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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA
MINISTRY OF WATER RESOURCES

THE STUDY
ON
ELEVEN CENTERS WATER SUPPLY AND SANITATION
IN
FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

OPERATION & MAINTENANCE MANUAL

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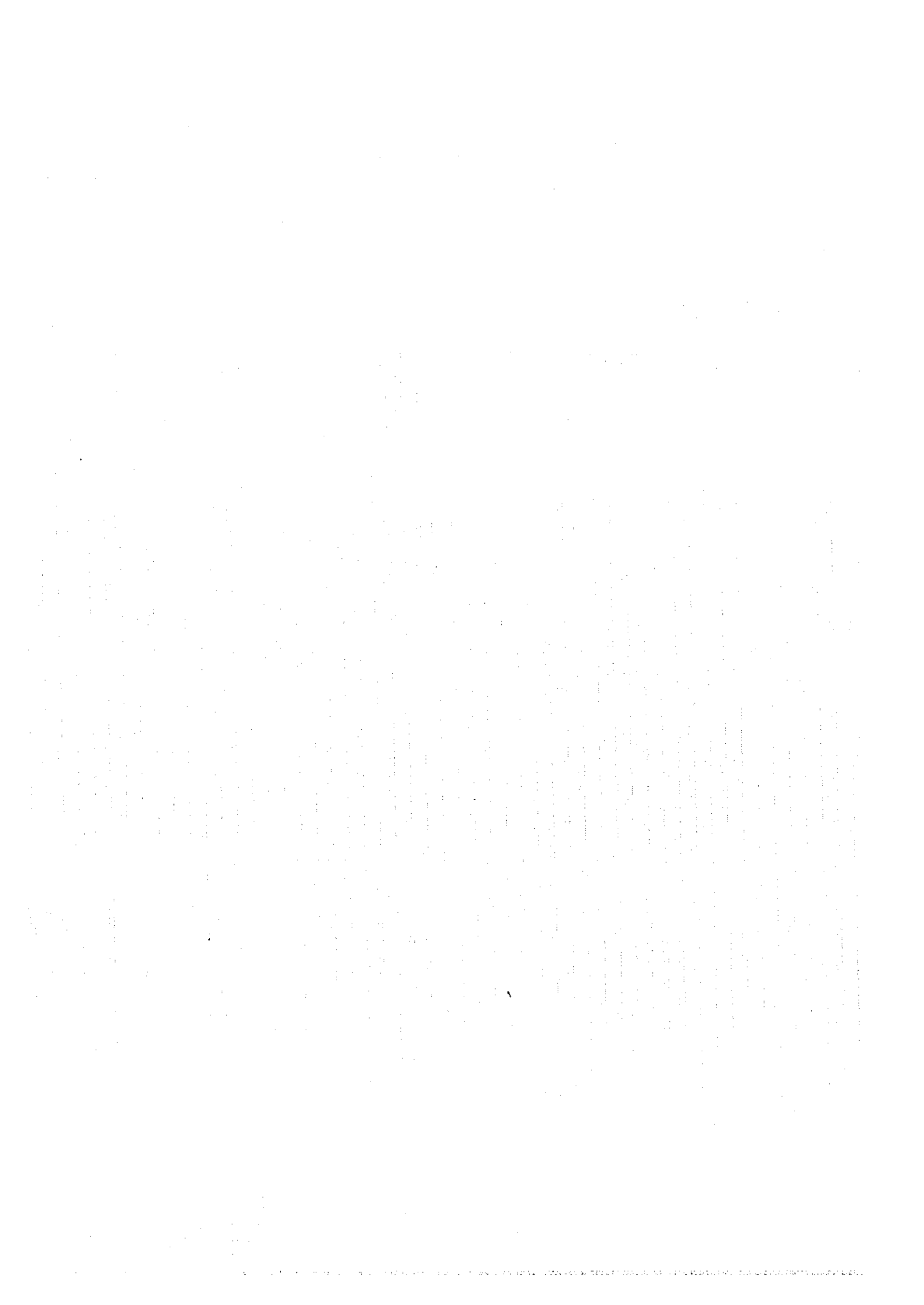
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FEBRUARY, 1996

SANYU CONSULTANTS INC.
KYOWA ENGINEERING CONSULTANTS CO., LTD.

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**GOVERNMENT OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)
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MINISTRY OF WATER RESOURCES**

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Abbreviations & Glossary

WSS :Water Supply Service
WSSA :Water Supply and Sewerage Agency
pH :Potential hydrogen
NH₄ :Ammonium Salt
Cl :Chloride
Fe :Iron
Mn :Manganese
F :Flouride
NO₃ :Nitrate Nitrogen

1. INTRODUCTION

The objective of water supply is to provide the public with a stable supply of safe water which meets the water demand. Operation and Maintenance (hereinafter referred to as O&M) of waterworks play an important role in realizing this objective. O&M works are divided into the following;

- inspection, maintenance and repair,
- water volume control,
- water quality control and
- measures for accidents.

This O&M Manual aims at preventing the facilities from damage and accidents, so as to enable uninterrupted water supply service. It is prepared exclusively for the staff in charge of O&M stationed at the Water Supply Service (WSS) Office and its regional offices. The present status of O&M in the Eleven Centers is taken into consideration in this manual. However, it is considered difficult to implement some parts of this manual at present and therefore it is recommended that O&M be implemented, stage by stage, based on this manual.

With regard to the intake facilities, groundwater is utilized as the water source in the Eleven Centers. This manual therefore covers the superintendence of groundwater pumping facilities.

2. WATER QUALITY CONTROL

2.1 General

In order to supply safe water stably to the water users who are served with piped water, the water shall be disinfected or its quality shall be well controlled by the responsible agency in the region. The quality of the water to be supplied shall be within the limits specified in the WHO Guidelines or the water quality standards formulated by the responsible agency.

2.2 Water Quality Analysis

Water quality analysis is divided into three types according to frequency they are carried out; namely, those to be conducted daily, monthly or yearly. Water quality analysis shall be carried out for the following by responsible staff in the WSS Office, Regional Offices or other relevant organizations such as health centers, hospital.

- water quality analysis of the raw water,
- water quality analysis of the tap water at the end user to check the residual chlorine.

2.2.1 Analysis to be Carried Out Daily

The following items shall be analyzed daily, and the water for analysis shall be sampled at the end of the distribution network.

- Odor
- Color
- Taste
- pH
- Residual Chlorine.

2.2.2 Analysis to be Carried Out Monthly

The following items shall be analyzed monthly, and the water for analysis shall be sampled at the end of the distribution network.

- Odor
- Color
- Taste
- pH
- Residual Chlorine
- Temperature
- Conductivity
- Total Dissolved Solids
- Total Hardness
- Organic Substance

- Total Alkalinity
- NH₄
- P
- Cl
- Fe
- Mn
- F
- NO₃
- Coliforms
- Total Colonies.

2.2.3 Analysis to be Carried Out Yearly

The tap water which is to be sampled at the end of the distribution network and the raw water shall be analyzed yearly. The analysis items shall be as same as the monthly analysis items.

- Odor,
- Color,
- Taste
- pH
- Residual chlorine.

2.2.4 Measures to be Taken Based on the Results

In the event the water quality analysis shows unsatisfactory results, appropriate measures shall be taken immediately. Simultaneously, it is desirable to identify the cause/s in association with the health center, clinic or hospital.

2.3 Water Quality Control on Raw Water

2.3.1 Inspection of Water Source

The water source shall be properly guarded with a fence to prevent entry of animals, and there shall be no space for dumping or disposal of garbage and waste around the water

source. If a mechanical operator is stationed at the water source, the operator shall pay attention to such matters and inform the WSS Office when he has any doubts about the quality or environmental conditions of the water source.

2.3.2 Measures on Abnormal Water Quality

In order to take immediate action in the event if an abnormal condition is identified in the quality of raw water, the superintendent shall, in advance, grasp the necessary measures that should be taken and prepare a schematic flow chart of actions for the emergency case. The schematic flow chart shall be prepared taking into account of the status of the WSS.

The superintendent in the WSS shall identify whether the abnormal condition of the raw water quality would affect the public health or not, by checking the following;

- whether the remarkable difference in color and turbidity identified is due to an unknown reason,
- whether any remarkable difference is identified in odor and taste.

If there is an obvious danger to public health, the following measures shall be taken first of all.

- The pumping up of groundwater and the water supply shall be suspended immediately.
- The WSS or the Regional Office shall inform the necessary matters to the water users and the relevant personnel of the health center, clinic or hospital. It is preferable to have the water quality analysis conducted by the health center, clinic or hospital. The necessary actions shall then be taken based on the results of the analysis.
- The WSS or the Regional Office, through public relations,

shall inform the water users about the suspension of water supply and the tentative measures taken to supply the water, for example, using water bowsers.

3. SANITARY CONTROL OF THE FACILITIES

3.1 General

In order to supply safe water constantly to the people according to the water demand, the water supply facilities shall be free from any contamination. Sanitary control of the water supply facilities is therefore extremely important. The personnel who are engaged with water supply shall pay utmost attention to the sanitary condition of the facilities.

3.2 Prevention of Contamination

The water supply facilities such as intake facilities, pumping facilities, rising mains, reservoirs shall be kept clean at all times, because there is the possibility of contamination from outside. It is preferable to take following measures to prevent contamination.

- Water supply facilities shall be fenced to prevent access of outsiders.
- Signboards or notices shall be displayed for the attention of the people.
- Drainage facilities in the water supply facilities shall be kept in good condition.
- In the event of suspension of water supply for maintenance works or rehabilitation, the pressure within distribution and service pipes will be decreased, and there is the possibility of drain water/ contaminated groundwater

entering into the pipes under suction. Therefore, after such works, attention must be paid not only to suck this water out, but also to disinfect the water that is to be supplied.

3.3 Suspension of Water Supply During Emergencies

In order to maintain the water supplied being safe, the superintendent in the WSS shall suspend the water supply when abnormal condition in water quality is identified. The water supply shall be suspended in the case of following;

- When the water that is being pumped up or being transmitted is contaminated with a harmful substance or pathogens.
- When a remarkable difference is identified in color and turbidity due to unknown reasons.
- When a remarkable difference is identified in odor and taste.

In addition, the water supply should be suspended, if necessary, when it is difficult to implement disinfection due to facilities being out of order or due to shortage of chemicals.

3.4 Disinfection

3.4.1 Disinfection of the Water

The water shall be disinfected in order to keep the supplied water being safe and to prevent accidents due to contaminated pipeline. Therefore, the disinfection system shall be well maintained at all times and preferably a standby system must be installed. The dosing ratio shall be decided so as to keep the residual chlorine within 1 ppm.

3.4.2 Disinfection of the Facilities

When the water supply facilities are constructed newly or rehabilitated drastically, water supply shall be commenced only after the facilities are disinfected with water which contains ample chlorine.

Reservoirs and collecting chambers shall be filled with disinfected water which has a residual chlorine content of about 10 ppm and allowed for five to six days before commencement of operation. In the case cleaning, disinfection shall be done with water which has a residual chlorine content of about 2 ppm.

Rising mains and distribution pipelines shall be disinfected by the following procedure:

- wash inside of the newly installed pipes with water,
- inject water which has a residual chlorine content of about 10 ppm into the pipe letting the water inside to drain off,
- ensure that drained water changes to clean water and that residual chlorine content does not decrease drastically,
- inject the piped water and commence operation when drained water completely turns to piped water.

4. SUPERINTENDENCE OF THE FACILITIES

4.1 Intake Facilities

Maintenance of the deep well is aimed at prevention of over-pumping and ensuring that groundwater is pumped up stably within the safe pumping rate specified based on the pumping analysis. The draw down will increase due to over-pumping and besides, the following are mainly caused by over-pumping.

- speeding up of velocity at the screen
- appearance of a spiral stream at the screen
- clogging of the screen by sand
- adherence of scale and slime on the screen
- compression of aquifer.

4.1.1 Inspection and Observation Works for Deep well

(1) Intake facilities

In order to keep the intake facilities in good condition, the staff stationed at the WSS Office shall inspect the status of the facilities of the water source and the collecting chamber once a day. The WSS Office shall take suitable action, if necessary.

In case the collecting chamber is installed beside the borehole, the staff shall observe the turbidity and color, any inflow of sand and the water level.

(2) Observation of Groundwater

1) Static Water Level

In order to grasp the change of groundwater table, observation of the static water level shall be made by the staff of the technical section in the Regional Office at least twice a year.

The observation of the static water level shall be carried out during a period of time when the hourly water consumption is the lowest. The period of time for the observation shall be decided according to the water consumption pattern of the town.

Based on the results of the observations, the groundwater balance and the borehole characteristics shall be analyzed. The decline of water table within the borehole is usually caused by over-pumping and clogged filter. In case of over-pumping, the optimum pumping rate shall be checked or the pumping rate shall be modified. In case of

a clogged screen, well development with measures such as swabbing and over-pumping shall be carried out.

2) Dynamic Water Level

In order to ensure proper operation of submersible pumps and the control of pumping rate, regular observations of the dynamic water level shall be carried monthly by the staff stationed at the WSS. However, such observations shall be carried out, as much as possible, by the staff of the technical section in the Regional Office.

Necessary action shall be taken when a remarkable change is noticed from the observation of the dynamic water level. The change of the dynamic water level is usually attributed to the borehole and/or the pumping facilities. In case the problem is with the borehole itself, the measures to be taken are as same as those stated in 1) Static Water Level. In case the problem is with the pumping facilities, their rehabilitation or replacement is necessary.

The groundwater shall be pumped within the pumping rate decided based on pumping tests conducted at the construction stage. Therefore, it is necessary to grasp the relationship of pumping rate and dynamic water level from the past records. The optimum pumping rate shall be modified when there is a large difference.

3) Water Quality

Water quality analysis shall be carried out for the raw water as stated in section 2.2 above. Concerning the items of water quality identified by visual observation, the effect, and the measures to be taken are mentioned below.

- Turbidity

The change in turbidity is usually caused by the inflow of sand. In case inflow of sand is observed temporarily at the commencement of operation, the submersible motor

pump shall be operated at a lower rate, the position of the pump shall be changed or the water pumped up shall be drained off until the water becomes clean.

- Color

The groundwater usually changes in color due to presence of Mn and Fe. When Mn or Fe is identified from water quality analysis, purification facilities will be needed for their removal.

4) Measurement Instruments

In order to ensure proper maintenance of the borehole, pumping facilities shall be equipped with measurement instruments such as pressure gauges and flow meters. These instruments shall be inspected daily by the operator stationed at the water source, by visual observation, to confirm whether these are operational or not.

In addition to the above, when the submersible motor pump is newly installed or replaced, it is recommended to install a guide pipe, along with the riser pipe, for measuring the groundwater level.

4.1.2 Inspection of Pumping Facilities

In order to prevent breakdowns and accidents, the staff in charge of mechanical facilities shall grasp the mechanical structure, capability and maintenance method, operation status of the submersible motor pump. The facilities to be inspected are the submersible motor pump and the electrical system. The following items shall be inspected by visual observation.

(1) Inspection and Observation of the Submersible Motor Pump

Inspection procedure by visual observation is as follows;

- During commencement, the gate valve shall be fully closed in order to prevent suction of sand. The gate valve shall be opened gradually while confirming the pressure

indicated on the pressure gauge.

- Check whether suction of sand occurs or not.
- Check whether abnormal vibrations and noise are identified. This inspection shall be conducted once a week and the results shall be recorded.
- Check whether leakage occurs at the pressure gauge.
- Check whether big water hammer occurs or not when switching off the pump.
- Occasionally, the total head shall be checked with the gate valve kept in fully closed condition. The total head shall be obtained by adding the pressure ratio and the head difference between pressure gauge and static water level.
- Check whether the electric current ratio is below the ratio specified. This inspection shall be conducted once a week and the results shall be recorded.
- Check whether the pumping rate is almost the same as the optimum pumping rate specified by the staff of the technical section in the Regional Office. This inspection shall be conducted once a week and the results shall be recorded.
- In case there is a standby borehole, it shall be operated once a month.

(2) Inspection of Electrical Systems

The following items shall be inspected by visual observation.

- The insulation resistance shall be measured once every six months.

- The protection instruments shall be inspected and adjusted.

4.1.3 Maintenance of the Facilities

(1) Submersible Motor Pump

The submersible motor pump can be operated at least for 5 years. However, life span of the pump depends on the conditions of operation and maintenance. Therefore it is necessary to survey and grasp the status of operation. The consumable items such as mechanical seal, oil seal, o-ring, cable packing shall be replaced periodically. In addition, the enduring parts such as impeller, cable shall be inspected and replaced if and when necessary.

(2) Control Panel

The various kinds of switches and measurement instruments shall be gathered in the control panel. It is preferable to replace the spare parts at intervals of about ten years.

4.2 Transmission and Distribution Facilities

4.2.1 Objectives of the Facilities and Fundamentals of Superintendence

Transmission facilities will convey the water from the borehole to the reservoir and are composed of boosting pump facilities and rising mains. The distribution facilities will store the transmitted water and distribute it to the service area. The distribution facilities are composed of reservoir, elevation tank, distribution pump and distribution network.

These transmission and distribution facilities account for a large percentage of the construction cost. These facilities require meticulous superintendence for controlling of water pressure, water quality and consumption rate.

In addition, as the pipelines are usually laid underground along the roads, it is required to maintain close contact with the officials of the Public Works & Urban Development Bureau which is in charge of the roads.

The fundamentals of superintendence of the transmission and distribution facilities are as follows:

- to prevent the piped water from contamination and to keep the piped water being safe,
- to supply the necessary volume of water under proper pressure by adjusting the pumps and gate valves,
- to prevent leakage,
- to take measures for replacements and against corrosion,
- to exchange views with the officials of the Public Works & Urban Development Bureau regarding laying of pipelines,
- to sort out and keep the as-built drawings of pipeline routes, structural drawings and plans,
- to measure and record the distribution rate, pressure rate, water quality data and valve operation, and
- to reinforce the organization of WSS to meet emergency situations.

4.2.2 Reservoir

(1) General

The reservoir will not only cope with the peak demand, but also store the water required for emergencies such as fire, electric suspension and contamination of the raw water. Therefore, in case the available storage capacity is inadequate, it is required to construct extra reservoir.

(2) Measurement and Adjustment of Water Volume

Generally, the consumption rate is low soon after the completion of expansion and the water storage will hold for a longer period than before. Therefore, it is necessary to keep the water level low so that the residual chlorine content will not fall below the specified ratio.

The distribution rate shall be adjusted taking into consideration of the residual chlorine at the end of the distribution network. In adjusting the distribution rate, attention shall be paid on the following:

- not to allow the water level to be lower than the design low water level,
- not to allow the water level rise above the design high water level as a result of water storage from midnight to early morning,
- to record daily distribution rate and hourly peak demand for distribution adjustments and future expansion plans.

(3) Inspection and cleaning

In the case of reservoirs made of reinforced concrete, the concrete will be corroded by the chlorine. Therefore, the reservoir shall be emptied once a year and the leakages shall be inspected. Inlet pipe, drain pipe etc., shall be inspected as well. The sediments and fur shall be taken out, and the inside of the reservoir shall be disinfected.

In the case of reservoirs made of metal, inside of the reservoir shall be repainted at the intervals of five years. The paint shall be harmless and safe from the point of water quality.

The water level indicator shall be maintained once a month and repaired, if necessary.

In order to avoid contamination from external elements and animals, the reservoir shall be fenced and kept locked. The overflow pipe and vent shall be inspected to ensure that they do not give access to small animals. The valve boxes shall be kept covered and locked.

4.2.3 Pumping Station

(1) Objective and Fundamentals

The pumping station is generally composed of pumps, generator, control panel, measurement instruments and collection chamber. Inspection of the pumping facilities shall be carried out regularly as a measure of preventive maintenance.

(2) Operation and Inspection

The pump will be operated according to the water level of the basin. Therefore a method to confirm the water level shall be formulated.

In case of distribution and boosting pumps, it is necessary to pay attention to inlet water level, inlet pressure and outlet pressure. Flow control shall be carried out for the pumps. Moreover, the standby pump shall be operated by turns.

(3) Inspection and Maintenance

The collection chamber shall be emptied once a year. The inside of the chamber, water level indicator and inlet pipe shall be inspected and cleaned up.

Ventilation and rainwater drainage shall be given due consideration in the design of pumping room.

(4) Prevention of Contamination

The pumping room shall be fenced to prevent entry of animals, and the drainage facilities shall be constructed in such a way to avoid contamination.

(5) On-site Power generators

In towns where the water supply facilities are operated with hydroelectricity, it is recommended to install on-site generators to meet emergencies caused by power interruption. In this case, the on-site generator shall be inspected and maintained regularly.

4.2.4 Rising Mains and Distribution Networks

Rising mains are usually laid underground over long distances. Because the distribution pipelines are laid over a large area, their inspection by visual observation and maintenance are difficult.

In order to check leakage from pipelines, it is recommended to confirm, using an electric conductivity meter, whether the water in puddles is rain water or piped water. The conductivity of rain water is lower than that of piped water.

For proper maintenance of the pipelines, the date of laying, replacement and removal of pipes shall be recorded along with the diameter and length of the pipe.

4.2.5 Valves

(1) Gate Valve

Gate valve changes the distribution zone and controls the pressure and volume. In order to maintain its proper operation, the gate valve including the blow-off shall be inspected.

In order to avoid contamination, the valve box shall be kept covered.

(2) Air Pressure Valve

Air pressure valves are installed to release the air from the pipe or to prevent damage by earth pressure. The float valve shall be inspected occasionally.

(3) Pressure Reducing Valve

When the distribution network is expanded, it is necessary to install pressure reducing valves where large head difference occurs. Secondary pressure shall be observed, inspected and maintained.

4.2.6 Distribution Control

The aim of distribution control is to supply the water to the whole service area by pressure. The pressure shall be adjusted according to the rate specified in the criteria formulated by the WSSA.

The control shall be done by adjusting the valve operation. The opening ratio of the valve shall be decided based on the measurement of the pressure at important points.

4.2.7 Measures Against Accidents

In case the distribution rate is lower than the water demand due to deficiency of water source, for example due to drying up of wells, measures shall be taken tentatively to restrict the water supply and to control the water stored in the reservoir. Appropriate measures such as construction of new boreholes shall be taken based on the results of the survey.

4.2.8 Replacement of the Pipes

Replacement of the pipes shall be carried out according to the future plans. The drawings related to the pipeline shall be revised and sorted out based on the replacement works.

4.2.9 Restoration works

(1) Water Suspension Works

Valve operation shall be done carefully and the water shall be drained off after completion of the valve operation works.

(2) Filling of Water

When filling the pipeline with water, high pressure will sometimes develop due to the residual air thereby damaging the pipes or disconnecting the joints. Therefore, it is preferable to fill the pipes with water from the lower side of the pipe. If filling is done from the higher side of the pipe, it shall be done gradually with small amounts of water.

(3) Cleaning and Disinfection

The cleaning of the pipes shall be done by draining the entrapped water through drain pipe or fire hydrant. It is preferable to maintain the velocity of flow within 1.0 m/sec.

4.2.10 Prevention of Water Leakage

(1) Water Leakage

Water leakages from the pipeline will cause low pressure at the taps, caving of roads and contamination of the water due to suction of polluted water during suspension of water or at times of low pressure.

Unaccounted losses range from about 20% to 40%. In the Eleven Centers, unaccounted losses are mainly due to water leakage and any counter measures are yet to be taken.

As a measure of preventive maintenance, the following actions are recommended;

- Ground observation work
- Measurement by flow meter

(2) Ground Observation Work

Ground observation works shall be carried out by the staff in WSS based on information from the public and from their own regular inspections. Regular inspection of the pipelines shall be conducted once in every six months.

When a puddle is found during regular inspection, the electric conductivity of the water shall be measured. In case

the measured value is less than 100 $\mu\text{s}/\text{cm}$, it could be rainwater.

(3) Measurement by Flow Meter

In case a movable flow meter is available in the Regional Office or any other organization related to waterworks, it is recommended to measure the leakage using the flow meter.

The zone to be measured shall be isolated by closing the gate valve and the volume of water flows into the zone shall be measured by the meter.

(4) Preventive Measures for Leakage

In order to prevent water leakage, it is preferable to take measures such as replacement of aged pipes, prevention of corrosion, utilization of flexible joints.

In case of high pressure, water leakage could be avoided to some extent by adjustment of pressure using the gate valve.

Water leakage occurs also from the service pipes. Therefore the material of the service pipes shall be inspected. Use of short service pipes is preferable.

4.3 Service Facilities

4.3.1 Fundamentals of Service Facilities

Water users are responsible for the inspection of the service facilities. WSS Office shall inform the water users regarding the following and request cooperation in their responsibilities;

- necessity of the service facilities and the responsibilities of the water users,
- informing the WSS on occurrence of leakage, if identified,
- illegal connections,

-- abuse of the facilities.

4.3.2 Maintenance of the Service Facilities

(1) Improvement of the Facilities

According to the increase in water consumption due to improvement of living standards, improvement of facilities will be carried out by the WSS from a preventive view point.

(2) Water Leakage

Water users are responsible for maintenance of the service facilities. However, it is necessary that the service facilities are repaired by the WSS.

When a water user moves to another place, it is preferable to disconnect the service facilities.

(3) Illegal Connections and Abuse of Facilities

The service pipe or distribution pipe shall not be connected with a service pipe from another water source.

The service pipe shall not be connected to the rising mains.

(4) Water Meter

In order to ensure correct measurements, water meters shall be selected by the Regional Office or recommended by the Central level.

In order to read the water meter easily, the WSS shall instruct or recommend the water users where the water meter should be installed.

Any disorders shall be identified by the meter reader of the WSS at the time of meter reading.

When replacing a water meter, attention shall be paid to the following points;

- to avoid any shocks to the meter,
- to set the meter counter board in horizontal position,
- to install the meter only after closing the gate valve and draining off the water,
- to confirm the inflow direction, and
- to fill the water gradually to take the air out, and to check if there is any leakage.

(5) Taps

The taps shall also be inspected by the meter reader of the WSS at the opportunity of meter reading.

4.4 Mechanical and Electrical Facilities

4.4.1 Fundamentals of Maintenance of Mechanical and Electrical Facilities

The mechanical and electrical facilities are significant parts of the water supply facilities, and therefore the maintenance of these facilities is extremely important. The superintendence of these facilities is divided into the following;

- operation works such as observation, operation and maintaining records, and
- preventive works such as inspection and repair.

The operation works shall be carried out by the WSS and, for the moment, the preventive works shall be carried out by the O&M Section of the Regional Office.

Such preventive works shall preferably be carried out by the WSS, after the mechanic and electrician are employed and

stationed in the WSS.

In addition to the above, the on-site generator that is provided for emergencies such as suspension of electricity, and the standby booster pump shall be inspected regularly.

4.4.2 Maintenance of the Pumping Facilities

Various kinds of pumps are utilized in the water supply facilities. In order to ensure continued and smooth operation of the pumps, proper inspection and maintenance are essential. It is necessary to keep the pumping facilities in good condition at all times through careful O&M.

The pumping facilities shall be inspected daily by the operator, or the staff of the WSS, for any abnormal sounds and, oil and water leakages. Results of the inspection, including operation conditions of the pumps, shall be recorded and classified.

Some pumping facilities are provided with standby pumps so that immediate action could be taken in the event of a breakdown. Such standby pumps shall be operated regularly, by turns. In order to ensure stable supply of water, also the other components of the pumping facilities shall be inspected and maintained regularly.

In case of a breakdown of the pumps including standby pump, the WSS shall request the water users to conserve water. In order to minimize the damage due to accidents, it is necessary to maintain the reservoir full of water.

In addition to the above, it is necessary to construct proper drainage facilities in and around the compound of the pumping facilities to prevent the facilities from being submerged.

4.5 Disinfectin System

4.5.1 Disinfection Methods and Chemicals

The water supplied to the water users shall be safe and free from contamination. Therefore, a disinfection system shall be installed in the water supply facilities, and the water shall be disinfected using this system without any interruption.

At the Eleven Centers, disinfection is now implemented only occasionally, and any facilities for chemical injection are yet to be provided. Considering the present availability of the WSS staff in charge of handling chemicals, the recommended disinfection facilities shall be provided when suitable staff are assigned for this facilities.

As disinfection chemicals, there are liquid chlorine, hypochlorite and bleaching powder. Considering its availability, hypochlorite, which is used also in other Ethiopian towns, is adopted here as the chemical for disinfection. Hypochlorite is an unstable substance even at the normal temperature. Therefore, it is necessary not only to take precautions against chlorine efficiency becoming lower, but also to grasp the changes in concentration.

Hypochlorite is a highly alkaline chemical, and therefore, anti-corrosive materials shall be adopted for the storage tanks and pipes. In case of handling this chemical, namely, in receiving, delivering and inspection, it is necessary to pay attention not to have direct contact with the skin. Further, this chemical shall not be mixed with acidic solutions such as aluminum sulfate.

A standby disinfection system shall also be installed in order to ensure immediate action during accidents. Additional parts such as injection facilities shall also be secured.

In addition to the above, the disinfection facilities shall be

installed and maintained in the control room. The location of the disinfection facilities shall be decided considering the accessibility to the facilities.

4.5.2 Storage Facilities

(1) Inspection Items and Methods

The storage tank shall be fixed on to the floor, and it is necessary to pay attention to its safety.

Before and after receiving of the chemical, the following items shall be inspected.

- status of level indicator before receiving,
- whether electricity is supplied or not before receiving,
- whether the ratio indicated is within the specified ratio before receiving,
- to operate according to the specified procedure and adjust the manual valve gradually after receiving,
- to observe liquid level in the tank at every time of receiving,
- to check any leakages from the valve and pipe of ammonia solution.

(2) Building and Storage Tank

The storage tank and the exterior of the building for the storage tank shall be inspected once a day.

The storage tank shall be inspected once a day for any leakage of hypochlorite.

The consumption rate of hypochlorite shall be estimated based on the difference in levels on a particular day and two days

earlier. Leakage shall be checked based on the consumption volume as well.

(3) Corrosion and Cracking of the Storage Tank

Inside and bottom of the tank shall be inspected every six months for corrosion and cracks, when liquid level is low.

If there is something wrong, the standby system shall be operated, and the system shall be inspected and repaired. Corrosion of components such as ladder, manhole covers etc., which are made of metal shall be inspected.

(4) Liquid level indicator

The difference between the actual liquid level and the level indicated shall be calibrated once a year.

(5) Strainer

The strainer shall be inspected once a year and any scale formed shall be taken away. After cleaning, the spare parts shall be replaced.

(6) Storage Tank

The storage tank shall be inspected and necessary repairs shall be done. Replacement of the tank shall be considered based on the status of necessity.

(7) Others

The volume of chemical required for more than ten (10) days consumption shall be secured.

4.5.3 Injection Facilities

(1) Inspection Items and Methods

1) Injection Pump

The connections between injection pump and pipes shall be inspected once a day for any leakage of hypochlorite. The protection facilities, such as small embankment provided against hypochlorite leakage, also shall be inspected.

In case of abnormal sound and vibration generating from the injection pump during its operation, the current of the pump shall be inspected. In addition, whether the pump and pipes are loose or not shall be inspected daily.

The temperature of the pump when it is in operation shall be inspected and compared with the temperature during of normal operation.

2) Injector

In case scale adheres around the injection outlet, injection rate becomes unstable, and there is a tendency for the opening ratio of the valve to be larger. The parts shall be replaced according to the necessity.

3) Valves and Pipes

As well as the pump and injector, the valves and pipes shall be inspected in the dry season and replaced according to the necessity.

4.5.4 Facilities for Formation of Hypochlorite

(1) Method of Formation

Hypochlorite is formed by the following reactions:

- electrolysis of salty water in the tank, and
- forming chlorine gas and NaCl.

There are two methods for mixing; the non ion exchange method and the ion exchange method. It is possible to obtain the required volume of hypochlorite by these methods. The method shall be adopted according to the availability, skill and experience etc., of the WSS staff in charge of chemical handling.

(2) Maintenance of the Facilities

The following points shall be considered in the maintenance of the facilities, in the case of non ion exchange method.

- There is the possibility of scale formation during electrolysis. The volume of scale depends on the quality of raw salt used. The cost of raw salt, difficulties in handling, cost of scale removal etc. shall be analyzed comprehensively.
- In case the solvent water has high hardness, it will cause formation of scale. Water with low hardness shall be used as the solvent, or softening facilities shall be provided.
- The electrodes shall be cleaned at intervals of about thousand (1000) hours. The scale shall be dissolved and removed, and the electrodes shall be well rinsed. The waste fluid after cleaning shall be drained off after neutralizing with caustic soda.
- The electrodes shall be replaced according to necessity.
- The facilities shall be operated so that the effective chlorine density is kept around 0.8%.

4.5.5 Dosing Ratio

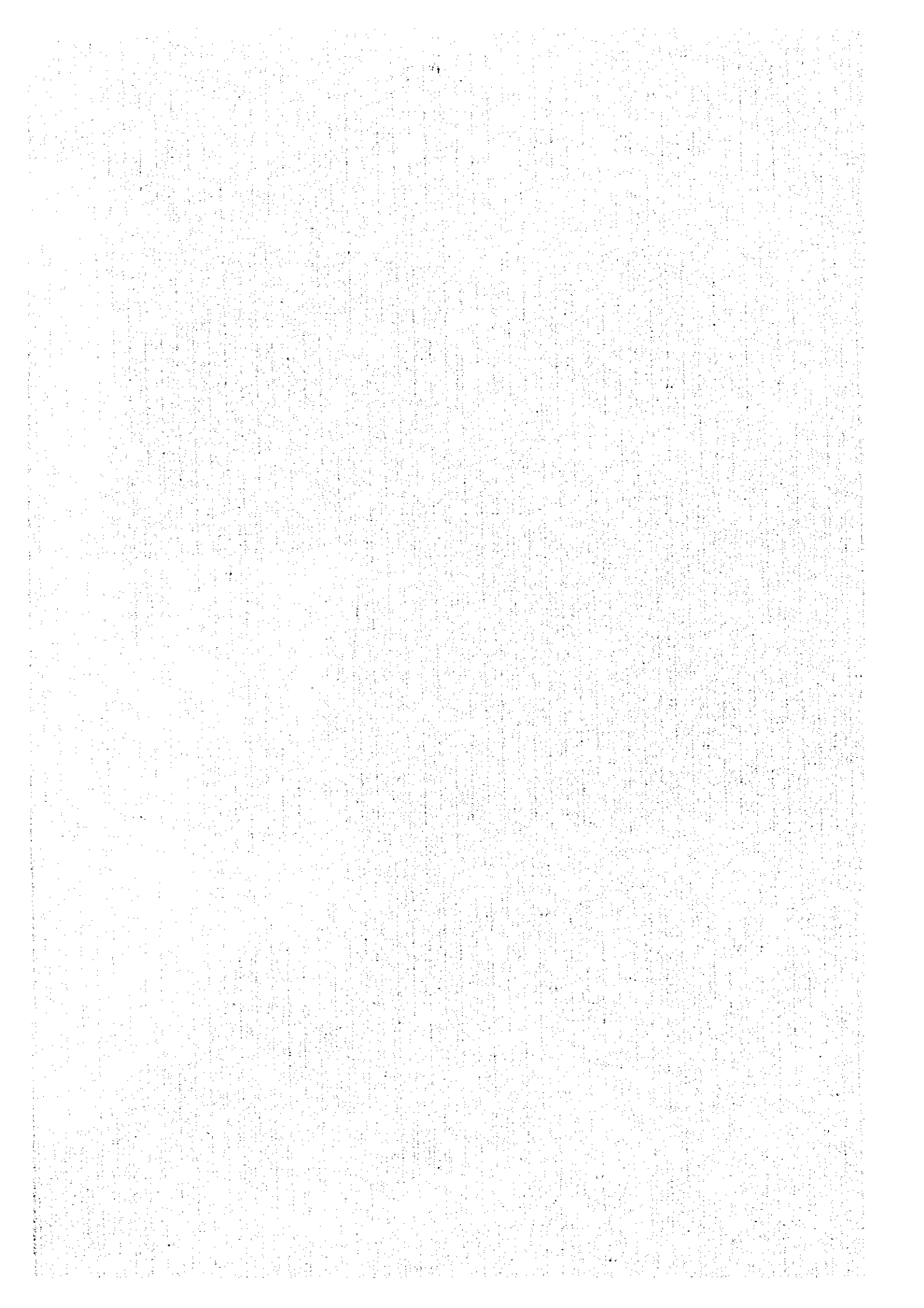
The dosing ratio shall be decided in such a way, in order to keep the residual chlorine being one (1) ppm at the end of the distribution pipeline. In deciding the dosing ratio, the chlorine consumption, not only by the water with which chlorine is mixed, but also by the equipment that is in contact with the water, shall be taken into consideration.

The dosing ratio of hypochlorite is obtained by the following formula.

$$V=Q \times R \times (100/c) \times (1/d) \times 10^{-3}$$

where,

- V : Injection volume (liter/hour)
- Q : Volume of water to be disinfected (m³/hour)
- R : Dosing ratio (ppm)
- C : Effective chlorine density (%)
- d : Specific gravity at c %.



Appendix 1. Inspection Items for Protection Relay of Pumping Facilities

	Equipment	Inspection Items	Interval	Measures
Routine Inspection	Protection Relay	-Whether there is any changes on the exterior	Weekly	Cleaning
		-Whether there is any abnormal sound	Weekly	Adjustment
		-Whether there is any abnormal vibration	Weekly	Adjustment
Regular Inspection	Protection Relay	-Whether there is any loosened bolts	Yearly	Tightening
		-Whether manual recovery equipment properly operates or not	Yearly	Adjustment
		-Whether there is any dust inside	Yearly	Cleaning
		-Whether control coil is deformed or faded	Yearly	Repair or replacement
		-Whether connection is damaged	Yearly	Polishing or replacement
		-Whether gears are properly meshed		Adjustment
		-Resistance of insulation		Measurement

Appendix 2. Inspection Items for Electromagnetic Switch of Control Panel

	Equipment	Inspection Items	Interval	Measures
General Inspection	Exterior	-Whether there is any abnormal sound in electromagnetic parts	Weekly	Adjustment
		-Whether there is any abnormal smell due to overheating	Weekly	Adjustment
		-Whether there is any dirt due to water, oil, dust etc.	Weekly	Cleaning
		-Whether there are any cracks, Insulation	Weekly	Adjustment
Regular Inspection	Exterior	-Whether there is any loosened bolts	Yearly	Tightening
		-Whether there is any rust or corrosion in the metal parts	Yearly	Repair or replacement
	Main connection	-Whether there is any damage at the connection	Yearly	Polishing or replacement
	Operation equipment	-Whether switch is normal	Yearly	Adjustment
	Coil part	-Whether there is any fading due to overheating	Yearly	Repair
	Electromagnetic part	-Whether there are any frictional wear and damage at the connection face		Repair or replacement

Appendix 3. Inspection Items for Submersible Motor Pump

	Equipment	Inspection Items	Interval	Measures
Daily Inspection	Pump	-Characteristics of pump: sound, vibration, temperature, rotation	Daily	Observation of changes in flow and pressure
	Measurement of current	-Regular sorting out of current measurement	Daily	Observation of changes in current and voltage
	Measurement of resistance of insulation	-Sorting out of current measurement	Daily	Checking of resistance of insulation
Regular Inspection	Casing	-Scratch, damage, corrosion of paint	5 years	Repair, repaint, removal of rust
	Impellor	-Frictional wear, deformation	5 years	Replacement if a big damage
	Bush	-Damage and frictional wear	5 years	Replacement
	Liner ring	-do-	5 years	Replacement
	Strainer	-Corrosion, damage, clog	5 years	Replacement
	Cable tie cable	-Confirmation of measurement records of the resistance of insulation	5 years	Inspection or replacement
	Radial metal	-Damage and frictional wear	5 years	Replacement if a big damage
	Mechanical Seal	-Damage and frictional wear	5 years	Replacement
	Oil seal	-Damage and deformation	5 years	Replacement
	O-ring	-Damage	5 years	Replacement
	Cable packing	-Damage	5 years	Replacement
Liquid	-Turbidity and volume	5 years	Replacement	

Appendix 4. Inspection Items for Disinfection Facilities

Equipment		Inspection		Maintenance	
		Interval	Items	Interval	Items
Storage Tank		Daily	-Damage, deformation, cracks and leakage on the exterior	Monthly	Cleaning of strainer
		Daily	-Operation status of liquid indicator	Yearly	Cleaning of the inside
		Monthly	-Rust and paint on the outside	5 to 7 years	Painting
		Yearly	-Exhaustion of connection packing	Yearly	Tightening of bolts
		Yearly	-Cracks, pinholes, paint and lining on the inside		
		Yearly	-Adjustment of liquid indicator		
		Monthly	-Checking of density measurement instrument		
Injection Facilities	Pump	Daily	-Leakage, abnormal noise, vibration, heat	3 months	Cleaning of check valve
		Daily	-Gas release	3 months	Adding of lubricating oil
		Monthly	-Fitting for fixing	5 months	Cleaning of rotor
		3 months	-Injection rate	Yearly	Disassembling of pump
		6 months	-Wear of brushes	Yearly	Tightening of bolts
	Flow Meter	Daily	-Operation status	Yearly	Cleaning of the inside
		Daily	-Rate indicated		
	Adjustment Valve	Daily	-Operation status	Yearly	Repair of frictional wear
		Daily	-Leakage		
	Injector	Daily	-Solution volume	Monthly	Removal of scale
		Daily	-Suction pressure		
		Daily	-Leakage		
	Control Instrument	Daily	-Operation status		
		Daily	-Ratio indicated		
		Daily	-Leakage		
Valves and Pipes		Daily	-Deformation of pipes	Monthly	Tightening of bolts
		Daily	-Leakage	Monthly	Cleaning of strainer
		Daily	-Operation status of valves	Yearly	Scale removal of pipes
		Daily	-Wearing-out of packing	Yearly	Disassembling and cleaning of valve
				3 to 5 years	Painting

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