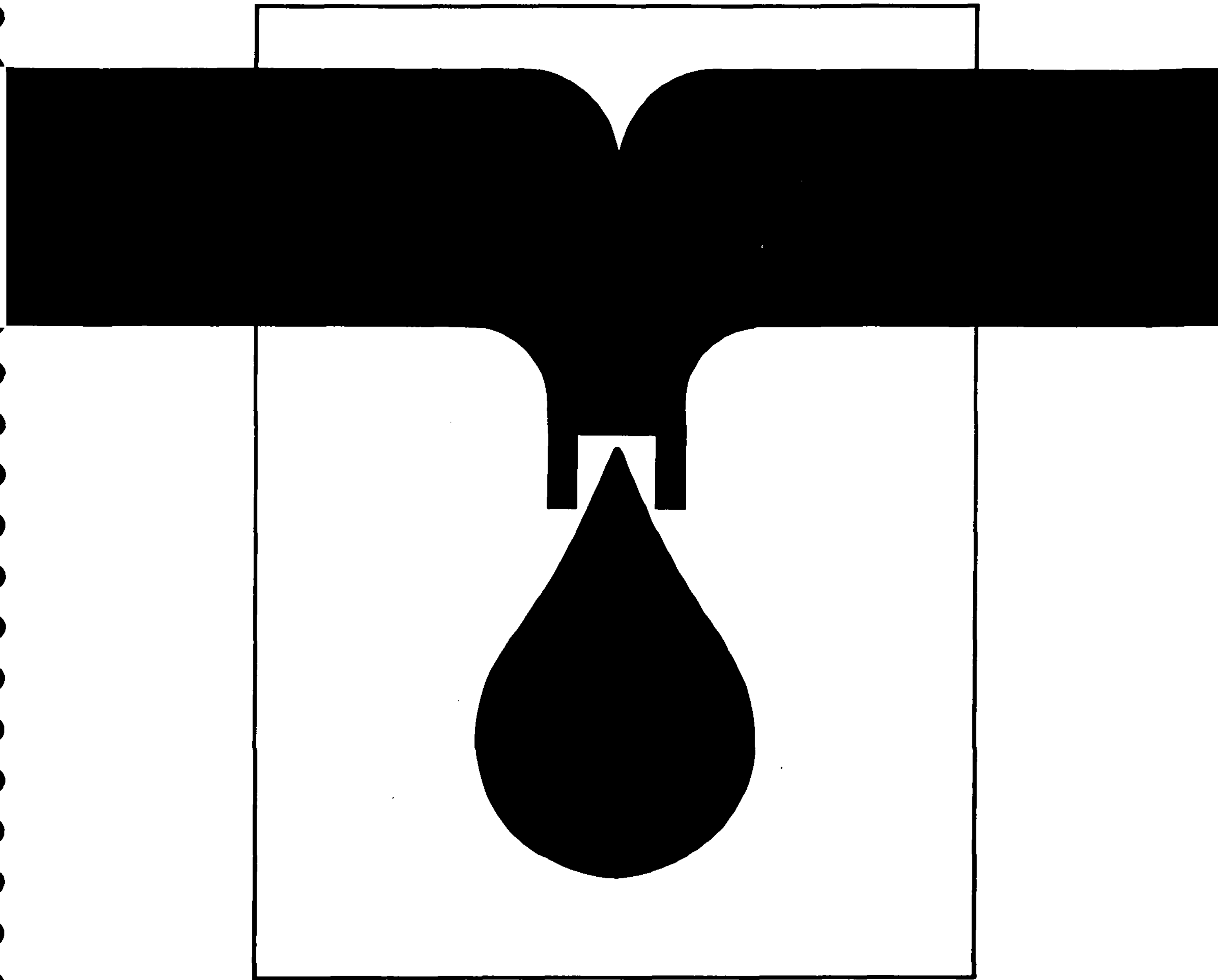
TRAINING MODULES FOR WATERWORKS PERSONNEL



Special Skills

3.7

Inspection, maintenance and repair of water mains

Foreword

Even the greatest optimists are no longer sure that the goals of the UN "International Drinking Water Supply and Sanitation Decade", set in 1977 in Mar del Plata, can be achieved by 1990. High population growth in the Third World combined with stagnating financial and personnel resources have led to modifications to the strategies in cooperation with developing countries. A reorientation process has commenced which can be characterized by the following catchwords:

- use of appropriate, simple and – if possible – low-cost technologies,
- lowering of excessively high water-supply and disposal standards,
- priority to optimal operation and maintenance, rather than new investments,
- emphasis on institution-building and human resources development.

Our training modules are an effort to translate the last two strategies into practice. Experience has shown that a standardized training system for waterworks personnel in developing countries does not meet our partners' varying individual needs. But to prepare specific documents for each new project or compile them anew from existing materials on hand cannot be justified from the economic viewpoint. We have therefore opted for a flexible system of training modules which can be combined to suit the situation and needs of the target group in each case, and thus put existing personnel in a position to optimally maintain and operate the plant.

The modules will primarily be used as guidelines and basic training aids by GTZ staff and GTZ consultants in institution-building and operation and maintenance projects. In the medium term, however, they could be used by local instructors, trainers, plant managers and operating personnel in their daily work, as check lists and working instructions.

45 modules are presently available, each covering subject-specific knowledge and skills required in individual areas of waterworks operations, preventive maintenance and repair. Different combinations of modules will be required for classroom work, exercises, and practical application, to suit in each case the type of project, size of plant and the previous qualifications and practical experience of potential users.

Practical day-to-day use will of course generate hints on how to supplement or modify the texts. In other words: this edition is by no means a finalized version. We hope to receive your critical comments on the modules so that they can be optimized over the course of time.

Our grateful thanks are due to

Prof. Dr.-Ing. H.P. Haug
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for their committed coordination work and also to the following co-authors for preparing the modules:

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It is my sincere wish that these training modules will be put to successful use and will thus support world-wide efforts in improving water supply and raising living standards.

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Eschborn, May 1987

Title: Inspection, maintenance and repair of water mains

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1 Marking the locations of pipes and installed components

1.1 Marking in the field

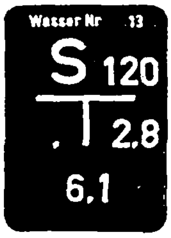


Fig. 1 Sluice valve sign

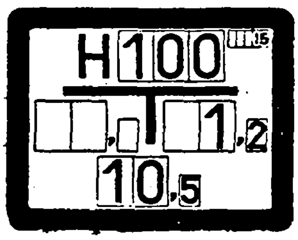


Fig. 2 Hydrant sign

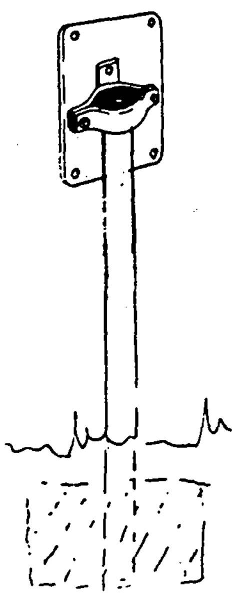


Fig. 3 Sluice valve sign with concrete foundation

The positions of hydrants, air valves, flushing and stop valves in pipes laid underground are marked on the surface so that they can be more quickly and easily found.

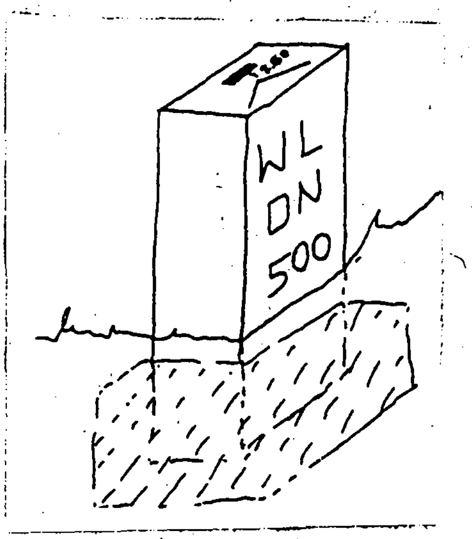
In the case of service mains in built-up areas, marking signs can usually be attached to the side of a building; if this is not possible they are fixed on posts.

The sign gives the distance to the valve or other component and the diameter of the water main.

- Cf. figs. 1 and 2 -

Where mains run through open ground, the positions of bends are marked by stones (cf. fig. 4).

The marking stone - wherever possible a natural stone - is set in concrete exactly above the apex of the pipe. If this is not possible, for instance if the main runs under or very close to a road or track, the marker is set as close to the apex as possible and the distance between stone and apex cut into its top surface.



The stone must refer clearly to the water main, giving its diameter. The height of the stone above the level of the ground depends on the expected eventual height of the vegetation around it.

Fig. 4 Marking stone at a distance from the main

1.2 Field and location plans

Drawn plans of the location of underground water mains make it easier to find the installations when necessary, e.g. to carry out maintenance, inspection or repair work or to fit new pipe sections. They are also used in hydraulic calculations and, in urban areas, as a source of information for the routing and laying of other utilities.

Examples of such plans are shown and discussed below.

Field plans

Field plans (cf. fig. 5) are sketches, not drawn to scale, showing important components such as fittings, hydrants, valves, drain outlets, air valves; also references to permanent fixed points such as cadastral boundaries or buildings.

As a rule, the field plans are drawn in the course of pipe-laying work by the team foreman, employing standardized symbols.

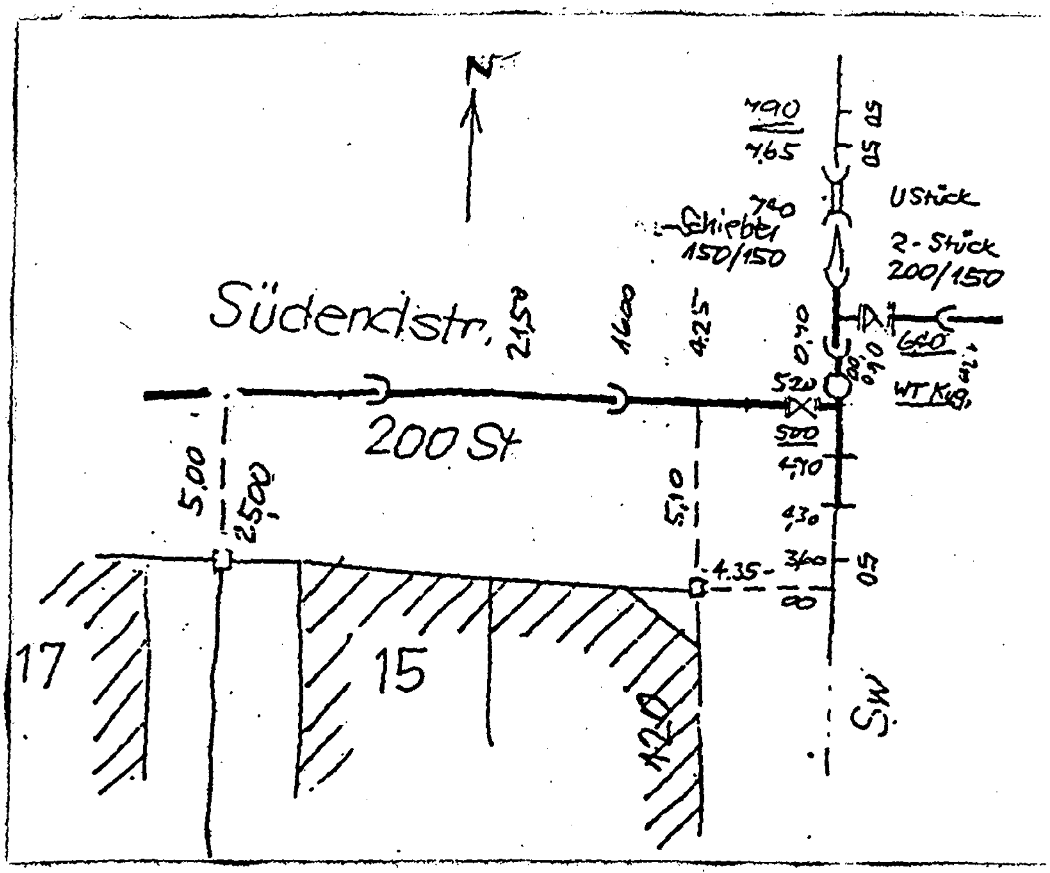


Fig. 5: Field plan

Location plans

Location plans (cf. fig. 6) are plans plotted to a given scale showing existing mains with complete details, such as diameter and material of the pipes, important fittings, valves, branches, communication pipes, plus the locations of pipe bends and distances from boundaries.

Commonly used scales:

for larger service mains systems 1:500

for long-distance transmission mains 1:1000

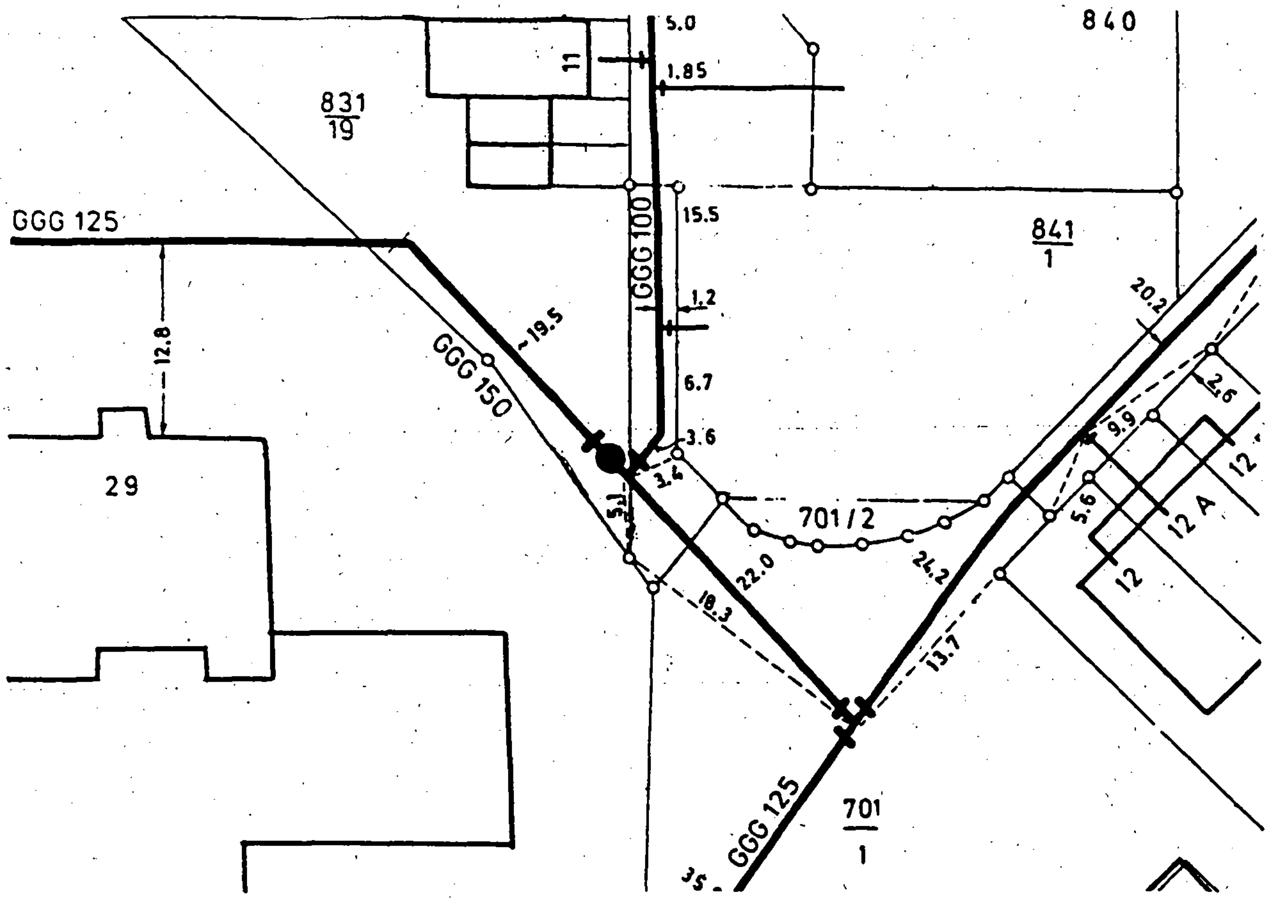


Fig. 6: Location plan, scale 1:500

Lay-out plans (cf. fig. 7) give the principal information on water mains, i.e. their routes, diameters, material and valves, etc. plotted to a relatively small scale. For larger mains systems, the scale should be 1:2000 and the sheets based on the grid system.

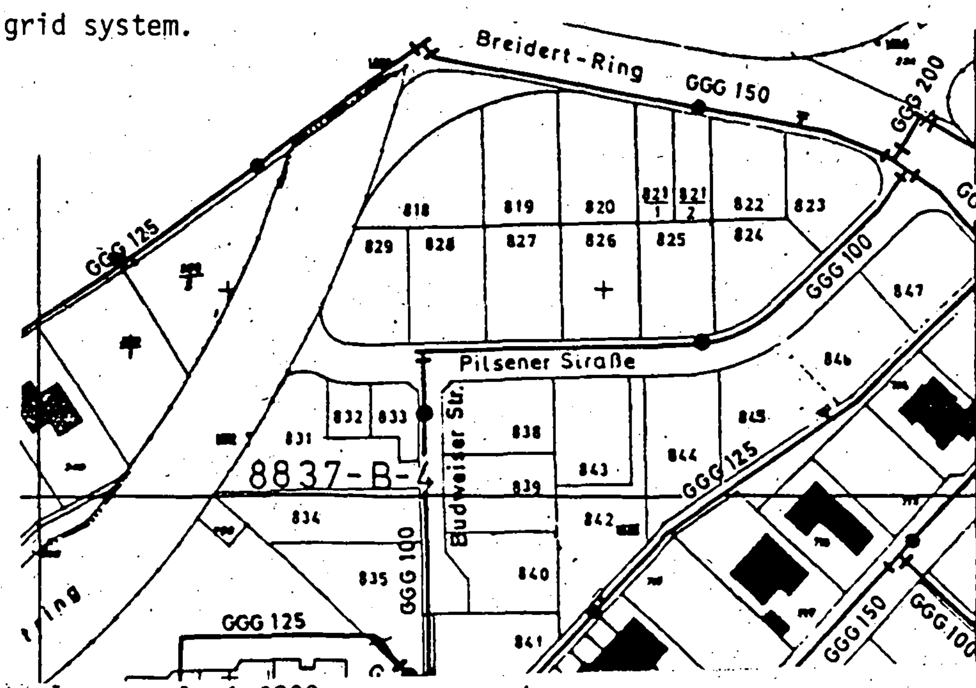


Fig. 7 Lay-out plan, scale 1:2000

1.3 Marking and safeguarding of stop valves with special functions

Stop valves which have been given functions in addition or contrary to their normal task must be especially safeguarded and marked (cf. fig. 8). This applies in particular to stop valves which ought normally to be closed; e.g. sluice valves which separate different pressure zones, washout valves or sluice valves in diversion or by-pass pipes.

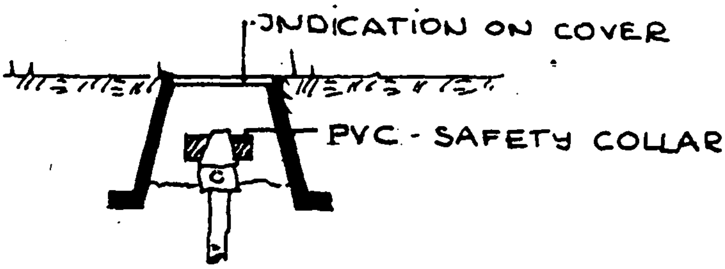


Fig. 8: Safeguarding of a sluice valve

2 Causes of water losses, monitoring of losses

2.1 Causes of water losses

2.1.1 Genuine losses

These are caused by:
defective material, damage during transport, mechanical damage,

mistakes made in bedding, such as laying pipes on or covering them with stony material, pipe not properly supported, damage caused by frost,

mistakes made in operation, such as pressure surges ("water hammer") due to incomplete release of air, too rapid closing of valves, switching on and off of pumps,

corrosion resulting from aggressive soils, inadequate insulation of metal pipes, aggressive water, leaking pipe joints, e.g. because pipe is angled too much out of its axis or a bend is inadequately supported by an thrust block,

leaking valves, e.g. due to brittle or worn stuffing-box packings, drain sluice valves which are not longer watertight, defective seating of tapping clamps.

2.1.2 Causes of unauthentic water losses

These can be due to meter inaccuracy, dirt or air accumulation round the meter, unauthorized drawing-off of water, dripping or running taps.

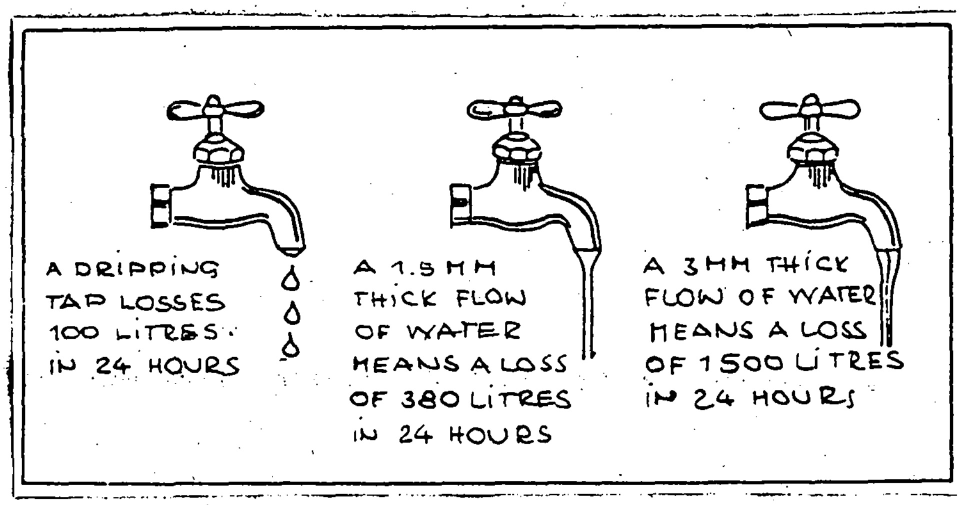


Fig. 9: Losses from leaking taps

2.2 Methods of monitoring losses

2.2.1 Through measuring and comparing infeed and consumption volumes

If both infeed and consumption volumes can be measured, the water losses from a system are given by the difference between the volume fed in a defined period of time into the system, and the amount supplied during the same period from the system to the consumers.

Use of this method is usually not practicable, however, due to the considerable time and effort involved in reading the domestic water meters in order to register consumption; often no meters have been installed or they are in need of repair.

2.2.2 Continuous comparison of infeed volumes

Experience shows that relatively stable patterns of water consumption over certain periods of time, e.g. a day, week, month or year, can be determined for separate areas, depending on their character - e.g. residential areas where people have comparatively regular habits.

Through a continuous comparison of the volumes of water fed into the mains during each unit of time, relative to the number of residents - e.g. consumption per person per day, month or year - a relatively clear picture of water losses can be obtained without measuring individual consumption. Amounts of water supplied to large-scale consumers - e.g. factories, hospitals etc., and also the effects of temperature, must be taken especially into account when using this method.

2.2.3 Monitoring of nocturnal consumption

As a rule, the sonsumption of water in residential areas drops to virtually 0 between 1 a.m. and 4 a.m. - the "zero consumption period".

If the actual amount of water going into the mains during this "zero consumption period" is measured, this gives a sufficiently accurate indication of losses from the system. The section of the mains system examined in this way should be kept as small as possible.

The measurement itself can be carried out either via the level in water tanks, with the feed pump switched off, or else by using water meters.

Fig. 10 shows the progress line of water consumption in a district with 2,800 inhabitants. Intake into the mains during the "zero cosumption period" is approx. 3 m³/h; this figure is within the limit of what is to be expected and does not give grounds to suspect major defects in the system.

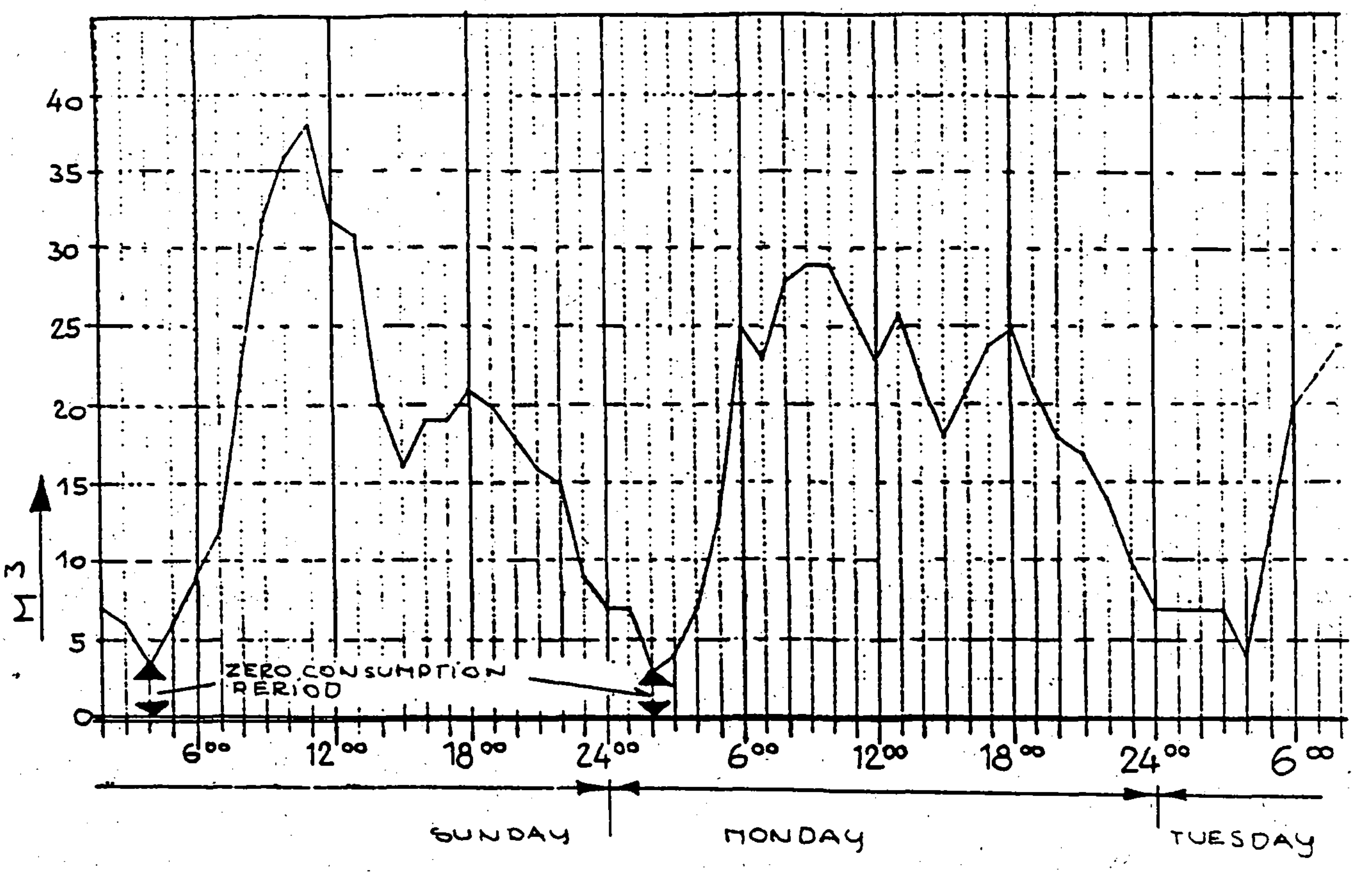


Fig. 10: Progress line showing the amounts of water supplied to a district with approx. 2,800 inhabitants

2.2.4 Measurement of intake

The principle of measuring intake into the system lies in establishing times when, in the area under consideration, there is no consumption of water - "zero consumption periods" - and simultaneously measuring the volume of water actually flowing into the mains.

The assumption is that there is a virtually constant amount of water flowing continuously into every supply area, which escapes from defective pipes, valves etc., and that the genuine consumption of water is in addition of this quantity.

When using this method of measurement, the following conditions must be observed:

Measurements must be carried out between the hours of 1 and 4 at night - the "zero consumption period".

The intervals between separate measurements depends on the number of inhabitants in the district.

General guide:

up to 1500 inhabitants: measurement of intake every 2 minutes;

up to 3000 inhabitants: measurement of intake once a minute.

The following figures show the relationships between the number of inhabitants, the timing of measurements and their results.

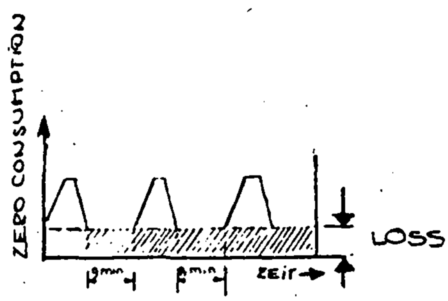


Fig. 11:
Low number of inhabitants, short intervals between measurements. The result is good, but measurements are unnecessarily close together.

Fig. 11

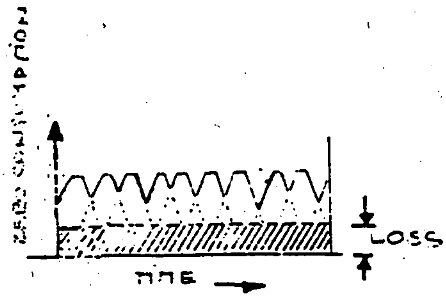


Fig. 12:
The number of inhabitants is too large; the draw-off times intersect. The zero consumtion quantity is not indicated.

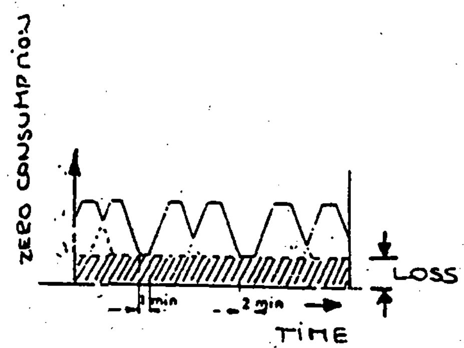


Fig. 13:
Number of inhabitants and timing of measurements are in optimum relation to each other. The results are good.

The procedure followed in measuring intake quantities is shown in figs. 14 and 15. The section of the mains system to be examined is isolated by means of sluice valves and supplied via a by-pass pipe with built-in water meter.

Since the colume of water expected to flow through the pipe is relatively low, a small-diameter by-pass pipe and corresponding water meter are adequate.

Measurement of the flow through the pipe is then carried out by reading the meter at predetermined intervals, or by use of a transmitter which records the flow volume via measurement pulses and a recorder.

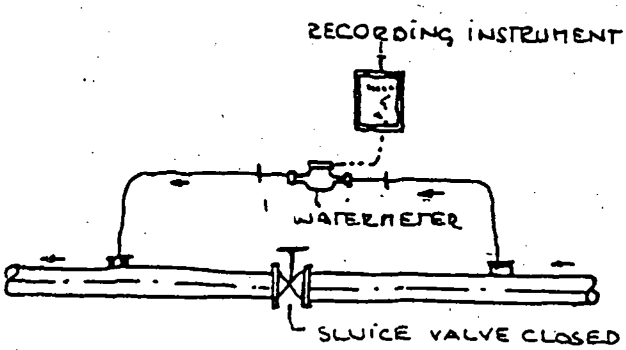


Fig. 14: Test run with by-pass hose and meter between hydrants

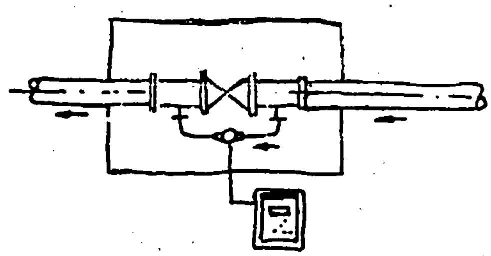


Fig. 15: Test run in a manhole

If this procedure shows that major leakages must be occurring, the exact positions of these can be narrowed down by methodically isolating sections of the main.

3 Location of leaks and pipe locating devices

3.1 Visual inspection of mains

By walking along the route of the main, various observations can be made, any of which could indicate that there is leakage: e.g. damp or boggy ground, differences in the vegation, ground subsidence due to sub-surface erosion, thawing of snow or unexpected, not previously registered emergence of water on the surface. In built-up areas with a sewerage system, increases in the volume of water in the sewers with clear water can indicate that water is entering the drains from the drinking water supply system.

3.2 Auditory location of leaks

When water escapes through a small opening at high speed, it causes a rushing noise which is transmitted through the pipe and, to a lesser extent, also through the earth covering the pipe. The nearer the point of escape to the listener, the louder the noise. Leak detection by means of sound location is best carried out at night, when there is no interfering background noise from traffic or water being drawn off by consumers. Location of the leak is carried out in two separate operations.

Preliminary location (narrowing down) of the fault using existing points of contact, such as hydrants or sluice valve rods (coarse location).

Precise location of the fault

Electro-acoustic sound location devices are used here.

3.2.1 Coarse location

In the coarse location of a leak, a test rod with a microphone is firmly attached to a piece of equipment in contact with the pipe, e.g. a sluice valve rod or hydrant. Often a simple rod already transmits the sound adequately.

As a rule, headphones are used to allow the listener to differentiate between the noise of flowing water and that of water escaping from the pipe; a discriminatory sense of hearing is essential. If a sound is detected which differs from the normal sound background, comparative tests are made at other points in the vicinity, with the sound location device set at the same amplification factor. The position of the leak can be expected to be between the two points at which the sound was loudest.

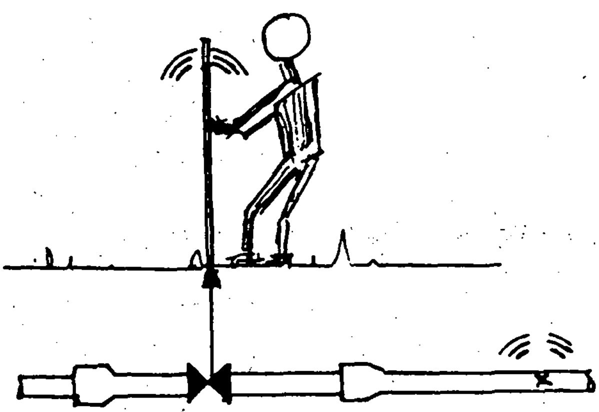


Fig. 16: Coarse location with metal rod

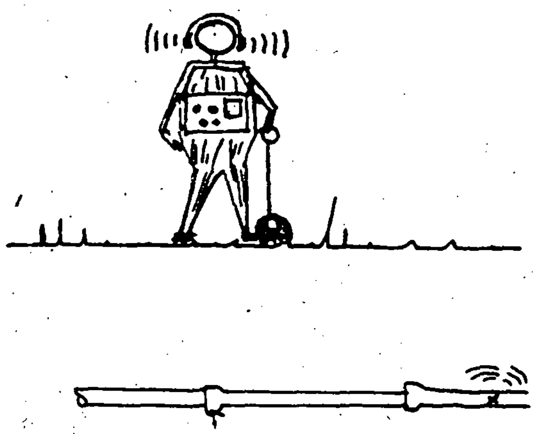


Fig. 17: Presice location with ground microphone

3.2.2 Precise location

Precise location of the leak within the section established during the first phase is carried out using a ground microphone. Unlike the test rod, which is in direct contact with the pipe, the microphone works with indirect contact. The microphone is placed every 0.5 to 1.5 m along the route ot the main, and the sound pattern which is transmitted to an instrument and through headphones to the listener is continuously compared. The point at which the sound reaches its highest intensity will usually indicate the position

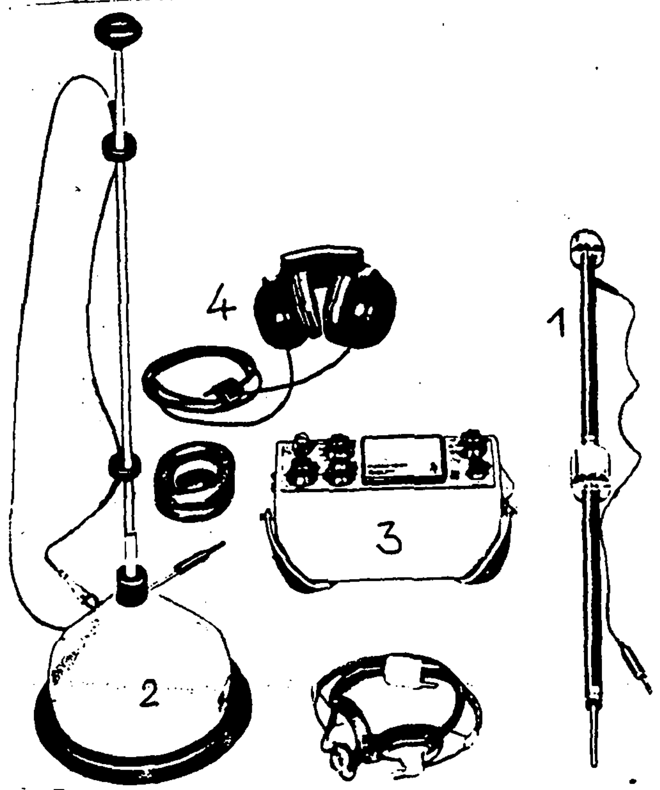


Fig. 18

Fig. 18:
Equipment used in electro-acoustic sound location

1 Test rod
2 Ground microphone
3 Indicating instrument

3.3 Correlation method

This method, which is a comparatively recent development, permits leaks to be located regardless of background noise.

Procedure:

By means of magnetic sound sensors, attached to equipment which is in direct contact with the main, the sound waves produced by the leak are fed to a computer. The computer can localize the leak in a very short space of time through a continuous analysis of the sound waves.

3.4 Chemical method

If it is unclear whether water emerging on the surface originates from a water main or not, comparison of its composition with the characteristic known composition or properties of the mains water can be carried out.

This technique does not give conclusive results, however. The water flowing from the leak to the point of emergence on the surface can take up substances on its way through the subsoil, resulting in an alteration of its composition and properties.

3.5 Pipe locating devices

Metal pipes can be located with the aid of an electro-magnetic field. The pipe locating device required here consists of a two-way radio set. The transmitter produces a weak electric current in the pipe, which is then tracked by the receiver. As the observer crosses the pipe, the receiver gives an optical and auditory rising and then falling signal; the maximum suddenly drops to a minimum precisely above the pipe.

The transmitter generally has a power between 8 and 50 watts.

In the most reliable pipe location method - the galvanic technique - the transmitter is connected to the pipe via a sluice valve rod or other conductive medium.

If there is no way of establishing direct contact with the pipe, the inductive method, without direct coupling is used.

The transmitter is then provided with a frame aerial, and transmission to the pipe is carried out from a point with known location.

This method has only limited use, however.

4 Monitoring of pressure losses

4.1 General points

Pressure monitoring registers pressure surges, fluctuations of pressure and excessive pressure losses in a water main, all of which are detrimental to the efficiency of the water-supply system.

If measurements show an excessive pressure gradient, this may be due to inadequate dimensioning of the equipment or to restictions in the main caused by deposits, blockages, partially or completely closed sluice valves.

If an excessively high pressure is measure, the cause may be unintended connection with a higher pressure zone, defective pressure-reducing valves, faulty switching of pump or a lower demand than was anticipated.

Permanently reduced pressure points to an open sluice valve, a leak or communication with a zone operated at lower pressure.

4.2 Testing through comparison of measured and calculated pressure levels

The technique of monitoring pressure losses by comparing measured and calculated pressure levels in explained below by the following example.

Example

The pressure gradient in a main, DN 150, is excessive; a defect in one of the two pipe sections shown in fig. 19 is suspected.

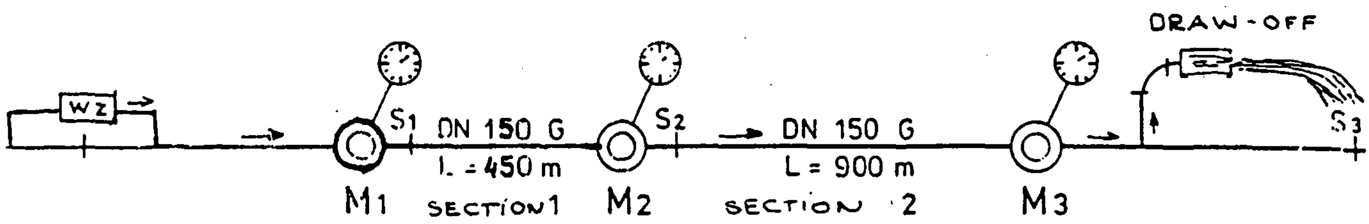


Fig. 19: Plan of the test sections

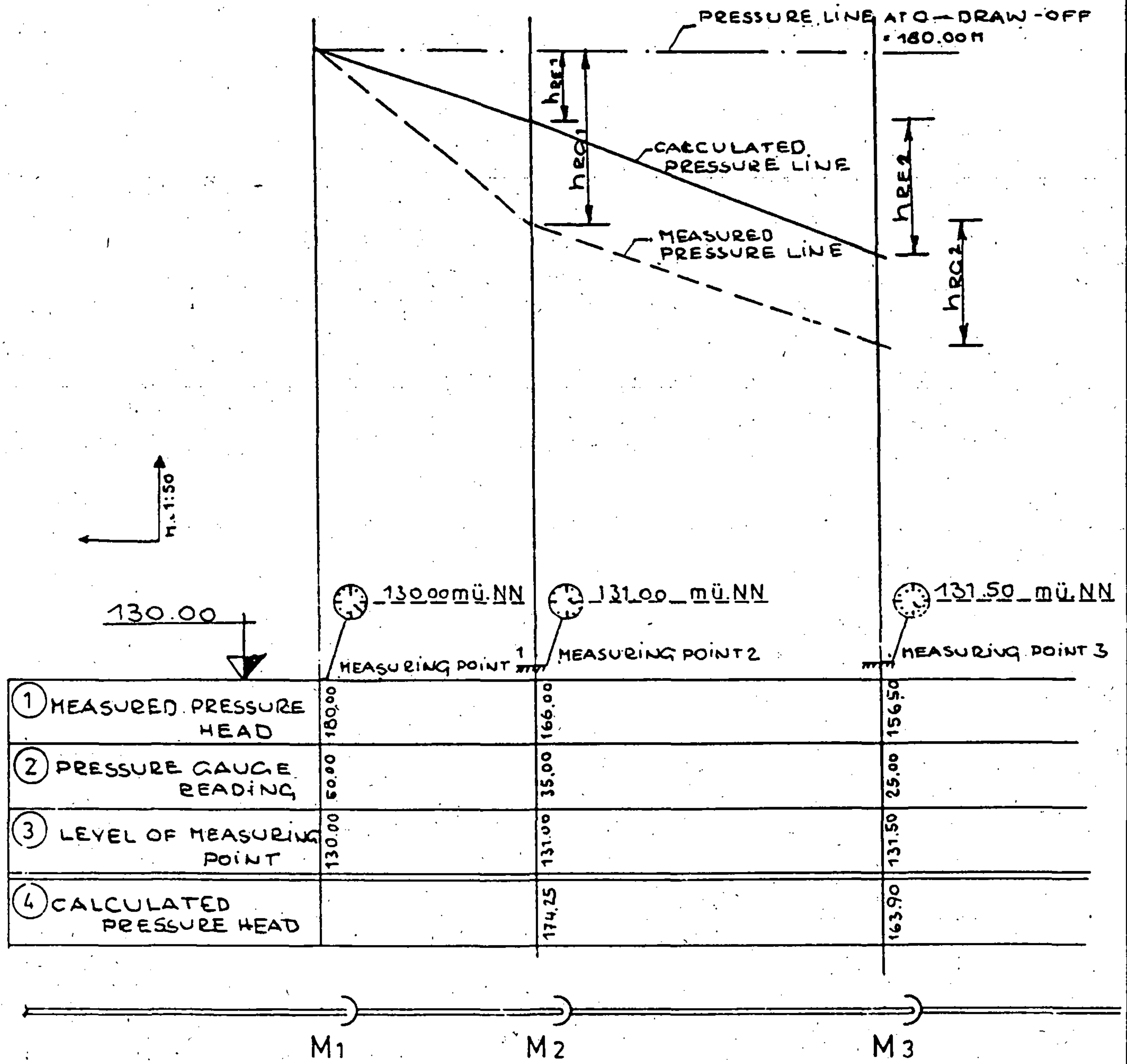


Fig. 20: Pressure heads

Preparatory work

The pipe run is divided into 2 test sections by establishing 3 measuring points. Suitable measuring points are all outflows such as hydrants, branches and communication pipes which are connected to the tested main.

Pressure gauges, possibly with recording instruments attached, are installed at the measuring points. The exact installation level of the pressure gauge must be accurately registered.

A water meter should be installed before the test section; possibly with use of a by-pass as shown under 2.2.4.

In the example, the measuring points are at the following levels:

M_1 = 130.00 m above m.s.l.
M_2 = 131.00 m above m.s.l.
M_3 = 131.50 m above m.s.l.

The end of the test section is separated from the rest of the main by a sluice valve - S_3 in the example. A draw-off point, preferrably with meter, is installed in front of the stop valve.

When installing the meters, care should be taken to observe the required limitation of distances of inflow and outflow zones approaching and leaving the meter.

Performance of measurements and calculations

First a trial measurement is carried out.
Sluice valve S_3 is closed, the draw-off pipe opened and finally the readings on meters and pressure gauges taken.

The example gives the following results:

Flow rate at water meter = Q = 20 l/s
Pressure gauge M_1 = 5 bars = 50.00 m
Pressure gauge M_2 = 3.5 bars = 35.00 m
Pressure gauge M_3 = 2.5 bars = 25.00 m

<u>The measured pressure heads are then given by adding the level of the measuring point to the pressure gauge reading,</u> i.e., in the example:

Measured pressure head M_1 = 130.00 + 50.00 = 180.00 m
" " " M_2 = 131.00 + 35.00 = 166.00 m
" " " M_3 = 131.50 + 25.00 = 156.50 m

For comparison of the measured values, friction losses are calculated for a flow rate of 20 l/s and a pipe roughness of 0.4.

On the basis of the pressure loss table as given in Module 0.4, the following figures result for the DN 150 pipe:

Flow speed V = 1.13 m/s
Pressure head loss I = 11.49 m/km

For the test sections, the friction head h_R is:

Section 1 h_{R_1} = 11.49 x 0.45 km = <u>5.75 m</u>

Section 2 h_{R_2} = 11.49 x 0.90 km = <u>10.35 m</u>

Thus the calculated pressure heads are

M_1 as measured = 180.00 m

$M_2 = M_1 - h_{R_1} = 180.00 - 5.75 = 174.25$ m

$M_3 = M_2 - h_{R_2} = 174.25 - 10.35 = 163.90$ m

The measured and calculated pressure heads are plotted on the chart shown in fig. 20.

Comparison of results

Comparison of the measured and of the calculated pressure heads plotted on the chart in fig. 20 shows a noticeable deviation within section 1. In section 2, the calculated and measured pressure head losses or friction heads are more or less equivalent; the slight descrepancy is still inside the tolerance range of the assumed pipe roughness.

Comparison of head losses

Section 1	h_{Rg1}	180.00 - 166.00 = 14.00 m	- measured -
	h_{RE1}	180.00 - 174.25 = 5.75 m	- calculated -
Section 2	h_{Rg2}	166.00 - 156.50 = 9.50 m	- measured -
	h_{RE2}	174.25 - 163.90 = 10.35 m	- calculated -

Analysis of results

The considerable difference between the measured and the calculated head losses in section 1 is very probably due to a closed sluice valve or to some other constriction of the pipe's cross-section, such as a blockage or pronounced air bubbles. Increased roughness of the pipe walls due to deposits, e.g. encrustation, is unlikely, since section 2 exhibits similar frictional losses under the same operating conditions.

4.3 Testing through comparison of the measured and calculated pipe characteristic curves

By a similar method to that described under 4.2, excessive pressure losses can be determined by comparing calculated and measured head losses.

Using the pipe characteristic curves, a graph can be drawn showing the efficiency of a pipe run. The horizontal axis represents flow volumes and the vertical axis the head losses.

If the roughness factor of the pipe is known, there is a direct relationship for every pipe diameter between flow volume and friction head, as shown by the tables and hydraulic principles given in Module 0.4.

This relationship is shown in figs. 21 and 22 as a graph, using the figures in the tables.

Using the same method as described under 4.2, the actual head losses at varying, defined flow rates are measured and also plotted on the graph.

The comparison of the measured with the calculated curves then allows a conclusion to be drawn on the possible size and type of the defect.

The following example is based on the same conditions as in 4.2.

SECTION 1 450 m

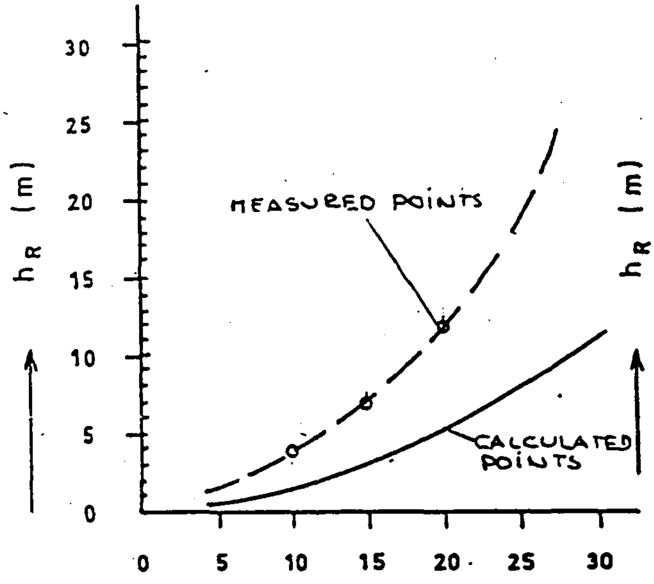


FIG. 21 PIPE CHARACTERISTIC CURVES SECTION 1

SECTION 2 900 m

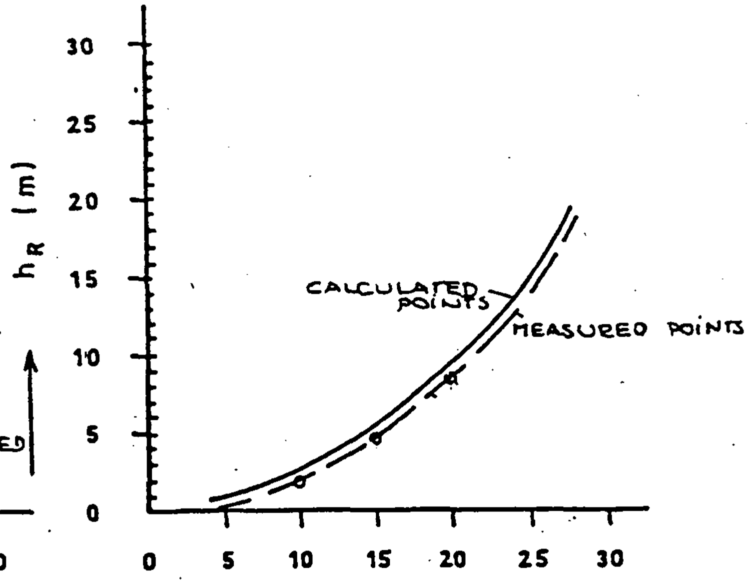


FIG. 22 PIPE CHARACTERISTIC CURVES SECTION 2

TABLE 1

HEAD LOSSES FOR PIPES DN 150 K = 0.4 acc. TO TABLE

Q (l/s)	5	10	15	20	30	l/s	
J (m/km) TABULAR VALUES	0,79	2,98	6,55	11,49	25,50	m/km	
SECTION 1 (450 m) h_{R1} (m)	0,35	1,34	2,95	5,75	11,48	m/	1
SECTION 2 (900m) h_{R2} (m)	0,71	2,68	5,89	10,35	22,95	m/	2

TABLE 2 MEASURED HEAD LOSSES

Q (l/s)	5	10	15	20	30	l/s
SECTION 1	1,60	3,90	7,25	14,00	—	
SECTION 2	0,50	2,40	5,70	9,60	22,10	

5 Repair of defective pipes

5.1 General operations

When a defect has been located, it is first isolated by closing the sluice valves next to the fault. All those affected must be notified on the interruption of water supply; hospitals and other institutions which are dependent on a continuous supply of water are supplied via emergency pipes.

The isolated section of the main should not be drained until the defective part is accessible, so that dirt and earth cannot be sucked into the pipe by the negative pressure in it.

When the defect has been repaired, the isolated pipe section should be re-filled slowly with water. Care must be taken to allow all the air to escape from the pipe while filling it. Opening the stop valve too quickly causes pressure surges and may thus lead to further damage.

Before the main is put back into service, it must be flushed and disinfected.

5.2 Earth and water retaining work

The water escaping from leaks often considerably reduces the stability of the ground in their vicinity. Special care should therefore be taken to secure pits dug for repair work properly, either by sloping the sides or with the use of sheeting. The water escaping from the leaking pipe should be pumped off using a non-chokeable pump. The water level in the pit must be kept below that of the pipe, so that no dirty water can re-enter the main after drainage and during the repair work.

The pit is best constructed so that there is enough room on one side of the pipe to carry out the repair work and adequate space round the pipe for the application of tools.

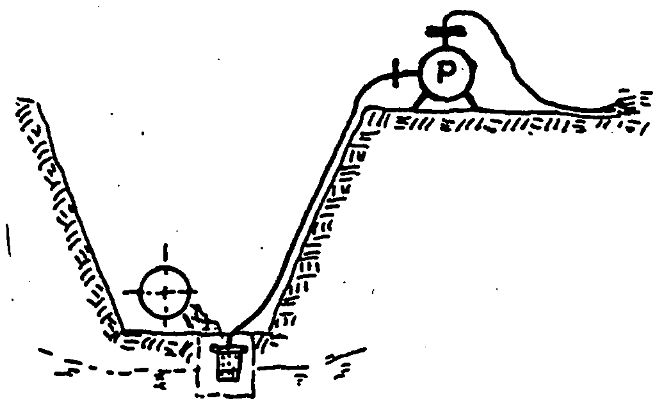


Fig. 23: Pit for repair work

5.3 Repair work

Depending on the extent and cause of the defect, either a simple repair or a replacement of a section of the pipe will be necessary.

5.3.1 Circumferential cracks or holes in the pipe are repaired with multi-part sealing clamps.

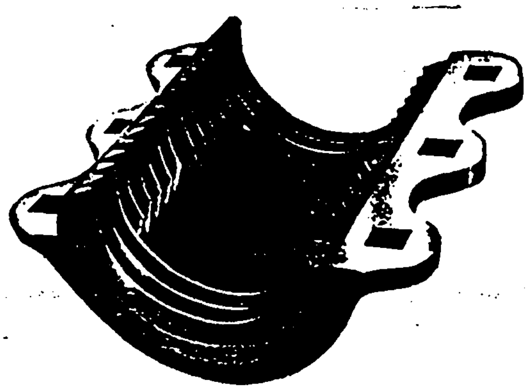


Fig. 24: Half of a sealing clamp

Sealing clamps are used for all pipe materials. The seal is achieved by pressing a rubber packing over the leak.

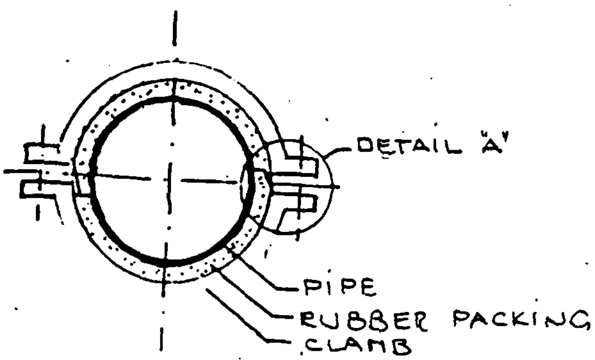


Fig. 25 Assembly of a clamp

Installation:

1. Clean the position of the clamp on the pipe thoroughly and coat with lubricant (if recommended by manufacturer).

2. Place clamp round pipe, making sure that the rubber packings grip each other properly at the joint (e.g. groove-and-tongue joint).

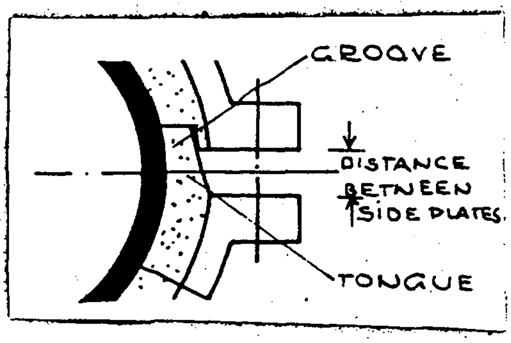


Fig. 26 Detail of Clamp

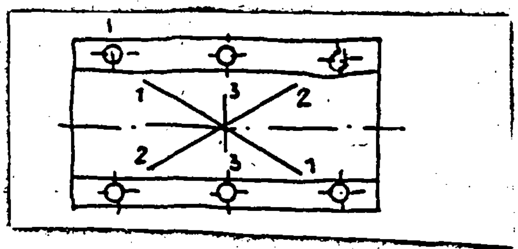


Fig. 27

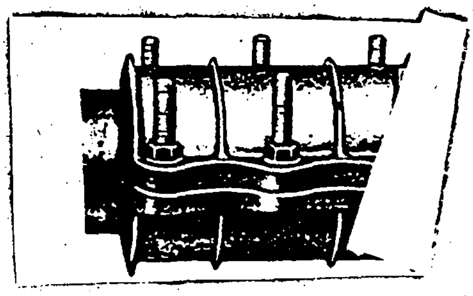


Fig. 28 Installed clamp

3. Engage screws lightly on both sides in crosswise order.

4. Check whether the rubber packings at the joint have engaged properly - i.e. whether the tongue fits evenly into the groove.

5. Tighten screws evenly in crosswise order (cf. fig. 27).

6. Correct positioning of the clamp is checked via the space between the holes, which is prescribed by the manufacturer; whereby the distance between the side plates varies according to the make and material of the clamp.

In the repair of corrosion damage to metal pipes, the impairment is overlap welded. The main must first be drained, the pipe insulating layer removed before welding and afterwards replaced.

5.3.2 Replacement of pipe section

Where longitudinal cracks or other large-surfaced pipe defects have occurred, the faulty pipe section must be replaced by a new piece. The procedure is described below, taking two examples of non-weldable pipes. In example 1 (figs. 29 to 34), the replacement of a pipe section next to an existing and undamaged socket is shown; example 2 (figs. 35 to 38) illustrates the replacement of a pipe section in the middle of a pipe run. Cf. Module 3.6 for a description of the tools to be used.

Example 1

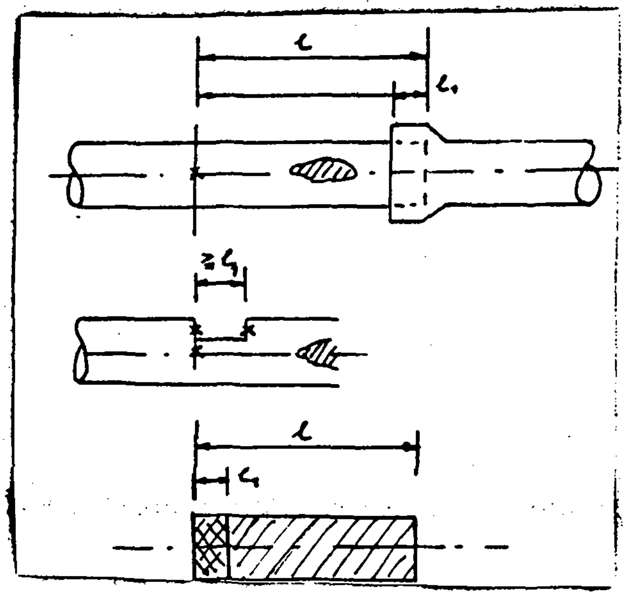
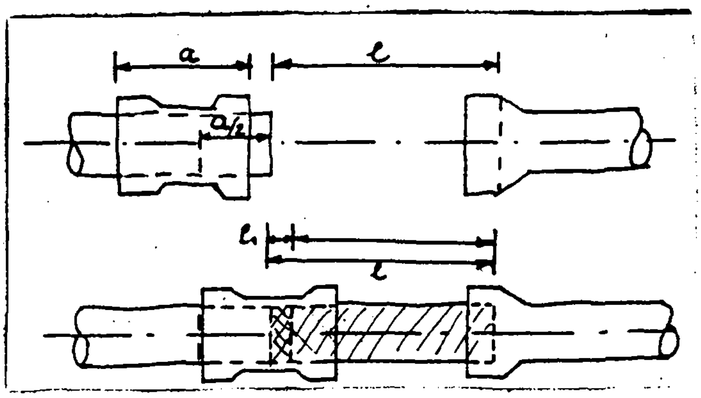


Fig. 29 - 31 Removal of the defective pipe section



Figs. 32 - 34 Installation of the new pipe length

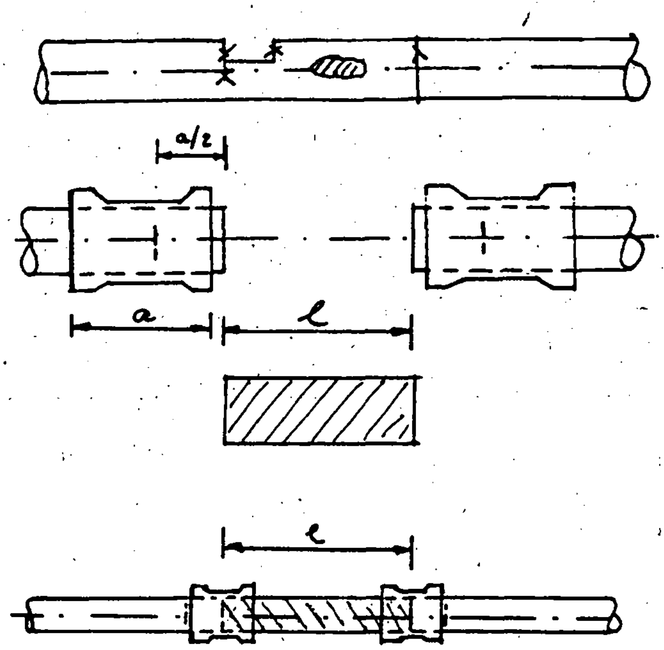
Procedure:

1. The farthest extent of the fault is established and cutting lines marked at a suitable additional distance from the defect.

2. To prevent jamming of the pipe section which is to be removed, or to obtain sufficient room to pull the pipe out of the socket, a so-called "window" is removed with the first cut.

3. The ends of the pipe or the socket are carefully cleaned where the double sockets or spigot of the new section are to be fitted, and the double sockets moved into their temporary positions.

Example 2



Figs. 35 - 38 Removal and installation of a pipe length without existing socket

4. Next, the new pipe sections are cut to the right length. Note that in example 1, the new length must be shorter by the depth of the socket. Since these joints do not transmit longitudinal force, subsequent movement of pipes and replacement lengths must be precluded by using an auxiliary ring in example 1. This also applies if a pipe length with a socket at one end is used instead of one with two spigots.

5. To position the double sockets correctly, half of their length is marked on the pipe ends.

When fitting pipe lengths with a socket, or in the example where the socket is already in position, the auxiliary ring should be positioned within the socket, but not on the sealing surfaces.

6. Before fitting is completed, a certain amount of disinfectant, measured according to the extent of contamination and to the length of the pipe section, is placed inside the pipe, in the form of chlorine tablets or granules.

6 Frequently occurring faults; causes and methods of prevention

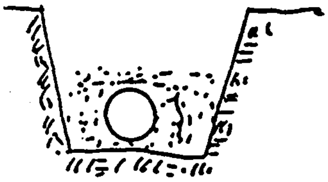


Fig. 39 right

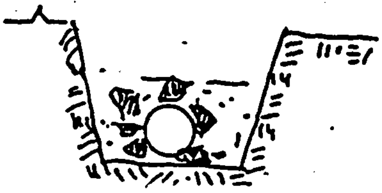
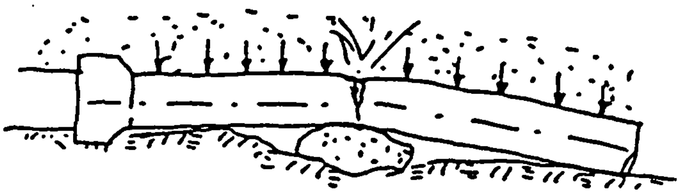


Fig. 40 wrong



Fig, 41 wrong

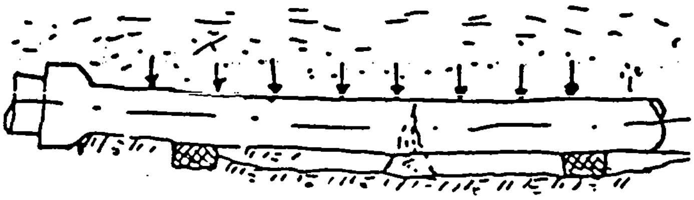


Fig. 42 wrong

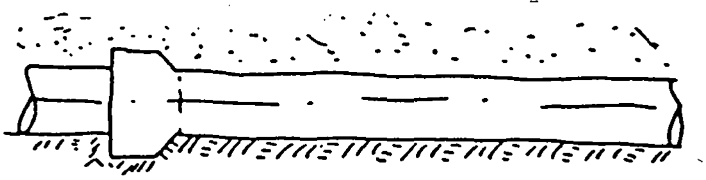


Fig. 43

1 Incorrect preparation of trench floor and unsuitable backfilling material

If a pipe is not in full contact with the ground along its complete length, forces concentrated on individual points can cause cracks (figs. 40 to 41). This is especially true of plactics and asbestos cement pipes.

Prevention:

Bedding the pipes correctly on an evenly prepared trench floor; use of stone-free material for backfilling (figs. 39 + 43).

2 Earth loads

If water mains are laid near or through old pipe trenches or construction pits, damage often results from the weight of the earth cover and traffic on the surface (fig. 44 and 46).

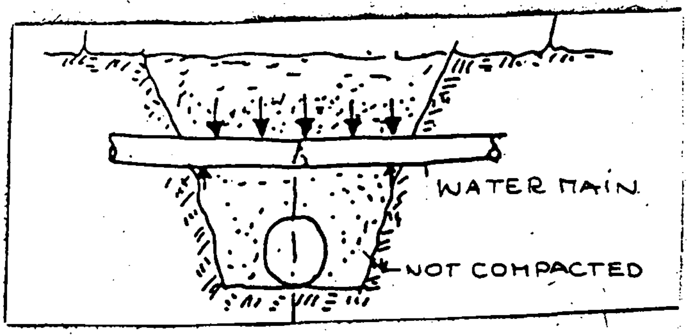


Fig. 44 wrong

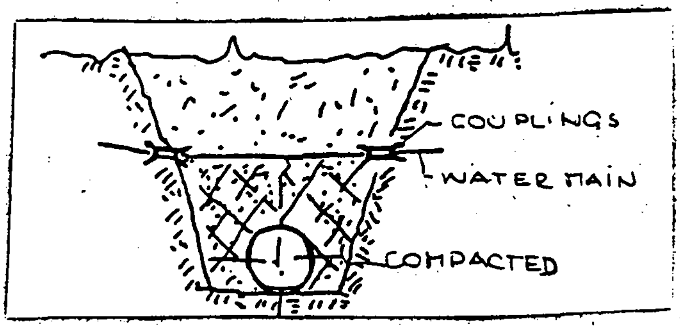


Fig. 45 right

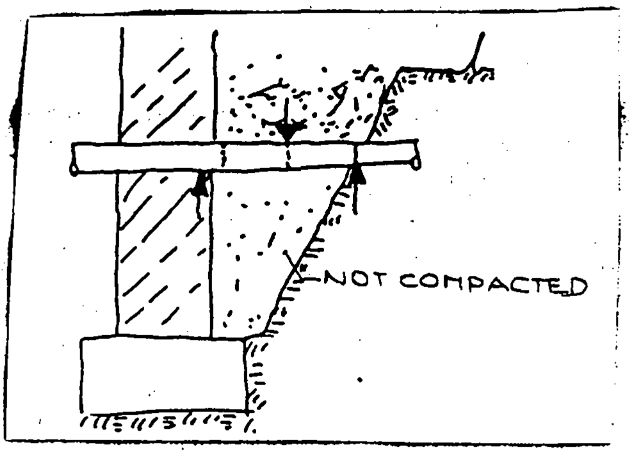


Fig. 46 wrong

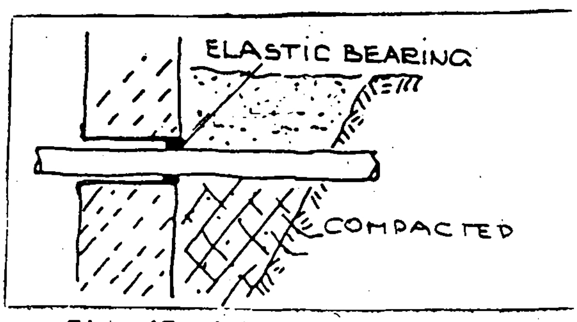


Fig. 47 right

Prevention:
The old backfilling can be post-compacted; possibly with the addition of lean-mixed concrete.
Installation of couplings and double sockets, which permit some angling of the pipes out of their longitudinal axis (fig. 45).
Use of mobile or elastic pipe lead-ins (fig. 47).

<u>3 Joints bent at an excessive angle; inadequately supported bends and pipe ends</u>
(figs. 48 + 49)

Prevention:
Use of adequately dimensioned bend supports; use of pipe joints able to transmit longitudinal force; observance of the permissible socket angles given by the manufacturer.

<u>4 Excessive pressure and pressure surges</u>

Pressure surges and sudden fluctuations of pressure sometimes arise in water mains; chiefly when extreme alterations

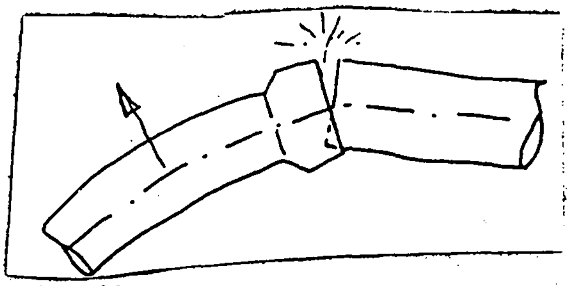


Fig. 48 wrong

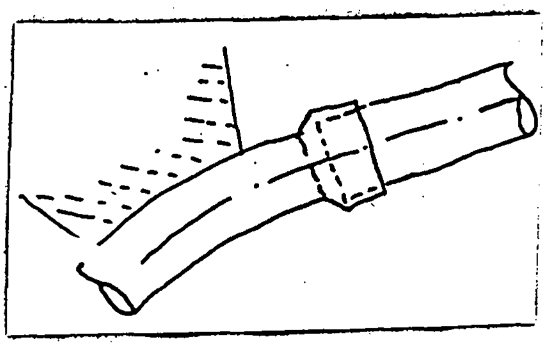


Fig. 49 right

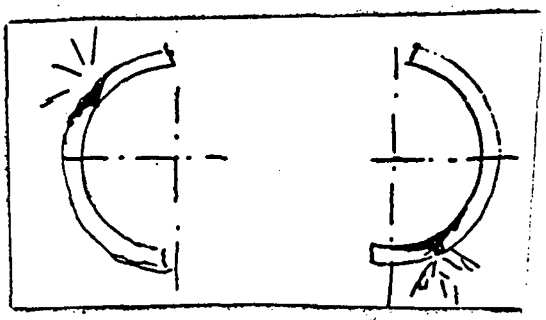


Fig. 50 Corrosion from inside

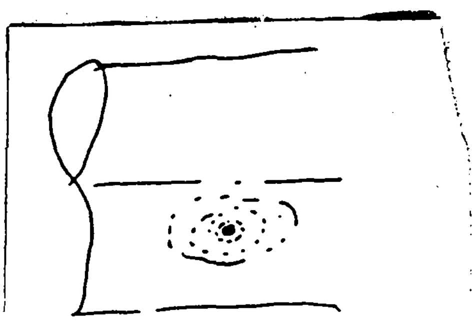


Fig. 51 Exterior corrosion

of flow speed occur. The intensity of a pressure surge ("water hammer") depends on the length of the pipe, the flow speed and the rapidity of the change of speed. Other factors are the closing speed of valves and switching times of pumps.

Prevention

Pressure surges can be avoided by closing stop valves slowly.
Pumps should be started up against closed stop valves.
Combination of pipe closure and switching off of pump.
Cushioning of excess pressure with air - surge tank.
Proper ventilation of pipes.

5 Corrosion (figs. 50 to 52)

Damage of this type is caused by electrolytic processes which either attack the pipe material over a large surface area or else at individual points.
If the pipe is inadequately protected, corrosion processes take place on the exterior and interior of the pipe walls. They are

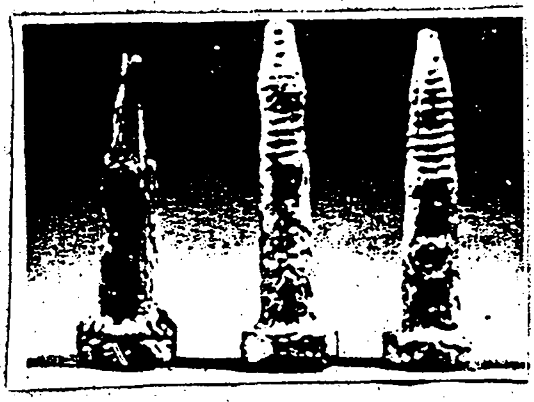


Fig. 52 Strongly corroded screws

promoted by certain properties of the surrounding soil and the water flowing through the pipe. Corrosion is largely restricted to pipes made of metal.

Prevention:

Replacement of the corrosive soil - usually heavy clay - and bedding of the pipe in neutral sand. Protection of the metal pipe with an exterior insulating layer or galvanization.

Installation of sockets instead of flanges with corrosion-prone screws.
Damage to the exterior insulation layers should be repaired using the hot or cold technique with insulating bandages.

Internal corrosion of metal pipes is due to the aggressive properties of the piped water. Preventive measures therefore consist mainly of an improvement of preliminary treatment. Nowadays, metal pipes are given an internal lining of cement mortar. With the aid of special devices, pipe linings can also be inserted into mains which are already laid and in operation.

7 Keeping water mains clean

7.1 General points

Drinking water supplied to the consumer must not be in any way harmful; in particular it should contain no disease-causing agents.

In the operation of a mains network it is, however, never possible completely to prevent contaminating particles from entering the system at some point. The presence of such particles can lead to a pollution of the entire mains system, due to the multiplying and spreading of the micro-organisms. This process is particularly rapid in tropical and subtropical countries because of the relatively high temperatures of the water. As a precautionary measure, therefore, any water intended for human consumption must be tested at regular intervals. Indicators of a possible contamination are the bacterium Coli, which points to the presence of intestinal bacteria, and the concentration of colony-forming micro-organisms.

The water is no longer suitabel for human consumption if the maximum permissible levels of either of these indicators are exceeded.

7.2 Precautionary measures

7.2.1 Passive measures

The chief method of preventing bacteriological contamination of the mains is to stop dirt particles entering the system. It should not be possible for dirt to be sucked in through taps or drain outlets by negative pressure in the pipe. Communication pipes must therefore be provided with back-siphonage prevention devices and air valves.

Care must be taken never to install dirty pipe lengths, fittings or valves. Pipe dead ends and little-used pipe lengths must be flushed regularly.

7.2.2 Disinfection with chlorine

Chlorine is the principal agent used for sterilization of water supply systems. It is used in various forms, depending on the application and existing conditions. Special precautionary measures must be taken when handling chlorine; details can be found in manufacturers' instructions or in the relevant safety regulations.

7.2.3 Forms of chlorine

Chlorine gas is a pungent-smelling, non-combustible, very poisonous gas. It is liquified under pressure and supplied in drums and flasks. Chlorine metering and controlling devices are necessary for its use.

Calcium hypochlorite is available in tablet or granule form; it contains approx. 60% active chlorine. When using calcium hypochlorite, this active chlorine content must be taken into account.

Sodium hypochlorite (bleach) is supplied as an aqueous solution; the active chlorine content is generally about 150 mg/l. As with calcium hypochlorite and chloride of lime, the active chlorine content decreases with time.

Chlorine preparations must be stored in a cool, dark and safe place.

7.2.4 Application

Continuous chlorination

In many countries, continuous chlorination of drinking water supplies is a legal requirement. The amount of chlorine added - i.e. the chlorine concentration - depends on the chlorine consumption of the water and the transport distance. The chlorine concentration of the water reaching the consumer should not be higher than 0.3 mg/l. Details on continuous chlorination are contained in Module 3.5 .

7.2.5 Individual chlorination of new or contaminated pipe lenghts

7.2.5.1 General points

Sterilization of pipes which are to be taken into service for the first time, or of pipes contaminated due to repairs or other causes, takes place by individual chlorination. Most suitable is chlorine in solid form as granules, or in fluid form as a solution; chlorine gas should not be used for this purpose due to the risk of accident involved.

In individual chlorination operations, the reaction time method is the most suitable. The method can be applied with varying chlorine concentrations and reaction times. Experience has shown that a chlorine concentration of 50 mg/l at a reaction time of 24 hours gives good results. If the supply system permits the main to be taken out of service for a shorter time only, the chlorine concentration must be correspondingly increased to compensate for the shorter reaction time. Penetration of the sterilizing solution into neighbouring sections of the system which are in operation must be reliably prevented.

7.2.5.2 Calculation of the necessary amount of chlorine

Due to the loss of active chlorine when using sodium hypochlorite and calcium hypochlorite, minor inaccuracies in the calculation of the amounts of chlorine are not serious.

Calculation of the chlorine dose is explained below with the aid of an example:

<u>Example</u>:

A water main with a diameter of DN 150 mm and a length of 200 m is to be sterilized with chlorine.

For each litre of pipe content, 50 mg of active chlorine are to be used.

Calcultion of the amount of active chlorine:

Calculation of chlorine dose per "1.00 m" pipe length
= cross-sectional area of pipe x 1.00 m

$$\text{Cross-sectional area} = \frac{d^2\ (dm) \times \pi}{4}$$

$$= \frac{1.5^2 \times 3.14}{4} = 1.76\ dm^2$$

Pipe content at 1.00 m (10 dm) pipe length

$$= 1.76\ dm^2 \times 10\ dm = 17.6\ dm^3$$
$$= 17.6\ l$$

Thus the chlorine dose for a pipe length of 1.00 m
= 17.6 l x 50 mg/l = 880 mg = 0.88 g per "m" pipe length.

The table gives the required amounts of active chlorine for various diameters, with a sterilizing solution of 50 mg/l and 1.00 m pipe length.

Table 3: Required chlorine amounts for a concentration of the sterilizing solution of 50 mg/l Cl_2 and a pipe length of 1.00 m

Pipe diameter (mm)	g Cl_2 per 1 m pipe length
80	0.25
100	0.39
150	0.88
200	1.57
250	2.45
300	3.53
350	4.8
400	6.3
500	9.8
600	14.1
700	19.2
800	25.1
900	31.8
1000	39.3
1200	56.5

When using bonded chlorine in solid or fluid form, the percentage of active chlorine must be taken into account in the calculation.

In the example, assuming use of sodium hypochlorite (percentage of active chlorine 150 mg/l), the amount of solution required is calculated as follows:

Active chlorine requirement per "m" pipe length = 0.88 g
Requirement for a pipe length of 200 m
= 200 m x 0.88 = 176 g

Sodium hypochlorite solution requirement (concentration 150 g active chlorine per litre) is thus
$\frac{176}{150}$ = 1.17 l of sodium hypochlorite solution for a pipe length of 200 m.

7.2.5.3 Addition of disinfectant

The disinfectant can be added in a variety of ways, depending on the given conditions.

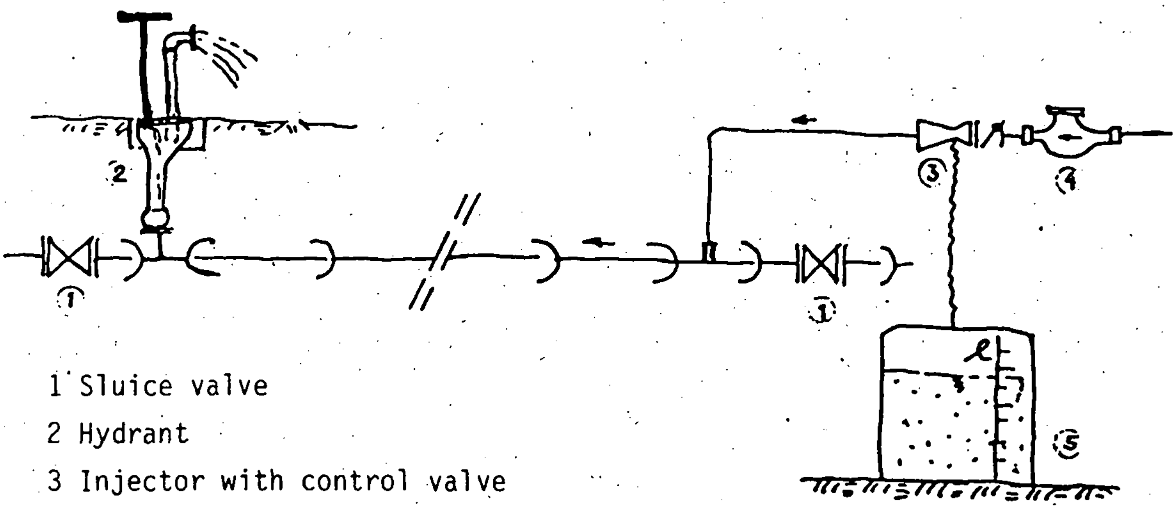
Addition in tablet or granule form

If the pipe has been drained and there is an opening available, the calculated amount can be placed in the pipe in the form of tablets or granules. The tablets or granules slowly dissolve in the inflowing water and thereby release the active chlorine.

If the pipe which is to be sterilized is filled via a pressure pipe (fig. 53), the disinfectant solution is metered with the aid of a control valve via an injector (3), corresponding to the flow volume reading on the water meter (4) and to the scale on the tank containing the solution.

If the disinfectant solution is to be fed under pressure into the contaminated pipe, a mechanically or manually operated pump is used (fig. 54).

In both cases, it must be ensured that the pipe which is to be sterilized is well ventilated via a hydrant or other opening. This opening is then utilized to flush out the chlorine residue when the sterilizing process is completed.



1 Sluice valve
2 Hydrant
3 Injector with control valve
4 Water meter
5 Solution tank

Fig. 53 Addition of chlorine via an injector

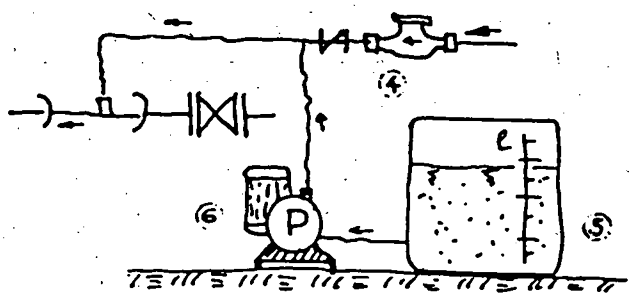


Fig. 54 Addition of chlorine via a pump

8 Cleaning of pipes

8.1 Pipe flushing

Pipes are flushed to remove any deposits which may have accumulated and to wash stagnant water out of dead ends or seldom-used pipe runs.

Flushing of pipes plays a major part in improving the transportation efficiency of the pipes and the quality of the water.

In more detail, flushing operations are carried out for the following reasons:

1. To remove foreign matter.
2. To improve water quality in dead ends and in little-used pipe runs.
3. After sterilization of a main and before taking it into service.

8.1.1 Flushing to remove foreign matter

Depending on the properties of the water, deposits may form in the main. This is especially true of pipes for raw water or in which different waters are mixed. These deposits can be removed by flushing at regular intervals. The frequency and duration of such flushing operations should be determined in each case according to the extent and adherence ot the deposits. Generally speaking, flushing is continued until clear water flows out of the flushing outlet.

The deposits are loosened and the particles removed by using as high a flow speed of the flushing water as possible.

Use of the flushing method to clean pipes is limited by the availability of adequate amounts of water, the opportunity to discharge these amounts properly and the available water pressure.

The following table shows the water volumes in approximate relationship to pipe diameters, at the necessary flow speed (approx. 1.5 m/s) and a pipe roughness ki = 0.4.

Table 4

Diameter	Flow volume	
	l/s	m^3/h
100	12	43.2
150	26	93.6
200	41	147.6
250	72	259.2
300	105	378

Since the volumes which would be necessary to flush large-diameter pipes are not generally available, the flow speed is usually increased through an artificial reduction of the pipe cross-section. This is shown in fig. 55.

Here, a metal or rubber ball with a diameter smaller than the interior diameter of the pipe is carried by the pressure of the water in the direction of flow and held back by a cable in the appropriate position

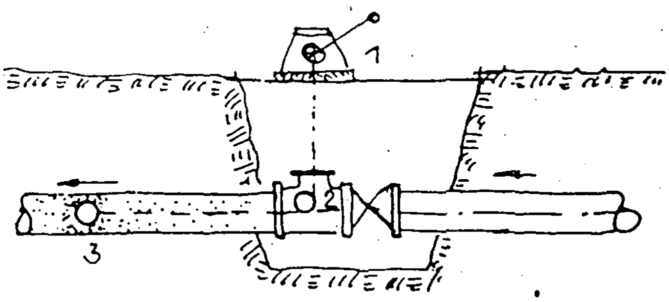


Fig. 55 Cleaning a pipe by means of an artifical constriction

Stop valves must be used to prevent dirty water from the section being cleaned entering other sections of the system which are in operation.

The wash-out - hydrant or drain outlet - shoult be as large as possible.

8.1.2 Flushing of little-used mains sections

These include, in particular, dead ends from which "stagnant" water must be removed, The flow speed of the flushing water need not be particularly high here, since the aim is merely to exchange the water in the pipe. The flushing operation is completed when clear, clean water flows from the draw-off point.

8.1.3 Flushing after disinfection

In this operation, the residual chlorine in the pipe has to be removed. The speed of the water can be relatively low; the volume should be 3 to 5 times the content of the pipe.

8.2 Mechanical cleaning and lining

Mechanical pipe cleaning is carried out with brushes or pigs to remove stubborn deposits (encrustations). In the long run, mechanical cleaning can only bring improvement if the pipes are afterwards provided with an inner lining of cement mortar. Various techniques are used here, carried out by specialized companies.

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- provision of materials and equipment for projects, planning work, selection, purchasing and shipment to the developing countries
- management of all financial obligations to the partnercountry.

The series **"Sonderpublikationen der GTZ"** includes more than 190 publications. A list detailing the subjects covered can be obtained from the GTZ-Unit 02: Press and Public Relations, or from the TZ-Verlagsgesellschaft mbH, Postfach 36, D 6101 Roßdorf 1, Federal Republic of Germany.

TRAINING MODULES FOR WATERWORKS PERSONNEL

List of training modules:

Basic Knowledge

0.1 Basic and applied arithmetic
0.2 Basic concepts of physics
0.3 Basic concepts of water chemistry
0.4 Basic principles of water transport
1.1 The function and technical composition of a watersupply system
1.2 Organisation and administration of waterworks

Special Knowledge

2.1 Engineering, building and auxiliary materials
2.2 Hygienic standards of drinking water
2.3a Maintenance and repair of diesel engines and petrol engines
2.3b Maintenance and repair of electric motors
2.3c Maintenance and repair of simple driven systems
2.3d Design, functioning, operation, maintenance and repair of power transmission mechanisms
2.3e Maintenance and repair of pumps
2.3f Maintenance and repair of blowers and compressors
2.3g Design, functioning, operation, maintenance and repair of pipe fittings
2.3h Design, functioning, operation, maintenance and repair of hoisting gear
2.3i Maintenance and repair of electrical motor controls and protective equipment
2.4 Process control and instrumentation
2.5 Principal components of water-treatment systems (definition and description)
2.6 Pipe laying procedures and testing of water mains
2.7 General operation of water main systems
2.8 Construction of water supply units
2.9 Maintenance of water supply units Principles and general procedures
2.10 Industrial safety and accident prevention
2.11 Simple surveying and technical drawing

Special Skills

3.1 Basic skills in workshop technology
3.2 Performance of simple water analysis
3.3a Design and working principles of diesel engines and petrol engines
3.3b Design and working principles of electric motors
3.3c –
3.3d Design and working principle of power transmission mechanisms
3.3e Installation, operation, maintenance and repair of pumps
3.3f Handling, maintenance and repair of blowers and compressors
3.3g Handling, maintenance and repair of pipe fittings
3.3h Handling, maintenance and repair of hoisting gear
3.3i Servicing and maintaining electrical equipment
3.4 Servicing and maintaining process controls and instrumentation
3.5 Water-treatment systems: construction and operation of principal components: Part I - Part II
3.6 Pipe-laying procedures and testing of water mains
3.7 Inspection, maintenance and repair of water mains
3.8a Construction in concrete and masonry
3.8b Installation of appurtenances
3.9 Maintenance of water supply units Inspection and action guide
3.10 –
3.11 Simple surveying and drawing work

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