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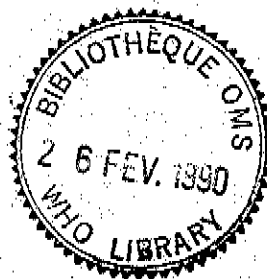
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SMALL RURAL DRINKING-WATER SYSTEMS IN HUNGARY
OPERATION AND MAINTENANCE GUIDELINES

by

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1990

EUR/HFA target 20

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TARGET 20

Water pollution

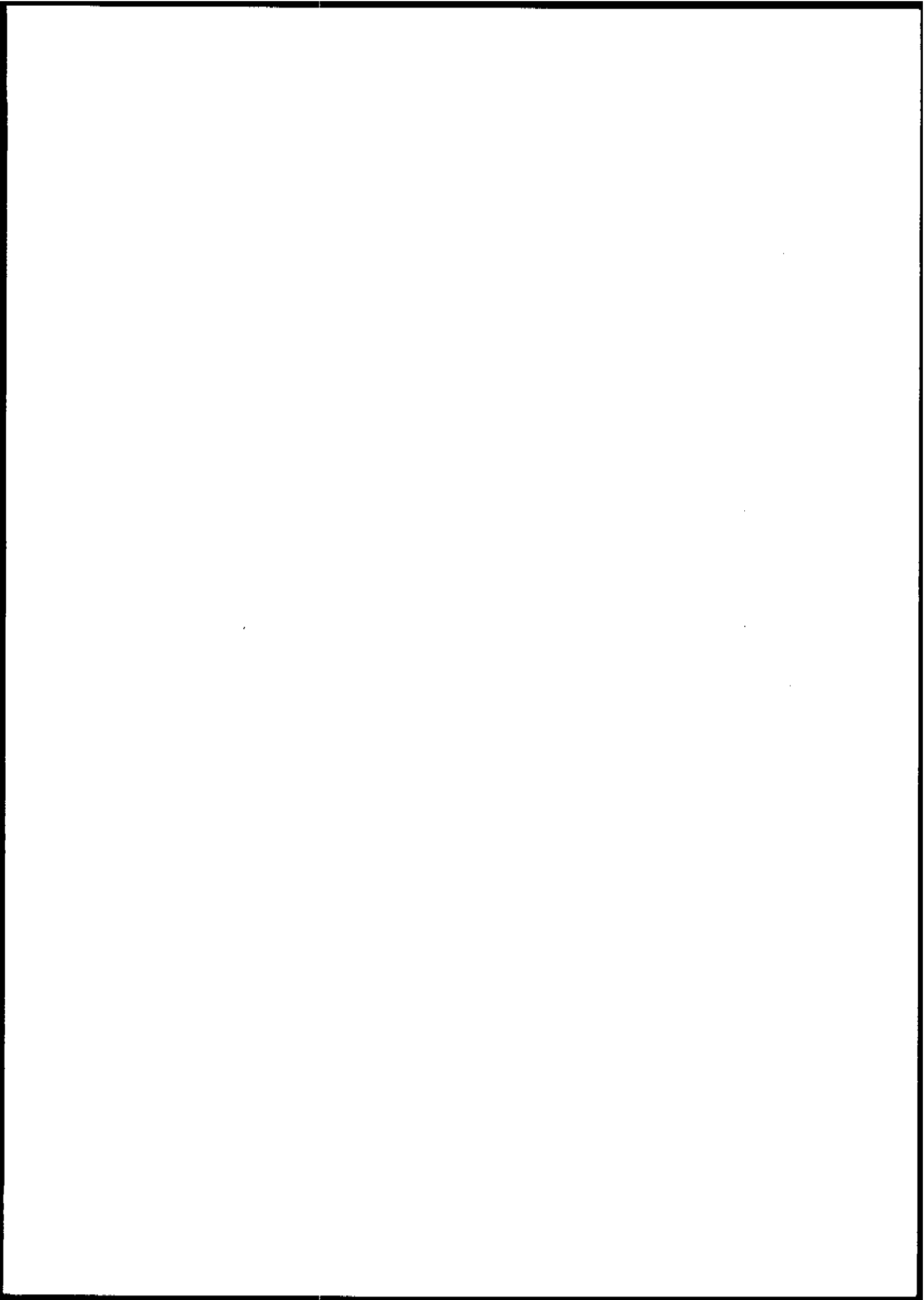
By 1990, all people of the Region should have adequate supplies of safe drinking-water, and by the year 1995 pollution of rivers, lakes and seas should no longer pose a threat to human health.

Index:

DRINKING WATER
RURAL SANITATION
MAINTENANCE
HUNGARY

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PREFACE

The following document has been prepared by Mr Janos Kiss, a staff member of the Institute for Water Pollution Control (VITUKI), Budapest, Hungary, a WHO Collaborating Centre, at the request of the Regional Office for Europe of the World Health Organization, and within the framework of a Collaboration Agreement between WHO/EURO and the above-mentioned institute.

The basic principles and criteria enunciated in this publication are based on the experience gained over many years by a number of small rural water supply systems in Hungary.

Since our Organization recognized that one of the main constraints of the International Water Supply and Sanitation Decade Programme (IDWSSD) is the lack of adequate operation and maintenance services for water networks, WHO/EURO decided that in order to improve the efficacy of existing installations, there was a need for promoting and implementing a programme of operation and maintenance of water services, particularly in rural areas, where the needs appear to be greater.

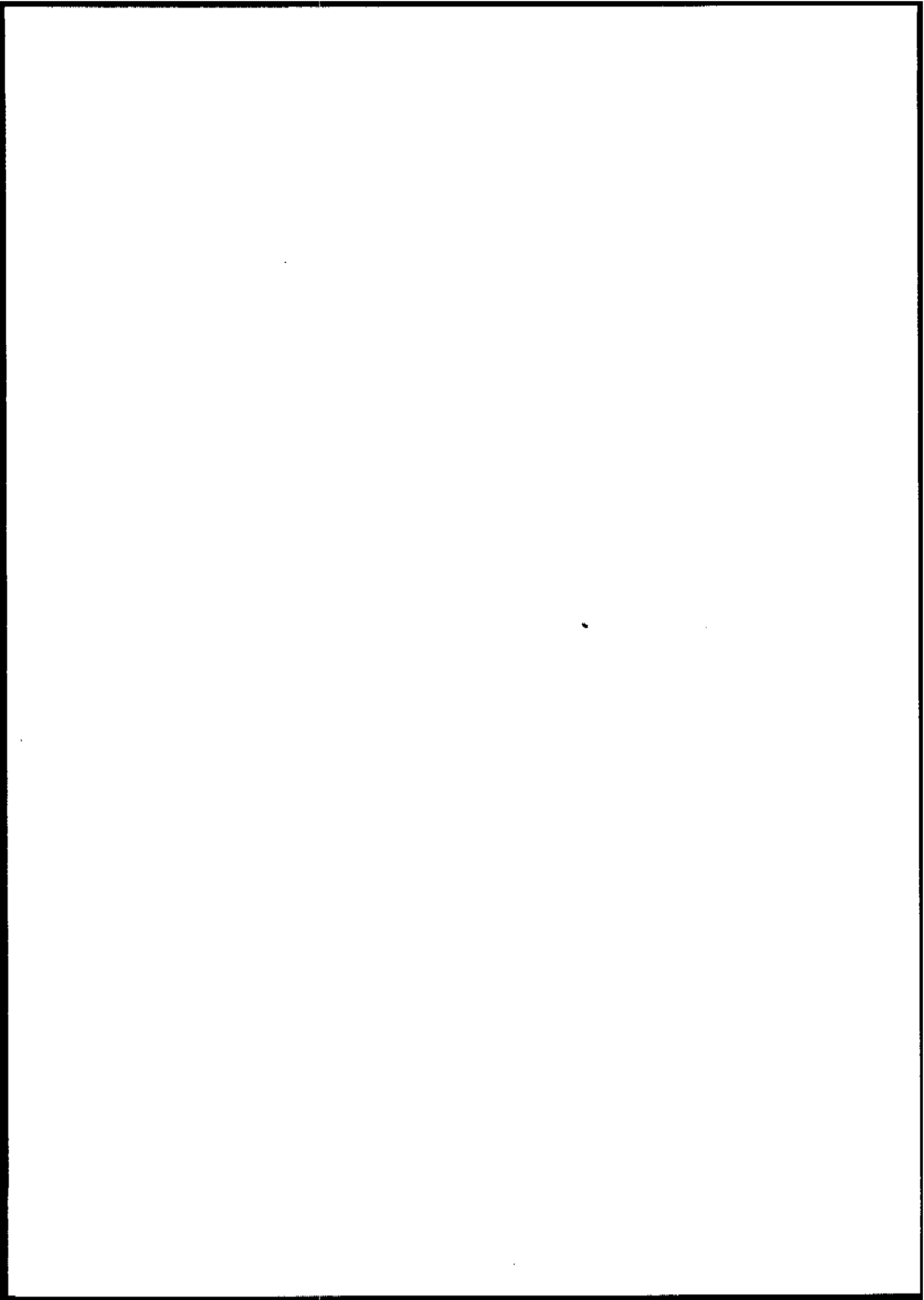
It was considered that the first step of the development of an Operation and Maintenance Programme was the preparation of simple and practical guidelines for waterwork operators, to advise them in a systematic way, step by step, on all the actions which are needed for keeping a small water system operating at its maximum efficiency and effectiveness.

Our Regional Office hopes that the present guidelines will be of assistance to water workers of small communities not only in our Region but also in other parts of the world.

INTRODUCTION

Rural water supply systems in Hungary, hereafter referred to as small waterworks, include water supply units with a capacity under 5000 cubic metres per day. The mains networks associated with these may not exceed 25 km in length, whereas the mains diameter is limited to 300 mm. Small waterworks usually draw water from drilled wells, and only rarely from river or lake catchments. Drawing of surface water hardly ever occurs. However, high-capacity waterworks supplying a rural region can be based on surface water sources as well.

Since small waterworks usually draw water from drilled wells, water treatment equipment is mostly made up of filters for removing iron and manganese, and chlorination-type disinfection plants.



CHAPTER I

DESCRIPTION OF TASKS

1. Task description

The management of rural water supply systems involves three main tasks:

- (a) Water production, obtaining water from different sources, i.e. operating and maintaining water production networks.
- (b) Water treatment, i.e. operation and maintenance of water treatment plants and systems.
- (c) Water distribution, supplying water to consumers, i.e. operating and maintaining supply mains and water reservoirs.

2. Operational activities involved

- optimal exploitation of water source tapping plants (wells, catchments, etc.) in order to meet seasonal requirements;
- coordinating operation of water production and storage facilities in order to achieve a steady and efficient operation, as well as to maintain adequate reserves;
- operating water transfer plants, as well as power plants and process equipment of water treatment plants;
- supplying consumers with water by operating and maintaining supply mains network in a trouble-free manner;
- monitoring the quality of water by routine and scheduled laboratory tests performed during all phases of the production, treatment and delivery of water, together with accurate recording of control tests;
- remedying any unexpected defect that occurs at the water plant or in mains system in a quick and competent manner;
- maintaining power transmission system, as well as telecommunication, remote control and remote operation systems.

Regarding the operation of a water plant established on a water source, two modes of operation are considered:

- small waterwork with automatic operation, requiring no personnel
- small waterwork operated by personnel:

Automatic operation of small waterworks depends on the level of water stored in the overhead reservoir, since the latter keeps changing with the rates of consumption and production, thus sending signals to the delivery pumps in the supply mains. If no water treatment is necessary, the pumps draw water direct into the supply mains and the overhead reservoir respectively,

and can be controlled in a failproof manner through the changes of water level. As a consequence, such small waterworks require no personnel for operation (Fig. 1).

If water treatment must be incorporated into the system, automatic control should consist of two stages. The pumps located in the mains system are controlled by the overhead reservoir; these pumps are to be interlocked with the water level in the underground reservoir, as a consequence of which operating the water treatment plant requires personnel for the periodical filter cleaning processes only (Fig. 2).

Automatic control of the operational pressure of small waterworks with hydrophor service is made by switching on and off the pumps in accordance with the fluctuation of the preset pressure.

Water is supplied to the mains during the changes of pressure and air volume, while the pumps are at a standstill between the preset pressure limits.

Since some of the air in the hydrophor (pressure booster) is being lost together with the water, the mains monitoring engineer on duty should recharge the unit with an air compressor from time to time (Fig. 3).

Both processes are suitable for supplying the consumers with adequate quantities of water. For power rooms with automatic control, it is advisable to record the data of water flow, so as to facilitate the evaluation of trends in production and consumption, especially if also the fluctuation of water level in the underground water reservoir is recorded.

Operation of small waterworks controlled manually is based on the water level indications received from the underground reservoir. Functions of the engineer on duty in the power room are to switch the pumps on and off, clean the filter (if any) and record data of operation in the log book.

Water treatment plants shall be operated in accordance with the manufacturer's specification.

Fig. 1 Schematic diagram, automatic control of small waterworks

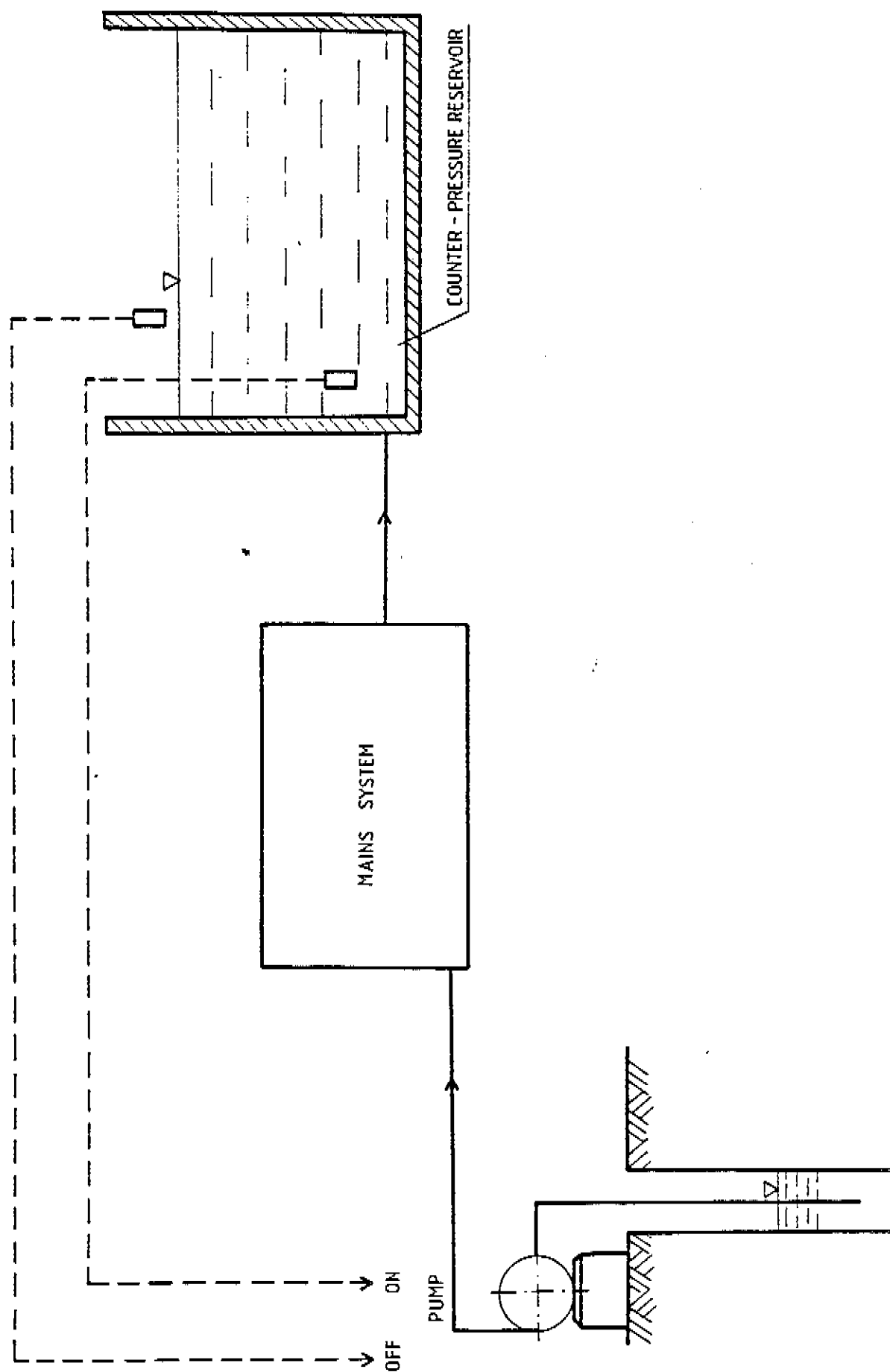


Fig. 2 Schematic diagram, automatic control of small waterworks with water treatment plant

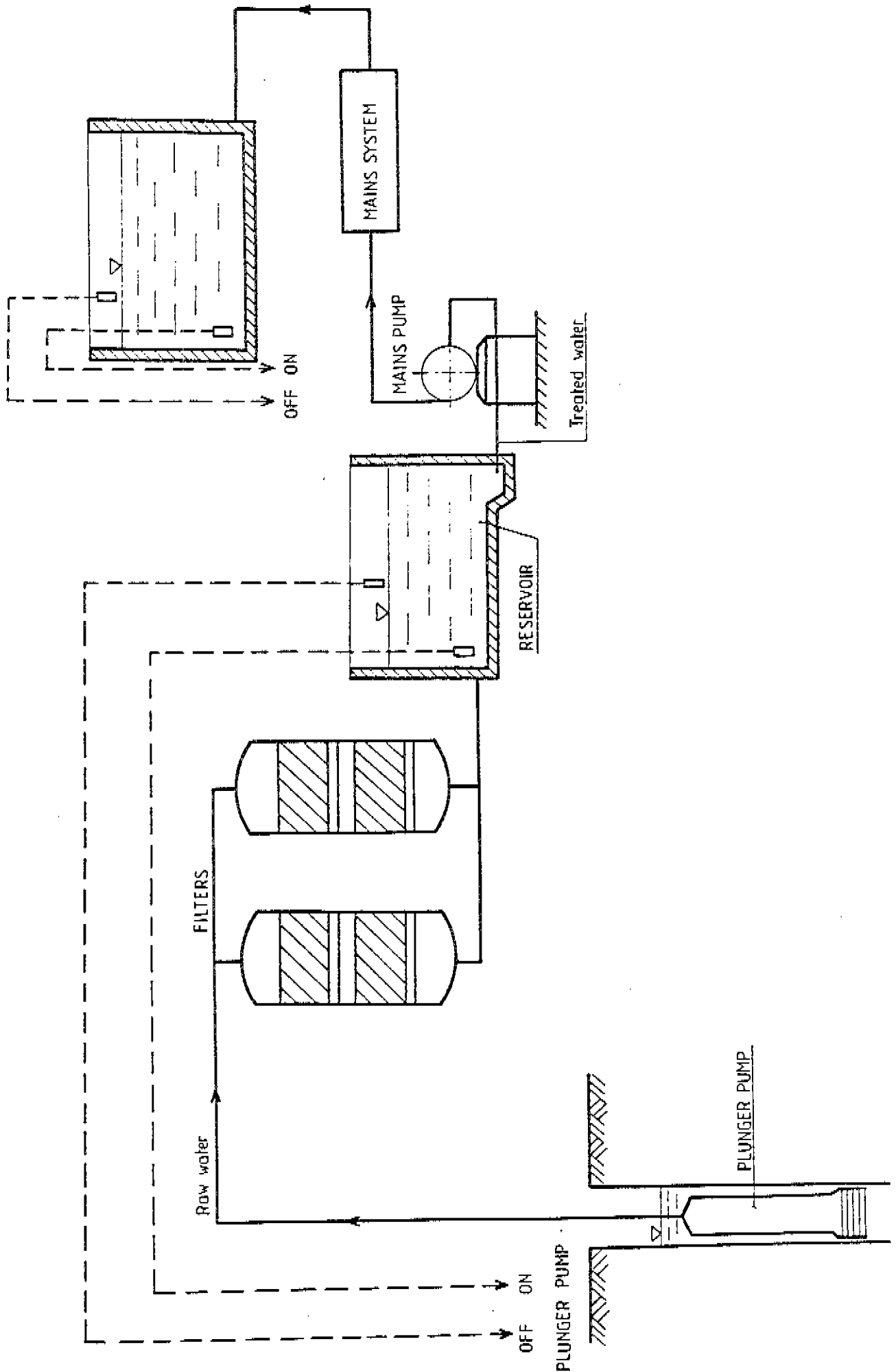
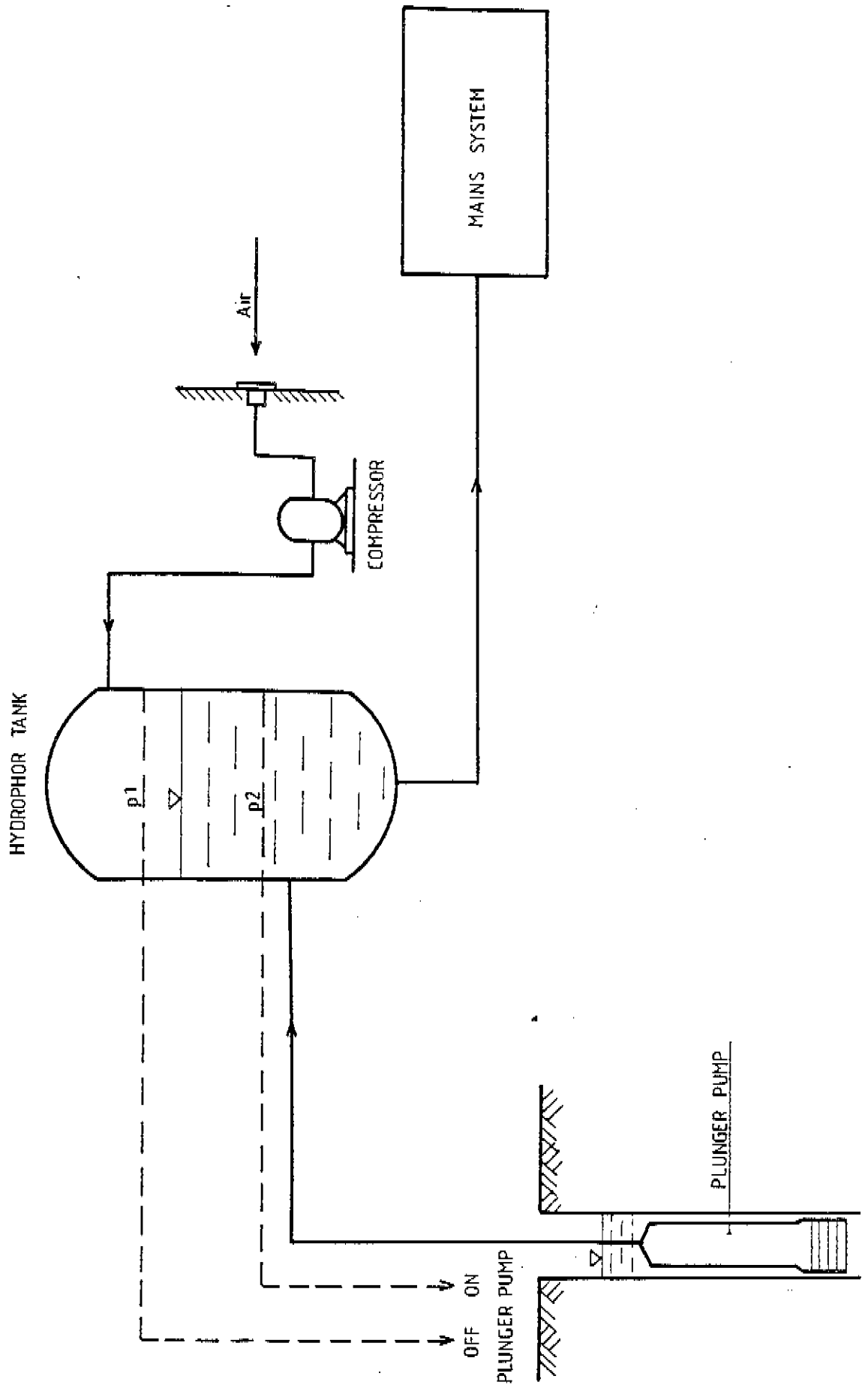


Fig. 3 Schematic diagram, operation of small waterworks with hydrophor pressure booster



CHAPTER II

PLAN OF MAINTENANCE

In order to keep small waterworks in safely operable condition it is absolutely necessary to work out a maintenance schedule for capital assets and act accordingly.

Maintenance is aimed at maintaining or restoring the operability of all items of equipment, improving technological operational standard by any means except investments, and enhancing the reliability of operation.

Maintenance is therefore partly a continuous activity and partly a periodical one.

In the course of maintenance, none of the fundamental functions of capital assets may be changed, and plant capacity may not be increased either.

Maintenance of individual sub-assemblies or of components of capital assets often results in enhancing the applicability or accuracy of the relevant equipment or in increasing its productivity provided that no change has occurred in the function of assets, and their volume has not increased either.

Within the scope of maintenance activities, yearly maintenance rosters should be drawn up for every water production and supply unit. The rosters should include detailed plans for continuous maintenance and periodical overhaul for the renovation of equipment reaching its age limit.

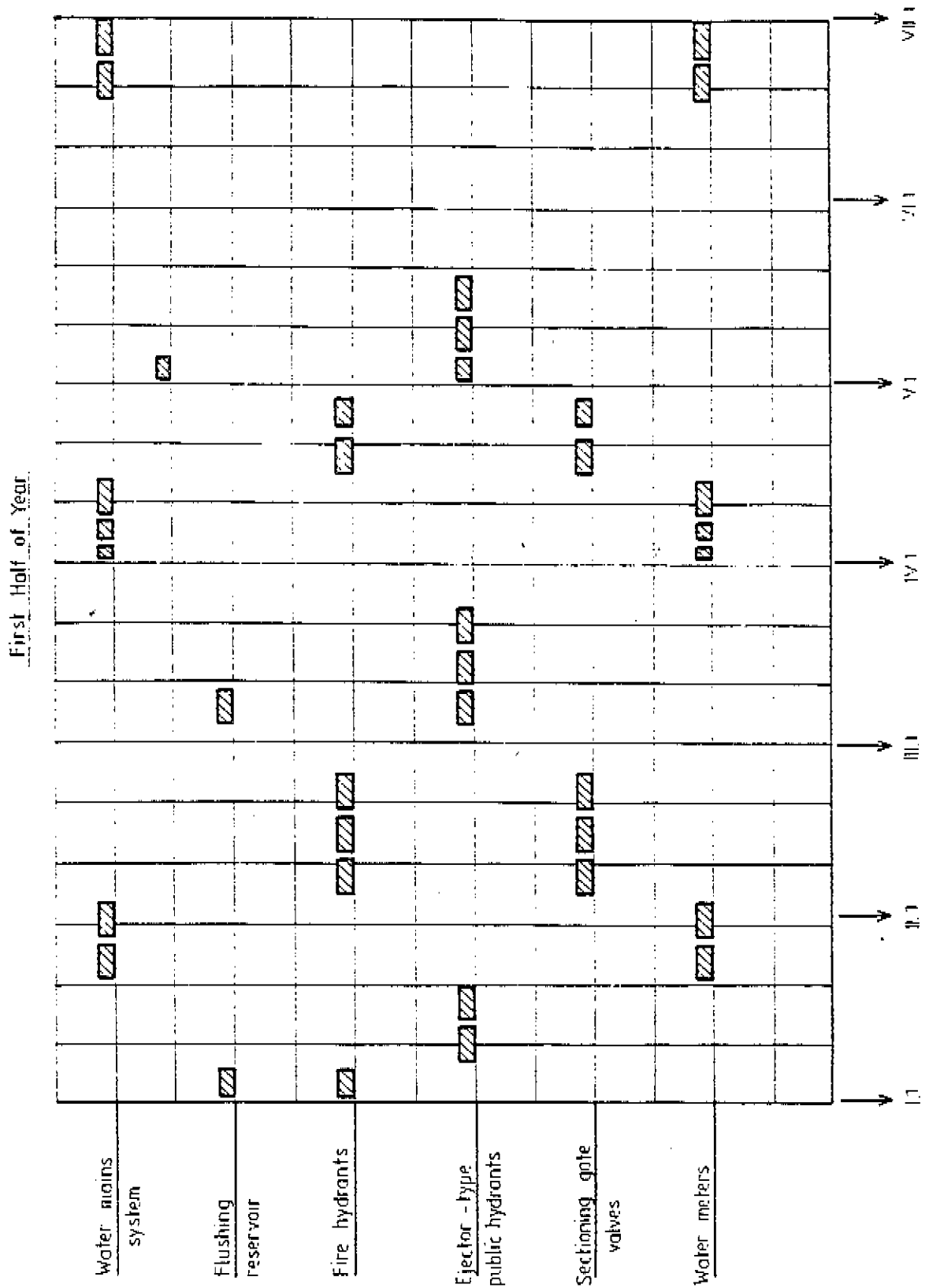
Execution of maintenance can be facilitated by operative schedules. In order to have a better grasp of the procedure, it is advisable to make a GANTT diagram (Fig. 4). Execution of the maintenance plan should be evaluated every three months.

All minor operations required for ensuring trouble-free operation and preventing premature wear of equipment should be performed under a maintenance roster. Since these operations are regularly repeated, they can be accurately scheduled, e.g. checking engineering structures and fittings along with their repair and corrosion protection, as well as disinfecting and flushing reservoirs, water-towers and supply mains, monitoring mains, measuring efficiency of machines, replacing bearings and other components.

All types of work beyond the scope of maintenance should be included in the renovation plan.

The procedures to be performed should be listed in the renovation plan on the basis of a previous inspection of capital assets. The individual items of the renovation plan should be provided with technical descriptions, execution plans and cost displays.

Fig. 4 GANT diagram to maintaining supply mains



CHAPTER III

MANPOWER FOR OPERATIONAL PURPOSES

Small waterworks can be operated in the following organizational setups:

- small waterworks operated by a regional framework or regional water infrastructure; direction of the waterworks is from the dispatcher room of regional waterwork (Picture No. 1);
- automatically operated small waterworks without any regular operator, but requiring at least one engineer on duty for monitoring of mains; (Picture No. 2)
- small waterworks under periodical attention; they usually do not undergo any treatment processes, except maybe iron removal and disinfection; (Picture No. 3);
- small waterworks under constant attention; they always undergo water treatment processes, e.g. iron and/or manganese removal and disinfection; (Picture No. 4);

The operation of small waterworks should proceed as specified in the job descriptions and operating instructions for each water worker, the tasks of such operators depending on the following:

- the organizational setup of the respective small waterworks;
- the degree of automation established;
- the distance separating the centre or subcentre of regional waterworks and the small waterworks;
- the existing telecommunications facilities;
- the rate of water supply and capacity of underground reservoirs, i.e. the likely ratio of consumption covered by the reservoir;

The manager or supervisor of a water production plant should have the following functions:

- establishment of job descriptions for all workers assigned to the plant, and supervision of their activities;
- responsibility for the continuous functioning of the production plant and supply mains, elimination of defects, competent operation of process equipment, as well as full adherence to operating instructions, labour safety and health protection regulations;
- execution of the maintenance programme of the plant, checking the quality of all work done and performing or supervising the tests specified for putting the plant into commission, including measuring of parameters.

The industrial labour force necessary to operate a plant should be determined according to the types of skilled workers and the number of operators required to perform such activities.

Small waterworks require the following kinds of skilled worker:

- foreman, skilled electrician or fitter qualified to operate waterwork equipment;
- operator, skilled electrician or fitter qualified to operate waterwork equipment.

Depending on the size of the power room and the instruments installed, the extent of the protective area surrounding the plant and the number of shifts envisaged, provision should be made for unskilled labour to clean the plant and attend garden in the protective area.

The number of shifts to be organized per day in the power room should suit the degree of automation and the type of water production process.

For a power room operated on a three-shift basis and a 44-hour week, the labour force proposed is 1 foreman, 4 operators and 2 unskilled workers, as specified earlier.

For a power room operated on a two-shift basis and a 44-hour week, the labour force proposed is 1 foreman, 2 operators and 1 or 2 unskilled workers, as specified earlier.

If the pumps are automatically controlled, the operator on duty merely supervises the operation, making sure that the automatic control system functions without a hitch (see Picture 1). For this type of operation a mains monitoring engineer will usually be engaged to supervise both the mains and the power room. In power rooms operated by a single operator or periodically supervised by a main's monitoring engineer, the latter's functions do not include elimination of engineering or electrical defects. Should any intervention of this nature be necessary, expert help will have to be obtained from the centre or subcentre of the respective regional waterworks.

In such power rooms, control can be reversed from automatic to manual by means of a push-button, and from then on the pumps can be switched on and off, as well as bled and primed, by means of push-buttons.

The functions of mains monitoring engineers includes daily supervision of the mains system in operation, disconnecting defective sections and reporting defects without delay. The number of mains monitoring engineers will depend upon the overall length of the mains system, since the section to be supervised by each should be covered on foot every day.

To maintain the mains system and repair any defect likely to be encountered, a team consisting of a plumber and two unskilled labourers should be provided for every 10 to 15 km section.

CHAPTER IV

PLANS, DOCUMENTS AND RECORD EVALUATION

Handling and evaluation of records, documents, water law certificates and mains maps are all part of the appropriate administration and management of a waterwork system.

In order to operate waterworks efficiently, it is absolutely essential to have a complete set of technical documents relating to the waterwork system. The documents should be kept up to date, and any change carried out on the mains system, as well as all replacements and transfers of fittings, pipes and functions duly recorded. It is advisable to record mains failures on the mains maps.

Up to date recording of technical files also applies to machine files, on which the replacement of components should be recorded on the basis of the hours of operation completed. The results of regularly performed efficiency tests should also be recorded, together with a brief description of the measures taken in this connection. In addition, the causes of defects, and the measures taken to remedy them, should be recorded.

The crossing points and parallel routes of various public supply mains should be recorded on mains maps and the respective permits of mains crossings indicated. All permits issued for, and interventions performed in, public supply mains should be recorded in the respective documents corresponding to the area where the intervention took place.

All changes carried out in the course of the previous year should be recorded in the basic documents.

The following drawings should be kept in the drawing store:

- mains systems, scale 1-1000
- mains junctions, scale 1-100 (relatively complicated mains junctions)
- power transmission lines, signal transmissions, measuring and operating cables, scale 1-1000
- well piping, based on hydrogeological documents
- structural engineering and architectural designs
- electrical wiring
- hydrological engineering
- siting of protective earthing.

Fire hydrants, public outlets (see Picture 2), consumer connections and the number of water meters installed should also be included in the mains files.

CHAPTER V

ESTABLISHMENT OF CONNECTIONS TO SUPPLY MAINS

Connections are established to the supply mains operated by small waterworks in the following cases:

- establishing new mains, or extending existing mains;
- establishing new pressure regions or installing pressure boosters for high buildings;
- establishing consumer connections.

On establishing new connections to the mains, it is advisable to specify whether pipe connections can be made by an employee of the waterworks alone, or if a waterworks inspector has also to be present. The mains under construction, extending mains system by skilled workers (Picture No. 5). Connection may only be established after all conditions specified in the respective certificate have been provided, and any defect noted and objected to in the course of installing the connection has been remedied.

Two copies of the documents amended in accordance with the actual situation should be handed over to the water authorities on takeover of the installation, for guidance during use.

In order to ensure an outlet pressure of minimum 15 m, "pressure regions" may be established in relation to the actual terrain characteristics. Such regions are usually established in hilly country or for high buildings. As regards the operation of mains in pressure regions, the same rules are applied as for water mains systems. If deemed necessary, more than one pressure region should be established. Water supply systems in "pressure regions" (or zones of special pressure) should preferably follow two different designs:

- with hydrophor-type pressure booster
- with pressure boosting pump and underground reservoir

Hydrophor-type pressure boosters are installed in relatively low pressure regions. The system operates on the following principles: the pump delivers water from the primary mains via the hydrophor tank to the respective supply mains at a constant pressure. In this arrangement, constant pressure means that the pressure booster is switched on at minimum mains pressure, and switched off at maximum.

It is advisable to ensure supply to pressure booster pumps in two different ways:

The intake line of the pump is directly connected to the primary mains and the pump operates by making use of the pressure in that mains section. In this case it is absolutely necessary that the intake line of the pump be directly connected to the primary mains and that the cross-sectional area of the latter be three times the size of the intake line. It goes without saying that not only the ratio of cross-sectional areas is important, but also the

capacity of pump and the difference between the water flow circulated in the primary mains and the rate of delivery; this is important for preventing the pump from creating suction in the primary mains.

Should this not be feasible, a suction reservoir must be established between the primary mains and the pressure boosting pump. The primary mains should be connected to the top edge of the reservoir and the intake line of the pump to the bottom edge. Operation of the pressure booster is to be controlled by means of a water meter.

A fundamental condition of operating a pressure booster is that the pump be appropriately locked on both the intake end and the delivery end. If the pump is directly connected to the primary mains, it should be interlocked with the pressure prevailing in that mains, or to the drop in pressure. Consequently, should a mains breakage result in a sudden drop in pressure, no suction can be caused by the boosting pump in the mains. Should a breakage occur on the delivery side, the boosting pump can be prevented from delivering water to the leakage by installing a similar interlock at the delivery end. It is absolutely necessary to select the hydrophor tank to suit the requirements of operation, and to set the pressure limits according to the rate of water consumption so as to be able to maintain operation at a constant level.

As a rule, zones of special pressure are supplied with water by pumps and storage reservoirs at relatively large-size areas of water supply. In such cases, the pumps are controlled by the water level in the reservoir, and the setup at the intake end is as specified before.

Connections to private homes should be made with the written approval of the waterworks authorities and an official authorization will have to be acquired in each case.

Private consumer connections range from public mains to water meters located within the boundaries of private plots. The waterworks authorities are responsible for all private consumer connections.

CHAPTER VI

SUPERVISION OF WATER PRODUCTION AND OF TREATMENT PLANTS

It is recommended that operation of small waterworks systems be supervised and that all operational factors should be measured and controlled, i.e.:

- level of undisturbed water in wells (metres);
- suction water level based on data obtained in production and observation wells (metres);
- yield of springs (cubic metres per day) (see Pictures 3 and 4);
- changes in water quality based on physical, chemical and bacteriological tests; the quality of water yielded by various sources should be checked through regular laboratory tests, with special emphasis laid on bacteriology (Picture No. 6).

Changes in certain chemical constituents characteristic of water quality should be monitored by chemical testing for the presence of ammonia, nitrite and nitrate, since these substances are indicators of pollution;

- ammonia is tolerable in traces only; in the water yielded by deep-sunken wells on protected water strata, max. 20 mg of ammonia per litre is still tolerable;
- nitrite is also tolerable in traces only; for protected strata of water, max. 0.10 mg of nitrite per litre represents a tolerable level; this is so because in protected strata of water no dangerous level of pollution is possible;
- nitrate is tolerable in quantity of up to 50 mg per litre;
- neither iron nor manganese should be tolerated. Water processing high carbonic acid will dissolve iron and manganese from rock-bearing strata. Consequently, water containing iron and manganese is mostly of aggressive character (acidiferous). Such water is mostly found in deep wells. High carbonic acid content usually goes with low oxygen content. In addition to being harmful to health, carbonic acid water damages the pipe lining of drilled wells. In this way the iron content of water comes only partly from the natural iron content of the soil and to some degree from the pipe lining. Iron content is tolerable up to 0.3 mg per litre, and manganese content up to 0.2 mg per litre;
- bacterium count may not exceed 100 per cubic centimetre of water;
- absolutely no coli bacteria should be tolerated;

- process equipment should be checked for sound functioning once a month and the effectiveness of cleaning controlled; the latter should be done by chemical and bacteriological testing. The quality of freshly produced water, mains water and water stored in reservoirs is to be checked by chemical and bacteriological testing every three months. Test results should be evaluated in accordance with the water production process, and if any change in water quality is observed, the necessary corrective measures should be taken, e.g. cleaning, flushing, increase in chlorine dosage, draining of water from reservoirs, etc.;
- the internal protective area should be regularly inspected for tidiness, and this rule also applies to the fences and the belt ditch. The external protective area should be inspected to ensure that warning signs are legible and to find any evidence of pollution by agricultural processes, e.g. organic manure, grazing, etc.;

the hydrogeological protective area should be inspected for evidence of new sink holes, bodies of perished animals as well as damages caused by deep ploughing or forestry, all of which could jeopardize the water quality.

Every waterworks should have an operational log-book in which not only the water levels mentioned before are to be recorded, but also the following particulars entered every day:

- daily water production (m^3 per day)
- power consumption of water production (kWh)
- magnitude of power consumption, if measurable (min. and max. kW)
- volume of water stored in reservoirs (m^3)
- service pressure in mains.

Unless the plant is equipped with a recording instrument, the latter three data should be read and recorded every three hours.

- weather conditions (to be entered daily)

Should a plant capable of extracting iron and manganese be operated, the dates of flushing and the quantities of water used for that purpose are also to be recorded. For demanganizing filters, also the dates of regeneration should be entered in the log-book. Moreover, the dates on which wells, sunken basins and underground reservoirs are cleaned should also be recorded.

The log-book should contain the service roster of operators, the names of operators on duty in each shift, as well as the manner in which duty was handed over and taken over at the end of shifts.

Any possible irregularity or defect observed during every shift should be duly recorded, along with the utilization of coal reserve, if any.

The name of the person in charge of operations at the water production plant should be entered, along with his official functions. The person in charge of operations must enter all remarks related to the plant operation in the log-book and sign underneath.

In connection with the engineering and electrical equipment, efficiency test results obtained for pumps and cos d measurements of electric motors are to be recorded every year. The main water meters of the water production plant, as well as the water level remote indicators and other hydraulic and electrical instruments of the underground reservoir, are to be checked for measuring accuracy once a year.

All power transmission, signal, measuring and operating cables are to be measured for insulation resistance once a year. If intended for use with power-current equipment of max. 1000 V, shock-protection earthing must be tested for soundness every alternate year. Also lightning protection is to be tested periodically for effectiveness.

CHAPTER VII

CONTROL OF SUPPLY MAINS

In built-up areas, the routes of supply mains should be inspected on foot once a year, while the routes running through open countryside should be inspected in this manner every three months; any irregularity, such as leakage, sunken road topping, damaged surface irregularity, dislocated valve cabinets etc., must be recorded without delay.

On inspection, special attention must be paid to the crossing points of mains and roads, railroads and water courses.

All fittings should be manipulated through their entire range of movement at least once a year to make sure that they still function correctly. Any possible deficiency or malfunction observed is to be notified in a special report.

The high point of supply mains should be bled at regular intervals, depending on the diameter and routing of the mains section under test. Bleeding should be continued until a steady flow of water is obtained at the bleeder cock. For low diameter mains, failing to perform bleeding at proper intervals could easily lead to a breakdown in water supply.

On inspecting mains routes, all line and fitting signs should be checked for appropriate lettering. It is recommended to mount such signs at approximately 2.5 m above ground level and, preferably, that they should be clearly visible at night.

Long distance supply lines should be checked for seepage once a year, and other line sections every three or four years; points of leakage can be located by such instruments as acoustic leakage detectors or transistorized amplifiers.

When fitted with extra equipment, such instruments are suitable for detecting the routing of metallic supply lines and the location of valve cabinets lost under ground-level. It is advisable to undertake instrumental route checking at night.

Hydraulic conditions prevailing in the mains system should be controlled by means of pressure measurements, and the recommendations for renovation and extension based on the result of the tests performed.

A series of pressure measurements should be performed every year. In order to ensure comparability of test results, the pressure should be measured in the same season of the year and at the same points and under the same conditions of operation. Changes in hydraulic conditions, as well as the causes of water shortages arising from these, are clearly visible on the pressure maps based on the above-mentioned pressure measurements.

Any of the following causes can restrict the water supply: encrustation inside pipes, air accumulated at high points of mains systems, slide-valves remaining in a half open position, inappropriate diameter of mains.

In order to enhance operational reliability, it is recommended that recording pressure gauges be mounted at some characteristic points of the mains system.

Internal surfaces of piping should be inspected occasionally; when repairing broken pipe sections, when repairing defective slide valves and establishing new consumer connections, the mains system can be inspected for deposits, corrosion damage and similar failures. Results of such inspections must be recorded for each type of supply line.

Abnormal water losses detected during maintenance/service of the mains should be checked. The quantities of water consumed by the waterworks should not be included.

Reliability of water service losses depends on the following:

- accuracy in measuring the quantities of water delivered into and consumed from supply mains;
- reliability in estimating the quantities of water lost at pipe breakages, water used for maintenance (flushing) or expended on fire extinguishing and similar emergency purposes.

In order to ensure the accuracy of measurements, it is necessary to check and calibrate water meters regularly and also to replace them at the appropriate intervals.

Supply mains must be checked for absence of damage which may be caused when structural engineering work is being performed in their vicinity, and regulations adhered to, e.g. side clearances on both sides of supply mains, suspension or shoring up of supply lines, covering of bare pipes with wooden planks.

The entire mains system should be flushed either once or twice a year. This is necessary in order to remove deposits and encrustation from the pipes.

Flushing should preferably be scheduled during off-peak seasons, and be performed in successive stages from pump station to reservoir.

Effective flushing can only be achieved by using a flow rate that exceeds the service rate by 150 percent. By appropriate setting of slide valves, a counter-current should be generated in the mains, and the water used for flushing drained via the drain branch or a separate flushing line.

Provided that the rate of flow is adequate, a quantity of water exceeding the volume of supply lines two or three times is usually sufficient for effective cleaning.

After flushing the mains, the water meter filters are usually blocked with dirt. It is, therefore, advisable to clean these after every flushing.

Flushing water should be disposed of in an appropriate manner.

In order to prevent water from becoming slack in the branches not included in the ring mains, the former require to be flushed more frequently than the mains system.

Underground reservoirs (or water towers) should be flushed once or twice a year as deemed necessary to safeguard water quality. All personnel engaged in such activity must wear clean overalls and rubber boots especially provided for this purpose.

Reservoirs, water towers (see Picture 5) and engineering structures are to be regularly inspected and tested for soundness and tightness of sealing as necessary, and the test results evaluated retrospectively to several years.

Preparation for the summer season should begin in the early months of the year. Peak consumption lasts from 15 May until end September in the central European climate. Prior to the beginning of the peak season, all water draw facilities, pumps and auxiliary equipment should have been supervised, maintained, repaired and disinfected to schedule. Spare units of machinery must also be put into operable condition.

Preparations for the winter season include taking protective measures against frost damage as well as precautions to cope with heavy snowfalls and heavily iccd surroundings.

Frost protection: all pipe sections and fittings exposed to frost must be protected against freezing (see Picture 6). Pipe sections and mains equipment not in use in winter should be drained of water. The parts of sensitive equipment located above ground level should be covered with some heat-insulating material.

Labour safety regulations specifically applicable to each operation should be demonstrated to all workers assigned to the waterworks and efforts made to ensure that they follow these in all cases of emergency.

The person in charge of the water production plant must continuously control adherence to labour safety regulations. The wooden platform located in front of the switch panels must be covered with rubber matting, rubber gauntlets provided with all major switch gear, and signs clearly indicating ON and OFF positions of all switches.

The person in charge of the waterworks must also make sure that fire-fighting equipment is kept in working condition, first-aid signs are placed where they can be clearly seen and read, chequer plates covering cable ducts and access ladders are kept dry, washrooms and locker rooms kept tidy, and that the staff is provided with washing and toilet facilities as specified in the relevant instructions.

CHAPTER VIII

ORGANIZING THE ELIMINATION OF DEFECTS

In accordance with the actual organizational setup, defects can be eliminated in a small waterworks in two different ways. If the staff is qualified, the skilled operators can undertake the necessary tasks without supervision. Should a breakdown in any of the automatically controlled units occur in small waterworks only provided with supervisory operators (mains overseer), the affected sector of the network can either be partially shut-down, or manual control taken over, and the regional centre or subcentre of waterworks notified.

If a waterworks has a permanent staff, elimination of the following types of defect can be undertaken by their skilled personnel:

- mains failures, pipe breakages
- breakdowns in mains fittings, gate valves, public hydrants, fire hydrants and water meters
- failures in the power-room equipment
- replacing burned fuses
- air leaks or water leaks in pumps
- in case of leakage in compressed air reservoirs, staff must switch from automatic to manual operation
- if water gauges of water reservoirs are defective, operators must check water levels regularly and visually
- replacing a defective pump with a spare one.

Regarding automatically operated small waterworks only periodically attended by a mains supervisor, the following defects must be reported to the regional centre without delay:

- breakdown of plunger pump
- breakdown of mains pump
- breakdown of electric motor
- mains power outing and any other electrical failure
- any defect in the automatic control systems
- failure of main water meter
- breakage in supply mains
- any other type of mains defect.

By interrupting the defective mains sections and switching on spare units, the mains supervising engineer can either eliminate defects without assistance or restore water supply as fully as possible until the maintenance crew from the waterworks centre arrives to carry out the repair.

All types of malfunctioning, failures and breakdowns must be entered in the respective record book, noting the date of observation and the date on which the repair has been completed.

CHAPTER IX

LOCATION AND ELIMINATION OF MAINS DEFECTS

The following signs are useful indicators of mains leakages:

- water appearing outside the pipelines
- water flowing up from the ground or on road surfaces
- noise from water escaping from pipeline
- changes in hydraulic pressure ratios
- decrease in the rate of delivery.

Defects causing high losses of water (pipeline breakage, gasket failure, etc.) are generally indicated by the appearance of water on the surface of the ground. The water flowing from large-size pipes at the points of breakage washes away large areas of soil, not only causing road structures to collapse but even endangering the safety of buildings nearby. Consequently, locating defects is seldom problematic since consumers or the police report them almost immediately.

Leakages occurring in densely packed strata, rubble, landfill, cracked rock, or in minor supply lines present far greater problems to waterworks operators, since the water tends to seep deep into the ground and observation and location of the point of failure can therefore take time. The problem is that such hidden water flows erode large cavities deep in the ground, the consequences of which are likely to appear on the surface only much later, e.g. collapsed road structures and cracked walls of buildings. Should the water rushing out of a pipeline find an easy route of escape, e.g. into a sewer system, the leakage can go undetected for years. Hidden breakages in water supply lines are often detected by sewage line inspection crews who spot the unusually high inflow of water into the sewage system.

Hidden losses of water can also be spotted by means of special instruments. Such instruments are based on the principle that the sound of water leaking from lines at a high speed can be amplified through a contact feeler so as to be audible to the human ear. The stronger the sound, the nearer the site of leakage. The simplest model is called a listening pipe; this is a thin-walled brass pipe of 1 to 1.5 m in length with a diaphragm-type earpiece on one end. By pressing the other end of the pipe against the surface of the line section being tested, detection through the earpiece is possible. Although the instrument is very simple indeed (actually being a do-it-yourself gadget), its application requires a great deal of experience in supply mains operation; experienced operators can use the pipe with a high degree of precision. The same principle has already been adopted for instruments with electrical amplification of sound, the electric listeners, which amplify sounds by electrical means (Picture No. 7).

A more sophisticated model is the electronic leakage finder; having highly sensitive sound probes and a high-capacity amplifier, the instrument is a highly effective tool in the hands of trained personnel. This system has the ability to differentiate the sound of water outrush from other noises. Moreover, the instrument can be used not only by direct contact with pipes, but also by running it over the ground surface. For this type of probing, it is of course necessary to know the precise routing of the line being tested.

Listening devices should preferably be used at night, when there is less noise interference. An approach can be made by connecting the prober to the metallic components of fire hydrants, gate valves, consumer shut-off valves and similar fittings, thus locating the site of the defect from the noises picked up in this manner.

Although instruments can be of much use in cases of emergency, accurate mapping and recording is essential. To determine the routing, trenches must be made at right angles to the axis of the mains being tested.

Sudden changes observed in hydraulic pressure ratios (especially high pressure ones) are clear indicators of mains failure. For minor waterworks, sudden drops of pressure can be observed on the pressure gauges in the power rooms. For major waterworks, only the failures of main delivery lines can be detected in this manner. Pressure tests must be performed at individual points along the mains systems; recordings of rather low pressure are likely indications of pipe failure; an accurate location of the leakage should then be made as described above.

The pressure measurements obtained in the course of a single control test series (performed with the knowledge of service pressure ratios in the system) should be closely compared with the records; any deviation from them may indicate a mains failure.

In addition, a major outflow of water is likely to be indicated by a sudden and unexplainable increase in the rate of water delivery. Operators of waterworks must know not only the pressure ratios prevailing in their systems, but also the rates of delivery associated with normal service conditions. The rates of water flow are recorded by water meters. For minor waterworks, such meters are mounted in the power rooms, whereas for major ones they can also be found at several points along the mains systems. Deviations from the data obtained for normal operating conditions indicate mains failures.

Special mention should be made of water losses caused by leakages inside blocks of flats and homes. It is advisable to inspect the water pipes and fittings in homes at regular intervals, so that repairs can be carried out when necessary. Leakages can be detected in homes by means of the instruments described above and also by use of built-in water meters that can furnish data in this respect.

Line sections should be listened to at night for failure detection; any unexpected increase in water consumption is a fairly sure sign of internal leakage in a building.

The method adopted for repairing defective water pipes is determined by the characteristics of the defect and the structural material of the line. The cause of the defect must be discovered and eliminated as soon as, and to the extent, possible.

As a rule, pipe breakages can have two causes: poor foundations, e.g. inappropriate laying, use of defective materials, heavy corrosion; and mechanical effects stemming from the surrounding environment, e.g. heavy traffic, impact on pipes by moving objects, or ground movement.

On observing pipe breakages and any upsurge of water, the damaged line section must be separated from the mains system as quickly as possible by means of the gate valves serving this purpose. The same measures must be taken if the health authorities announce that the water supplied to consumers is injurious. Thereafter, powerful chlorine flushing must be carried out and the cause of pollution clearly determined.

The most widely adopted method for repairing broken lines is to replace either the damaged piece, or the entire line section involved. It is advisable to use spare flanges (Fig. 5) to repair all types of water pipe. Spare flanges can facilitate matching line sections of different materials quickly and easily and function as assembly adapters in joining flanged couplings to pipe sections.

Except for steel lines and prestressed concrete lines, damaged lines should be repaired by making use of double-sliding sockets, Gibault joints or fasteners of a similar design.

Damages covering small surface areas, as well as lateral breaks, can be repaired simply and quickly by means of split-type bolted flanges with rubber seals or with single-piece chromium steel clamping collars provided with rubber seals. In this manner the damaged lines need not be cut off while being repaired.

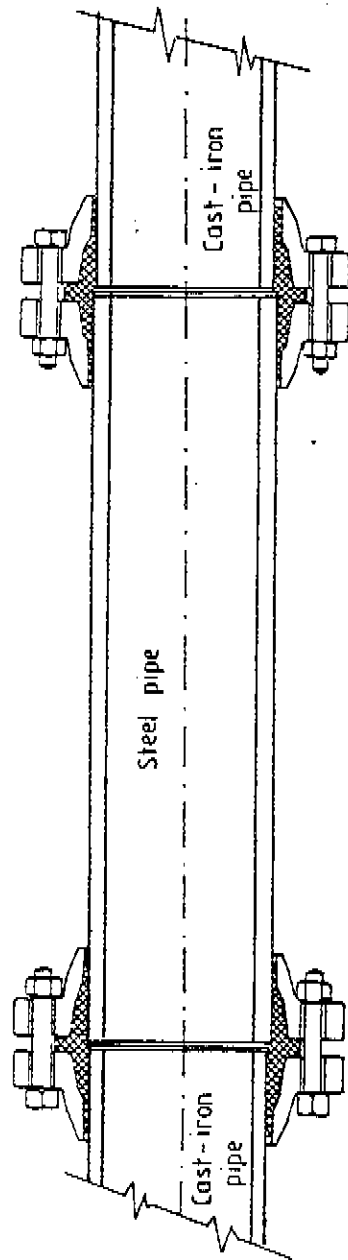
Steel piping must be repaired by welding; after making the repair it is important to apply corrosion protection to the original pipe. When installing flanged gate valves, mounting adapters may have to be used. Underground lines may only be secured with bolts and nuts, either made of corrosion resistant steel or adequately protected against corrosion. When repairing damaged consumer connections, the materials and devices originally installed should preferably be used. Defects most likely to hinder the appropriate functioning of fittings are:

- fasteners (damaged by corrosion)
- threads (stripped)
- spindles (broken)
- support rings of spindles (broken)
- seal rings (missing)
- gate valve covers (cracked)
- Vee-groves (sedimentary deposits)
- gate valves (incomplete sealings)

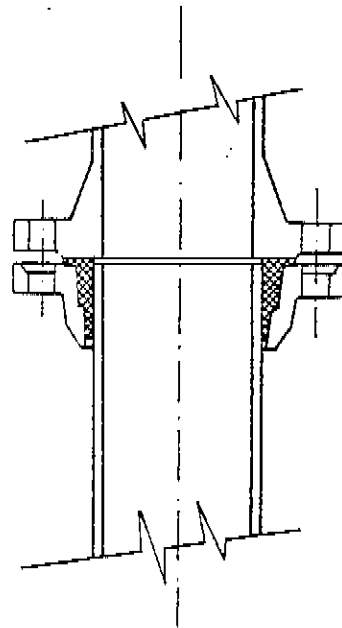
Such defects can be detected in time through regular and careful inspection of fittings; some of the repairs can be carried out at the site and some in a workshop. Repair is greatly facilitated by an adequate supply of spare parts; under normal conditions defective components can be removed to a workshop for competent repair. Overhauled components can be recycled as replacements. Worn-out components and fittings should be discarded.

Following repair of potable water lines, the sections affected must always be disinfected, since they could have been polluted while undergoing repair and thereby represent a health risk to consumers.

Fig. 5 Application of spare flange



JOINING PIPES OF DIFFERENT STRUCTURAL MATERIALS BY MEANS OF SPARE FLANGES



SPARE FLANGE AS MOUNTING ADAPTER AT JOINT OF FLANGED FITTING AND PIPE

No clear estimates can be given regarding the quantity of fitting parts and other components needed for repairs since this depends on a host of factors such as pressure ratios, ground conditions, degree of building density, rate of traffic and quality of maintenance. As a rule of thumb, an estimate of one pipe breakage and 20 pipe damages can be made for every 10 km of line per year. It is not worthwhile to keep in stock more than 5 percent of the pipe sections and fittings installed. Line sections, fittings, etc., earmarked for repair, should be stored separately.

CHAPTER X

DEFECTS OF PUMPS AND THEIR REMEDY

Causes of defects most frequently encountered and methods for their remedy:

1. Pump fails to deliver any water at all; manometer swings out heavily. Disorder suspected on intake end of pump. Likely causes:

- Either the pump has not been primed properly before starting and consequently air has entered the intake line, or the foot valve at the end of the intake line failed to close and the water which flowed in during priming was lost just before switching on.

Whether the foot valve and intake line have been sealed appropriately can be ascertained by priming the pump again and inspecting it for leakages. The foot valve can be leaky because of a worn out leather seal or because grit has lodged under the valve plate. To remedy this a new leather seal and/or clean foot valve should be mounted.

- Leakage in an intake line can cut off water delivery, since air would then be able to enter the pump. Correct sealing of an intake line can be checked by means of a pressure test.
 - Air could have entered the pump via the stuffing gland on the intake end if the stuffing compound has worn off or become hardened.
 - Failure in water delivery can be due to a blockage in the intake line. This defect is difficult to detect and remedy, and is frequently encountered when ferrous and manganiferous water is being delivered.
 - Air can enter the pump via a short delivery line, especially if the delivery head is low and the distance of suction is high. Consequently, it is deemed absolutely necessary to install a gate valve on the delivery branch of every pump and to shut off that valve when starting.
 - The speed of a pump is lower than specified, thus being inadequate for achieving effective delivery head. The cause of this can be a too low cross-sectional area of power feed cable, or too great a voltage drop occurring in a cable which is too long.
 - A pump runs in the wrong direction. The correct direction of revolution is indicated by an arrow on the pump scroll. The direction can be reversed by interchanging power cables on the driving motor.
2. Gradual decrease in the rate of delivery. Likely causes:
- Level of suction keeps dropping during operation; as a consequence, delivery head keeps increasing and rate of delivery keeps decreasing. This malfunction often occurs with shaft and driven wells, where an inadequate supply of water results in a reducing level. To remedy this, either the pump should be operated intermittently, or the gate valve partly closed.

- A voltage or frequency failure causes pump speed to decrease. To remedy, switch off driving motor until normal mains power can be restored.
 - Owing to a partial blockage of the inlet rose head and/or intake line, the resistance will increase and an unusually high vacuum reading will be observed. To remedy, clean blocked parts.
3. Water is delivered in an explosive manner. Likely causes:
- Air has entered the pump via either the leaky parts in the intake line or the stuffing gland. To remedy, stop leakages. The same malfunction can be observed if the foot valve or inlet rose head is not installed at a sufficient depth under the water level, and the vortex occurring over it carries air into the scroll. To remedy, sink inlet rose head deeper into the water.
4. The driving motor of the pump consumes too much power. Likely causes:
- because the delivery head is lower than envisaged, the pump delivers more water and thus increases power consumption;
 - grit between impeller and scroll case of pump causes friction and retards impeller;
 - shaft of impeller is bent under stress stemming from an overtightened stuffing gland or misaligned coupling.
5. Pump fails to deliver water at a sufficient rate. Likely causes:
- pipeline is blocked or gate valve not fully open;
 - impeller blades are worn;
 - direction of revolution is wrong;
 - phase failure in electric motor.
6. Pump runs hot. Likely causes:
- owing to excessive wear, impeller chafes against scroll case;
 - presence of grit between impeller and scroll case;
7. Stuffing gland is overheated. Likely causes:
- gland is overtightened or unevenly tightened;
 - lubricant contains sand;
 - lubricant is inadequate;
 - bearing is out of alignment.
8. Pump is vibrating while in operation. Likely cause:
- nuts on set bolts are slack.

9. Pump makes too much noise. Likely causes:

- air has entered the scroll case via leaky points. To remedy, stop leakages;
- water level has dropped in well, thus increasing actual suction head; perhaps a cavity has been created;
- rate of water delivery is too high, whereas head of delivery is too low; defect can be ascertained by taking a manometer reading. To remedy, adjust setting of gate valve.

Maintenance of pumps should be scheduled in accordance with the desired standard of operation and the structural material of pumps (bronze or iron impellers). Provided that management is sufficiently experienced, the dates for servicing can be accurately estimated for every pump in the system.

Even if operated within their optimal range of delivery, pumps will continue to lose effectiveness with every completed hour of operation. Consequently, within the framework of preventive maintenance, every pump must be completely disassembled from time to time for thorough inspection for wear. For pumps operating with clear water, this period is 10 to 15 thousand hours of operation; in other words, one or two years for units almost constantly in operation. Plunger pumps should be dismantled for inspection and cleaning after every 4 to 5 thousand hours of operation. A drop in efficiency observed on the instrument panel will indicate that the maintenance programme has not been adhered to and that an overhaul is overdue.

The slit ring located at the intake hole should be inspected for an excessive increase in the clearance between the impeller and scroll casing. The clearance should measure 0.2 mm to 0.3 mm, so as to ensure an adequate delivery head. The load relief disc must also be inspected for wear, since if either the disc or the seal ring facing it shows excessive wear, a high axial force is being applied to the bearing, resulting in overheating.

It is also possible that owing to chemical, electrolytic, cavitation or erosion effects, both the impeller and the scroll case are heavily damaged. Both frictional resistance and clearance leakage occurring via the cavities will impair efficiency. If such defects are detected, the pump must be disassembled for inspection as often as once a year or even every six months; at the first sign, cavities must be filled in by welding and the original surface restored by filing and grinding. Some components may simply have to be replaced by new ones.

Cavitation damage can be prevented by operating the pump at a suction head corresponding to its suction capacity.

Abrasion wear occurs when delivering sandy water, e.g. from wells. This type of damage can be reduced if the gate valve is opened gradually at the delivery end on starting, and by cleaning the wells very thoroughly by compressor blasting before commissioning. Cleaning by compressor should be repeated every two to four years, so as to minimize the quantity of sand entering the filter case.

Heavy shaft end and stuffing gland wear can be the effect of abrasion. This can be caused by the pressure applied on the friction surfaces by solidified or inappropriately selected sealing compound. To protect the shaft end from heavy wear, it is advisable either to pull a sleeve over the section matching the stuffing gland, so that only the sleeve will have to be replaced and not the entire shaft, or to restore the shaft end to its original size by metal spraying.

In pumps delivering highly ferrous water, ferrous hydroxide often sticks to the surface in contact with water, also in between the impeller blades. The likelihood of such deposits is especially high when iron is present in water in the form of decomposing carbohydrates. Since such deposits lower the cross-sectional areas, the rate of delivery is reduced and thereby also pump efficiency. To remedy, disassembly for cleaning should be scheduled after every six months of operation, and not later than a year.

Pump operators should be aware of the fact that bearings have a service temperature of 50°C. (max.70°C.). The oil level in plain bearings, usually at the axis of the shaft, should be checked from time to time. Bearing recesses and lubricated rolling bearings should be filled with lubricant to a maximum of three-quarters capacity. Spent lubricant should be removed from the bearings about every six months, after which the bearings should be cleaned with petroleum and filled with fresh lubricant. Stuffing compound must be placed into the stuffing glands accurately, matching square ends which are to be turned in relation to each other after insertion. Pumps must never be operated dry, since without water the impellers will overheat and quickly seize up. Stuffing glands should not be overtightened since this would cause the stuffing compound to harden and retard the shaft, thus not only increasing power consumption but also leaving heavy seizing marks on the shaft. It is preferable to let the stuffing glands drip to a slight extent, even at the intake ends, provided they are supplied with sealing water.

CHAPTER XI

DEFECTS OF ELECTRIC MOTORS

In mounting electric motors, care must be exercised to prevent bearings from coming under stress, to adjust coupling discs parallel to each other, and to leave adequate axial play.

Load applied to electric motors can be controlled on the ammeters (if mounted). Pump operators should be acquainted with the power consumption of their electric motors under normal operating conditions.

The following major sources of defects are likely to be encountered:

- overload
- drop in mains voltage
- phase failure in mains supply (one phase drops out of three phases)
- overload due to coil short-circuit or some other defect in motor coil.

Fuses serve to protect electrical equipment from overloading. Overloading in the circuit will cause the fuse wire in the standard fuse cartridge to melt, thus breaking the circuit. On replacing fuse cartridges, care should be taken to insert only brand new, factory-made fuses of standard rating corresponding to the circuit in question. To avoid a repetition of the problem, the cause of the overload should be found. Melted fuse wires should under no circumstances be replaced with the wrong type or gauge of wire, since this could jeopardize the safety of the circuits.

Overload protection is provided by the thermal outputs (protective switches, contacts) which are tripped through the fourth-wire system as soon as power supply fails or mains voltage drops under a preset level. Should an electric motor stop as a consequence of mains power failure, the motor switch should be reversed to OFF and the cause of the failure found before switching on again.

Fuses and switches should always be accommodated in cabinets and these ought to be kept safely locked.

During operation, the bearings and cowls of electric motors must be regularly checked for overheating.

Induction motors require little attention and can operate for years without repair. Moreover such motors can endure prolonged overload, but they are not absolutely "fail-safe"; the following defects can occur:

1. Three-phase induction motor (asynchronous motor) fails to start, or can start only very slowly, emitting a loud humming noise. Likely causes:
 - broken cable in stator
 - broken cable in rotor
 - broken cable leading to ON switch
 - dirty contacts in switches
 - uneven air gap between the rotor and stator
 - too high resistance in rotor
 - stuffing glands of pump driven by motor are too tight, or coupling is misaligned.

2. Motor lagging when switched on, and speed tending to drop under load.
Likely causes:

- overload
- too low mains voltage, possibly due to undersize cables
- incomplete contact in stator coil
- faulty circuit
- phase failure
- broken solder in rotor.

Failure of the main voltage will mean that the motor will fail to hum when switched on.

Should any of the phase leads be broken in the stator, the motor will continue to run on two phases, but tends to overheat when loads exceed 50 percent.

Should a rotor lead break during operation, speed tends to drop under high loads.

If difficulty is experienced in starting a motor (producing a deep growling noise), and the bearings are hot, these may be defective and replacement of shells or rolling bearings necessary.

A deep growling noise can also be an indication of short-circuits in the stator coils.

3. Overheating in stator coils. Likely causes:

- overload
- wrong circuitry
- short-circuits in coils.

Large motors are cooled during operation by built-in ventilating fans.

4. Motor bearings can overheat for the following reasons:

- use of low-grade oil
- inadequate lubrication (oil level is low)
- blocked oil grooves (passages) (if plain bearings)
- lubricator rings seized in oil compartments (if plain bearing)
- bearing seized
- motor shield misaligned.

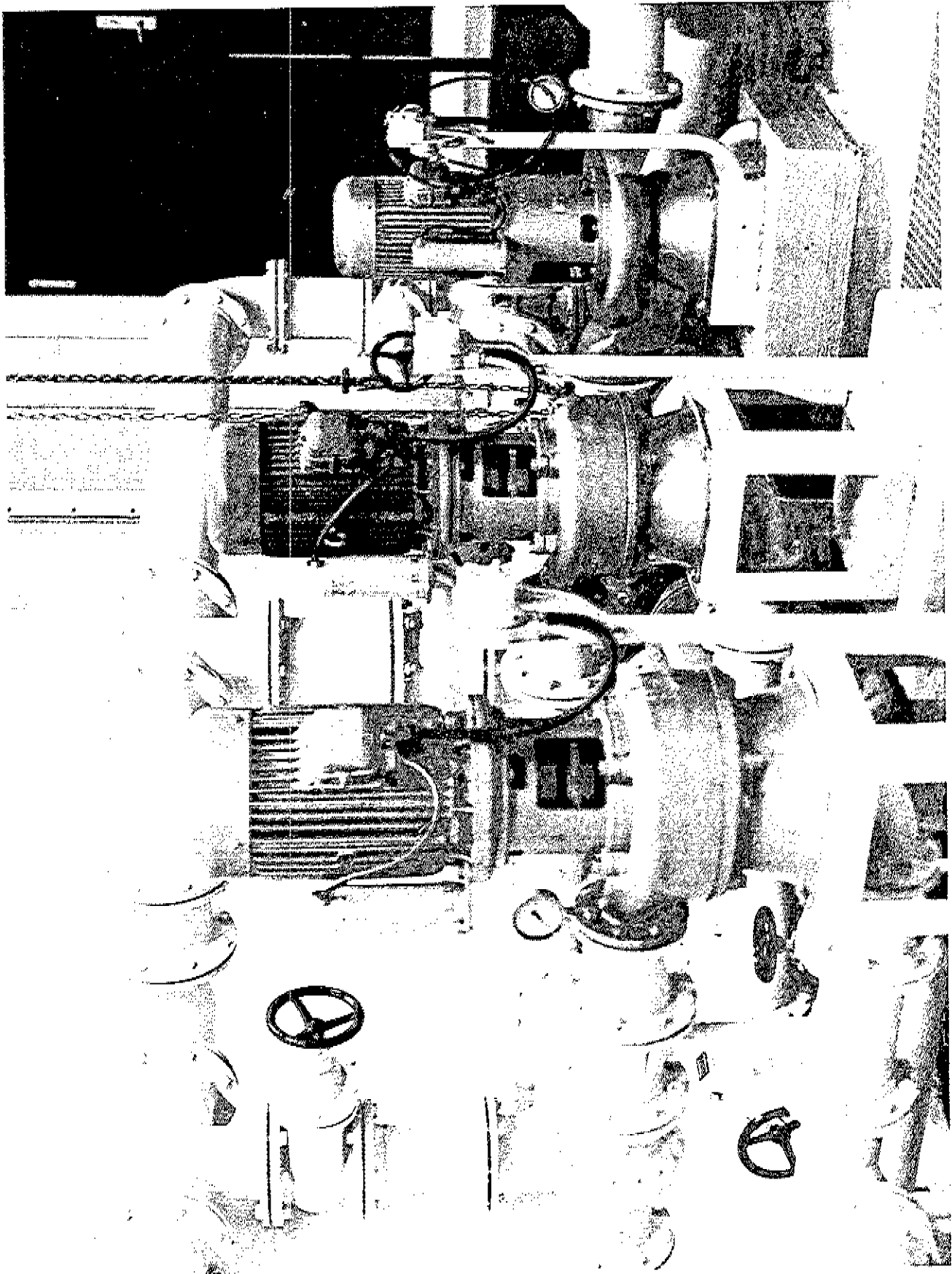
CONCLUSION

The purpose of this document has been to draw the attention of responsible officers of small rural waterwork systems to the importance of specific aspects of an operation and maintenance programme, for the optimization of water supply.

Special emphasis has been placed on the need for preparing a plan of maintenance and for availability of job descriptions for each of the workers involved in the operation of the system. Mention has also been made of the importance of the existence of appropriate documentation (plans, charts, engine diagrams, statistical records, etc.) to allow for an effective evaluation of the water supply systems. Systematic supervision together with availability of essential spare parts and tools were considered of utmost importance for the achievement of the objectives of the operation and maintenance programme.

However, the author without disregard for the importance of other aspects of an operation and maintenance programme has focussed his major contribution on the detection and elimination of defects in all phases of the production and distribution of water. From this point of view, the efforts of the author will be highly rewarded if this document will help water workers overcome the difficult task of identifying and solving operational problems.

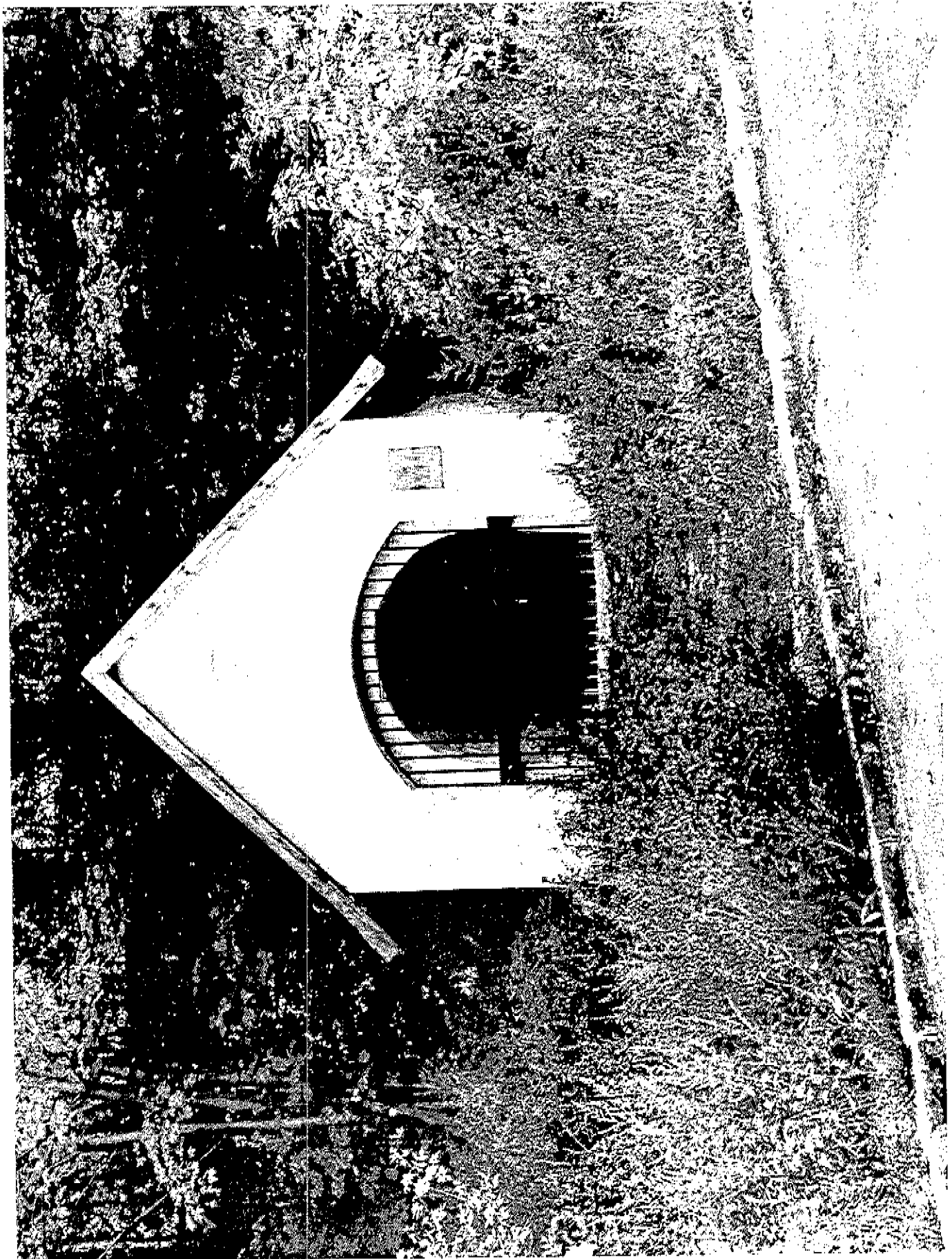
Picture 1



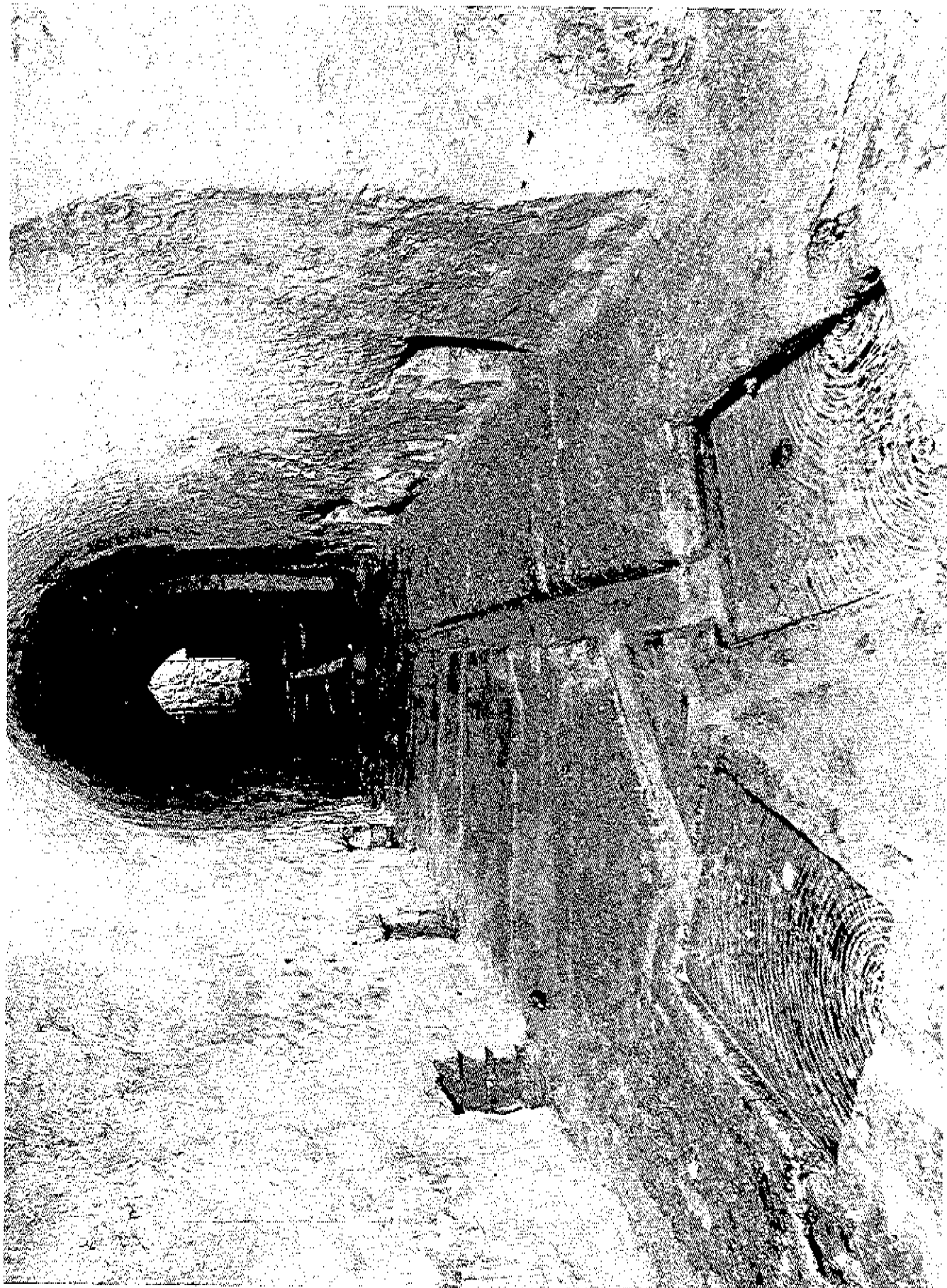
Picture 2



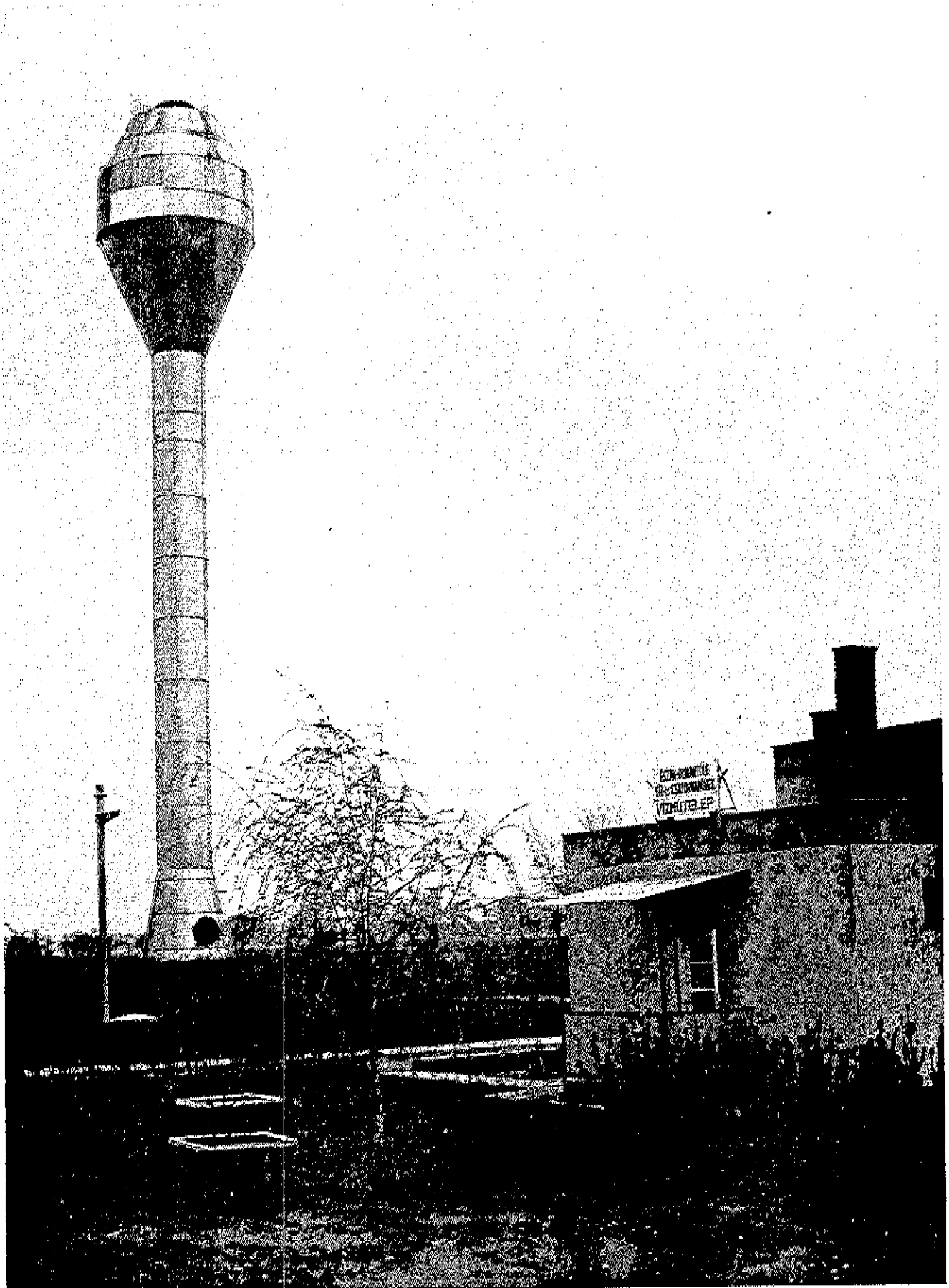
Picture 3



Picture 4



Picture 5



Picture 6

