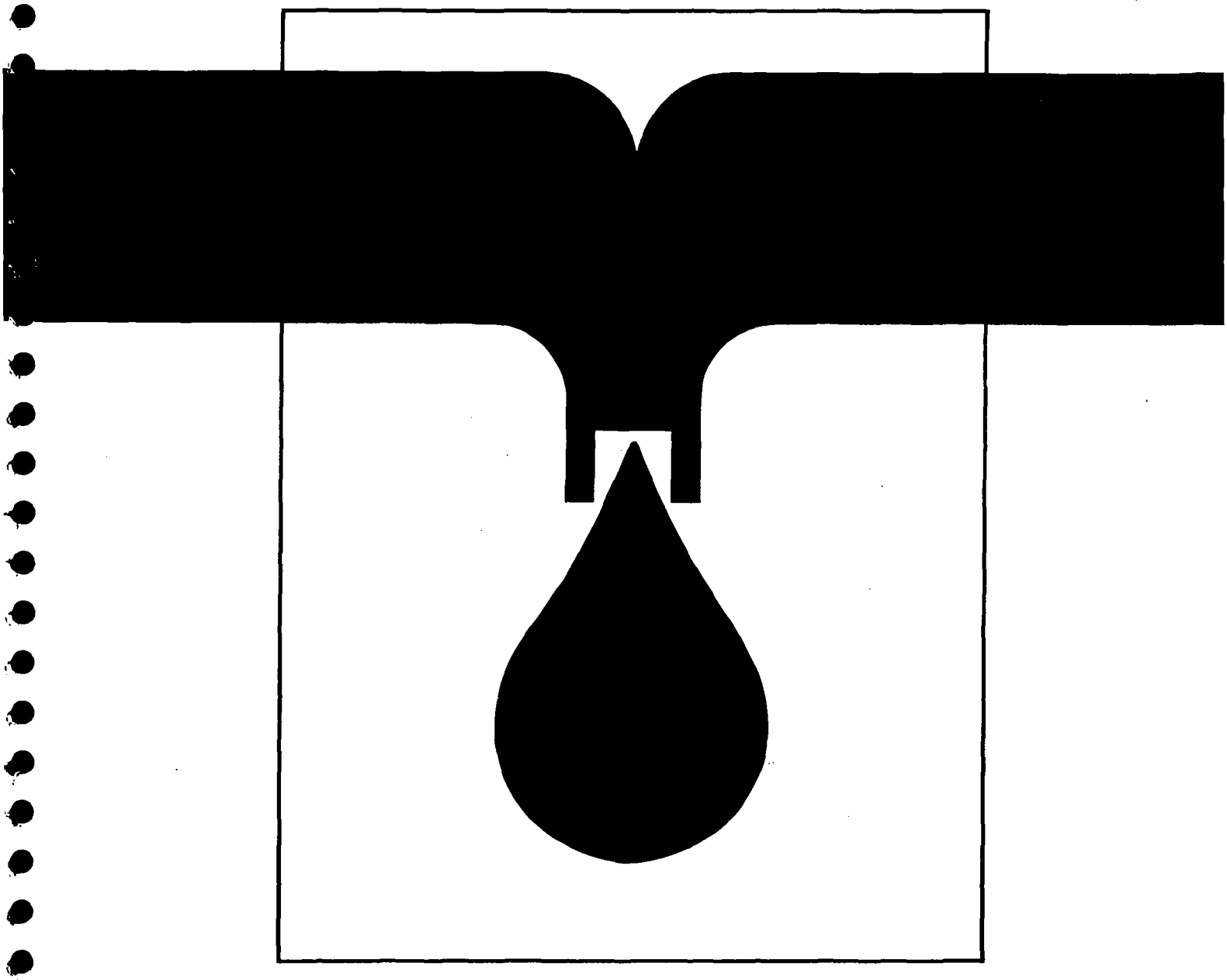
TRAINING MODULES
FOR
WATERWORKS PERSONNEL



Special Knowledge

2.7

General operation of water main systems

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
and
Ing.-Grad. H. Hack

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.

Dr. Ing. Klaus Erbel
Head of Division
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Eschborn, May 1987

Title: General operation of water main systems.

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1 Supervision of mains systems

1.1 General requirements

All pipe systems which carry potable water must be inspected both at regular intervals and whenever particular circumstances necessitate a special check. Inspections should cover

- location and accessibility;
- water-tightness;
- technical efficiency and condition of all parts;
- quality of the water.

The type and extent of the various measures to be carried out during an inspection depend on

- the function and relative importance of the main (e.g. long-distance transmission main, communication pipe);
- the specific operating conditions (e.g. pressure zones, water losses, composition of the water, pressure, rate of flow etc.);
- the type and exact composition of the soil surrounding the pipe, stresses caused by traffic and earth movements; the type and number of installed control and monitoring instruments (pressure and volume measuring instruments, level indicators etc.);
- the material of which the pipes are made and the types of joints used;
  the need to monitor valves and measuring instruments.

When deciding on what basis and with what frequency inspections should be carried out, it is useful to look at a statistical analysis of the results of earlier inspections, a survey of the incidence of faults in the mains or the files kept on the equipment.

If there is any concrete reason to suppose that there is a fault somewhere in the system, an inspection must be carried out immediately.

Reasons for a special inspection can be:

- visible emergence of water in the vicinity of a water main;
- unusual loss of pressure;
- unusual increase of the input of water into the system; conspicuous increase of water losses;
- noticeably higher frequency of faults within a certain period of time or a certain section of the system;
- disturbances or faults reported by others;
- pressure surges (water hammer) in the mains;
- increases of operating pressure;
- earth movements in the vicinity of mains, or the possibilitiy of damage from building or excavation work carried out by others;
- the suspicion or confirmed evidence of a deterioration in the quality of the water.

The age of a water main is not a factor in deciding when an inspection is to be performed.

1.2 Location and accessibility

Water mains and other components of a water-supply system must always be easily located and accessible, to allow normal servicing or maintenance work to be performed. The route of the water main should be free of buildings or other permanent obstacles. Care should be taken not to damage or detract from the operational reliability of the water mains, or hinder access to them, by planting trees or bushes in the vicinity. Th fixed minimum distances must be observed. Caps and manhole covers, signs and any other markings must all be clearly visible and accessible.

Caps should identify the medium and type of the fitted valves. Signs must be legible; the data on them must give the position of the relevant components with sufficient accuracy.

Inspection schedule: once or twice a year.

1.3 Monitoring of water losses

As a general rule, checking mains for water-tightness discovers only the faulty pipe sections or fittings, etc. where actual leakage of water has occurred. Regular, i.e. scheduled inspections should, however, include if possible the following measures, which either individually or in combination cover the points listed under 1.1.

1.3.1 Continuous measurements

Here, rates of flow, pressures and levels in tanks are measured and recorded in a continuous process. Continuous supervision is especially suitable for monitoring important parts of a mains system, long-distance transmission, feeder or trunk mains. The measuring instruments can be connected to control centres and give a warning if a disturbance occurs.

The application of this procedure is limited generally to the detection of only relatively large-scale defects (e.g. burst pipes) in long-distance transmission, feeder or trunk mains.

Smaller sections of the pipe network can be monitored by means of stationary district measuring equipment, e.g. by a measurement of water consumption at night.

1.3.2 Inspections at regular intervals

Inspection of location lines

By walking, driving or flying along the route taken by the water main, water emergence, changes in the soil surface, damp spots, changes in the vegetation etc. can be observed. Any of these may indicate that the water main is damaged. The results of this procedure should be considered with care, however, since the observed phenomena may also be due to geological causes, weather, etc.

An inspection of the location lines of long-distance transmission or feeder mains should be carried out once a year.

The location lines of communication pipes on private land should also be inspected regularly.

1.3.3 Testing for water-tightness using acoustic leak-detecting devices

Mobile monitoring equipment operating on an acoustic or electro-acoustic basis generally succeeds in establishing and locating leakages from the mains or from valves.

1.3.4 Testing for water-tightness using short-duration measurements

Here, the volume of water fed into a sufficiently limited, isolated section of the supply system (control district) is registered by suitable measuring equipment (e.g. a district measuring device, or hose connecting two hydrants, with an intermediate, mobile measuring instrument).

Nocturnal minimum consumption measurement

The amount of water fed into the control district during the night is measured and compared with statistics. Any amounts fed in over and above a certain upper limit established on the basis of these statistics can be regarded as leakage.

Zero consumption measurement

This procedure is more exact, but requires smaller areas (control districts) to give accurate results. It is based on the assumption that in a sufficiently small section of the mains system, no consumer draws water off inside a certain, short period of time. The amount of water then flowing into this control district must therefore represent leakage. Any permanent consumption of water in this district must of course be taken into account.

Experience has shown that relatively small losses result

from dripping pipe joints and valves and from slight losses at the water meters, and cannot be classified as leakages.

1.3.5 Location of defective parts

If relatively large amounts of water remain unaccounted for, the exact position of the leaks must be located with the aid of leak-detecting devices. After dividing the districts up into smaller areas on a logical basis, it may be necessary to further reduce these areas to enable the location of the fault.

1.4 Technical efficiency

In addition to tests on various components, described below, checks should also be carried out on stuffing boxes (watertightness), the external condition of visible parts (corrosion) and the proper functioning and legibilitiy of indicating and measuring instruments.

Manhole covers, caps and signs

Manhole covers and caps must be level with the surface of the ground, kept clear of obstructions and marked by signs.

Stop valves

Stop valves should be checked for freedom of movement and correct position.

Stop valves used for separating pressure or water zones (different pressure stages) or draining devices, or set (partially closed) stop valves should be checked at least once a year to ensure that they are properly adjusted.

Automatic air supply/relief valves

The checks carried out on these valves should include an examination of ball play and inspection of the nozzle for obstruction. Any installed stop valves should be inspected at the same time.

Inspections should be carried out as required by the given operating conditions, but at least once a year.

When taking mains into or out of service, any air valves located in the isolated section should be additionally checked.

Pressure reducers

Inspection of pressure reducers should include checking the control line for obstructions and ensuring that the set output pressure is maintained.

Any installed stop or safety valves should be included in the inspection.

The inspection should be carried out as required according to the particular operating conditions, but at least once a year.

Self-closing valves

These must be checked for:

- maintenance of closing characteristic;
- functioning of leak-detecting devices;
- functioning of the closure-triggering devices.

Depending on the type of valve and given operating conditions, inspections should generally be carried out here once a year.

A test which involves closing the valve can only be performed if this is possible without affecting normal operation of the system.

If the valve is not opened under automatic control, it should be opened slowly enough to prevent any sudden alterations of flow volume or pressure.

Control equipment

This inspection covers:

- pressure-measuring instruments;
- flow meters (water meters, Venturi tubes, orifice meters, inductive measuring instruments);

level-measuring instruments;
recording instruments;
control devices.

The interval between inspections depends on the application and sensitivity of the instruments. The manufacturer's recommendations should also be consulted.

1.5 Water quality

Regular monitoring

To be able to assess, with a reasonable degree of accuracy, the quality of the water being supplied to consumers, a predetermined number of samples taken at regular intervals from the mains have to be analyzed.

Additional inspections

Apart from these routine analyses, all controlled discharges of water (e.g. water discharged in flushing operations) should be checked for any perceptible changes in quality, such as turbidity, discoloration, smell.

Unscheduled tests necessitated by special circumstances

Inspections may be necessary on certain occasions or due to special circumstances, e.g:

when pipe sections are brought into service, either for the first time or after an interval;

if the quality of the water has perceptibly changed, i.e. is discoloured, turbid, has a noticeable taste or smell;

if there are grounds to suspect a back-siphonage of non-potable water into the system, e.g. due to negative pressure via communication pipes, or during repairs to pipes;

if public taps or hydrants have been improperly used;

if there is uncontrolled mixing of different waters in the system, possibly leading to corrosion or encrustations.

2 Measurements of pressure and flow volume in the mains

2.1 Type of measurement and use of results

In the operation of a water mains system, measuring and recording flow volumes and pressures is essential. Depending on requirements, these measurements can either be carried out continuously, often with transfer of results to a central control point, or as necessary at longer or shorter intervals on a sampling basis.

The measurements cover:

- the input of water into the mains
- the flow volume through individual sections;
- the volume of water supplied to consumers or retailers;
- the water pressure at arbitrary points in the system;
- fluctuations of pressure;
- pressure losses.

The results of these measurements are used for:

- control and monitoring of certain operations, such as input into the system and switching of pressure-raising equipment;
- determination of the correct dosage of chlorine or other additives;
- calculation of water losses and location of faults; hydraulic dimensioning of new or replacement mains or complete networks;
- control of the mains pressure;
- calculation of water rates and drawing up of customers' accounts.

2.2 Meters

2.2.1 General points

Mains systems contain various kinds of meters. A distinction is made between water meters, which determine the total volume of water (in "m^3" or "l") which has flowed through

a pipe during a certain, arbitrary period; and flow meters, which determine the quantity of fluid which flows in a unit of time, e.g. "l/s" or "m³/h".

Water meters are used to measure and indicate what amounts of water have been piped or supplied. Flow meters, on the other hand, are generally installed in larger plants, where instantaneous results are required for control or dosage purposes, e.g. to judge the correct chlorine dosage, which is proportional to the volume of water.

In many cases, a combination of flow meter and water meter provides a good solution.

With the aid of additional devices such as contactors, which give an electrical signal after a certain amount of water has passed, the flow per unit of time can be recorded on a chart.

The continuous recording of water quantities and pressures can also be carried out by mechanical quantity recorders which are operated directly by the pointer of the water meter.

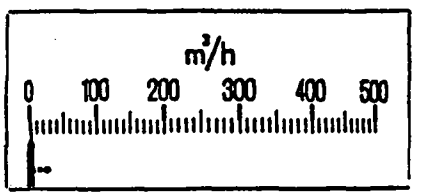


Fig. 1 Indicator scale

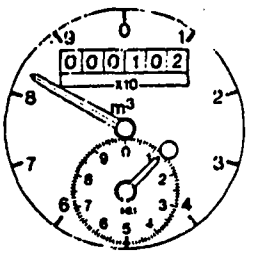
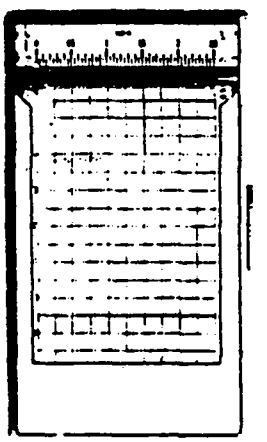


Fig. 2 Calibrated dial



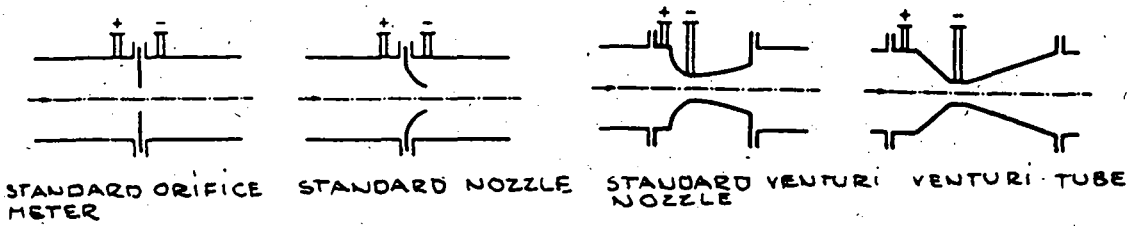
2.2.2 Differential pressure measuring devices

The principle of these instruments is that a constriction in the pipe causes an increase in the flow speed of the water,

which is combined with a reduction of pressure at this point. The difference in pressure before and at this point is called the differential pressure. The differential pressure is a measure of the speed of the water and therefore of the rate of flow.

<u>The differential pressure h is proportional to the square of the rate of flow.</u>

$$h\ (m) = c \times Q^2\ (l/s).$$



Figs. 4 to 7 Various differential pressure devices

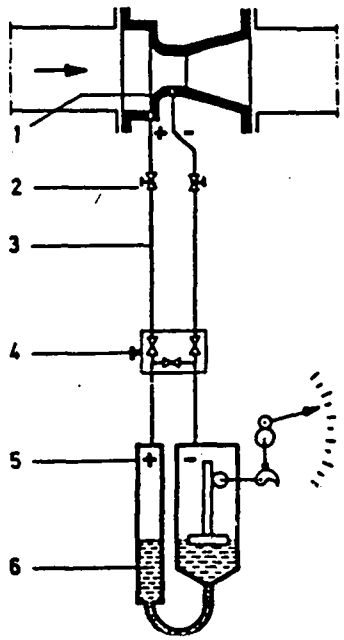
The differential pressure produced by the constricting device is indicated by a differential pressure gauge.

The simplest and most widely-used version of this measuring device is constructed on the U-tube manometer principle, which makes the differential pressure visible as a movement of a column of mercury. To allow the measurement to be recorded, a float is placed in one arm of the U. The rise and fall of the float are transferred to an indicator scale or recording chart.

Since the relationship between flow rate and differential pressure is quadratic, the cam disc can give a linear indication of the flow rate.

Besides translating the differential pressure into an instanteneous flow rate which can be read off a scale or chart, it is also possible to attach a counter, usually driven by a synchronous motor, to the device.

The accuracy of differential pressure measuring instruments is approx. ± 1.5 % of the maximum value on the scale.



1 Constricting device (Venturi nozzle)
2 Connecting valves
3 Differential pressure pipes
4 Stop and equalizing valve
5 Differential pressure gauge
6 Sealing liquid

Fig. 8 Differential pressure measuring instrument

Features of differential pressure gauges

Simple, reliable measuring procedure
No moving parts in the measured flow
No wear and tear; low maintenance
High economy
Transmission of data without auxiliary energy
Examination of the connected measuring instruments possible without interrupting operation
Narrow range of measurement
Large space requirement due to need for unobstructed inflow and outflow zones
Economic use from DN 200 only

2.2.3 Rotary meters (Woltmann current meters)

In the rotary meter, the flow of water turns a vane, which rotates according to the rate of flow with increasing or decreasing speed. There is a linear relationship between the flow volume and the rotation of the impeller. A worm gear transmits the rotary movement of the vane to a revolution counter.

Depending on the position of the vane, a distinction is made between rotary meters with vanes which are at right angles (fig. 9) or parallel (fig. 10) to the pipe axis.

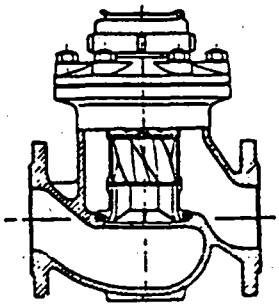


Fig. 9 Rotary meter, vane at right angles to pipe

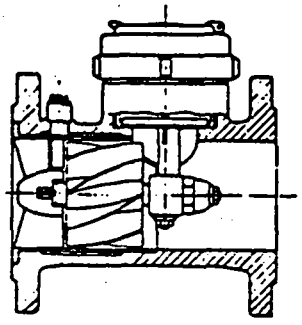


Fig. 10 Rotary meter, vane parallel to pipe

As a further distinguishing feature, there are wet-running and dry-running versions. In the wet-running design, the water comes up to just below the glass plate.

The wet-running rotary meter achieves the most accurate measurements, since there are no transferring elements from the dry to the wet chamber, and offers optimum operational reliability. It is simpler in design than the dry-running version and therefore cheaper.

Unlike the wet-running version, the dry-running meter has its counter showing the reading outside the wet chamber. As a result, the counter is not in any danger of contamination from the water.

Properties of the rotary meter

The version with vanes at right angles to the pipe has a particularly wide range of measurement and high accuracy. Economic use between DN 50 and DN 200.

The version with vanes parallel to the pipe is chiefly used for high rates of flow. It has low pressure loss. Economic use between DN 50 and Dn 500.

Properties in common

Low space requirement, due to relatively short inflow zones. No auxiliary devices or auxiliary energy required.

There are moving parts in the measured flow, therefore increased wear and tear and need for repairs.

Large number of seperate component parts.

2.2.4 Domestic water meters

Domestic water meters are meters which are designed for a flow rate of 3 to 20 m^3/h. The meters are manufactured in various intermediate sizes and categorized according to their rated load (rate of flow). The rated load is the zone between the lower and the upper limits of the measuring range. Within the rated load the meter should not cause a pressure higher than 1 bar (10 m water head).

Rotary piston meter

This is a meter for direct measurement of the volume of liquid, where the flow of water is continuously and automatically separated into and counted in spaces having a fixed volume. The rotary piston meter thus operates in both directions of flow, backwards and forwards, with equal accuracy and is suitable for installation in any position.

The rotary piston meter is particularly valuable for its accuracy of measurement.

Precondition for the use of a rotary piston meter is, however, clean water containing if possible no suspended matter.

Iron/lime deposits and sand may also have detrimental effects in this context.

Impeller meter

As in the rotary meter, the impeller is set in motion by the inflowing water. The water flows through an impeller case with opposing inflow and outflow channels. The number of rotations is directly proportional to the flow volume and is recorded by a revolution counter.

The impeller and its mounting are subjected to extreme stress, so it is important for the vane to be well-balanced and strongly mounted.

Impeller meters of standard design are suitable for horizontal installation; special versions for vertical installation are also available.

The impeller meter is more reliable than the rotary piston meter and its use is therefore more widespread.

2.3. Measurement of pressure

A further important dimension in water supply systems is the water pressure, measured with the aid of pressure gauges in bars. Points of application of pressure gauges are, for instance, pumping equipment, control systems operating on the basis of pressure, pressure-increasing equipment and filter resistance measuring devices.

Pressure is measured in the unit of pressure, the bar:

1 bar = a water head of approx. 10 m

In the type of pressure gauge commonly used in water supply systems (Bourdon gauge), the pressure is transmitted from

inside the casing via a tube of oval cross-section with connecting rod and quadrant, and shown by a pointer on a calibrated dial.

Pressure gauges are manufactured in individual categories, measuring pressures from 1 to 400 bars.

Categorization is usually on the basis of the accuracy of indication in relation to the maximum value on the scale. Example: Class 3 means that the accuracy of indication is better than 3% of the maximum value on the scale.

Connection of the pressure gauge is by means of a pipe thread or flange.

Depending on conditions at the point of measurement, pressure gauges can be supplied with a watertight casing (for open-air applications) or filled with glycerine (for applications where there are wide pressure fluctuations or considerable vibration).

There are portable instruments available, with a chart recorder.

Pressure gauges are often provided with limit contacts, to act as limit switches for the control of pumping and pressure-increasing equipment.

The limit contacts can be activated over the complete scale and are installed underneath the dial. Indication of the measured values is not affected by the position of the switching points.

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The government-owned GTZ operates in the field of Technical Cooperation. Some 4,500 German experts are working together with partners from some 100 countries in Africa, Asia and Latin America in projects covering practically every sector of agriculture, forestry, economic development, social services and institutional and physical infrastructure. – The GTZ is commissioned to do this work by the Government of the Federal Republic of Germany and by other national and international organizations.

GTZ activities encompass:

- appraisal, technical planning, control and supervision of technical cooperation projects commissioned by the Government of the Federal Republic of Germany or by other authorities
- advisory services to other agencies implementing development projects
- the recruitment, selection, briefing and assignment of expert personnel and assuring their welfare and technical backstopping during their period of assignment
- 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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