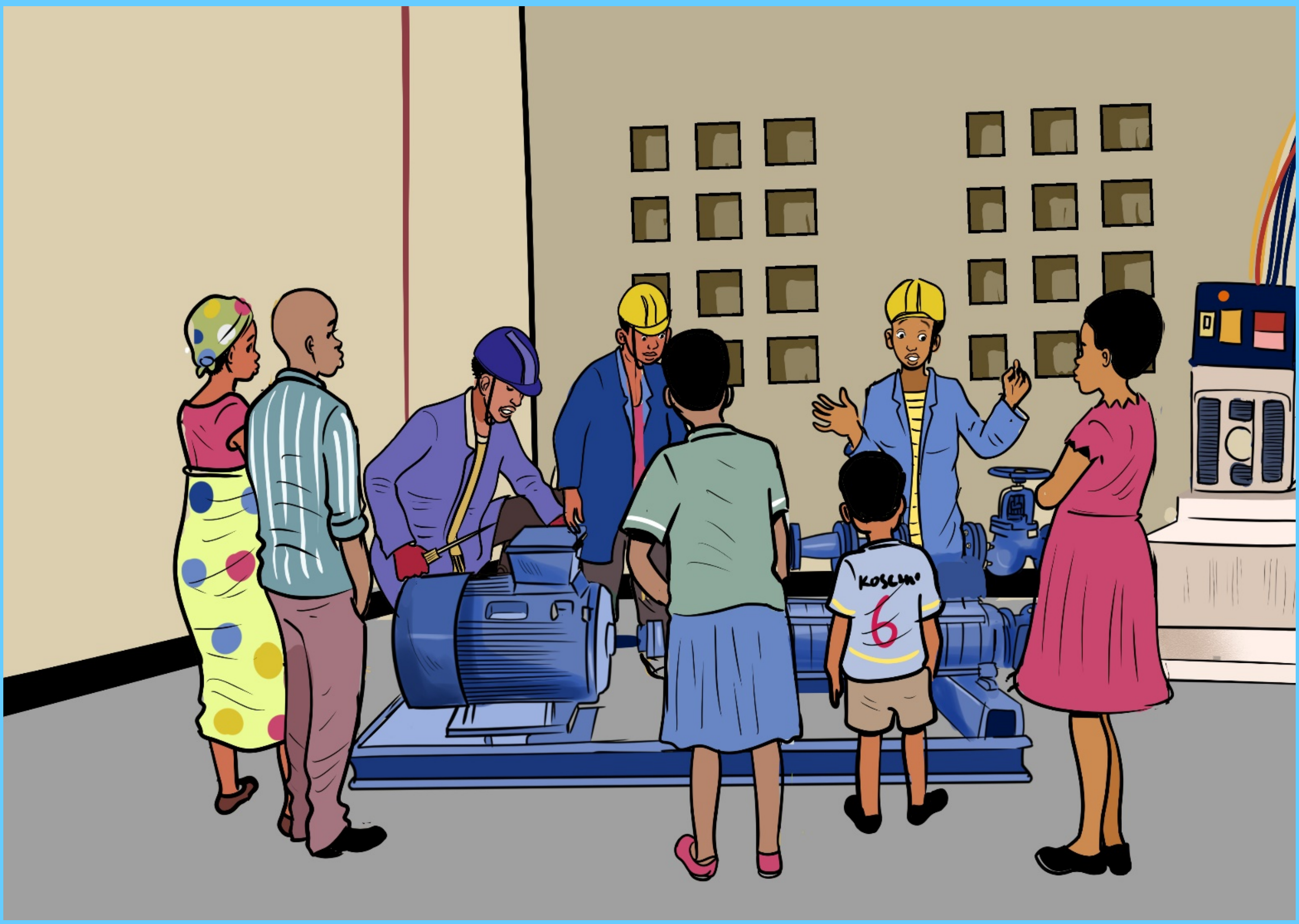
REPUBLIC OF RWANDA

MINISTRY OF INFRASTRUCTURE

Training Module on Operation and Maintenance of Pumps in Rural Water Supply Systems



Edition 3.0

May 2019

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PREFACE

Access to safe drinking water is crucial, not only for people's health and wellbeing, but also for poverty reduction and economic development;

Improving the access, quality, availability and sustainability of water supply services in RWANDA is the top priority in the Sector;

Rwanda has committed to reach SDGs targets by 2030 through the different programs such as the NST1 and 7 Years Government Program with the aim of achieving universal access to basic water and sanitation services by 2024. In order to achieve this target, an appropriate institutional system has to be in place.

The development of the National guidelines for Sustainable Rural Water Supply Services and all its supporting documents (Manuals, Training Modules, etc.) is part of the mechanism to develop the Operation and Maintenance in the Rural Water Supply, and make an important guidelines to Districts, Private Operators, User communities and all the stakeholders in the Rural Water Supply Services sub-sector.

I want to extend my appreciation to the stakeholders, especially JICA/RWANDA through the RWASOM Project, for the effort to have these important documents in place.

We look forward to positive impact of the developed documents through the O&M framework in the rural water services, sustainability of existing water infrastructures and overall, an improved and sustainable clean water supply service toward the communities in RWANDA.

Patricie UWASE

PERMANENT SECRETARY

ACKNOWLEDGEMENT

Many stakeholders in the water sector have tried to develop training modules adapted to the systems they have made. The content of this training module is based on WSP modules written by Philippe Casterman. Great thanks are own to him.

Edition 1.0 of this training module was composed by engineers of AquaRwanda Consultants.

Edition 2.0 of this training module is directed by PWN/Aquanet as part of the SUSWAS - project.

This edition 3.0 of the training module is revised by the Project for Strengthening Operation and Maintenance of Rural Water Supply Systems in Rwanda by WASAC and JICA.

TABLE OF CONTENTS

PARAMETERS

PARAMETER	SYMBOL	UNIT	SYMBOL
pressure relative to atmosferic pressure, head	h	meter water column	Mwc
		bar	Bar
		Pascal	Pa
elevation / distance to reference level	z	meter	M
Force	F	Newton	N
headloss per meter	j	meter water column per meter length	mwc/m
Power	P	Watt	W
		1000 Volt Ampère	kVA = kW
Length	L	meter	M
discharge / flow	Q	cubic meter per second	m^3/s
		liters per second	ℓ/s
efficiency	η	percentage	%
revolution	r	revolution per minute	r/min
surface	A	square meters	m^2
velocity / speed	v	meter per second	m/s
volume	V	cubic meter	m^3
gravity constant	g	meter per square second	m/s^2
density	ρ	kilogram per cubic meter	kg/m^3
friction coefficient	λ	[-]	
wallroughness	k	meter	M
D	diameter	meter	M

ACRONYMS AND ABBREVIATION

ABBREVIATION	CLARIFICATION
AC	Alternating Current
DC	Direct Current
EG	Electrical Generator
JICA	Japan International Cooperation Agency
MININFRA	Ministry of Infrastructure
O&M	Operation and Maintenance
Qn	nominal flow
RWSS	Rural Water Supply System
WASAC Ltd	Water And Sanitation Corporation
WHO	World Health Organisation

1 Lesson 1: GENERAL INTRODUCTION

1.1 Introduction

In general, a water supply system consists of infrastructure for catchment, for treatment, for storage, for pumping and for distribution of potable water. Infrastructure for pumping is only necessary when natural elevations of the area are not enough to overcome energy losses. If water is produced on a high location the water can flow by gravity to the consumers.

In this training module the operation and maintenance (O&M) of infrastructure for pumping, is described. All other infrastructure is taken care of in the other training module 'Training Module on O&M of Gravitational Rural Water Supply Systems'.

In the past, insufficient O&M led to a short life span of the infrastructure. Sustainable O&M of rural water supply infrastructure is the key challenge of drinking water supply.

The number of pumping stations goes on increasing in the rural area of Rwanda because of the intensification of the agglomerations (imidugudu) on the hilltops and the location of drinking water sources in lowland valleys.

1.2 Training module objective

The objective of this module is to provide practical knowledge to operate and maintain pumping stations and associated electrical and mechanical equipment.

1.3 Module description

This module is not a theoretical course on pumps. This module gives the practical knowledge that the operator of the pumping station must have with respect to the ensuring sustainability of the installation. This module contains less text but figures and tables to illustrate the reality of equipment.

This module focus on:

- Good understanding of the functions of the various elements that may be encountered in any rural pumping station in Rwanda.
- An understanding of O&M activities required in order to plan, budget, schedule and monitor them.

The main items developed are:

- Management aspects;
- Overview of water supply preliminary;
- Configuration of a pumping station;
- Type of pumps;
- Power supply;
- Sources of energy.

From every asset the following items are discussed:

- Description and background information;
- Operation;
- Preventive maintenance;
- Curative maintenance.

1.4 Target group

The development of the training module is in line to respond to a call for a comprehensive capacity development addressing to both districts and private operator's staff involved in the operation and maintenance.

This training module is specifically dedicated to increase the skills of WASH-officers, technical directors, plumbers, water treatment operators and other water technicians responsible for daily monitor the functionality of RWSS. The minimum pre-qualification required for the trainees is A3 grade level.

1.5 Methodology

By this method based on prepared notes, the trainer will expose and calls to trainees to react and exchange ideas.

The training must preferably be held near a pumping station well equipped with appropriate tools.

Participative approach by which trainees will express their ideas without shame; The trainers will take into consideration the participants expectations on the learning objectives and on what topics is likely more interesting in.

The trainers have to use video projection, questions, exercises, and practice on the field.

1.6 Expected benefit /outcome

Upon completion of the module the participants have significantly increased their knowledge of the operation and maintenance of a pumped system.

- The technical and managerial skills are improved for better participating in the design, the work surveillance during the implementation, technical consideration during O&M.
- The private operator will be empowered in technical skills of O&M and will effectively improve the working condition in ensure the functionality and reliability of the water supply system.
- The district will improve the follow up of the delegation management contract.
- Improvement of reporting system on both districts and private operator using the developed tools for monitoring.
- This module will be used country wide as a basic supporting tools in the O&M of RWSS.

2 Lesson 2: MANAGEMENT ASPECTS

2.1 Operation and Maintenance

2.1.1 Definitions

Operation: All daily actions to secure the drinking water supply to the customers.

Operation refers to timely and daily operation of the assets of a RWSS effectively by various technical personnel in order to provide safe drinking water under adequate pressure to all customers. Some examples:

- Start and stop a pump;
- Open and close a valve;
- Add chemicals to the water;
- Fill the buckets at the public tap;
- Read the water meter.

Maintenance: All actions that keep the assets of the system in a proper working order during their life-cycle.

There are two types of maintenance:

Preventive maintenance: are actions that performed on a regular schedule to keep assets operating effectively and to minimize unforeseen failures.

These actions consist of inspections and maintenance tasks.

Some examples:

- Change engine-oil of a pump;
- Grease rotating parts of a motor;
- Flush a distribution system without complaints;
- Repaint the connecting mains to a reservoir;
- Inspect the functioning of a valve.

Curative maintenance: Actions performed to repair or restore malfunctioning assets to effective operating conditions.

These actions may result from problems discovered during preventive maintenance or as a result of failures during operation.

Some examples:

- Repair a broken main;
- Repair a worn out impeller of pump
- Replace a failing water meter

The replacement of a main after having too many ruptures is not called curative maintenance. This is called replacement for which financial investments are needed.

2.1.2 Organizing the operation

Operations aims to keep the system in service continuously or at least during service hours. According to the operating environment the manager will decide on the appropriate course of actions.

The Manager must have clear overview of vital day-to-day activities and avail technical specifications of all installed equipment from the manufacturers and suppliers, identify the appropriate tools and study of logistics needs.

Establish the need for parts and consumables, and enter these elements to the annual budget.

2.1.3 Maintenance planning

Preventive Maintenance is planned.

- An action plan for the year, with the financial budget and the human resources appropriate.
- The action plan will be broken down by months and even weeks for some tasks to be more precise.

Maintenance is a form of insurance in the medium and long term, allowing assets reaching their normal life (that provided by the manufacturer or constructor).

- Sometimes the maintenance is neglected because it costs money or is has no clear and immediate impact.

It is important for managers to estimate the cost of maintenance in their budget, which will affect the price of the service.

- The Operator must be in position to calculate the cost which will cover all the operation and maintenance activities.

2.1.4 Key issues

Some of the key issues contributing to the poor O&M have been identified as follows:

- **Budgeting:**

  Lack of finance for proper maintenance.
- **Monitoring:**

  Lack of performance evaluation and regular monitoring. The monitoring gives the managers the opportunity to learn from the impact of executed O&M works, inadequate data and real time field information.
- **Standardization:**

  Inappropriate system design; The standardization greatly improves the efficiency of O&M in reducing costs, facilitating learning, allowing the exchange of parts, tools, and experiences between operators, lack of operation manuals, guidelines and operational strategy at all levels

- **Human resources:**

  Inadequate training of personnel. This affects proper monitoring during implementation and O&M. This can also result to less attraction of maintenance jobs in career planning.

- **Appropriate technologies:**

  Appropriate technologies are those that are adapted to the local context. The choice of appropriate technologies can promote O&M scope of local actors, technically and financially, or otherwise this will make it difficult and leading to low sustainability of the service. Lack of appreciation of the importance of facilities by the community.

- **Example:**

  A water treatment requiring a chemist and laboratory with reagents, is not suitable for a system supplying water to only 4,000 rural customers consuming less than 10 liters a day.

2.2 Safety Regulations

Special attention must be taken to the following words before the O&M of any equipment or unit in drinking water facility like a catchment area, a treatment plant, a storage reservoir or a pump station:

DANGER indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.

WARNING indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices.

IMPORTANT indicates important caution messages for the performance or durability of the unit, which has no concern to injury or accident of or to a human body.

Safety must be ensured continually. It will be adapted to each situation by following this few guideline:

- The drinking water facility must be closed. Access to this area is prohibited to any person not authorized by the Operator. The note ban should be displayed.
- All visitors must be registered (visitors lists in registration book kept in the drinking water facility).
- The reserve of fuel, lubricants and reagents must be closed and kept clean.
- It is forbidden to smoke and to make fire within the confines of the drinking water facility. This must be displayed visibly.
- The emergency stop instructions should be highlighted.
- The telephone numbers of emergency contacts (manager, police or local authorities, doctor, nurse) should be displayed.

- First aid kit should be present.

An interesting example to meditate on: a photo taken in a pumping station in Morocco.

It is a mirror, which reminds us that each has the primary responsibility for its own security (even visitors!)

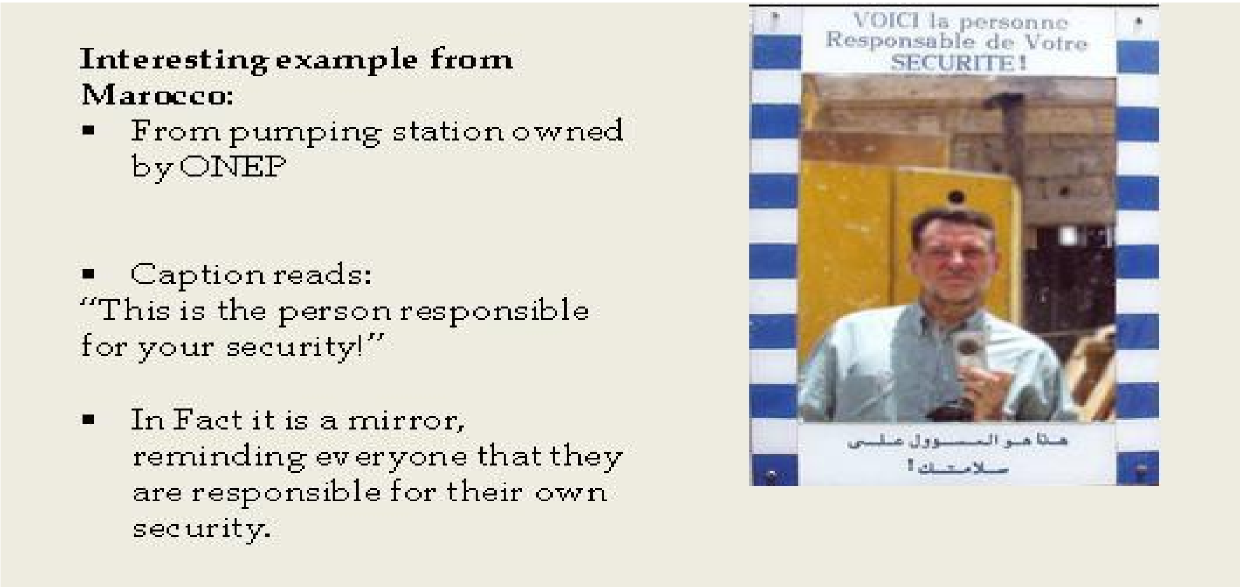


Figure 2.1: Primary person for safety responsibility

2.3 Record activities, follow up and analysis

The Manager must ensure that all O&M activities are regularly recorded.

He must make at least quarterly inspection to ensure the consistency of the data reported then records or register them for further analysis.

- It is important to review the books and records, to flush out clerical errors, and assess the quality of attendant work.
- The analysis will first refer to the data in a summary table and graphs.
- These are graphics that allow analysis by interpreting trends curves that develop over the quarters.
- Tables to calculate averages that can be compared to other pumping stations or gravitational systems

Thorough checks and analyses to show that the staff is able to fill out the registers and records in a proper way. This is a kind of motivation to perform well next time.

2.4 Responsibilities of the personnel

Responsibility of the technical manager:

- Organize the work and skills so that the assets of the RWSS operates on their normal life.
- To know in detail, the assets, their rules of operation and their maintenance needs.

- Guiding and controlling staff.
- Provide staff with the appropriate hardware and tools.
- Establish contacts according the problem of spare parts.
- Prepare a sufficient annual budget for continuous and sustainable exploitation.
- Operate registers and records, make analysis, and present in the official forms.

Responsibility of Pump Attendant:

- Ensure O&M of the pumping station.
- Manage the stock fuel and lubricant.
- Place an order on time to avoid stock outs.
- Save the tools.
- Stay in place until the pump is running (unless all is running by electricity).
- Fill out all operating records or holding registers.
- Report any discrepancies to the technical manager.
- Involve the engineer designated by the Manager for any action beyond his level of competence, or for which he does not have the appropriate tools.

Responsibility of the Guardian:

- Keep security and ensure the cleaning of the pumping station.
- Never leave the station without being relayed by another or by the pump attendant.
- Inform attendant or technical manager about any abnormal situation.

2.5 Tools

All workers must have on hand the following groups of tools:

- Manufacturer's documentation on the operation of assets.
- Operating forms to fill out, pens, binder or folder for storage.
- Means of communication if areas are isolated, such as mobile phone.
- Cleaning equipment.
- Access key to tanks, valves chambers, stock, etcetera.
- Tools to carry out the operation and maintenance; examples are shown in the Annex.

2.6 Spare Parts

Access to spare parts is a major problem for Operators.

This problem is aggravated by the wide variety of equipment installed by projects in the past and the lack of (national) standardized guidelines.

The Operator can find the parts, if he has the money to pay a supplier, but it may take a long time (time control, routing from abroad, customs clearance, delivery to station, and installation).

These realities must be anticipated because, unfortunately, all that is mechanical or electronic can fail at any time.

Some guidelines, therefore, are required:

- Require from the owner all documentation on the installed equipment:
  Manufacturers ‘catalogues, contact addresses in the country, operation manuals, maintenance manuals.
- Identify brands, types and numbers of equipment, local suppliers who can provide spare parts, specialists in pumping equipment and measurements.
- Take advantage of the FEPEAR-Operators to locate other stations which have the same equipment.
- With these contacts, build a list of prices to facilitate budgeting of maintenance and repairs.

3 Lesson 3: Overview of Water Supply

3.1 Sources of water

There are basically three categories of naturally occurring water resources: Groundwater, rainwater and surface water.

3.1.1 Groundwater

Part of the precipitation that falls infiltrates the soil. This water replenishes the soil moisture, or is used by growing plants and returned to the atmosphere by transpiration.

Water that drains downward (percolates) below the root zone finally reaches a level at which all the openings or voids in the earth's materials are filled with water. This zone is called the zone of saturation. The water in the zone of saturation is called the ground water.

Groundwater occurs under most of the world's land surface, but there are great variations in the depths at which it is found, it's mineral quality, the quantities present and the rates of infiltration (thus yield potential) and the nature of the ground above it (thus accessibility).

In hilly areas it emerges from the ground in places as natural springs, otherwise wells have to be constructed and pumps or other lift mechanisms installed.

Springs:

- A spring is a visible outlet from a natural underground water system. Management and protection of the whole system, including the unseen underground part, is essential if the spring is to be used for water supply.
- The conservation of Wetlands or spring seepage areas is an extremely important and integral part of spring water development and management.

3.1.2 Rainwater

Rainwater collection, from roofs or larger catchment areas, can be utilized as a source of drinking water, particularly where there are no other safe water sources available, for example in areas where groundwater is polluted or too deep to economically tap.

3.1.3 Surface Water

Surface Water, in streams, lakes and ponds is readily available in many populated areas, but it is almost always polluted. It should only be used if there are no other safe sources of water available.

In general, a water supply system with surface water comprises the following processes:

- Raw water extraction and transport;
- Water treatment and storage;
- Clear water transport and distribution.

3.2 Types of distribution systems

With respect to the way the water is supplied, the following distribution systems can be distinguished:

- Gravity systems;
- Pumping systems.

The choice of one of the above alternatives is closely linked to the existing topographical conditions.

3.2.1 Gravity systems

Gravity systems makes use of the existing topography. In this case the source is located at a higher elevation than the distribution area itself.

The water distribution can take place without pumping and nevertheless under acceptable pressure. The advantages of this system are:

- No energy costs;
- Simple operation: fewer mechanical components, no power supply needed;
- Low maintenance costs;
- Slower pressure changes.

3.2.2 Pumped systems

In pumped systems, the energy needed for water conveyance is obtained from the pump operation.

This energy, generated by the pump impeller, is usually expressed as a head of water column and is called the pumping head: it represents the difference between the energy levels at the pump entrance at the suction pipe and at the discharge pipe.

Highly elevated reservoirs will usually be located at the downstream side of the pumping station in order to be refilled during the periods of low demand.

The low-level reservoirs, on the other hand, will be positioned at the upstream side of the pumping station

Apart from that, pumps can be located anywhere in the network where additional pressure is required: these pumps are called booster pumps.

3.2.2.1 Direct pumping scheme

In the direct pumping scheme, the system operates without storage provision for demand balancing.

The entire demand is directly pumped into the network. As the pumping schedule has to follow variations in water demand, the proper selection of pumps is important in order to optimize the energy consumption. Reserve pumping capacity for irregular situations should also be planned.

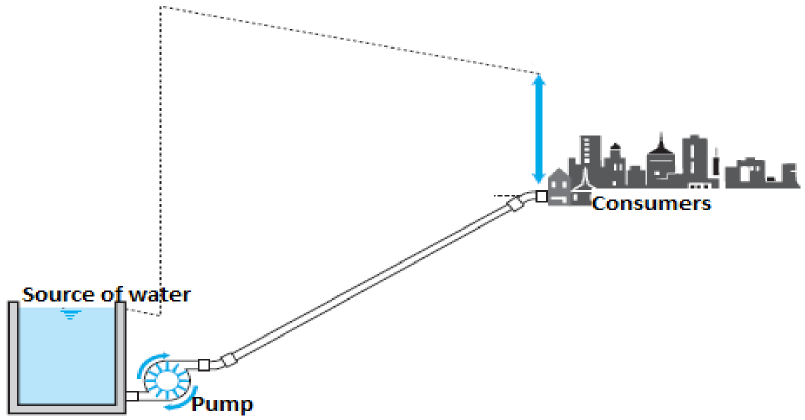


Figure 3.1: Direct pumping scheme

Advantages of the direct pumping scheme are opposite to those of the gravity scheme. With good design and operation, any pressure in the system can be reached. However, these are systems with rather complicated O&M, and they are dependent on a reliable energy supply. Additional precautions are therefore necessary, such as an alternative source of energy supply, automatic mode of pump operation, stock of spare parts, etc.

3.2.2.2 Indirect pumping scheme

Indirect pumping assumes an operation with pumping stations and require balancing reservoirs. A considerable storage volume is needed in this case but pumping capacities will be below those in the direct pumping scheme. The indirect systems are common in hilly distribution areas. Water enters and exits out of the bottom of the reservoir.

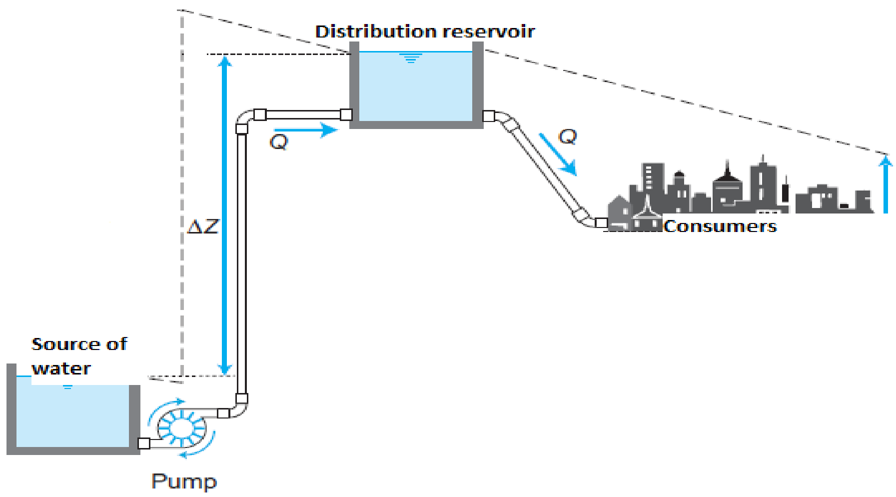


Figure 3.2: Indirect pumping scheme

4 Lesson 4: PUMPING STATION GENERAL

4.1 Description and background information

The major components inside the pumping station are pumps, motor (s), pipework, valves and a range of pump monitoring and controlling devices. The pump itself includes an encased impeller. The impeller is powered using a motor.

Water flows into the suction pipework, and flows out into the discharge pipework. There is often additional infrastructure outside a pumping station building. This may include connecting pipework, on site electrical transformer, cables, external pipe valves and water storage tanks.

In figure 4.1 an example is given of a pumping station in Rwanda. In the upper part of the drawing the suction reservoir is shown and the drawing below two pumps, the water meter and the anti-water hammer construction are schematized.

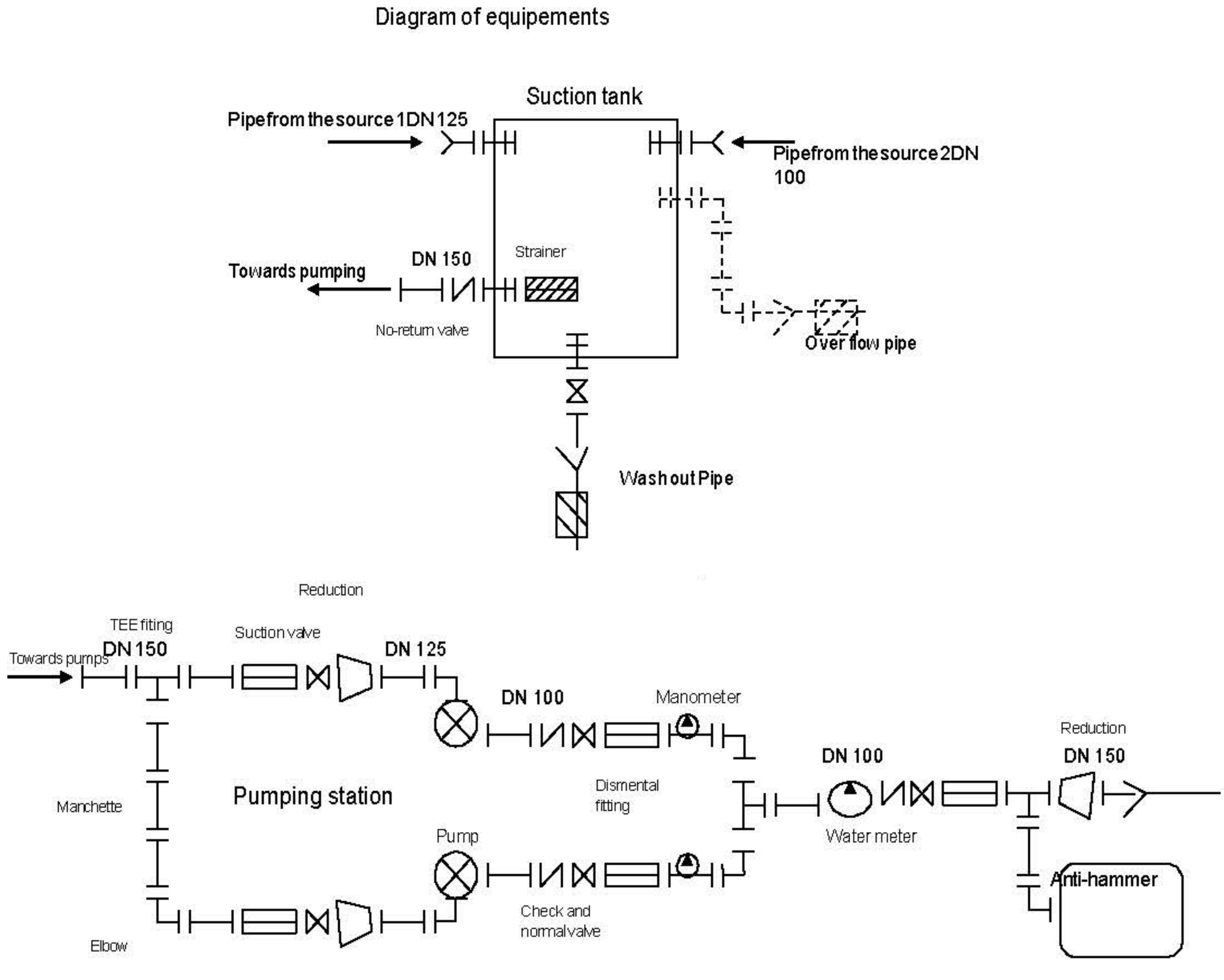
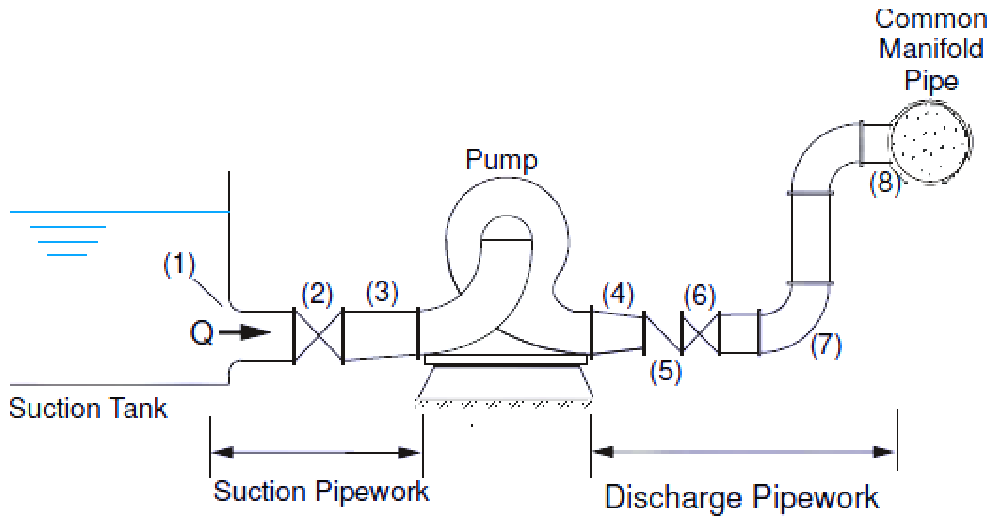


Figure 4.1: Equipment in pumping station Muyinga

In figure 4.2 a detailed drawing of a pump is shown together with its connecting appendages.



Legend:

1. Entrance with Rounded Edge
2. Isolating Valve
3. Offset Conical Reducer
4. Concentric Conical Increaser
5. Non-return Valve
6. Isolating Valve
7. 90° Elbow (or short radius bend)
8. Tee Fitting.

Figure 4.2: Pump with connecting appendages

In figure 4.3 another example is given.

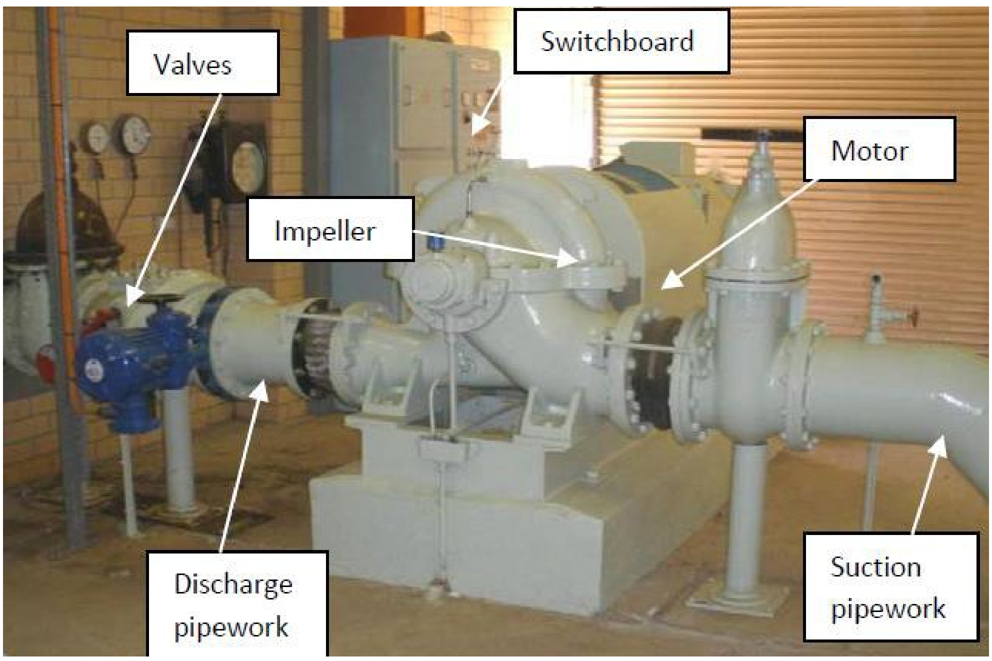


Figure 4.3: Pump with connection appendages

Pumping station control

There are a range of devices inside the pumping station which assist in controlling how the pumping station operates and how the flow and pressure of the water is managed. The pipework has a number of isolation valves which allow segments to be switched off. Installed on the discharge pipework, control valves control the water flow when the pumps are starting and stopping. There is also a non-return valve on the discharge pipework. It's a simple gate valve which shuts off water backflow into the pumping station, if needed. Some control devices are listed in table 4.1 (suction side) and table 4.2 (discharge side).

Table 4.1: Suction side equipment

Equipment	Description
Strainer or filter	Prevent the introduction of coarse objects in the suction pipeline
Back foot check valve	Prevent the water back into the reservoir located in the suction line to facilitate priming.
Piping	Made of metal pipes often assembled with flanges
Elbows	Change the orientation of the pipe
Tee	Facilitate removable lead
Decreasing cones	Facilitate change of diameters of pipe to connect to the inlet pump
Shutoff valve	Facilitate the interchangeability of pumps in operation.
Part disassembly	Facilitate the dismantling of parts placed at each place where you must disassemble for maintenance
Seals	Soft rubber parts for easy sealing
Flanges	Metal parts in the form of circular ring with standardized holes often fixed by welding on the pipe fitting
Bolts	Round and threaded metal parts to facilitate the clamping flange

Table 4.2: Discharge side equipment

Equipment	Description
Motor	Keep the pump running
Decreasing cones	Facilitate change diameters of pipe to connect to inlet tubing of the pump
Piping	Made of metal pipes often assembled with flanges.
Elbows	Change the orientation of the pipe
Air valve	Lead the air out, at the high point with no straight pipe
Non-return valve	Prevent the backflow of discharge pipe to the pump
Shut-off valve	Facilitate flow control and if necessary in removing the pump
Part disassembly	Facilitate dismantling parts
Gauge	Indicate delivery height

Equipment	Description
Air vessel	Dampen oscillations due to shock waves when stopping pump
Increasing cones	Enlarge the diameter of the pipe
Discharge pipe	Water transport to the discharge tank

Protection against water hammer

Water hammer is a phenomenon caused by the transient (unsteady) flow of water in a pipeline. Water hammer is important in pumping station design as it can cause the rupture of pipe and pump casing, vibration, pipe collapse and excessive displacement of pipes and fittings.

- When you close a faucet you sometimes hear a shock in the pipe.
- In practice, the water hammer is a series high speed wave due the overpressure and depression.

Figure 4.4: Air vessel

To prevent problems associated with transients in a system, a number of alternatives can be investigated which include the:

- Selection of pipes and fittings to withstand the anticipated pressures
- Selection and location of control devices (air vessels, surge relief valves, air valves, etc.) to alleviate the adverse effects of transients.
- Identification of appropriate pump start-up and shutdown procedures, as well as suitable valve closure times.

Consulting firms can calculate the required volume of an air vessel to alleviate water hammer in a system.

4.2 Operation

A pumping station is a very sensitive facility to be guarded and protected. No one can access the perimeter of a pumping station, which must be closed:

- This is to protect the station (fragile material, valuable equipment, fuel reserve, tools);
- And also protect people (risk of fire, burn, cut).

A pumping station must be clean:

- It is a proof of professionalism and competence;
- It is a good prevention against overheating of the devices, and for tracking slight leakage (oil, fuel, water).

Any incident at the station may have a detrimental effect on water service; contrary to the obligation of the operator to ensure the continuity of public service.

4.3 Preventive Maintenance

Most equipment on a pumping station needs preventive maintenance.

This maintenance can be well prepared on standardized schedules which should thoroughly and accurately be filled in by the persons who carry out this kind of maintenance.

In table 4.3 and example is given of a schedule for preventive maintenance of a reservoir.

Table 4.3: Schedule of preventive maintenance

Subject	Action	Staff	Frequency
TANK outside	• Check the appearance, • Check seals, clean if necessary. • Check that there are no threatening erosions around the facility. • Fix what does not need a mason, otherwise report and propose action.	Plumber/ Water technician	Quarterly
METALIC COVER ON THE TOP SLAB	• Check the condition of the closure, grease hinges, clean. • If corrosion or need welding to report and propose action.		
VALVES: Inlet, Outlet, By-pass	• Check the operation by pressing, • Clean up all valves, fittings, unions etc..		
INLET Pipe, flow limiter, float valve	• Check inlet, the operation of float (adjust if necessary) • Dismantle the coupling, clean up		
VENTILATIO N	Check air passage valves and sealing		

4.4 Curative Maintenance

If any equipment is not functioning, it should be repaired.

5 Lesson 5: PUMPS

5.1 All pumps

5.1.1 Description and background information

There are many types of pumps. These different types of pumps are grouped into two categories in which the principles of operation are completely different:

- **Turbine pumps like centrifugal pumps;**
- **Volumetric pumps like piston pump.**

In the **turbine pump**, a wheel provided with blades and vanes, driven by a rotational movement provides the fluid (water) to a kinetic energy which is converted into pressure by a reduction in speed of member called recuperator (diffuser).

In the **volumetric pumps** instead the energy is provided by the successive variations of a volume alternately connected to the suction port and the discharge port.

Adapted from GUYER (2012)

Volumetric pumps are not used in drinking water supply.

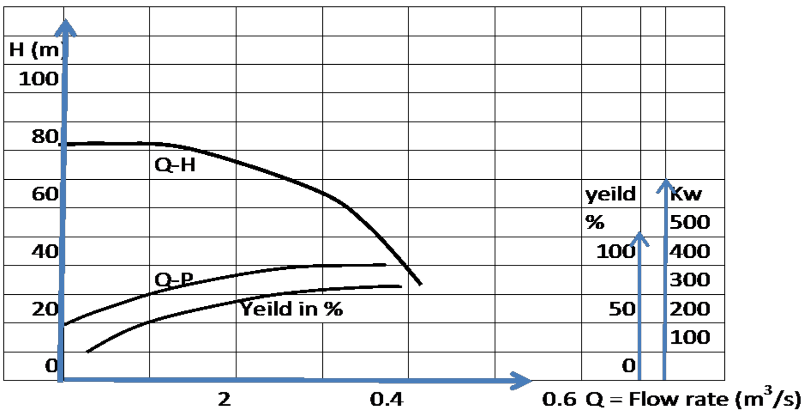
There are generally two types of turbine pumps used for potable water pumping applications:

- The **vertical *turbine* pump** (line shaft and submersible types);
- The **centrifugal horizontal or vertical split case pump** designed for water-works service.

Adapted from THE WORLD BANK RWSS (2012)

- If the suction level is less than 6 meters, use a **centrifugal pump**.
- If the suction level is from 6-20 meters, use a **submersible**.
- If the suction level greater than 20 meters, use a **submersible or a *turbine* pump**.

In figure 5.1 the three graphs of a pump are presented: the pump characteristics.



Q-H = Flow rate-Manometric height
Q-P = Flow rate-power output of the pump
Yield = ratio of power output/ power input of the pump in %

Figure 5.1: Pump characteristics

The curve flow – head (QH):

It presents the changes in the total head H by the pump as a function of the flow rate Q.

Curve is a parabola more or less diving.

The curve of power absorbed by the pump according to the flow is also parabolic. In centrifugal pumps, the concavity of the curve is facing downwards. This helps to prevent motor overload if the conditions are expected to vary. For propeller pump, it is better to avoid the discharge valve because for zero flow there is a risk of surges when the pump is driven by an electrical motor.

The yield curve η represents the variations in performance (ratio of input power and output) of the pump according to the flows: the curve for each type of pump should have a maximum in the vicinity of the flow corresponding to the water demand.

Manufacturers give for each pump a graph according to the change of rotation speed, throughput, power consumption, and the pressure. See figure 5.2.

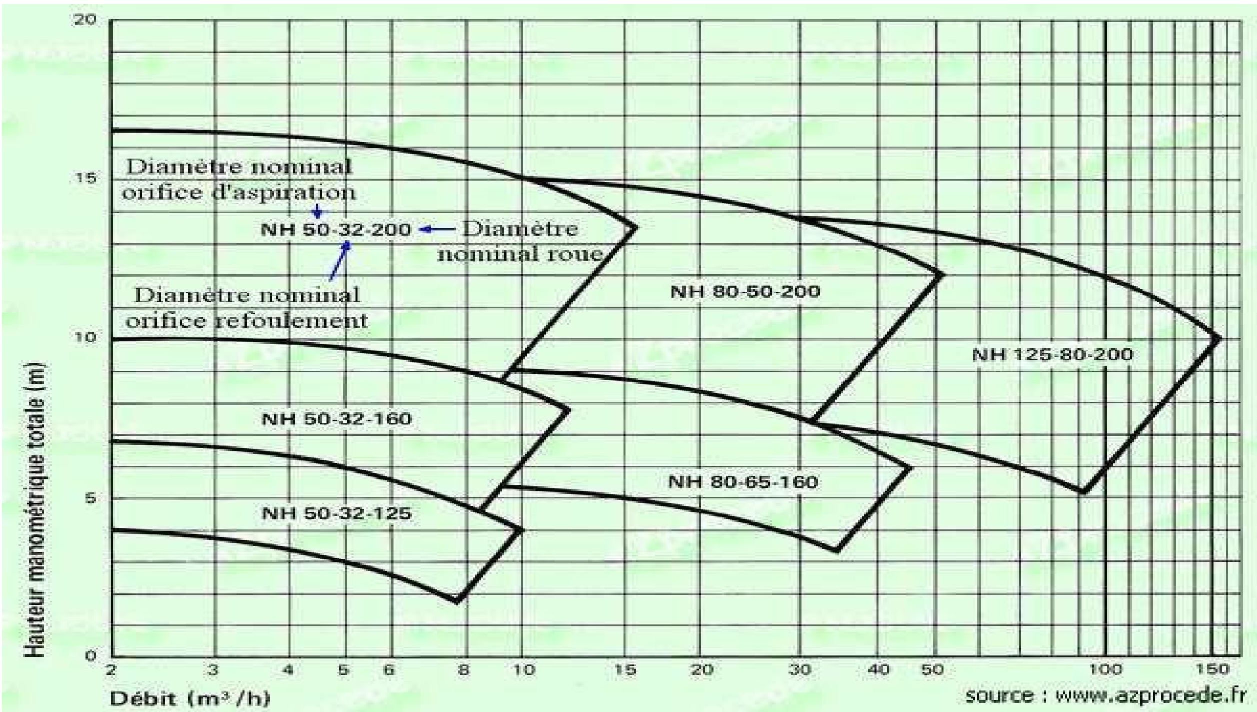


Figure 5.2: different QH-curves

5.1.2 Operation

(1) The starting-up of the pump

- **Case 1: The pump automatically starts and stops.**

This requires a connection to the public power grid, an automatic pump and telemetry.

- Telemetry: system for monitoring and remote control the filling of the suction tank and discharge tank, by electrical cable or wireless command.
- This is the safest position, provided that the quality of the grid current is well controlled.
- There is no human intervention, except a daily monitoring visit by an unskilled agent.

- This does not apply to stations with generator.

➢ **Case 2: The pump stops automatically; but manually starts:**

The system is equipped with a pressure switch, which cuts off the electric current of the pump when it reaches a predetermined pressure.

- This pressure is reached when the float valve of the reservoir closes (the reservoir is full, the float rises and closes the flow, like a water flush of WC).
- To restart the pump, wait until the reservoir empties a little and manually restart.
- This system avoids the overflow on the reservoir, without the need for telemetry (electricity and electronics) or a tank's guard for monitoring and prevention purposes.

➢ **Case 3: The pump starts and stops manually:**

The system has no automatism.

- It needs a pump attendant at the station for the start. This allows checking everything before the pump starts.

To stop:

- Either you put a watchman on the reservoir, who, by phone, will give the stop signal;
- Either the pump attendant has enough experience to know how long it must pump. But it's pretty random because you never know the actual level of the reservoir at the start of pumping;
- To improve the system, reservoirs normally include outdoor levels to monitor the filling. In practice, it is extremely rare that they work properly.

Start-up operations:

- Check the cleanliness.
- Check the water level in the suction tank, and the absence of impurities.
- Check and adjust levels: oil and diesel fuel of diesel motor or EG.
- Check inventory, fill out the forms.
- Mark index of available devices on the record: water levels in reservoirs, water meters, electric meters, pressure gauges, indexes schedules machines and the start time.
- Start EG. Let it run without load for 3 minutes to heat
- Check volts and Amperes dials (if any) and all indicator lights.
- Engage the pump.
- Monitor all lights and indicators. Attention should be paid to the sounds of machines. Check that there are no leaks of fuel or water.

(2) **During pumping operation time**

- Except for fully automated stations, all others must have a guardian at all times during pumping.
- This may be the station's day or night guard, who has received specific instructions about what to monitor and how he can stop pumping (emergency procedure).
- The Operator must be aware of the value of the pumping facilities, and his responsibility

for their life span.

(3) Pump stop procedure in normal situation

Under normal circumstances, stop pumping takes place more or less by taking reverse actions at start up.

Normal stopping occurs when:

- The discharge tank is full;
- The suction tank is empty;
- Time is up for stopping machines.

Stop operations:

- Monitor all lights and indicators. Attention should be paid to the sounds of machines. Check that there are no leaks of fuel or water and no overheating.
- Start pumping stopping procedure.
- If there is a EG, the pump should be stopped first and after that the EG.
- Record water meter reading, pressure gauges reading and stop time.
- Check stocks, whether they are sufficient for the next day.
- Check the cleanliness, clean the station and appliances.

(4) Pump stop procedure in emergency situation

The emergency stop should be a procedure in which attendants must be prepared in advance and trained.

The emergency stop occurs when a wrong item is noticed: red light, heating, dials showing abnormal data.

The emergency procedure should be defined case by case depending on the configuration of the station.

- It will be written and displayed in the station.
- All personnel on the station will be trained on it twice a year. The following principles should be applied to define the procedure:
- An Operator's employee shall be permanently at the station while working.
- They need to know all the specific points that can trigger an emergency stop.
  - ✓ Abnormal noise;
  - ✓ Heating of device;
  - ✓ Red lights;
  - ✓ Loss of oil, fuel or water;
  - ✓ Gauge that is not at it is routine pressure;
  - ✓ Voltage or amperage that is not normal (heat up and burn the control box);
  - ✓ Safety Issues: heavy rains, thunderstorm with lightning, suspicious people.

5.2 Centrifugal pump

5.2.1 Description and background information

A centrifugal pump is one of the simplest pieces of equipment in any process plant. Liquid is forced into an impeller either by atmospheric pressure or in case of a jet pumps by artificial pressure.

The impeller vanes pass kinetic energy to the liquid, thereby causing the liquid to rotate. The liquid leaves the impeller at high velocity. The impeller is surrounded by a volute casing or in case of a turbine pumps a stationary diffuser ring. The volute or stationary diffuser ring converts the kinetic energy into pressure energy.

In figure 5.3 two examples of centrifugal pumps are given.

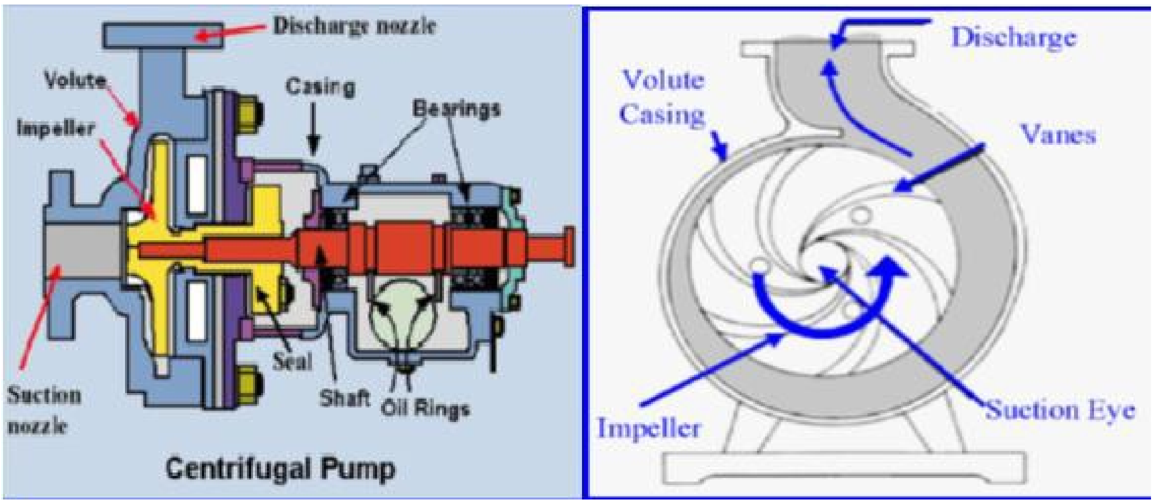


Figure 5.3: examples of centrifugal pumps

5.2.2 Operation

To operate a centrifugal pump, certain procedures need to be followed, which are found in the manual supplied by the manufacturer. They generally involve the following steps:

1. Before starting the motor, make sure that the discharge gate valve is closed.
2. If the pump is not self-priming or has defective suction line or foot valve, add priming water. Priming displaces the air in the suction line of the pump with water.
3. Allow the pressure to build up, and then slowly open the discharge valve. Doing this slowly avoid water hammer, which could destroy the pipes and valves.
4. Start the pump motor.
5. After the pressure has built up, slowly open the discharge gate valve. In case the pump has been primed with water, waste the water pumped during the first 1-2 minutes by opening the drain valve.
6. Make a routine check for faults in the operation of the system (abnormal noise, vibration, heat, and odor).

5.2.3 Preventive maintenance

Bearings, gears and other pump moving parts should be lubricated on the regular schedules, using the lubricants recommended by the supplier.

5.2.4 Curative maintenance

The following are specifications to remedy centrifugal pump problems.

5.2.4.1 Low Pump Efficiency

If the pump performance tests reveal that the pump is operating at significantly lowered efficiencies, the pump should be pulled out, inspected and repaired or reconditioned. This work is best referred for servicing to the manufacturer or a pump repair specialist.

5.2.4.2 Packing Adjustment

The water flowing through the stuffing box should be maintained at a level just enough to prevent overheating. The gland nuts should be loosened or tightened one-quarter turn only to allow the packing to equalize against the pressure.

5.2.4.3 Checking and Adjusting Misaligned Head Shaft

Pump vibrations could indicate a misalignment of the head shaft. This can be checked by the following procedure:

- Remove the motor dust cover, motor head nut and key, and take out the motor drive flange.
- Check if the head shaft is concentric with the motor hollow shaft bore.
- If needed, adjust by using shims.

Documentation from manufactures gives common problems and remedy as below for a centrifugal pump: see table 5.1.

Table 5.1: Common problems and remedy of centrifugal pump

Trouble	Likely Cause of Trouble	Remedy
Pump Motor fails to start	Blown fuse or open circuit breaker.	Replace fuse or reset circuit breaker.
	Motor or starting switch out of order.	Inspect /repair. Refer to equipment supplier or experienced mechanic or electrician.
	Break in wiring.	Repair circuit wires.
	Stuffing box may be binding or tightly packed	Check packing by manually rotating shaft.
		Loosen packing nut just enough to allow a slow seepage of water and free the shaft.
	Scale or sand in the impeller.	Open pump and remove scale by acid treatment and/or sand.
Pump runs but delivers no water	Pump lost first priming.	Repeat priming. Follow manufacturer's priming instructions.
	Pump repeatedly loses priming due to leaky drop pipe or suction pipe.	Pull out drop pipe and seal the leaks.
	No water at source due to overpumping	Reduce pumping rate or deepen the well.
	Collapse of well casing or screens	Replace with new one. If diameter of old casing is large, insert new casing inside the damaged casing. Consult driller.
	Clogging of well screens	Surging or acid treatment. Consult driller.
Pump runs but delivers only a small amount of water	Well not yielding enough water.	Do pumping test or deepen the well.
	Air leaks in suction pipe.	Pull the drop pipe from the well & seal leak/s.
	Incrustation or partial clogging of well screens.	Surging or acid treatment. Consult driller.
	Impeller is worn out or lugged with scale or trash.	Open the pump and clean/replace impellers.
	Foot valve may be obstructed.	Clean foot valve.
Noisy Pump	Bearing or other working parts of pumps are loose or need to be replaced	Tighten or replace defective parts.
	Pump motor is loosely mounted.	Tighten mounting.
	Low water level in well.	Reduce pumping rate.
	Presence of air in suction line.	Repair air leaks.

5.3 Submersible pump

5.3.1 Description and background information

In figure 5.4, an example of a submersible pump is given.

Figure 5.4: submersible pump

5.3.2 Operation

Submersible pumps may be operated manually with a switch located above ground level or automatically with a pressure switch, electrodes or float control devices. Submersible pumps should always be operated below the water level. The pump should be installed higher than the well screen (a kind of filter) to prevent pump break on which will lead to a burned pump motor.

5.3.3 Preventive maintenance

To begin a maintenance job analysis, the assigned person needs the following information:

- Pump motor unit size and type;
- Static and pumping water level of the well;
- Size of drop pipe;
- Pump setting;
- Discharge pressure required;
- Capacity pumped;

5.3.4 Curative maintenance

Documentation from manufactures gives common problems and remedy as below for a submersible pump: see table 5.2.

Table 5.2: Common problems and remedy for submersible pumps

Trouble	Likely Causes	Remedies
Pump motor fails to start	Motor Overload	Overloaded contacts close automatically. Check cause of overload.
	Low voltage	Check voltage.
	Blown fuse, broken or loose connections	Check fuses, relays, electric condensers and all electrical connections.
	Motor control box not in proper position	Ensure box is in right position.
	Damaged cable installation	Locate and repair the damaged cable.
	Cable, splice or motor windings may be grounded or wet.	Check the ground by using an ohmmeter. If grounded, pull out the unit and inspect cable and splice. Cut the unit loose from the cable and check each part separately using an ohmmeter.
	Pump stuck by corrosion or abrasive	Pull out pump, examine and remove foreign matter.
Pump runs but delivers little or no water	Pump not submerged	Lower the unit into the well or replace by a smaller capacity pump
	Discharge pipe may be leaking	Examine discharge line by pulling out one joint at a time.
	Check valve may be clogged or corroded	Pull out pump and clean or replace check valve
	Pump badly worn-out by sand or abrasive	Replace pump. Clean well thoroughly of abrasive before putting the new unit in.
	Strainers or impellers clogged with sand or scale	Pull out pump unit and remove the scale/sand.
	Scaled or corroded discharge pipe	Replace pipe.
Pressure valve fails to shut	Switch may be defective or out of adjustment	Adjust or replace pressure switch.
	Discharge pipe may be leaking	Raise unit one pipe joint at a time until leak is found. Repair leaks.

5.4 Hand pump

5.4.1 Introduction

Most of handpump types are AFRIDEV or India Mark II in Rwanda. AFRIDEV pumps are used for the boreholes which groundwater table is relatively shallow (0-20m). India Mark II pumps are used for the boreholes which groundwater table is relatively deep (20-40m).

5.4.2 AFRIDEV Hand Pump

5.4.2.1 Pump parts and function

The assembly of the AFRIDEV pump is shown in the Figure 5.5. AFRIDEV pump parts are divided into two categories "Above ground parts" shown in the Table 5.3 and "Below ground parts" shown in the Table 5.4.

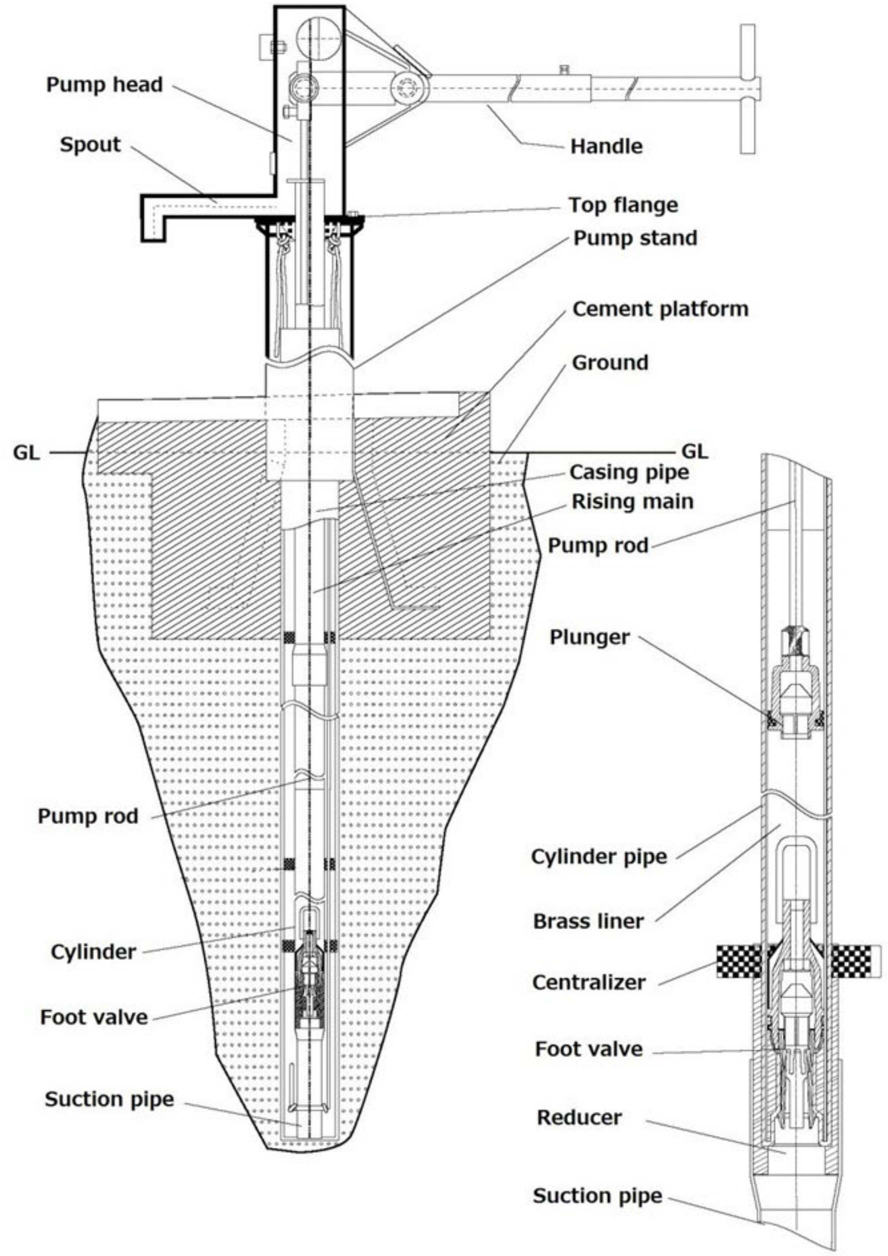
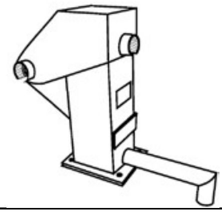
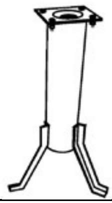
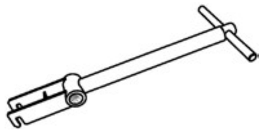
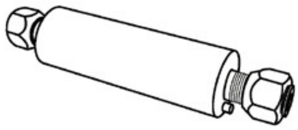
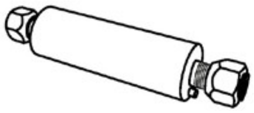


Figure 5.5: Assembly of AFRIDEV pump

Table 5.3: Name and functions of each spare parts for above ground component

No.	COMPONENT	FUNCTION	ILLUSTRATION
1	Head pump and cover	Encloses the topmost part of the pump to prevent dust and foreign materials from getting inside the pump, it houses the hanger assembly and supports the handle bar	
2	Pump pedestal	Main body supporting above ground components and below ground components	
3	T/bar	This is the part that is held to pump water. It can be adjusted to correspond to the depth of the borehole	
4	Hanger Assembly	Rods are suspended from this	
5	Fulcrum pin	Joins the handle bar to the head pump and acts as a movement joint for the handle pumping water	
6	Hanger pin	Joins the end part of the handle to the hanger to allow for upward and downward movement of the rods	
7	Bush bearing	Allows free movement of the fulcrum pin and hanger pin. There are four in a pump, two on the fulcrum pin and two on the hanger pin	
8	Rubber flapper	Installed on the top rod to prevent foreign materials from getting into the rising main and to prevent water from gushing out	
9	Rubber cone	Sits between the pump head and pedestal acts as a seal to stop water from spilling between the pump head and pedestal	

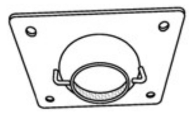
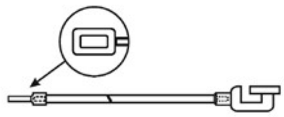
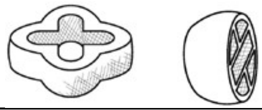
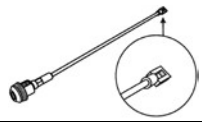
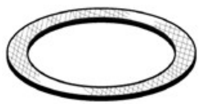
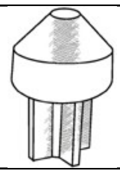
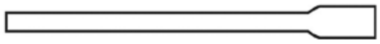
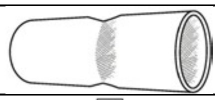
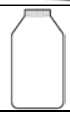
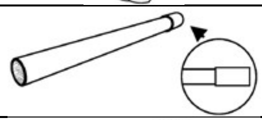
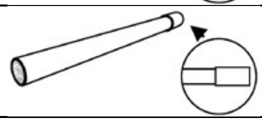
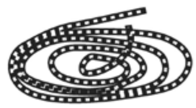
No.	COMPONENT	FUNCTION	ILLUSTRATION
10	Steel cone plate	A metal plate holding the rising main	
11	Top sleeve (collar)	It prevents the rising main from slipping through the rubber cone	

Table 5.4: Name and functions of each spare parts for below ground component

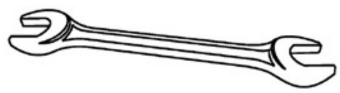
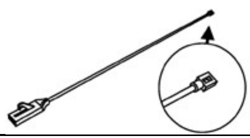
No.	COMPONENT	FUNCTION	ILLUSTRATION
1	Pump rod	To connect plunger so that the pump can be operated above the ground using the handle	
2	Rod centralizer /	Fitted on rod joints to centralize rods and prevent friction between the rod and the rising main	
3	Plunger	Connected to pump rods; moves up and down with the movement of the handle to facilitate suction of and delivery of water	
4	Foot-valve	Keeps the pumped water from going back down the bore hole	
5	U-seal	Fitted to the plunger body; seals water above plunger and pushes water up with every upward movement of the plunger (plastic plunger only)	
6	Cup-seal	Fitted to the plunger body; seals water above plunger and pushes water up with every upward movement of the plunger (brass plunger only)	
7	O-ring	Fitted to the foot valve to prevent water inside the cylinder from getting back into the bore hole	
8	Bobbin	Fitted inside plunger and foot valve; moves up and down to allow water to move in one direction only and prevents water	

No.	COMPONENT	FUNCTION	ILLUSTRATION
		from getting back into the bore hole	
9	Rising main	A pipe connected to cylinder assembly carries water from the cylinder to ground level	
10	Double end socket	To join two rising mains after repairing (use solvent cement)	
11	Solvent cement	To join two rising mains after repairing (use solvent cement)	
12	Rising main centralizer	Fitted every 3 meters, rising main prevents excessive swaying of the rising main in the borehole	
13	Cylinder assembly	Most important part of the pump, it draws water from the borehole and pumps it up to ground level	
14	Suction pipe	Fitted at the bottom end of the cylinder it draws water into the cylinder and controls sand intake	
15	Rope (nylon rope 6mm)	Connected to the suction pipe and passes through the pipe centralizer to the cone plate to hold the rising main from falling into the borehole in case of joint failure	

5.4.2.2 Tools

Necessary tools for dismantling and reassembling AFRIDEV pump are shown in the Table 5.5.

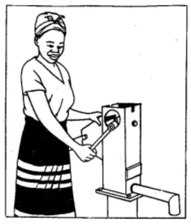
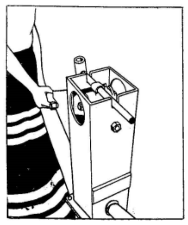
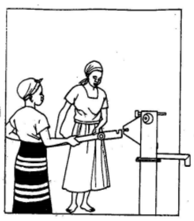
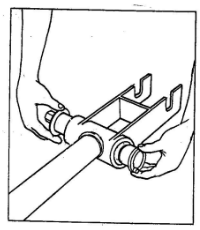
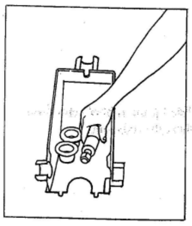
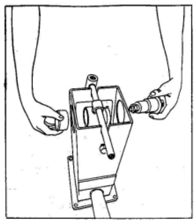
Table 5.5: Tools for AFRIDEV pump

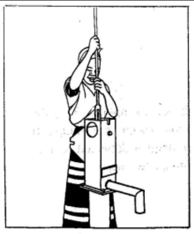
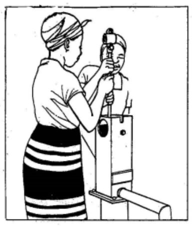
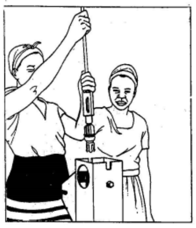
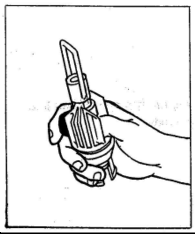
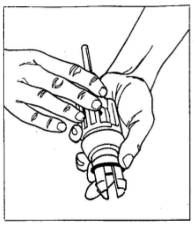
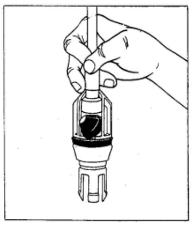
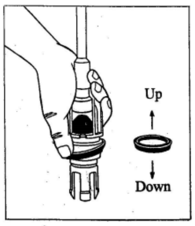
No.	COMPONENT	FUNCTION	ILLUSTRATION
1	Socket spanner 24mm	To remove head cover and to hold the hanger assembly when removing rods	
2	Flat spanner17/19mm	To remove the bolts between head and pedestal	
3	Fishing tool	To fish the foot valve and pump rods	

5.4.2.3 Dismantling

Necessary steps for dismantling are described as Table 5.6.

Table 5.6: Necessary steps for dismantling

No.	Step	Illustration	No.	Step	Illustration
1	Before starting wash your hands and fill some buckets with water to allow you to clean the parts		2	Loosen the pump head cover bolt	
3	Take off the cover		4	Loosen both hanger nuts	
5	Loosen both fulcrum nuts		6	Put spanner through hanger eye.	
7	Raise and withdraw handle. Take care! As you remove the handle make sure that the bush bearings and pin do not fall out as they may break on the floor.		8	Remove fulcrum pin and bush bearings.	
9	Place all parts in the cover for safe keeping.		10	Remove hanger pin and bush bearings.	
11	Pull up the hanger and first rod.		12	Slide up the rubber centralizer where the rods join.	
13	Disconnect and remove all the rods. Remember to keep the rods in the same order. The last rod taken out should be the first one put back.		14	Remove the plunger.	

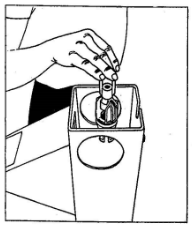
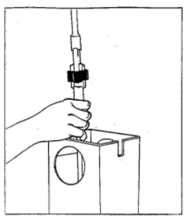
No.	Step	Illustration	No.	Step	Illustration
15	Lower the fishing tool and join to the rods.		16	Gently lower last rod and hanger until you feel that you have caught the foot valve.	
17	Remove all the rods, fishing tool and foot valve.		18	Push out the bobbin from the foot valve with your thumb. If the bobbin is damaged replace it with a new one.	
19	Remove the O- ring from the foot valve. If the O- ring is damaged replace it with a new one.		20	Push out the bobbin from the plunger with your thumb. If the bobbin is damaged replace it with a new one.	
21	Carefully remove the U-seal. If the U-seal is damaged replace it with a new one. Make sure that the groove faces upwards.				

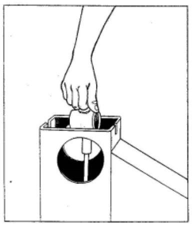
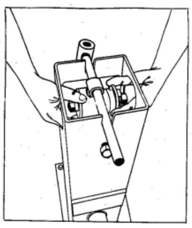
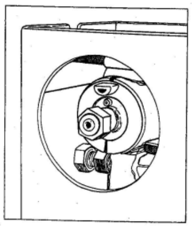
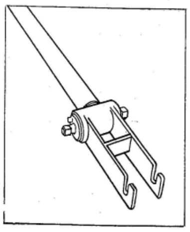
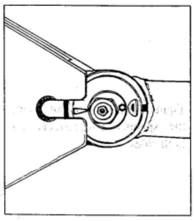
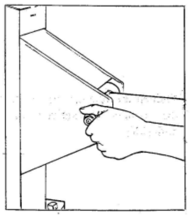
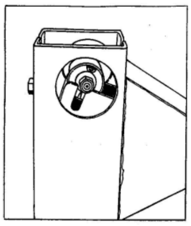
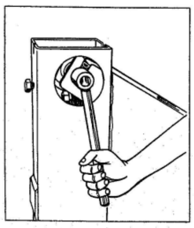
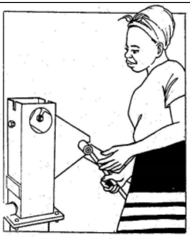
Source: Training Manual for Area Mechanics, Ministry of Agriculture, Irrigation and Water Development, Government of Malawi, March 2015

5.4.2.4 Reassembling

Necessary steps for reassembling are shown in the Table 5.7.

Table 5.7: Necessary steps for reassembling

No.	Step	Illustration	No.	Step	Illustration
1	Wash the foot valve, plunger and rods. Only use clean water.		2	To re-assemble the pump first drop the foot valve down the borehole. Make sure the hook is upwards.	
3	Put the plunger and pump rods back together and lower them down the borehole.		4	Make sure the rubber centralizer is slide down over each joint on the pump rods.	

No.	Step	Illustration	No.	Step	Illustration
5	Join all the rods together until the hanger rod is connected.		6	Make sure the foot valve is in place by pushing the rods at arm length down the borehole.	
7	Put the spanner through the hanger eye to support the rods and then replace the hanger pin and bush bearings. If the bush bearings are worn out or damaged then replace them with new ones.		8	Turn the hanger pin and bush bearings so that the small projecting lugs are at the top.	
9	Put back the fulcrum pin and bush bearings in the handle. If the bush bearings are worn out or damaged then replace them with new ones.		10	Put back the handle.	
11	Make sure the projection lugs on the pin and bush bearings will fit into slots on the pump body. Ensure that the pin is pushed right to the back of the slot.		12	Tighten the fulcrum nuts by hand.	
13	Push the handle down so that the slots engage in the hanger. Ensure that the hanger pin has slid to the bottom of the slots. Remove the spanner.		14	Tighten the hanger nuts with the spanner alternatively on both sides.	
15	Tighten the fulcrum nuts with the spanner alternatively on both sides.		16	Put back the cover.	

No.	Step	Illustration	No.	Step	Illustration
17	Tighten the cover nut.		18	Pump water until clean water comes out before using for drinking.	

Source: Training Manual for Area Mechanics, Ministry of Agriculture, Irrigation and Water Development, Government of Malawi, March 2015

5.4.2.5 Curative Maintenance

5.4.2.5.1 Trouble shooting

Identify problems at the water point. Possible problems and remedies are outlined as follows.

1) No water?
2) Delayed flow of water?
3) Reduced discharge water?
4) Water is turbid?
5) Taste is salty? or water smells?
6) Abnormal noise during operation?
7) Pump handle is shaky?

Table 5.8: Trouble shooting chart for AFRIDEV pump

Problem	Possible case	Remedy	Degree of repairs[*1]
1) No water	1) Riser pipes are disconnected	1) Pull out complete rising main and repair/replace pipes	B
	2) Pump rods are disconnected	2) Pull out pump rods and replace broken and corroded rods	A
	3) Cap seal is defective	3) Replace cap seal	A
	4) Borehole is clogged (silt or sand)	4) Rehabilitation of boreholes	C
	5) Water level has dropped under the cylinder	5) Add riser pipes and pump rods	B
2) Delayed discharge water	6) Leaking of valve bobbins	6) Check and replace bobbins (plunger and foot valve)	A
	7) Leaking of foot valve O-ring	7) Replace O-ring	A
	8) Leaking in pipe joint or rising main is perforated	8) Pull out complete rising main and repair/replace pipes	B
3) Reduced discharge water	9) Cup seal is too tight	9) Replace with seal of correct size	A
	10) Borehole screen is clogged by incrustation	10) Rehabilitation of borehole (cleaning with compressed air or by bailing)	C
	11) Full stroke is not possible	11) Check and adjust length of the top rod	B
	12) Cup seal is worn	12) Replace seal	A
	13) Leaking of valve bobbins	13) Check and replace bobbins (plunger and foot valve)	A

Problem	Possible case	Remedy	Degree of repairs*1
	14) Leaking of cylinder (cracked)	14) Pull out complete rising main and repair/replace cylinder (solvent cement joint)	B
4) Water is turbid	15) Accumulation by siltation becomes large	15) Rehabilitation of borehole (cleaning with compressed air or by bailing)	C
	16) Screen/casing pipes are torn	16) Rehabilitation of borehole (relining casing/screen pipes inside existing casing pipes, if possible)	C
5) Taste is salty or water smells	17) Sewage intrusion through cracks of platform/apron	17) Rehabilitation of platform	C
	18) Contamination through aquifer pathway	18) Check the distance from the pit latrine and abandon the pit latrine within a radius of 100 m of the borehole	A
6) Abnormal noise during operation	19) Bearings are worn, handle fork touching the sides	19) Check and replace bearing sets (4 pcs)	A
	20) Pump rods are touching riser	20) Straighten or replace bent pump rods and replace worn rods	A
	21) Pump rods rubbing on riser pipes	21) Check and replace worn pump rod centralizers	A
	22) Pump rod centralizers worn	22) Check and straighten bent pump rods and replace worn rods	A
7) Pump handle is shaky	23) Pump platform is cracked	23) Repair pump platform	C
	24) Flanges are loose	24) Tighten all bolts and nuts of the flanges	A
	25) Bearings are worn	25) Check and replace bearing sets (4 pcs)	A
	26) Fulcrum pin is loose	26) Check fulcrum pin (and bearing sets) and tighten both nuts fully	A
	27) Hanger pin is loose	27) Check hanger pin (and bearing sets) and tighten both nuts fully	A

*1 Degree of repair;

A: Caretaker (s) of Water Users Committee (WUC) can repair

B: It is recommended to ask professional technician (s) to repair (highlighted by grey color in above table)

C: It is recommended to ask District (s) to repair

(1) Identify fast wearing parts and their effects in pump operation

It is cheaper to replace the fast wearing parts than to allow effects of the worn parts to damage more expensive parts. Fast wearing parts are as follows.

Spare parts for handle

- Bush bearing
- Spare pump rod
- Rod centralizer

Spare parts for cylinder

- U-seal (cup-seal)

- O-ring
- Bobbin

(2) Identification of problems in the rising main

Possible reasons of problems of the rising main are as follows;

- Leakage at joints due to poor practice when making joints
- Perforations made on pipe due to rubbing with rods or worn out centralizers
- Cracks in pipe

(3) Repairing rising main

The rising main will need to be removed if;

- There is excessive leakage that cannot be attributed to a leaking foot valve bobbin or "O" ring.
- Items have been dropped or have jammed inside the rising main that cannot be fished out.
- The cylinder is suspected of needing replacement.
- The riser pipes are disconnected.

Traditionally when the rising main was removed it was cut into manageable lengths, a maximum of 2 lengths (6m), which meant that a large number of joints had to be re-made upon replacement. In addition, suitable double sockets were not available and joints were formed by warming the PVC pipes in a fire. It is very important that joints in the PVC rising main are correctly made to ensure a sustainable long-term repair.

To minimize the number of joints that need to be made during a repair the rising main is removed from the borehole in one length without making any cuts. The problem is identified and repaired before replacing the rising main back in the borehole, once again in one length.

During removal of the rising main in one length the joints will come under considerable stress.

This procedure should only be attempted if it is known that the uPVC joints were correctly made in accordance with "6.3.2 Making joints" during the installation. Otherwise there is a danger that a joint may break and could cause injury.

In addition to the tools needed for pump repair the additional resources needed to withdraw the rising main are:

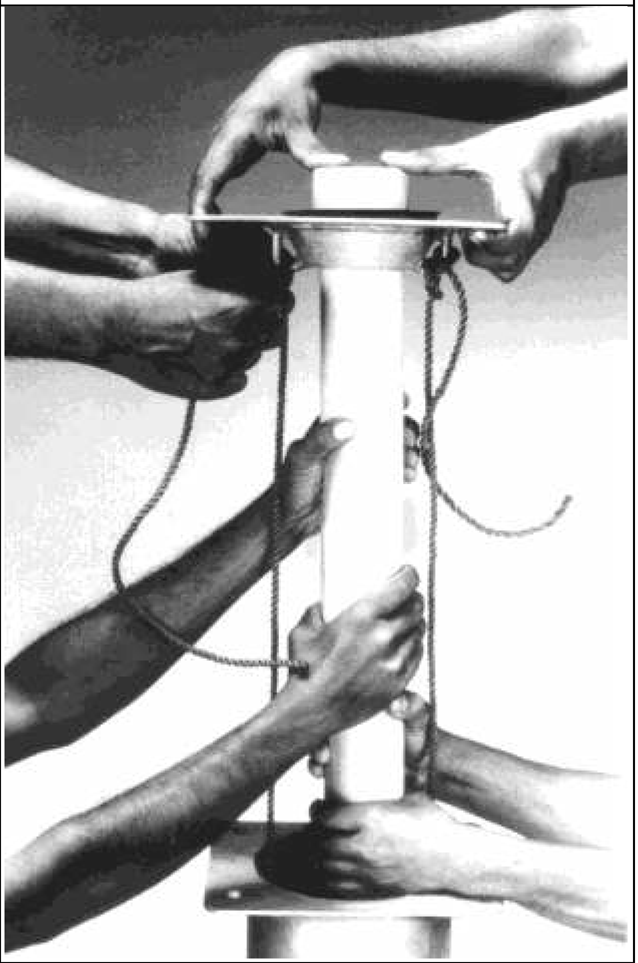
- At least 8 people, preferably including all or some of the pump caretakers.
- It is recommended that more people should be available.
- Poles with forked ends and the number should be equal to the number of rising mains in the installation. Four should be 3.5m long and the rest should be 4m long.
- A guide rope at least 10m long

A cleared area long enough to accommodate the rising main so that it may be laid down without delay after withdrawal.

1) Removing and replacing of rising main

The procedure is shown in the below Table 5.9.

Table 5.9: Procedure for removing and replacement of rising main

Step	Activity	Note / Photo
1	Remove the foot valve.	This may not be possible if there are components stuck inside the rising main. It is still possible to remove the rising main in one piece but extra care must be taken as the weight of water and components will make the control of the rising main as it comes out of the borehole much more difficult.
2	Remove the pump head	As shown in the Table 5.6
3	Tie the guide rope to the cone plate.	
4	Start to pull the rising main of the borehole by pulling the two ends of the support rope and the pipe. The guide rope is used to control the free end of the pipe	The support rope should have knots made on both sides to coincide with the top of the rising main pipe before pulling out the rising main. These marks can be used to check if the rising main length has been changed during repairs.
5	As the rising main comes out of the borehole start to bend it in the direction chosen for it to be laid down. Using the short forked poles start to take the weight of the pipes at the same time keeping the radius of the bend as long as possible.	The direction might be chosen considering where there is space.

Step	Activity	Note / Photo
		
6	As the pipe is pulled out the longer forked poles are used to support the free end of the pipe which should be kept up and the pipe horizontal so that the bend is at least three pipes long. If it has not been possible to remove the foot valve, the open end of the pipe should be lowered just enough to drain the water out so that the weight is reduced. The shorter poles at the borehole end of the pipe need to be held off the ground to allow them to be moved easily along the line of removal. The longer poles in the middle and the free end can be allowed to rest on the ground to take the weight and stabilize the pipe.	There is a minimum of one forked stick per length of rising main. The radius of curvature is kept as long as possible. The section of pipe already extracted, on the left in the photo below, is kept horizontal and curvature is spread over at least three pipe lengths. Additional support is given to the pipes being bent. Leaking and broken parts should be marked as the rising main is being removed. 
7	If at any time a joint appears to be weak (e.g. there is evidence of burning as in a homemade joint) the pipe should be carefully supported and cut at the suspect joint. Do not try to bend a weak joint.	-
8	When the cylinder and suction pipe are reached they are carefully withdrawn, making sure to maintain control of the whole pipe. The whole pipe length can now be laid down.	Select a suitable place to lay down the pipes and carefully examine the rising main for damage and signs of leaking
9	After the necessary repairs have been carried out the whole length of pipe must be carefully cleaned before replacement. Before replacing the pipe the borehole should be sterilized using at least 250 grams of high test hypochlorite (HTH). At the very least all down hole components must be thoroughly cleaned.	-
10	The pipe is then replaced in the reverse procedure of removal. Some difficulty may be experienced inserting the cylinder and suction pipe, as some force has to be applied to bend the pipe sufficiently to insert it into the borehole.	When the cylinder and suction pipe are ready, they are carefully inserted into the borehole, making sure to maintain control of the whole pipe.

2) Repairing of rising main

Unless an obstruction can be removed by tipping the pipe up, which is very unlikely, or there is leakage from a joint that can be reconnected, it will be necessary to cut the rising main.

The choice of where to cut depends upon the repair that needs to be carried out. If there is a hole in the pipe, which may be caused by the internal rubbing of a rod joint because rod centralizers have not been replaced when worn, the pipe will need to be cut in two places one on each side of the hole. If the problem only requires access to the inside of the rising main or cylinder, such as the removal of an obstruction, then the pipe only needs to be cut in one place. The location of the cut depends upon the problem to be resolved.

The overall length of the rising main must not be changed. It is very important that the timing of the pump is not changed, i.e., the lengths of the pipes and of the rods are not changed.

All joints must be made using a "Double Socket". A Double Socket is a straight piece of pipe 230 mm long with an internal diameter that just fits over the outside of the rising main pipe. Each end of the pipe at the joint must be marked at 115 mm to ensure that the double socket is equally distributed over the joint. The joining of PVC pipe should be done in accordance with "Making joints on rising main".

If a length of pipe has had to be cut out, for example if it has a hole in it, it must be replaced by a pipe of equal length and two double socket joints made. The shortest length of a repair should be 300mm to ensure that the joints on each side are adequate. Do not be tempted to make a patch with a piece of pipe and stick it on using solvent cement. It will not last and the rod centraliser will be quickly damaged as it rubs past the inside of the hole.

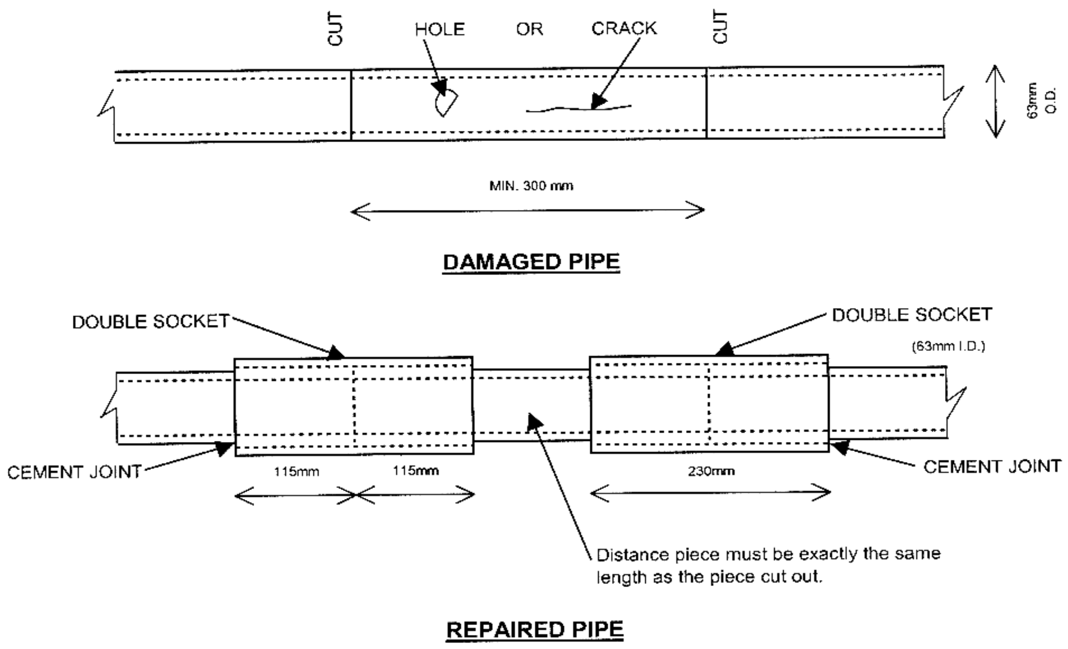


Figure 5.6: Typical pipe repairing method

3) Making joints on rising main

◆ Tools and materials

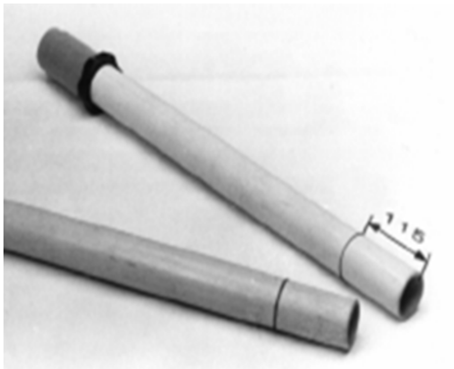
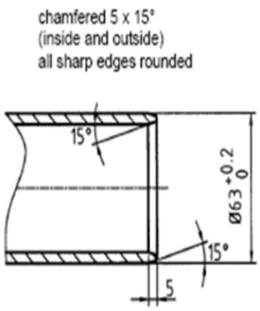
Before making joints on the rising main the tools and materials mentioned below should be prepared:

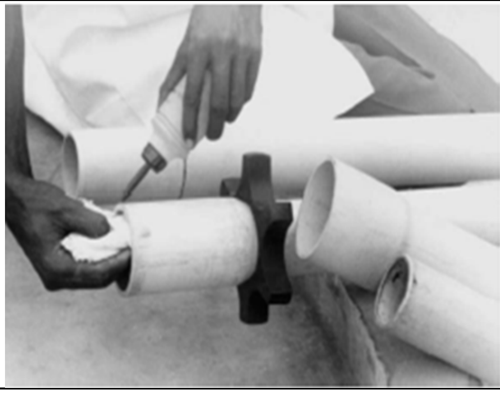
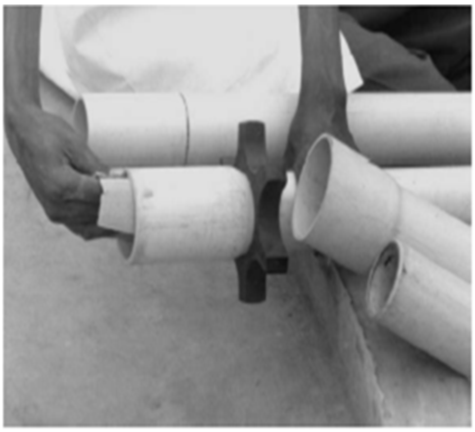
- A hacksaw with spare blades
- A measuring tape and marker
- Solvent cement
- Cleaning fluid
- File
- Sand paper
- Cloth

◆ Making joints

The procedure is shown in the Table 5.10.

Table 5.10: Procedure for making joints

Step	Activity	Note / Photo
1	Mark the depth of the socket (115 mm) on the plain end of the pipe. If the mark is removed during cleaning the pipe centralizer can be located at the correct place as a depth gauge.	
2	The outer edge of the plain end should be bevelled at 15° to 20°(if not already done at the factory).	 
3	If a pipe has had to be cut on site during a repair the inner edge of the plain end should also be smoothed and all burrs removed, otherwise the plunger and foot valve may be difficult to remove. In the case of a plunger with a cup seal it may prove impossible to remove all of the burrs	-
4	Clean the pipe (bell end inside and plain end up to 115mm) with cloth	

Step	Activity	Note / Photo
	and cleaning fluid (Carbon tetra chloride).	
5	Roughen the cleaned surfaces with sandpaper.	
6	Clean again with cleaning fluid.	-
7	Apply solvent cement up to the mark on the outside of the plain end and on the inside of the bell end of the rising main with a brush. Replace the caps tightly on the cleaning fluid and the solvent cement after each use.	Care must be taken not to apply too much solvent cement which could weaken the pipe wall by dissolving it. Also a bead of excess dissolved uPVC on the inside of the joint may interfere with the plunger and rod centralizers.
8	Insert the plain end into the bell end of the other pipe as quickly as possible. Do not twist or rotate the pipe during insertion. Push hard to make sure that the plain end enters the full length to the mark (or the centralizer).	-
9	Wipe off any excess solvent cement with a cloth.	-
10	Allow to set for at least five minutes. The nylon rope should be anchored during these five minutes.	-
11	Check the mark and ascertain how far the plain end entered.	-
12	Lower the pipe into the borehole using the nylon rope.	-
13	Allow pipes to cure for about 24 hours before applying any pressure, i.e., do not use the pump.	-

5.4.2.6 Preventive maintenance

5.4.2.6.1 Identification of problems

This section is re-edited based on "Installation and Maintenance Manual for the AFRIDEV Hand pump, Revision 2-2007, SKAT-RWSN".

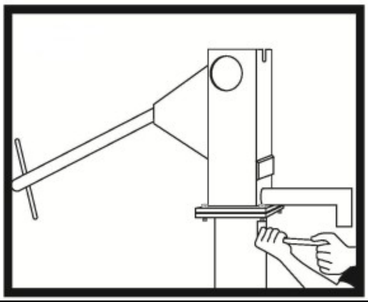
Problems may be identified during regular preventive maintenance and it will be necessary to diagnose the faults and determine the possible reasons for them. Preventive maintenance means regular check-up of the hand pump at a fixed time interval (weekly or monthly) and changing of spare parts before they are fully worn.

Such interventions help in preventing the sudden failure of the pump.

(1) Weekly checks

Weekly check shall be conducted in accordance with the Table 5.11.

Table 5.11: Weekly checks

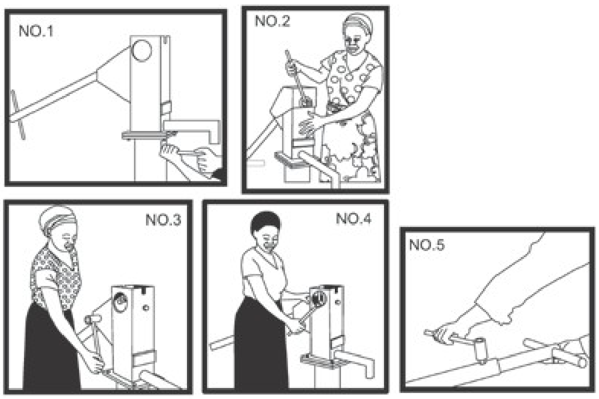
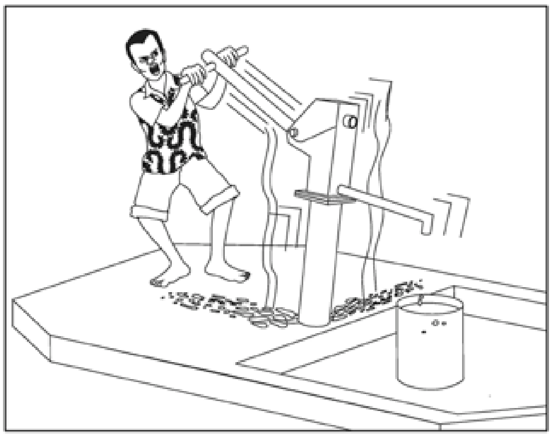
No.	Item	Illustration
1	Check that the flange bolts and nuts are tight.	
2	Check that the fulcrum pin and hanger pin nuts are tight.	 

(2) Monthly checks

Monthly check shall be conducted in accordance with the Table 5.12.

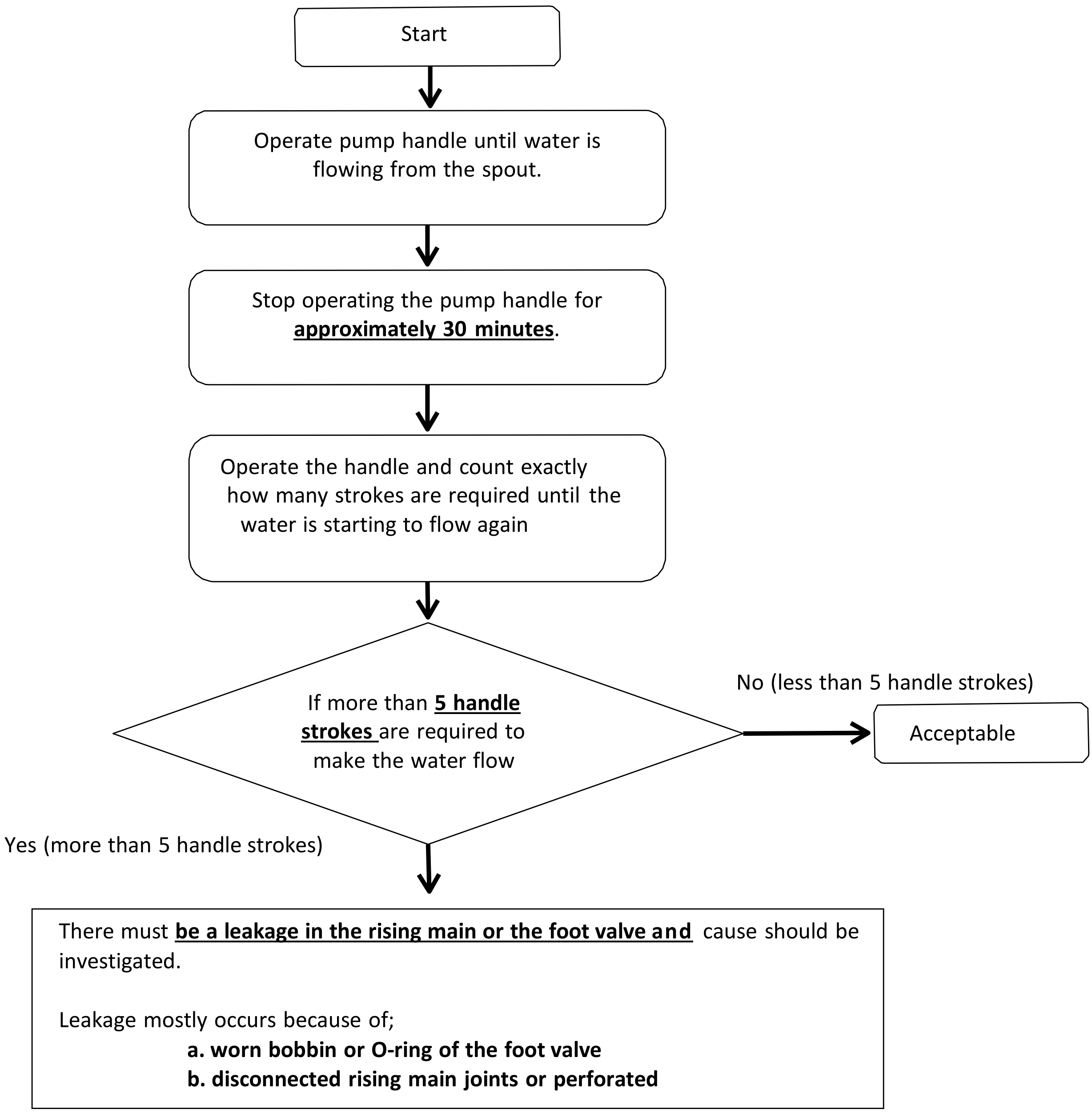
Table 5.12: Monthly checks

No.	Item	Illustration
1	Check if any fasteners or parts in the pump head are missing. If so, replace the parts.	

No.	Item	Illustration
		
2	If any unusual noise is noticed, check reason for the same and take corrective actions.	
3	Check if the pump stand is shaky during operation. If yes, the stand is loose in the foundation and contamination of the well can take place. Take corrective measures to repair the foundation.	
4	Carry out a “Leakage Test” as detailed below.	
5	Carry out a “Discharge Test” as detailed below.	

1) Leakage test

Leakage test proceed as follows.

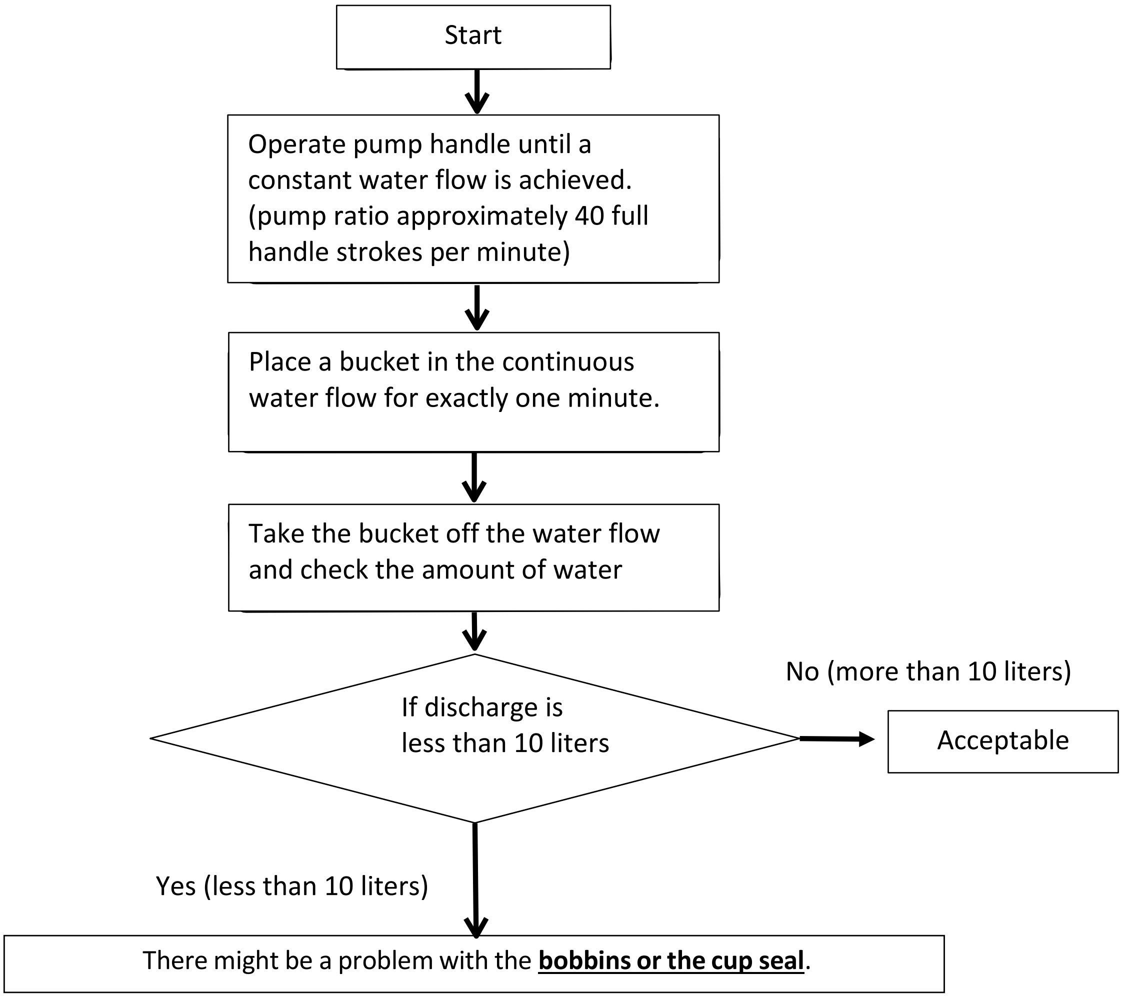


Source: Installation and Maintenance Manual for the AFRIDEV Handpump, Revision 2- 2007, SKAT-RWSN

Figure 5.7: Flowchart of leakage test

2） Discharge test

Discharge test proceed as follows.



Source: Installation and Maintenance Manual for the AFRIDEV Handpump, Revision 2- 2007, SKAT-RWSN

Figure 5.8: Flowchart of discharge test

5.4.2.6.2 Records

Any repairs must be recorded in the Water Users Committees (WUCs) record book. Full details of repairs must be entered such as;

- Date of repairs
- Nature of problem(s) encountered
- Cost of parts replaced
- Cost of labour
- Who carried out the repairs?

5.4.3 India Mark II hand Pump

5.4.3.1 Pump parts and function

India Mark II pump parts are divided into two categories "Above ground parts" and "Below ground parts". Assembly of India Mark II pump is shown in the Figure 5.9 and India Mark II pump cylinder is shown in the Figure 5.10.

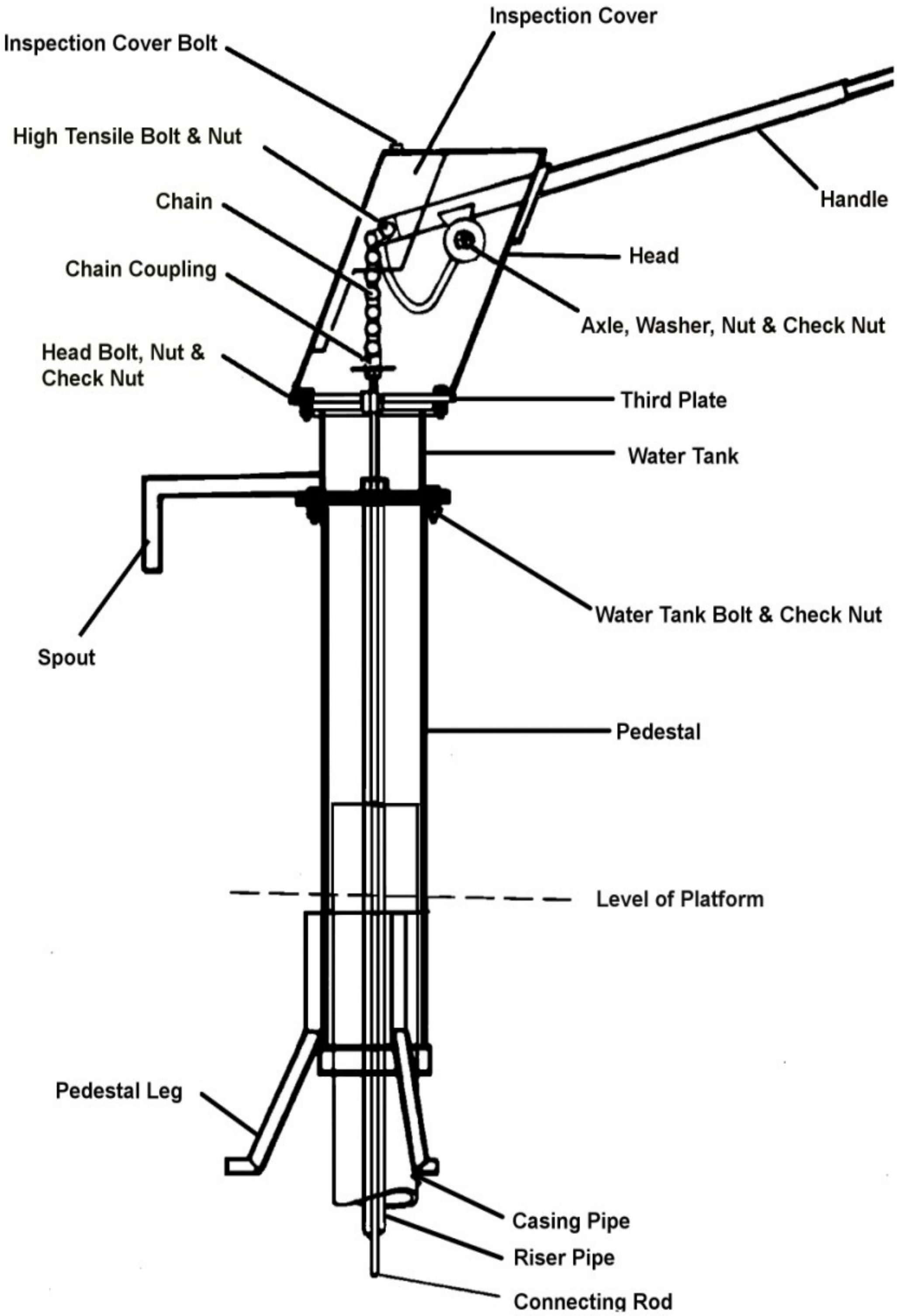


Figure 5.9: Assembly of India Mark II pump

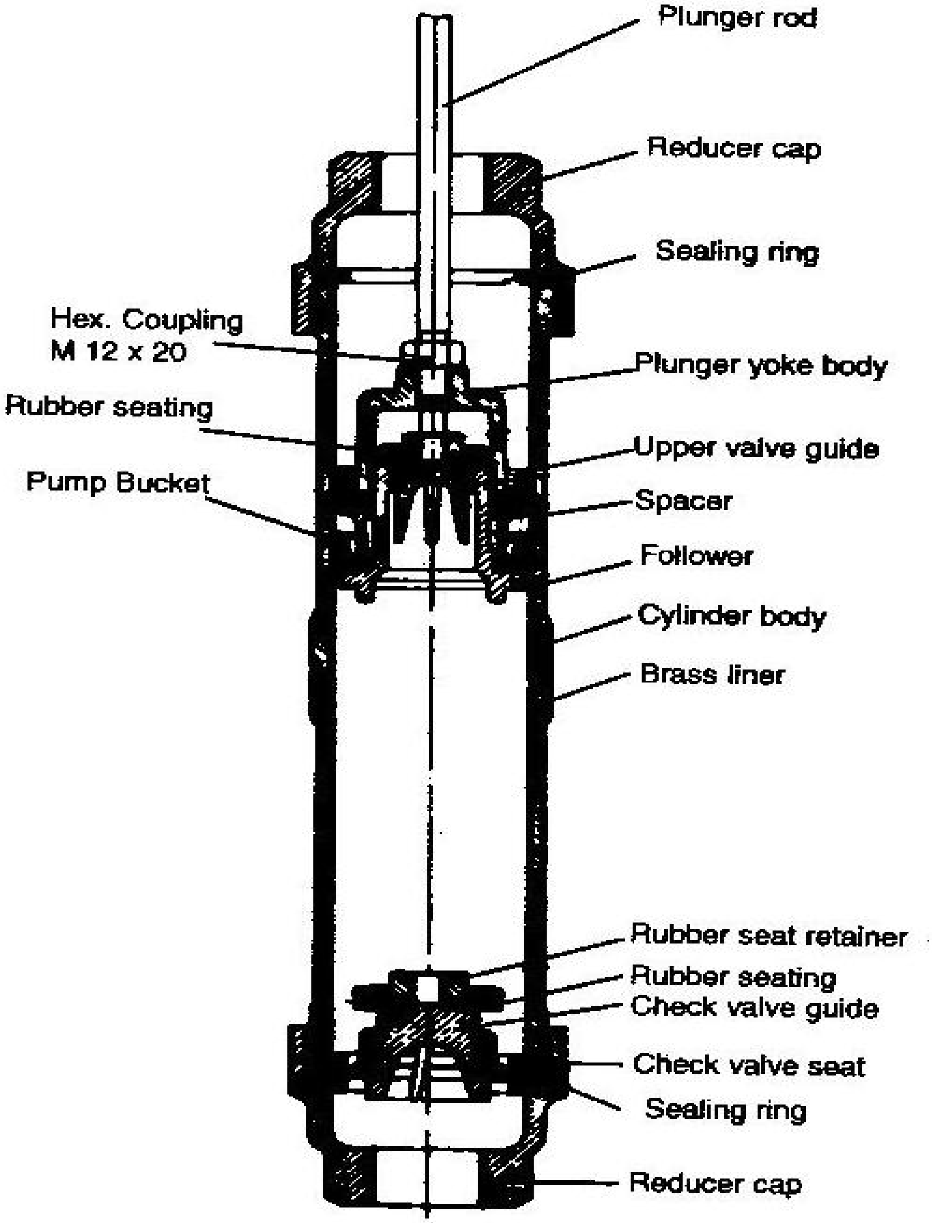


Figure 5.10: India Mark II pump cylinder

5.4.3.2 Tools

The India Mark II has two kinds of tool kits; the Standard tool kit and the Special tool kit. These tools are shown in the Figure 5.11.

Standard tool kit

Special tool kit

Figure 5.11: India Mark II tools

5.4.3.2.1 Standard tools

Standard tools for India Mark II pump are listed in the Table 5.13 and shown in the Figure 5.12.

Table 5.13: Standard tools for India Mark II

No.	Tools	Qty
1	Button Die (to suit 12mm rod) M 12 x 1.75mm Threads	**1 set**
2	Die set for 32mm GI pipe	**1 set**
3	600mm pipe wrench	**1 no.**
4	450mm pipe wrench	**1 no.**
5	300mm pipe wrench	**1 no.**
6	M17 x M19 double ended spanners (to suit 10mm x 12mm bolts & nuts)	**2 nos.**
7	300mm adjustable spanner	**1 no.**
8	Screw driver 300mm long	**1 no.**
9	Screw driver 150mm long	**1 no.**
10	1kg ball pein hammer with handle	**1 no.**
11	Hacksaw frame with two spare blades 300mm	**1 no.**
12	Pressure type oil can (1/2 pint with oil)	**1 no.**
13	Wire brush	**1 no.**
14	250mm half round file with handle	**1 no.**
15	250mm flat file with handle	**1 no.**
16	Lithium base / multipurpose grease	**1 kg**
17	Graphite Grease	**1 kg**
18	**Nylon rope (3mm thick)**	**75 m**

Button Die

Die set

	
Pipe wrench	Double ended spanners
	
Screw driver	Ball pein hammer
	
Hacksaw	Wire brush
	
Flat file with handle	Multipurpose grease

Figure 5.12: Standard tools for India Mark II

5.4.3.2.2 Special tools

The special tools for India Mark II pumps as shown in the Figure 5.13 and should be used for the repair technician while dismantling, reassembling or repairing.

1. SELF LOCKING CLAMP
2. TANK PIPE LIFTER
3. COUPLING SPANNER
4. HANDLE AXLE PUNCH
5. CONNECTING ROD LIFTER
6. CRANK SPANNER
7. LIFTING SPANNER
8. CONNECTING ROD VICE
9. CHAIN COUPLER SUPPORTING TOOL
10. BEARING PRESSING TOOL
11. TOOL BOX

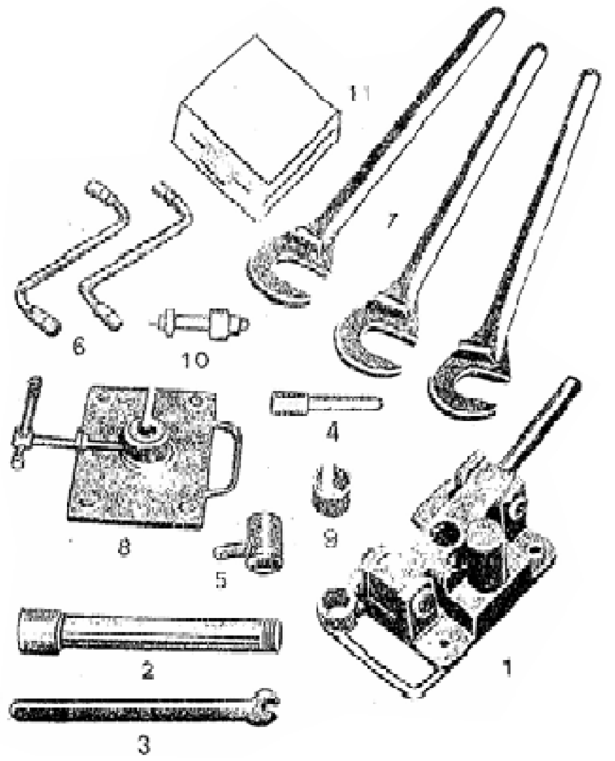


Figure 5.13: Special tools for India Mark II

Tools	Description
Tool No.1: Self-locking Clamp	Use this tool for holding rising main while lifting or lowering. While raising the pipe, you need not operate the handle to open out the jaws, as the tool has been devised to facilitate pulling out the rising main couplers without opening of the jaws by hand.
Tool No.2: Tank pipe lifter	Use this tool to lower or lift the water tank with rising main. 1. Screw it on to water tank coupling 2. Use 2 or 3 lifting spanners equally spaced on the tank pipe lifter to raise or lower water tank assembly.
Tool No.3: Coupling Spanner	Use this tool for tightening the connecting rod coupler faster and with ease.
Tool No.4: Handle Axle Punch	This tool is used for driving out the handle axle without damage to axle threads (A) For driving out the handle axle, the sequence should be: 1. Remove axle nuts and washers 2. Put handle axle punch on taper portion of axle 3. Hammer gently handles axle punch until you are able to pull out axle by hand. (B) While driving the handle axle, the sequence should be as under: 1. Insert the handle axle punch through left bush and bearings 2. Insert the handle axle through right bush so that threaded portion goes into the handle axle punch

Tools	Description
	3. Hold the handle axle punch by one hand hammer gently the handle axle. 4. Hammer the handle axle till the handle axle threaded portion comes out through left bush. The handle axle punch would have come out by then.
Tool No.5: Connecting Rod Lifter	Use this tool for raising or lowering the connecting rod. 1. Thread on the tool to the connecting rod 2. Insert lifting spanner 3. Lift or lower as required
Tool No.6: Crank Spanner	Use crank spanners for tightening or loosening flange bolts. Check nuts, nylon nuts and anchor bolts.
Tool No.7: Lifting Spanner	Use this tool to raise or lower rising main. These lifting spanners are suitable for 32mm (1 1/4 inch) pipes. 1. Lifting spanners should be spaced equally around the rising main. 2. Use two lifting spanners to lower or lift up to 30m of rising main. 3. Use three lifting spanners if the rising main is longer than 30m. Do not use pipe, wrenches for lifting or lowering the rising main. 4. You can also use one lifting spanner to lock the pipe with the help of a pipe wrench.
Tool No.8: Connecting Rod vice	Use this tool for holding the connecting rod, while connecting rod is cut and threaded.
Tool No.9: Chain coupler supporting tool	Place this tool between the chain coupler and the flange of conversion head assembly. This facilitates easy fixing of chain on to the handle assembly as the entire rod weight is supported by this tool.

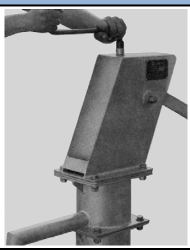
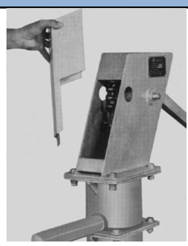
5.4.3.3 Dismantling

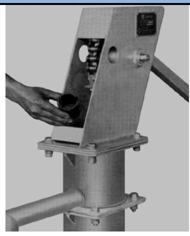
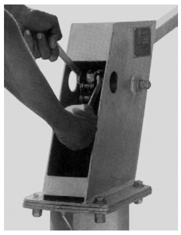
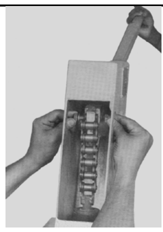
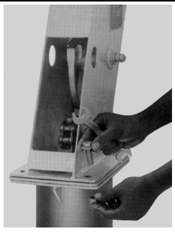
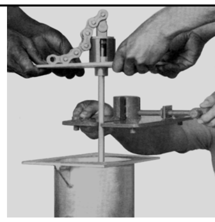
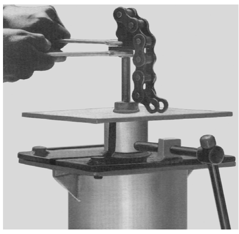
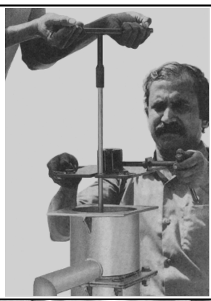
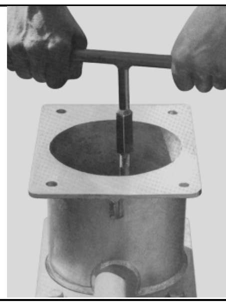
Necessary steps for dismantling are described as follows:

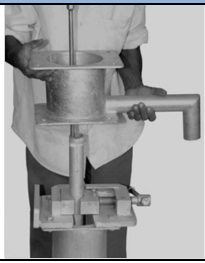
5.4.3.3.1 Above ground component

Necessary steps for dismantling above ground component are described in the Table 5.14.

Table 5.14: Necessary steps of dismantling above ground component

No.	Step	Illustration	No.	Step	Illustration
1	Loosen pump head cover bolt.		2	Remove pump head cover.	

No.	Step	Illustration	No.	Step	Illustration
3	Lower pump handle. Put chain supporting support below the chain assembly.		4	Lift up the pump handle to top position. Use two open-ended spanners to loosen "Nyloc" nut.	
5	Remove the "Nyloc" nut anchor bolt and pull out chain from the handle.		6	Loosen and remove bolts and nuts connecting head and water tank.	
7	Lift and remove head assembly. The chain will go through hole in the bottom flange.		8	Turn flange 90º. Lift connecting rod by holding middle flange and insert connecting rod vice.	
9	Place rods vice on water tank top flange and tighten it. Leave the middle flange resting on the rod vice. Take off the chain support and loosen and remove the chain assembly from top rod.		10	Unscrew check nut and remove middle flange.	
11	Attach the rod lifter (in clockwise direction). Hold the rod lifter firmly, open the vice and remove it.		12	Gently lower the pump rod assembly until it sits on top of the check valve. Unscrew the rod lifter.	
13	Remove all bolts between water tank and pump stand.		14	Lift the water tank up wards (about 50 cm) and introduce and fasten pipe vice.	

No.	Step	Illustration	No.	Step	Illustration
15	Unscrew water tank by turning the spout by hand.				

5.4.3.3.2 Below ground component

The below ground components of the India Mark II pump can be dismantled (and re-installed) with two different systems.

1) For pump installations between 10 to 30 m, the rising main pipe with pump rods and the cylinder can be lifted with 2 or 3 specially designed Lifting spanners. Therefore, a short piece of a threaded riser pipe can be connected to the thread of the water tank, so that the Lifting spanners can be applied.

2) For pump installations between 30 to 50 m, the weight of the below ground components is increasing and therefore a Tripod with a Chain block (or pulley wheel with rope) can be used for lifting the rising main pipe with pump rods and cylinder.

For getting a secure grip on the rising main, a pipe clamp needs to be attached and a piece of rope is used to attach the pipe with pipe clamp to the hook of the lifting device (chain block).

After lifting the below ground components for a complete pipe length (3 m), a Pipe vice is used to fix the riser pipe in position when the retrieved riser pipe and the pump rod are getting unscrewed.

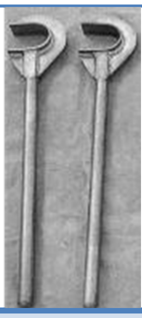
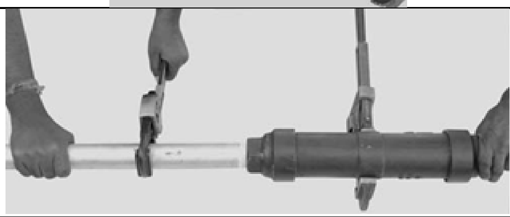
	
Lifting spanners	Tripod with chain block
	
Pipe clamp	Pipe vice

Figure 5.14: Lifting devise

The Table 5.15 shows the necessary steps of dismantling the below ground components with a tripod & chain block.

Table 5.15: Necessary steps of dismantling below ground component

No.	Step	Illustration
1	Attach pipe clamp and connect it with a piece of rope to the hook of the chain block.	
2	Operate chain block until the chain is tight and then open the pipe vice slowly and remove it.	
3	Lift rising main pipe, pump rods and cylinder until the next pipe socket is about 0.5 m above the top flange of pump stand.	
4	Introduce the pipe vice and clamp the rising main securely.	
5	Remove the pipe clamp and open the protruding riser pipe with two pipe wrenches.	
6	Lift the unscrewed riser pipe by hand, so that the pump rod connection is visible.	
7	Unscrew the pump rod connection and place the rods and pipes separately on a clean place.	
8	Attach pipe clamp to the remaining rising main pipe (close to the pipe vice).	
9	Connect pipe clamp to the hook of the chain block and tighten the chain.	
10	Continue with Step 1 to Step 9 until the whole rising main, pump rods and cylinder are retrieved.	
	Please note: For shallow dismantling an installations where the total weight of the rising main, pump rods and cylinder is not so heavy, dismantling (and also re-installation) of the below ground components can be done easily with the Lifting spanners.	
11	The last riser pipe can then be removed from the cylinder.	
12	Then the last pump rod gets disconnected from the plunger rod.	

No.	Step	Illustration
13	From the cylinders, both caps can be opened and the plunger & check valve removed.	
14	The plunger and the check valve can also be dismantled to check or replace worn parts (cup seal and rubber seating).	
15	Once the defective pump components have been replaced and the pump is re-assembled again, explanations needs to be given to the pump users about the diagnostic (what the problem was and why the break down might has happened).	

5.4.3.4 Reassembling

5.4.3.4.1 Preparation

Necessary steps for preparation for reassembling are described in the Table 5.16.

(1) Below ground component

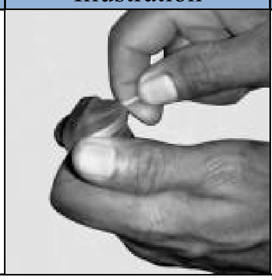
1) Riser pipes and pump rods

Table 5.16: Necessary steps of preparation of riser pipes and pump rods

No.	Step	Illustration
1	Check all pipe threads with socket for good engagement,	
2	Check all pump rod threads with couplers for good engagement,	
3	Apply hemp fiber with grease or sealing liquid to one threaded end of all pipes and attach one socket,	
4	Place a number of logs or a pipe stand near the installation place,	
5	Place all prepared pipes neatly on top of the logs or pipe stand (above the ground) so that all threads remain clean,	
6	Introduce one pump rod to each of the riser pipes and make sure that the long hexagonal couplers are on the same side as the riser pipe sockets.	

2) Pump cylinder (From Step1 to Step4)

Table 5.17: Step1: Assemble all components of the plunger

No.	Step	Illustration	No.	Step	Illustration
1	Place Rubber seating to the Upper valve		2	Attach a Cup seal to the lower part of the Spacer	

No.	Step	Illustration	No.	Step	Illustration
3	Attach a Cup seal to the lower part of the Spacer		4	Attach another Cup seal at the top of the Spacer	
5	Introduce the follower into the spacer and place the upper valve on top of the assembly		6	Introduce the follower into the spacer and place the upper valve on top of the assembly	
7	Attach Plunger body and tighten securely		8	Take Plunger rod and tighten it to the Plunger assembly	
9	Take Plunger rod and tighten it to the Plunger assembly				

Table 5.18: Step 2: Assemble all components of the check valve body

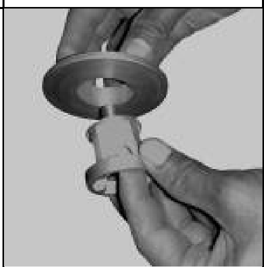
No.	Step	Illustration	No.	Step	Illustration
1	Assemble Check valve with Check valve seat		2	Place rubber seating and secure with seat retainer	
3	Place rubber seating and secure with seat retainer				

Table 5.19: Step3: Assemble the pump cylinder

No.	Step	Illustration	No.	Step	Illustration
1	Prior to assembling check cleanliness of cylinder liner and clean all threads and prepare them with sealing fluid or hemp fiber with grease (cylinder pipe and Reducer caps).		2	Place first sealing ring into a reducer cap	
3	Introduce Check valve and place second sealing ring		4	Attach the cylinder with liner to the Reducer cap	
5	Introduce plunger assembly into the cylinder pipe		6	Place third sealing ring and attach reducer cap	
7	Tighten both reducer caps with pipe wrenches				

Table 5.20: Step 4: Leakage test

No.	Step	Illustration
1	Immerse suction part of cylinder into a bucket with clean water. Operate the plunger by pulling and pushing the plunger rod.	

No.	Step	Illustration
2	As soon as the cylinder is filled, place it in a vertical position and check for any leaks. Be aware that a small amount of water is dripping from the outer surface of the cylinder. Wait therefore for some minutes until the cylinder surface is dry, not to assume any dripping water automatically as leakage. If there is any leakage, try to tighten both reducer caps, before dismantling the cylinder for finding the reason of the leakage. Once the cylinder is water tight, the installation of the "down hole components" can start.	

(2) Above ground component (From Step1 to Step2)

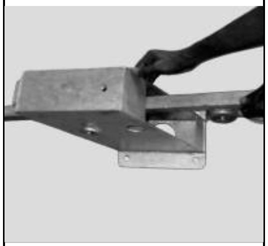
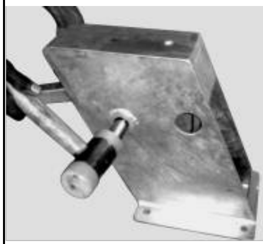
1) Assembling of pump handle

Table 5.21: Step1: Assembling pump handle

No.	Step	Illustration	No.	Step	Illustration
1	Place first ball bearing to bearing mounting tool		2	Introduce mounting tool into bearing housing	
3	Insert spacer into bearing housing		4	Place second ball bearing on bearing mounting tool	
5	Introduce pressure plate on bearing mounting tool		6	Add the hexagonal nut	
7	Take two spanners (19 mm) and tighten the nut of the bearing mounting tool, so that both ball bearings are pushed into their end position. If ball bearings are mounted, remove bearing mounting tool.				

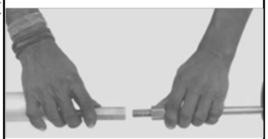
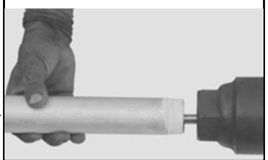
2) Assembling of pump head

Table 5.22: Step 2: Assembling of pump head

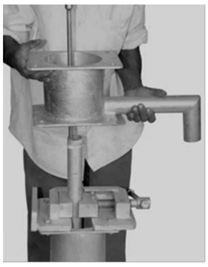
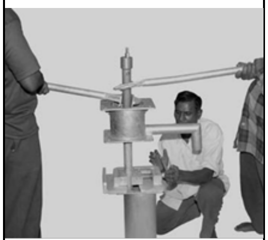
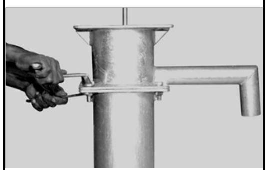
No.	Step	Illustration	No.	Step	Illustration
1	Introduce the pre-assembled pump handle into the pump head assembly and place the ball bearings near the axle bushes at the sides of the Pump head.		2	Knock the handle axle gently into the end position (use a plastic hammer if available).	
3	Introduce axle washer and fasten one nut by hand.		4	If the pump handle is moving smoothly (up- & down), take second nut as a check nut to secure the correct position.	
5	If the pump handle is moving smoothly (up- & down), take second nut as a check nut to secure the correct position.				

5.4.3.4.2 Below ground component

Table 5.23: Necessary steps of reassembling below ground component

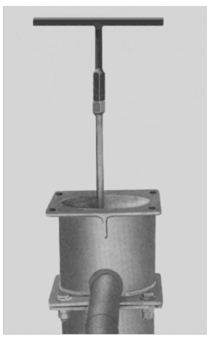
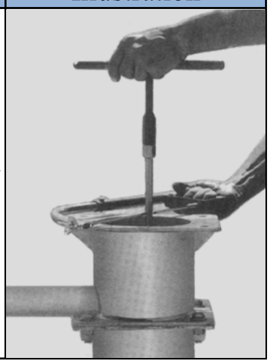
No.	Step	Illustration	No.	Step	Illustration
1	Take the first riser pipe with pump rod from the logs. Place it horizontally on the pump platform and connect the pump rod to the plunger rod of the cylinder.		2	If the pump rod is tight, apply hemp fibers with grease, sealing liquid or Teflon tape to the pipe thread and screw the riser pipe into the reducer cap of the cylinder.	

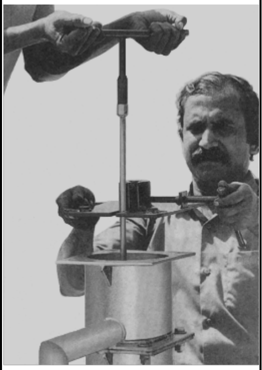
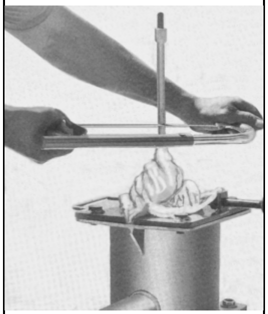
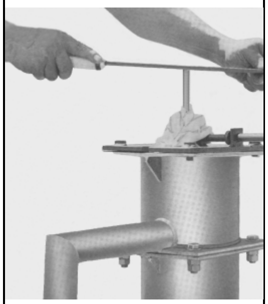
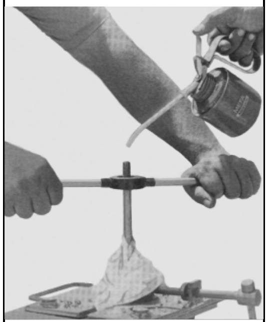
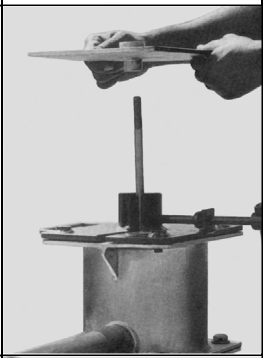
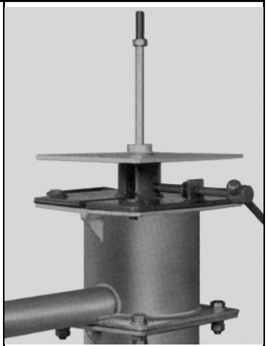
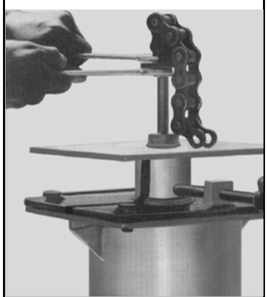
No.	Step	Illustration	No.	Step	Illustration
3	Tighten riser pipe with reducer cap of the cylinder with two pipe wrenches.		4	Lower the first riser pipe with cylinder into the pump stand (by hand) until the riser pipe protrudes the top face of the pump stand by approx. 50 cm.	
5	Introduce the pipe vice and fasten the riser pipe in this position (ideal working height)		6	Take the second riser pipe with pump rod from the logs, connect the pump rods first and then the riser pipe after hemp fibers with grease, sealing liquid or Teflon tape has been applied.	
7	With the help of the two lifting spanners, the rising main can be lowered after the pipe vice has been opened and removed.		8	Proceed in the same manner until the last pump rod and riser pipe is connected.	
	Please note: As soon as the rising main is too heavy for being handled with the lifting spanners (5 to 10 pipe lengths), attach the pipe clamp and connect it with the hook of the chain block. Lower the rising main with the help of the chain block on the tripod until the height required (50 cm) for the next connection is reached!		9	At the end of the last riser pipe located in the pipe vice, the water tank will be attached. Therefore take off the last socket of the last riser pipe and re-apply hemp fibers with grease or sealing liquid to the pipe thread.	

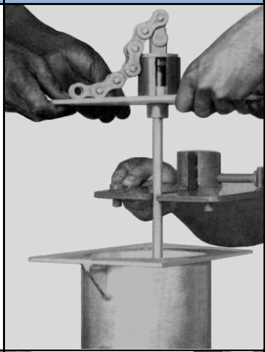
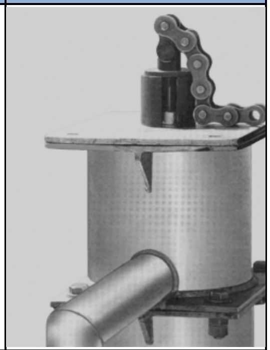
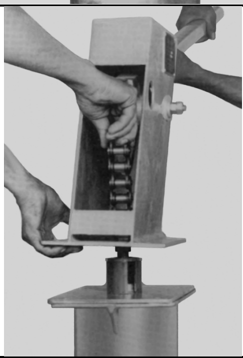
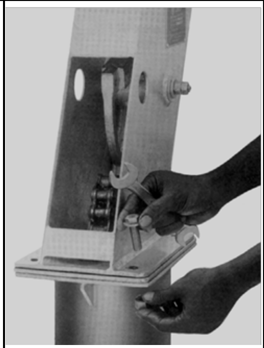
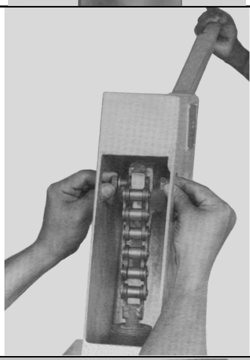
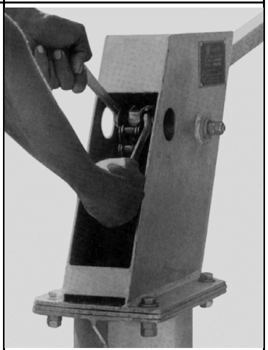
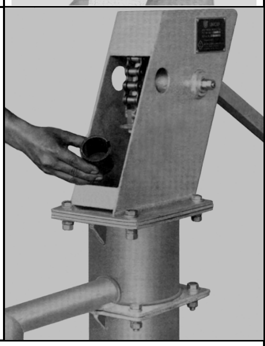
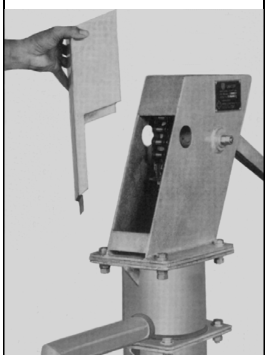
No.	Step	Illustration	No.	Step	Illustration
10	Then the water tank is screwed on to the last pipe end and tighten by hand.		11a	(For shallow installations, when rising main is not heavy). With the help of a short piece of riser pipe attached to the socket in the water tank, the entire rising main can be held in place with the help of 2 or 3 lifting spanners. As soon as the pipe vice has been removed, the riser pipe assembly with water tank can be lowered slowly to the pump stand flange.	
11b	(For deep installations with heavy rising main assemblies). With a short piece of rope attached to the hook of the chain block, the water tank can be held securely in position, so that the pipe vice can be removed from the pump stand. Then the water tank with rising main attached can be slowly lowered to the pump stand flange.		12	Turn the water tank so that the spout is pointing into the required direction and tighten it properly to the pump stand with 4 x M12 bolts and nuts. Now the installation of the "above ground components" can start.	

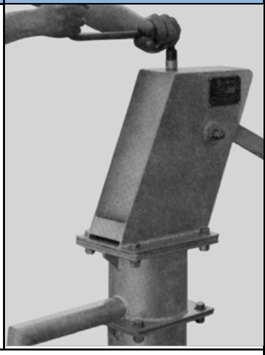
5.4.3.4.3 Above ground component

Table 5.24: Necessary steps of reassembling above ground component

No.	Step	Illustration	No.	Step	Illustration
1	The protruding last pump rod needs to be cut to the exact length, so that the plunger connected is not knocking the check valve or the cylinder cap during pump operation.		2	Use a hacksaw for marking the exact length of the last pump rod (at the top face of the water tank flange).	

No.	Step	Illustration	No.	Step	Illustration
3	Lift marked pump rod for easy cutting and fasten with connecting rod vice on the top flange of the water tank. Take a clean piece of cloth and wrap it around the marked rod, in order to prevent metal shavings or oil from falling into the well (contamination).		4	Cut last pump rod at the mark.	
5	Remove sharp edges and make a nice chamfer prior to threading.		6	Use little oil for cutting the M12 thread (40 mm long). As soon as thread is finished, remove cloth carefully and clean pump rod, vice and pump stand from remaining oil and shavings. Prevent shavings from falling into well.	
7	Insert middle flange.		8	Allow middle flange to rest on top of connecting rod vice and fix the check nut on the newly threaded top rod.	
9	Screw the chain coupler on the connecting rod threads by hand		10	Tighten check nut of connecting rod with the chain coupler.	

No.	Step	Illustration	No.	Step	Illustration
11	Insert chain coupler supporting tool below the chain coupler. Hold middle flange and remove connecting rod vice.		12	Carefully lower the middle flange to the top of water tank and ensure that all four corners coincide.	
13	Hold head assembly in position and insert chain through the hole in the bottom/flange. Lower head on top of middle flange ensuring all four corners to coincide.		14	Tighten head, middle flange and water tank with bolts and nuts.	
15	Lift handle up and attach free end of the chain with high tensile bolt, washer and "Nyloc" nut.		16	Tighten "Nyloc" nut.	
17	Lower the handle and remove chain coupler supporting tool.		18	Lift handle up and apply grease on the chain.	
19	Make sure: that the connecting rod moves up and down freely. If it does not, the rod has been bent. Check the rod, that the chain coupler is fully engaged on the connecting rod and that the lock nut is tight, that the axle nut and lock nut on the handle are tight, that the handle axle is firm in place, that the "Nyloc" nut has been tightened securely with the chain anchor bolt, that all 8 flange bolts and nuts are tight, that nothing has been left inside the pump head (tools, cloth etc.).		20	Fit inspection cover.	

No.	Step	Illustration	No.	Step	Illustration
21	Tighten the cover bolt.		22	Now the hand pump must be operated for first filling of the rising main pipe. Depending on the depth of the cylinder setting, the pump handle has to be operated for many strokes (as an example: a 40 m cylinder setting requires approx. 100 full handle strokes for filling the entire rising main).	
23	As soon as the water is flowing from the spout, operate the pump for another 100 full strokes. Check whether the water is clean (no oil or dirt). If the water is not clean, the pump operation needs to be continued until the water is acceptable.		24	If the water quality is acceptable (optically), the leakage test and the discharge test must be made (see f. i. ii and iii).	

5.4.3.5 Curative Maintenance

5.4.3.5.1 Trouble shooting

Below is a table illustrating the common causes and their respective remedies for the India Mark II.

Table 5.25: Trouble shooting chart for India Mark II pump

Trouble	Possible Causes	Remedy	Who
Pump works easily, but no flow of water	Worn cup-seals	Pull out rising main, open cylinder and replace all worn cup-seals	Pump mechanic
	Water level dropped below cylinder	Add more riser pipes and pump rods	Pump mechanic
	Broken chain	Replace chain	Pump users
	Check valve jammed (not closing)	Pull out rising main, open cylinder, check function of check valve and make needed replacements	Pump mechanic
	Pump rod disconnected	Pull out rising main and join disconnected pump rod	Pump mechanic
Delayed flow or little flow of water	Check valve leaking	Pull out rising main, open cylinder, check leaking of check valve and make replacements if required	Pump mechanic
	Worn sealing rings	Pull out rising main, check sealing rings and make replacements if needed	Pump mechanic
	Worn cup-seals	Pull out rising main, open cylinder and replace all worn cup-seals	Pump mechanic
	Damaged rising main (leaking pipe threads or severe pipe corrosion)	Pull out rising main, check all riser pipes and make replacements if required	Pump mechanic
Folding of chain during down-stroke	Plunger jammed inside cylinder	Pull out rising main, open cylinder, check size of plunger and cylinder and replace wrong or defective components	Pump mechanic
	Top rod too long, plunger is sitting on top of the check	Take off pump head, check correct length of pump rod assembly and trace top rod if	Pump mechanic

Trouble	Possible Causes	Remedy	Who
	valve	needed	
Noise during pump operation	Lack of grease on chain	Grease chain	Pump user
	Worn ball bearings	Replace ball bearings	Pump mechanic
	Shaky foundation	Check foundation and make necessary repair	Pump mechanic
Shaky pump handle	Loose handle axle nuts	Tighten handle axle nuts	
	Worn or damaged spacer	Replace spacer	
	Worn or damaged axle	Replace handle axle	Pump mechanic
	Worn ball bearings	Replace ball bearings	Pump mechanic
	Bearings loose in bearing house	Replace handle assembly (for possible repair)	Pump mechanic

5.4.3.5.2 Identify fast wearing parts and their effects in pump operation

It is cheaper to replace the fast wearing parts than to allow effects of the worn parts to damage more expensive parts. Fast wearing parts are as follows.

(1) Spare for pump head

- Hexagonal bolt for pump head and water tank M12 x 1.75 x 40mm long
- Hexagonal nut for pump head, water tank and handle axe M12 x 1.75mm
- High tensile bolt for chain assembly M10 x 1.5 x 40mm long
- “Nyloc” nut for chain assembly M10 x 1.5mm
- Handle axle (stainless steel)
- Washer for handle axle 4mm thick
- Ball bearing (No.620422)
- Spacer for handle axe
- Chain with coupling
- Bolt for front cover M12 x 1.75 x 20mm long

(2) Spare for riser pipes and pump rods

- Riser pipe socket 32mm ND medium grade hot dip galvanized
- Hexagonal coupling for connecting pump rod M12 x 1.75 x 50mm

(3) Spare for cylinder

- Leather cup washer
- Leather sealing ring
- Rubber seating (big)
- Rubber seating (small)

5.4.3.6 Preventive maintenance

5.4.3.6.1 Identification of problems

This section is re-edited based on “Installation and Maintenance Manual for the India Mark II Handpump, Edition 2008, SKAT-RWSN”.

The India Mark II hand pump is to be properly maintained to ensure safe potable drinking water supply. Maintenance will prevent breakdowns and ensure continuous working of the hand pump. India Mark II hand pump is like any other mechanical machine. Any machine should be kept clean, if for no other reason than that in cleaning all parts are inspected for formation of rust, insufficient lubrication, loose, bolts, nuts, etc., and also for missing parts in time to prevent major failures.

The following schedule of maintenance has been drawn at fixed intervals.

(1) Monthly

- Tighten the handle axle nut and lock nut
- Look for loose or missing flange bolts and nuts
- Open the front cover, clean inside the pump
- Check the chain anchor bolt for proper fitment
- Tighten, if necessary
- Clean the chain assembly. Apply graphite grease
- Look for rusty patches. If seen, the same may be cleaned with the help of wire brush/ sand paper and apply anti-corrosive paint
- Find out whether the hand pump is loose at the base. If it is loose, arrange for fresh foundation to be constructed.

(2) Yearly

1) Examine the hand pump carefully and check whether:

- Discharge is satisfactory
- Handle is shaky
- Guide bush is excessively worn out
- All bolts, nuts and washers are in position
- Chain has worn out
- Roller chain guide is excessively worn out

2) Pull out the hand pump and follow the instruction given below: -

- If chain, bearing and spacer are damaged, replace them
- If roller chain guide is badly worn out replace handle assembly
- If any pipes are damaged replace them
- Open out cylinder assembly and replace cup washers, sealing rings and also any other part found defective
- Check the condition of water tank riser pipe holder. If threads are worn out, replace water chamber.
- Check all sub-assemblies for crack in weld and other visual defects. If defects are serious replace sub-assemblies

- Reinstall the hand pump as per instructions given in the manual. Paint the pump head inside/ outside with the recommended color after cleaning/ sanding the surfaces.

5.4.3.6.2 Leakage test

Testing shall start after a continuous flow of water through the spout has been obtained. The water shall then be collected in a container or bucket for 40 continuous full strokes of the plunger in one minute. Measure the quantity of water collected. Then allow the pump to rest for 30 minutes.

Repeat the test and measure the discharge. The difference between the first and the second reading of discharge indicates leakage. If the difference is more than 2 litres, there is an un- acceptable leak and the cause should be investigated.

Another method is to count the number of strokes required before water comes out of the spout after stopping operation for 30 minutes. If the number exceeds 5 strokes until water is flowing, it is an indication that there is an un-acceptable leak and the cause should be investigated.

Leakage mostly occurs because of worn rubber components in the cylinder, leaking rising main joints or severely corroded riser pipes.

5.4.3.6.3 Discharge test

Testing shall start after a continuous flow of water through the spout has been obtained. The water shall then be collected in a container or bucket for 40 continuous full strokes of the plunger in approximately one minute. The water collected should be generally not less than 16 litres.

If the discharge is less than 10 litres for 40 strokes, the repair technician needs to be called for pulling out the rising main pipe and dismantling the cylinder for detecting the reason of the leakage.

Another cause for a low discharge could be a perforated or cracked riser pipe due to severe corrosion or a non-tight riser pipe joint.

5.4.3.6.4 Records

Any repairs must be recorded in the Water Users Committees (WUCs) record book. Full details of repairs must be entered such as;

- Nature of problem (s) encountered
- Cost of parts replaced
- Cost of labour
- Who carried out the repairs

5.4.4 Disinfection

Method of disinfection is shown in the “Cleaning and Disinfecting Wells, Technical Notes on Drinking Water, Sanitation and Hygiene for Emergency Cases” by WEDC, World Health Organization (WHO).

5.4.4.1 Disinfection of the borehole

WHO endorses the disinfection of drinking-water in emergency situations. There are various ways of doing this but the most common is chlorination as it leaves a residual disinfectant in the water after chlorination.

Chlorine has the advantage of being widely available, simple to measure and use, and it dissolves easily in water. Its disadvantages are that it is a hazardous substance (to be stored and handled with care) and that at commonly applied concentrations it is not effective against all pathogens (e.g. cysts and viruses, which require higher chlorine concentrations).

The chlorine compound most commonly used is high strength calcium hypochlorite (HSCH) in powder or granular form which contains 60-80% chlorine. Also used is sodium hypochlorite in liquid bleach or bleaching powder form. Each chlorine compound has a different amount of usable chlorine depending on the quantity of time the product has been stored or exposed to the atmosphere and the way it is made.

Figure 5.14 outlines methods for calculating appropriate chlorine doses for HSCH granule chlorine.

HSCH and bleach give off chlorine gas which is a serious health hazard.

Calculating the chlorine dosage for disinfecting a well using high strength calcium hypochlorite (HSCH)

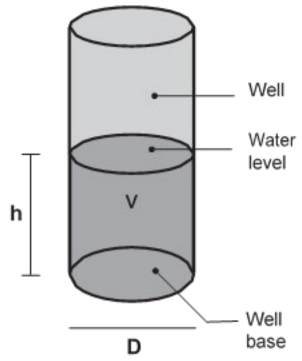
Equipment

- 20 litre bucket
- HSCH chlorine granules or powder

Method

- Calculate the volume of water in the well using the formula:

$$V = \frac{\pi D^2 h}{4}$$



Where

V = volume of water in the well (m3)
D = diameter of the well (m)
h = depth of water (m)
π = 3.142

- Fill the bucket with clear water from the well.
- Add about 300g of HSCH and stir until dissolved.
- For every cubic metre (m^3) of water in the well add 10 litres (half bucket) of the chlorine solution.
- Double the quantity of HSCH added if the solution is to be used for cleaning well linings or aprons.

Figure 5.14: Methods for calculating appropriate chlorine doses (source: Cleaning and Disinfecting Wells, Technical Notes on Drinking Water, Sanitation and Hygiene for Emergency Cases: WEDC, WHO).

5.4.4.2 Dewatering of the borehole

Following the minimum 30 minutes of contact period, remove water in the borehole using a hand pump until the bad smell in the water will be disappeared. If there is a bad smell, do not use the water for any purpose.

The following issues need extra care when dewatering boreholes:

1) The water will have a strong concentration of chlorine that will give it a bad taste and smell and could be dangerous for human beings, animals, fishes, plants and other creatures.
2) Do not allow anyone to use the water in the borehole during the disinfection and dewatering process.
3) Water with high concentration of chlorine should not flow into streams or wetlands.

4) Remaining sediments or powders of HSCH in the bucket shall be buried in the ground of secure place.

5) If the material of borehole casing is steel, chlorine causes corrosion. Contact period shall be minimized and dewatering shall be done immediately.

5.5 Turbo pump

5.5.1 Description and background information

In fact, Turbo pumps is a term used to name a grouped components made by pump and pelton turbine, the last provide required power by using falling water to make a turbine rotate to drive the pump, depending on the source of the energy used. Turbo pumps are little used because of its low yield: it only delivers about 30% of water used as energy source.

The repression height is limited by the allowable pressure of the materials of the pump and repression pipes, but turbo pumps have also advantages:

- No need of other power source because water is used as energy source;
- Mechanical simplicity;
- Less maintenance;
- Relative long life-span comparing to other pumps.

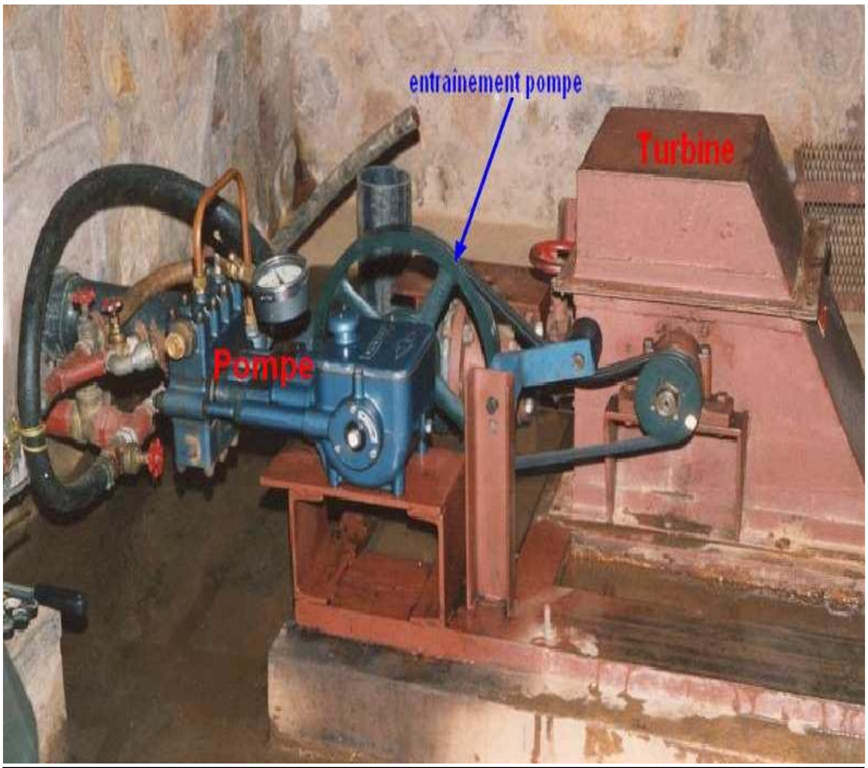


Figure 5.11: Example of a turbo pump

Figure 5.12: Nyamabuye II/ Gicumbi turbopump

5.6 Hydraulic ram

5.6.1 Description and background information

5.6.1.1 General

The hydraulic ram needs no external source of power. The ram utilizes the energy contained in a flow of water running through it, to lift a small volume of this water to a higher level. The phenomenon involved is that of a pressure surge, which develops when a moving mass of water is suddenly stopped. A steady and reliable supply of water is required with a fall sufficient to operate the hydraulic ram. Favorable conditions are mostly found in mountainous areas.

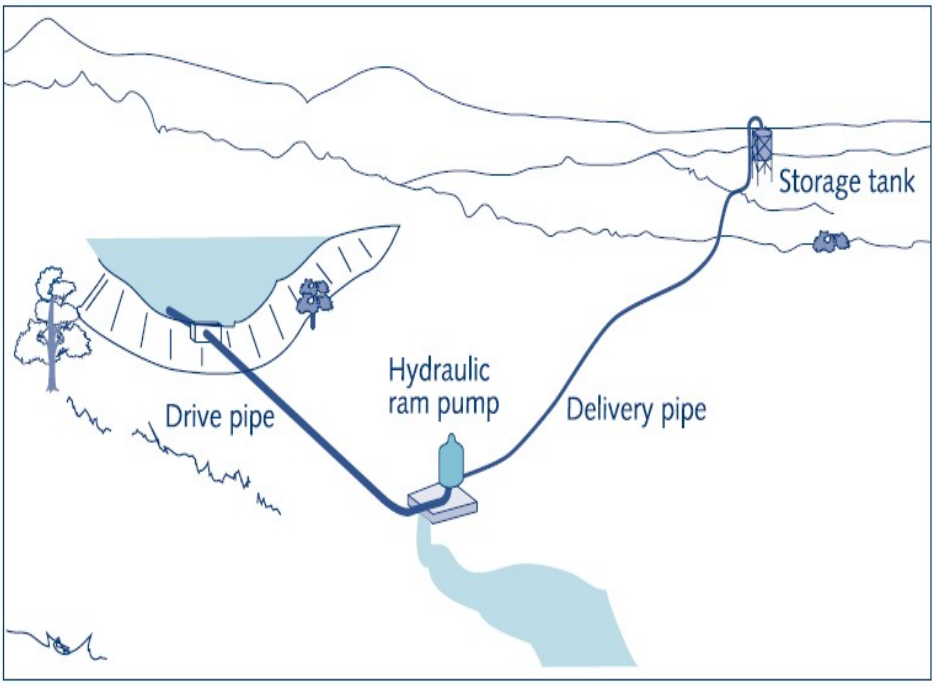


Figure 5.13: Hydraulic ram

5.6.1.2 Principle

The ram operates on a flow of water running from the source down through the drive pipe into the pump chamber. The water escapes through the opened impulse valve. When the flow of water through the impulse valve is fast enough, the upward force on the valve will exceed the spring tension of the valve adjustment and the impulse valve is suddenly shut.

The moving mass of water is stopped, with its momentum producing a pressure surge along the drive pipe. Due to the pressure surge, water is forced through the non-return (delivery) valve and into the delivery pipe.

Water continues to pass the non-return valve until the energy of the pressure surge in the drive pipe is exhausted. The air chamber serves to smooth out the delivery flow of water, as it absorbs part of the pressure surge that is released after the initial pressure wave.

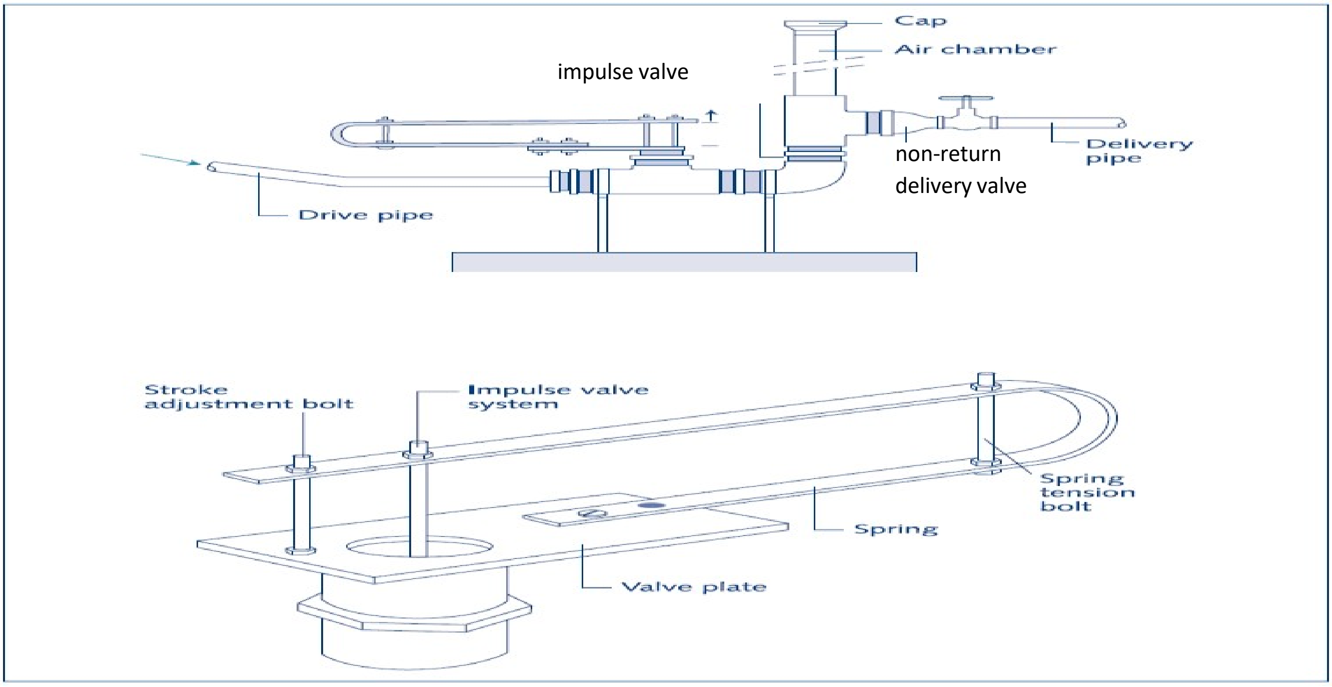


Figure 5.14: principle of a hydraulic ram

When the pressure surge is fully exhausted, a slight suction created by the momentum of the water flow, together with the weight of the water in the delivery pipe, shuts the non-return delivery valve and prevents the water from running back into the pump chamber.

The adjustment spring now opens the impulse valve, water begins to escape through it, and a new operating cycle is started.

Once the adjustment of the impulse valve has been set, the hydraulic ram needs no attention provided the water flow from the supply source is continuous at an adequate rate and no foreign matter gets into the pump, blocking the valves.

An air valve is provided to allow a certain amount of air to bleed in and keep the air chamber charged. Water under pressure will absorb air and without a suitable air valve the air chamber would soon be full of water. The hydraulic ram would cease to function.

5.6.1.3 Advantages

- No power sources are needed, and therefore no running costs.
- Suitable for local production.
- Only two moving parts.

5.6.1.4 Preconditions

Most hydraulic rams will work at their best efficiency if the supply head is about one third of the delivery head. The higher the pumping head required, the smaller the amount of water delivered. In cases where the required pumping capacity is greater than one hydraulic ram can provide, a battery of several rams may be used, provided the supply source is of sufficient capacity.

5.6.2 Operation

In fact, the water ram is self-operating and needs no human intervention.

5.6.3 Preventive maintenance

It is essential that as little debris as possible enters the drive pipe. For this reason, it is necessary to provide a grate or strainer to keep back floating leaves and debris.

5.6.4 Curative maintenance

The maintenance required for a hydraulic ram is very little and infrequent. It includes activities as replacement of the valve rubbers when they wear out, adjusting the tuning, and tightening bolts if they get loose. Occasionally the hydraulic ram may need dismantling for cleaning.

6 Lesson 6: POWER DRIVERS

6.1 Power supply

The energy needed for water conveyance is obtained from the pump operation. This energy, generated by the pump impeller, is usually expressed as a head of water column (in mwc) and is called the pumping head, hp. It represents the difference between the energy levels at the pump entrance i.e. at the suction pipe and at the pump exit.

In the case of a single pump unit, the higher the pumping head hp is, the smaller the pumped flow Q will be. For a combination of Q-hp values, the power P required to lift the water is calculated as:

$$P = \rho . g . h_p . Q$$

The power P_p (or N_p) to drive the pump will be higher, due to energy losses in the pump:

$$N_p = \frac{\rho g Q h_p}{\eta_p}$$

Where ηp is the pump efficiency dependant on the pump model and working regime. Finally, the power Pm (or Nm) required for the pump motor will be:

$$N_m = \frac{N_p}{\eta_m}$$

Where ηm indicates the motor efficiency.

The above information is very crucial in pump selection, manufacturer provide all necessary information to indicate the equipment characteristics.

6.2 Diesel Engine

6.2.1 Description and background information

Diesel engines have the important advantage that they can operate independently at remote sites. The principal requirement is a supply of fuel and lubricants and these, once obtained, can be easily transported to almost any location. Diesel engines, because of their ability to run independently of electrical power supplies, are especially suitable for driving isolated pumping units such as raw water intake pumps.

Diesel engines may be used to drive reciprocating plunger pumps as well as centrifugal pumps. Gearing or another suitable transmission connects the engine with the pump. For any diesel-driven pump installation, it is generally prudent to select an engine with 25-30 % surplus power to allow for a possible heavier duty than under normal conditions.

6.2.2 Preventive maintenance

In almost all cases, diesel engine prime movers are designed as standby units, these must be given proper care to prolong their life and for their efficient operation. In the absence of the equipment operating manual, listed below are suggested preventive maintenance practices.

◆ **Every Third Day:**

Operate the diesel engine at about 1,000 rpm for at least 5 minutes or until warm. This would allow the lubricant and coolant to circulate around the engine.

◆ **Every 8 hours Operation:**

Check coolant level, sump oil level, oil reservoirs, for oil, water or fuel leaks and clean oil bath cleaner.

◆ **Every 200 hours of Operation:**

- Drain and renew engine lubricating oil.
- Renew lubricating oil canisters.
- Check tension of drive belt.
- Clean fuel water trap.
- Lubricate dynamo rear brush.
- Clean air filter element

◆ **Every 400 hours of Operation:**

- Renew fuel and air filter elements.
- Check hoses and clips.
- Clean lift pumps sediment chamber.

◆ **Every 2,400 Hours of Operation:**

- Check and adjust valve clearances.
- Service injector units.

6.3 Electrical Engine

6.3.1 Description and background information

Electric motors generally need less maintenance and are more reliable than diesel engines. They are therefore preferable as a source of power for pumping, if a reliable supply of electric power is available. The electric motor should be capable of carrying the workload that will be imposed, taking into consideration the various adverse operating conditions under which the pump has to work. If the power requirement of a pump exceeds the safe operating load of the electric motor, the motor may be damaged or burnt out. Attention must also be paid to the characteristics of the motor and the supply voltage.

There is sometimes a tendency to use general-purpose motors offered by the manufacturers without giving due consideration to the characteristics of the particular pump used. This results in frequent failure or burning out of the motor. The squirrel-cage motor is mostly selected for driving a centrifugal pump as it is the simplest electric motor manufactured.

6.3.2 Preventive maintenance

The most important items for good maintenance of an electric motor, aside from checking for bearing wear, are regular use, and keeping it warm (from operation), clean, and dry. Moisture is an enemy of insulation along with oil and dust.

Every motor should be operated for 5-6 hours at least every week. The longest useful life of a motor is obtained from a unit which is never shut down and cooled off, especially in a humid climate. Listed below are some maintenance tips.

◆ **Every Day:**

- Check temperature of motor housing with hand.
- Check lubrication reservoir level.
- Check air vents for blockage.
- Check external wiring for frayed insulation or loose connections.
- Check voltage and current at each leg of the three phases.

◆ **Every Month:**

- Check motor housing temperature.
- Check shaft alignment.
- Check input horsepower under load.

◆ **Every Year:**

- Vacuum all dust out of windings and motor case.
- Drain lubricant, flush out oil reservoir with kerosene, and replace with factory-approved lubricant.

◆ **Every Three Years:**

- Examine winding insulation for damage.
- Clean oil connectors and contact points with fine emery cloth.
- Inspect shaft and bearings for scour, wear or damage.
- Check input horsepower under load.

7 Lesson 7: SOURCES OF ENERGY

7.1 Diesel

The fuel diesel is a source of energy for a diesel engine of for an EG.

7.2 Electrical Grid

Electrical energy can just be taken out of a 24 hours functioning electrical grid.

7.3 Electrical Generator

If the electrical grid is not available or not functioning electrical energy can be taken from an EG which uses diesel fuel.

7.4 Solar Power

Solar panels made of photovoltaic cells arranged into array convert sunlight into a direct current (DC). This current is used to drive a (submersible) pump of the DC type. Another option is that the DC is first converted to alternating current (AC) as most (submersible) pumps on the market are of the AC type. On the other hand, converting DC means a substantial loss of energy (about 25 %). In photovoltaic pumping systems, the pump works whenever there is adequate sunshine, and this is independent of the ambient temperature.

The water is pumped into a storage tank to cater for water demands during the periods that there is no sunlight and therefore no pumping. Solar powered pumps can lift water up to 100-200 m, but the system is most economical up to a pumping head of 50 m.

The solar powered pumping system is an attractive option for remote areas where power and fuel supply is difficult and expensive. The only requirement is sufficient sunlight. The investment cost is high due to the (still) high price of solar panels, but O&M costs are low. Though the solar system is vulnerable to vandalism and theft because solar panels have many applications.

7.5 Hydopower

Water which is fallen from a higher point is the energy source for a turbine pump.

7.6 Human Power

Using human power for pumping water with hand pumps has important benefits for small communities in developing countries:

- The power requirements can be met from within the users' group.
- The capital cost is generally low.
- The discharge capacity of one or more manual pumping devices is usually adequate to meet the domestic water requirements of a small community, including, if needed, for small-scale commercial use within households.

- Design developments during the last 20 years mean that pumps can be repaired and maintained by appropriately trained local caretakers.

The power available from human muscle depends on the individual, the environment and the duration of the task. For work of long duration, for example eight hours per day, a healthy man is estimated to produce 60-75 watts (0.08-0.10 horsepower). This value must be reduced for women, children and the aged. It also must be reduced for high temperature and high humidity. Where the pump user and the pump are poorly matched, much of the power input is wasted, for example, when a person operates a pump from a stooped position. Tests and user evaluations help to bring out problems, such as rejection of foot pumps because pregnant women and young children could not easily operate them or the movement was not culturally acceptable.

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ANNEXES

Annex I: water meters at a pumping station

Water meters measure the amount of water repressed. A water meter type used to measure high flow rates is the Woltman type. It can be used for flow rates higher than 15 m^3/h. They are thereby distinguished by ensuring an especially low head loss, even with high flow rates. The newly developed measuring insert with a special construction of the turbine where the water flows through, guarantees a high measuring accuracy and long-term stability of the measuring results.

Main characteristics of Woltman water meter

METROLOGICAL PERFORMANCE:

Size of meter		Acc(%)	50 mm	65 mm	80 mm	100mm	150mm	200mm	250mm	300mm	400mm	500mm
Minimum flow Q min	m^3/h	±5	0.45	0.75	1.20	1.80	4.50	7.50	12.00	18.00	30.00	45.00
Transitional flow Qt	m^3/h	±2	3	5	8	12	30	50	80	120	200	300
Nominal flow Qn	m^3/h	±2	15	25	40	60	150	250	400	600	1000	1500
Maximum flow Q max	m^3/h	±2	30	50	80	120	300	500	800	1200	2000	3000
Minimum Reading	m^3		0.0002	0.0002	0.0002	0.0002	0.002	0.002	0.002	0.002	0.1	0.1
Maximum Reading	m^3		999999	999999	999999	999999	9999999	9999999	99999999	99999999	99999999	99999999
Temperature Suitability	°C		50°C									
Working Pressure	Mpa		≤1.6 MPa									

DIMENSIONS

Size of meter	50 mm	65 mm	80 mm	100 mm	150 mm	200 mm	250 mm	300 mm	400 mm	500 mm
Length (L) mm	200	200	225	250	300	350	450	500	600	800
Height (H) mm	232	242	252	262	325	352	470	492	631	740
Weight kg	10.6	12.6	15.4	18.6	31.6	46	94	114	199	340

Installation of Woltman meters

The best measuring results can be achieved if some simple but important installation rules are followed.

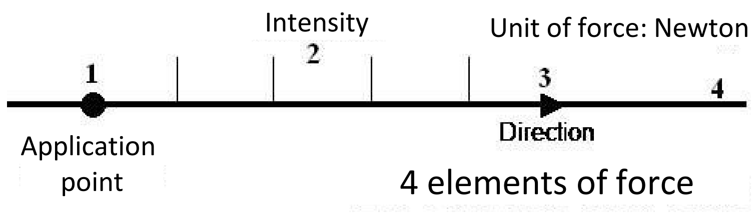
- Woltman meters must be operated in the correct flow direction.
- There must be a minimum of 3 x DN of straight pipe section for WPH type upstream of the meter (from Tee to water meter).
- There must be a minimum of 5 x DN of straight pipe section for WS type upstream of the meter (from elbow to).
- If a sufficient straight pipe section is not possible, then a honeycomb flow straightener should be installed.
- Ideally a straight pipe section of at least 2 x DN is present downstream of the meter.
- To avoid air pockets in the meter, it should not be installed on the highest point of the piping.
- Gate valves or other shut-off valves in front of the meter should be completely opened during operation.

Annex II: Hydraulical background information

(1) Some fundamental laws

Force

Force = any action tending to change the status of a body



Pressure

- Pressure = Force / surface.
- The pressure is measured with a manometer.
- The unit of pressure is the [mwc]
- Scientists use the Pascal Pa = N/m^2
- Correspondence of units: 1 bar = $1kg/cm^2$ = 10^5 Pa = 1MPa = 100 kPa = 10 mwc.

Force and Pressure

Assuming constant equal pressure, the degree of force is proportionally related to the pipe section.

- F(N) = p [Pa] x A [m^2]

Flow

The flow rate is the volume of water in m^3 that passes per second

- Q = A x v
- v = velocity [m/s].

Power

- Power = work done by a force in a unit of time.
- 1 kW = 1,36 Horse Power

Head pressure

The pressure required to enable a column of water to reach a reservoir through pumping is:

- Manometric Height = $\Delta z + (I \times \ell)$ [mwc]
- Δz = The topographic level, difference between the starting level of the water body and the level of the reservoir.
- I = loss of pressure per meter of repression [mwc/m]; Complex calculation by using specialized software or graphical charts.
- ℓ = length of the discharge pipe [m]

(2) Hydraulic Definitions

Discharge (Q): Also termed capacity or flow rate, is the volume of liquid pumped per unit of time. Usually measured in SI units of m^3/s, though for small pumps either l/s or m^3/hr often used.

Reference level: The reference level is defined as the elevation from the horizontal plane that passes through the pump 'eye'.

Operating Point of a pump Intersection flow and discharge head point in a system flow-height curve.

Allowable Operating Range: A manufacturer's recommended flow range for a pump of specified speed and impeller diameter. The range is limited by cavitation (heating, vibration, noise, shaft deflection, tiredness and other related criteria)

Total Static Head (H_{st}): The difference in elevation between the water level in the suction well and the water level at the discharge reservoir**.**

Static Suction Head (h_s). The difference in elevation between suction well water level and the reference level**.**

Static Discharge Head (h_d). The difference in elevation between discharge water level and the reference level.

Manometric Suction Head (h_{gs}). The suction gauge reading as measured at the suction nozzle of a pump and is referenced to the reference level

Manometric Discharge Head (h_{gd}). The discharge gauge reading as measured at the discharge nozzle of a pump and is referenced to the reference level

Manometric head (H_g). The increase in pressure head generated by the pump ($h_{gd} - h_{gs}$).

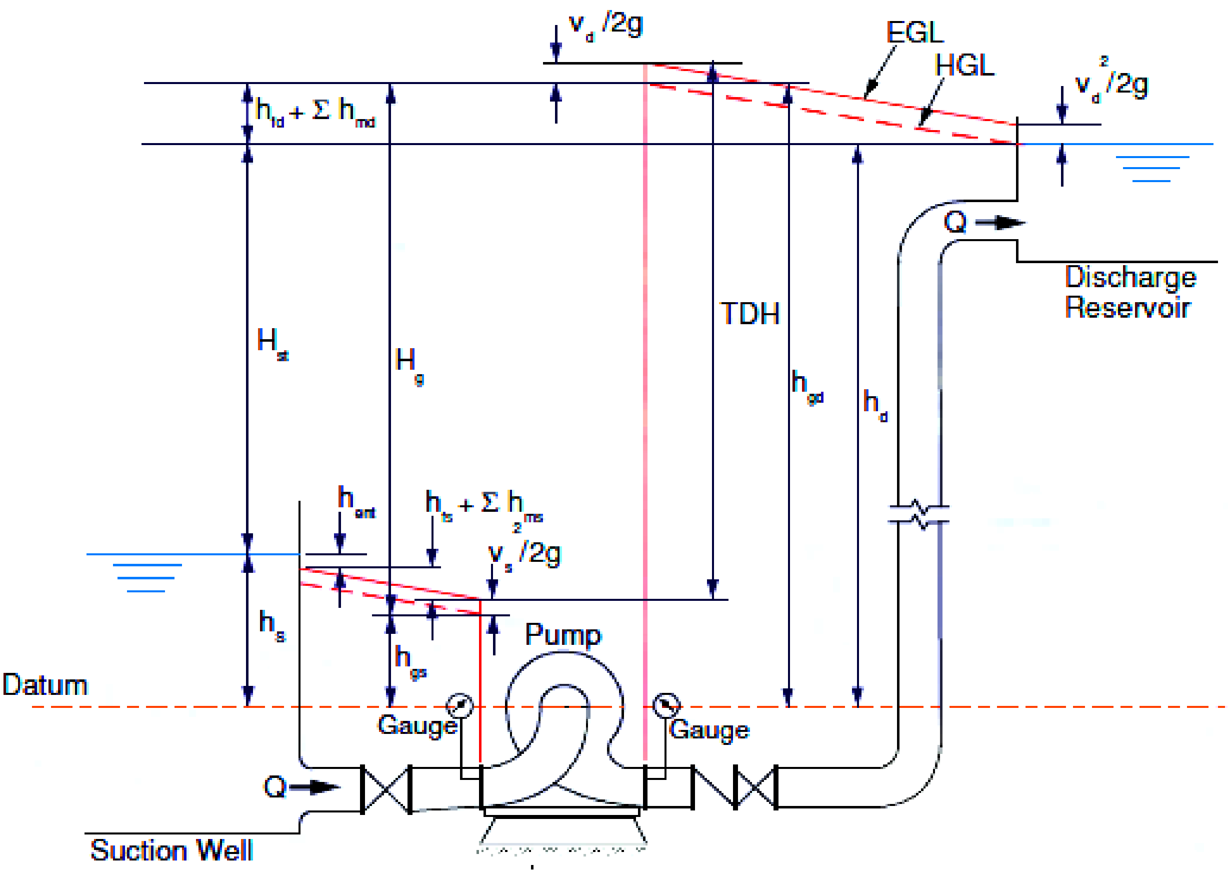
Friction Headloss (h_{fs}, h_{fd}). The head of water that must be supplied to overcome frictional resistance on the pipe wall.

Velocity Head ($v^2/2g$). The kinetic energy of the pumped liquid at any point in system. The Energy Gradeline (EGL) is always above the Hydraulic Gradeline (HGL) by $v^2/2g$. HGL is termed piezometric or manometric gradeline.

Minor Headlosses (h_{ms}, h_{md}): Each fitting type will result in a different minor head loss on suction and discharge sides of pumps.

Total Dynamic Head (TDH): The total head at which a pump operates at any given discharge rate. It is calculated by adding the total static head, the frictional headlosses, the velocity heads, and the minor headlosses.

$$TDH = h_{gd} - h_{gs} + \frac{v_d^2}{2g} - \frac{v_s^2}{2g}$$



(3) **Required pressure at the discharge side of the pump**

The pressure at the discharge side of the pump is composed of two components:

- Dynamic head
- Static head

Dynamic head covers the head-losses i.e. loss due to pipe resistance (h_f) and loss due to fitting resistance (h_m). This component depends on the flow. The more flow, the more dynamic head.

$$H_{dyn} = \Delta E = \Delta H = h_f + h_m$$

The h_f for one pipe can be calculated by the formula of Darcy-Weisbach.

$h_f = \lambda \times \ell / D \times v^2/2g$

The hf is to the fifth power dependant from the D because the velocity v does also contain D.

The h_f is quadractic related to the velocity (and indirectly to the flow Q).

To calculate the h_f from a full distribution system you need the help of a computer.

The h_m can be calculated with the help of tables.

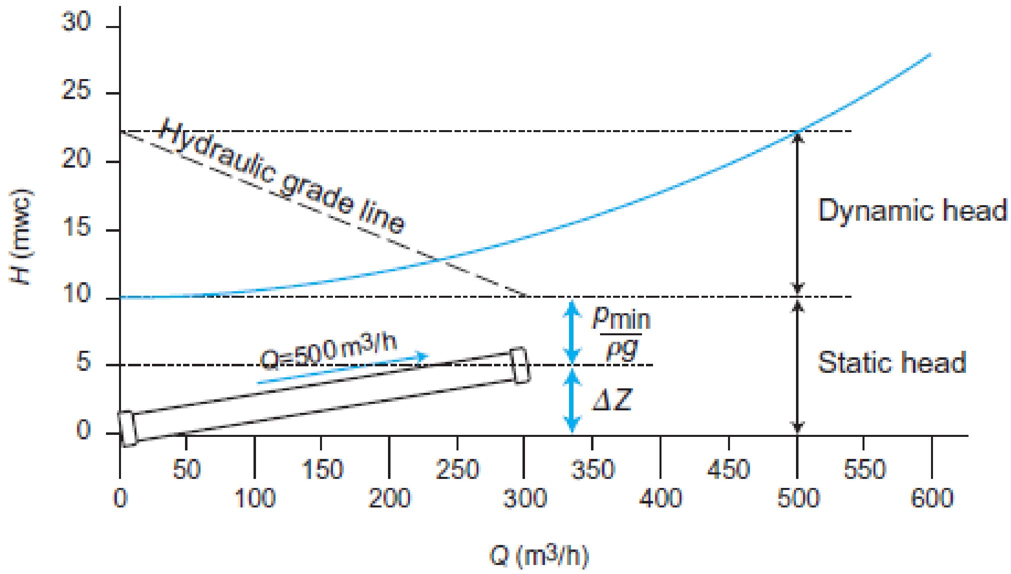
In a distribution system the h_f is far bigger comparing to the h_m

The *static head* is independent of the flow:

$$H_{st} = \frac{p_{end}}{\rho g} \pm \Delta Z$$

The static head includes:

- The required pressure at the end of the distribution system: p_{end}
- Elevation difference Δz between the end of the distribution system and the location of the pump



The pumping head required (hp) at the supply side of the system to maintain given pressure (pend) at its end will be:

$$h_p = \Delta H + \frac{p}{\rho g} + \Delta z$$

(4) Cavitation, vapor pressure and NPSH

The Net Positive Suction Head (NPSH) is the parameter used for risk analysis of cavitation. This phenomenon occurs in situations when the pressure at the suction side of the pump drops below the vapour pressure. As a result, fine air bubbles are formed indicating the water is boiling at room temperature. When the water moves towards the area of high pressure, i.e. to the area around the impeller, the bubbles suddenly collapse causing dynamic forces, ultimately resulting in pump erosion.

The damage becomes visible after the pump has been in operation for some time, and causes a reduction of the pump capacity: the actual pumping curve shifts lower than the original one.

To understand Cavitation, you must first understand vapor pressure. Vapor pressure is the pressure required to boil a liquid at a given temperature. Soda water is a good example of a high vapor pressure liquid. Even at room temperature the carbon dioxide entrained in the soda is released. In a closed container, the soda is pressurized, keeping the vapor entrained.

Temperature affects vapor pressure. A chilled bottle of soda has a lower vapor pressure than a warm bottle. Water, as another example, will not boil at room temperature since its vapor pressure is lower than the surrounding atmospheric pressure. But, raise the water's temperature 100°C and the vapors are released because at that increased temperature the vapor pressure is greater than the atmospheric pressure.

Pump cavitation occurs when the pressure in the pump inlet drops below the vapor pressure of the liquid. Vapor bubbles form at the inlet of the pump and are moved to the discharge of the pump where they collapse, often taking small pieces of the pump with them. Cavitation is often characterized by:

- Loud noise often described as a grinding or "marbles" in the pump;
- Loss of capacity (bubbles are now taking up space where liquid should be);
- Pitting damage to parts as material is removed by the collapsing bubbles.

Noise is a nuisance and lower flows will slow your process, but pitting damage will ultimately decrease the life of the pump. Often this is mistaken for corrosion, but unlike corrosion, the pitting is isolated within the pump (corrosion attacks the pump material throughout).

No engineer wants to be responsible for installing a noisy, slow, damaged pump. It's critical to get the NPSH value from the pump manufacturer and to insure that your NPSH pressure will be adequate to cover that requirement.

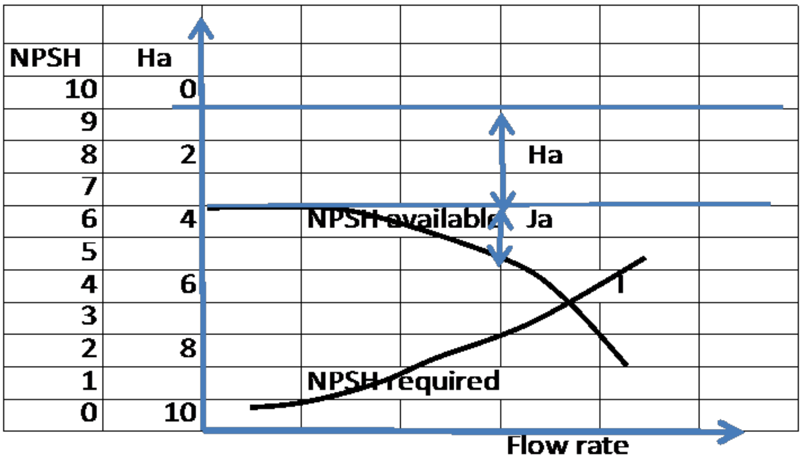
The NSPH Available (NPSHA) indicates how much the pump suction exceeds the liquid vapor pressure, and is a characteristic of the system design. The NPSH Required (NPSHR) is the pump suction needed to avoid cavitation, and is a characteristic of the pump design, to prevent cavitation. The NPSHA has to be greater than the NPSHR.

The formula for calculating NPSHA:

$$NPSHA = H_A \pm H_Z - H_F + H_V - H_{VP}$$

Term	Definition	Notes
H_A	The absolute pressure on the surface of the liquid in the supply tank	Typically, atmospheric pressure (vented supply tank), but can be different for closed tanks. • Don't forget that altitude affects atmospheric pressure (H_A in Denver, CO will be lower than in Miami, FL). • Always positive (may be low, but even vacuum vessels are at a positive absolute pressure)
H_Z	The vertical distance between the surface of the liquid in the supply tank and the centerline of the pump	Can be positive when liquid level is above the centerline of the pump (called static head) • Can be negative when liquid level is below the centerline of the pump (called suction lift) • Always be sure to use the lowest liquid level

Term	Definition	Notes
H_F	Friction losses in the suction piping	Piping and fittings act as a restriction, working against liquid as it flows towards the pump inlet. H_F come from the calculation of the hydraulic head losses according to the Darcy–Weisbach,
H_V	Velocity head at the pump suction port	Often not included as it's normally quite small
H_{VP}	Absolute vapor pressure of the liquid at the pumping temperature	Must be subtracted in the end to make sure that the inlet pressure stays above the vapor pressure. • Remember, as temperature goes up, so does the vapor pressure



NPSH available = 10-(Ha + Ja)
Ha = geometric suction height
Ja =head losess in the suction
I = operating point

Annex III: Tools

Maintenance tools

a) Flat key set from 6 to 32 mm
b) Set of key rings from 6 to 32 mm
c) Mixed key set from 6 to 32 mm
d) Socket wrench set from 6 to 32 + Accessories
e) 3 kg hammer with handle
f) Shears 24 "
g) Side cutting nippers
h) Adjustable self-locking plier
i) Screwdriver set flat and Phillips
j) Clipper
k) Set of adjustable wrenches
l) Complete set of chisels
m) Set of flat files
n) Set of round files

Mechanic tools

a) Set of needles
b) Pliers cutter
c) Hacksaw frame
d) Grease gun
e) Mallet
f) Key chain
g) Assortment of chromes-steel taps and dies
h) Hard pulley
i) Drill machine 720W-220V
j) Grinding machine 2200w – 220V
k) Engineering vice
l) Water pump (5m3 /hour to 15m H)
m) Riveting machine
n) Hand drill

Electrician tools

a) 2 kg hammer
b) Cutting nippers
c) Electrician + spare blade knife
d) Pliers cutter
e) Strippers pliers
f) Socket wrench set for electrician + Accessories
g) Complete set of pliers
h) Detector current
i) Hacksaw frame
j) Hexagon key wrenches set
k) Multi meter to DC and AC digital
l) Soldering iron
m) Clip ampere meter
n) Glasses for welding
o) Solder mask

Plumbing tools

a) Hammer 2 kg
b) Adjustable self-locking plier
c) Set of adjustable wrenches
d) Side cutter plier
e) Pipe cutter
f) Pipe threading machine
g) Pipe wrenches
h) End cutting nippers
i) Hacksaw frame
j) Spirit levels
k) Square
l) Chain pipe wrenches
m) Pipe wrenches
n) Pipe fixing device

Annex IV: Site exercise

Practical details depend on the configuration of the selected stations. It is up to the trainer to adapt to circumstances.

The following activities will be conducted on site:

- Identify the elements.
- Read the plates and instructions.
- Draw a diagram of the station.
- Perform routine operations.
- Perform emergency operations.

All these activities will be conducted on site at a pumping station.

This sequence is scheduled in 3 hours by which one hour is to draw and finalize a station diagram, another hour for an exercise to establish O&M plan adapted to existing equipment.

The practice of routine operations requires the presence of an electromechanical engineer accepted by the operator and the owner in any case the trainer and the participants cannot handle the practice themselves.