inclusion of safety requirements, e.g. fire service regulations, etc.

The flow rates are classified as small flows, medium flows and large flows. Most residential services are small flows metered with 16 mm (5/8") size having 20 mm (3/4") connections. Various manuals have been developed and used by design engineers. JICA (1991 a) recommends the meter selection based on planned maximum daily demand (Table 1).

Table 1. Selection of types of meter (JICA 1991 a).

Size mm (inch)	Meter type	Maximum daily demand m^3/d	Regulated maximum flow m^3/h
13 (1/2)	straight line, inferential	6	1
20 (3/4)	dual-pipe, inferential	12	2
25 (1)	dual-pipe, inferential	15	2
40 (1 5/8)	vertical, axial flow	48	8
50 (2)	vertical, axial flow	120	25
75 (3)	vertical, axial flow	240	40
100 (4)	vertical, axial flow	360	60
150 (6)	vertical, axial flow	720	120

Knowledge of data about the customer's maximum probable water demand is essential in meter sizing. The customer's service line from the meter to the building must be examined to assess whether or not it is adequate to supply the peak demand. If the pipe is not of sufficient size, changes must be suggested. Otherwise the water utility may wish to refuse service pending installation of the proper size of pipe. AWWA (1986 b) recommends the system design to be based on provision of adequate pressure at the consumer's meter outlet during the period of highest demand.

2.2.2 Meter installation

Poor installation may cause the meter to be under mud or ground water, thereby creating difficulties in reading, replacement and maintenance. Water meter for customer services are installed in two basic ways: indoor and outdoor setting. In an indoor setting the meter is installed inside the customer's premises, usually in the basement. In an outdoor setting, the meter is installed underground in a pit (Figures 5 and 6) or meter box which is usually located under the curb end of the service line. According to Manson (1989) it is cheaper to install meters indoor even if an out reader is used. They are easier for the customers to read, less prone to vandalism and less problematic to common services, e.g. repair of leaks and replacement. Outdoor installations are relatively free of access problems, a distinct advantage when it comes to reading and maintenance.

Albro (1985) concluded the following features to depict a good meter setting:

- protection against environmental hazards, particularly freezing, excessive heat and vandalism
- convenience for reading
- easy accessibility for maintenance and replacement
- should not be unobtrusive as possible and offer no hazards to pedestrians or to customers.

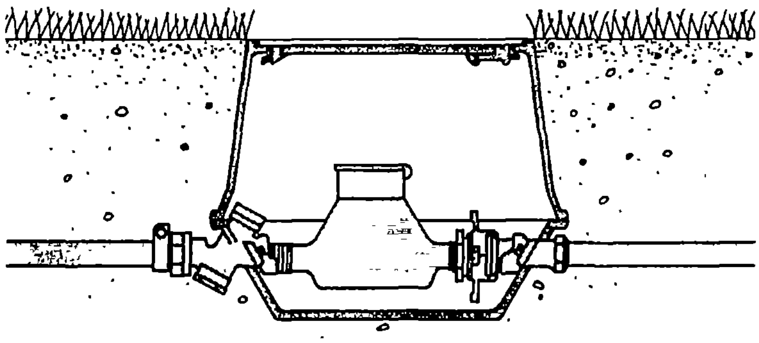

Figure 5. Outdoor meter setting with integral yoke (AWWA 1986 a).

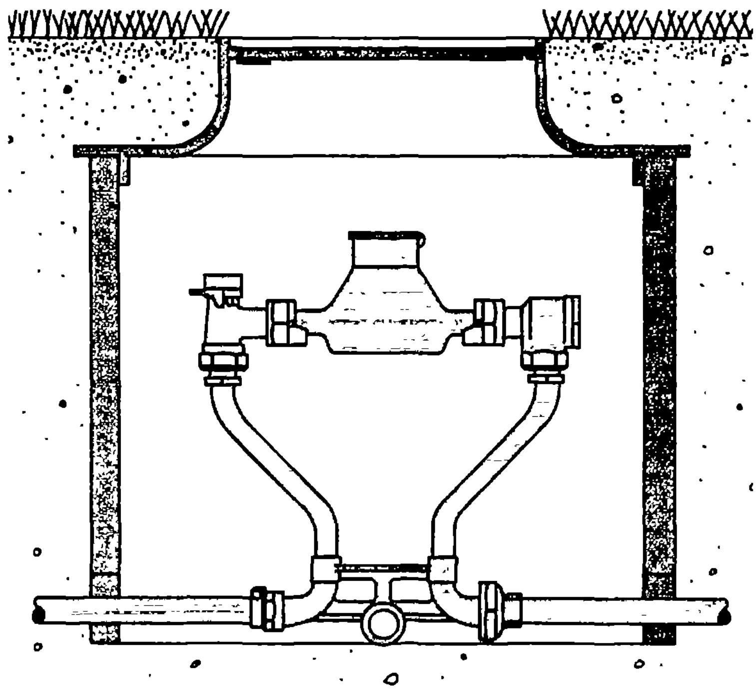

Figure 6. Outdoor meter setting with meter yoke (AWWA 1986 a).

There are advantages and disadvantages resulting from the two settings. Advantages of outdoor setting are (Albro 1985 and Brainard 1985):

- The meter is always accessible. There is no need for entering the customer's premises for inspection, reading and replacement.

- Since meter box lid can usually be locked, only utility personnel have access to the meter, hence safe against vandalism.

- Reduced in-house hazards, e.g. fire.

Disadvantage of outdoor setting may be summarized as (Albro 1985 and Brainard 1985):

- High costs for protection against hazards, e.g. frost during winter, storm run-off, etc.

- If box lids are not properly secured, pedestrians can step into the open pit resulting liability problems for the utility.

For the indoor setting, the main advantages are:

- excellent protection against cold weather during winter (Albro 1985)

- lower installation costs (Albro 1985)

- reduced damage and maintenance costs due to elimination of exposure to outdoor conditions (AWWA 1986 a).

Disadvantages include (Albro 1985):

- The meter setting is not completely under control of the utility, therefore prone to high risks of vandalism and tempering.

- Missed readings due to entry problems.

- Unregistered service line leaks can take place between the main and the house. There is always a question of whose responsibility it is to repair leaks.

Large meters are used where high flows of water are required. With large water meters there is a potential revenue in jeopardy if it does not register properly. Assuming that an accurate, carefully selected large meter is to be installed, it is worth to observe water meter design parameters that affect installations. AWWA (1986 a) noticed large water meters installed horizontally, to work best when there is a swirl free, uniform flow velocity profile in the pipe immediately upstream of the meter.

Brainard (1985) recommended the following for optimum life and best accuracy of large turbine meters:

- Piping upstream of the meter should be straight and to standard as per meter manufacturer's specification to minimize the flow disturbances in the meter.

- Piping downstream the meter may disturb the flow upstream of the meter. Therefore no fittings that will cause low disturbances should be bolted directly to the meter's outlet flange.

- Shut-off valve should be provided for isolation of any meter installation, because eventually maintenance will be required.

- Control valves of any form should be installed upstream of the meter regardless of the piping separation.

- Strainers upstream the meter are essential to protect the device against possible damages and also to assist in correcting upstream flow disturbances.

- By-pass around the meter is necessary if water services must be maintained at all times.

- Periodic accuracy testing is important for large water meters than for positive displacement, because the revenue loss through an inaccurate large meter can represent a considerable amount.

- Flexible couplings are recommended to prevent problems of dismantling and settling of pipe after a period of time.

2.2.3 Meter testing

Meter testing may be carried out in a workshop or in the field. Meters should be tested to protect the customer against meter inaccuracy that result to overcharges. Conversely, the water utility looses revenue if meter inaccuracy results to undercharges. The method used to determine the optimum number of years a meter should remain in service between tests, is to test 5 % of meters scheduled for next periodic testing under an existing testing program. AWWA (1986 a) suggested that if the results of the tests fall within the accuracy shown in Table 2, it can be assumed that the remaining meters would produce the same average test results.

Table 2. Required accuracy limits for compliance with guidelines (AWWA 1986 a).

Meter type (all sizes)	Accuracy limits as found by test	
	Normal test flow rates %	Minimum test flow rates %
Displacement	96 - 102	80 - 102
Multi-jet	96 - 102	80 - 104
Propeller and turbine	96 - 103	not applicable
Compound and fire service	95 - 104	not applicable

All new meters should be tested for accuracy of registration at low rates and test flow quantities, in accordance with manufacturers recommendations before they are put in service. Further a program of periodic testing should be established. It is advisable to provide more frequent tests for large meters, because an error in their registration affects revenue to a much greater extent. The cost effective time to replace a meter in the system is revealed only in an on-going meter testing program.

Field testing is essentially the same as workshop testing, except that instead of using a tank for the test water, a comparison is made between the meter to be tested and one that has been previously calibrated. Field testing is used for convenience, and especially for meters which require large quantities of water and if facilities at the shop are not adequate. AWWA (1986 a) advised to field test all sizes of compound meters and those larger than 50 mm.

2.3 Methods of controlling unaccounted-for water in the distribution system

Unaccounted-for water (UFW), also known as non-revenue water (NRW), was defined by Jeffcoate and Saravanapavan (1987), as the difference between the water delivered into the distribution system and the volume of water consumed that can be accounted for, whether metered or not metered. This definition may be expressed in formula form as:

$$UFW = T - (M + uP) \tag{1}$$

where, T = total water supplied
M = metered consumption
u = unmetered per capita consumption based on estimate
P = population served.

This may be expressed in percentage form as $UFW/T \cdot 100$ %.

There are several methods developed in practice that are used for controlling non-revenue water in distribution systems. The reasons for non-revenue water are many and almost continuous requiring a definite policy for their control. In practice there is no system without unaccounted-for water. Low and high percentages of UFW in distribution systems are used to distinguish between efficient and poorly managed systems. In pursuit of the control policy, strategies are established to contain the magnitude of UFW within acceptable limits. The strategies should cover but not be limited to effective cost recovery policy, provision of incentives and staff motivation, leakage control, corrosion control, maintenance and replacement of facilities.

2.3.1 Effective cost recovery policy

The cost recovery policy should stipulate mechanisms necessary to mobilize input resources in order to maintain the services. Such mechanisms if introduced and administered correctly should lead to more efficient operations of development projects. Developing countries are not yet fully committed to the "user pays principle" applicable in developing countries.

When citing Rimer and Associates 1970, Katko (1991) gave an example of Eastern African countries. Since achieving independence, these countries adopted the policy of supplying water totally or, almost, free of charge to rural and urban fringe consumers. In Tanzania for example, it took more than two decades to realize that this policy is not sustainable. In 1965 the government of Tanzania took over the investment costs and in 1970 the operation and maintenance costs were also taken over (Katko 1989). Absence of an effective cost recovery policy acts as a disincentive to proper use of facilities and resources, because the subsidies provided by the government tend to lead to dependency. To create independency cost recovery measures must be adopted and utilized. If financial subsidies are to be provided they should be justified.

Water authorities employing the "user pays principle" are required to consider economic efficiency in the formulation of pricing structures and determination of tariff levels. They should also consider environmental and conservation objectives, need to raise sufficient revenue to cover costs and creation of equity (United Nations 1981, cited by Katko 1989). Katko (1989), noted the concept of equity or fairness to be complex, and urged that it must be approached differently depending on situations. He, however, stressed the need for developing countries not to provide the basic need consumption free, but rather at a fairly low rate. The bigger consumers should be charged at a higher rate per volume consumed.

Revenue raised by water utilities must cover operation, maintenance and investment costs. In Dar es Salaam other costs such as current depreciation as well as earning the opportunity cost of the public sector capital are being considered in recent inflation accounting (SAT 1991).

2.3.2 Provision of incentives and staff motivation

Limited financial resources in developing countries has caused most of the water authorities to oversee the need for provision of incentives and motivation of their staff. Control of UFW is a continuous process requiring investment in human and financial resources. In developing countries where manual operations are still widely used, employees need incentives to approach their task with enthusiasm. The most valuable approach is the day to day maintenance, which can be effectively accomplished by motivated staff. Public recognition works equally effective as financial rewards. Each aspect works better when employed in its right place at the right time.

Training of staff may be employed in a motivation package. The fact that facilities for operation and maintenance are used by few who are skilled, training of additional people will motivate them. Acquisition of such a knowledge may lift one up to a better working environment. Some may have picked up the knowledge gradually and use such facilities ineffectively. The management should pay interest to improve their skills. If selected carefully, only a few persons can play a key role in organizing the intensified training of additional operators.

Use of latest technology in modern water undertakings, has altered the status of engineers and technicians engaged in water supply so that they are now key employees. This is recognized as an incentive to effective managements and control, unfortunately unknown in many developing countries. Jeffcoate and Pond (1989) proposed that latest emerging technologies and proposed installation in developing countries should be planned to overcome possible operational problems. The immediate plans, however, must always be to improve things slowly where that seems possible.

2.3.3 Leakage control

Leakage control is feasible when the entire supply network is monitored and pressure controlled. It is indeed an expensive undertaking, requiring effective tools and equipment besides skilled personnel. Usually an estimated amount of UFW should be known in order to detect and finally locate leaks. Whenever the estimated allowable value is exceeded it is recommended to conduct an appropriate leakage control measure. According to Bays (1984) the following methods are used in leakage control:

- passive control
- regular sounding
- district metering
- waste metering
- combined district and waste metering
- pressure control.

Passive control is used without the need to measure or detect leaks. Leaks are repaired when reported either by the public or the utility personnel engaged in other tasks. The reporting can be through goodwill if the public notices visible leaks, or through complaints of no water flow or low pressure. In most cases the invisible leaks may cause a considerable water loss.

Invisible leaks are difficult to detect, requiring special equipment and skills. They may be through valves, service connections or pipe busts. In this case the sounding technic used by trained inspectors is employed by systematically working around the distribution system. The technic requires listening and distinguishing the characteristic noise of leaking water. According to Bays (1984), regular sounding is relatively inexpensive method, and therefore most effective in areas where the value of saving water is fairly low.

In district metering the supply zone is sub-divided into small convenient districts and the flow to each district is permanently supplied with water through a metered line. The meters installed at strategic points should be read at regular intervals. Jeffcoate and Saravanapavan (1987) cautioned that the districts may be completely isolated except for the meter entry points. By selecting the areas where the leaks are likely, the authority may wish to include as many properties as practicable. The normal range is between 5 000 to 10 000 properties (Bays 1984). This method is accompanied by a disadvantage, that selecting leaking districts would make the high consumption become the normal figure for that district. The strategy used to curb this, is to convert the metered flow into liters per property per hour say for a day, and basing on the district with high figures the investigation is conducted immediately. It is worth to note that district metering is not sensitive to increased leakage, neither does it determine the position of the leaks very closely (Bays 1984).

Waste metering has the merit of detecting the occurrence of small leaks. Bays (1984) recommended this method to be applied in areas where the value of water saving is very high. This is because much time may be spent in areas where no leakage has occurred since the last test. This is an expensive undertaking which must be justified only after considering the cost-benefit of the exercise. The method involves dividing the district into smaller areas. By test isolation, the flows to all these areas of the system can be checked regularly and any unaccountable changes investigated. Jeffcoate and Pond (1989) recommended 1 000 properties in these areas. When the correct valves are closed, the area can be supplied by a single main in which a waste meter can be installed capable of measuring low rates of flow.

Measurement of night flow rates helps to identify possible leakages in the system. In this respect the waste meter either installed on a bypass or mounted on a mobile truck, may be used by connecting it to the main by means of hydrants. The recording type meter is left in operation when the normal flow has ceased say at midnight, to record minimum flows. If there has been significant increases in flow from previous test in the same district, then further investigation should be conducted. By stepwise shutting the valves in the entire waste district, the point of leakage can be pinpointed to a particularly small section for sounding and location. Bays (1984) recommended to take measurements at least twice a year or even more frequently. A combination of waste and district metering is another possible method.

Pressure control ensures the system against the possibility of surges in the pipe line. Especially where intermittent water supplies are experienced, the pressure surges are difficult to prevent. There is evidence that where high pressures exist, the probability of having leaks and bursts is higher. Jeffcoate and Saravanapavan (1987) identified the phenomenon where the pressure-flow relationship did not follow formulas established. Instead the relationship formed a curve (Figure 7). The phenomenon was attributed to the tendency of orifice size to increase with pressure. This explains why the leakage increases with pressure.

Pressure reduction as a method of leakage control, should be carried out carefully because it might have a negative effect on service level (Bays 1984). Pressure reduction may be accomplished by the following methods:

1) maintaining desired pressure level on the downstream side by installing automatic pressure regulating valves

2) use of break pressure tanks

3) by dividing the supply area into pressure zones

4) reinforcing the network to minimize friction losses and permit operations with reduced working pressure

5) introducing pump speed control or other means of reducing night flows.

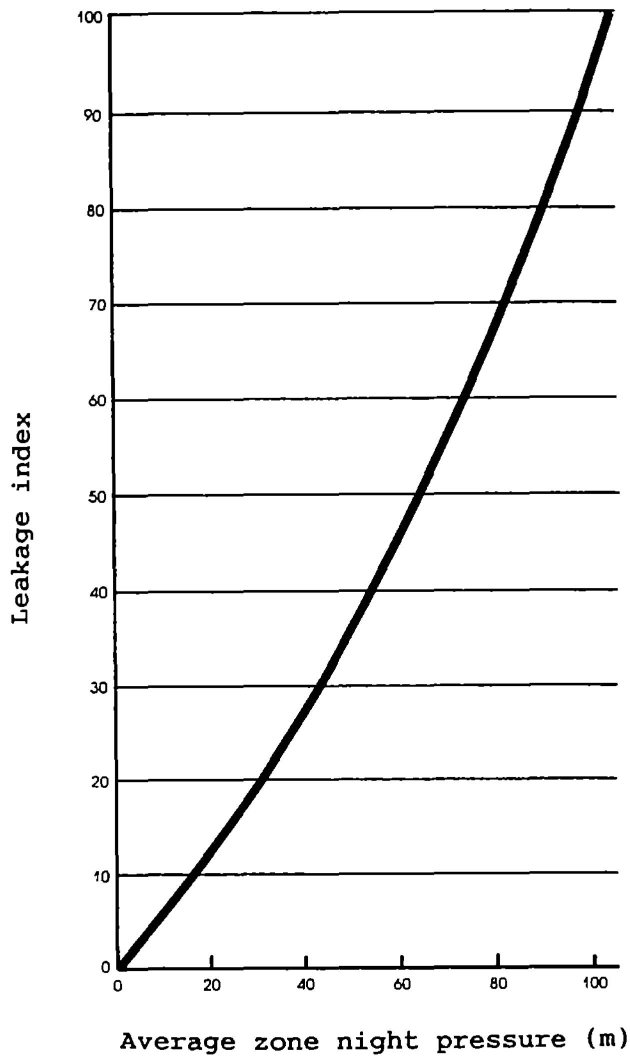

Figure 7. Typical relationship between leakage and pressure (Jeffcoate and Saravanapavan 1987).

2.3.4 Corrosion control

Corrosion of pipes and accessories can be a major source of water leakage in the system. Especially in high pressure zones,new pipes and accessories must be protected against possible corrosion. O'Day et al (1986) remarked that it is not economically feasible to protect old pipes, unless those with significant remaining life in areas of highly corrosive condition. Unfortunately the pipelines are normally buried some meters below the ground, which requires higher replacement and maintenance costs.

Corrosion of pipes happens either internally or externally. If the pipes (especially iron and steel) are not internally lined with anticorrosive material, the thickness of wall is gradually lost by corrosion. The internal wall of the pipes which are not homogeneous will create a corrosion cell with water in contact. The external corrosion of pipes results after the pipe-soil corrosion cell has been formed. The extent of corrosion depends upon the resistivity of the soil which is affected by the soil type and the moisture content of the soil (O'Day et al 1986).

Protection of pipe corrosion in practice is trying to limit the formation of the corrosion cell around the surface of the pipe. For internal protection, nonmetallic materials have been used extensively, e.g. cement lining. Another method used is the application of corrosion inhibitors to the water prior to distribution. O'Day et al (1986) enumerated commonly used inhibitors to be: phosphates, silicates, calcium hydroxide, sodium hydroxide, sodium carbonate and sodium bicarbonate. External corrosion are protected by: control of galvanic and impressed electrolysis, cathode protection, polyethylene wrap and the use of plastic and epoxy coatings. Polyethylene has been used to provide a barrier between the pipe and the soil. Plastic and epoxy coatings have been utilized in much higher corrosive areas.

2.3.5 Maintenance and replacement of meters

To maintain an effective water metering system a comprehensive maintenance and replacement program should be preplanned and effectively implemented. Like many other facilities, water meters require repair for maintenance soon after installation. There can be a variety of reasons ranging from vandalism, accidents, natural disasters to poor water quality especially in developing countries.

Operational or new meters need to be in stock for immediate replacement of malfunctioning meters if consistent metering is to be ensured. To carry out a continued maintenance program, means of communication, transport, recording and spare parts should be constantly available. Standardization and minimizing variety of water meter brands in the system is an important prerequisite in a smooth operation and maintenance program. This limits the training expenses required for the meter repairers to master each brand in the network.

After laying and maintaining pipes, pipelines must be thoroughly flushed through before fitting a meter. There is a possibility to have foreign matter in the pipeline which may easily clog the meter. Various materials have been recovered ranging from small animals to pieces of cloth. For this purpose, a blank of the same length as the meter is fitted into the pipeline instead of the meter. After the piping has been flushed, the meter can be fitted in its place. To prevent the consumer from fraudulently reversing the meter from time to time, thus making it run backwards and in this way drawing unpaid water, the union upstream the meter can be lead sealed. Where there is a need to maintain service, as to a hospital, commercial or processing industry, a temporary or permanent bypass around the meter is installed (AWWA 1986 a).

Water meter replacement is immediately required once the meter is removed. The urgency of replacement depends on the importance of the service line. Some lines require continuous water supply, for example in hospitals and production lines. In such cases bypass pipes and meters must be provided to ensure continued supply and registration of water supplied (Figure 8).

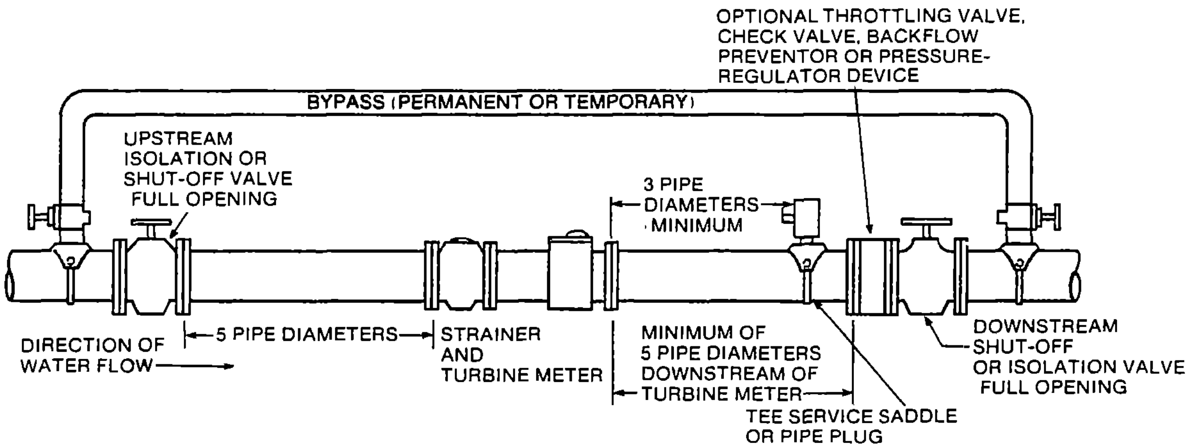

Figure 8. Meter installation with a by-pass pipe (AWWA 1986 a).

In developing countries problems ranging from inadequate financial resources to shortage of material and spare parts have resulted in a rate of implementation far below planned targets. UNDP and the World Bank (1990) identified major unresolved water supply and sanitation issues causing such problems in Tanzania to include:

- unclear and overlapping institutional responsibilities

- insufficient coordination of donor activities resulting in projects and programs with different objectives and approaches

- lack of firm and clear investment, financial and implementation policies and strategies.

3 STUDY METHODOLOGY

The study comprised two main activities:

1. evaluation of water meters in use, based on available literature and information gathered through questionnaires prepared and used in interviews

2. field investigation on selected reference meters working in series with the prototype meter.

In evaluating the water meters in use, practices in sizing, selection, installation, operation and maintenance and replacement of meters were assessed.

3.1 Selection of meters

The assessment of sizing and selection was conducted through interviews to NUWA (National Urban Water Authority) personnel, because the meters selected were already existing in the network.

The target meters selected were those employed in the distribution network. It was not convenient to collect all available water meter types and brands to accomplish the study. The selection was limited to Dar es Salaam and Tanga water supply networks because of time and human resources limitations. The water utility and customers in Tanga were known to complain about the suitability of the meters used in the water supply network. This paid a special interest to investigate how the same meters would behave in other environment like Dar es Salaam.

The target meters in Dar es Salaam were those meters existing in the distribution system. After earmarking the installation sites, all meters existing were taken for recalibration. Each target meter was connected in series with the prototype meter.

The prototype meter originally manufactured by Valmet in Finland is no longer in production (Mäntylä 1991). The working machinery of this meter is not manufactured by modern cheap plastic materials. According to Mäntylä, it is reliable, less sensitive to air flow, less sensitive to small flows and more durable to turbid and aggressive water. This rose interest to have it tested in series with the existing meters.

3.2 Selection of sites

To undertake field investigation, selected sample meters and prototype meters were installed in six strategic zones selected with the help of NUWA personnel. Problems that occurred in practice were recorded and compared with those obtained during interviews. In order to get enough data, a weekly reading system was introduced.

The field study was conducted in Dar es Salaam, the largest city in Tanzania with a population of approximately 1 360 000 according to 1988 census. Dar es Salaam city has got the oldest history of water supply in Tanzania, being established in 1891 (JICA 1991 a). The water meters are known to have been used since the early 1950s. The water supply inherited after independence in 1961 contained mainly water meters manufactured in England, the last colony master. Hitherto various brands of water meters from different countries are found in different water supply networks. This depicts the range of co-operation the country selected to pursue in implementing its metering policy.

3.3 Data collection

Information and data were collected from literature and through interviews. In literature review current publications e.g. journals, books, seminar/conference papers, etc. were used. This supplemented the information gathered from interviews.

The objectives of the interviews were to assess:

1) customers' attitude, knowledge and practices towards water meter utilization

2) acceptability of water meters among customers

3) necessity of water meters utilization in the water supply network

4) management and planning practices in sustaining a metering policy

5) practices in sizing, selection, installation, replacement, operation and maintenance

6) effectiveness of water meter utilization.

Because of limited resources both in terms of time and manpower, a statistical approach in carrying interviews was not used, instead a checklist of questions was prepared. The questions constituting the checklist was developed after consulting a sociologist. In the process of gathering more ideas to formulate an exhaustive checklist, testing was conducted to the Ministry of Water Energy and Minerals (MWEM) personnel. Interviews were conducted by physically visiting the prospective respondents and asking questions following a check list. As the interviews continued, most of the questions were modified depending on the respondent's education level, social status, economic status, international orientation, etc.

The persons to be interviewed were selected based on the following criteria:

1) big consumers of water and especially those who have used water meters for a long time

2) those who show interest to view their opinions based on their previous experience on meter utilization

3) customers whose service lines will be connected with target meters

4) customers who know the interviewer. This may eliminate the possible doubts the respondent might have on intentions of the interview

5) customers and personnel in the water utility whom the interviewer can contact easily

6) social status of the respondent

7) international orientation, e.g. expatriates working in Tanzania.

To assess the operation and maintenance of the water meters, the meter repairers and readers were involved in the program of inspecting and reading meters once per week. It was necessary to cross-check the data collected by anonymously visiting the sites and collecting information. The method was deemed to establish the main problems of the metering system, highlighting the linkage between intended inputs, planned activities and expected results. The method enabled to analyze and define the metering problems, and alternative approaches. The input data mainly resulted from the questionnaires prepared and used in an in-depth study.

4 STATUS OF WATER METERING IN DAR ES SALAAM

Collection of information regarding the status of water metering in Dar es Salaam water supply distribution network was two-fold: use of interview and review of available literature in the Ministry of Water, Energy and Minerals (MWEM) and National Urban Water Authority (NUWA). The following two approaches for conducting interviews were considered:

1) Preparation of questionnaires and distributing them to prospective respondents.

2) Preparation of a check list of questions and conducting interviews. The interviews were conducted by visiting the interviewee and asking questions based on the check list. The check list was modified as the interviews continued.

4.1 Control of unaccounted-for water in the distribution system

Water losses in the distribution system are mainly found in house service pipes, valve seatings and public stand-posts. It is estimated that the domestic water consumption is 57 % of the total water consumption. The total production is 40.3 million gallons (183 000 m^3) per day. According to JICA (1991 b), the losses were estimated to be 25 % - 40 % of the flow in the system. Approximately 14 million gallons per day (62 000 m^3/d) is available for domestic consumption. The following reasons were found to be responsible for water lost and wasted (JICA 1991 a):

1) leakage from reservoirs, pipe mains, appurtenances and service connections and wastage of water in treatment plants

2) unauthorized or unknown use, and wastage of water through disuse or abandoned connections

3) inordinate consumption of water by consumers due to excessive use of water for gardening, washing vehicles, floor, etc.

4) misuse of water for miscellaneous purposes

5) failure to turn off taps in premises, purposely or inadvertently

6) in intermittent supplies emptying of stored water in a receptacle, when fresh water arrives and, keeping the tap open throughout, thus allowing water to go waste

7) unduly high pressures in the distribution system intensifying leakage and wastage

8) water which is legitimately used, but not properly accounted for, e.g. at public standpipes

9) errors in measurements at any stage of production, supply and distribution.

The use of water meters to determine the water supply network efficiency is no longer applied in Dar es Salaam water supply. The method of district metering was applied to detect and control leakages in Sinza area as a pilot project (Mihambo 1992). In this pilot project, several metering districts were earmarked and the flow to each district was to be permanently supplied with water through one or several meters. The meters were installed in carefully selected points and flow in the districts measured. The meters were read weekly during day times and night times, while noting significant changes. Inspectors made sounding of the fittings such as valves, stopcocks, etc. and listened for sounds of leaking water. Initial indicators of the project were promising. The leakages were reduced from the initial 40 % in the area to 25 %. The improvement of this figure could be obtained if waste metering was to be conducted effectively. The waste meter can be installed on a bypass or mounted on a mobile truck which can be connected to the mains by means of hydrants and is used to measure night flows. The team lacked recording meters usually put into operation when the normal flow has ceased say at midnight. The meter is left in place overnight and the minimum night flow can be read from the recorder. The project was abandoned following failure to obtain enough meters as per requirement (Mihambo 1992). Figure 9 shows the plan of the waste district initially used.

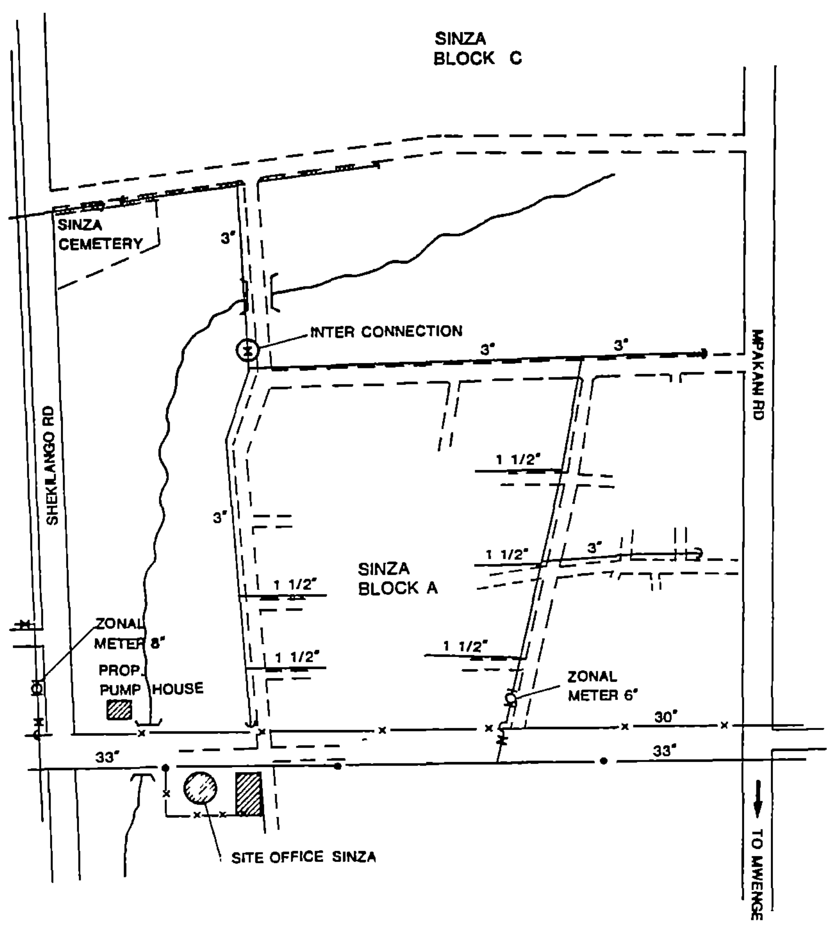

Figure 9. Plan of district metering as designed and used in Sinza area - Dar es Salaam (Mihambo 1992).

The current method used is passive control. In this method, only visible and reported leaks, or those found as a result of reported low pressure, no water supply or of noises in the internal system are repaired. This method has not been effective in reducing the UFW to acceptable limit of 10 %. There may exist areas of high invisible leaks that might not be identified by physical inspection. This method requires reliable transport which fails the exercise to a greater extent. Coupled with poor tools and old equipment only "first-aid" repairs can be attended. Table 3 shows reported against repaired leaks.

Table 3. Cases of leakage reported and repaired in Dar es Salaam water supply distribution system (SAT 1991).

Year	Number of leaks reported	Number of leaks repaired
1984/85	848	807
1985/86	1 072	991
1986/87	1 575	1 299
1987/88	5 831	5 523

Continued monitoring requires substantial investments in human and financial resources. Modern computers enable centrally monitored operations, which assist in managing operations of large schemes. Limited financial resources have always forced developing countries to rely on manual operations. This has limited the operational capacity and efficiency of many projects.

4.2 Practices in planning and management of metering

The outstanding obstacle in provision of sufficient water services in Tanzania is institutional weakness. The problem is that responsible authorities of different projects fail to quantify to extent possible, operational indicators that can be used as corner marks during execution of projects. The governments of developing countries ranked major constraints according to their severeness as (Pineo and Subrahmanyam (1975), cited by Katko 1986):

- insufficient internal financing
- lack of trained personnel
- inappropriate administrative structure
- lack of external finance
- inappropriate financial framework
- insufficient production of local material
- inadequate or outmoded legal framework.

Lack of firm and clear investment policy may be considered the main problem in Dar es Salaam water supply. There is no clear benefit-cost analysis made to justify the water metering investment. Surface water used in Dar es Salaam, is not effectively cleaned to ensure a constant quality. Usually sand and high variations in pressure add an extra cost to the maintenance of meters.

Water supply in Dar es Salaam currently managed by NUWA, is not enjoyed by the entire city population. The authority was established in 1981 as a parastatal organization to manage all urban water supply systems, taking over all activities from the Dar es Salaam Water Supply Corporation Sole. The problem is to improve the water supply to the city by considering the wider social and physical features of the system. In Dar es Salaam, the population and the urbanized areas have increased rapidly in recent years. According to JICA (1991 b), the total water consumption in 1990 was 144 000 m^3/d, of which, 128 000 m^3/d for domestic; 5 000 m^3/d for industrial; 6 000 m^3/d for commercial and 5 000 m^3/d for institutional. Apart from working against an increasing population, it was noticed that water supply suffers from the following:

- heavy water loss through leakages, illegal connections, which results in vending and reselling

- insufficient utilization of existing water supply facilities, e.g. treatment plants, storage tanks, water meters, etc.

- poor raw water quality

- insufficient water supply.

Lindh (1983) commented that when planning it is certainly difficult to account for all the possibly dependent processes which take place in the urban water sphere. Untimely upgrading of facilities coupled with rapid urbanization have rendered the infrastructure services inadequate. In fact that does not prevent the planner from proceeding systematically.

Like· other projects in developing countries insufficient water supply may be attributed to lack of sufficient cost recovery needed to contribute to the system expansion and maintenance of existing facilities.

The history of water metering in Dar es Salaam is made clear by looking at the pavements between buildings usually where installed meters may be found. There can be seen a variety of water meters connected to almost every service line. Getting closer to the site reveals that the majority of them are not operational. Those meters which are not working have been left in place to minimize the replacement costs of meters, fittings and oftentimes pipes that can be broken during connections or disconnections.
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This has resulted to unoperational meters being left in service lines. This practice may be contributing to friction losses in the system and sometimes unnecessary blockings of the pipeline.

Apart from prohibitive costs of metering, low pressure in the system has rendered water metering always impractical. Nevertheless, apart from these drawbacks NUWA maintains water metering to at least big consumers. If NUWA found water metering totally not beneficial, it could have been rejected. This shows that metering has had a great impact on consumers.

According to JICA (1991 a) universal water metering in Dar es Salaam would not be feasible. The study conducted revealed that selective metering of target customers is a better solution. It is thought that this practice would result in 10 % reduction in high consumption house connections. Metering is deemed for water conservation and revenue increase. According to this study, metering high income households would decrease per capita consumption from 1 800 - 1 600 m^3/d. With 15 000 high income households metered, saved water will amount to 1.2 million m^3/a. By distributing this water to other consumers, a monetary gain of TZS 65 million per year will be realized. This is an auxiliary achievement, which according to Bhattacharya (1982), most of the developing countries have always neglected to evaluate.

Water meters should be read once per month and bills prepared according to monthly consumption. The meter readers are required to visit each meter to collect consumption data and inspect them for possible repair needs. Each meter reader is assigned one zone. Not all meters are read or inspected according to schedule. Lack of transport was accused to be the major problem. Another problem is lack of working tools and equipment to enable repairs of water meters for immediate replacement. A consumer may deliberately break the meter so that he may be billed on flat rate if the neighbor is said to pay less based on flat rate.

Some consumers may have water meters operational but not charged according to the meter reading. The customers interviewed revealed this to be attributable to poor management of the meter reading system. Most of the domestic consumers prefer charges based on flat rate because the system has less complications between them and the water utility. Before MWEM intervened, the customers were required to pay their bills regardless of the level of service. It is still difficult to justify how long water flowed in disputed ares and how much water the customer consumed. Some places may not receive water for days or weeks. Water meters are concentrated mainly in areas where water supply is reliable. They are used to test average consumption to develop charging units for the small consumers and justify the basis for the bills provided. In areas where water supply is intermittent it is a common to see non operational water meters. Some have been destroyed by virtue of vandalism, while some were left in position following failure to obtain spare parts. Defective meter removal exercise may cause extra expenses in terms of fittings and replacement of old pipes that can break.

NUWA does not have enough facilities for calibration and repairing meters. The water meter repair workshop built in collaboration with Lodigiani SpA from Italy is nearing completion. It is anticipated that meters will be regularly calibrated in the near future to ensure continued accuracy. Calibration is required because meters gradually become inaccurate with time when in operation. For the meter to work properly, its regular maintenance and calibration is necessary. Due to silt problems and low water velocities in Dar es Salaam water supply, water meter inspection is mandatory during meter reading. There is no calibration activity being carried out for the time being, except if the customer complaints are to be justified. The arrangement used can assure only rough accuracy, but can not be used for continuous meter calibration.

4.3 Consumer knowledge, attitudes and practices

All thirty consumers interviewed were aware of the water meter use in their service lines. Parker (1988) noted attitudes of the suppliers and the supplied to vary very little throughout the world. Without exception all suppliers want their customers satisfied with the service provided. The supplied take for granted the supplier undertakings and feels that water is a gift of nature requiring simple process to provide.

Large consumers (mainly industrial) in Dar es Salaam who have attempted to develop their own water sources realize the costs involved to supply and maintain the service. Through such knowledge large consumers who have opted to depend on the public water supply will do every effort to support the supplier in maintenance of the water service. It is uncommon for that matter to find water meters installed in their premises tampered with. Conversely, few consumers (usually domestic) would risk to tamper with the meter or divert water flow from passing through the meter. Exceptions are public service stand pipes which are usually not connected to water meters.

The questions asked in the interview were directed to assess the public acceptance of water meter utilization to estimate water cost based on established tariff structures. It was revealed that water metering is understood to be the least disputable method of establishing a water cost. It is uncommon to find water meters in the local market.

NUWA procures water meters through the government stores or through international tenders. Any meter out of service requiring replacement means a complicated procurement procedure requiring foreign currency. Consumers usually take advantage of this weakness to break the meters forcing NUWA to charge them according to flat rate. Domestic and small commercial consumers prefer this method, because they can be assured of using excessive water without worrying to pay substantial amounts.

Another cause of vandalism identified was lack of universal metering. The consumer feels to loose money when payments are based on water meter reading, while the neighbor is paying less on flat rate though her/his use is similar. Immediate solution is to break, choke the meter or by-pass it. A penalty against such conducts are usually not effective. Usually a customer will be required to pay all costs for the meter in local currency. As long as water meters are imported, that amount cannot assure replacement of the meter destroyed.

Consumers must be educated and involved in safeguarding water meters and other facilities. Franceys (1990) commented that unless consumers are involved, systems will not be maintained correctly and will fail. Water consumers in Dar es Salaam have known water meters to register volumes of air entrapped in their service lines before water flows through the tap. This phenomenon is highly pronounced in areas where water supply is intermittent. NUWA has constantly advised its customers to close water taps whenever there is no water flow.

Usually the taps are left open whenever there is no water flow. In case the water flows the water drops will alert the consumer to come and store some water ready for the next dry period. This practice permits the water tap to act as an air valve. The air flows through this tap more freely than through air valves provided. The quantity of air passed through the meter is registered. It is true for the reverse when the water supply is cut, that water inertia and gravity force may cause backward flow thereby canceling some of the registered readings. The reverse argument is not true for all occasions because it depends on the land topography.

The conflicting behavior of the water meter subject to intermittent water supply is confusing especially to the customers who are interested in getting water only. To get rid of this confusion the customers choose to destroy the water meter or collude with dishonest meter repairers to remove the meter. As long as water meters are not readily available for replacement, the next move is to bill the customer based on other estimation methods.

Where flat rates are used, it is a common practice to resell water. Reselling is a means of selling water from a private connection or source without any control. The owner of a private connection can sell water at a higher price depending on the area and scarcity of the commodity. Only a small amount of the income which equals the flat rate charge is paid as water bill and the rest is pocketed. This denies the water utility to collect revenue equivalent to water supplied. Water reselling in Dar es Salaam is legal.

There are about 50 licensed water resellers in various parts of the city (Mihambo 1992). Water resellers do not transport water to a customer. The customer comes to buy and transport water by himself. These resellers are licensed to operate provided they pay the bills prepared against meter reading. Legal resellers have a commercial status in the utility. They pay their bills according to the commercial tariff introduced to accommodate the business. Their importance emerged after noticing that they extend the service of safe water beyond limits of the utility.

Despite legalizing to resell water, there are few anonymous resellers who have not registered with NUWA. These are specially found in areas where water supply is not reliable, and for other reasons the water utility is charging them according to flat rate. This causes a considerable loss of revenue as far as the water utility is concerned. Usually they do not consider reselling of water as a formal business, but sells the commodity once the supply resumes. Such resellers are domestic water consumers owning a private connection.

Other tricks used to steal water may be summarized as:

a) Illegal connection

This is practiced where agreements have been made between the owner of a private connection and the anonymous user.

b) Periodic jamming or choking of the water meter turbine

Water meters are usually sealed at the factory or after repair and calibration. Any attempt to access the working parts of the meter require breakage of the seal. If this happens unnoticed its a clear evidence of agreement between a zonal meter reader and the consumer. In usual practice the culprit unchoke the meter periodically and let few readings be registered to satisfy that nothing happened to the account holder. Knowledge of the user consumption pattern and abrupt change of zonal meter readers helps to identify defaulters.

c) By-passing the water meter

A parallel pipe may be used to divert a certain amount of water. This pipe can be buried without water utility personnel noticing unless tipped by someone happening to know what is going on. Knowledge of the water consumption pattern helps to identify the tricks.

d) Reversing the meter against direction of water flow

The consumer may fraudulently reverse the meter from time to time, thus making it run backwards and in this way drawing unpaid water.

4.3.1 Willingness to join and willingness to pay

The mentality of free water services is responsible for failure of any attempt to assume a total cost recovery policy. Already in the early 1970s, Viitasaari (1972) cited by Katko (1991) remarked that it would not be possible to construct and maintain the continuously growing number of water supply systems just as a free service. Intensified public education is required to reverse the mentality. The government has realized that providing free water is not sustainable and is now embarked on cost sharing approach at least in urban water supplies. The spirit of project ownership and responsibility among users is slowly accepted. Still water resources are not utilized economically so that the community would get optimum benefits out of them.

Accepting to cover water costs by consumers is hardly realized because customers feel that the pricing policy does not reflect equity. Thus expenses of low income households are not carefully considered during formulation of tariff structures. The consumers are not educated about the pricing system which results low acceptability of prices introduced. The consumers have no choice because of limited alternative water sources. Through water vending and reselling the public is already paying more than normal water rates.

While questioning water consumers in areas badly hit by intermittent water supply in the city, it came evident that a single household is spending more than TZS 2 000 in an average per month. In such areas like Vingunguti, water vendors use carts with bicycle wheels which can carry up to six 20 l water containers. Water vendors are those who sells and brings water to the customer. The vendors scoop TZS 20 - TZS 30 per 20 l of water depending on the water supply situation. For a family of six requiring 30 l/capita/d on an average, it costs the family TZS 5 400 to 8 100 in 30 days.

The current flat rate requires each household to pay TZS 200 to a maximum of TZS 650 per month. The families part with this money, otherwise they have to walk long distances and waste a lot of time for the water they are not sure to get. This is an indication that water consumers are already paying more. Bigger number of consumers are willing to join if the services can reach them. This is explained when the consumers walk long distances in search of piped water. Alternatively they could use unimproved water sources.

To hasten the expansion of water services, it may be proposed that economically capable consumers should be given reliable water services and made to pay enough revenue which should be used in expanding and sustaining the system. The planning of the water supply must reflect the primary level of service while giving individual users the opportunity to pay for higher levels of service if they require so.

4.4 Effectiveness of water metering

4.4.1 Impacts of water metering

Utilization of water meters have expected impacts. Usually positive impacts must outweigh negative impacts in an economic selection based on worth-cost analysis. Katko (1991) stressed the need to look into the life cycle economics and not only life cycle costs. The life cycle economy considers benefits and costs over the life time to achieve low cost solutions, though not necessarily for every area and every consumer. In water supply the benefits are related to economic effects health improvements and other direct and indirect effects.

To realize effectiveness in water metering, meters should be used consistently and universally. This is not the case in Dar es Salaam water supply. Continued utilization of water meters in Dar es salaam water supply exhibit their importance in the system. The effectiveness of meter utilization in Dar es Salaam is reflected through:

- knowledge of customer water consumption patterns

- established tariff structure based on quantity of water supplied, unit cost for water supplied at least to larger consumers can be established at any time

- monitoring water production, distribution and estimating wastage through leakage, illegal connection, public utility, etc.

- data keeping, e.g. daily per capita consumption, percentage of population served, per capita cost of water, etc.

Knowing the user consumption patterns have helped NUWA to identify insincere water meter readers who collude with the customers to steal water for their personal gain. If water consumption readings obtained through the meter drops suddenly some doubts must be raised, if the account holder has not changed. Necessary measures taken may include changing the water meter, changing the zonal meter reader and or checking the entire service line for possible meter by-passed pipe.

Estimation of domestic water consumption without metering has always resulted either overcharging or undercharging of customers. JICA (1991 a), conducted a study by temporary metering domestic customers in selected parts of the city. It was found that water consumption can vary sevenfold between households, as found out in Kinondoni area.

The consumption varied 495 - 3 500 m^3 per household per day. In this case, the current flat rates of domestic customers, 200 and 450 TZS per month, underrate the water consumption of higher consuming customers. The metered consumption has always exceeded these estimations. It appears interesting to note these effects, and therefore a need arises to verify the methods used to estimate the domestic consumption.

As suggested by Sectoral Advisory Team (SAT 1991), domestic consumers should be metered temporarily after evaluating the cost-benefit of metering. This kind of approach is already employed in some parts of Tanzania, e.g. in Tanga municipal water supply.

Industrial, commercial and institutional consumers identified as large consumers are usually metered. Those who remain unmetered are charged according to the average water consumption observed when the installed water meters were operational, or whenever necessary estimating the average consumption over a period of time by installing test meters. This has considerably reduced the water use and effectively used to silence the otherwise would be angry customers.

Once the customers are informed that the tariff structure is developed based on quantities of water supplied, as per meter reading, it helps to accept the structure. Through water meter utilization the water authority has been able to a certain extent, realize surplus water. Surplus water which has been difficult to obtain, is used by redistributing to other users and is measured by expanded service level.

Monitoring the water production is effectively accomplished. The main problem remains with identifying the loss of water in transmission and distribution system. Water meters are not effectively utilized to identify water losses. Efforts to detect water leakage are accomplished by the use of physical checking (passive control method) along the pipe line. Discussion with NUWA personnel revealed that use of water meters in leakage detection was abandoned due to unavailability of water distribution maps and lack of meters and fittings for isolation.

Illegal connections are limited to areas with less metered connections. Despite having zonal meters illegal connections in such areas are difficult to identify. The authority occasionally embarks on house to house checking to identify illegal connections. The recent house to house connection survey conducted in Kawe area has enabled the utility to update the masterfile. The survey discovered 4 800 connections against the 1 200 known connections (SAT 1991).

Dar es Salaam city is expanding faster than the city planners can ensure infrastructure service coverage. Water meters have helped the authority to keep data necessary for continued future planning. Such data are daily per capita consumption and per capita cost of water.

4.4.2 Tariff structure

Domestic consumers are mostly charged according to estimated water consumption. The charges can vary from the minimum of TZS 200 to a maximum of TZS 650 per month. The minimum estimated consumption per month is 3 500 gallons (16 m^3). The water consumption is estimated by the sub-branch managers and the meter readers.

The tariff structure has been adjusted only twice since NUWA was established in 1981. The tariff structure is not necessarily adjusted when NUWA requests. Proposals for the new tariff are prepared annually and decided by MWEM. The current tariff structure effected in July 1988 based on categories of consumers is shown in Table 4.

Table 4. Tariff structure in Dar es Salaam (SAT 1991).

Consumer category	Tariff TZS/1 000 gal*)
Commercial	192.00
Industrial	248.00
Institutional	90.00
Domestic	57.25

*) 1 000 gal = 4.54 m^3.

Figures in Table 5 reflect the real charge per 1 000 gallons (4.54 m^3) for different customer groups in 1984 - 1991. The tariffs have been adjusted with the national consumer index at 1991 price level. The figures in Table 5 reflect great decrease, attributable to high inflation rate and infrequent tariff adjustments. With this trend of development it is apparent that cash flow management as well as financial planning becomes difficult as income remains the same but expenditures are increasing due to inflation.

Table 5. Real water charge gallons for different customer groups - price level 1991 (SAT 1991).

Year	Rate charged				
	Domestic TZS/1000 gal	Commercial TZS/1000 gal	Institutional TZS/1000 gal	Industrial TZS/1000 gal	Average TZS/1000 gal
1984	72.90	72.90	72.90	72.90	72.90
1985	55.35	55.35	55.35	55.35	55.35
1986	41.85	41.85	41.85	41.85	41.85
1987	55.08	55.08	55.08	55.08	55.08
1988	345.60	447.12	162.00	103.05	264.44
1989	268.80	347.76	126.00	80.15	205.68
1990	230.40	298.08	108.00	68.70	176.30
1991	192.00	248.40	90.00	57.25	146.91

4.4.3 Revenue collection

The house to house survey conducted by the Price Water-house in 1989 revealed 43 % of the houses in Dar es Salaam to have been connected to the pipeline (SAT 1991). The survey was deemed to update the customer database of NUWA. The study identified 55 700 water connections, out of which 32 400 connections were linked to the billing record, with 23 300 connections unlinked. This task which was conclusively done by the Ardhi Institute in July 1991, revealed 75 300 connections. Of these, 63 700 connections could be linked to NUWA records and 11 600 connections were found non-existing in the masterfile. Later the whole data were linked to the masterfile.

Of all the existing connections, only 19 % are paying the water bills. This was identified from receipts and invoices prepared in March 1991 for different consumer groups as shown in Table 6.

Table 6. Amount of connections in different consumer groups invoiced and receipted in March 1991 (SAT 1991).

Consumer group	Number of invoices	Receipts	Paid %
Commercial	2 833	572	20
industrial	550	137	25
Institutional	1 149	298	25
Domestic	58 637	11 393	19
Standpipe	89	18	20
Total	63 258	12 418	19

If the same comparison is made between the invoices and receipts in shillings the figures in Table 7 are reflected.

Table 7. Water bills and revenues in different consumer groups invoiced and collected in March 1991 (SAT 1991).

Consumer group	Water bills invoiced 1000 TZS	Revenue actually collected 1000 TZS	Paid %
Commercial	19 452	8 335	42
Industrial	20 148	8 532	42
Institutional	23 567	7 785	33
Domestic	37 483	25 577	68
Standpipe	154	116	75
Total	100 804	50 345	49

To reflect the idea that revenue collection is not effectively done, SAT (1991) made the following simple estimate:

The city of Dar es Salaam had 345 000 households in 1991, according to Population Census preliminary report. If only half of the lot is connected to the network, the antici pated revenue collection from domestic consumers (average rate TZS 325/household/month) per month would be:

(345 000/2)·325 TZS = 56 225 000 TZS/month.

The amount of receipts in March 1991 was TZS 25 577 000 and the amount of invoices TZS 37 483 000. This shows uncollected revenue of domestic customers per month in an average to be:

TZS 56 225 000 - TZS 25 577 000 = TZS 30 648 000.

The above sum concludes that domestic revenue collection could be more than double the amount collected. With conditions of intermittent water supply, some consumers may go without water in their pipeline for weeks. Because of this The Minister for MWEM, Honorable Lt. Col. Jakaya Kikwete announced that no payment should be made for unavailable water since April, 1991. This could have a negative impact on revenue collection.

The possibility to prove the availability of water supply could be through the meter reading. Since these areas are the ones where meters are not connected (some destroyed to avoid air registration), it would be difficult to estimate the amount of water chargeable. Likely a great number of unsatisfied customers will leave water bills unpaid even if water is running satisfactorily. One suggestion may be introduction of areal meters or group of households metered by a single meter. The monthly consumption can in that case be divided according to the number of households in each group. This may go undisputed if the public is educated and the whole idea is made clear before implementation.

Revenue collection has not reached the expected level in order to meet at least operation and maintenance. Hashil (1988) concluded this to result from:

1) failure to workout the tariff imposed on July 1, 1988 on a cost recovery basis

2) wrong interpretation and application of charges based on flat rate system resulting lower charges compared to metered charges

3) poor customer records.

4.4.4 Joint water and waste water billing

According to SAT (1991) joint billing of water supplied and waste water has not been introduced in Dar es Salaam contrary to the recommendation by the Price Waterhouse study conducted in 1987. SAT attributed this to lack of confidence by the Dar es Salaam Sewage and Sanitation Department (DSSD) towards NUWA's revenue collection. Before the joint billing the study recommended that NUWA should first solve the problems of debt recovery, amendments and delays of bills. Due to poor debt recovery the outstanding balance had reached the level as high as two billion shillings. According to SAT (1991), debt recovery is the core problem of revenue collection in NUWA.

The joint billing approach was to be tried in Dar es Salaam and experiences would set as a guide to introducing similar approaches in other regions (Mutalemwa 1988). The computer software and hardware currently used by NUWA were planned to meet the requirements of both water and sewarage charges collection.

4.5 Practices in operation, maintenance and replacement of meters

Meters in operation will gradually become inaccurate. The rate of decrease of accuracy depends on water quality and type of meter in operation. Usually meters are provided with strainers in the water inlet. The function of the filter is to screen grit particles and debris that are present in water. These filters can assure safety if the particles are big enough to be retained. Encrustation increases with time especially when the velocity of water is very low. Siltation takes place and accumulates in small openings of the meter assembly. In the long run this clogs the water meter.

Different frequencies of removing silt and debris in the meter parts have been reported by local meter repairers depending on the type of water meter and condition of waters. The normal routine adopted by NUWA, to clean silt and debris accumulated in any type of a meter is at least once in two months.

Dry water meters seldom get affected with silt accumulation. Wet water meters operate with all working parts submerged in water being measured. In case of low water velocities, settling of suspended matter may result. Added with grit particles that might not be retained by the filter, the accumulated matter becomes detrimental to water meter operation. The meters should be removed and cleaned and possibly recalibrated to resume their efficiency. The frequency of removal will depend on the water source and seasons, with the rainy season requiring frequent repairs.

According to the meter repair foreman, during rainy seasons the meters require cleaning once in two months in case of Dar es Salaam. Silt formation on the meter dial face causes difficulties during reading. Algal growth on the dial face poses yet another challenge to the meter reader. Such operational problems require substantial investment of manpower and financial resources.

NUWA has a lot of experience in metering. This experience is vested in individual skills that can be displayed when faced with various challenges. For example the water utility has no workshop where particularly meters should be repaired and calibrated. All repair work and calibration necessary are conducted at the field. Perhaps this also contributes to lack of a comprehensive maintenance and replacement program. Lack of transport is the common accuse for all kinds of problems, ranging from lack of disconnections follow up to lack of repair and replacement of meters.

Bearing in mind the need for human resources to maintain operational status of projects, the question of incentives and staff motivation should be given due attention. The Water Policy available in Kiswahili (Sera ya Maji 1991) developed by MWEM emphasizes on vocational skills. It adheres to the national policy which recommends that individual employers develop their own craftsmen through supplementary training programs.

Faced with limited number of skilled staff, NUWA obtained most of its professionals through MWEM. Their continued training have been either through MWEM or sponsored directly by International organizations. To the level of technicians and craftsmen, NUWA in collaboration with Canadian International Development Agency (CIDA), conducts plant maintenance courses at the Lower Ruvu plant. This has helped the authority to obtain specialized skilled personnel for various operations.

There is not a particular place where water meter repairers go for training. They have to relay on their personal innovative skills until the meter suppliers offer to train some. Currently there is only one meter repair foreman who received specialized training in meter repairs in Germany.

Private water companies are almost non existing. This is because water supply was initially considered to be a social service provided by the government. Special training has limited the concerned to remain within the utility even if they lacked incentives. They may lack requisite qualifications to join other non-water organizations in search of green pastures. Since the water utility still depends on their initiatives to undertake various innovative repairs, they can easily paralyze the system. Such incidents may be the accumulation of water meters removed and not replaced in various service lines.

The meter may be disconnected to execute water disconnection campaign, when rejected by the customer or to undergo workshop repair. This happens because of lack of initiative which results partially as a consequence of lack of motivation. NUWA has been operating without facilities for repair and recalibration of water meters. All related activities have been taking place based on personal innovative skills which the utility should have developed. Developing such skills and honoring the concerned may tremendously motivate the working force.

Transport is the major problem encountered in executing daily operations. Employees can spend most of their working hours idle while waiting for transport. In some cases the meter repairers carry tools on their shoulders if the job is pressing and very important (Lutende 1992). Walking is limited to short distances and becomes exhaustive when they carry tools and replacement materials. Provision of reliable transport such as bicycles and motorcycles in this case is a valuable incen tive to the meter repairer.

SAT (1991) noticed the transport as the major cause of enormous financial losses in the water sector. According to SAT internal report, it was observed that employees spend most of their working hours idle, while waiting for transport. The repair of meters cannot be done in time because there is no reliable transport allocated to the section. Whether temporary or permanent metering is adopted, transport facilities should be made available. Programs for maintenance and replacement can not be effec tively honored without reliable transport. Investments on cheaper transport, like motorbikes for senior inspectors and bicycles for meter readers and repairers, could be a better choice. The benefit is vested in speed, convenience and favorable prices.

5 METER INSTALLATION AND DATA COLLECTION

5.1 Meter installation

Before installing the meters, both site and meter selection was conducted. The sites were selected with the help of the NUWA personnel. The activity included visiting various areas identified by considering the status of water supply. The required area was to have a continuous water supply to enable adequate data collection. The condition of intermittent water supply is expected every where, although some areas may still get water more frequently.

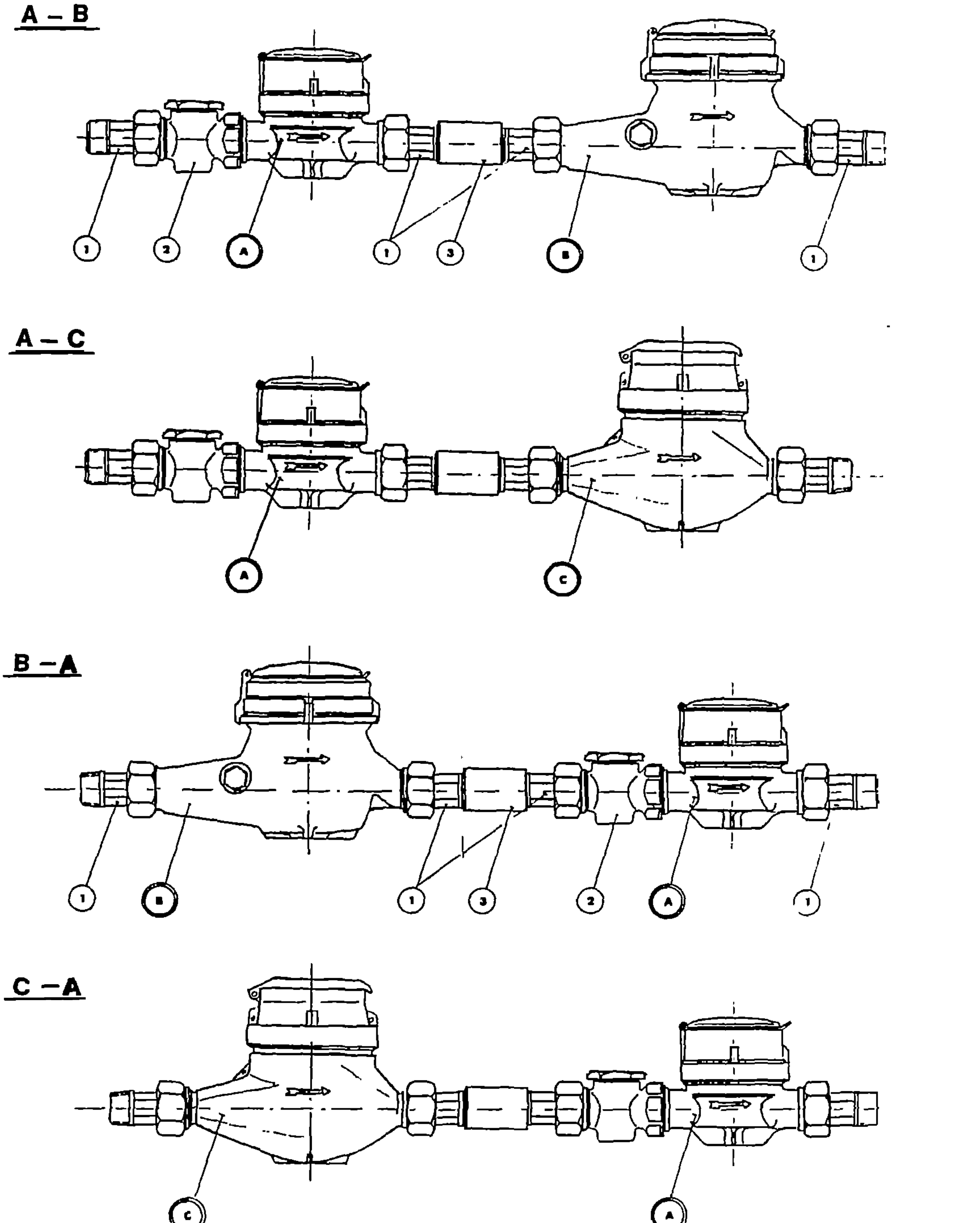
Another factor considered was security for the water meters to be installed. Some areas do not get water through their service lines completely within a month, but are required to pay water bills prepared on flat rate basis. In such areas water meters have either been removed by the water authority or destroyed. The areas affected most by intermittent water supply are Tandika, Tabata and Vingunguti. These areas were not included in the installation strategic zones because the meters would be destroyed, and therefore jeopardizing development of the study. The areas having operational water meters were preferred because the author had to conduct interviews related to prevailing problems of water meters. The water utility maintains metering in these areas because through them the unit charges for small consumers are developed. This is necessary to justify the rates for the bills prepared.

Excluding the areas with intermittent water supply, the sites were chosen on the merit of: where operational water meter existed, possibility to install an additional water meter in series, good accessibility and various use of water. Based on these factors the following strategic sites were identified and finally selected (Table 8).

Table 8. Installation sites selected and respective water uses.

Site identification	District	Water use
Amana Bar	Ilala	Commercial
AISCO Pugu Road	Temeke	Industrial
UWT/Zanaki Street	Ilala	Domestic
Oysterbay	Kinondoni	Domestic
Morocco Road brick factory	Kinondoni	Industrial

The meters were installed by NUWA personnel. It was possible to use private plumbers if authority was available from NUWA. Private plumbers originated from NUWA where they used to work before they were laid-off. They have now formed their working groups with hand tools capable of doing simple installations. These are accused to undertake illegal connections and disconnections pretending to work for NUWA.



Legend:

A = Prototype meter, single/multi-jet, dry dial (Valmet M5-C, Finland)
B = Target meter, multi-jet, wet dial turbine meter (Spanner--Pollux = SPX, Germany)
C = Target meter, 1) multi-jet, dry dial turbine meter (Kent) 2) single-jet, dry dial turbine meter (Bosco)

1 = 20 mm couplings supplied with the water meter
2 = strainer for Valmet M5-C water meter
3 = plain socket 20 mm

Figure 10. Proposed alternative connections of the target meter and the prototype meter used in the study.

The target meters were installed according to the strategic sites earmarked. Those meters which were found connected to the service lines were replaced with the same brand after calibration. Because of limited number of prototype meters (6) only three brands of target meters were installed. The idea was that, each target meter was to be connected alternatively to the prototype meter as shown in Figure 10. Table 9 below summarizes the particulars of the meters used in the study.

Table 9. Particulars of meters used in Dar es Salaam distribution network.

Meter	Particulars of the meter	Country of origin	Category of meter
Kent	Qn = 3.5 m^3/h Size NS 25 mm, KMJ, multi-jet, dry dial	United Kingdom	target
Bosco	Qn = 1.5 m^3/h PN 10, 50 °C Size NS 20 mm, single-jet, dry dial	Italy	target
Spanner Pollux	Qn = 2.5 m^3/h minimum rate = 20 l/h cold water, 40 °C DIN - ISO 4064 Multi-jet, wet dial	Germany	target
Valmet	Qn = 3/5 m^3/h Size NS20 mm, single-jet, dry dial	Finland	proto-type
Valmet M-5C *)	Qn = 5 m^3/h Size NS 20 mm, Multi-jet, dry dial	Finland	proto-type

*) see Appendix 2 for more detailed specifications.

The target water meters found in the selected service lines were replaced by new calibrated meters of the same type and brand. The calibration carried out at the University of Dar es Salaam was aimed to assess the accuracy of the meters before installation. Arrangement for calibration included a target water meter which discharged the registered water into a flume connected with a 60° V-notch. The volumes of water discharged through the target meter were timed by a stop watch and recorded. The same discharge went through the V-notch. By calculating the discharge through the V-notch, volumes of water which were supposed to tally with that of the target meter were determined. Figures 11 - 13 show the behavior of the three target meters according to the calibration conducted.

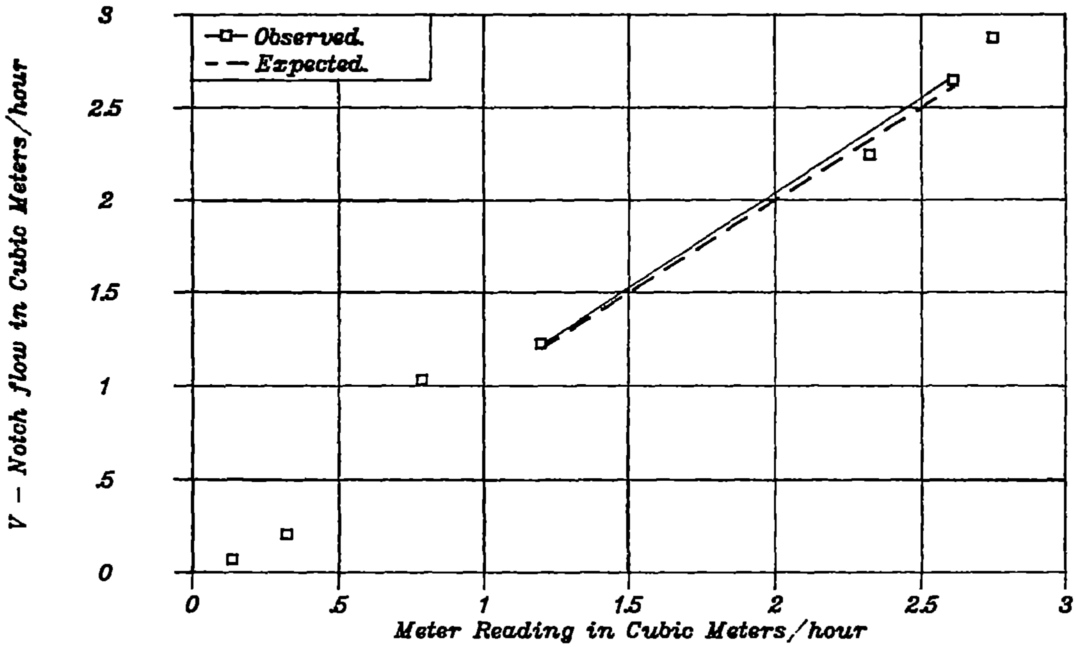


Figure 11. Deviation of registration of Bosco target meter during calibration.

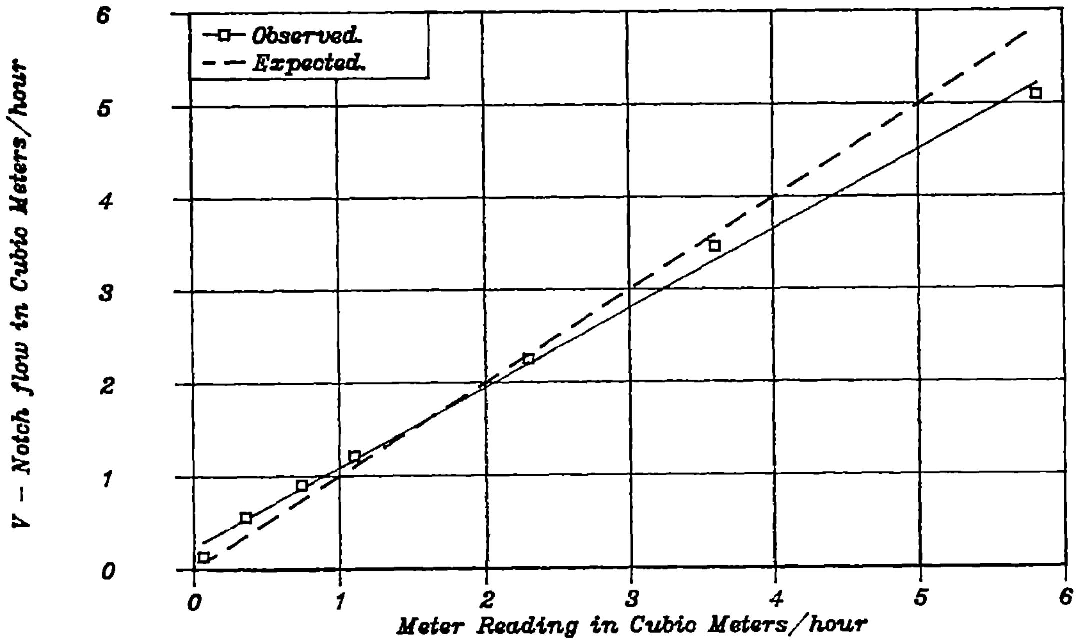


Figure 12. Deviation of registration of Kent target meter during calibration.

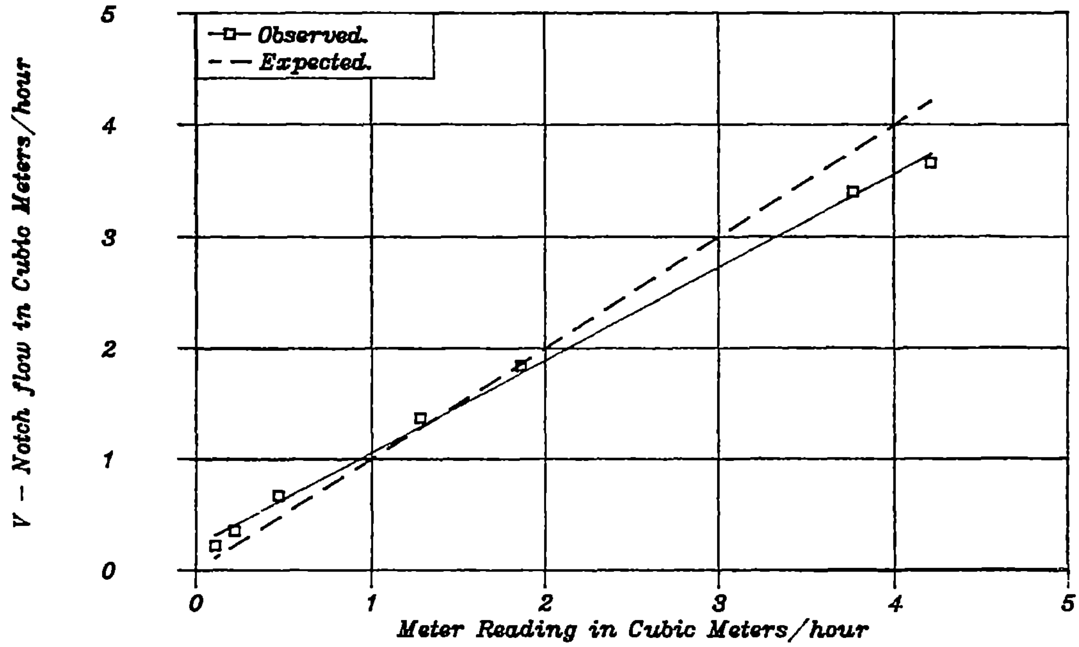
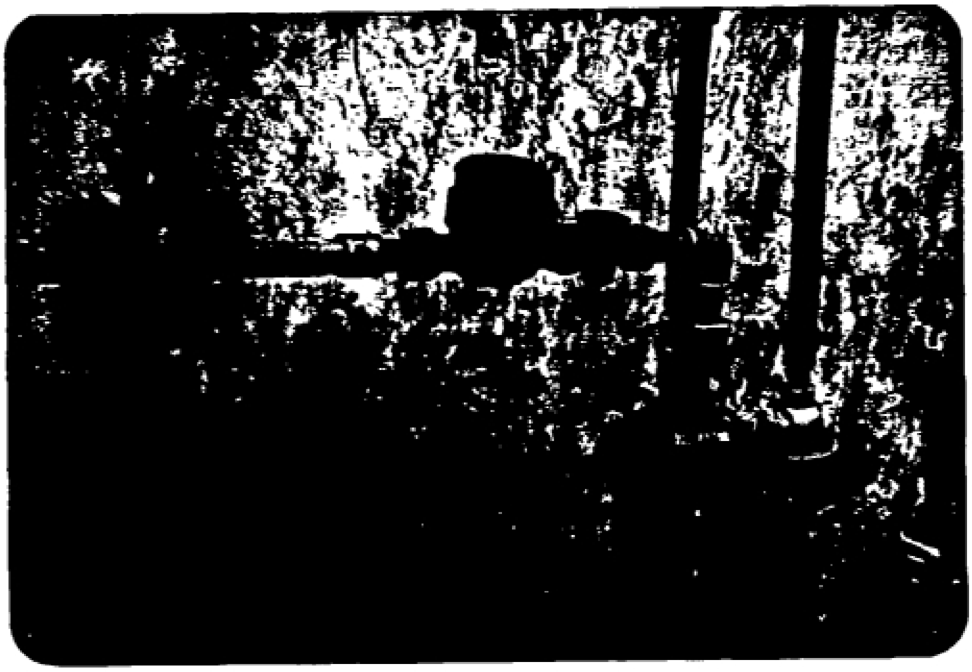


Figure 13. Deviation of registration of SPX target meter during calibration.

Installation conducted in six strategic zones were done according to the previous layout. This move was aimed at assessing the installation practices of the water authority. Some minor modifications were required to accommodate the additional prototype meters (Figure 14).

After each installation water flow was tested to ensure that water supply was normal. Intentions of the double water meter installation were explained to respective customers to maintain good relations. Knowing the previous water meter, the customer was also acknowledged that charges will be based on that same meter.



a)

b)

Figure 14. Installations of the meters in the Dar es Salaam distribution system.

5.2 Data collection

Data collection was carried out with the help of meter readers from NUWA. This enabled the assessment of the meter reading system. The meter reading system used in Dar es Salaam water supply is direct reading. This method is used to record readings manually after physically observing the registered volume on the meter. The readings must be clearly visible to enable the reader to record the actual figures observed. Otherwise the reader has to estimate the readings thereby defeating the whole purpose of metering the service line.

In Dar es Salaam distribution network meters are supposed to be read once per month. For the purpose of this study data were collected once per week. Meter readers from three NUWA branches (Temeke, Ilala and Kinondoni) collected data independently. The investigation focused on the following:

1) readability of the water meter
2) quantities of water registered by each meter
3) water quality effects on meters
4) other effects on the meter, e.g. effects of temperature, humidity, solar radiation, etc.

The data collected mainly concerned relating the consumption of water as registered by the two meters in series. The law of mass flow require the two meters to register equal volumes of water at any time. Other factors were investigated to determine how they affect the performance of the meters as well as the reading method. Subjected to the same environment it is expected that each meters would be affected equally. If this is not the case, a reason should be sought and analyzed to determine its validity.

SPX meters collected from Tanga were accused of poor readability mainly due to accumulation of silt on the dial plate and registration of air as a result of intermittent water supply. Figure 15 shows the situation when the meters are disconnected from the lines ready for service. In this situation one may wonder if the last reading was correctly recorded or estimated. After installing the meter, the same manifestation of the silt formation on the meter dial face was observed. Although the meter was still readable, it was enough to conclude that the meter will not be clearly read in the long run.

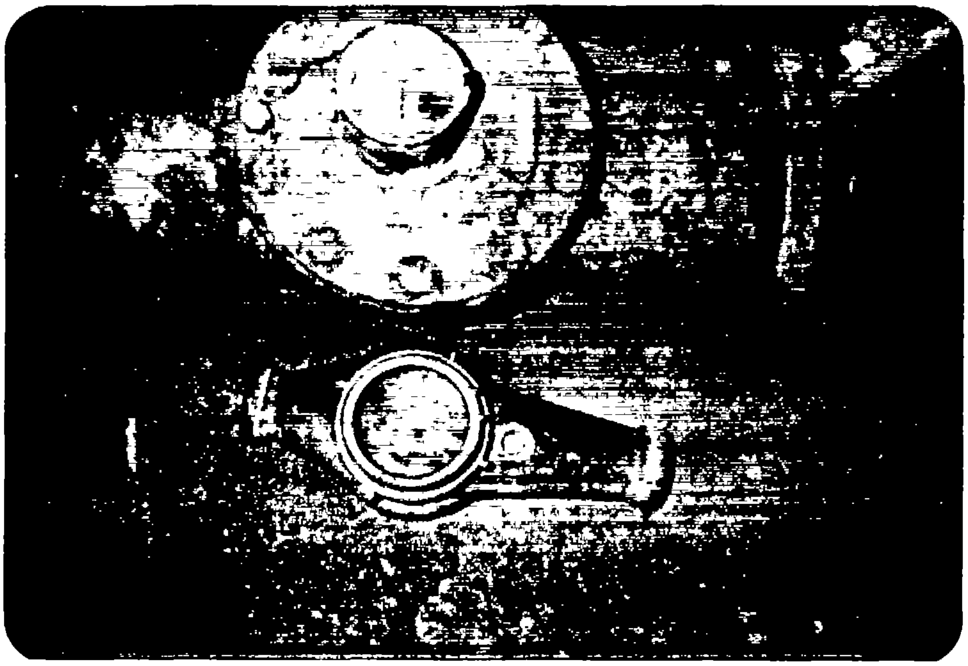


Figure 15. SPX meters removed from the service lines ready for repair in Tanga.

Apart from siltation problem, the SPX meter formed a water meniscus as a result of low water pressure. The meter is to run full of water all the time. If there is low pressure, the meter shows sections which have water and those without. This results in poor readability, requiring more attention and time to accomplish the exercise. The fog or moisture formation under the glass was not a significant problem for the SPX meter. When water runs full in the meter it collects all the droplets under the glass. This may be proved to work better after a long time observation.

The Bosco meter's poor readability was caused by the fog formation under the glass. The design does not permit the water flow over the meter dial face. For the Bosco meter design a mechanism to wipe water droplets under the glass would be appropriate. According to retired water meter repairers, this kind of mechanism was used in older versions. The mechanism constituted a turning knob over the glass and linked to the wiper under the glass. In case the meter reader failed to read due to fog, the knob would be turned once to clear the glass.

The Kent and the prototype meters were read clearly during the observation period. These designs are sealed against water and moisture from entering the glass-dial interface. All meters used in the study were easily read without the need for manipulations or special skill.

6 ANALYSIS AND DISCUSSION OF RESULTS

Tables 10 - 14 show results of the respective consumption data registered by various meters.

Table 10. Consumption as registered by SPX domestic meter versus the prototype meter based on volume on site UWT Road/Zanaki street.

Time in weeks	Volume registered *)		Registered difference **)	
	Target m^3	Prototype m^3	m^3	%
1	6.72	6.44	- 0.28	- 4.35
2	4.49	4.36	- 0.13	- 2.98
3	5.36	4.35	- 1.01	- 23.22
4	4.06	4.89	+ 0.83	+ 16.97
5	3.80	3.88	+ 0.08	+ 2.06
6	3.91	3.79	- 0.12	- 3.17
Total	28.3	27.714	- 0.04	- 0.14

*) series connection with water flowing through SPX meter first

**) the positive sign indicate that the target meter has registered more.

Table 11. Consumption as registered by Bosco domestic meter versus the prototype (multi-jet) meter based on volume on site UWT Road/Zanaki street.

Time in weeks	Volume registered *)		Registered difference	
	Target m^3	Prototype m^3	m^3	%
1	9.60	4.13	- 5.47	- 132.45
2	6.88	2.73	- 4.15	- 252.01
3	7.86	4.32	- 3.54	- 81.94
4	9.24	2.25	- 6.99	- 310.67
5	7.96	3.54	- 4.42	- 124.86
6	7.15	4.10	- 3.05	- 74.39
Total	48.69	20.64	- 28.05	- 135.90

*) series connection with water flowing through Valmet meter first

Table 12. Consumption as registered by Kent domestic meter versus the prototype meter based on volume on site Oysterbay.

Time in weeks	Volume registered *)		Registered difference	
	Target m^3	Prototype m^3	m^3	%
1	75.46	72.50	- 2.96	- 4.08
2	33.04	31.26	- 1.78	- 5.69
3	40.29	37.86	- 2.43	- 6.42
4	43.51	40.73	- 2.78	- 6.83
5	35.32	32.95	- 2.37	- 7.19
6	26.78	25.33	- 1.45	- 5.72
	254.40	240.63	- 13.77	- 5.72

*) series connection with water flowing through Valmet meter first

Table 13. Consumption as registered by Kent commercial meter versus the prototype (multi-jet) meter based on volume on site Amana Bar-Ilala.

Time in weeks	Volume registered *)		Registered difference	
	Target m^3	Prototype m^3	m^3	%
1	59.50	60.22	0.79	1.20
2	30.80	31.06	0.26	0.86
3	44.50	48.72	4.22	8.66
4	19.13	20.99	1.80	8.58
5	23.31	25.61	2.30	8.98
6	10.62	19.63	9.01	45.90
	187.86	206.23	18.37	8.91

*) series connection with water flowing through Kent meter first

Table 14. Consumption as registered by SPX industrial meter versus the prototype meter based on volume on site AISCO Pugu Road.

Time in weeks	Volume registered *)		Registered difference	
	Target m^3	Prototype m^3	m^3	%
1	32.60	31.84	- 0.76	- 2.39
2	24.30	24.01	- 0.29	- 1.21
3	32.80	28.83	- 3.97	- 13.77
4	26.88	21.33	- 5.55	- 26.02
5	26.39	28.77	+ 2.38	+ 8.27
6	22.12	22.49	+ 0.37	+ 1.65
Total	165.09	157.27	- 7.82	- 4.97

*) series connection with water flowing through Valmet meter first

Table 15. Consumption as registered by Bosco industrial meter versus the prototype meter based on volume on site Morocco Road.

Time in weeks	Volume registered *)		Registered difference	
	Target m^3	Prototype m^3	m^3	%
1	36.94	37.19	+ 0.25	+ 0.67
2	7.00	6.87	- 0.13	- 1.89
3	38.43	34.18	- 4.25	- 12.43
4	31.28	27.21	- 4.07	- 14.96
5	31.03	11.15	- 19.88	- 178.30
Total	144.68	116.60	- 20.08	- 24.08

*) series connection with water flowing through Bosco meter first

The data in Tables 10 - 14 reflect the true picture of the problem predicted before implementation of the field study. The question here should be viewed as to the performance of the two meters connected in series subject to the same conditions of: water quality, intermittent water supply, humidity, solar radiation, pressure fluctuation, etc.

In view of the above the following observations were made:

1) Any of the water meters connected in series with the prototype meter do not register equal volumes contrary to the law of mass flow (Figures 16 - 21).

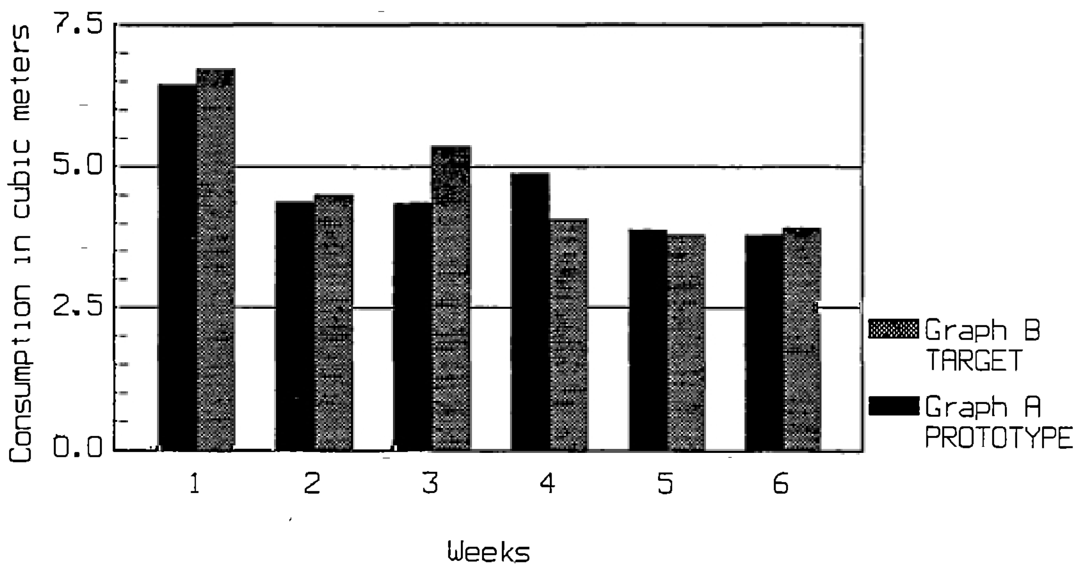


Figure 16. Consumption as registered by SPX meter versus prototype meter based on volumes.

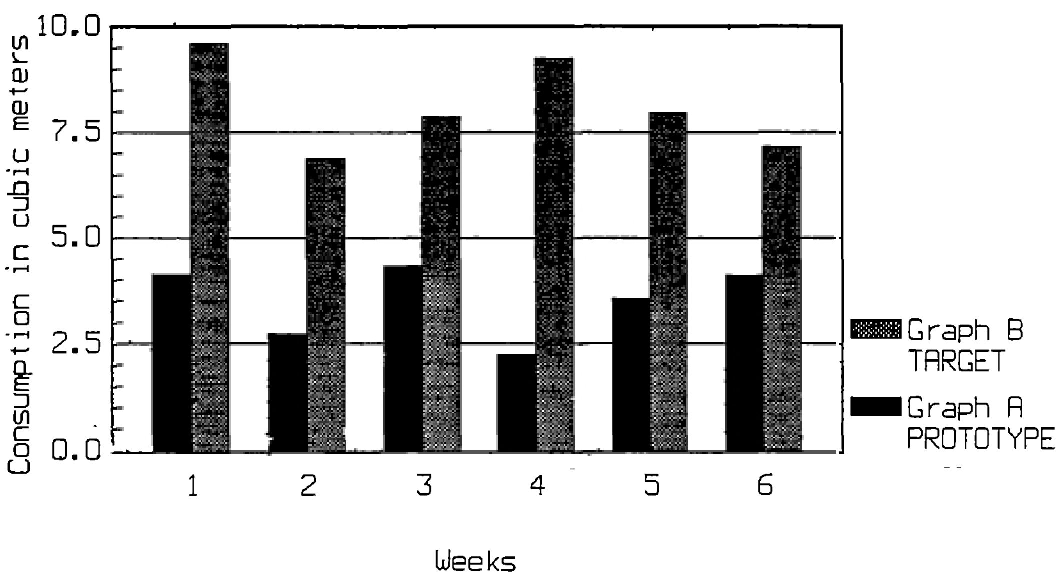


Figure 17. Consumption as registered by Bosco domestic meter versus prototype meter based on volumes.

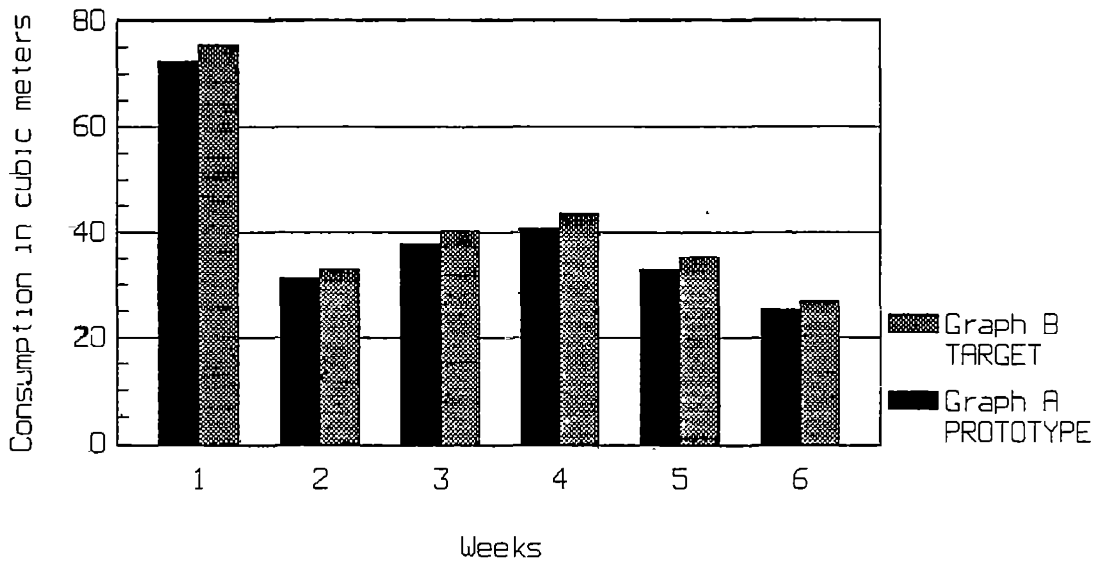


Figure 18. Consumption as registered by Kent domestic meter versus prototype meter based on volumes.

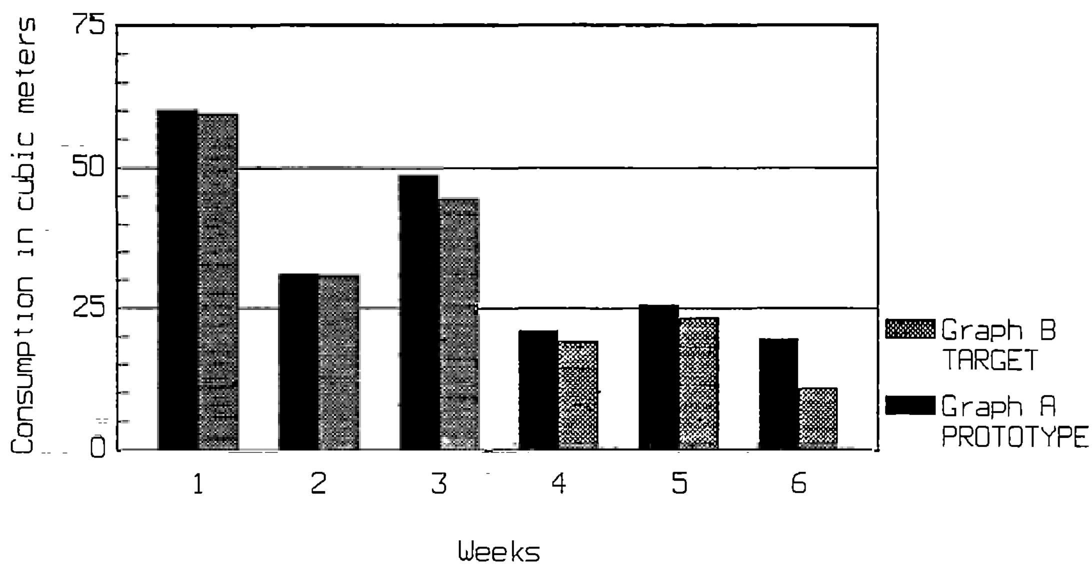


Figure 19. Consumption as registered by Kent commercial meter versus prototype meter based on volumes.

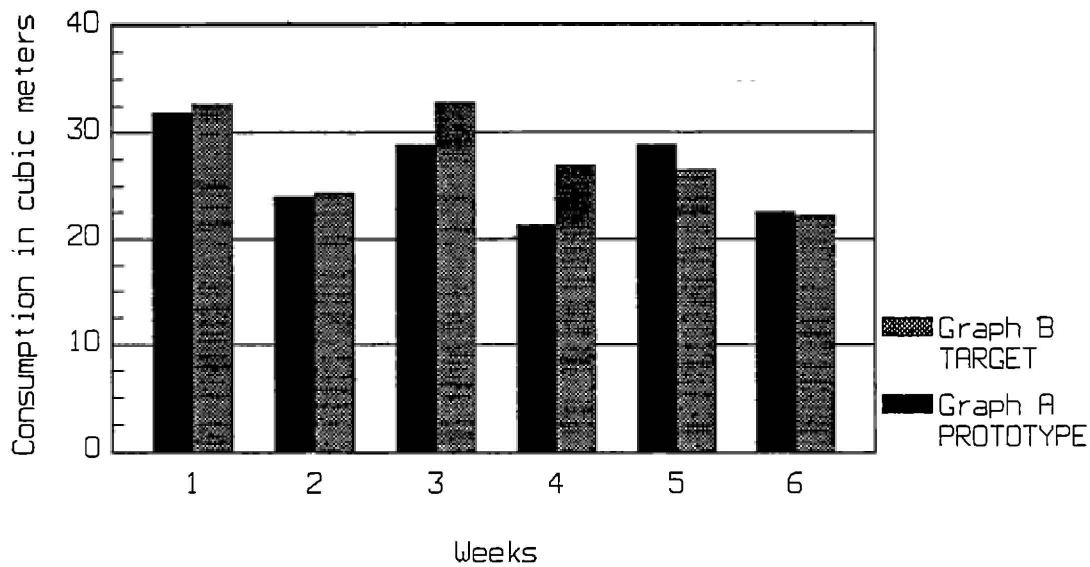


Figure 20. Consumption as registered by SPX industrial meter versus prototype meter based on volumes.

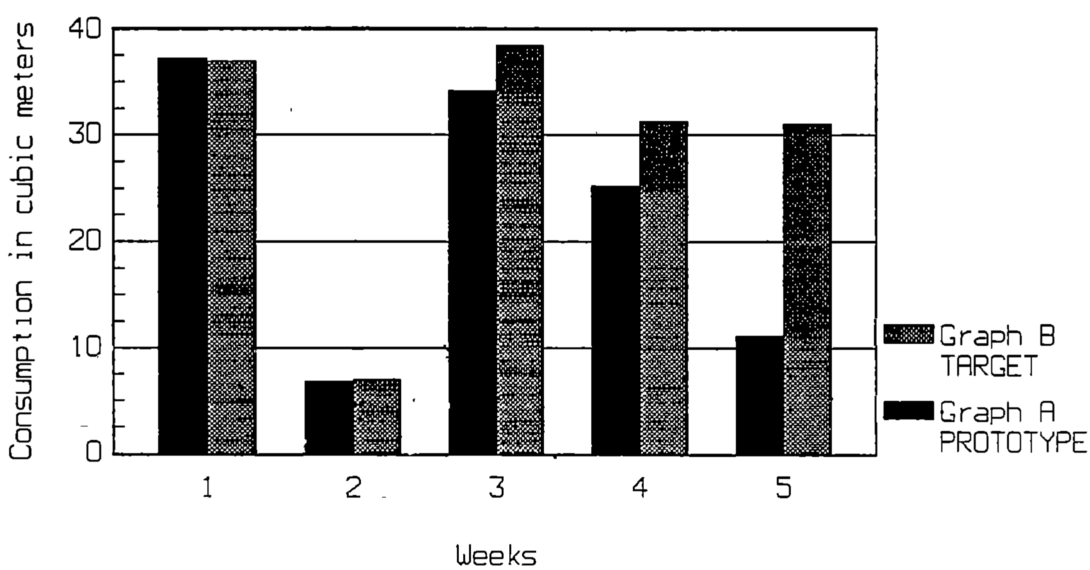


Figure 21. Consumption as registered by Bosco industrial meter versus prototype meter based on volumes.

2) All meters with their initial positions interchanged register unequal amount of water contrary to the law of mass flow.

3) The prototype meter register smaller volumes of water compared to the target or reference meters. An exception case indicated only with the Kent meter installed in vertical position with the prototype meter installed in horizontal position (Tables 12 and 13).

4) Only Kent meter showed a unique characteristic after interchanging the installation position. That is the differences in volume registered remained positive for one position and negative for the other position (Tables 12 and 13).

5) Bosco meter showed relatively higher percentage of volumes registered compared to the rest of the target or reference meters (Tables 11 and 15).

6) SPX meter showed the smallest percentage differences relative to the rest of the target meters (Tables 10 and 14).

From the above observations the following may be concluded:

1) During data collection the water supply was intermittent. All meters being turbine or vane type must show the same characteristics of air registration because of the same design features. Since the target meters showed relatively higher values of volumes, it can be concluded that air registration is dependent on the sensitivity of the meter. It may be true that the target meters have higher sensitivity compared to the prototype meter. This phenomenon did not change after interchanging the meter position.

2) Since the prototype meter has generally shown to register less than the target meters (Figures 16-21), it may be true that the counting threshold of this meter is higher than that of the target meters. This is the maximum amount of water that can pass through the meter without being registered. These results emphasize that meters should be a bit robust and not too sensitive in conditions of intermittent water supply.

3) Installation has an impact on the performance of the meter. The installation of the Kent meter in vertical position changed the trend of observed characteristics. In the vertical position the Kent meter registered less than that in the horizontal position. The meter installations are specified by the manufacturers.

   When the metes are procured through government stores, the technicians do not bother to request for the installation specifications. In this case it is likely that there was no specification provided. usually the technicians responsible for meter installations assume to know the specifications by experience. Once the specifications require otherwise, the mistake can cause inaccuracy of the meter falsely installed.

4) The alternating positive and negative differences predict that siltation may have affected the performance of the meter. The filters provided can only retain grit particles to a limited size. The rest

of the particles may settle in between the meter parts depending on flow velocity of water, settling velocity of the particle, and the surface area available. The settled particles between moving parts can hinder and clog the meter.

5) The pressure fluctuation did not cause considerable harm to the meter. Since the pressure cannot be constant throughout, loss of accuracy might have resulted. The arrangement did not permit detection of pressure effects on meter accuracy.

6) Water quality effects on the working parts of the meter may be witnessed after a long run. This will require disconnecting the water meter from the service line and investigating the parts against tear and wear, meter parts - water reaction, etc. One of the results expected from the SPX meter is some sort of reaction between the meter dial face and the water. This unknown effect is being experienced on SPX water meters in Tanga urban water supply (Figure 22).

   Since the meters have been in operation for two months only, it was too early to judge whether or not the same effects will happen to the meter. For this matter, the water meters have been left connected in the service line and will be maintained according to NUWA practices. To substantiate the complaints continuous monitoring of the meters will be required.

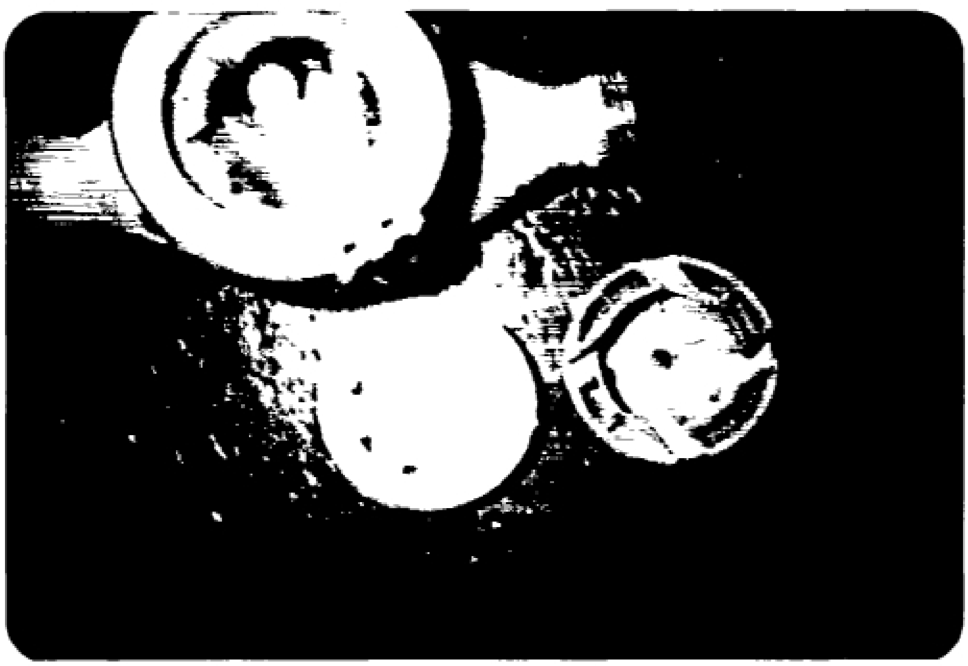


Figure 22. Reaction of the meter dial face with the water in Tanga municipal water supply.

7 CONCLUSIONS AND RECOMMENDATIONS

Dar es Salaam water supply has remarkable experience of water metering. Through metering and application of estimation methods the water authority has been able to realize some benefits vested in meter utilization. The responsible authority has applied the metering partly at least for the big consumers. In view of the study the following may be concluded:

1) Water metering by itself does not control UFW, but rather helps in identifying whether UFW problems exist before deciding to invest on control measures.

2) Debt recovery identified to be the core problem in Dar es Salaam is a management problem. To realize an effective cost recovery, and appropriate policy should be established and effectively executed.

3) Water meters can help to determine the unit cost of water supplied, and hence to develop and appropriate tariff structure based on actual water consumption. Based on this fact NUWA has considered it appropriate to meter selected customers with an objective to establish a water charge for non-metered consumption. This is a commendable approach which can effectively be used to off-set the substantial investment of water metering.

4) Water vending and reselling taking place in Dar es Salaam is a clear indication that water supplied does not satisfy the demand. The higher costs of water through reselling managed by the people predicts willingness to pay and join the water supply. If correctly applied, water metering may create a saving in water that can be used to expand the service area. With the prevailing capacity, it is wise if the practice of water reselling can be left under the control of NUWA.

5) Unreliable or inadequate water services encourage vandalism. Water meters are mainly destroyed in areas where customers do not receive adequate water services.

6) In part of the problems existing in water metering, inappropriateness of water meters has proved to be a contributing factor. The field study conducted showed that meters in operation are not performing as required. None of the tested meters showed equal volumes against the prototype meter installed in series. Also some of the water meters showed poor readability which may be continue to be worse due to poor water quality. Although the meters were not investigated against the effects of water quality on the working parts, the over-registration and under-registration against the prototype meter predicted water quality effects. Turbine meters despite registering air are more appropriate to be used in turbid water than the positive displacement meters.

Single-jet, dry dial turbine meters are in principle the most suitable meter type, provided that they have adequate protection against external disturbance (vandalism, manipulation of readings etc.) and have adequately high counting threshold to avoid air registration.

7) Meter operation and maintenance problems in Dar es Salaam water supply are mainly due to lack of adequate transport, spare parts, replacement meters, poor water quality and intermittent water supply. The water supply system has a variety of water meters in operation. These meters imported through various programs have always complicated the procurement of spare parts and replacement meters. Dar es Salaam water supply like any other water utility in developing countries cannot cope with the development trend of the meter industry. This is due to poor economy which usually necessitates them to pursue maintenance by crisis and not by programs established. Cheap labor is available but not cheap spare parts. if water meters are standardized, it is easy to procure spare parts and replacement meters, easy to master their maintenance and easy to transfer the technology for local manufacture of appropriate meters.

8) The study conducted indicates a good possibility for a working cost-recovery. The willingness to pay and join is very high as envisaged through vending and reselling of water. The major problem is debt recovery.

9) On the appropriateness of the water meters, the study showed that meters used in the distribution network do not perform well under the local conditions. Under these conditions it is concluded that an appropriate meter should:

   a) not register air as a result of intermittent water supply

   b) be easily repaired with parts capable of being reused several times

   c) be easily readable without any manipulative skills

   d) have a strong but simple construction and not attractive for vandalism of theft

   e) not form fog or any water bubbles under the glass of the meter thereby causing poor readability

   f) be easy to install in any position without causing loss of accuracy of the water meter

   g) withstand fluctuation of pressure without loss of accuracy

   h) be resistant to corrosion, abrasion and other reaction, related effects of water quality.

It was observed that the amount of UFW in the water supply network ranges from 35 % - 40 % and the attempt to control this was thwarted by lack of water meters. Also observed was the lack of effectively followed replacement, operation and maintenance programs due to prohibitive costs involved.

To ensure sustainability of standard water services and reduced UFW, it is recommended that:

1) Passive control method practised be enhanced and augmented by the district metering control method where leakage cannot be easily noticed. For this purpose the districts established may be considerably larger necessitating the use of fewer meters.

2) NUWA should concentrate on temporary metering of consumers capable of generating revenue that can help operation and maintenance of meters. Water meter brands should be reduced through standardization to reduce complications in procurement procedures.

3) Evaluation of water meter utilization should be conducted to establish non-quantifiable benefits. The saving in water due to water meter utilization can be used to expand service capacity.

B4) Debt recovery should be given priority. Monthly billing should not include the balance of the previous month. To enhance debt recovery, penalty of not less than the inflation percent should be imposed on unpaid bills. The public and particularly the customers must be educated through the news media. Advance billing should be used to speed up the cash flow and improve profitability.

5) To complete the study and prove the complaints over appropriateness of the meters, long time investigation of the meters should be conducted. The meters left in the distribution can be used to derive some of the factors that could not be accomplished due to time limit. In fact the study has proved that the meters used are not appropriate for our local conditions.

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INTERVIEW SCHEDULE FOR EVALUATION AND DEVELOPMENT OF AN APPROPRIATE WATER METER FOR DEVELOPING COUNTRIES

The interview schedule is based on a checklist of priority questions. It was recognized that some of the priority questions appeared in both side of the customers and the water utility.

It was not feasible to use the broad main question in an interview or observation. Each main question is to be disaggregated into a number of sub-questions. The answer to all sub-questions for each question would then give a valid answer on the originally formulated main question.

This exercise resulted 6 main questions for the customer and 8 for the water utility. All priority questions fell into one of the following groups, reflecting an important aspect of the water metering system.

I Ownership and security of water meters
II Understanding of the water metering objectives
III Appropriateness of the meter
IV Justification of the metering policy
V Practices in the metering system

1. PRIORITY QUESTIONS FOR THE CUSTOMER

1) Do you understand the water metering objectives?

- Do you have a water meter connected to your water service line?
- Do you understand the objective of connecting this device to your service line ?
- Does the water bills you receive have any relation with the water meter reading?
- Before you proceed to pay your water bills do you cross check recorded reading and the current meter reading?
- How do you use the water supplied?

2) Who owns the meter and what measures are taken to ensure the security of the water meter?

<u>Sub-questions</u>

- Did you buy this meter yourself? Yes ( ) No ( )
- If no, who owns it?
- Did you pay any fee to have the meter installed to your service line? Yes ( ) No ( )
- If yes, how much?
- Should the fee be paid anyway?
- How do you feel about the security of a facility you don't own or not rented to you?
- How do you care if it went out of order?

3) What sort of problems do you face on using meters?

<u>Sub-questions</u>

- Do you like to continue using the water meters?
- Does meter utilization cause any inconvenience to you?

4) Is the water meter appropriate for your use?

<u>Sub-questions</u>

- Are you aware that a meter can under-register or over-register?
- Have you ever experienced any discrepancy in the performance of any meter you have used?
- What complaints do you have over the meter?

5) Do you think the meter utilization is effective?

<u>Sub-questions</u>

- Do you pay according to what you use?
- Should the water meters be used?
- What should be improved to enhance efficiency in the metering system?

6) What are the tricks used to evade actual bills according to water supplied?

<u>Sub-question</u>

- Do you know that some water is lost through the system?
- Are you aware that theft of water accounts to these losses?
- Do you know any tricks used by your neighbors to use water that can not be billed?
- What suggestion do you have to reduce such losses?

2. PRIORITY QUESTIONS FOR THE WATER UTILITY

1) What is the use of water meters in your distribution system?

Sub-questions

- What type of metering do you undertake?
- Is the whole distribution network metered?
- How do you make your priorities in selecting customers to be metered?
- How do you monitor water losses?

2) Do you own all water meters in the distribution system?

Sub-questions

- Is it possible for a customer to procure and ask you to install it in the service line?
- Do you charge any rental fee for each meter connected?

3) How do you ensure security of meters?

Sub-questions

- Do you experience vandalism caused to water meters?
- What measures do you take against such incidence?
- Do you have precautionary measures to avoid possible future incidents?

4) Do you find it necessary to use water meters?

Sub-question

- What are the methods you use to establish a water cost?
- Does the water metering play any important role?
- How is your relationship with the customers
  a) those who are using water meters ?
  b) those who are not using meters?
- How does the water meter use help in forecasting water demand ?

5) Do you find water metering cost effective?

Sub-questions

- Are all water meters installed operational?
- Does the Authority benefit compared to the costs involved in installation, operation and maintenance, and replacement of meters?
- Do you think the water authority should invest more in the metering system?

6) What are your opinions over the meter reading system used in your authority?

Sub-questions

- Do you feel that the system of meter reading is efficient to effect timely and precise billing?
- What are the setbacks in your meter reading system?
- What is the frequency of meter reading?
- Do you believe that all meters are read according to records provided?

7) Do you know any tricks used by customers using meters to steal water?

Sub-questions

- Are you aware that water meter users use tricks to consume water without the meter system?
- How do you net culprits who use tricks to increase non-revenue water?
- Are all metered customers free to use any amount of water?

8) Do you find meters used to be appropriate ?

Sub-questions

- Do you have any operational or maintenance problems with water meters?
- How often do you repair and replace meters?
- How do you know that the water meter is not operational?
- Do you know any complaint from the metered customer regarding meter performance?
- What is your opinion regarding the appropriateness of these meters?
- What are the basic problems you face with them?
- Do you have any complaint over any particular type or model of the meter?

APPENDIX 2

PROTOTYPE WATER METER SPECIFICATIONS

Valmet M-5C

Wide-flow-range water meter NS20 3/5 m^3/h

- multi-jet inferential dry dial vane wheel meter
- 5-digit roll counter enclosed in a case
- eccentric rotor at center face directly coupled to vane wheel for easy checking of meter, and 3 pointers: 1 l, 10 l and 100 l
- mounting dimensions according to DIN 3260 standard
- connections with thread
- two years' guarantee.

Specifications

Permissible continuous load	5 m^3/h
Permissible short-duration peak load	unlimited
Pressure drop with nominal flow 5 m^3/h	0.95 bar
Maximum error of measurement	
- from lower limit to medium limit	± 5 %
- from medium limit to upper limit	± 2 %
Lower limit of measurement	20 l/h
Medium limit of measurement	150 l/h
Counting threshold	5 l/h
Counter	
- smallest reading	0.001 m^3
- largest reading	100 000 m^3
Operating temperature, max.	40 °C
Operating pressure, max.	16 bar
Test pressure	24 bar
Materials	
- body	chilled brass
- measuring machinery	polystyrene, polyamide
- strainer	polyethylene
- connections (ordered separately)	brass
Colour	golden bronze
Mounting	horizontally with thread connections R1/2K or R3/4K
Weight	
- meter, length 190 mm	1.7 kg
- meter, length 220 mm	1.8 kg

Table 16. Domestic consumption of water as registered by Bosco meter versus the prototype meter Zanaki str/UWT Road site.

Date	Meter reading		Observational remarks
	Bosco m^3	Prototype m^3	
5.12.1991	27.65	17.54	
16.12.1991	37.26	21.67	Readability of the Bosco meter was poor due to moisture formation under the meter glass.
22.12.1991	44.14	24.40	
29.12.1991	52.00	28.72	
5.1.1992	61.24	30.97	The area experiences low water pressure and fairly continuous water supply.
12.1.1992	69.20	34.51	
19.1.1992	76.35	38.61	

Table 17. Domestic consumption of water as registered by SPX versus prototype meter Zanaki str/UWT Road site.

Date	Meter reading		Observational remarks
	Bosco m^3	Prototype m^3	
5.12.1991	16.37	14.05	
16.12.1991	23.09	20.49	Readability of the SPX meter was poor due to formation of the water meniscus between the meter glass and the dial.
22.12.1991	27.58	24.85	
29.12.1991	32.97	29.20	
5.1.1992	37.00	34.09	
12.1.1992	40.80	37.97	The area experiences low water pressure and fairly continuous water supply.
19.1.1992	44.71	41.76	

APPENDIX 3 (2/3)

Table 18. Commercial water consumption as registered by Kent versus prototype meter on site Amana Bar - Ilala.

Date	Meter reading		Observational remarks
	Kent m^3	Prototype m^3	
5.12.1991	51.40	52.35	
16.12.1991	110.90	112.57	Readability of both meters were very good. The meters were dirty revealing that people were accessed to it. The installations were not safe against possible vandalism.
22.12.1991	141.71	143.63	
29.1.1992	186.20	192.35	
5.1.1992	205.33	213.34	
12.1.1992	228.64	238.95	Water supply was intermittent during the time of study.
19.1.1992	239.26	250.58	

Table 19. Domestic consumption as registered by Kent versus prototype meter on site Oysterbay.

Date	Meter reading		Observational remarks
	Kent m^3	Prototype m^3	
5.12.1991	153.0	145.30	
16.12.1991	228.46	217.80	Readability of both meters was good.The area was safe against vandalism.
22.12.1991	261.50	249.06	
29.12.1991	301.79	286.92	
5.1.1992	345.30	327.65	Water supply was observed to be fairly continuous.
12.1.1992	380.62	360.60	
19.1.1992	407.40	385.93	

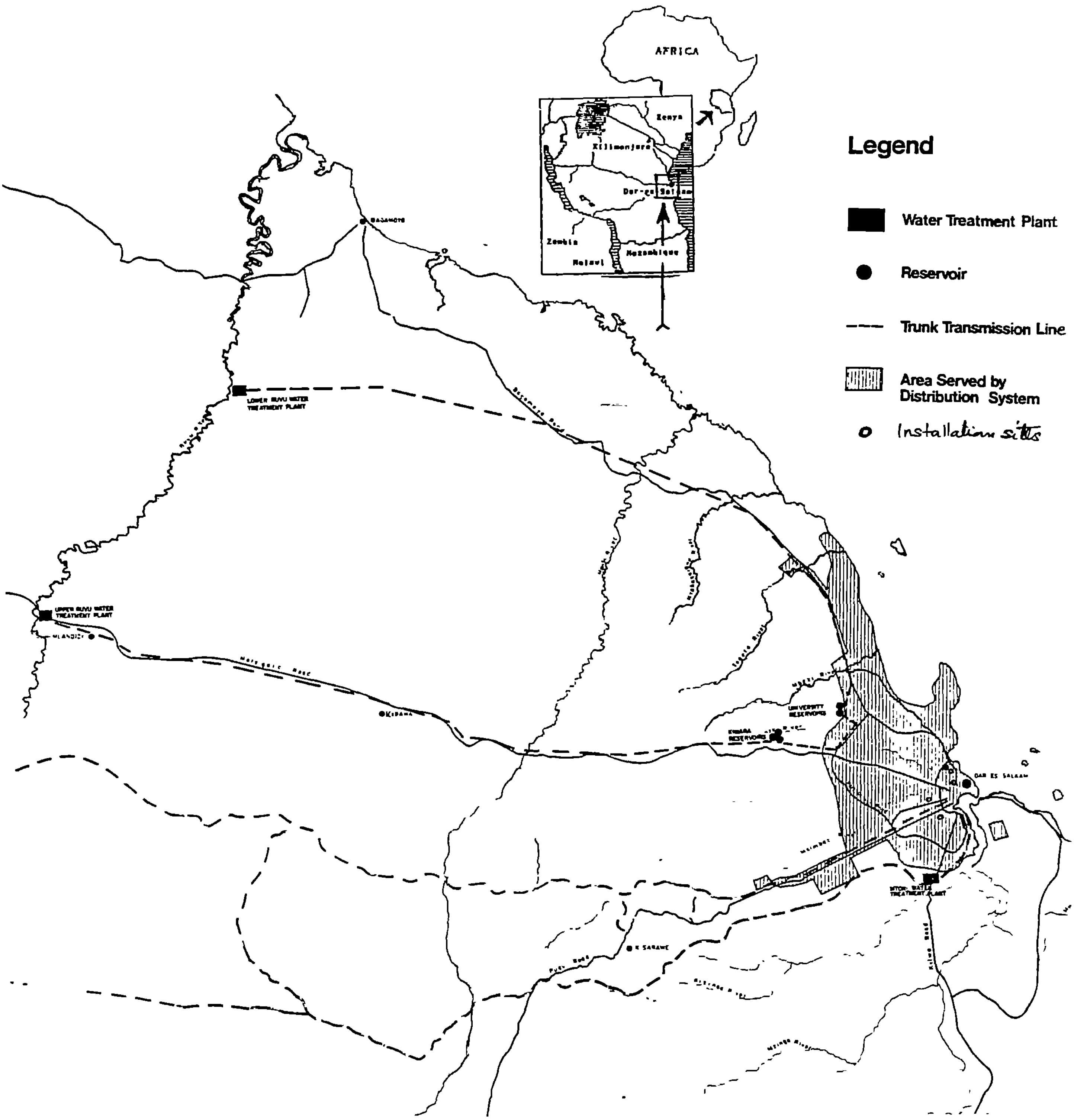
Table 20. Industrial consumption as registered by SPX versus prototype meter on site AISCO Pugu Road.

Date	Meter reading		Observational remarks
	SPX m^3	Prototype m^3	
5.12.1991	44.81	43.17	The area received fairly constant supply.
16.12.1991	77.37	75.04	The meter readability was poor due to water
22.12.1991	101.68	99.05	droplets formed under the glass.
29.12.1991	134.15	127.88	
5.1.1992	161.38	149.21	The installation was safe built underground and
12.1.1992	187.77	171.98	within the fence.
19.1.1992	209.81	194.47	

Table 21. Industrial water consumption as registered by Bosco versus prototype meter on site Morocco Road.

Date	Meter reading		Observational remarks
	Bosco m^3	Prototype m^3	
5.12.1991	85.24	84.37	Fog formed under the glass after installing
16.12.1991	122.18	121.56	meters.
22.12.1991	-	124.40	Missed data due to lock-out. Owner locked
29.12.1991	129.10	128.43	to avoid misuse of water in his absence.
5.1.1992	167.16	162.61	The area experienced intermittent water
12.1.1992	189.82	198.89	supply occasionally.
19.1.1992	220.85	210.04	

APPENDIX 4



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Environmental Engineering (IWEE)
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SF-33101 Tampere, FINLAND
Phone +358 31 162111
Telefax +358 31 162869
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