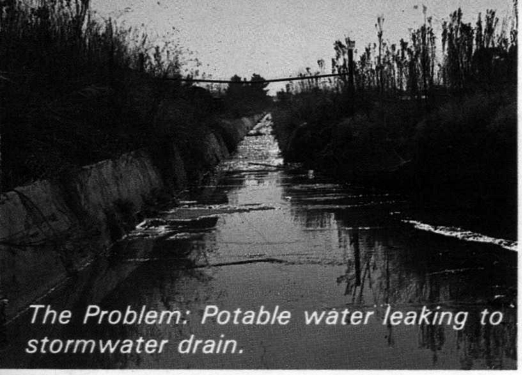


The Problem: Potable water leaking to stormwater drain.

SA WATERBULLETIN

SPECIAL ISSUE ON LEAK DETECTION APRIL 1984

Local authorities could benefit:

LEAK DETECTION STUDIED

Leak detection and repair programmes in water supply distribution systems overseas are fairly common, but very little has been done in this regard in South Africa. All local authorities rely almost entirely on surface wetness to detect and locate leaks, notwithstanding the fact that overseas experience points to water losses as high as 75 per cent. To rectify this situation the Water Research Commission has initiated a leak detection research programme in collaboration with the National Building Research Institute of the CSIR.

What are the benefits of leak detection?

- **Water saved. This implies higher income per unit for water entering the distribution network.**
- **Energy saved as treatment and distribution costs are reduced.**
- **Money saved by tackling leaks at source, rather than simply pumping more water into the system and out through leak holes, will pay dividends in reduced need for additional capital expenditure for new facilities and reduced damage to property, roads etc.**
- **Capacity saved, thus deferring new facilities.**
- **Capital expenditure deferred.**
- **Confidence in and knowledge of the supply system are gained enabling better business judgements to be made which are liable to public scrutiny.**
- **Added confidence on decision whether to repair or replace.**
- **Metering reviewed and improved. Leak detection demands a review of consumer and bulk meter accuracy.**
- **Improved control of the distribution system. Leak detection programme demands a review of the entire distribution system and the updating of all records.**
- **Discovery of unauthorised connections.**
- **Improved public relations between supplier and consumer.**
- **Possibility of reduced tariffs to consumers.**

In this special edition of *SA Waterbulletin* guidelines are presented to local authorities for the planning and conduct of a leak detection and repair programme.

INTRODUCTION

During August 1983, the National Building Research Institute entered into a contractual agreement with the Water Research Commission to carry out a pilot investigation into the detection of unseen leakage from water reticulation systems, using the latest available equipment.

A further task covered by the agreement was the drawing up of this set of guidelines for use by local authorities in the development of leakage control programmes. The guidelines have been based on both field experience (gained during the pilot investigation) and the content of the report 'Leakage Control Policy and Practice'[1]. This comprehensive report should be read in conjunction with these guidelines.

A hidden leak after excavation.

Illustrated above is the equipment for establishing that a leak exists. In front of the wooden box containing sounding equipment, is the special waste water meter with its electronic flow recorder and fire hoses used to bypass the isolating valve.

The term 'waste flow' used in these guidelines may be defined as that water which, having been put into a supply system, leaks out or is allowed to escape or is removed for no useful purpose.

'Leakage' may be defined as that part of the waste flow which leaks or escapes by means other than a deliberate or controllable action. Leakage can originate from trunk mains, reservoirs, reticulations, consumer connections or from supply systems on private properties.

These guidelines deal with pipelines in general, but more specifically with reticulation systems, including consumer connections.

DISTRICT METERING

A leakage control programme commences with the bulk monitoring of discrete, manageable sections of the total supply system.

The relevant reticulation system drawings should be studied with the aim of dividing an area into several metering districts, each comprising 2 000 to 5 000 properties.

The bulk meter (or meters) should be installed to monitor the flow into each district. Such a meter should have an integrating register and should, preferably, also have a facility for obtaining recordings of the rate of this flow, in order to measure the average and peak demand for the district. Integration of the consumption permits quantification of the unaccounted-for water entering the district, ('unaccounted-for water' being defined as the difference between the bulk metered flow into an area and the total consumption recorded on individual metered connections). The average and peak flows recorded form an important part of the data needed for the management and forward planning of water supply systems.

In order to monitor accurately the minimum (or night) flow into a district, provision should be made for a valve-controlled bypass around the bulk meter, this bypass should incorporate a waste-flow meter, permanently installed, or alternatively, be designed to accommodate a waste-flow meter. The waste-flow meter should be equipped with a rate-of-flow indicator and a chart recorder.

By isolating the bulk meter during the period of minimum flow, usually from midnight to 04h00 between Mondays and Fridays, the minimum night flow for the district can be measured via the waste-flow meter. The minimum night flow will, in most cases, equal the leakage.

Where consumers draw water all night, such as through continuously running machinery or automatic flushing urinals, the leakage for the district can be ascertained by deducting their consumption metered over the period of measurement from the total, or by isolating them over the same period.

The leakage figures (converted to litres per property, per hour) for various districts can be compared, and an acceptable norm arrived at. Overseas experience in urban residential areas suggests a norm of 4,5 ℓ/property/hour.

The leakage flow into a district should be measured periodically. The interval between checks will depend on the general condition of the reticulation system, but should not exceed two months. Bulk meters should be checked and calibrated regularly to ensure that accuracy is maintained.

The waste-flow meter, if permanently installed, should not remain in use between leakage measuring exercises. Isolating valves should be provided on both sides of the meter. Some meters are designed with removable turbine elements which can conveniently be used in more than one waste-flow meter.

Senior Adviser HC Chapman "sounding" a noisy hydrant using a geohydrophone.

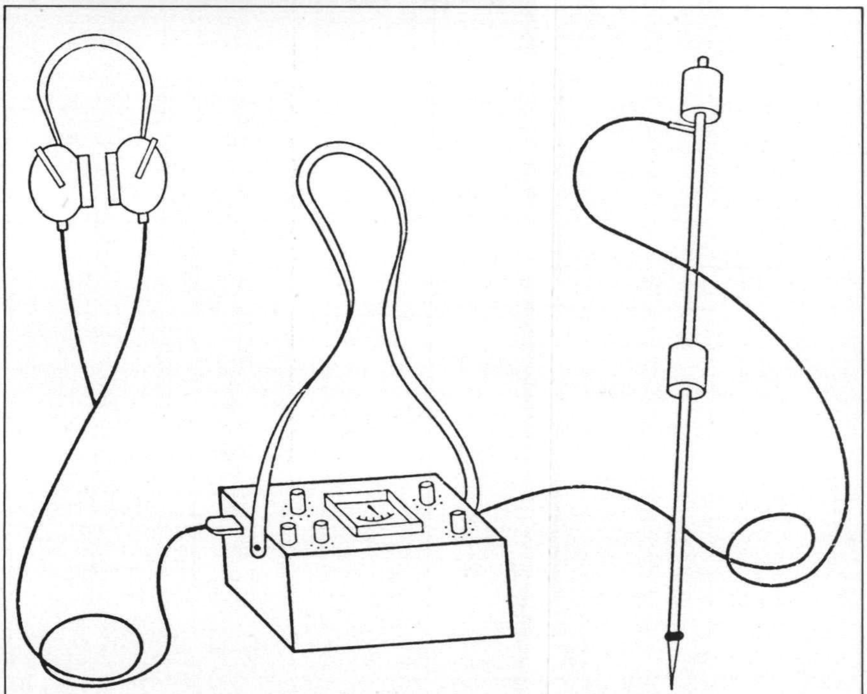


Figure 1: Portable sound amplification equipment incorporating probe, headphones and sound-intensity indicator.

DISTRICT INSPECTION

When the leakage for a district exceeds the proposed acceptable norm, it is necessary to conduct a district inspection, followed by an attempt to pinpoint the source(s) of leaks.

Before the commencement of a district inspection, the lay-out drawings of both the water reticulation and the stormwater drainage system should be studied. The water supply drawings should show the position, diameter and type of material used for all water mains, together with the distances from boundaries, the positions of isolating, air and control valves.

A district inspection is carried out on foot; this involves an inspection of major stormwater drains serving the area and the 'sounding' of all valves, hydrants and, if necessary, stopcocks on consumer connections. Fittings are 'sounded' with the help of portable sound amplification equipment (Figure 1) comprising a probe, a pair of headphones and a sound-intensity indicator.

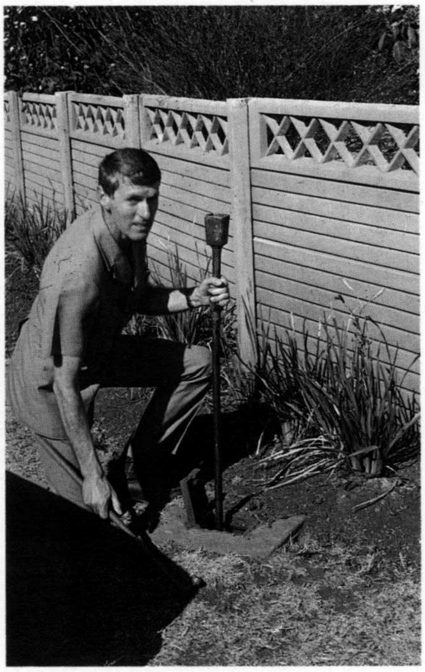
The locality of particularly noisy fittings should be noted, as well as that of stormwater drains observed to be flowing during dry weather. Abnormally lush patches of grass on sidewalks should also be noted. Such symptoms will indicate the existence and approximate position of unseen leaks. The inspection may, however, not result in the detection of all serious leaks, since water pouring from a large hole in a pipe is generally quieter than water jetting from a small hole; a major leak can thus be overlooked by an observer using the sounding equipment.

The transmission of the sound of the leak is also affected by both the material and the diameter of the pipe. Copper transmits sound best, followed by steel, cast iron, ductile iron, asbestos-cement, concrete and plastic in descending order of efficiency. Sound waves transmitted along a pipeline are partially absorbed by the pipe wall. The larger the wall area the shorter the distance the sound is transmitted.

Because of this, leak detection methods relying on sound transmission are generally only effective on pipes of 375 mm or less.

PINPOINTING LEAKS

Once the existence of leaks and their approximate locality is known, it is necessary to determine their position. All methods of pinpointing leaks (with the exception of the gas tracer technique) rely on the sound generated by the leak.



George Malan, NBRI, preparing to close and isolate valves prior to the step testing.

Because of the substantial expense of digging 'dry' holes (or the mislocation of leaks), there is a definite need for highly effective leak detection equipment.

A recent development, which has greatly enhanced the reliable tracing of leaks, is the electronic acoustic correlator. This instrument, (which does not seek the point of maximum sound as does portable sound amplification equipment), uses two microphones or transducers which are placed in contact with the pipe (Figure 2). It determines the distance of the leak from one of the contact points by recording the time the noise of the leak takes to reach each transducer via the pipeline, and then calculating the difference.

Every leak generates a unique sound which is converted into an electronic signal by the transducers; it is then pre-amplified, collected and stored in the correlator. The correlator proceeds to delay, progressively, the coded signal coming from the transducer nearer the leak, until, at a specific time delay value, the correlator receives a matched signal from both transducers simultaneously. When this happens, a peak in the signal trace appears on the oscilloscope of the instrument, signifying that a correlation has been achieved. If no leak is present no correlation can be obtained.

Two vital parameters required by the correlator are the velocity of sound in the pipeline (which is dependent on the pipe material) and the length of the pipeline between the transducers. This length is accurately measured on site by running a special measuring wheel along the ground over the pipeline. The typical velocity at which sound travels in a pipeline of 375 mm diameter and smaller has been found to be 1,4 m per millisecond for metal pipes, 1,0 m/ms for pipes of asbestos-cement and 0,4 m/ms in the case of UPVC. These values can be affected by the condition of the pipe and the bedding. The velocity in a pipeline comprised of different materials, such as of steel under roads and of asbestos-cement under sidewalks, will be a combination of the different successive rates. It is important, therefore, for the materials of which pipes are made to be clearly recorded on layout drawings.

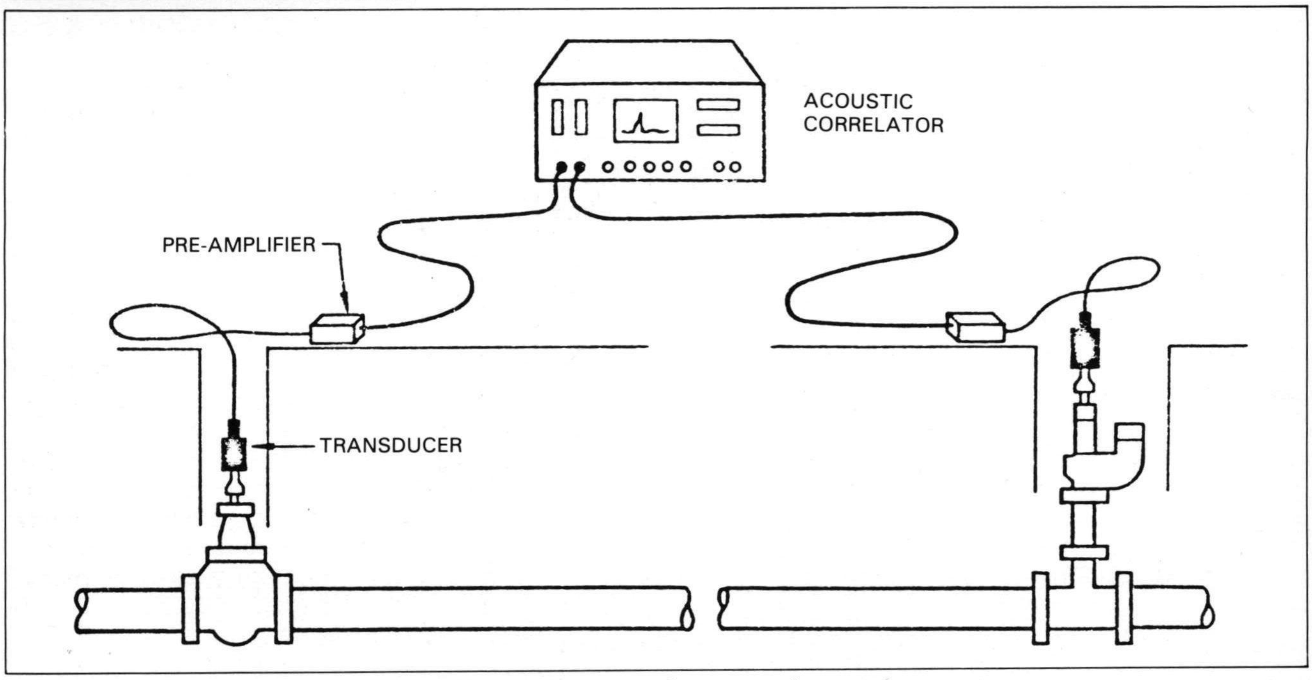
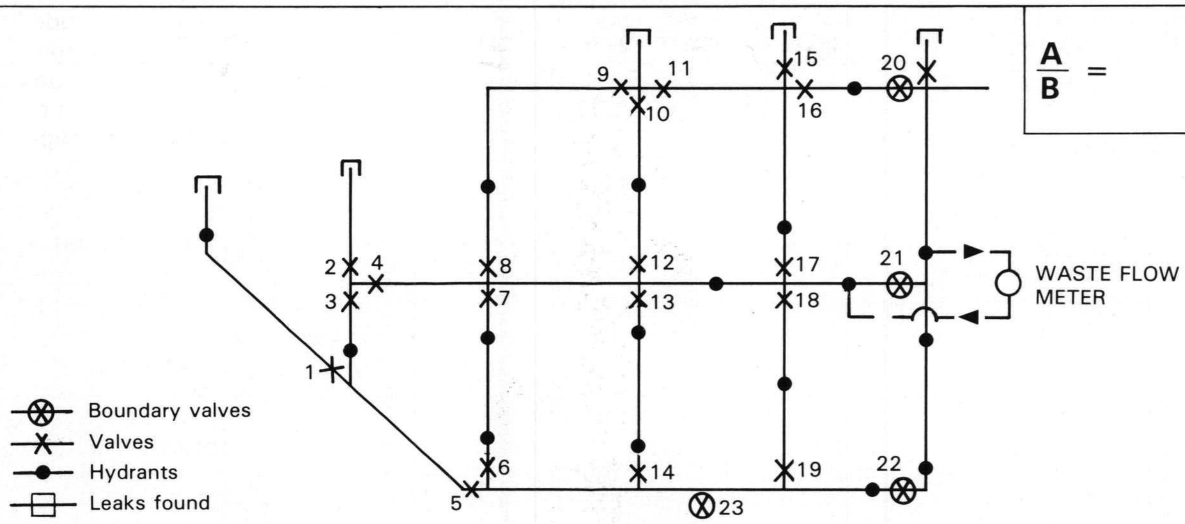


Figure 2. Field set-up for acoustic correlator.

Figure 3. Programme for step test.



$\frac{A}{B}$ =

Details on plan requiring prior attention	

METHOD: After setting up waste-flow meter (WFM) and pressure gauge, close all boundary valves and "sound" each one for water tightness. Check for pressure drop. If pressure drop is not achieved, locate faulty (or uncharted) boundary valve and apply necessary maintenance. Repeat until pressure drop is achieved. Measure minimum waste-flow into district in litres per hour (= A). Compare with number of properties in district × 4,5 litres (= B). Determine the ratio $\frac{A}{B}$ and insert in the space provided. Continue with step test.

OPERATING SEQUENCE OF VALVES FOR "STEP TEST"		ACTION/COMMENT
Close	Open	
20, 21, 22, 23		Boundary valves
1	1	
2	2	
4, 7, 8, 12, 13, 17, 18	}	Pipe between 4 and 21 isolated-checked
	17, 18	
5		Pipe 5 – 3 – 4 checked
6	6	Pipe 6 – 7 checked
14	14	
19	19	Pipe 5 – 22 checked
	5	
15		
16	15	Pipe 16 – 20 checked
	16	

(Continued p 6)

OPERATING SEQUENCE OF VALVES FOR "STEP TEST"		ACTION/COMMENT
Close	Open	
11	11	Pipe 11 – 9 – 8 checked
10	10	Pipe 10 – 12 checked
17	17	Pipe 17 – 16 – 11 checked
18	18	Pipe 18 – 19 checked
	4, 7, 8, 12, 13	
	20, 21, 22, 23	

No. of leaks	Date	District	Township	Local Authority
	16 SEP 1983	No 1	VALHALLA	PRETORIA

Using the parameters of time delay, the velocity of the sound and the length of the pipeline, the correlator calculates the distance between the leak and one of the transducers, and then displays this.

The acoustic correlator can only pinpoint the leak position if the leak lies between (or is bracketed by) the two contact points. If the leak lies outside the bracketed section, the instrument does, however, indicate which of the transducers receives the signal first, and hence on which side the leak lies.

The accurate pinpointing of the leak is improved by transferring one of the transducers to a new access point on the pipeline (such as at a consumer connection). This allows for the solving of two simultaneous equations and the eliminating of the need for the velocity, which is not always accurately known.

The maximum distance obtainable between transducer mounting points is rarely more than 250 m. Under favourable conditions, about 12 correlator set-ups can be achieved in a day. It is worth noting that the correlator is not affected by extraneous noise.

When leaks have been pinpointed and repairs carried out, the leakage for the district should again be measured, taking into account any additional out of hours consumers who may have established themselves in the area since the previous check.

Any measurable leakage remaining may be caused by a multitude of small leaks, or several major 'quiet' ones. There is always the possibility that water which is not emerging on the surface could be entering broken sewers or merging with ground water to feed boreholes. The frequency of district inspections will depend on their effectiveness, but should not exceed two years.

STEP TEST

As part of the leak pinpointing procedure, it may be necessary to carry out a step test, or a step by step process of elimination to identify a specific section of pipeline between isolating valves as that containing the leak. The procedure also allows the magnitude of the leakage flow to be measured.

The step test involves the selection of a sub-district comprising about 100 properties bounded by suitable isolating valves (boundary valves). Because of time constraints, the number of valves operated during the step test does not in general exceed 20.

Before the commencement of the step test, a programme should be drawn up for the sub-district (Figure 3), showing the layout of the mains and listing the planned sequence for opening and closing valves.

It is important to check the operation of valves and to carry out any maintenance work required, prior to the test.

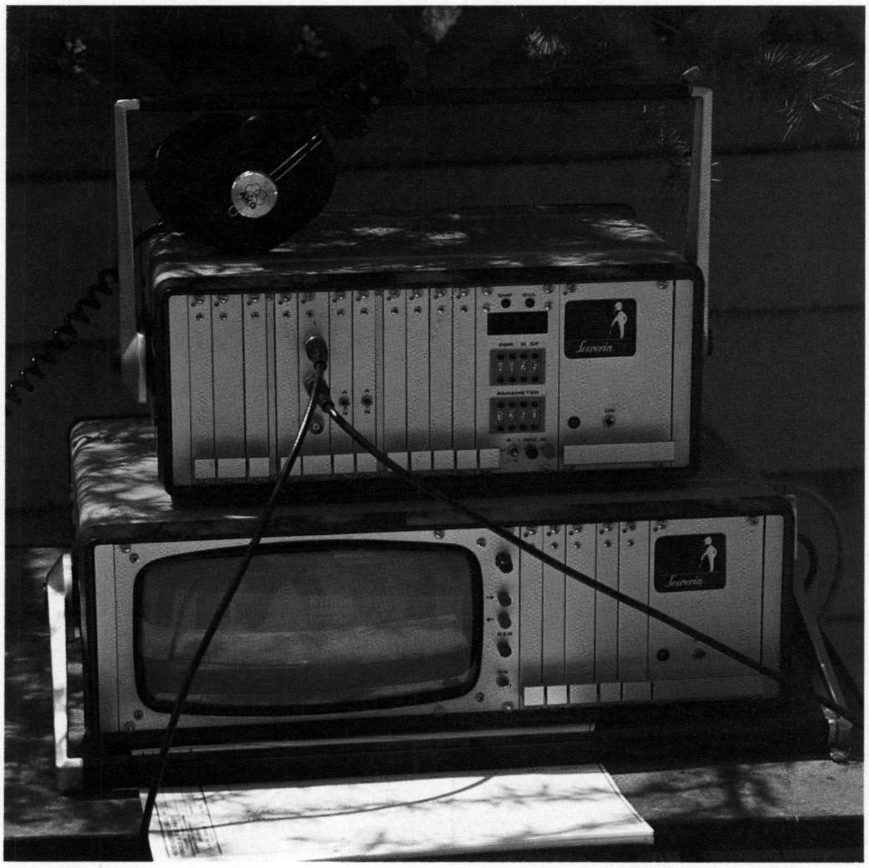
A waste-flow meter (Figure 4) is set up between two convenient hydrants, one inside and one outside the sub-district, such that the total flow into the sub-district passes through the wast-flow meter.

By successively closing valves within the isolated area, different sections of water main are taken out of service, and the effect on the flow rate noted. A significant drop in the flow rate will indicate the presence of a leak in the section just isolated.

For the test to be successful it is important that isolating valves seal properly. This requirement can be checked by sounding each valve, while closing it, with the portable sound amplification equipment.

The time of day selected for carrying out the step test should be when the consumer water demand is at an absolute minimum. In

A typical leak noise correlator used to pinpoint the position of a leak in a pipe.



residential areas for example, the step test should be carried out beween midnight and 04h00 from Monday to Friday. Weekends are inappropriate since people are more likely to arrive home after midnight and draw off water.

Complicated networks can be simplified by isolating loops, thus breaking their continuity and creating a tree-like pattern of distribution mains.

There are several ways in which the sequence of closing valves for the step test can be carried out. One way is to isolate sections, commencing at a point furthest from the waste-flow meter and working successively closer to the meter until all valves are closed. The disadvantage of this method is that some consumers will be without a water supply for the duration of the test, and mains can empty, thus increasing the risk of entry of polluted water and air.

Another recommended method is to isolate sections of the main, commencing at a point furthest from the waste-flow meter, but each time a valve is closed, a corresponding valve is opened behind it, starting with the boundary valves, thus water is again allowed to enter that part of the system which has been tested. Since the success of this method relies heavily on valves closing completely it is advisable to ensure that there are at least two closed valves between the section under test and that already tested.

The use of two-way radios by the personnel operating valves and those recording leakage rates at waste-flow meters, is essential to avoid errors and wasted time.

After connecting up the bypass between two hydrants and charging it with water, the step test should not be commenced until it

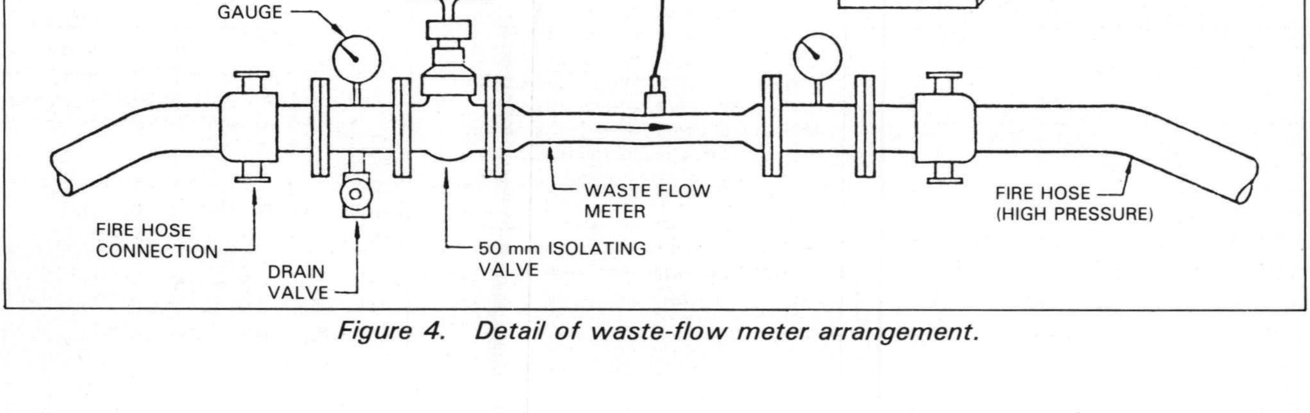


Figure 4. Detail of waste-flow meter arrangement.

has been verified that the area has been properly isolated at the boundary valves and that there is no uncharted supply into the area. To do this, the isolating valves in the waste-flow meter bypass should be closed off and the pressure gauge downstream of the meter observed (Figure 4). Isolation of the area will be confirmed by a fairly rapid fall-off in pressure.

In sloping areas it may be necessary to observe the pressure at a hydrant situated at a high point within the isolated area, using a pressure gauge fitted to special hydrant adaptor.

Because the step test has to be completed within a few hours, it is advisable to arrange for the setting up of the waste-flow meter and for the closure of all boundary valves (except for two or three) on the afternoon before the step test. A watchman should be left to guard the waste-flow meter. The waste-flow meter should be kept isolated until actually required for the step test.

Some points worth noting when conducting a step test are listed below.

- If possible, avoid laying fire hoses across main roads.
- Portable ramps placed on either side of a hose laid across a road will facilitate vehicle crossing.
- Care must be taken to avoid contamination of the mains via the hydrants, through the use of unsterile equipment or from dirt taken into the bodies of hydrants by birds, insects or rodents.
- Fire hoses which are new, or have been in storage, or have been contaminated, should be flushed and filled with water containing 20 mg/ℓ chlorine and then left to stand for at least 2 hours before use.
- Cap the ends of hoses when not in use, or join the two end couplings together.
- Couplings should be raised on blocks to prevent contamination from puddles, dirty water and soil.
- Hydrants should be flushed out before hoses are connected to them.
- Fire hoses are usually 30 m in length. It is useful to have, in addition, one half-length hose and one quarter-length hose, to avoid the difficulty of having to 'snake' hoses, since under full mains pressure the hoses cannot tolerate curves of a radius of 2 m or less.
- Make a sketch of the hydrant hook-up. Such a record will save considerable time on future occasions.

ECONOMIC CONSIDERATIONS

The extent and sophistication of the leakage control programme adopted by a local authority will depend on economic considerations.

The installation of bulk district meters, together with a bypass for waste-flow metering, is a basic essential in any water supply system.

The cost of a district inspection, followed by leak detection and repair, can be set against the loss of revenue arising from water being produced or bought in bulk and not sold to consumers. The cost of having to prematurely increase the water supply because of uncontrolled leakage, should also be considered.

A district inspection is carried out with the use of portable sound amplification equipment (Figure 1) presently costing about R1 600. Proficiency in its use grows with experience.

The acoustic correlator, together with appurtenances, costs about R25 000 and requires a trained operator for optimum efficiency. While the larger local authorities would be able to justify the purchase and use of a correlator, the smaller local authorities would, in general, not. The services of commercial firms using a correlator can be obtained on a hire basis (R400 to R600 per day), or on a tender basis (in terms of length of pipeline investigated).

A waste-flow meter should measure the flow rate to within an accuracy of 2 per cent and should have an instantaneous rate-of-flow indicator and a strip chart recorder. A suitable meter costs between R2 000 and R7 000 (1984 prices), depending on its size, type and accuracy.

The procedures for carrying out detailed cost-benefit analyses for leakage control are described in the report 'Leakage Control and Practice'[1].

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1. **Department of the Environment (UK). 'Leakage Control Policy and Practice'. Standing Technical Committee Report No 26, July 1980.**

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