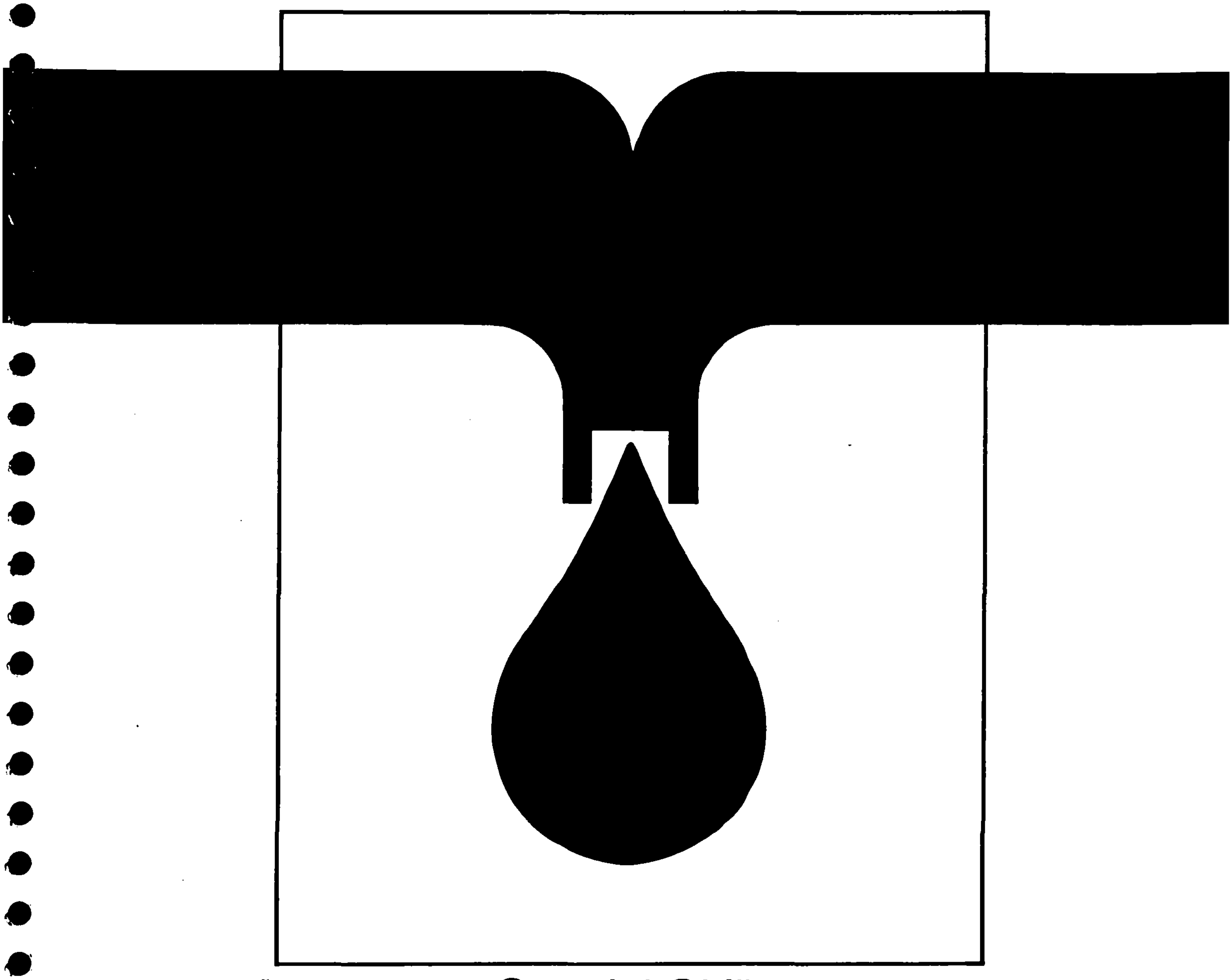
TRAINING MODULES FOR WATERWORKS PERSONNEL



Special Skills

3.4

Servicing and maintaining process controls and instrumentation

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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
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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.

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

Title: Servicing and Maintaining Process Controls and Instrumentation

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1 Process Control Instrument Servicing.

1.1 Introduction.

Process control instruments which monitor and supervise the performance of water supply and sewage treatment systems consist primarily of -

1 - Primary sensing devices of process variables,
2 - Indicating, recording and command devices.

The operating principles of the above devices are covered in modules 0.5, 2.3i and 2.4. The following chapters will deal with the servicing of these devices. The recommendations made are not to replace but to supplement the manufacturers service instruction which should always take preference.

1.2 Service Personnel.

An important factor in an effective service and maintenance operation is a well-trained staff of technicians. This is especially true when it comes to maintaining process instruments. Many manufacturers offer training courses at their plants and district offices and many provide training at the customers facilities. These services should be utilized where available. Some manufacturers maintain service facilities at their district offices or through franchise agreements. It may be more advantageous and more economical to retain these services on a contract basis wherever they are available.

1.3 Service Requirements.

Instruments are designed, so that maintenance and service requirements are reduced to a bare minimum. An initial periodic inspection of all parts of the system should serve to determine the amount of maintenance and when it should be done. Most areas of application within a water supply and sewage treatment system require an annual inspection and recalibration. In areas where corrosive vapors are present, the inspection intervals may have to be shortened depending upon the aggressiveness of the atmosphere and equipment design. The same applies to areas of moisture and condensation.

2 Mechanical Flowmeters.

The manufacturers instructions should be carefully followed. This is very important in the installation of the primary element (or sensor) with respect to the upstream and downstream piping conditions. The manufacturer specifies the minimum length of straight pipe required in relation to the ratio of the diameter of the restriction to the internal pipe diameter. Should either the upstream or downstream distance to bends, elbows, valves etc be less than specified, the manufacturer should be consulted.

All primary elements are designed for specific operating conditions, if these conditions change, the measurement will be in error and correction factors may have to be applied. The manufacturers instruction books include tables of correction factors of formulas to calculate them for the equipment he furnished.

2.1 Checking at Zero

Stability of calibration is inherent in present-day flow meters and flow transmitters. After the first two to three weeks of service, it should be equalized and the zero reading observed. To equalize the meter, the method recommended by the manufacturer should be followed. If the meter does not zero, allow some time for pressure to equalize in the high-pressure and low-pressure chambers. If zero is not correct, check connecting piping for leaks and stop them. Only then make the zero adjustment as directed by the manufacturers instructions. If the zero adjustment is within 1 per cent, it is safe to assume that calibration is satisfactory and no further adjustments are necessary.

After the fourth or fifth week of operation recheck zero. If there is little or no change in zero, this checking procedure can safely be extended for several weeks. By following this procedure, it is possible to establish a service plan for the future.

2.2 Checking Calibration

The calibration can be checked either in the instrument lab or at the installation. Pneumatically actuated bellows meters, because of their size and weight as well as pneumatic-electronic transducers are better calibrated at the point of installation. If a complete overhaul is required and competent service personnel is available the work should be done at the instrument lab.

Flow transmitters and transducers can also be calibrated in the field. It is recommended that a lab calibrated replacement unit is installed. This procedure eliminates taking checking equipment to the field, where setting up and operation are sometimes difficult.

2.3 Calibration Equipment and Use.

To obtain the accuracy of calibration inherent in the design of present-day flow meters, transmitters and transducers, standards for pressure measurement must be of high accuracy.

- The input differential pressure should be measured with a water volumn for differential pressures up to 1000 to 1200 millimeters of water. For higher pressures a mercury column may be used, but it should be equipped to read pressure with the same accuracy as an equivalent water column. The mercury column (Fig. 1) is an ideally suited precision instrument, built for ease of observation. It can be used as a manometer, a differential pressure indicator, or a differential vacuum gauge.

- The transmitter output pressure (or transducer actuating pressure) should be measured on a mercury column that can be read to an accuracy of ± 7 millibar. This is an approx. ± 70 millimeter water column. An equivalent indicating gauge as shown in Fig. 2 is excellent for shop calibrations. It can be used for indicating pressure or differential pressure.

- For accurate reading, glass tube columns should be kept clean, mercury, oil or water must also be clean.

- To avoid errors, columns should be read at the same level as the height of liquid.

- After setting pressure on the column, allow pressure in the meter body to stabilize before reading the corresponding pen or indicator needle position.

2.4 General Calibrating Procedures.

1 - Connect the output of a precision pressure regulator to the high pressure connection of the meter body. Also tie it into the water column manometer. Leave the low pressure connection of the meter body open to atmosphere.

2 - With zero differential pressure, the pen or indicator should show a 0 percent reading. If the instrument is a pneumatic transmitter or an electronic transducer, the output signals of transmitter or transducer are specified in the manufacturers instructions. If necessary the zero adjustment should be made. Its location will be shown in the manufacturers instructions.

3 - Adjust the pressure regulator to a differential pressure which corresponds to a 90 percent pen reading on the square root chart. Determine this value of water column from the Water Column Tables in the flow meter manual. The pen should read 90 percent, if not, use the span adjustment, its location will also be shown in the manufacturers instructions.

4 - If a change is made on the span adjustment, step 1 should be repeated.

5 - After obtaining correct readings at 0 and 90 percent pen reading, apply a water column corresponding to 70 percent pen reading. If the pen does not read 70 percent, refer to the manufacturers manual and make a linearity adjustment according to the instructions. The location of this adjustment is shown in the manufacturers instructions.

6 - If a change is made in the linearity adjustment, it will be necessary to rezero and to respan as in steps 2,3 and 4.

3 Mechanical Pressure Gauges.

Most pressure gauges, like flow meters, have the pressure-actuating element in direct contact with the process fluid. Exceptions are those equipped with a diaphragm seal which is located at the pressure tap and connected to the

actuating element by capillary tubing. This closed system is liquid filled. Pressure gauges are frequently subjected to severe damage. This includes corrosive action, solidification, high overloads, rapid pressure fluctuations etc.
The manufacturers instruction books provide installation information. A number of general but important instructions which are frequently violated are the following:

- An operating range should be selected so that the maximum operating point is approximately 75 percent of the full scale value. Longer life can be expected because of the lower material stresses of the actuating element, and the extent of overload protection will be increased.
- When pressure being measured fluctuates rapidly and over a considerable portion of the scale, pressure snubbers should be installed.
- Pressure gauges should be installed where they are not subject to vibrations from pumps, pipes, compressors etc. It is desirable under these conditions to use a flexible connection between pipe and gauge.
- When measuring liquids, if the gauge is installed below the point of pressure measurement, the connecting piping should be sloped to avoid the formation of gas pockets, which can cause errors.

3.1 Checking of Calibration

Pressure gauges can be checked either by removing the gauge from service and checking it at the instrument lab, or by checking it at its point of installation. They can be checked by using a primary standard, such as water or mercury columns, or dead-weight testers. They can also be checked by using test gauges which in turn are periodically calibrated against a primary standard. These test gauges usually have a very high accuracy, see Fig. 3).

3.2 Field Calibration.

The piping arrangement shown in Fig. 4 is very convenient for field calibration. The pressure source for checking is that of the main pipeline. The most common method using main pressure for calibration is as follows:

1 - Close valve 1 and valve 2. If the connecting line to the gauge is filled with liquid, close the valve immediately when the pressure drops

to zero so as not to drain the line. If gas pressure is being measured valve 2 need not be closed.

2 - Zero adjustments should not be made at this time, because with the gauge located above the main it may have been adjusted for the head effect of the liquid in the connecting piping.

3 - Connect the test gauge at the point shown.

4 - Apply increasing pressure in successive steps by alternately cracking and closing valve 1 and record the readings of the two gauges. Decrease pressure in successive steps by alternately cracking and closing valve 3 and record the readings of the two gauges.

5 - Separately average the up- and downscale readings of each gauge. Compare the value of the two gauges. This will determine the accuracy of the operating gauge with that of the test gauge. If the system is water filled, the readings of the test gauge must be corrected by the pressure equivalent to the elevation between valve 1 and test gauge. The correction factor for water is 0.1 bar for each meter of elevation. This value is to be added to the test readings. The data obtained is used to determine whether re-calibration is necessary.

6 - For low pressure ranges, a water or mercury column is substituted for the test gauge. No corrections are required for elevation.

3.3 Shop Calibration

Checking and recalibration in the shop is better than that done in the field. Not only can it be done more accurately, it also provides an opportunity for careful inspection of components, their replacement if required, as well as a general cleaning.

Water or mercury columns should be available to serve as a primary standard for checking low range gauges. Precalibrated test gauges as previously described should be available covering the required pressure ranges.

When test gauges are used, they are connected parallel to the gauge being tested. An adjustable supply of compressed air or water can be used for actuation. If the range of water or mercury columns is inadequate, a dead weight pressure gauge tester which is also a primary standard, should be provided. A dead weight tester consists of a vertical cylinder and piston, on the upper end of the piston is a tray, on which one or more standard test weights are placed. A plunger operated by hand-screw applies pressure to the liquid inside the cylinder. This liquid is oil or glycerin, stored in a reservoir connected to the cylinder through a two way valve. The gauge to be tested is mounted on the dead-weight tester and is connected to the cylinder through a three way cock, so that it is subject to the same pressure as the liquid in the cylinder. While measurements are being made, the piston carrying the weights is rotated to reduce friction. The pressure in weight per area applied by the dead-weight tester is the sum of the weights and plunger in grams divided by the cross-sectional area of the plunger in square millimeters.

The calibration is essentially performed as follows:

1 - Apply pressure of approximately 10 percent of full scale and observe readings of pressure gauge to be tested and of manometer of dead-weight tester - make no adjustments.

2 - Apply pressure equal to 90 percent (approximately) of full scale and observe readings - make no adjustments.

3 - If the instrument under test reads an equal amount higher or lower than the pressure in step 1 and 2, a zero adjustment only is required.

4 - If the instrument under test reads correct at the low pressure, but high or low at the high pressure, a span adjustment only is required.

5 - If the instrument under test reading is not correct at either low or high readings, both, zero and span adjustments are required.

6 - Use the zero adjustment when the instrument is at the low reading and the span adjustment when the instrument is at the high reading.

7 - Changing either zero or span will effect the other adjustment. It may be necessary to go back and forth between the two adjustments several times until the instrument under test reads correctly at both high and low pressures.

4 Mechanical Liquid Level Gauges.

Much of the liquid level measuring instrument equipment used is similar to the instruments used in flow meters and pressure gauges. The recommendations given in these respective sections therefore also apply to liquid level installations.

For these reasons no specific calibration procedures apply. Instead, it is recommended that reference be made to the manufacturers manuals which describe the sequence of steps for the particular type of instrument involved and for the specific way that it is installed.

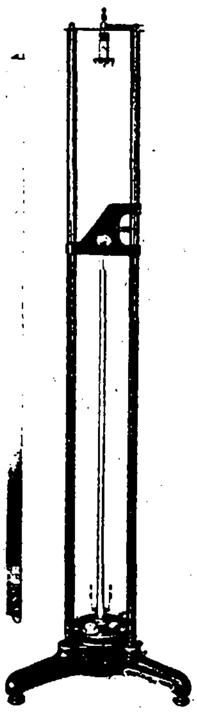


Fig. 1 - Precision mercury column used for testing pressure transmitter output.

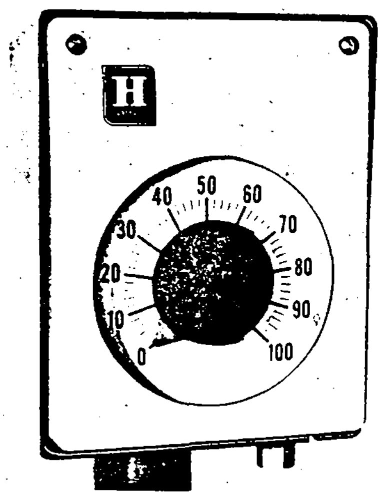


Fig. 2 - Indicating pneumatic type pressure transmitter for pressure or differential pressure.

Fig. 3 - Precison pressure indicating gauge used for instrument calibration.

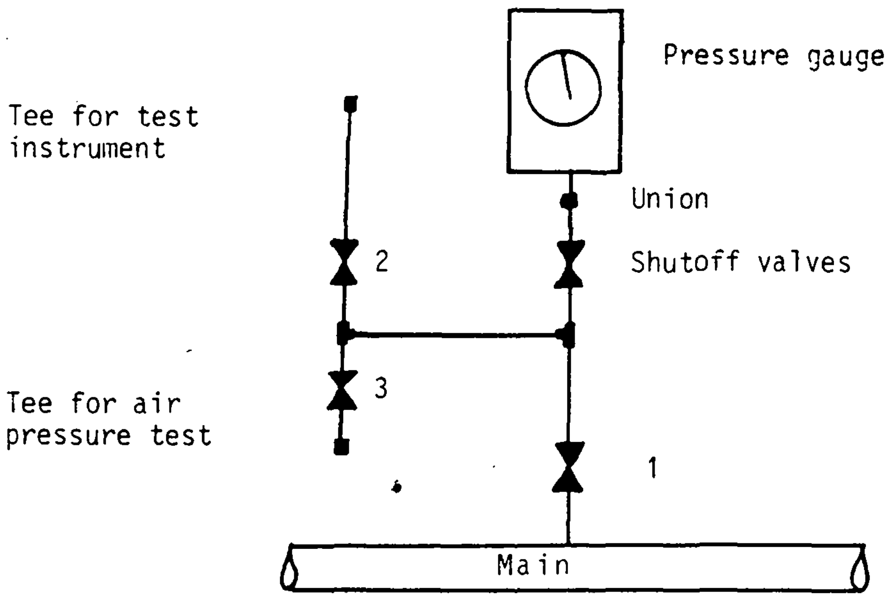


Fig. 4 - Piping arrangement for pressure gauge field testing.

5 Electric and Electronic Devices.

5.1 General.

The previous chapters cover service and calibration procedures for mechanical instruments. However, only in rare instances are instrumentation systems comprised of solely mechanical instruments. In the majority of cases, they consist of a combination of mechanical, electrical and electronic devices. Mechanical devices are often used as primary sensing elements of process variables in water supply and sewage treatment installations. The mechanical or pneumatic signal output of the primary element is then converted into an electrical voltage- or current-signal, proportional to the mechanical or pneumatic signal.

The device responsible for signal conversion is called a transducer. The voltage -or current- output signal of such a transducer is used to operate recorders, indicators or perform other functions to control and regulate a given process.

Another group of instruments use electromagnetic, ultrasonic and even radioactive emitters and sensors as primary elements to sense process variables. These devices are primarily being used to sense liquid-flow, and levels. These devices also have their primary sensing signal converted into an electrical voltage- or current-signal for further utilisation as described above.

5.2 Calibration.

The manufacturers instruction should again be closely followed. It makes very little difference whether an instrument or a group of instruments within a system operate on a mechanical, pneumatic, electric or electronic principle. The three basic calibration requirements are "zero", "span" and "linearity". What has been said on the subject of calibration in the previous chapters for mechanical instruments does therefore generally also apply to electric and electronic parts of a system. If there are deviations, the manufacturers instruction manual always point them out.

5.3 Servicing.

The service recommendations of module 3.3i also apply to electrical components when they form part of an instrumentation system, and to some limited extent to electronic equipment and components.

Electronic equipment consists in the majority of cases of semiconductor circuitry, assembled on printed cards. A semi-conductor, which can be a diode, a transistor, a thyristor or similar device, performs its function within a solid block of material, without moving parts. They are therefore also called "solid-state" devices. Solid state devices do not wear out in the same sense as mechanical devices, even as mechanical parts of electric relays or as electron tubes. They have a small incidence of failure because of undisclosed defects, but if adequately protected, solid state components have an extremely long life.
The preassembled printed cards (Fig. 5) perform certain functions such as amplifiers, rectifiers, oscillators to name just a few. Usually a whole group of such circuit functions is wired onto a single card.

A complete instrumentation system can consist of just a few - to up to several hundred printed circuit cards, depending upon the complexity of the system. To form a working system, the individual cards have to be interconnected. This is done through plug-in strips mounted and interconnected with each other on the stationary frame of the controller. The printed plug-in cards are then just plugged into the stationary plug-in strip, Fig. 6.

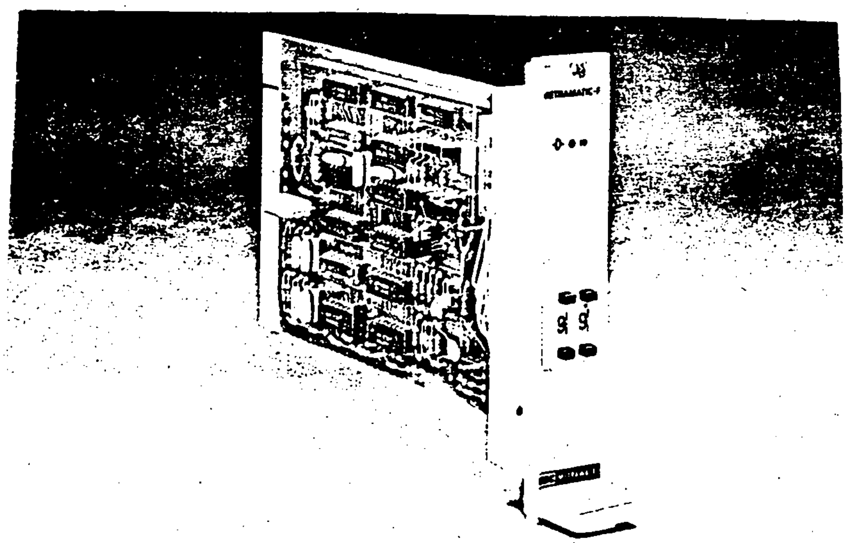
Beside periodic calibration checks, these systems require practically no service except periodic visual inspections to make sure that they are dry, clean and have unobstructed ventilation. The plug-in cards should always be properly secured in place by their plugs or connectors.

Troubleshooting of solid state control elements are simplified by the plug-in mounting arrangement which allows an easy removal and replacement of defective cards. Further simplifications are the use of indicating lights and the use of plug-in test units. Other systems are equipped with test points brought to the front of a circuit card which allows the measurement of voltages and currents from the outside, Fig. 7.

Since defective cards and sub-assemblies may be quickly replaced with good ones, most manufacturers recommend sending the faulty card back to the factory for repair or replacement, rather than attempting to locate the individual component which is giving trouble. Using this procedure will make it mandatory to keep an adequate supply of spare cards on hand at all times.

If the local operating staff has a skilled electronic technician at its disposal, an attempt should be made to repair defective cards or sub-assemblies. Such work should be performed on the test bench with specific test set-ups and should not be attempted at the equipment site. It will also be necessary to have the manufacturers schematic diagrams and bill of materials available.

Fig. 5 - Typical printed circuit card with plug-in feature.



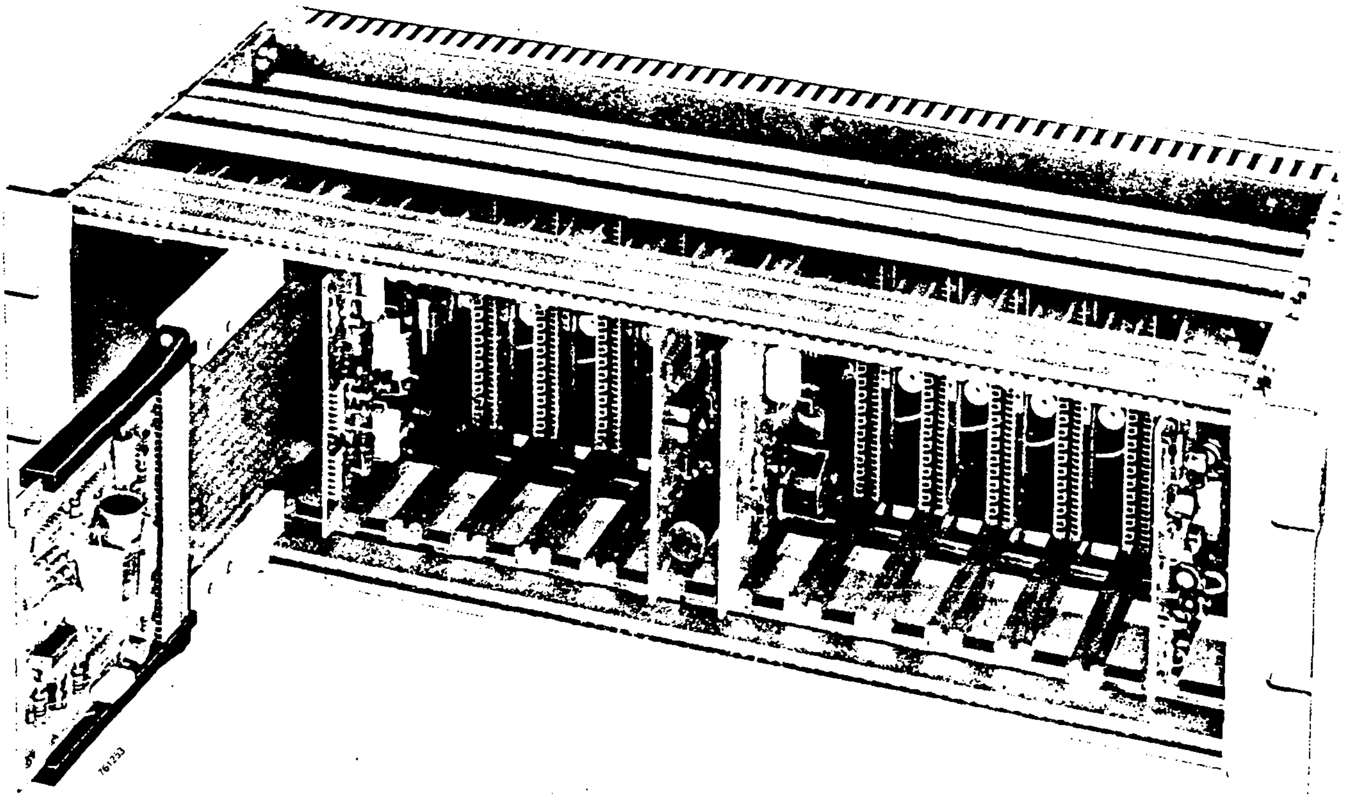


Fig. 6 - Stationary card frame with plug-in strips for 16 cards, showing 4 cards in normal operating position and one card in test position.

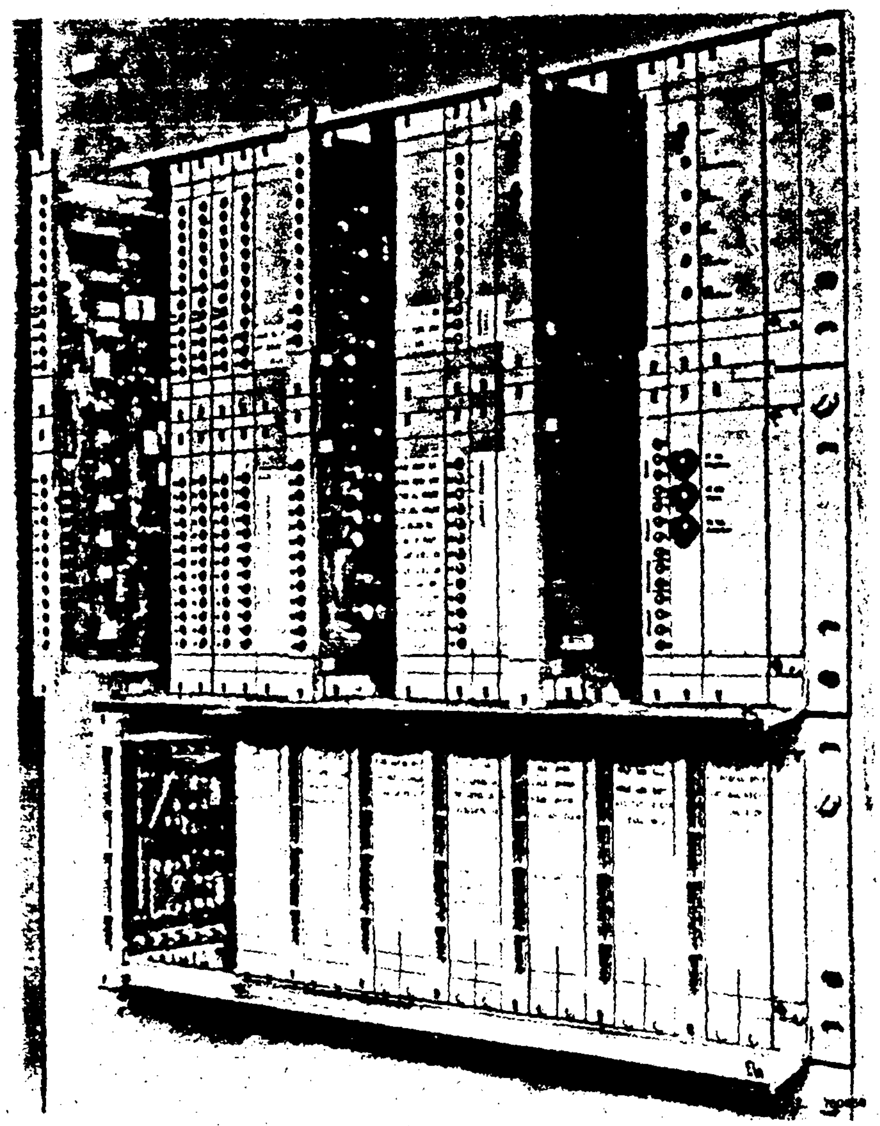


Fig. 7 - Two tier card frame with plug-in sub-assemblies.

1 - Indicating lights.
2 - Test plugs for external voltage and current measurements.
3 - Test knobs.
4 - Sub-assembly in operating position.
5 - Sub-assembly in test position.

Illustrations shown in this module by courtesy of:

Fig. 2	Honeywell Inc	Minniapolis, Minn. USA
Fig. 3	Wallace and Tiernan GmbH	Günzburg W Germany
Fig. 5,6,7	Brown Bovery Cie	Mannheim W Germany

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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:

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