Technical Guideline for Drinking Water Distribution Network Pumps (Selection and Management) in Kenya

Foreword

Pumps, valves & pipes are essential inputs in the normal operations of water utilities. Pumps for instance enable water service providers draw water from either underground sources or surface areas and push it through transport lines (pipes) to treatment facilities and eventually to consumers.

It is imperative that proper selection and sizing of pumps has a direct correlation to energy consumption. While the market delivers several variety of products, the Energy Regulatory Commission in Kenya is keen to have energy consuming entities improve on the applications installed in their facilities which impact negatively on energy efficiency. With ageing pipe networks, the water sector is ripe for new and modern technologies especially to match the requirements for durability, malleability and water quality standards.

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

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

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

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

Reuben Tuei

Chairman
Water Services Providers Association

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- Water Services Regulatory Board

Abbreviations

ERC - Energy Regulatory Commission

KEBS – Kenya Bureau of Standards

NPSH - Net Positive Suction Head

NRW – Non Revenue Water

PE – Public Entity

PPRA - Public Procurement Regulatory Authority

Specs – Specifications

TOR – Terms of Reference

WASPA – Water Services Providers Association

WASREB – Water Services Regulatory Board

WSP – Water Service Provider

1 Introduction

Kenya has made good strides in expanding access to safe and clean drinking water, sanitation, and sewerage. With respect to Non Revenue Water (NRW), a primary performance indicator for water utilities, water services providers (WSPs) have reduced NRW from 47% in 2008/2009 to 44% in 2011/12. However, more improvements are needed to reach the national target of 30% set in the National Water Services Strategy (NWSS, 2007-2015) [1]. As a recent performance review reported, "Despite the positive trend, NRW levels remain unacceptably high despite the increase in sector investment over the years. The total amount of money lost in 2012/13 can be estimated at a staggering *KSh 11.4 billion*" [2]. With further improvements, it is possible for WSPs to go beyond the NWSS goal of 30% to reach the sector benchmark of 20%. Reducing NRW is essential in order to decrease drinking water wastage, increase revenue, extend coverage, and ultimately ensure a more efficient provision of water to consumers, and should therefore be the number one priority for WSPs in Kenya.

In order to achieve this ambitious goal, this Technical Guideline addresses the observation made in the NWSS that the "missing standardization of water equipment has resulted in a multiplicity of technologies which is not only a disincentive for private sector involvement but also a reason for lengthening break downtimes" [3].

Pumping stations in a water distribution system are necessary where water is pumped directly into the system (e.g. from a borehole) or where pressure has to be increased because there is an insufficient difference in water levels in gravity flow distribution systems. The most common type of pump used in Kenya for water distribution is the centrifugal pump. Initial investment costs for pumps and motors are high, but the operation costs are far more expensive, as the energy (i.e., electrical) supply for the pump's motors accounts for more than 90% of its life cycle cost. Therefore, to control costs and ensure return on investment, pumps and motors must have a high degree of efficiency and be maintained properly.

Pump and motor malfunctioning is one of the major causes of disruptions of water supply in Kenya. The main reasons for pump/motor malfunctioning are improper pump/motor type, substandard equipment, and poor installation and maintenance of the pump and motor. Additionally, poor system design and improper use of the pump can result in unintended pressure problems in the water distribution system. Pressure variation and water hammer during the starting and stopping of pumping equipment is one of the main causes of pipe/joints breakage and increases in water loss and energy consumption. Minimizing water loss through an active leakage reduction program will reduce the waste of energy embedded in the lost water. Hence, installation of appropriate, high-quality pump/motor in the required locations is critical to reducing service downtime, minimizing water loss, and increasing the energy efficiency of the water deliver system.

Increasing energy efficiency is one of the primary mandates of the Energy Regulatory Commission (ERC). In 2015 ERC issued the Energy (Appliances' Energy Performance and Labelling) Regulations to address this issue. These Regulations apply to appliances manufactured, imported, distributed, or retailed for use in Kenya, including electric motors used with pumps in water distribution networks.

This Technical Guideline comprises recommendations for the procurement process, the selection of pumps used in the drinking water distribution network, the establishment of technical specifications, and the installation and maintenance of pumps. This guideline also includes recommendations for the selection of motors used in conjunction with the pumps, focusing on optimizing energy efficiency.

The Guideline is designed to close efficiency gaps in Kenya's current system, based on an assessment of the current water distribution network conducted through questionnaires (completed by approximately 25% of WASPA's member WSPs), interviews with stakeholders, and reviews of relevant documents and best available practices in the local and international market. The Guideline is intended to support and guide the WSPs through each step of procurement, installation, and maintenance of all relevant pumps and motors needed for the provision of water services.

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

2 Recommendations for a Generic Procurement Process

Within Kenya, each WSP has established its own procurement process based on its specific requirements and experience. We therefore offer recommendations for further improvements rather than a "one size fits all" solution. These recommendations are based on the Kenyan Public Procurement and Asset Disposal Act (2015), its subsidiary legislation entitled Public Procurement and Disposal Regulations (2006), and the ISO standard 10845-1:2010 – *Construction Procurement – Processes, methods and procedures*. These documents support the establishment of procurement processes that are fair, equitable, transparent, competitive, and cost effective.

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

2.1 Basic Procurement Process

This compliance includes the basic procurement process, consisting of 17 steps to be followed by all PEs, shown in Table 1. The main roles and responsibilities for these steps fall to the PE's user department, accounting officer, tender committee, procurement unit, and evaluation committee.

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

	Steps	Roles & Responsibilities
Step 1	Procurement Plan & Budget	Accounting Officer
Step 2	Procurement Requisition Filled with clear Specs/TOR	User Department
Step 3	Confirmation of Availability of Funds	Accounting Officer
Step 4	Review of Specifications/TOR, Procurement Method, Evaluation Criteria, Potential Supply Market	User Department & Procurement Unit
Step 5	Procurement Method Approval	Tender Committee
Step 6	Preparation of Tendering Documents	Accounting Officer; User and other relevant departments
Step 7	Approval of Tendering Documents	Accounting Officer Tender Committee
Step 8	Advertisement & Invitation for Tender	Accounting Officer
Step 9	Receipt & Opening of Tenders	Tender Opening Committee 3 member
Step 10	Evaluation of / Proposals (testing of provided samples)	Evaluation Committee
Step 11	Review of Evaluation Report (Approval or Rejection)	Accounting Officer
Step 12	Award of Contract	Accounting Officer
Step 13	Communicate Award	Accounting Officer
Step 14	Review	Public Procurement Regulatory Authority (optional)
Step 15	Sign Contract	Accounting Officer

	Steps	Roles & Responsibilities
Step 16	Contract Monitoring	Accounting Officer
Step 17	Contract Performance Evaluation	Accounting Officer; User Department & Procurement Unit

For those steps associated with shortcomings identified during the assessment, recommendations are given in the Section 2 of the 'Technical Guideline for Water Meter (Management) in Kenya'. More detailed information on each of the steps and the main roles and responsibilities associated with them can be found in the "User Guide to The Public Procurement and Disposal Act, 2005" [4].

2.2 Documentation

The following documents must be submitted with tenders in order to be eligible for evaluation:

a) Name of the standard(s) used to certify the product(s);
b) Certificates of manufacturing quality testing (e.g., methods of manufacturing);
c) Certificates of final product quality testing;
d) Kenya Bureau of Standards (KEBS) certificates of testing (note that KEBS marks must also appear on the product);
e) Proof of suppliers' approval status:
    i. Obtained from the supplier, and
    ii. Obtained from the manufacturer;
f) Warranty documents with clear terms and conditions;
g) Service contract documents with clear terms and conditions (to be obtained regardless of the WSP's intent to include these terms and conditions in the final contract; this document offers additional evidence of the supplier's credibility);
h) Spare parts availability contract with clear terms and conditions;
i) Supplier's rating by WASPA; and
j) References provided by suppliers from previous projects.

2.3 Inspection and Acceptance of the Goods

Each pump, motor, and elements of related equipment should be checked visually for defects and evidence of poor workmanship. If any defect is detected, the product should be rejected. All required certificates and documents should be provided upon delivery of the product.

For large pumping stations requiring high energy consumption, responsible technical personnel should participate during the manufacturer's pump testing in the factory (Factory Acceptance Tests) to control the requested specifications and to receive training.

After installation, the test run should be conducted to confirm the performance against the pump specification (e.g., flow rate, head, and efficiency), and against the motor specification (e.g., volt, current, and efficiency). Noise and vibration of the operating setup must be checked against relevant specifications. Additionally, proper insulation of the motor and cables must be verified.

3 Selection of Pumps and Motors

3.1 Introduction to Pumps and Motors Widely Used in Kenya

Pumps provide reliable and efficient transport and distribution of drinking water to guarantee the availability of water for human, industrial, and agricultural uses. Two types of centrifugal pumps are used in various types of water systems (e.g. wells, transmission, and distribution): vertical turbine pumps (line shaft and submersible types) and horizontal pumps. Pumps and motors widely used in Kenya are described in more detail in Table 2.

Table 2: Description of Centrifugal Pumps and Motors used in Kenya (Ref: "Centrifugal Pumps, Vertical Turbine Pumps and Submersible Pumps," [8].

Type	General application	Key Considerations
Horizontal pumps	o Widely used as a distribution pump and for irrigation, water supply, and sewage services o Rotating impeller draws in liquid at center and distributes through side opening o Priming techniques include self-priming and use of a foot valve.	o Advantages: simple, easy to operate, low initial cost, steady discharge -
Vertical turbine pumps (multi stage)	o Used where pumping water level is below the limits of horizontal centrifugal pump. o Staged pump accommodates rotating impellers and stationary bowls with guide vanes.	o Higher initial cost and more difficult to install and repair. o Pressure head is dependent on diameter of impeller and speed of rotation; a single impeller may be insufficient, requiring the addition of more bowl assemblies or stages.
Submersible pumps	o Pump and motor operate under submerged conditions; can be used in deep tube wells o Vertical turbine pump is coupled to a small diameter submersible electric motor, enclosed in an oil-filled steel case and fixed below the pump intake with a seal to prevent oil leakage or water ingress.	o Useful where a long shaft is impractical
Motor	o Electricity powered o Single-phase or Three-phase induction motors	

Additional pump classifications refer to their purpose within a water distribution system:

— *High lift pumps* pump water directly into transmission lines and distribution systems

— *Booster pumps* increase pressure locally (to reach areas far from the main pumping station, especially in hilly regions) or temporarily (during peak flows that exceed normal flow requirements).

3.2 Recommendation for Selection

Total system hydraulic analysis should be consulted during the selection of a pump. The size of each component in the distribution system depends on the effective combination of the major system elements, such as supply source, storage (e.g. in reservoirs), pipe, and pumps.

3.2.1 General Considerations

The most important consideration is to purchase only new pumps and motors. No reused or recycled pumps and motors nor spare parts shall be purchased.

Proper consideration of the size and shape of a candidate pump is critical to model selection in order to ensure that the pump can be installed easily in the intended location.

3.2.2 Type

The selection of pumps should be based on their intended function. See Table 2, Section 3.1, for general descriptions of pump types and key considerations in their selection.

Pump type selection: The accepted rule of thumb for pump selection is as follows (Adapted from the World Bank (2012) [5]).

- If the pumping water level is less than 6 meters, use a centrifugal pump (maximum suction lift = 6 meters).
- If the pumping water level is between 6 and 20 meters, use a submersible pump.
- If the pumping water level is greater than 20 meters, use a submersible or a vertical line shaft turbine pump.

Motor type selection: Selection of a single-phase or three-phase induction motor will depend on the type of power supply (e.g., single-phase or three-phase alternate current) readily available in the pump installation site. Note that a single-phase motor draws significantly more current than the equivalent three-phase motor, making three-phase power a more efficient choice for motors with large power requirements (e.g., more than 5 horsepower).

3.2.3 Specification

Calculate the flow rate (Q, m^3/h) and head (H, m) for the pumping stations according to the hydraulic conditions and the demand of the attached transmission or distribution system.

Figure 1 depicts the pump operating conditions:

- The dark red line shows the system curve (e.g. transmission or distribution system); and
- The light red line shows the Q-H curve of the pump.

Pump and system curves will match at the operation point.

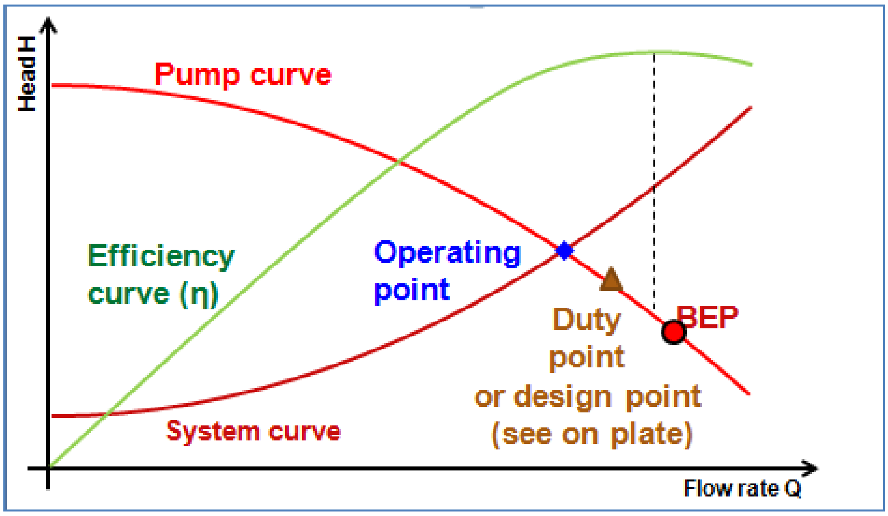


Figure 1. Operating condition of a pump (Source: Hamburg WASSER)

The pump is designed to be operated at the Best Operation Point (Qopt).

Figure 2 summarizes the recommended operating conditions prescribed by the Hydraulic Institute (pumps.org) and the European Association of Pump Manufacturers (europump.org):

- Recommended operating conditions: Best Practice Q = -10% to +5% of Qopt
- For short periods only (limited time): Better Practice Q = -20% to +10% of Qopt
- Avoid operation in these conditions: Good Practice Q = -30% to +15% of Qopt

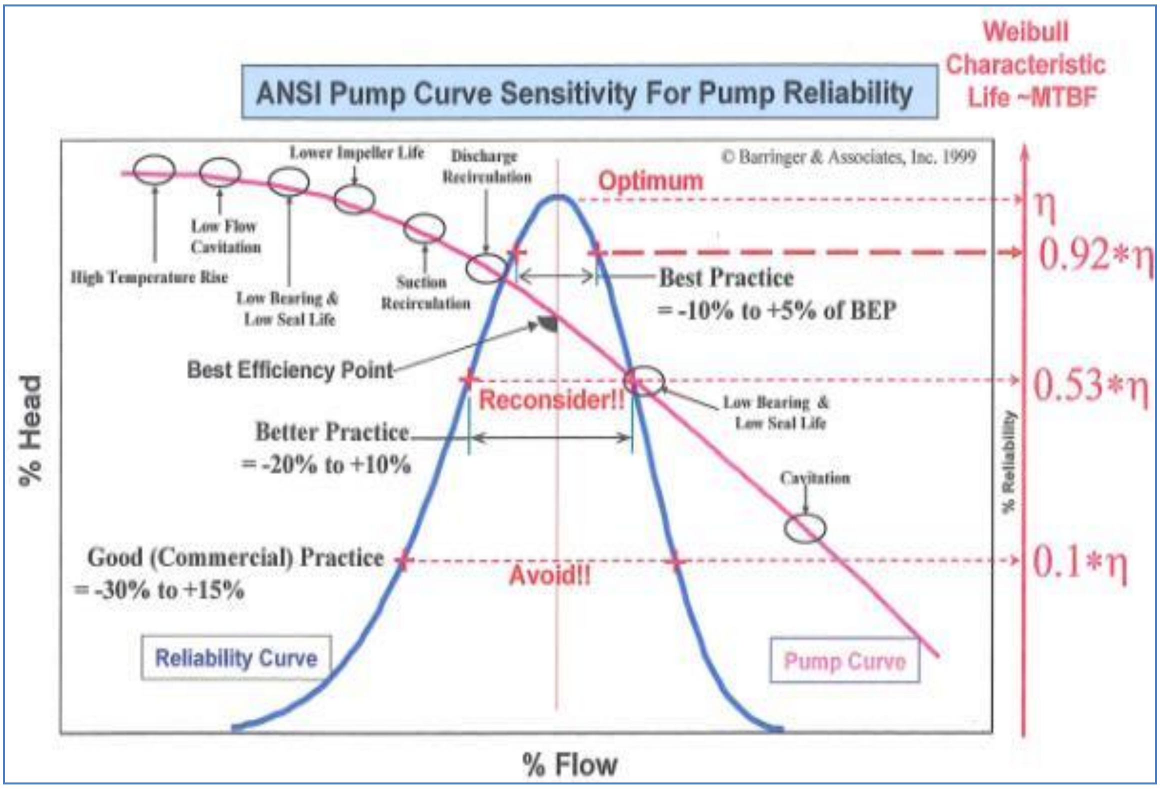


Figure 2: Pump performance evaluation (Source: Hamburg WASSER)

Figure 2 also identifies the damage to the pumps that occurs if these conditions are not met. Daily patterns of flow demand and pressure can vary at many pump stations. Hence, the most important challenge is to select the pumps and design the pumping station to keep each individual pump operating in the Best Practice range of the Best Operation Point in order to optimize energy consumption and maximize pump longevity and efficiency.

Water quality (e.g., salinity, presence of sand) must also be taken into consideration among other operating conditions. Experienced engineers will be needed to adapt these specifications to accommodate the local water quality.

When selecting the pump according to the specifications (Q and H), some amount of head may be added to compensate for pump aging. However, the safety factor should not be so high as to result in over-sizing of the pump/motor, nor should a model previously used for similar purposes be chosen simply for convenience.

Specific manufacturer software may be used to obtain information concerning availability of pumps and their relevant characteristics (e.g., dimensions). However, the design engineer shall not pre-select a specific pump.

Trusted pump manufacturers' software should be used to select the right pump/motor. The following inputs must be available to for the software-based selection process:

a) Discharge flow rate, Q;
b) Total dynamic head, H;
c) Properly calculated net positive suction head (NPSH) value, which can be obtained by inputting the following information to the software (recommended over other calculation methods):
    i. Distance from the intake to the pump location;
    ii. Elevation difference between the intake water surface and the pump location;
    iii. Exact geological location of the pump station; and
    iv. Atmospheric pressure at the pump station;
d) Material specifications;
e) Power supply (e.g., voltage level, frequency, speed); and
f) Installation mode (e.g., horizontal, vertical, submersible).

Software can also be useful for selecting the correct pipe for the suction side of the pump, using the details listed above.

Pump(s) should not be chosen prior to obtaining the field information regarding the bore hole(s); the completed borehole information should guide pump selection.

In preparation of the tender documents, the design engineers must prepare all required specifications to enable manufacturers or their agents to offer the most appropriate pump and motor type.

3.2.4 Material

Regarding the material and construction of pumps and motors, the following requirements shall be followed. Additionally, the buyer (WSP) shall ensure that the selected pumps and motors meet the Kenyan laws and regulations regarding material requirements, with certificates provided as documentary evidence.

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

a) The material used shall not be adversely affected by water temperature variations within the working temperature range. In Kenya, pumps must endure a water temperature of 50ºC.
b) Pumps should be made of non-toxic, non-contaminating, and biologically inert material.
c) The material used for pumps, motors, and couplings shall be resistant to internal and external corrosion.

3.2.5 Efficiency

The following formula can be used to calculate the *overall efficiency* of the whole system (pump and motor).

$$\eta = \frac{\text{Hydraulic Energy (output)}}{\text{Electric Energy (input)}} = \frac{Ppump}{P_{el}} = \frac{Q \cdot H \cdot \rho \cdot g}{P_{el}} \qquad \text{(Eq. 1)}$$

where

P is Electricity consumption (kW), measured by tension (Power meter);
Q is Flow rate (m^3/h), measured by flow meter;
H is Head (m), measured by manometer (for wells, using dynamic water level);
ρ is Density of the liquid (kg/ m^3); and
g is Gravitational acceleration (m/s^2).

As described in Section 3.2.3, due to the temporal variation of flow demand and pressure, it is challenging to design the pumps or pumping station to keep the individual pump in the range of the Best Operation Point in order to optimize the energy consumption and to guarantee a long lifetime with high efficiency. To optimize operation within these varying conditions, one or more of the following options should be considered:

a) **Highly recommended: Use Variable Speed Drive (VFD) for pumps as required.** VFD provides significant flexibility and improves operational efficiency, especially when pumping into a distribution system with variable head and flow. VFD also reduces the number of pump starts and stops, and consequently reduces the number of water hammers in the distribution system and number of pipe/joint breaks. (If the pump station pumps with fixed flow and head, there is no need for VFD.)
b) Choose multiple pump units, either of the same size or a combination of different sizes, based on the optimal design requirements.
c) Adjust the pump curve slope control to the required operating conditions using flow control valves. (This option is less desirable than (a) or (b) due to the additional energy loss in the partially closed valves).

Efficiency of the Motors

In the International Electrotechnical Commission standard IEC 60034-30-1, induction motors are categorized in the following four efficiency classes (where IE = International Efficiency):

- IE1 (Standard Efficiency)
- IE2 (High Efficiency)
- IE3 (Premium Efficiency)
- IE4 (Super Premium Efficiency)

Kenya's Energy (Appliances' Energy Performance and Labeling) Regulations (2015) impose new Minimum Energy Performance Standards (MEPS) for electric motors. The regulation states that:

a) Every importer shall affix the applicable energy label approved by the Commission on every appliance that has been registered under these Regulations.
b) The label shall bear the respective star rating. For example, for three-phase cage induction motors, the minimum energy efficiency should be 87.6% (1-star rating, Figure 3).
c) The label shall be affixed in a clearly visible position (e.g., on the top side of the motor).
d) These regulations should also be applied for rewound motors.

Selected motors for the pumps should have at least 1-star rating according the regulations referenced above.

Figure 3: Proposed Kenya Energy Saving Guide Labels for Electric Motor
(Adopted from the flyer of the Standards and Labeling Program in Kenya, Ministry of Industrialization and Enterprise Development)

Efficiency of the Pumps

It is also important to choose pumps with high hydraulic efficiency. The Minimum Efficiency Index (MEI) is a measure of hydraulic efficiency. According to "Ecodesign Requirements for Water Pumps" (European Commission Regulation 547/2012/EC) [6]:

Water pumps shall have:

a) A minimum efficiency at the best efficiency point (BEP) of at least $(\eta_{BEP})_{min\ requ}$;
b) A minimum efficiency at part load (PL) of at least $(\eta_{PL})_{min\ requ}$; and
c) A minimum efficiency at over load (OL) of at least $(\eta_{OL})_{min\ requ}$.

The following formula shall be used to calculate the required minimum efficiency at BEP [6]:

$$(\eta_{BEP})_{min\ requ} = 88.59\ x + 13.46\ y - 11.48\ x^2 - 0.85\ y^2 - 0.38\ x\ y - C_{Pump\ Type,rpm} \quad \text{(Eq. 2)}$$

where

$x = \ln(n_s)$;

$y = \ln(Q)$;

ln is natural logarithm; and

n_s is specific speed.According to 547/2012/EC, at the time of adoption of the regulation, the benchmark for minimum efficiency index (MEI) for the best available technology on the market for water pumps was MEI ≥ 0.70 [6].

3.2.6 onsiderations for Source Selection

In Kenya, pumps can be either imported from foreign manufacturers or produced by domestic manufacturers. The following actions are recommended for WASPA and WSPs to ensure the purchase of high-quality pumps and motors.

- WASPA should create a master list of reliable pump/motor manufactures, agents, distributors, suppliers, contractors, and models, based on previous experience gained from projects in Kenya and/or overseas.
- The purchaser (WSP) should consult the WASPA list to choose a recommended pump manufacturer, model, and supplier.
- The purchaser (WSP) should consult with other WSPs that have used the same pump(s) in order to learn from their experience.

3.2.7 Summary of Recommendations

Select high-performance pumps from companies that meet international standards and guarantee a high quality of materials, workmanship, and performance, Selecting high-quality pumps and motors is critical for containing costs because initial investment costs are minimal compared to the cost of operation: purchase costs are only 5% to 10% of the full life cycle cost of a pump, with more than 90% of the life cycle cost spent on electricity. This strategy of investing in reliability and efficiency is the most cost effective approach in the long run, particularly when considering the increasing cost of electricity.

The importance of the energy cost is highlighted in Figure 4.

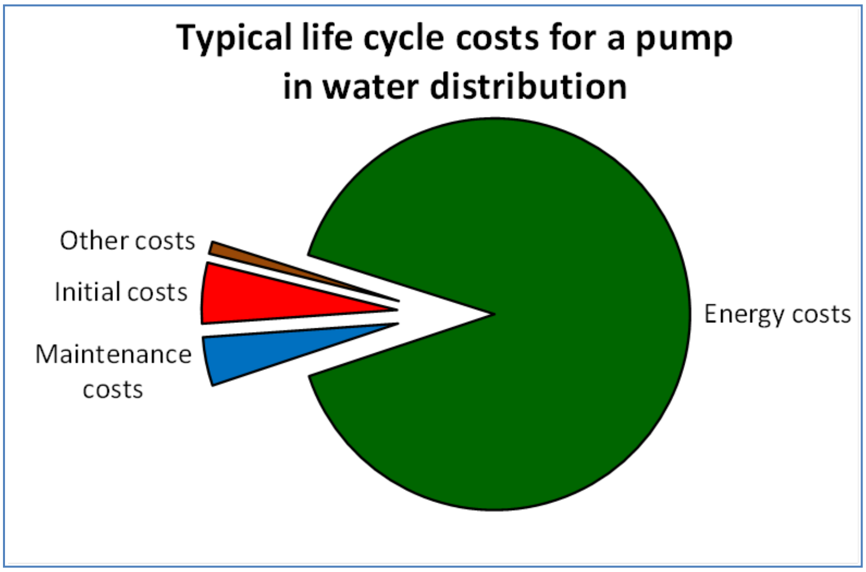


Figure 4. Life cycle cost for a pump (Hamburg Wasser data)

Additionally, choosing a relatively expensive pump/motor, even if its efficiency gain appears modest (e.g., 3%), could be a beneficial strategy in the long run. Annex B provides an example calculation to demonstrate how the return on investment can be substantial, even during a short period, and can be very significant when calculated over the pump/motor's operational life.

Experience with different kinds of specifications and different manufacturers plays an important role in effective pump and motor selection. Therefore, WSPs should develop asset management policies to procure high-quality pumps and motors. Policies that maximize the reliability of equipment will also limit the number of spares pumps and parts that must be purchased and stored.

WSPs are strongly advised to involve pump/motor suppliers at the initial stage of the procurement process (e.g., allow supplier to visit the installation site).

For larger motor/pump systems (i.e., >50KW), a factory acceptance test (FAT) should be considered.

Important: **Pump models for which spare parts supply has been terminated shall not be selected for new purchase. WSPs' experience with such models shall not be a reason to overlook this requirement. Availability of spare parts for the entire lifespan of a pump is of utmost importance.**

4 Technical Specifications of Tender Document

Technical specifications of a tender document for the procurement of pumps and motors should incorporate the following information.

4.1 Certificates

The manufacturer of the pump shall hold the Quality System Certificate for the standard ISO 9001, and should also hold certification corresponding to ISO 14001.

Additionally, the specific pump/motor model purchased shall be certified according to applicable standards (e.g., ISO 9906).

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

The purchaser (WSP) must ensure that the specific model purchased is the one for which the certificate was issued.

The acceptance grade shall be as follows:

- 2B for pumps with shaft power >10 kW and ≤100 kW; and
- 1B for pumps with shaft power >100 kW,

in accordance with the grades given through application of the provisions of ISO 9906.

Hence, the certificates should incorporate the pump grade information.

4.2 Statement of Type, Specification, Material, and Efficiency of Pumps and Motors

The selected pump type, specification, material, and efficiency as described in Section 3.2 should be stated in the technical specifications of the tender document.

4.3 Additional Technical Specifications

The following additional technical specifications should be incorporated in the tender document:

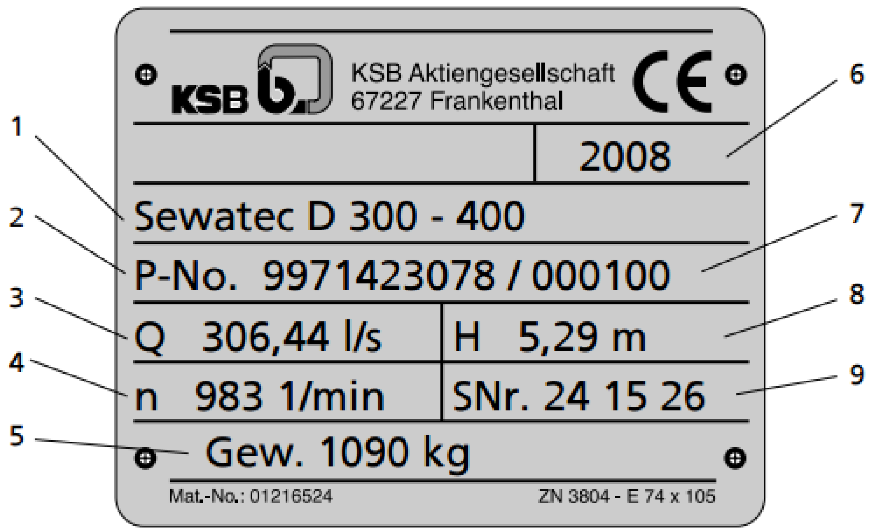
a) The direction of rotation shall be indicated by a durable and clearly visible arrow.

b) In addition to the inscription requirement in ISO 9905 (see subclause 4.15, Labelling), the following shall be marked on every pump:
   i. Name (or trademark) and address of the manufacturer/supplier;
   ii. Identification number of the pump (e.g., serial number or product number);
   iii. Type;
   iv. Size;
   v. Flow;
   vi. Pump total head;
   vii. Pump speed;
   viii. Impeller diameter (maximum and installed); and
   ix. Allowable working pressure and rated temperature.

c) In addition to the inscription requirement in NEMA MG 1-10.40 (see Clause "Nameplate Marking for Medium Single-Phase and Poly-phase Induction Motors), the following shall be marked on every motor:
   i. Name (or trademark) and address of the manufacturer/supplier;
   ii. Identification number of the motor (e.g., serial number or product number);
   iii. Type;
   iv. Size;
   v. Operating volt;
   vi. Current;
   vii. Power;
   viii. Motor speed; and
   ix. Rated temperature.

d) Marking should be achieved through engrave printing on corrosion resistant material (e.g., metal plates) appropriate for the local conditions; name plates should be securely attached on the pumps and motors. Figures 5 and 6 provide examples of recommended marking on the pumps and motors.

e) Pumps and motors should be stored and delivered according to ISO 9905, subclause 7.3, Preparation for transport and storage.



1	Designation of the pump set	2	Order number
3	Flow rate	4	Speed
5	Weight of Fig. 0 pump	6	Year of supply
7	Order item number	8	Head
9	Series number		

Figure 5. A typical name plate for a pump with minimum required information

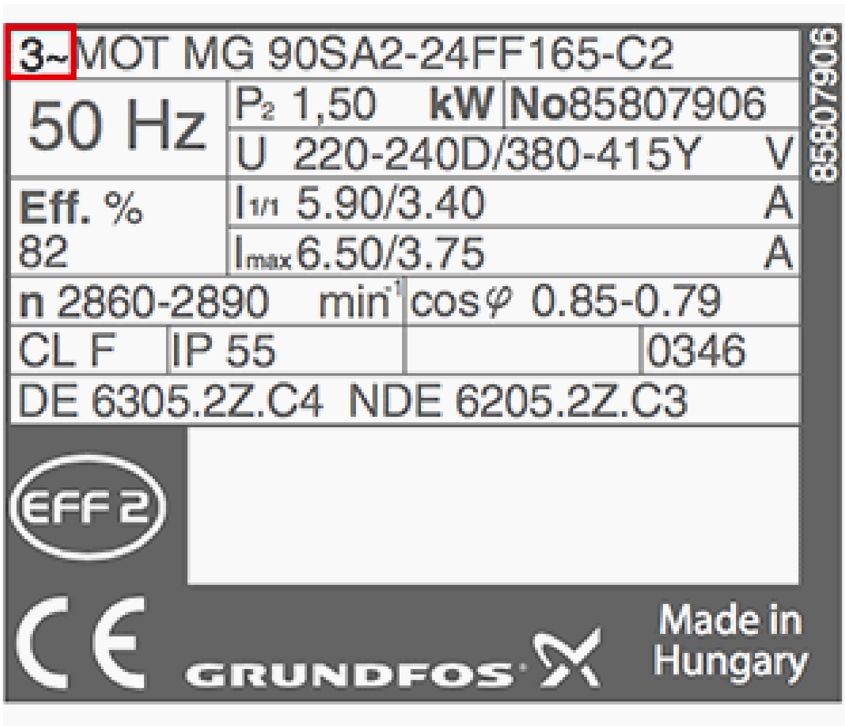


Figure 6. A typical name plate for a motor with minimum required information

4.4 Additional Non-Technical Specifications

The following additional non-technical specifications should be incorporated in the tender document:

a) **Spare parts/after sales service:** Availability of spare parts must be proven. The manufacturer should provide a complete list of available spare parts (in English), their specific costs (at the time of purchase), and delivery time. The manufacturer should guarantee the supply of spare parts for at least five years after the expiry of warranty of the relevant pump/motor. The name, address, and contact details of the local agent responsible for providing spare parts and maintenance shall be indicated.
b) **Installation manuals**: Installation manuals (in English) shall be provided.
c) **Warranty**: The minimum warranty period shall be one year for pumps and six months for motors.

5 Installation of Pumps and Motors

5.1 Instruments

Flow meter, pressure gauges, and a power controller should be installed for each pump and maintained in working condition.

5.2 Electric surge protectors

At this time, the power supply in Kenya is not very stable, and surge-related damage to motors is a common occurrence. Applying appropriate surge protection in the right location will prevent damage to the motors and associated electrical components. Hence, it is strongly recommended that every pump station be protected from damage through the use of electric surge protection devices.

Investment in surge protection will reduce costs substantially for WSPs. Although surge protection carries a small cost, revenue lost to downtime and costs of equipment repair are far higher. WSPs should prioritize surge protection for sensitive and vital equipment, in particular the drive/inverter that controls the pump.

5.3 Associated Fittings

In addition to the purchase of high-quality pumps, the following fittings and instructions should be applied and followed in order to ensure correct pump functioning.

5.3.1 Flanged connection

Key aspects of flange connection include the following:

a) For flange-connected pumps, pipes, and fittings, use gaskets that properly match the diameter of the pipe. Flow interruption may occur when gaskets are projecting inwards.
b) Gaskets should be made of recommended compatible material (e.g. EPDM, Teflon, PTFE).
c) Torque wrenches should be used for bolt tightening.
d) Tightening torque value depends on the type of gasket and, amount and diameter of bolts.
e) Appropriate torque values and tightening procedures should be used to ensure proper connections.

Most pipe manufacturers provide detailed written connection procedures. Additionally, many publications describe flanged connection techniques. A good reference source is the collection of technical manuals published by Georg Fischer Piping Systems (gfps.com).

Some important points regarding flange connection are provided in Annex E of the "Technical Guideline for Drinking Water Distribution Pipes in Kenya."

5.3.2 Coupling

The pump is normally coupled to the motor shaft by flexible coupling. Other types of coupling (e.g., rigid coupling) may be used, if appropriate. Table 3 summarizes the typical coupling types used in Kenya.

Table 3. Description of coupling types used in Kenya
(Ref: "Back to Basics: Pump Coupling Selection," [10])

Type	General application	Key considerations
Rigid Couplings	o Generally used in vertical turbine pump (including submersible pump) applications	o No compensation for misalignment between the pump and motor shafts; failure to ensure precise alignment of will result in increased vibration, bearing wear, and shortened mechanical seal life
Flexible Couplings	o Generally used for horizontal pump applications o Mechanically flexible, material-flexible are the two major types **Mechanically Flexible Couplings** o Compensate for misalignment of shafts through clearances incorporated in the design o Gear coupling is most common type	**Advantages of mechanically flexible couplings:** -Compact gear couplings can transmit high torque at high speeds -Axial force and moment transmission can be significant **Disadvantages of mechanically flexible couplings:** -Axial force must be absorbed by thrust bearings in the driver and driven machines -Coupling specific grease necessary for lubrication, adding to maintenance cost -Gear teeth are prone to wear
	Material-Flexible Couplings o Rely on flexing of one or more coupling elements to compensate for shaft misalignment. o Flexing elements can be made of any suitable material (e.g., metal, elastomer, or plastic) with sufficient resistance to fatigue failure.	**Advantages of material-flexible couplings:** -Do not require periodic lubrication; reducing downtime and cost -Generally transmit low, known thrust forces -Can be designed for very long (i.e., theoretically infinite) life -,Easier to maintain balance than for gear couplings (with the exception of rubber tire-type couplings) **Disadvantages of material-flexible couplings**: -Flexing action can generate excessive heat (a potential problem with elastomer or plastic couplings), and/or can cause fatigue (a potential problem with metals), if loads or misalignment exceed defined limits. Either result will shorten lifespan.
	Elastomeric Material Flexible Couplings	**Advantages of elastomeric material flexible couplings advantages over metallic flexible**

Type	General application	Key considerations
	o Employ elastometic (as opposed to metallic) materials o Despite general claims, elastomeric material flexible couplings will not operate at severe misalignments. Anything more than moderate misalignment will severely limit coupling life.	**couplings**: -Generally do not have defined fatigue limits -Torsionally soft; provide good vibration damping -Less expensive -Lower reactionary loads on bearings -More tolerant of misalignment **Elastomeric flexible material coupling limitations:** -Sensitive to chemicals / high temperatures -Larger outside diameters than metallic couplings -Difficult to balance as an assembly -Some types have low overload torque capacity

According to ISO 9905, appropriate coupling shall be chosen to transmit the maximum torque. The speed limitation of the coupling shall correspond to all possible operating speeds of the intended pump driver. Always use the pump/motor manufacturers' recommended couplings.

5.3.3 Base-plate

The following points shall be considered for base-plate design and installation (ISO 9905):

a) The base-plate and pump supports shall be designed to withstand external forces on pump branches, as well as other mechanical forces (e.g., internal differential thermal expansion and hydraulic piping thrust), without exceeding shaft misalignment specified by the coupling manufacturer/supplier.
b) Base-plate for horizontal pumps:
    i. Shall extend under the pump and drive, unless otherwise agreed upon.
    ii. A minimum of six vertical levelling screws spaced for stability shall be provided on the outside perimeter of base-plate, if specified by the purchaser.
c) Base-plate for vertical pumps:
    i. A minimum of four alignment-positioning screws shall be provided for each drive element (drive and gear) to facilitate horizontal adjustments, if specified by the purchaser.

The base plate shall be supplied by the pump/motor supplier as an integral part of the equipment package.

5.4 Installation Instructions

5.4.1 General Recommendations

Installation of pumps and motors shall be carried out professionally according to the installation instructions provided by the specific manufacturer. It is recommended that the pump supplier be involved in the pump and motor installation. Additionally, the following requirements and recommendations apply:

a) Pumps and motors shall be easily accessible for installation, maintenance, and removal, and for in situ dismantling of the mechanism, if required.
b) Measures shall be employed to avoid contamination, especially when the pumps and motor are installed in a pit, by mounting the pumps, motors, and fittings at a sufficient

height above the floor. If necessary, the pit shall be provided with a sump or drain for water removal.

c) The pump and motors shall be protected from the risk of damage by shock or vibration, extreme temperatures, water or ambient air, and external environmental corrosion.
d) The pumps and motors shall not be subjected to undue stresses caused by pipes and fittings. If applicable, the pump and motor shall be mounted on a skid.
e) Unfavourable hydraulic conditions (e.g. cavitations, surging, and water hammer) should be avoided.

5.4.2 Step-by-Step Installation

In general, pump manuals include a step-by-step installation guide, which should be followed. Furthermore, step-by-step guidelines established by any WSP based on extensive experience may be followed.

5.4.3 Alignment of the shafts and coupling

Proper alignment of the pump and motor shafts are very important for the longevity of the equipment. Alignment checks shall be performed according to manufacturer guidelines.

Proper coupling should be used according to manufacturer guidelines.

5.5 Operation of New or Repaired/Serviced Pumps and/or Motors

The following points shall be considered before pumps and motors are used for the first time.

1. Before installation, the water mains shall be flushed.
2. Care shall be taken to prevent the ingress of debris into the supply lines.

If requested in the specification, a performance test for the pump and motor shall be undertaken by the manufacturer with the required documentation provided. Engineers from the WSP can also participate in conducting these tests.

Insulation tests for the motor and cables must also be performed.

After installation, only operation parameters such as flow, pressure, and power consumption will be verified..

6 Management of Pumps and Motors

A pump and motor registry provides complete information for each pump and motor used in the water distribution network. If possible, the pump and motor registry should be integrated or linked with a Geographic Information System (GIS)[1]. A simplified option is to create the pump and motor registry as a separate Excel file.

We recommend the inclusion of the following pump attributes in the registry:

a) GPS coordinates;
b) (Administrative) zone code;
c) Serial number;
d) Brand;
e) Type: pump, motor, and coupling;

[1] Training for GIS is offered by WASPA.

f) Capacity, pump (hp), motor (kw);
g) Q, H, NPSH;
h) Volt, Amp, single- or three-phase;
i) Manufacturing date;
j) First installation date (can be used to establish the age of the pump/motor in combination with the manufacturing data, if known);
k) Last installation (or servicing) date (can be used to estimate the age of the pump/motor if the first installation date is unknown);
l) Operational status: functional, non-functional, damaged (but functional), or testing requested;
m) Visible defects; and
n) Remarks of the registrant.

7 Maintenance of Pumps and Motors

Operators must regularly check physical conditions and the basic operation parameters of pumps and motors (e.g., daily visual observation and weekly parameters check) using the supervisory control and data acquisition (SCADA) system. Checks/analysis/audits are tools to monitor the working conditions and to assist in analyzing deviations from the designed specifications (Q and H), which might indicate damage to the mechanical parts or the motor.

To ensure pumps and motors are functioning correctly, the utility should establish a pump and motor maintenance program. This maintenance program should include checking the accuracy of function of pumps (e.g., Q, H and efficiency) and motors (e.g., efficiency, temperature, rpm, volt, current).

General information about operation maintenance tasks and frequency is provided in Annex C.

Annual technical and energy audits are recommended for larger pumps in order to ensure the proper performance of each pump and minimize operation costs, Refer to Figure 2 regarding pump performance evaluation.

A sample operation and maintenance schedule for pumps and motors is shown in Table D1 in Annex D.

A sample inspection report and a sample maintenance activity report are provided in Annex D in Table D2 and Table D3, respectively.

7.1 Preventive Maintenance

Preventative inspections shall be undertaken regularly:

a) Daily inspection by the operators shall check visually for leakages of the sealing and check for any unusual noise, temperature, and vibration. Vibration and noise of the pump motor assembly must be checked carefully, as these phenomena can provide an early indication of failure (e.g., misalignment of shafts).
   Weekly and monthly inspection shall be conducted by the mechanics, including greasing and changing of the motor and pump bearings, general inspection of the pump and motor parts, insulation tests for the motors and cables, and cleaning of the motor if it is exposed to dust or other particulates.

b) Complete overhauling of the pumps after a designated number of running hours.[2] The number of running hours should be designated based on experience and according to the water quality and operating conditions. Maintenance and overhauling of pumps and motors shall be performed by a qualified workshop.

A service contract with the supplier/manufacturer of the pump is highly recommended, as it will ensure proper maintenance of the pumps and motors, resulting in:

- A longer operating lifetime;
- Better performance and higher efficiency;
- Early detection of a failure; and
- Less downtime.

7.2 Energy Audits

In most water utilities, pumping stations are the largest energy consumer, and therefore also the major operating cost factor. In order to control costs, energy audits should be part of the life cycle control of the pumps and motors.

The following target overall efficiencies (pump and motor) are recommended for horizontal pumps:

- 60-70% for smaller pumps (e.g., <50 m^3); and (motor 88-93%, pump 68-75%)
- 70-80% for larger pumps (e.g., >50 m^3). (motor 93-96%, pump 75-83%)

Stable operating conditions from a pump station to an elevated reservoir will guarantee higher efficiency compared with pumping into distribution systems with larger variations in pressure. Variation in pressure or flow will negatively affect the overall pump efficiency and reduce the pump's lifespan ..

Once the inspection of the pump station or the individual pump has been completed, analysis should follow to evaluate the cause of any reduction of efficiency.

Each pump, as with all technical equipment, has its limited life cycle (see item (c) in 7.1). The technical lifetime of a pump is approximately 15 to 20 years if all operating conditions are respected. Financial evaluation of a pump should normally be calculated for 10 years.

7.3 Pump and Motor Management Team

WSPs should establish a pump and motor management team within the utility. Depending on the capacity of the utility, the team can range from 2-4 people (including staff responsible for maintenance) up to 6-10 people. This team will manage all required activities addressing all aspects of pump and motor management: pump and motor selection/sizing, procurement, installation, maintenance, and replacement.

As presented in Figure 7, three complete teams are required to design, operate, and maintain the pumping station in a WSP.

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[2] In Morocco, for example, all large pumps are completely overhauled in a specialized workshop after 20,000 running hours.

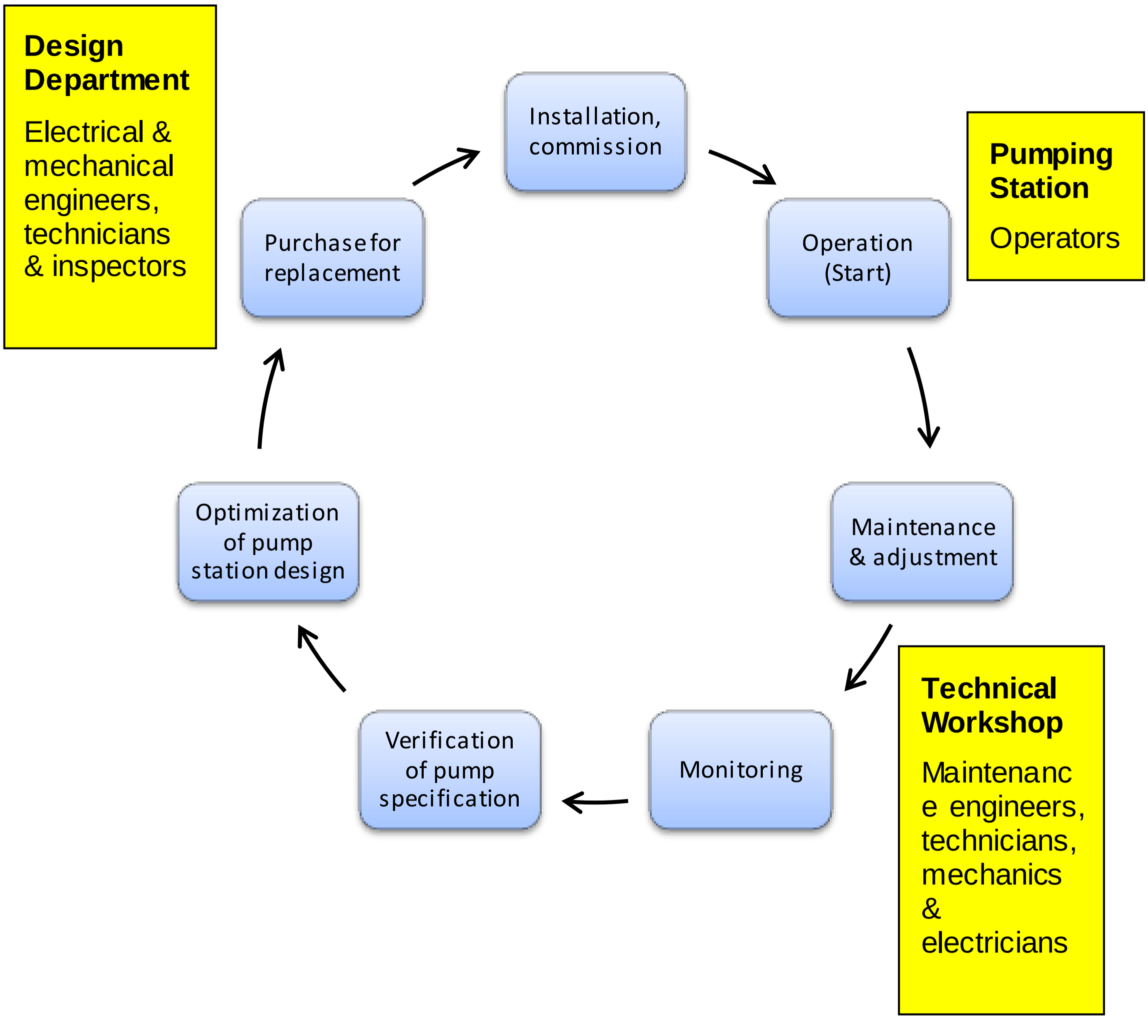

Figure 7. Composition of pump and motor management teams [7]

7.3.1 1st Team: Design engineers

According to the experience of consultants worldwide, the design of the pump station often causes the most significant problems for pump operation and maintenance. Design engineers tend to overdesign pumps, or design the pumps for future demand, resulting in pumps working outside of their specifications. Therefore, regular audits must be undertaken; if necessary, pumps shall be modified or replaced.

Required training: Hydraulic modeling and specification of pumps and motors to carry out technical-end energy audits. Assist the design engineer to analyze the existing problems at the different pump stations.

Required equipment: Computers, software for GIS, and hydraulic modeling.

7.3.2 2nd Team: Operators

Operators must control the pump operation according to the required schedule. Although the knowledge requirements and tasks are limited, operators play a vital role in pump station operation. The precondition for their work is the proper working of the instrumentation (electric flow meters, pressure gauges, and power controller).

Required training: Operation of pumps, starting and stopping, troubleshooting, greasing of the bearings.

Required equipment: Installation of needed flow meters and replacement of all nonworking instruments.

7.3.3 3rd Team: Maintenance

For larger WSPs, a qualified maintenance workshop is required and can be either in-house or contracted to a privately owned firm.

The technical team must carry out regular monthly preventive maintenance according to the instructions of the manufacturer and the operation time, covering:
- control of the operation condition and parameters; and
- control of the bearings (vibrations and temperature), as well as greasing.

On the basis of the technical and energy audits, this team must schedule the regular maintenance and overhauling of the pumps, including:
- changing the bearings according to the instruction of the supplier; and
- overhauling equipment according the designated number of running hours (see 7.2), which will be dependent on the operating conditions of the pumps and the water quality.

Required training: On-the-job training at a qualified workshop or from the manufacturer.

Required equipment: Mechanical workshop for overhauling of pumps, testing facilities for pumps, mobile maintenance car with tools and testing equipment (e.g. mobile flow meter, pressure gauges, power analyzer, vibration meter).

7.4 Maintenance Procedure

Details of specific pump and motor maintenance procedures are outside the scope of this Guideline, as every type and brand requires its own specific maintenance procedure. Hence, for more detailed guidance, the maintenance manual provided by the manufacturer should be consulted.

7.5 General Recommendations for Further Technical Assistance

For the life cycle management of pumps and motors, the following general recommendations are provided:

a) Organizational Assistance: It may be necessary to address organizational challenges by reorganizing the different teams involved in the life cycle management of pumps and motors. Proper team organization ensures that the different maintenance experts have a clear understanding of their individual tasks, are well coordinated, and have access to proper equipment, spare pumps, motors, parts, and tools.
b) Management and Budgeting Assistance: WSP managers should recognize the benefits of technical and energy audits in order to reduce the operating cost by optimizing energy efficiency. The management should not attempt to decrease operating costs by reducing the maintenance staff or closing down pump workshops, because these steps will result in increasing energy bills.

7.6 Disposal of Pumps and Motors

Pumps and motors should be disposed according to ISO 14001. This International Standard requires organizations to consider the full life cycle of their products and the need to provide information about potentially significant environmental impacts associated with products' end-of-life treatment and final disposal. The WSP shall maintain documentation that end-of-life and disposal processes have been carried out in accordance with ISO 14001.

Annex A: WASPA Pump and Motor Survey Findings

As is highlighted in the introduction to this document, this Guideline incorporates the findings of a valve management survey that was conducted by WASPA with bfz-SWAP support. The questionnaire was disseminated to all member WSPs. We would like to acknowledge and thank the following 11 WSPs for directly contributing to the Guideline by submitting their questionnaires: Eldoret, Isiolo, Kewasco, Kisumu, Mathira, Mawasco, Murang'a, Nakuru Rural (NARUWASCO), Nawasco, Nyeri, South West Kenya.

The bullets below summarize the major findings of the survey.[3].

- The most common types of pumps in use in Kenya are centrifugal pumps with bearings and submersible pumps.
- Motor failure due to electrical surge is a major problem.
- Shaft misalignment is another common problem.

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

Annex B. Effect of Minor Efficiency Improvement on Total Costs

		BRAND 'I'	BRAND 'W'	Difference
MOTOR EFFICIENCY		IE1	IE3	
MOTOR SIZE (KW)		22	18.5	3.5Kw
EFFICIENCY DIFFERENCE		89.90%	92.70%	2.80%
RUNNING HOURS		24	24	
ENERGY USED PER DAY (KWH)		528	444	
ELECTRICITY CHARGES PER KWH IN (KES) IN KENYA		20	20	
COST PER DAY (KES)		10,560	8,880	
RUNNING DAYS PER YEAR		300	300	
COST PER YEAR (KES)		3,168,000	2,664,000	504,000
LIFE SPAN OF THE PUMP (YEARS)		15	15	
COST IN 10 YEARS		47,520,000	39,960,000	7,560,000
SAVINGS BASED ON EFFICIENCY ALONE (2.8%) IN KES				1,330,560
SAVINGS BASED ON MOTOR SIZE (KES)				7,560,000
TOTAL SAVINGS BASED ON MOTOR (KES)				8,890,560
NUMBER OF PUMPS				9
TOTAL SAVINGS FOR 9 PUMPS (KES)				80,015,040

Annex C: Sample Table of Operation and Maintenance Tasks and Frequency

Location	Asset	Qty	Type of Maintenance	Activities	Requirements	Cost(s)	By who	Time Frame
Guta Raw Water Intake	*KSB(pump) WKLn 65/4*	*2*	**Inspection;**	vibration, leakage through stuffing box and pumps operation			Pump Attendant	24hrs (daily)
			Inspection;	Bearing temperature, noise and vibration			Pump Attendant	24hrs (daily)
			Inspection;	Coupling guard and Earthling connection			Pump Incharge	Monthly
				Check bearing lubrication	Grease gun and grease		Pump Attendant	2-3 months, depending on operation environment
				Replace deep-groove ball bearings	Deep-groove ball bearing		Pump Incharge	Depends on Manufacturer's specifications
			Overhauling	Check and replace (if any) bearings, casing and impeller wearing, shaft protecting sleeve, shaft bending, sealing elements and torsion play between two coupling parts.	Impeller, Pump shaft and its Components, ball bearings/ or Roller bearings and gland Packing.		Pump Incharge	Yearly

Source: Hamburg Wasser

Annex D: Sample Maintenance Schedules and Reports

Table D1. Sample Maintenance Schedule for WSP

S/N	Assets	Quantity	Types of maintenance	Activities	Requirements	Cost (KES)	By Who	Time frame
1	KSB (Pumb) Serial No. 1234ABC	1	Preventive and Emergency	Bearing lubrication Coupling replacement	Lubricants New coupling Wrench Level	40,000	Pump maintenance team members	20 Feb 2016 to 21 Feb 2016

Table D2. Sample Inspection Report

Inspection	Observation	Date
KSB (Pump) Serial No. 1234ABC Was not turning smoothly	Bearing lubrication, Coupling replacement was needed	**19 Feb 2016**

Table D3. Sample Maintenance Activity Report

Activity Performed	Location	Date
Bearing was lubricated, Coupling was replaced	KSB (Pump) Serial No. 1234ABC at the pump house in 'name of WSP'	**21 Feb 2016**

Annex E: Scope for Training

A trained pump management team is essential to ensure optimal functioning of pump stations. Following are the primary areas on which to focus training:

E1. Building the capacity to check the authenticity of the different test certificates

E2. Building the capacity to write and evaluate the service contract agreements

E3. Building the technical capacity for proper design and installation

E4. Building the technical capacity to execute a proper maintenance program

WASPA can facilitate the development of a group of trained personnel who can provide services to different WSPs to ensure proper design, installation, and maintenance of pump stations.

References and Additional Resources

[1] State department of water, Standards for non-revenue water management in Kenya, nairobi: Ministry of envrionment, water and natural resoures, 2014.

[2] WASREB, "IMPACT - A Performance Review of Kenya's Water Services Sector 2012 - 2013 - Issue No. 7," Nairobi, 2014.

[3] "National Water Service Strategy 2007-2015."

[4] P. P. O. Authority, "User Guide to the Public Procurement and Disposal Act, 2005, and the Public Procurement and Disposal Regulations, 2006," August 2009.

[5] The World Bank (Editor) (2012): Rural Water Supply Design Manual. Volume I. Manila: The World Bank Office Manila.

[6] Ecodesign Requirements for Water Pumps (2012): European Commission Regulation No 547/2012/EC, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32012R0547

[7] Hamburg Wasser

[8] "Centrifugal Pumps, Vertical Turbine Pumps and Submersible Pumps," http://agriinfo.in/?page=topic&superid=8&topicid=74.

[9] "Pumping Stations," http://www.sswm.info/category/implementation-tools/water-distribution/hardware/water-distribution-networks/pumping-statio.

[10] "Back to Basics: Pump Coupling Selection," http://www.waterworld.com/articles/print/volume-28/issue-9/departments/pump-tips-techniques/back-to-basics-pump-coupling-selection.html.

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