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Universiti Pertanian Campus, Serdang, Selangor, Malaysia

PUBLIC WATER SUPPLY LEAKAGE AND WASTAGE CONTROL

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**A COLLECTION OF PAPERS PRESENTED AT THE WHO
WORKSHOP ON PUBLIC WATER SUPPLY LEAKAGE
AND WASTAGE CONTROL
HELD IN SINGAPORE FROM
12 TO 17 DECEMBER 1983**

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WORLD HEALTH ORGANIZATION



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Western Pacific Regional Centre
for the Promotion of Environmental
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WASTAGE CONTROL**

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Public Water Supply

Mailing Address: c/o P.O. Box 12550
Kuala Lumpur, Malaysia

Tel. Nos.: 356101) Ext. 609
356304) 635
355425)

Telegramme: UNISANTE
KUALALUMPUR

Location: Universiti Pertanian Malaysia Campus
Serdang, Selangor, Malaysia

Telex No.: 31084

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FOREWORD

Leakage control is one of the main functions of operation and maintenance of public water supplies. Control of wasteful use of water is also gaining increasing attention especially in areas with scarcity of suitable water sources and in regions subject to frequent prolonged drought. With the launching of the International Drinking Water Supply and Sanitation Decade (IDWSSD), involving huge sums of capital investment, leakage and wastage control of public water supplies is becoming an economic necessity in cases where costs of additional water supply are relatively high. From the viewpoint of public health, a leaking pipe also represents a potential source of health hazard.

A WHO Workshop on Public Water Supply Leakage and Wastage Control was organized by the WHO Western Pacific Regional Centre for the Promotion of Environmental Planning and Applied Studies (PEPAS) from 12 to 17 December 1983 in Singapore to evaluate the latest concepts and technology in leakage control and to assess the various methods for the reduction of water uses in the home.

The technical support on leakage control was mainly provided by experts from the Water Research Centre (WRC) of Great Britain and valuable examples of wastage control were demonstrated by the Public Utilities Board of Singapore.

This document contains a selection of technical papers, reading materials and reports presented at the workshop for possible reference use by public agencies, consulting engineers and training institutions concerned with public water supplies. For reading materials already available in published form, only short summaries are presented in the document. Those interested in details of such materials may obtain copies from the publishers. Some of the papers and reports included in this document have been revised by the authors to bring the contents up-to-date. Otherwise, they are reproduced as they were presented.

A companion document entitled "Report on the WHO Workshop on Public Water Supply Leakage and Wastage Control" is available from PEPAS on request.

Kuan-Mu Yao
Dr K. M. Yao
Officer-in-Charge
PEPAS

REDUCING UNACCOUNTED-FOR WATER
IN MUNICIPAL WATER SUPPLY SYSTEMS

by

S. J. Goodwin¹
WHO Consultant

and

J. K. McElroy²
WHO Consultant

¹ Project Leader, Water Mains Group, Water Research Centre, Swindon, UK
² Leakage Control Engineer, Water Research Centre, Swindon, UK

REDUCING UNACCOUNTED-FOR WATER IN MUNICIPAL WATER SUPPLY SYSTEMS

UK Water Research Centre develops a practical economic approach to reducing Unaccounted-for water.

INTRODUCTION

The annual income of a water undertaking depends upon the amount of water it supplies which is paid for by its metered consumers. But the amount of water it puts into its distribution system can often be twice this quantity, sometimes more. The difference between these two quantities of water is referred to variously as unaccounted-for water (UFW) or non-revenue water (NRW).

It is clear that high levels of unaccounted-for water cannot be tolerated as this implies that operating costs are increased, revenue is reduced and expenditure on capital schemes is required earlier and partly serves no useful purpose. In order to achieve savings in these 4 areas, it is necessary to spend money to reduce the level of unaccounted-for water. The problems arise as to the level of expenditure necessary to ensure the maximum benefits and the manner in which this money should be spent.

The Water Research Centre (UK) has devised a rational procedure to determine how this can best be achieved for the leakage element of UFW.

A major advantage of this procedure is that the underlying approach is sufficiently general for it to be applicable, both to the other elements of UFW and to any supply and distribution system in the World.

After first defining the main components of unaccounted-for water, this article discusses the application of the WRC approach

to each, concentrating on how to select the best methods of reducing the leakage component of unaccounted-for water. Finally, application of the approach in the UK and to developing countries is discussed and examples are given of the substantial net savings that can be achieved from adopting a rational approach to dealing with this problem.

COMPONENTS OF UNACCOUNTED-FOR WATER

Unaccounted-for water can be sub-divided into three distinct categories;

- . Leakage from the water undertaking's own supply and distribution system
- . Meter under-reading
- . Illegal connections

In addition, wasteful use or consumers' leakage, although a component of accounted-for water, may also be considered as worthy of reduction. However it should be borne in mind that such wasteful use can form a significant part of the metered revenue.

In order to determine what is the best course of action to take to reduce unaccounted-for water, it is necessary to consider both the practical and the economic factors in a logical, ordered, fashion. First, the WRC approach does this by obtaining a reliable estimate of the scale, in both quantity and cost terms, for each category of the quantity of water which goes unaccounted-for. Then a review is made of the possible methods of control in each category before undertaking an analysis of the costs and benefits of each of the more promising options

identified. From the results of this analysis, and after careful consideration of the practical problems involved for each case, the most appropriate policy can be determined, confident that it has a sound practical and economic foundation.

Following such an approach not only ensures that the most appropriate and cost effective measures for reducing unaccounted-for water are chosen but also that the most beneficial level of expenditure (or effort) is expended on those measures.

Taking for example the problem of revenue meter under-registration, whilst not strictly a loss of water (as it is likely that the water is being usefully consumed) it is a source of revenue loss and the benefits of reducing it are substantial. It occurs for two basic reasons

- (a) deterioration of meter accuracy caused by age, use and the effects of particulate matter in the water
- and b) incipient under readings of even new meters caused by them being subjected to flows below their threshold of accurate registration. The latter is a particular problem in countries where domestic storage tanks are common, possibly being used to combat the effects of intermittent supply, because the controlling ball valves induce very low flows.

Application of the WRC approach would

- (a) identify the scale of the problem and the reasons for it
- (b) demonstrate to what extent it was worth selecting more accurate but more expensive meters,
- (c) identify the optimum meter replacement/repair policy.

- (d) identify the costs of such action and the likely increases in revenue resulting from it.

The decision of the most rational policy for dealing with illegal connections is less clear cut depending as it does, upon such factors as the water undertakings pricing policy (ie tariff structures for different consumers) and upon socio-political considerations which affect the overall policy on water supply provision. Remedial measures are concerned not just with reducing the existing problem but preventing further escalation. Here, economics are possibly of secondary importance as whilst an efficient detection campaign may not show immediate net benefits, it is undoubtedly an excellent preventative in the future. Nevertheless application of the approach will ensure that the decision on any course of action is taken in a rational manner and that the economic and resultant financial implications of that action are known.

However, world-wide, these two categories are generally considered to account for the minor part of water which goes unaccounted for. Under normal circumstances, the dominant portion of unaccounted-for water is lost from the supply and distribution system as leakage. Given this, we shall illustrate the general approach outlined above as it applies to reducing leakage.

LEAKAGE CONTROL

All water supply and distribution systems leak as it is clearly uneconomic to ensure that pipelines and reservoirs will never leak, it is also clear that there is an economic limit to the loss of water that should be tolerated through leakage. The problem, therefore, is how to select the most appropriate policy for dealing with leakage in a particular supply and distribution system, ensuring that the cost of the chosen measures is more

than compensated by the savings made.

While leakage may occur in any part of the system, extensive examination of service reservoirs, trunk mains and distribution networks in the UK has shown that in the majority of cases most leakage occurs within the distribution system.

The various methods of leakage control applicable within a distribution system may be categorised into five distinct types. Listed in order of increasing cost and effectiveness at reducing leakage, they are:

- . Passive Control
- . Regular Sounding
- . District Metering
- . Waste Metering
- . Combined Metering

Pressure control can be considered as a sixth method of leakage control which may be implemented separately or in conjunction with any of the above methods. A brief description of each of these methods is given separately (see inset).

Clearly no one of these methods is appropriate everywhere. The selection of method depends primarily upon the following factors:

- . the level of leakage within the system.
- . the cost of that leakage (or, conversely, the benefit to be derived from reducing that leakage)
- . the cost and effectiveness of each of the methods of control.

This may be illustrated by reference to Figure 1.

Where the total cost of leakage is low, i.e. both leakage and its costs are low, it will be uneconomic to spend a lot of money on leakage control and a simple method will suffice. Conversely, where the total cost of leakage is high, then a more expensive method can be justified because the savings which result are correspondingly higher.

The problem of determining the correct leakage control policy is, firstly, finding a way onto the diagonal economic band through the centre of Figure 1. Secondly, factors other than purely economic ones are taken into account. The design of the system, the type of area (urban, rural), availability of manpower and other practical, engineering and financial factors must also be considered.

The procedure developed by WRC and shown in Figure 2 sets out the various steps involved in order to perform this selection process in a rational manner.

This procedure which is sufficiently general to be applicable to virtually any distribution system throughout the world can be used to:

- . determine a leakage control policy where none exists.
- . review an existing policy
- . determine the operational resources required to implement the chosen method, the costs of implementation and the likely savings to be made.

One of the major advances in the WRC procedure is that it enables, for the first time, the benefits of reducing leakage to

be calculated (the unit cost of leakage). This is derived from the change in costs brought about by reducing the amount of leakage within the system. It consists of:

- (1) reductions in annual operating costs (pumping costs, treatment costs, etc).
- (2) deferment of capital schemes, or those parts of capital schemes, required to satisfy increases in demand (or in leakage!!!) (sources, reservoirs, treatment works, mains, etc).

APPLICATION IN THE UK

Since its development in 1980, the procedure outlined in Figure 2 has become the only method for the determination of Leakage Control Policy acceptable to the British Government. Indeed in order to secure funding for major new capital schemes, UK Water Authorities must first show that the level of leakage in the designated area has been reduced to economically acceptable levels. Thus all ten Water Authorities in the UK have adopted this procedure and are now implementing it over a large part of the country. Despite, historically, a good record of leakage control in the UK, it is estimated, from work carried out to date, that implementation of this policy should still result in changes in leakage control policy in some 45 per cent of the country. While the general trend has been to more intensive leakage control measures, in a few areas a reduction in the existing level of effort has been found to be warranted.

But perhaps the best testimony to the real benefits that can be derived from adopting, not just any leakage control policy, but that which can be shown to be the most technically and economically appropriate policy, is that this review of leakage control policy has taken place against a background of considerable contraction in the UK water industry. One

measure of the increased input into leakage control as a result of this review is that the net change in manpower employed on leakage control work in the UK is projected to rise by about 200 over the next 2-3 years.

This change of direction is only justified because the net savings from adopting the most appropriate policy are usually very significant. For example, taking the UK as a whole, it has been estimated that the total net savings obtained from implementing the necessary changes so far identified would be in the order of £20 million (US \$30 million) per annum.

At the local level it has been shown that the adoption of the correct policy can typically produce net annual savings of about £250,000 per annum for an undertaking of 80,000 properties where the average value of water saved is £0.04/m³ (normal UK range £0.01 - £0.10/m³), which hitherto had an inappropriate method of leakage control. This net saving is achieved after the cost of determining the most appropriate method of leakage control and the costs (£0.5 - £1.0m) of setting up the chosen method of control have been deducted.

APPLICATION IN DEVELOPING COUNTRIES

There are many differences between Water Industry practice in the UK and other countries. Factors such as intermittent supply and illegal connections may affect the feasibility of certain methods of leakage control whilst a lack of suitable access points to the main, such as stop valves on service pipes, would dictate a means of finally pinpointing the leak other than by manual sounding. Nevertheless, there will still remain a choice of several distinct methods of leakage control ranging from the bare minimum, ie passive control which is applicable everywhere, through to the most intensive methods involving comprehensive metering and inspection. Any one of these methods could be most appropriate and economic depending upon the circumstances of the

particular system. By suitable modification of the WRC procedure these local circumstances can be taken account of and the most appropriate method of control determined.

The savings which can result from application of the procedure in developing countries can be much more impressive than those quoted for the UK, particularly in more arid countries where the cost of water supply schemes may be relatively more expensive. In addition the return on investment can be much greater owing to the lower labour costs in many countries relative to the price of energy and capital works.

Whilst the diversity of situations found worldwide defies glib generalisations about such savings, the following two recent examples perhaps serve to demonstrate the likely order of magnitude of such saving for very different supply systems.

In the first, a town of 45,000 properties in Turkey, it was found that the cost of pumping water (about £0.01/m³) was sufficiently high compared to the cost of labour (about £0.040/hr) to justify a relatively high level of leakage control and savings on pumping alone were of the order of £30,000. Return on investment in labour was of the order of 500 per cent! Deferment of capital schemes was not considered as the supply system was well developed and this was unnecessary in order to determine the appropriate policy.

In the second system, a city of 50,000 properties in the Middle East, the production cost of desalinated water was £1.00/m³. Here reduction of leakage would also defer a further additional £20 million desalination plant, or more accurately release its capacity for supply to another area. It was estimated for this town that total savings of £2.85 million per year would result from an expenditure on leakage control of roughly £0.05 million per year!!

CONCLUSION

Adoption of some form of active leakage control is normally economic for a medium sized town at a unit cost of leakage of as little as £0.01/m³.

For higher unit leakage costs, more effective and therefore expensive leakage control measures may be justified.

In some cases substantial savings from adopting active leakage control measures are achieved through the deferment of capital schemes designed to increase the supply capacity of the water undertaking. In others, as was the case in the first example quoted above, the value of water saved through reducing operating costs is sufficient to justify intensive leakage control.

Increasingly the main development aid and loan organisations, such as the World Bank and the Asian Development Bank, together with an increasing number of governments around the world are realising that, in many towns, making new investments in appropriate leakage control schemes makes good economic sense.

The Water Research Centre, for its part, is now able to offer a service world wide to determine the most appropriate leakage control scheme for a particular distribution system.

Table 1 Changes in Leakage Control Policy Resulting from
the Application of the WRC Procedure

| LEAKAGE CONTROL METHOD | EXISTING POLICY % | PROPOSED FUTURE POLICY % |
|---------------------------|-------------------------|--------------------------------|
| Passive Control | 25 | 2 |
| Regular Sounding | 10 | 2 |
| District Metering | 18 | 35 |
| Waste Metering | 42 | 29 |
| Combined Metering | 5 | 32 |

Figures are percentage of population supplied

INSET

METHODS OF LEAKAGE CONTROL

The different methods of leakage control can usefully be grouped into active measures and passive control. Generally 'active' methods aim to reduce the level of leakage within the system by identifying and locating the more serious 'chronic' leaks within progressively smaller areas and within shorter periods after they occur. Regular sounding differs from this general pattern in that it relies upon locating major leaks directly.

PASSIVE CONTROL

With this method of control, only those leaks which become self-evident are located and repaired. Only repairing obvious leaks implies acceptance of generally high leakage level.

REGULAR SOUNDING

This method involves teams of men using listening equipment systematically working their way through the distribution system listening on valves, hydrants, stop valves, meters etc., for the characteristic sound of leaking water. When the teams get to the end of the system they start all over again. Typically sufficient staff are employed to completely cover the distribution system at a frequency of between one to two years.

DISTRICT METERING

Bulk Flow meters are installed within the distribution system such that separately defined areas (districts), typically containing between 2,000 and 5,000 properties, are metered continuously and the total quantity of water consumed in each district is recorded. A district may have water entering and leaving it, to supply other districts, through more than one meter. The meters are read at regular intervals (weekly) and the measurement of total consumption in each district is compared with previous measurements for that district. If the total consumption in one or more districts is inexplicably high, inspectors are sent in to locate and repair leaks.

WASTE METERING

The distribution system is arranged so that it can be sub-divided and isolated into areas typically containing between 1,000 and 2,000 properties when valves are closed. These valves are closed at night and the supply to each isolated area arranged through a single flow meter capable of measuring the low rates of flow that occur during the early hours of the morning. Measurements of night flow ratio are made at regular intervals (monthly/quarterly) and when large increases, compared to previous measurements, are encountered the inspectors are sent in to locate and repair the leaks. Additional night flow measurements combined with closing valves within the district may also be used to pinpoint the leakage more precisely.

COMBINED DISTRICT AND WASTE METERING

This method of leakage control consists of both district metering and waste metering as described above. When

increases in demand are indicated on the district meters, the waste meters downstream of them are used in order to sub-divide the district into more manageable units and thereby guide the inspectors to the areas containing the most leakage.

PRESSURE CONTROL

The relationship between pressure and leakage is now widely known. Experiments have shown that a given reduction in pressure causes a proportionately greater reduction in leakage. Therefore whilst in general, reductions in pressures are worthwhile, in systems with intermittent supply and very low pressures, arrangements for temporary pressure, increase may be required in order to make leakage detection easier.

DEALING WITH LEAKAGE

by

M. J. Rouse

Director of Engineering
Water Research Centre, UK

DEALING WITH LEAKAGE

Introduction

Leakage control is a serious problem the world over. High costs of energy, ageing pipelines and increasing costs of developing each new source of supply have resulted in leakage becoming more important and worth reducing. Much has been written on the subject of leakage control and that includes papers written more than one hundred years ago. Many such papers have claimed new methods of leakage control and there has been much discussion as to which was the best.

Recognising the increasing importance of leakage and the need to reduce it, the Water Research Centre working in conjunction with a National Working Group, set itself the task of answering the simple question 'What is the best method of controlling leakage?' The answer was no where near as simple as the question.

A UK Experience

Field Experiments

As a starting point in these investigations WRC decided to disbelieve everything that had been written on the subject of leakage control unless it could either be measured or demonstrated. The result was a series of over 500 field experiments or measurements designed to investigate leakage and the various methods of controlling it. Leakage from service reservoirs, trunk mains and distribution systems was measured and the effects of age, diameter and method of construction determined. Also the costs, capital and operating, associated with each method of leakage control were determined together with measurements of the effectiveness of each method at reducing leakage. Data relating to the effects of pressure on leakage, variations in leakage with time and costs of repair were also collected.

Results of Field Experiments

The results of the experimental programme provided interesting information some of which is summarised below.

Service Reservoirs

Measurements of service reservoir leakage were obtained from 250 reservoirs ranging in size from 50 to 20,000 m³ (11,000 gals to 4.4 mg) although the majority were in the range 2,500 to 5,000 m³ (about 0.5 to 1 mg) capacity. A histogram of the results is shown in Figure 1. The results are expressed as a percentage of their capacity leaking away each day. It was found that 86% of all reservoirs tested had less than half a percent of their capacity

leaking away each day. Most of the remaining reservoirs had leakage levels up to 3% of their capacity each day which is equivalent to approximately 100 m³/day (22,000 gals/day). 4% of reservoirs did have significant leakage of between 9% and 30% of their capacity per day, and generally this leakage was not known prior to the measurements. It was also found that older reservoirs were more likely to leak than newer ones although this may be related to the method of construction rather than a pure age effect.

Trunk Mains

Measurements of leakage from trunk mains were made on 113 different pipelines ranging in diameter from 150mm to 1050mm (6" to 42") and in age from 2 years to 110 years. The results are shown in figure 2. The majority of trunk mains tested (73%) had leakage of less than 500 litres per hour for each kilometre length (l/km/hr), 7% had leakage above 2,000 l/km/hr and the highest measured was 6,500 l/km/hr.

Examination of the results show that the old mains were more likely to leak than the newer ones, although again this may be an effect due to changes in materials or methods of construction rather than an age effect alone. There was no relationship between leakage expressed as litres per kilometre per hour and diameter. i.e. a small main is likely to lose as much water as a large one.

Distribution System

Measurements of leakage from distribution systems is much more difficult to measure and depends upon a number of factors, not least of which is whether any form of active leakage control is practiced. Estimates of leakage from distribution systems were however made by measuring minimum flow rates at night and subtracting from those measurements any legitimate night use. The legitimate night use was determined partly by reading consumers meters and partly by shutting off, in control areas, large numbers of consumers - by closing their outside stop valves - and measuring the resulting reduction in night flow rate. Figure 3 shows the results of these measurements made in 290 districts with active leakage control and 194 districts with no leakage control. In the former the leakage varied from 1 l/property/hr to 18 l/prop/hr with a mean of 6 l/prop/hr. With no control the leakage ranged from 2 to 50 l/prop/hr with a mean of 18 l/prop/hr.

Pressure

The effects of pressure on leakage from distribution systems was also measured, with surprising results. The flow through an orifice of fixed dimensions is proportional to the square root of the pressure drop across it. This relationship does not hold for

leakage from distribution systems. Seventeen experiments were undertaken where the average system pressure was reduced at weekly intervals and the corresponding net night flow rates (minimum night flow rate minus legitimate use) measured on each night of the week. At the end of the week the pressure was reduced a further step and the measurement process repeated. The results are shown in Figure 4. The scatter in the various curves is to be expected since the level of leakage in each of the measured zones is different. However, when the results are scaled to look at the changes in net night flow that occur for a given pressure change rather than the absolute values the curves fall onto the single line as shown in Figure 5. This is a very important result for it shows that a significant reduction in leakage can be achieved by reducing distribution pressures and contrary to the square root law, the change in leakage is proportionally greater than the pressure change which causes it. The curve can be used to determine the leakage reduction that can be expected in a system for a given reduction of pressure, so the potential advantages of pressure reduction can be determined without first having to install the equipment. The curve can also be used to convert leakage, determined from net night flow rate, into a 24 hour loss of water taking into account changes in system pressure which occur normally during the day.

Methods of Leakage Control

Careful examination of the various methods of leakage control practiced showed that they could be categorised into five methods although a number of variations around each method exists to suit local circumstances. The costs of setting up and running each of the method of leakage control was determined as was the effectiveness of each at reducing leakage. It was found that each method had a different cost associated with it but also that each method would reduce leakage to a different level. The five methods of leakage control are listed below in order of increasing cost which is also the order of increasing effectiveness.

1. Passive Control

With this method of control only those leaks which become self-evident are located and repaired. No attempt is made to measure or locate underground leaks that do not have water showing on the surface unless consumer complaints of low pressure are thought to be caused by leakage. Leaks showing on the surface are often reported by the police or members of the public.

2. Regular Sounding

This method involves teams of men using listening equipment systematically working their way through the distribution system

listening on valves, hydrants, stop valves or meters etc. for the characteristic noise of leaking water. When the teams get to the end of the system they start all over again. Typically, sufficient staff are employed to completely cover the distribution system at a frequency of between one to two years. This method is equivalent to the once-off surveys used in some areas with the exception that to be effective, effort is required continuously rather than intermittently.

3. District Metering

Flow meters are installed within the distribution system such that separately defined areas, typically containing between 2,000 and 5,000 properties, are metered continuously and the total quantity of water consumed in each district is recorded. A district may have water entering and leaving it, to supply other districts, through more than one meter. The meters are read at regular intervals (weekly/monthly) and the measurement of total consumption in each district compared with previous measurements for each district and also analysed for large changes in one district compared with changes in neighbouring districts. If the total consumption in one or more districts is inexplicably high, inspectors are sent in to locate and repair the leaks.

4. Waste Metering

The distribution system is arranged so that it can be sub-divided and isolated into areas typically containing between 500 and 2,000 properties when valves are closed. These valves are closed at night and the supply to each isolated area arranged via a single flow meter capable of measuring the low rates of flow that occur during the early hours of the morning. Measurements of night flow rate are made at regular intervals (monthly/quarterly) and where large increases, compared with previous measurements, are encountered the inspectors are sent in to locate and repair the leaks. Further night flow measurement combined with closing valves within the district may also be used to further pinpoint the leakage.

5. Combined District and Waste Metering

This method of leakage control consists of both district metering and waste metering as described above. When increases in demand are indicated on the district meters, the waste meters downstream of them are used in order to sub-divide the district into more manageable units and therefore guide the inspectors to the areas containing most leakage.

At this stage of the analysis it was known where leakage was likely to be occurring within the system and also the range of leakage levels likely to be encountered. The various methods of leakage control

available together with the costs and effectiveness of each method were known as were the effects of pressure control on leakage. However, it was not possible to determine which method of leakage control was most appropriate for any particular system until the value of the water lost through leakage could be determined. This value was termed the unit cost of leakage. Clearly just as more intensive leakage control may be justified in areas with high leakage levels, this is also true in areas where the cost of supplying water is high.

Unit Cost of Leakage

In order to determine the financial worth of reducing leakage it is necessary to answer the question, 'If 1 cubic metre of water is saved as a result of detecting and repairing a leak, how much money will be saved by the utility?' This saving is not the selling price of water, as some authors have suggested, since this figure includes the fixed costs of operating a water authority and these will not change. The true savings arise from two different sources. The first is an immediate saving that results from a reduction in operating costs since the 1 cubic metre saved will not have to be treated, chlorinated or pumped. The second is a saving that results from the deferment of demand related capital expenditure. Reduction in total demand means that the next source, treatment works or pipeline will not have to be built so soon and this in itself represents a saving to the utility. All other costs to the utility remain unchanged. These two cost savings added together give the unit cost of leakage.

A simplified and practical procedure for calculating these costs from water utility records has been developed by WRC and implemented in all UK Water Authorities. The range of values for the unit cost of leakage in the UK is between 0.01 and 0.1 £/m³.

Comparison of the Costs of Leakage Control Method with Expected Savings

Knowing the costs and effectiveness of each method of leakage control and the savings that are likely to result from reducing leakage it should be possible to determine which method of leakage control is most effective. There is, however, no general answer to this question as can be seen from Figure 6. Where the total cost of leakage is low (ie leakage levels and the unit cost of leakage are both low) it is not worth spending a lot of money on leakage control measures and a simple method of control will be most appropriate. Conversely, where the total cost of leakage is high then the savings which will result from leakage control will also be high and a more effective method of leakage control can be justified. From Figure 6 it can be seen that the top right hand corner of the diagram represents too much leakage control and a utility operating in this area will be spending more money on leakage control measures than will be gained from reduced leakage whereas the bottom left hand corner represents too little leakage control and a utility operating in this region will be losing money by having an unjustifiably high level of leakage. The problem of determining the correct leakage control policy for a particular

utility is now one of finding a way onto the diagonal 'economic' band through the centre of Figure 6.

Determination of the Most Appropriate Method of Leakage Control

Determination of the most appropriate method of leakage control requires not just an assessment of the unit cost of leakage but also assessment of the existing level of leakage. For even if the unit cost of leakage is high there is no point in spending a lot of money on leakage control if there is not much leakage to be found. This may be the case for example, in a distribution system laid in a soil where leaks readily show on the surface. Secondly, there are factors other than pure economic ones to take into account. The design of the system, the type of area, availability of manpower and many other factors must also be considered. Consequently a procedure was developed to determine the most appropriate method of leakage control in any particular system. The procedure is shown in Figure 7. In following this procedure economics are used to discard the options that are too expensive for that particular system and then engineering skills and judgement are used to determine which of the methods remaining is most appropriate for that system. Methods for determining the amount of effort to be put into running the appropriate method of leakage control have also been developed.

The procedure shown in Figure 7 is the only acceptable method for the determination of Leakage Control Policy which is acceptable to the UK Government. It has been adopted by all ten water authorities in the UK and has been widely implemented over a large part of the country. This has involved a substantial amount of effort; one authority alone measured the leakage levels (net night flows) in 290 zones. This work has resulted in the changes in leakage policy shown in Table 1.

TABLE 1

| Leakage Control Method | Existing Policy | Proposed Future Policy |
|------------------------|-----------------|------------------------|
| Passive Control | 25% | 2% |
| Regular Sounding | 10% | 2% |
| District Metering | 18% | 35% |
| Waste Metering | 42% | 29% |
| Combined Metering | 5% | 32% |

Figures are percentages of population supplied.

It can be seen from Table 1 that 35% of systems currently have passive or regular sounding as a method of leakage control. Working through the procedure (Figure 7), in those areas it was shown that only in 4%

of the systems were those policies justifiable. This would also apply to intermittent once-off surveys. In the remaining 31% of those systems a more effective method of leakage control was found to be worthwhile but no single method was appropriate and economic everywhere. It can also be seen that the increase in district metering is large both on its own, 18% existing going to 35% in the future and in terms of combined metering since many systems which currently have waste metering will have combined metering in the future. It was also found that although in general there was a trend towards more active leakage control, in some areas the present methods of control, usually waste metering was too intensive and a reduction in effort was required.

It is estimated that implementing the changes shown in Table 1 will require a capital expenditure of approximately £10 million and an increased annual expenditure of £3 million for running costs. The total saving including this increased expenditure is estimated to be in the order of £20 million per annum.

B Relevance to Leakage Control in Asia

Although the procedure in Figure 7 was developed for use in the UK, it is sufficiently general to be applicable in virtually any distribution system throughout the world. Clearly, there are many differences between Water Industry practice in Asian countries and the UK, but these can be accounted for by suitable modifications to suit these local circumstances.

Factors such as intermittent supply and illegal connections may affect the feasibility of certain methods of leakage control whilst a lack of suitable access points to the main such as stop valves on service pipes would dictate a means of finally pinpointing the leak, other than manual sounding. Nevertheless, there will still remain a choice of several distinct methods of leakage control ranging from the bare minimum ie passive control which is applicable anywhere, through to the most intensive methods involving comprehensive metering and inspection. Any one of these methods could be the most appropriate and economic depending upon the circumstances of the particular system.

Turning to the procedure itself, the proposed method for measuring leakage levels can be applied to any system irrespective of its size, complexity or number of large metered consumers and in most cases can be carried out with very simple portable equipment costing relatively little.

The methods adopted for valuing the water saved by leakage control can be simply modified to take into account different practices. Saving in operating costs such as pumping and treatment are directly relevant although allowances may be required for transfers of energy when Electricity and Water Utilities are combined. In many overseas countries the price of energy may be such that these savings are sufficient on which to base the future leakage control policy. Where capital costs are dominant, however, estimates will have to be made of

the economic benefits to be gained by deferring a particular capital works or in some cases the value of the increase in security of supply (or reduction in intermittent supply) to be gained by not deferring a particular works.

Costs of the various methods of leakage control can be determined for the labour and other resources required to implement the component tasks for each method and will depend primarily on rates of pay as leakage control is extremely labour intensive. The final comparison of costs, inclusion of the practical and engineering factors and local constraints can then be performed to arrive at a leakage control policy which has a sound engineering and economic foundation.

C New Developments

Undertaking the above programme of work had the additional advantage of identifying those procedures, methods or equipment that were in need of new thinking or further development. The important items identified included equipment for the accurate location of leaks in distribution systems, measurement and location of leaks in trunk mains, district metering, pressure control, waste metering, detection of leaks on consumers premises, location of leaks from service reservoirs, methods of repair and the design of new systems to facilitate subsequent leakage control measures. A more detailed discussion of some of these points is given below.

Pinpointing the Location of Leaks

Part of the data collected during the field experiment stage looked at the accuracy with which leaks are pinpointed using conventional sounding equipment and in particular the number of abortive or dry holes dug in attempting to locate a particular leak. Typical results are shown in Table 2.

TABLE 2 Number of Excavations required to Locate a Leak

| Number of Excavations To Locate Leak | Number of Occasions |
|---|---------------------|
| 1 | 13 |
| 2 | 17 |
| 3 | 7 |
| 4 | 2 |
| 5 | 1 |

Total of 81 excavations to locate total of 40 leaks

It can be seen from Table 2 whilst a third of all leaks are located first time using conventional equipment overall 81 holes were excavated in order to locate 40 leaks. An average cost of excavating and permanently reinstating a repair hole under a roadway in the UK is over £120 although the variation around this figure can be large. Clearly there was a need to improve the accuracy of location.

WRC has developed a method of leak detection which uses the technique of cross correlation of leak noises to accurately pinpoint their positions. Five years of repeated development and field testing went into the production of Palmer EAE/WRC Leak Noise Correlator shown in Figure 8. A diagrammatic sketch of the correlator is shown in Figure 9. Two transducers A and B are placed on the pipe containing the suspected leak at existing fittings such as valves, hydrants etc. The noise produced by the leak travels along the pipe in both directions at a velocity which is related to the velocity of sound in water, but also depends upon the pipe material and diameter. It can be seen that by the time a particular wave front leaving the leak has reached position B the wave front will have travelled an equal distance in the opposite direction to the point C. The wave front has a further distance D minus 2L to travel before reaching point A. If the signal received at B is delayed artificially until the same signal appears at A then the amount of time delay that is necessary to make the two signals appear to be coincident is the time taken for the signal to travel from point C to point A. This difference in travel time is determined using the method of cross correlation.

Thus if V is the velocity of sound in the pipeline we can write:

$$VTd = D - 2L$$

or rearranging

$$L = \frac{D - VTd}{2}$$

The Leak Noise Correlator is therefore a device for precisely determining the position of the leak which does not rely upon the personal skills of the operator in interpreting the results, as is the case with conventional listening techniques. Having said that the successful correlator operator requires different skills particularly in obtaining the best results on branched or inter-connected distribution systems.

Results obtained with the Leak Noise Correlator are shown in Figure 10. 86% of all leaks located are within one metre of the actual leak and 9% within two metres. Applying this success rate to the 40 leaks shown in Table 2 only 44 holes would be dug in locating those 40 leaks. Consequently using the Leak Noise Correlator a total of 37 excavations would be saved in locating those 40 leaks (about one excavation per leak). If the cost of excavation and reinstatement is £120 per hole then a correlator costing say £15,000 would pay for itself once it had been used to locate 130 leaks without even

considering the additional savings that result from a reduction in leakage.

Detection of Trunk Main Leakage

Although the field experiments demonstrated that the majority of trunk mains did not leak significantly, a proportion did warrant further investigation. Two developments for the measurement of leakage from trunk mains have been undertaken by WRC together with equipment and techniques for the location of such leakage.

The first development is the heat pulse flow meter which is an insertion meter capable of measuring the very low flow rates produced by leakage from trunk mains when the main is not in use. It is shown pictorially in Figure 12 and consists of a central heater with upstream and down stream thermistors. Velocities in the range 2mm to 25mm/sec can be measured with an accuracy of ± 1 mm/sec.

The second technique does not require the main to be isolated and utilises two insertion turbine meters which are positioned at each end of the main to be tested. The flow velocities are recorded at five minute intervals of a flow range for night minimum to peak day. Statistical analysis of these pairs of velocity measurements determines the existence of leakage. WRC have recently developed a data logger for use with this method which is capable of performing the necessary analysis and calculating the amount of leakage present.

Location of leakage for trunk mains is often frustrated by the lack of adequate sounding points. WRC have therefore developed equipment for the location of leaks from trunk mains which does not rely on acoustic methods. The technique consists of injecting sulphur hexafluoride gas into the main; the injection equipment is shown in Figure 13 at the leak position the gas escapes and collects in small 150 mm deep holes formed by pushing a bar into the ground above the line of the main. These bar holes are usually one metre apart and a hand held detector is used to detect the presence of gas in the holes and thus the position of the leak.

Use of Telemetry for Leakage Control

In the UK about 70% of the areas will be utilising some form of district metering. The Water Research Centre is evaluating the performance of flow meters for use in district metering and also a pilot scale project to investigate the advantages of reading these meters remotely using the public telephone system. A full scale trial will follow.

Installation of the above scheme has started but it is not expected to be fully operational for another eighteen months to two years and it will be that sort of time scale before the full costs and benefits of the system can be quantified.

Other Development at WRC

Other work at the Water Research Centre relevant to leakage control includes an assessment of equipment for pressure control and field trials of equipment for the remote reading of individual consumers meters.

Conclusions

The work on leakage control carried out in the UK has shown that there is no one method of leakage control that is appropriate to all distribution systems. The procedure for deciding how to deal with leakage has been extensively implemented in the UK. Reduction of distribution pressures has resulted in a significant reduction in leakage levels. Use of the Leak Noise Correlator to pinpoint leaks has significantly improved the overall efficiency. The extensive measurement work on leakage control carried out over the last five years within the UK has provided the foundation for deciding how to deal with leakage on any system in the world.

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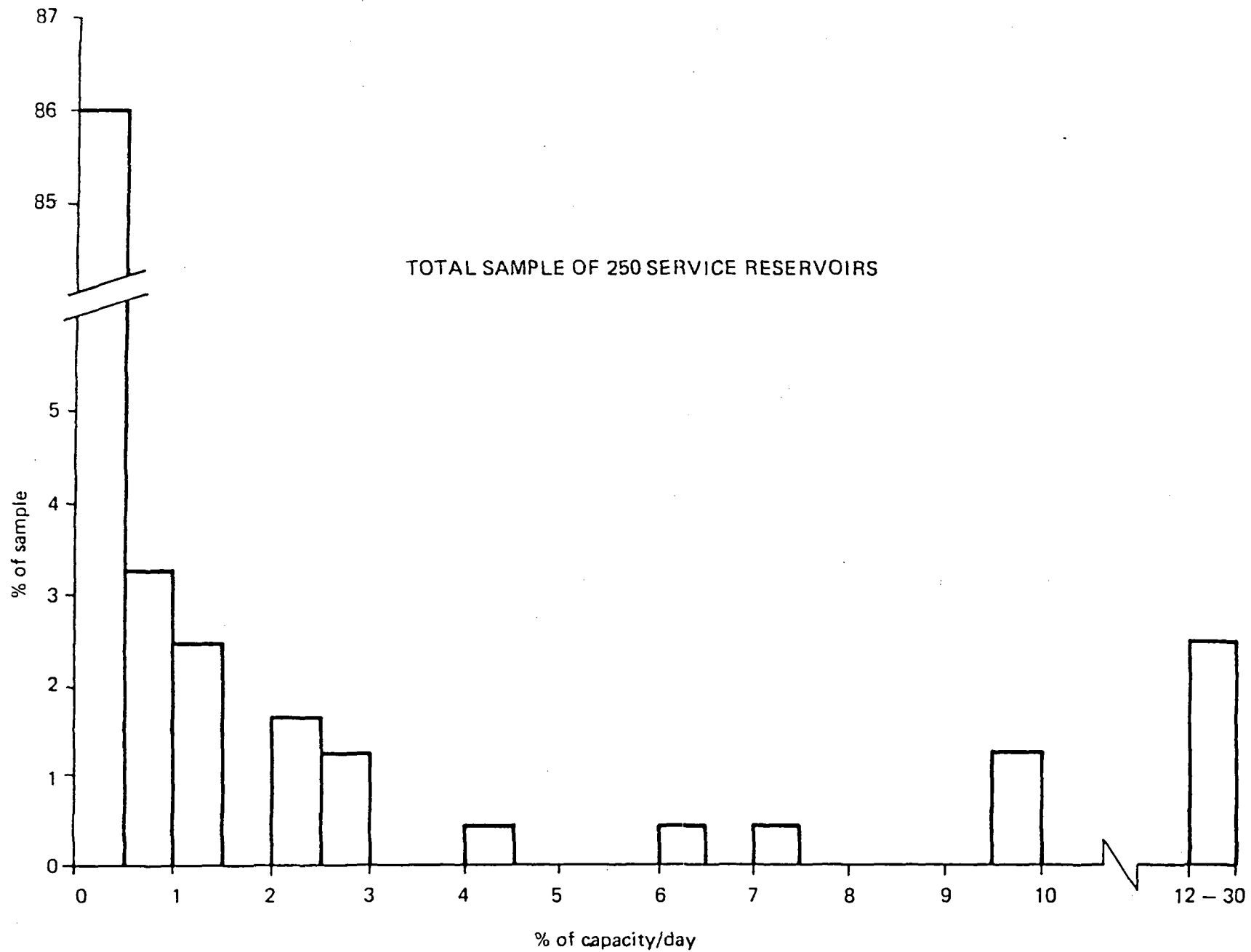


Fig 1. Histogram of results of reservoir leakage tests

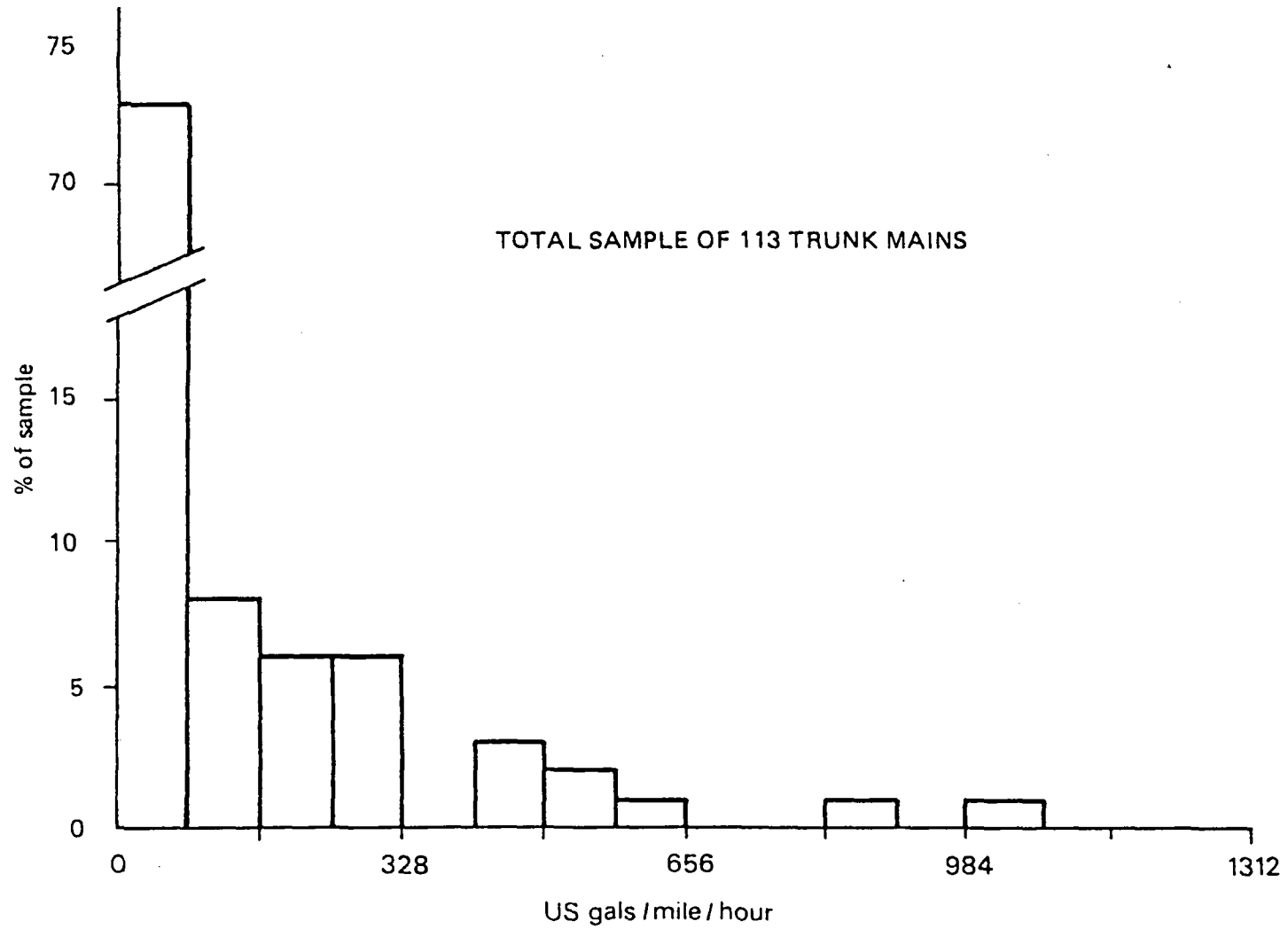


Fig 2. Histogram of results of trunk main leakage tests

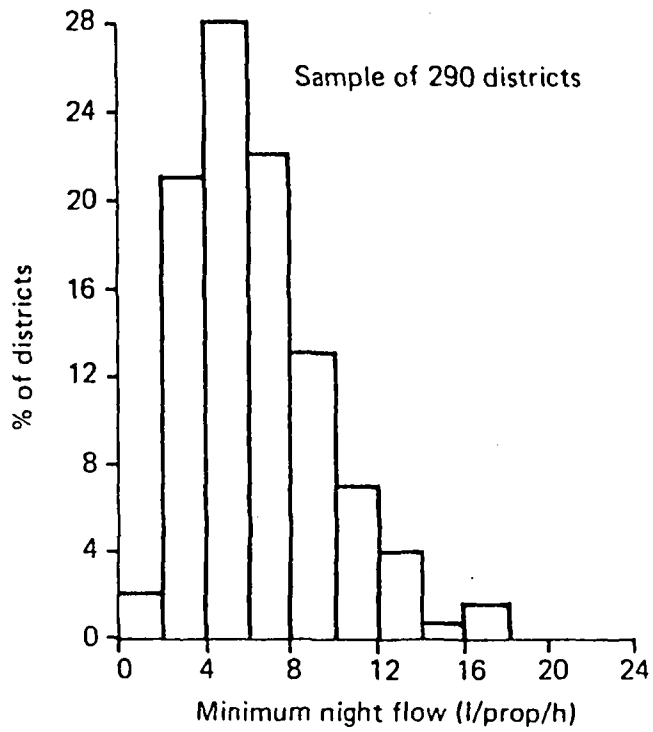


Fig. 3a. Histogram of night flows in districts with effective waste metering

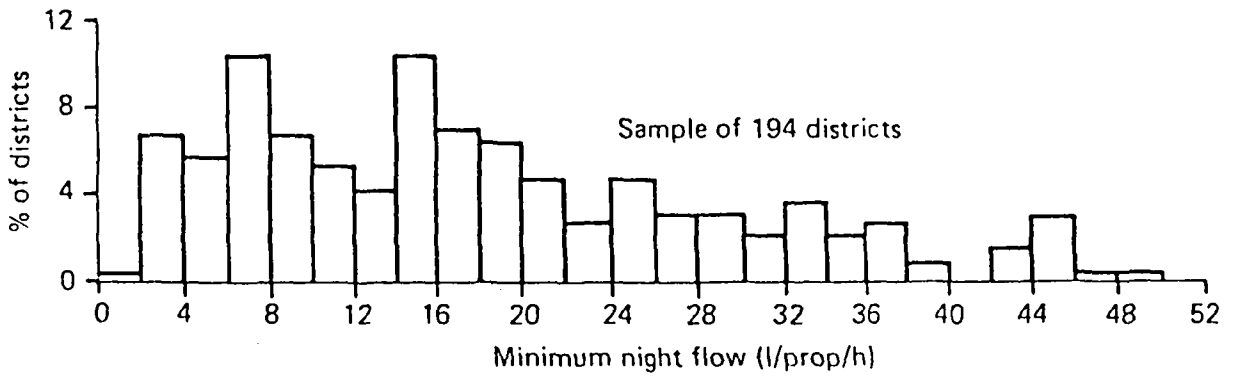


Fig. 3b. Histogram of night flows in districts with passive leakage control

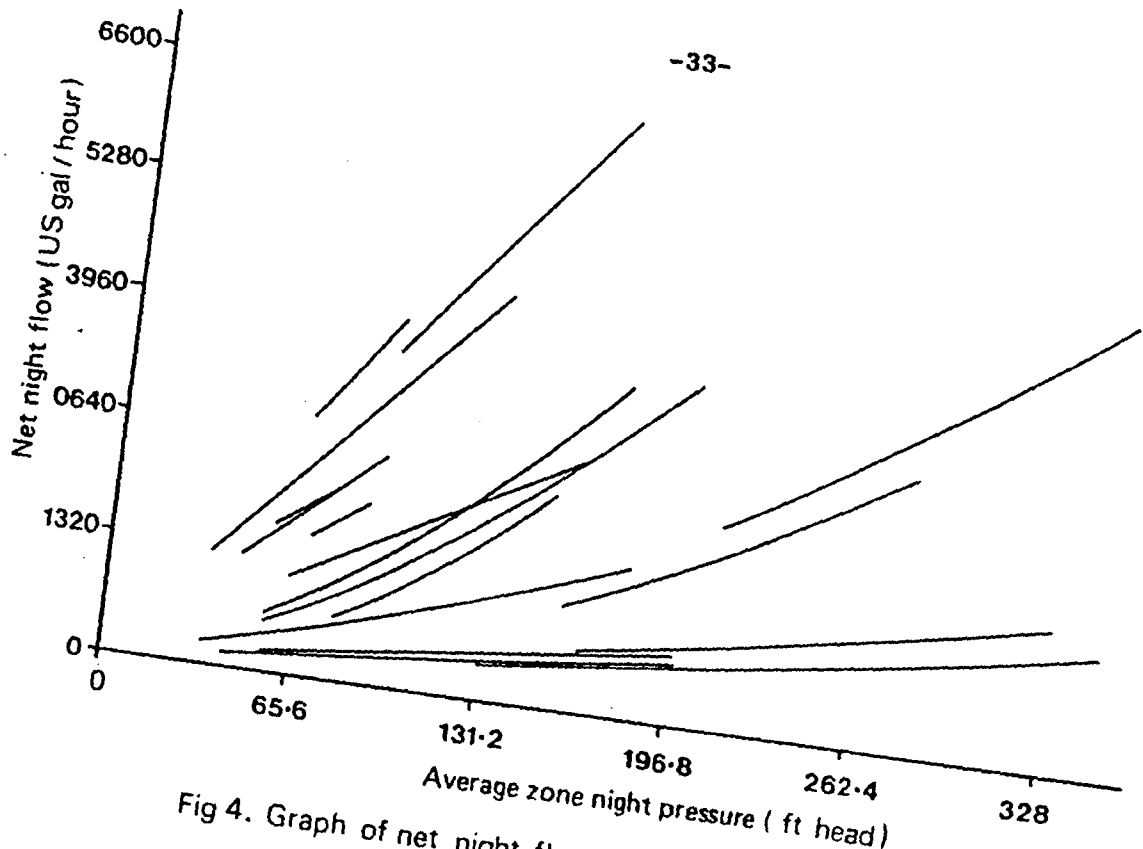


Fig 4. Graph of net night flow and pressure relationships

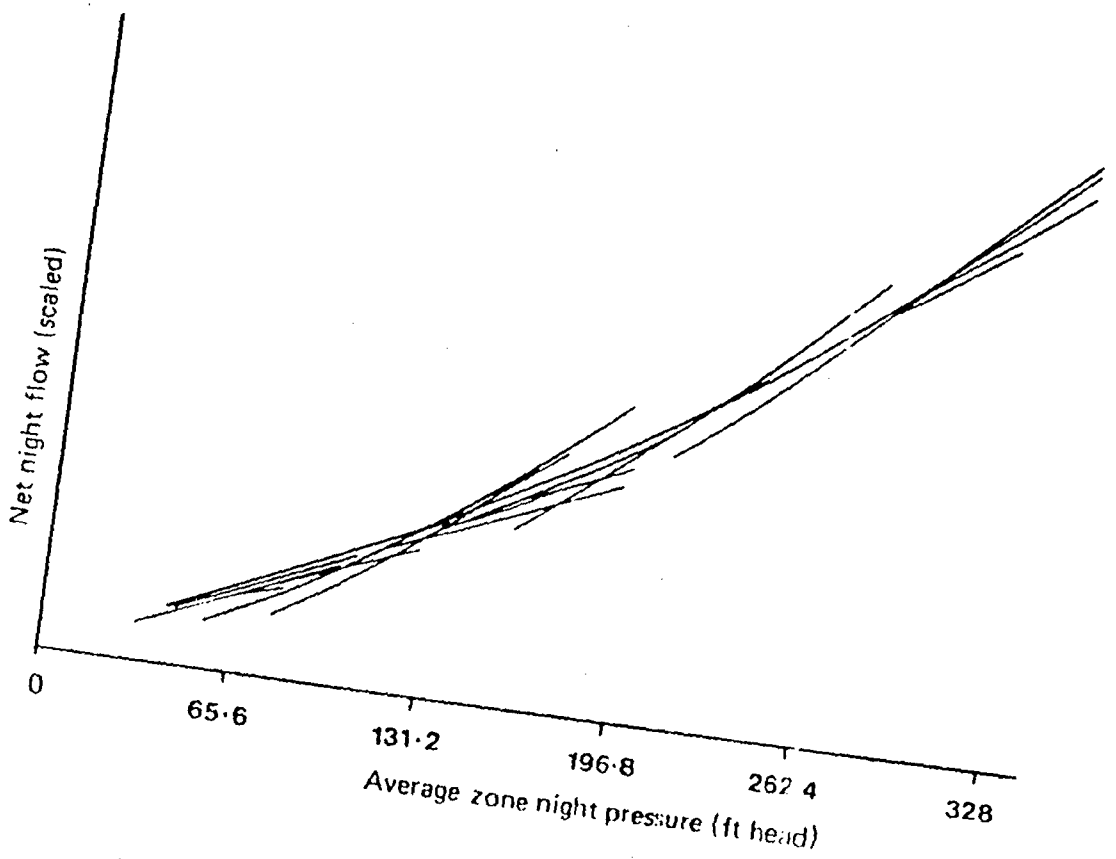


Fig 5. Graph of scaled net night flow and pressure relationships

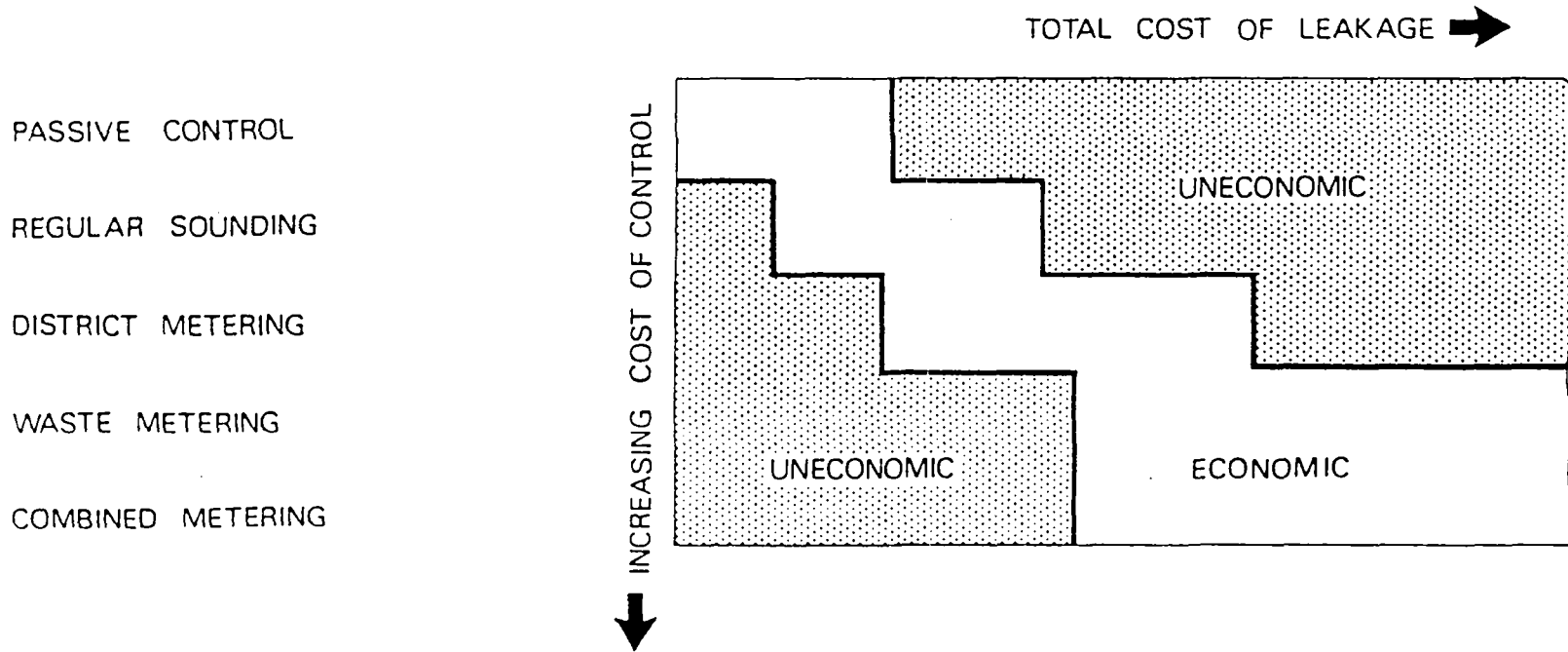


Fig. 6.

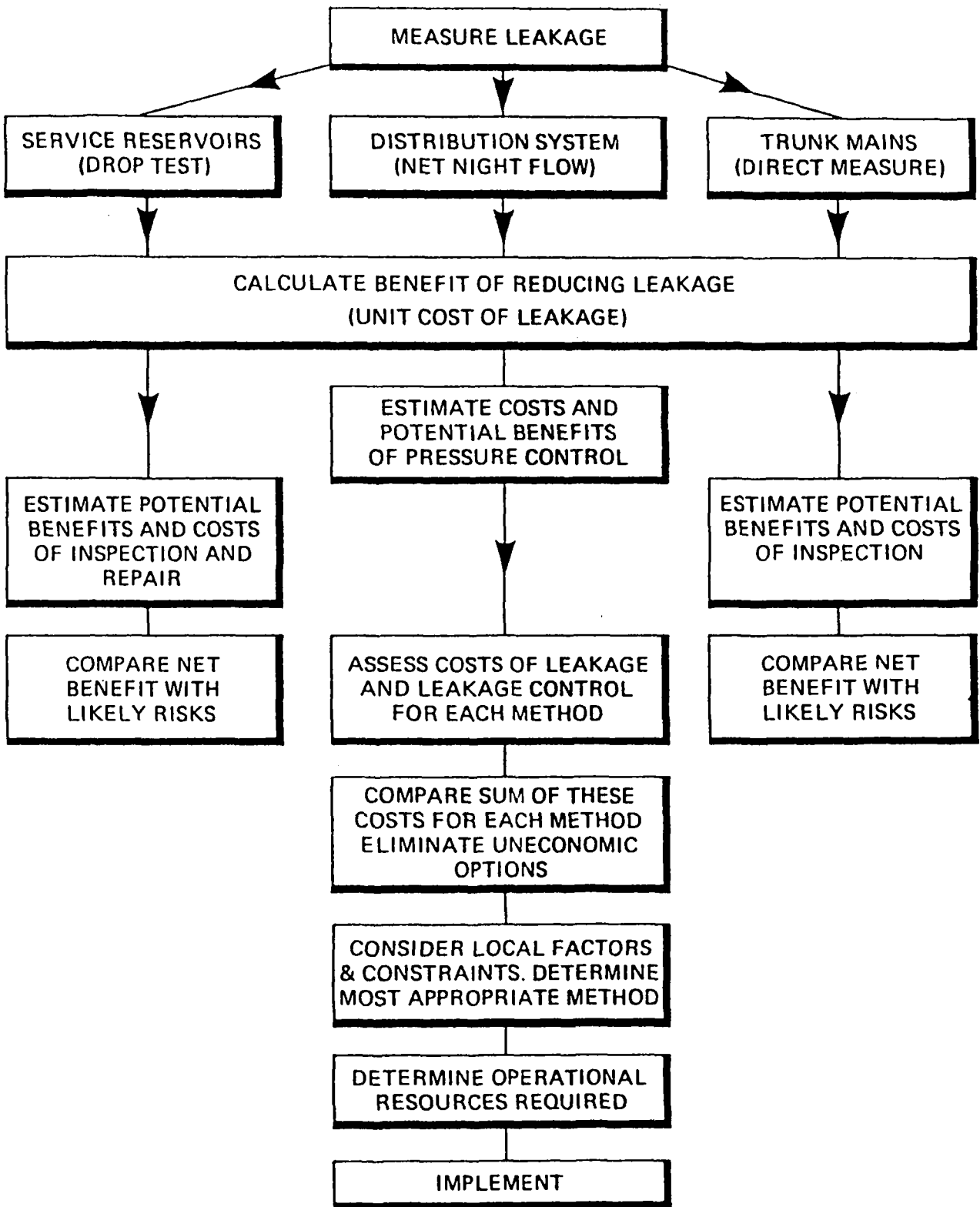


Fig. 7. Flow diagram of the procedure for the determination of leakage control policy

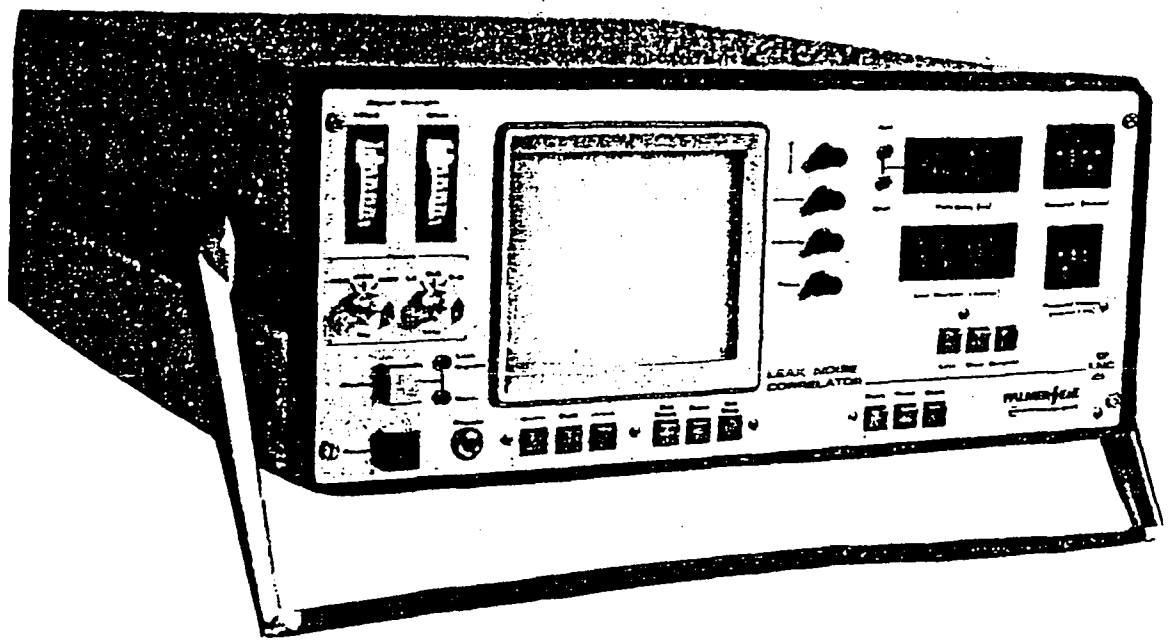


Fig. 8. WRC/Palmer EAE Leak Noise Correlator Mark 2

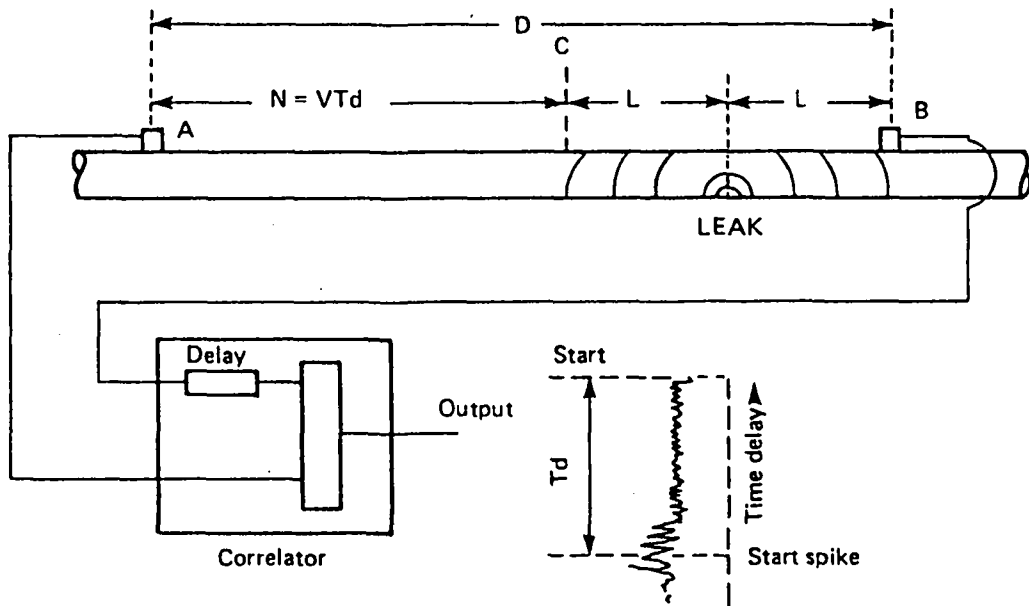


Fig. 9. Measurement of travel time difference

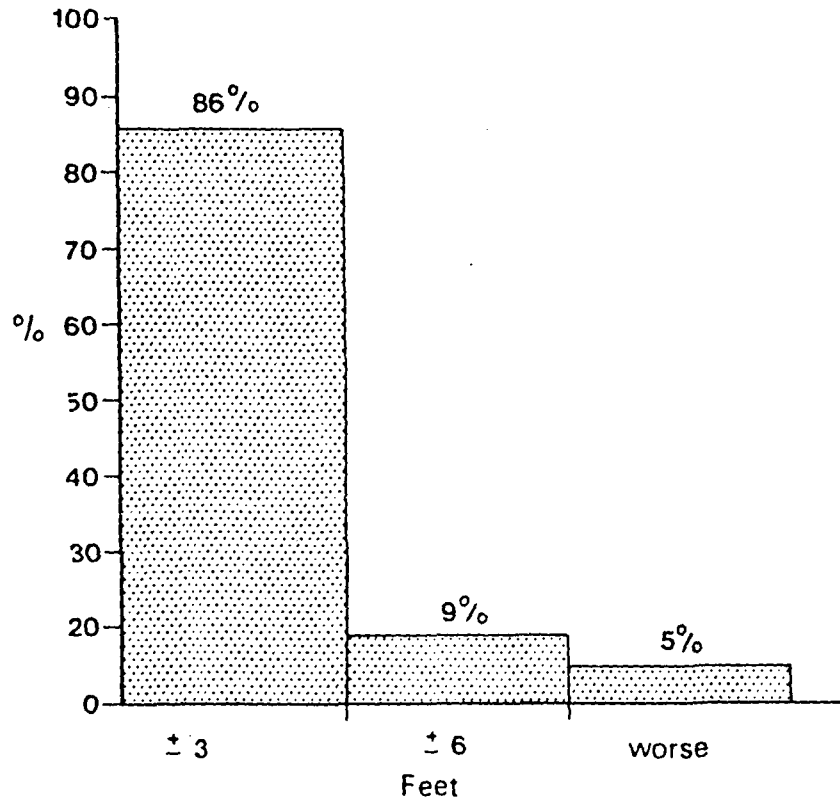


Fig.10. Histogram of location accuracy for 1671 leaks

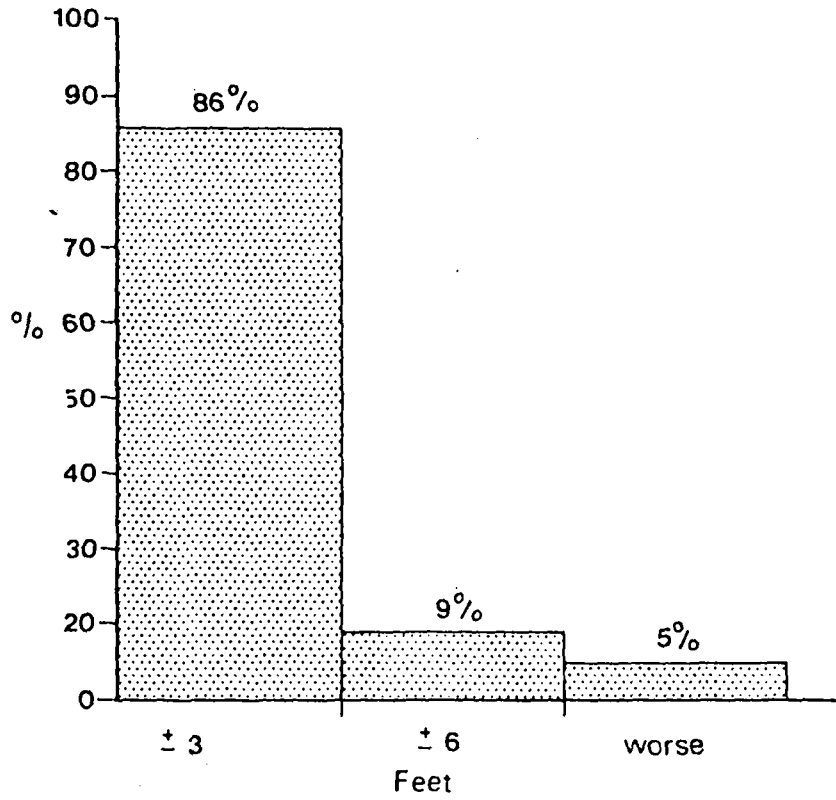


Fig.10. Histogram of location accuracy for 1671 leaks

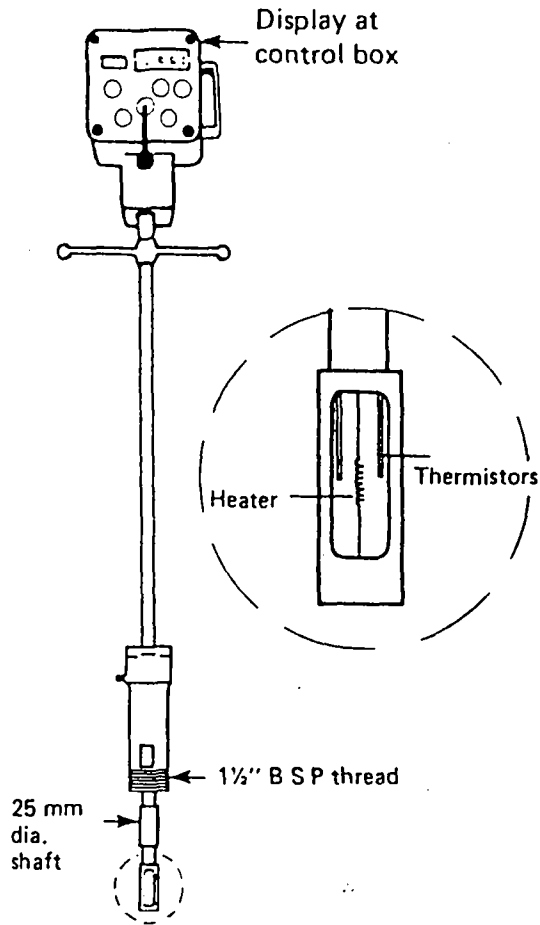


Fig. 12. Sketch of heat pulse flow meter

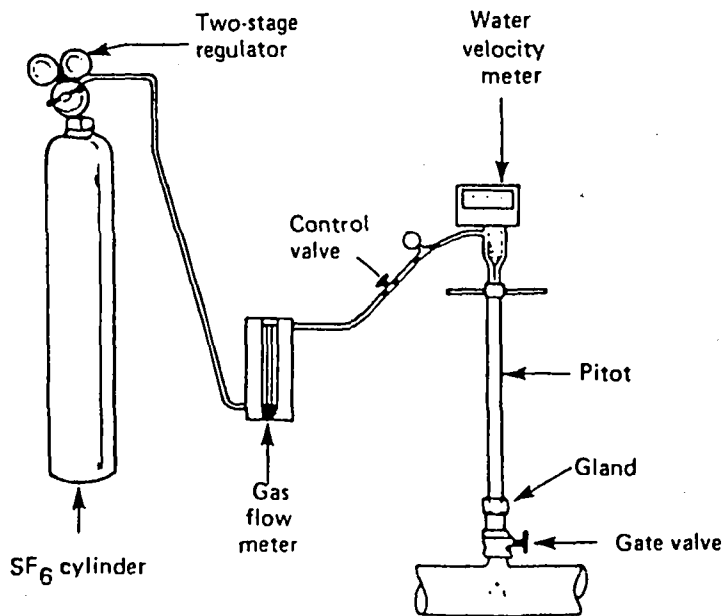


Fig. 13. General arrangement of equipment for gas injection

THE QUALITY CONTROL OF
PUBLIC WATER SUPPLY SYSTEMS

by

T. F. Lye

WHO Temporary Adviser

WHO Workshop on Public Water Supply Leakage and Wastage Control

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The Quality Control of Public Water Supply Systems

by Thim F. Lye*

Primary Requirement of Water for Human Consumption

Any water provided for public consumption should be both adequate in quantity and acceptable in quality. This is a primary requirement; and the operation and management of a public water supply system should not only produce the quantity of water necessary to meet the demand of the system's consumers, but should also ensure that the quality of such water is wholesome and safe for human consumption. Accordingly, there will have to be effective control of both quantity and quality in the production and supply of drinking-water.

Control Requirements in the Operation and Management of Public Water Supply Systems

The main components of a public water supply system can be conveniently arranged under the following headings:

- (1) Source;
- (2) Treatment;
- (3) Storage;
- (4) Distribution.

Some of the more important requirements for both quantity and quality control at each of these components of the water supply system are summarised below:

(1) Source

Whatever the source of supply, it must yield a reliable output to meet water demands throughout the year. The quality of the raw water should not vary unduly and the water must be amenable to conventional treatment processes. There should be adequate protection of the water source to prevent pollution; particularly watersheds and impounding reservoirs of surface water sources.

* Temporary Adviser

(2) Treatment

When the raw water requires treatment, the various treatment units and processes should be adequate to treat the quantity of water needed, and reliable enough to produce a consistently good drinking-water that meets the established drinking-water quality standards.

(3) Storage

Most public water supply systems will require some sort of storage so as to maintain a steady supply of treated water at adequate pressure to meet the variation in demand. There will have to be proper protection of such storage reservoirs to prevent the entry of animals and insects, wind blown dust, storm water run-off, and refuse or other foreign matter.

(4) Distribution

The distribution system should be capable of providing a continuity of supply of treated water at adequate pressure to all consumers; keeping leakage and wastage of water within reasonable limits. Proper measures are to be taken to prevent the treated water in the distribution system from being polluted, with particular attention to the prevention of cross-connections and back-siphonage.

Need for Effective Quality Control Procedures

While the measures and procedures to produce and supply a continuous and sufficient quantity of water at adequate pressure to meet consumers' demand are readily appreciated, there is often a lack of understanding among both engineers and public health officials of the methods to adopt for ensuring that such a water supply is also safe. There is need for a practical and realistic approach towards effective quality control by carrying out proper monitoring and surveillance of the quality of drinking-water at all stages in its production, from source to distribution, to ensure that the water so produced is in fact wholesome and safe to drink.

Surveillance of Drinking-Water Quality

Surveillance as defined in the WHO publication "Surveillance of Drinking-Water Quality", WHO Monograph Series No. 63, is "the continuous and vigilant public health assessment and overview of the safety and acceptability of drinking-water supplies".

Such surveillance to ensure the safety and acceptability of a drinking-water supply therefore is a dual responsibility, involving the water authority as well as the public health authority.

Most large water authorities usually have enough management expertise and experience to direct their complement of professional engineers, chemists, trained operators and technicians to routinely monitor and carry out their own surveillance activities to consistently produce good quality and safe drinking-water. On the other hand, some water authorities, particularly the smaller ones, for various economic, staffing or management reasons, may have difficulty in producing consistently safe drinking-water from their water supply systems.

However, even in the best managed organisational set-up, such institutional quality control may occasionally experience a lapse in thoroughness; or their supervisory and operational personnel may become complacent and lax in their work, resulting in a down-grading of the water quality, and a consequent hazard to health.

It is therefore necessary that institutional quality control activities should be supported by essential surveillance activities provided by an external agency. Such external agency will usually be the Ministry of Health, or the Ministry of Environment and will provide supervision, and make spot checks of the waterworks functions as well as offering advice and assistance to put matters right. Such surveillance is complementary to institutional quality control, and is essentially a health measure to ensure that the water is treated to the standards set and to protect the public from water-borne diseases.

Surveillance being a dual responsibility, there will have to be understanding and willingness on the part of the staff members of both the water authority and the surveillance agency to foster good working relations and develop cooperative efforts to ensure the continued production and distribution of safe drinking-water in their supply systems.

Legislative Support

For proper and effective surveillance, there will have to be adequate legislative support. Such legislation should specify the surveillance agency, and define its scope of authority. The agency should be responsible for administering the law, and be empowered to make, amend and enforce regulations and bylaws.

Among the more important regulations necessary for quality control in waterworks practice will be the drinking-water quality standards, as well as codes of practice for equipment, materials and installation, including those required for plumbing systems. These regulations, standards and codes of practice should cover all aspects of operation and management of public water supply systems, including such activities as: the protection of watersheds and reservoirs; the prevention of cross-connections

and back-siphonage; disinfection procedures; sanitary surveys; sampling; and laboratory analysis.

Surveillance Activities

The main purpose of surveillance is the periodic check and assessment of the operating effectiveness of a water supply system to ensure the consistent production of safe drinking-water. The two most important surveillance activities which can provide such checks and assessment are:

- (1) the sanitary survey;
- (2) sampling and laboratory analysis.

Sanitary Survey

This is an on-site inspection of one or more of the components of the water supply system, covering the engineering works and equipment, as well as their functioning and operation. The sanitary survey should reveal any inadequacy or deficiency in the system, which may affect proper operation, or may lead to an impairment of the water quality. In the case of a sanitary survey carried out in response to complaints or as a result of laboratory analysis indicating contamination of the water supply, such a survey should reveal the source of contamination.

Sanitary surveys should be carried out by qualified professional engineers with knowledge of waterworks practice and adequate public health experience. The frequency of sanitary surveys depends on whether the water supply system is being properly operated and managed, and will usually be about once every one or two years. As such an interval between surveys is relatively long, it is most desirable that such sanitary surveys should also be carried out more frequently as a routine institutional quality control activity by the water authorities' own operational and supervisory staff.

Sampling and Laboratory Analysis

As the risk of water-borne diseases is the main concern of both the public health and the water authorities, drinking-water should be frequently and routinely examined for its bacterial quality.

Samples of water for laboratory analysis should be representative of the water supply in the system. Frequency of sampling and the number of samples required will be dependent on the population served by the water supply system, and the recommendations in the WHO International Standards for Drinking-Water are usually followed.

Chemical analysis to determine whether the water complies with the established drinking-water standards will also be required but much less frequently.

Such sampling is usually carried out by public health inspectors of the surveillance agency, under the guidance and supervisory control of the agency's chemist or supervisory engineer; and the laboratory analysis performed in the surveillance agency's laboratory.

Similar sampling and laboratory analysis are also routinely carried out by the water authorities operational staff as an institutional quality control measure.

Follow-up Action

When any defect or deficiency in the operation or management of the water supply system is revealed by the sanitary survey, immediate measures to correct the faults should be carried out by the water authority.

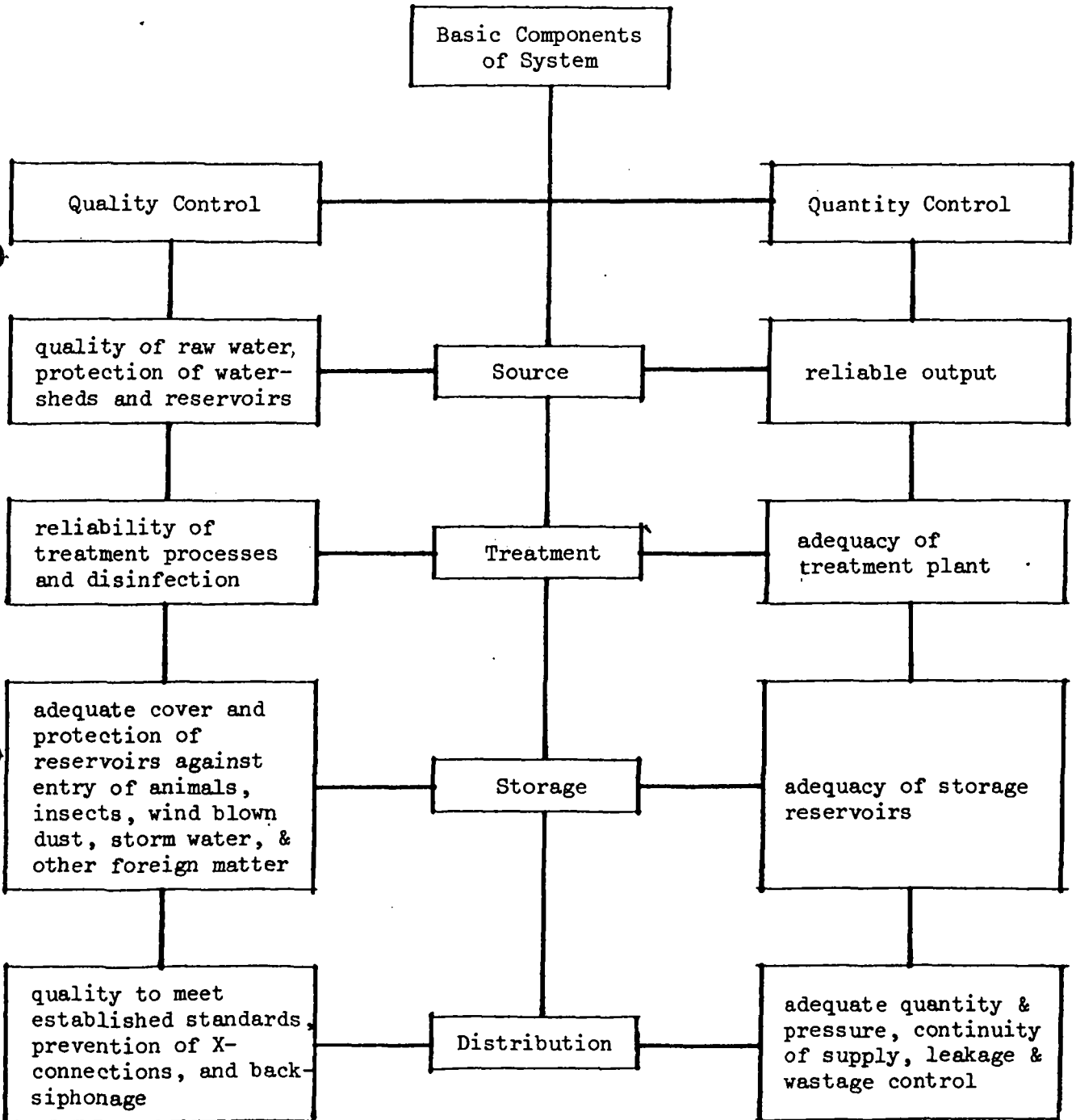
The surveillance agency should also recommend and assist the water authority to take remedial action to overcome such defect or deficiency, prevent reoccurrence of breakdowns, reduce health hazards, and improve operating techniques.

References

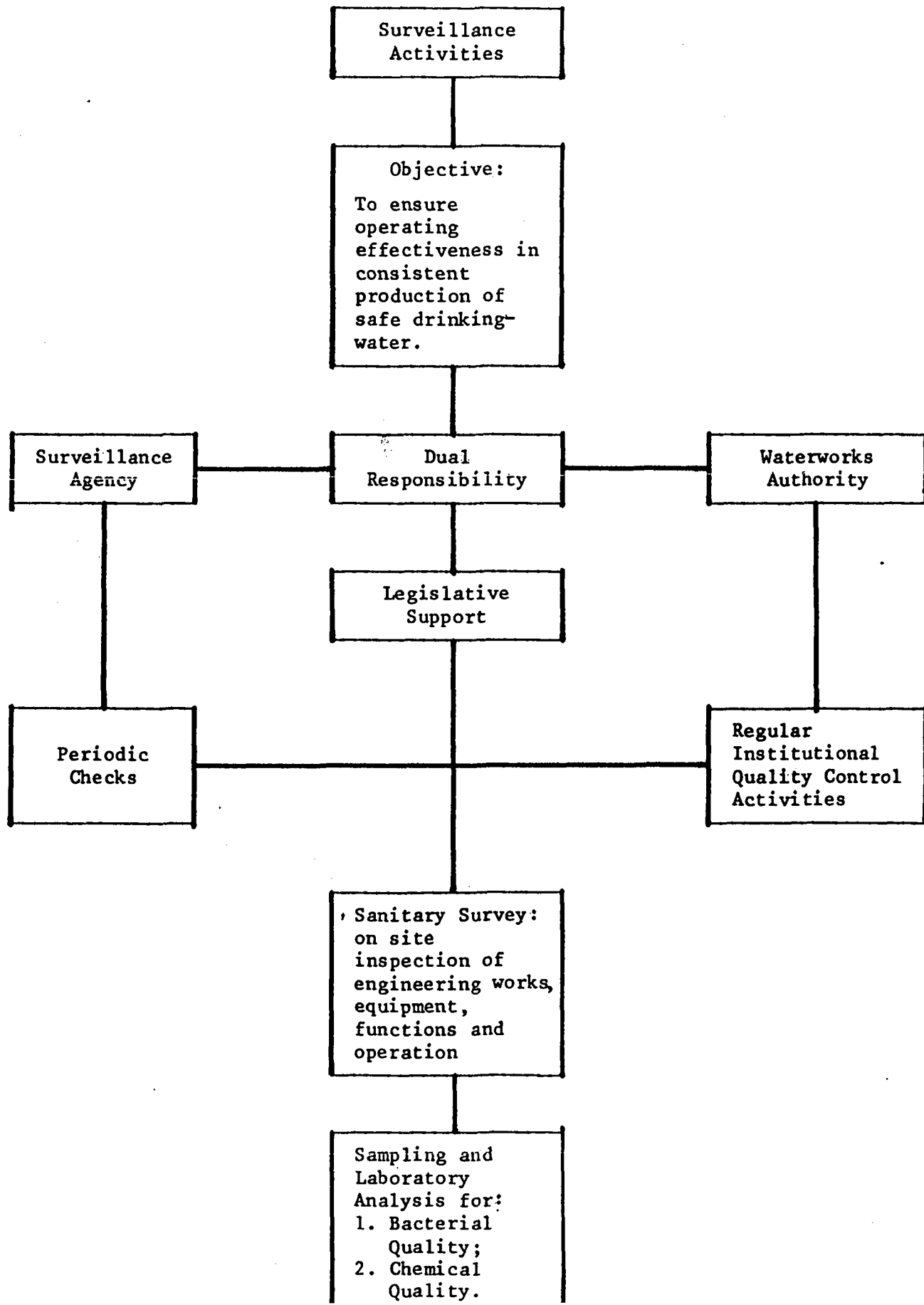
1. Surveillance of Drinking-Water Quality - WHO Monograph Series No. 63.
2. WHO International Standards for Drinking-Water, Third Edition 1971.
3. Water Quality and Treatment, Third Edition - American Water Works Association.
4. Standard Methods for the Examination of Water and Waste Water - 13th Edition 1971 - American Public Health Association.

The Operation and Management of Public Water

Supply Systems



Quality Control of Public Water Supply Systems



QUANTITY CONTROL OF WATER USES

by

K. M. Yao

WHO (PEPAS) Officer-in-Charge &
Water Quality Management Adviser

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QUANTITY CONTROL OF WATER USES

By

Dr K. M. Yao

Officer-in-Charge & Water Quality Management Adviser, PEPAS

Introduction

Water of high quality suitable for public water supplies is rapidly becoming an endangered species in many parts of the world due to increasing water demand for more people and more developments, and increasing pollution, in particular, of persistent toxic and other undesirable pollutants. Continuing supply of good quality water is further threatened by the unpredictable adverse meteorological occurrences. Severe prolonged drought were experienced frequently in many parts of the world resulting, in some cases, in the need for drastic actions to meet the basic water requirements. On top of all these, there is also the problem of the continuously rising cost of energy which affects water production and delivery costs. As a result, quantity control of water utility services is becoming a necessity rather than a matter of optional measures.

In the past, emphasis in the design and operation of public water supplies was mainly on the quality control for the promotion of public health. Quantity control was limited to reduction of leakage in the distribution systems and minimization of wastage in customers' premises chiefly by metering. With rare exceptions during emergencies such as unusually long dry periods, no attempt was normally made to restrict the ample use of water by the customers, in whichever way they want. This was, in a way, illustrated by the fact that an annual rate of increase for per capita water use of existing served population was often allowed in projecting future demand in water supply engineering. The rate was usually based on the past record of actual water usage of the municipality concerned. An annual rate of 2% was commonly used for water supply system planning in the USA (1). Published data in the early 1970s indicate an annual rate of 1.9% for Sydney and 0.7% for Melbourne, both in Australia (2).

After the energy crisis and with the general awareness of the need for conserving natural resources including water, municipalities, especially those having periodic water shortage problems, have started to take effective steps for quantity control of public water supplies. This was reflected in the results of a survey of 20 large water utilities in the USA in 1975. Thirteen of these utilities actually showed an average annual rate of decline of 0.5% in per capita water usage (3).

In many developing countries, quantity control of public water supplies appears to be getting little attention. One reason could be that since the per capita water consumption is very low, there is very little room for reduction. However, with improvement in living standards, especially in urban areas and new housing developments, modern plumbing including high water consuming devices such as flush toilets is spreading rapidly in developing countries. Preventive measures in quantity control of public water supplies could achieve tremendous savings in terms of less wastage and more conservative use of water in the homes in the years to come.

Metering

Theoretically, a water meter is a measuring device for making equitable charges to the customers based on the amount of water used. However, metering is also considered as a means to control water wastage. Installation of meters in previously non-metered areas usually results in decrease in water consumption estimated to be at least 25% (4). In some cases, metering is introduced mainly for wastage control.

The negative aspects of metering are heavy capital outlays, maintenance costs, the relatively high head loss across the meter, and, to a certain extent, as an additional source of water leakage. One alternative to metering as a means of controlling wastage would be public education. The effectiveness of the latter depends largely on the local conditions. The management of a water utility must make the decision based on its own best judgement.

An ideal water meter must be accurate within the expected range of flow variation, durable, easy to maintain and reasonably cheap. The selection of the type of meter to use and proper sizing of the meter for a particular customer are both important in getting good performance. Magnetic drive eliminates the need for direct transmission between the flow measuring component and the registering mechanism, resulting in fewer meter maintenance problems. Plastic parts and modular construction of meter interiors are on the increase with reduction in maintenance costs. In modular construction, the defective meter assembly can be easily lifted out of the casing and replaced with a good one with minimum interruption of service.

Inadequate matching of the performance characteristics of the meter selected with the particular water use pattern of the customer is probably a major cause of under-registration. Each meter design has its optimum range of flow with reasonable accuracy. If the flow of water use falls out of this range frequently, the result is inaccurate registration. In ordering meters, it is therefore important to obtain the meter characteristic graphs or specifications as guide in practical selection.

In-house water use control

In the past, in-house water use was purely a matter for the customer to decide. The main concern of a water utility is to provide water under reasonable pressure to the satisfaction of the customer. This kind of concept is now under critical review and measures are being adopted in some cases to reduce in-house water use without jeopardizing the objective of water use. However, it is not entirely unlikely that steps may be taken to restrict certain water uses such as highly water-consuming lawn watering on a regular basis rather than as emergency measures.

One of the most extensive studies on in-house water use control was made in California, USA, during the height of a prolonged drought. Table 1 presents a summary of the findings on potential residential in-house water savings by changing the water use conditions (4). As shown in Table 1, a potential reduction of water use up to 55% is possible.

In a handbook prepared by the American Water Works Association, it is suggested that the following water savings should be achievable by using proper devices (5) (6):

| | Water saving |
|-------------------------------|--------------------|
| Water-saving toilet | 5.6 - 11.3 l/flush |
| Low-flow shower head | 15-68 l/shower |
| Front-loading washing machine | 60 l/wash |
| Water-efficient dishwasher | 22 l/wash |
| Insulated hot water pipes | 15 l/d/home |

The optimistic projection given in Table 1 must be taken with caution, especially in developing countries. The main portion of savings comes from toilet flushing and shower use. The relative significance of these two water uses to the total water consumption in the premise is therefore a key factor in the overall water savings achievable. Table 2 presents the percentages of these two water uses in overall household water consumption in the USA, U.K. and Melbourne, Australia (2). In all cases, toilet flushing comprises more than one-third of the total household water use. Hence, substantial water savings in toilet flushing alone would result in appreciable overall household water use reduction.

Some items in Table 1 are probably not relevant in developing countries. For instance, pressure reduction from 55 m to 34 m would mean nothing in many Asian cities since the standard service pressure is, in many cases, around 34 m or less. Water savings in connection with hotwater piping insulation is usually not applicable in warm countries. Therefore the total potential in-house water saving in some countries is probably less than that given in Table 1 which is based on the U.S. conditions. There is however, no reason for doing nothing in in-house water savings in developing countries since, in some cases, technology for saving water is already available and there is a general tendency in many developing countries to follow the water use style and pattern of developed countries as living standards improve with successful economic developments in the country.

In-house water saving technology

A recent survey of water saving devices indicates that considerable progress has been made in achieving a high level of water-use reduction. Table 3 shows the extent of water use reduction obtainable by using these devices (7).

The following reasons have been advanced to explain why these devices are not being popularly used (7):

1. Technical reasons
 - (a) Insufficient performance information
 - (b) Non-conventional connections and dimensions

2. Social reasons
 - (a) Actual or perceived adverse user reaction
 - (b) Limited public awareness
 - (c) Resistance to change

3. Economic reasons
 - (a) Higher capital cost
 - (b) Potentially high operating and maintenance costs

4. Regulatory reasons
 - (a) Non-conformance with plumbing codes
 - (b) Hesitation to approve innovations

Table 4 is a summary of water saving devices promoted by the Public Utilities Board of Singapore (8). The water savings are achieved by control of both flow and running time.

Enforcement of in-house water use control

In most cases, in-house water use control would probably have to rely on voluntary action. However, attempts are being made to use administrative measures for achieving better compliance. One is through

the so-called socialized pricing. Under this system, a customer is charged at a certain rate for an initial quantity or block of water. The rate for succeeding blocks of water use increases with each block. In fact, such a pricing policy, though used only lately in the U.S., is quite common in Asian countries. In terms of using the pricing policy as a means for in-house water use control, the key factor is the elasticity of water use. As long as the customer is ready to pay higher rates without reducing water use, the end result will be socio-economic rather than resources conservation.

Another potentially effective administrative measure is to incorporate the concept of water savings into the plumbing code. In other words, only fixtures with low water uses are allowed to be installed in the premise. Table 5 presents an example of such an approach adopted by Fairfax County, Virginia, USA (4). The state of California, USA, also requires all new homes to install toilets using no more than 13 l/flush, showerheads using no more than 11 l/min and lavatory faucets using no more than 10.4 l/min (5).

Role of high-level government agencies

The responsibility for quantity control of public water supplies discussed so far falls more or less on the municipalities or authorities which operate the water utilities. Government agencies at high levels can also play an important role. One way is to require the adoption of water saving measures as prerequisite for government grants or guaranteed loans for public water supply projects. In the USA, there is the incentive of an additional amount of federal grant for municipal sewerage projects incorporating a wastewater reduction programme. Such a programme will include the use of water saving devices in the plumbing system.

Initiating a water use control programme

Before the initiation of a water use control programme in a country, it is essential to undertake the following to provide the basis for

assessing the potential benefit and impact of such a programme:

1. Collection of available literature on the subject;
2. Selection of one or two typical cities for the study of in-house water use pattern;
3. Review of existing water supply engineering practice for service meter sizing;
4. Survey of types of plumbing fixtures in use in the country.

National waterworks associations can play a leading role in the above activities.

With the information obtained from these activities, it should be possible to make a general assessment of the following:

1. Potential water savings if a water use control programme is undertaken;
2. Areas of major significance for a water use control programme;
3. Identification of areas where studies or applied research are necessary to develop appropriate technology on water savings suitable for local conditions;
4. Need for administrative measures such as modification of plumbing codes and water supply system design guidelines with special reference to water saving provisions.

Summary and conclusions

Water use control should be considered seriously along with quality control in public water supplies.

Technology is available for significant in-house water use reduction. Administrative options exist to achieve more effective cooperation from water users for implementing such control.

Before initiating a water use control programme, it is necessary to understand the water use pattern and other relevant facts to provide the basis for assessing the potential benefit and impact of such a programme.

References

1. Personal experience
2. Weeks, C.R. and McMahon, T.A., "A Comparison of Urban Water Use in Australia and the U.S.", J. AWWA (American Water Works Association), V65, April 1973, pp. 232-237.
3. "Water Use Trends Since 1970," Willing Water, AWWA, V20, No., March 1976.
4. "Water Conservation in California", Department of Water Resources, Bull No. 198, Calif., USA, May 1976.
5. Maddaus, W.O. et al., "Reducing Water Demand and Wastewater Flow", J. AWWA, V75, July 1983, pp. 330-335.
6. "Water Conservation Management", AWWA, 1981.
7. Siegrist, R.L., "Minimum-flow Plumbing Fixtures," J. AWWA, V75, July 1983, pp. 342-347.
8. Promotion leaflet, Public Utilities Board, Singapore.

TABLE 1

POTENTIAL RESIDENTIAL IN-HOUSE WATER SAVINGS

| Water use | Water savings as % of interior use | Water use condition | |
|------------------------------|--|---------------------|-----------------|
| | | Before change | After change |
| Flush toilet | 18 | 19-26 l/flush | 13 l/flush |
| Shower | 9-12 | Up to 45 l/min | 11 l/min |
| Faucet | 2 | 20 l/min | 5.7 l/min |
| Pressure reducing | 0-10 | 55 m | 34 m |
| Hot-water pipe insulation | 1-4 | no insulation | with insulation |
| Automatic clothes washer | 0-5 | 100-200 l/load | 61-72 l/load |
| Automatic dish washer | 0-4 | 28-61 l/load | 28 l/load |
| <hr/> | | | |
| Total | 30-55 | - | - |
| <hr/> | | | |

TABLE 2

RELATIVE IMPORTANCE OF TOILET FLUSH AND BATHING
IN HOUSEHOLD WATER USE
IN THE U.S.A., U.K. AND MELBOURNE, AUSTRALIA

| <u>Water Use</u> | <u>U.S.A.</u> <u>(Durfor &</u> <u>Becker)</u> | <u>U.S.A.</u> <u>(Howe, Russel</u> <u>& Young)</u> | <u>U. K.</u> <u>(Sharp)</u> | <u>Melbourne</u> <u>Aust.</u> |
|------------------------|---|--|--------------------------------|----------------------------------|
| Toilet | 41 | 45 | 41 | 31 |
| Bathing and washing | 37 | 30 | 37 | 38 |
| Others | 22 | 25 | 22 | 31 |
| Total | 100 | 100 | 100 | 100 |
| | === | === | === | === |

TABLE 3

EXAMPLES OF MINIMUM-FLOW FIXTURES

| Type of fixture | Flow | Percent Flow Reduction | Example Unit* |
|-----------------------|-----------|------------------------------|--|
| Toilet | | | |
| Conventional | 19 L/use | | - |
| Washdown | 4 L/use | 79 | Ifo: Ifo Sanitaire, Avery, Calif. |
| Siphonic | 4 L/use | 79 | Superinse: Thetford Corp, Ann Arbor, Mic. |
| Air-assisted | 2 L/use | 89 | Microflush: Microphor, Inc. Willitts, Calif. |
| Foam-assisted | 0.5 L/use | 97 | Nepon: Ecos, Concord, Mass. |
| Shower | | | |
| Conventional | 19 L/min | | - |
| Flow-limiting | 7 L/min | 63 | Nova: Ecological Water Products, Dunkirk, N.Y. |
| Air-assisted | 2 L/min | 89 | Minuse: Minuse Inc., Jackson, Calif. |
| Clothes washer | | | |
| Conventional | 140 L/use | | - |
| Wash recycle | 100 L/use | 29 | Subsaver: May Tag Co., Industry Calif. |
| Front-loading | 80 L/use | 43 | Westinghouse, Pittsburgh, Pa. |
| Sink | | | |
| Conventional | 12 L/min | | - |
| Aerator | 7 L/min | 42 | EWP: Ecological Water Products, Dunkirk, N.Y. |
| Flow-limiting | 6 L/min | 50 | DOLE: Eaton Corp. Carol Stream III. |

*For illustrative purposes only (not an endorsement)

TABLE 4

A SUMMARY OF WATER SAVING DEVICES PROMOTED BY
PUBLIC UTILITIES BOARD, SINGAPORE

| Device | Description |
|---|--|
| 1. Dual-flush toilet cistern | Half-flush at 4.5 l/flush and full flush at 9 l/flush |
| 2. Self-closing delayed action tap (basin taps and shower taps) | Flow cut-off after preset time up to 3 sec for basin taps and 15 sec for shower taps |
| 3. Constant flow regulator | Limiting flow to 12 l/min for showers and 8 l/min for basin taps |
| 4. Constant flow shower head | Limiting flow to 12 l/min |
| 5. Spring loaded delayed-action shower head | Limiting flow to 12 l/min and running time to no more than 15 seconds |
| 6. Spring loaded nozzle | Water flowing only when the control being depressed |
| 7. Mixer | Mixing of hot and cold water by a single handle |
| 8. Pressure reducing valve | Reducing pressure to a preset level |
| 9. Rain water collection | To replace potable water in some uses |
| 10. Earth removal platform for vehicle washing bay | Recycling of washwater for vehicle washing |

TABLE 5

WATER SAVING "STANDARDS" IN THE MODIFIED
PLUMBING CODE OF FAIRFAX COUNTY, VIRGINIA,
UNITED STATES OF AMERICA

| | |
|---------------------------|---|
| Tank toilets | 13 litres per flush |
| Flushometer toilets | 11 litres per flush |
| Urinals | 11 litres per flush |
| Shower heads | 11 litres per min. |
| Faucets | 15 litres per min. |
| Public use faucets | 15 litres per min. and self closing. |
| Car washes | Must have approved recycling. |
| Continuous flow equipment | Flow in excess of 19 litres per min. must have approved recycling. |

BACKGROUND READING MATERIALS - SUMMARIES

WATER RESEARCH CENTRE

The results of the experimental programme on leakage and leakage control, prepared by S. J. Goodwin, Water Research Centre, United Kingdom, Technical Report TR 154, (1980), 52 pp.¹

SUMMARY

This report contains complete results and analysis of a programme of co-ordinated experiments performed by the Water Industry during 1978 and 1979, which was designed to provide information on leakage and leakage control. The main objective of this programme of over 500 individual experiments was to provide factual information upon which a logical procedure for establishing leakage control policy could be determined. To this end, the experiments, and the sections in this report, are divided into:

- (a) Experiments to determine the levels of leakage in the various parts of a supply and distribution system.
- (b) Experiments to measure the effectiveness of each of the methods of leakage control.
- (c) Experiments to determine the costs associated with these methods of leakage control.

The results of these three categories of experiments are given in Sections 2, 3 and 4.

The manner in which these results were used to develop a procedure for determining the most appropriate methods of leakage control for a particular system can be found in Part 2 of the National Water Council (NWC) publication "Leakage Control Policy and Practice".

¹ Available from Publication Sales, Water Research Centre, P O Box 16, Henley Road, Medmenham, Marlow, Buckinghamshire SL7 2HD, England (£5.00)

WATER RESEARCH CENTRE

Location of leaks in pressurized pipelines using sulphur hexafluoride as a tracer, prepared by D. B. Field and B. Ratcliffe, Water Research Centre, United Kingdom, Technical Report TR 80, (1978), 30 pp.¹

SUMMARY

A technique which utilises sulphur hexafluoride (SF_6) gas as a tracer for the location of leaks in underground pressurised pipelines is already successfully employed by the Gas Industry and the Post Office. This report describes how the technique can be used for locating leaks in water mains and services. Details of the injection and detection equipment are given together with a step-by-step procedure for their use and the results of field trials carried out in differing situations.

In essence, the technique is the same as the nitrous oxide leak detection method which was developed by the Water Research Association in the early 1960s. The physical properties of sulphur hexafluoride however, made it a more suitable tracer than nitrous oxide and as a result the SF_6 technique has some advantages. These include:

- i) only shallow bar holes are required.
- ii) the mains does not have to be taken out of supply.
- iii) the gas is sampled with a light weight detector.

All of the equipment required is commercially available and names and addresses of suppliers are given.

¹Available from Publication Sales, Water Research Centre, P O Box 16, Henley Road, Medmenham, Marlow, Buckinghamshire SL7 2HD, England (£5.00)

WATER RESEARCH CENTRE

Location of underground leaks using the leak noise correlator,
prepared by D. Grunwell and B. Ratcliffe, Water Research Centre,
United Kingdom, Technical Report TR 157, (1981), 40 pp¹

SUMMARY

The Leak Noise Correlator, which has been developed jointly by WRC and the Plessey Company, is a new instrument for pin-pointing the position of underground leaks. The noise produced by a leak is detected at two positions along the mains on either side of the leak. The difference in time taken for the noise to reach the two positions is determined by the Correlator which utilises the technique of cross correlation. From this time difference, the distance between detection positions and the velocity of sound in the pipeline it is possible to determine the exact position of the leak.

The equipment has a number of advantages when compared with conventional leak locaters. These include, more accurate location of the leak, less dependence upon operator interpretation, and the equipment can be used in areas with a high background noise thus allowing leak location during the day in areas of busy traffic.

The equipment has been extensively field-tested and good results obtained. Of 220 leaks located, 75% were within 1 metre of the leak and 93% within 2 metres. The equipment has proved easy to use and all leaks have been located in less than 2 hours.

Comparisons of leak location accuracies obtained with conventional leak locaters and the Correlator have been undertaken. It has been shown that the use of the Correlator would significantly reduce the number of "dry holes". On average, the savings which would result from using the correlator to locate only 200 leaks per year would result in annual savings of at least £8000 (1980 prices).

¹Available from Publication Sales, Water Research Centre, P O Box 16, Henley Road, Medmenham, Marlow, Buckinghamshire SL7 2HD, England (£5.00)

The equipment is commercially available from Palmer Environmental, 284-285 Southtown Road, Great Yarmouth, Norfolk, United Kingdom (Telex 97207) and costs approximately £7,000 for the Mark I and £12,000 for the more automatic Mark II.

The report describes the equipment, the method for its use and discusses the results obtained in field trials. The report contains sufficient detail for it to be used, by the operator, as a training and reference manual, and forms the basis of a two-day operators course currently being offered by the NWC training division.

It is recommended that water utilities should consider the potential savings made possible by the incorporation of the Leak Noise Correlator into their leak detection facility.

DEPARTMENT OF THE ENVIRONMENT/NATIONAL WATER COUNCIL, UNITED KINGDOM

Leakage control policy and practice, Department of the Environment/National Water Council, United Kingdom, Standing Technical Committee Reports, Number 26, (1980), 151 pp¹

SUMMARY

A major programme of field experiments, believed to be the largest ever undertaken within the water industry in the United Kingdom, has provided a solid foundation upon which a procedure has been developed which can be used to determine the most appropriate method of leakage control for any system, and also the appropriate degree of effort required.

This is a major development, which provides a standard procedure with a firm economic and factual foundation, upon which leakage control policies can be based.

This report is published in three self-contained parts.

Part 1 is intended for senior management and policy makers and outlines the background of the report and states the Group's terms of reference and membership. A brief summary of the investigations that have been carried out is given and a procedure recommended for determining an appropriate leakage control policy.

Part 2 is a manual for determining a leakage control policy and is principally intended for operational staff concerned with the planning and implementation of such a policy. The field investigations and their implications are described in more detail and the procedure outlined in Part 1 is discussed fully. It also details the economic calculations necessary and gives advice on the implementation and review of procedures in changing circumstances.

¹Available from National Water Council, 1 Queen Anne's Gate, London SW1H 9BT, England (£4.00)

Part 3 is a manual of leakage control practice. It renews and updates current technology, practices and techniques and replaces Water Research Association publication TP 109, "Waste control," and should be referred to by staff concerned with the operational aspects of leakage control policy.

COUNTRY REPORT

HONG KONG

by

Chan Pui-Wah
Senior Engineer
Water Supplies Department, Hong Kong

Hong Kong is situated approximately 2400 Km north northeast of Singapore. It consists of the Hong Kong Island, the Kowloon Peninsula and the New Territories which include a number of outlying islands. The New Territories border with The People's Republic of China to the north.

Hong Kong is a hilly place and has a total area of about 1065 sq Km. The total population is 5.3 million at the end of 1982, which is a 27% increase over the preceding ten years. It is obvious that such a large population concentrating in a small place, coupled with the desire of the population to improve living standards as a result of progress made in trade and industry, produces an ever increasing demand for water. The current mean daily consumption is 1.5 million cubic metres.

The Water Supplies Department is a government department and is the sole organization in Hong Kong to collect, store, purify and distribute potable water to consumers and provide adequate new resources and installations to maintain a satisfactory standard of supply.

Hong Kong's main sources of water are :

1. rainfall from natural catchment
2. supply (piped) from China across the border
3. desalting

Over one - third of the territory's area has been developed as water gathering ground or catchment area. Further expansion of the catchment area would be both uneconomical and impractical. The annual rainfall (average 2225mm) is not sufficient to meet the demand. Hong Kong's desalter has a capacity of 181800 cubic metres a day. Desalting is a very expensive way of getting water. The desalter is therefore used only in time of severe drought and is now considered a reserve resource. Hong Kong has been depending on China for its water since 1960. In 1982/83, 240 million cubic metres of water was piped from China to Hong Kong, representing 30% of the total consumption.

Of the 5.3 million population, the majority (estimated to be 4.8 million) live in urban area of Hong Kong Island and Kowloon, and in designated New Towns in the New Territories. Almost the entire urban population is served with public water supplies. The exception is squatter population in elevated grounds. Many urban squatter areas are supplied with mains water, either metered or in the form of standpipes. The average average consumption in urban and New Town areas is 120 litres/head/day for public housing estates and 190 litres/head/day for the ordinary residential areas. These figures exclude trade uses.

The rural population, estimated to be 0.5 million, is scattered over the whole New Territories in the form of small villages. More than 70% of the rural population is served by public water supplies. There are plans to extend mains water supply to all but the most remotely situated villages. The average rural consumption is 110 litres/head/day.

All consumer connections in the urban and rural areas are metered to record consumption. A domestic consumer using less than 4000 gallons of water per billing period of 4 months does not have to pay for the water used. Consumption above this limit is charged at escalating rates. Standpipe water supply to squatter areas is also metered, but water is given free.

In Hong Kong, raw or untreated water is stored in large impounding reservoirs. The largest two are the Plover Cove Reservoir and the High Island Reservoir both built by dredging, damming and draining a part of the sea.

Water from impounding reservoirs is conveyed through tunnels and pipelines to treatment works where water is settled in clarifiers and then filtered. Treated water goes to covered service reservoirs through pipelines and pumping stations if pumping is required. The service reservoir is situated in an elevated position and each serves a well defined supply zone

the consumers in which receive water through the distribution network of pipes and service connections. The water pressure in the distribution system is maintained at a minimum of 30 m and a maximum of 90 m of water.

The pipe materials commonly used are related to the size of the pipe. Mild steel pipes with bitumen lining and sheathing are used for pipes of 600 mm diameter and above. Sizes up to 2000 mm diameter are not uncommon. Welded joints are normally used in mild steel pipelines. In recent years, large diameter ductile iron pipes and glass reinforced plastic (GRP) pipes were introduced.

For sizes ranging from 100 mm to 500 mm diameter, the practice was to use asbestos cement pipes. Since 1981, ductile iron pipes have been adopted in this range of sizes for pipelines traversing reclamation and made-up grounds or in roads with heavy vehicular traffic. Cast iron pipes are seldom used nowadays except in fittings and specials of asbestos cement pipelines.

Service connections are invariably small in size. Common materials used are galvanized mild steel (G.I.) and uPVC.

Water pipelines are normally hydraulically pressure tested to $1\frac{1}{2}$ times of the working pressure for watertightness and stability before they are put into service. However, detection of leakage in the pipe network has been an ending task in Hong Kong. Repair of leaks detected is rewarding because it will result in savings in the costs of producing water which is a scarce resource. Repair of leaks in time will also prevent them from developing into disastrous bursts which can endanger life and properties. In Hong Kong, a team of 100 technical staff and turncocks headed by a professional engineer is given the task of waste detection.

The fresh water distribution system of Hong Kong is divided into 350 waste detection areas of well defined boundaries. Minimum night flow (M.N.F.) tests are regularly performed in each waste detection area aiming at covering the whole territory in cycles of 4 to 5 months. Results of a M.N.F. test are compared with those from the previous test. Substantial increase in M.N.F. is then further investigated by performing the leakage test (also named step test) if no satisfactory explanation of the higher flow is found. Leaks confirmed by leakage test have to be pin - pointed by sounding and visual inspection. When leaking points are located, they are repaired and then the M.N.F. test is repeated to evaluate the success of the exercise.

Sounding equipment used in waste detection are :-

1. Stethoscope - a listening stick with a earphone at one end.
2. Seba Dynatronic - a potable electronic apparatus. The sound of the leak is picked up by a ground contact microphone and amplified and then transmitted through a headphone or indicated by the deflection of the needle of the noise meter.

The most common problem associated with M.N.F. tests and leakage tests are :-

1. valves not accessible e.g. cars park on top of valves
2. valves not operable i.e. defective valves.
3. valves cannot be closed drop-tight.

A recent test on a very old system on the Hong Kong Island indicated that leakage in the distribution system of that supply zone amounted to 16% of the total input into the same zone. The supply zone under test is a very small one being served by a service reservoir of 1800 cubic metres capacity. It is not possible to give a figure on the magnitude of leakage from the whole distribution system based on information available at this stage as other losses through the system are still under investigation.

Hong Kong has a separate salt water supply system for flushing in order to reduce the demand on fresh water. It is at present available to the majority of the urban areas. The salt water is pumped from the sea at pumping stations situated close to the seawall. The mean daily salt water consumption is 250,000 cubic metres. The salt water system is also tested regularly for leakage. The difficulties with waste detection is even more in the salt water system owing to the corrosiveness of salt water on valves.

The use of treated sewage effluent for flushing supply especially in New Towns is under active consideration.

COUNTRY REPORT

MALAYSIA

by

Ismail bin Mat Noor
Senior Executive Engineer
Water Works Section, Ministry of Public Works
Kuala Lumpur, Malaysia

and

Lim Meow See
Senior Water Works Engineer
Public Works Department, Alor Setar, Malaysia

QUANTITY CONTROL OF WATER SUPPLY
DISTRIBUTION SYSTEMS IN PENINSULAR MALAYSIA

1. Introduction

Malaysia's public water supply has a fairly long history dating back to the 1850s when the first public water supply system was installed in Kuala Lumpur, followed gradually by others covering major urban settlements. By the early 20th century most urban areas were served with public water supplies. During the colonial days development activities were at a slow pace and great emphasis was laid on operation and maintenance of water supply systems. Quality and quantity control of public supplies were generally of a high standard. Unaccounted for water was well below 15%. After independence in 1957, emphasis was shifted to development works to meet rapidly increasing water demand and also to extend supply to rural areas. Diversion of attention to development works has caused gradual neglect of maintenance of supply systems and a drop in the level of service.

This paper gives an outline of the present status of quantity control of water supply distribution systems in Peninsular Malaysia and the measures the water supply authorities have in mind to achieve a more efficient system control.

2. Water supply administrative system

Malaysia comprises in Peninsular Malaysia 11 States and one Federal Territory (Kuala Lumpur) and in East Malaysia the States of Sarawak and Sabah. Constitutionally, water supply is a State matter. The development of water resources in each State for public water supplies and the operation of such supplies are the responsibility of the respective State Governments. The States operate the supplies through either the State Public Works Department (PWD) or a water board. Except for water supply in Penang, Malacca, Kuching and Sibiu which is under the charge of water boards, all public water supply systems are operated by the PWD in the various States. In the PWD Headquarters in Kuala Lumpur, a Water Supplies Branch under the control of the Director-General of Public Works functions as a Federal agency for consultation and technical advice for the State PWDs in Peninsular Malaysia. The States of Sabah and Sarawak function independently insofar as water supply is concerned.

3. Water supply standards

Generally, water supply is available 24 hours a day and is fully treated. Water quality meets the WHO International Standards for Drinking Water. In the majority of cases rural water supply is of the same standard as that of urban supplies.

4. Financing of water supply

Up to a few years ago cost of operation and maintenance of water supplies including capital repayment for new construction used to be adequately met from revenue collected from the sale of water. However,

due to the great cost increase in capital works, operating cost and the fact that water rate revision is not keeping pace with such increases in the cost of production and investment levels, water supplies are now mostly operated on a deficit and have to be subsidised by State Governments. Projections indicate that for break-even operation, water rates may have to be doubled in most cases. Apart from other measures to overcome the problem of financing water supplies, one measure which needs to be looked into seriously is the reduction of unaccounted for water losses.

5. Water production, demand and coverage

The annual growth in demand for water both for domestic and industrial use, which used to be 6% per annum a few years ago, has now gone up to more than 10% per annum. Between 1959 and 1982, due to rapid industrial and housing development, increase in per capita consumption and increase in urban and rural coverage, water demand in Peninsular Malaysia has increased 7 times although population in this intervening period has not even doubled.

At the end of 1982, water demand in Peninsular Malaysia was 562 m.g.d. (2.6 million m³ per day) supplied from 240 treatment works. Water supply development is keeping pace with water demand. Number of service connections in Peninsular Malaysia is 1,230,900. Population served with piped water supply is 7.99 million people representing 72% of the population. Urban and rural coverage is 89% and 46% respectively.

6. Per capita consumption

The average per capita consumption is 50 Imperial gallons per day (250 litres per day) for urban areas, 40 Igpd (182 lpd) for semi-urban and 28 Igpd (127 lpd) for rural areas.

7. Water rates

All supplies are metered and water consumed is charged according to uses. Water rate is comparatively cheap. Low income groups pay less than 3% of monthly income. Water rates vary from State to State. On the average, commercial and industrial supplies which account for about 15% of the total demand are charged about 65% higher than domestic supplies. The present average rate for domestic supplies is US\$0.53 per 1,000 Imperial gallons (US\$0.12 per m³) while that for commercial/industrial supplies is US\$0.88 per 1,000 gallons (US\$0.20 per m³) About 77% of the revenue from the sale of water comes from domestic supplies. A few States charge flat rates irrespective of quantities consumed while others have block rates on an increasing scale. Due to political sensitivity connected with water rate increase, the rates in most States have remained the same for the last 5 to 10 years.

8. Distribution system

8.1 General system

Generally the distribution system used in Malaysia is the gravity-fed type in which the reticulation is fed from a service reservoir usually with storage equivalent to one day's demand. Very few systems have in-line boosting. Where supply has to be boosted, the suction tank combined with high level tank system is used.

8.2 Pressures

Pressure available in the mains varies slightly from system to system. Generally, day pressures available in most urban areas range from 40 ft. to 60 ft. and night pressures range from 60 ft. to 80 ft.

8.3 Types of mains

Various types of water mains have been used viz: steel, cast-iron, spun iron, asbestos-cement and lately some small size ductile iron pipes. Before introduction of asbestos-cement pipes into this country in mid-1950s, trunk mains and reticulation mains laid were mostly of cast iron. Today, asbestos-cement pipes form the greater part of the system. Asbestos-cement pipes of sizes 3" to 24" diameter are used extensively for reticulation and even trunk mains. Mains of larger sizes than 24" diameter are either of steel or cast iron. The biggest sized main laid is 62" diameter (1575 mm).

8.4 Mileage of pipes maintained

The total mileage of pipes 3" and above in diameter in Peninsular Malaysia is 23 041 miles (37,000 km). The mileage of pipes maintained by water supply authorities ranges from 233 miles (375 km) in Perlis State to 5,017 miles (8,072 km) in Johor State. The average mileage of pipes maintained by a water supply authority is 2,100 miles (3,380 km).

8.5 Pipe joints

Asbestos-cement pipes are mostly jointed with Humes or UAC type of A. C. collar joints and some cast iron gibault joints are also used. Cast iron pipes have lead caulked joints or bolted gland joints. Steel pipes have mostly welded joints.

8.6 Testing of new pipelines

All new pipelines are subjected to a pressure/strength test and a leakage test before being put into use. Pipes are tested (for strength) to a pressure of 300 ft. head of water for Class 'B' pipes, 450 ft. for Class 'C' pipes and 150% of the working

pressure of steel pipes. For the leakage test, the pressures used are 200 ft. head of water for Class 'B' pipes, 300 ft. head for Class 'C' pipes and working pressure for steel pipes. These pressures are maintained constant for 24 hours with addition of make-up water. The allowable leakage is one gallon per inch of diameter per mile of pipe per 24 hours per 100 ft. head of water pressure. It has been commented that the leakage test used in Malaysia is rather stringent. However, asbestos-cement pipes made in this country have no difficulty in passing the specified test.

8.7 Hydrants

Hydrants of both underground and pillar types are used and installed only on reticulation mains. They are spaced about 300 ft. apart. Hydrants are installed by the water supply authorities and maintained by them with maintenance funds provided by the Federal Fire Services Department. Hydrants are not metered. The Fire Department draws water freely and without charge from the public mains for fire-fighting. Water drawn from hydrants for washing markets is metered and paid for. Hydrant flows available range from 100 to 350 gallons per minute (7.6 to 27 lps).

8.8 Plumbing and water supply rules

For house plumbing, service pipes are of heavy duty galvanised iron pipes and distribution pipes are galvanised iron and unplasticised PVC pipes. Water supply rules require all taps in a house to be fed from a small storage cistern with the exception of the kitchen tap which is fed directly from the public mains. Because flow into the storage cistern is regulated and controlled by a ball-valve, there have been comments that even with the use of accurate meters, there will be some unregistered or under-registered flows which contribute to the percentage of unaccounted for water. It is for this reason that Malaysia not only specifies good accuracy for slow and fast flows, but also uses meters that begin to register at extremely low flows (say 3/4 gallon per hour).

9. Metering

9.1 At treatment plants

All treatment plants have flow recorders and integrators, mostly of Kent make to register outflow from the plant. Even if a particular outflow recorder is out of order, it will not be difficult to determine the production quantity because of the existence of other flow recorders for raw water, wash-water, etc.

9.2 Individual connections

All connections to houses, all premises including Government buildings and public standpipes are metered and water consumed is paid for. Hydrants in factories are bulk metered

either using compound meters or separate bulk meters. Public hydrants are not metered but flow tests are carried out to check on flow availability.

9.3 Water meters

Water meters used are practically all of the semi-positive displacement type with a few bigger meters of the inferential type. There are no more wet dial meters in service. There is a standing policy to replace meters every 7 years but due to shortage of staff, this policy has not been strictly adhered to by most water supply authorities. The Water Supply Rules stipulate that meters are considered as registering correctly when the inaccuracy does not exceed 3%.

The makes of meters in use are:

| | | |
|---------------|---|-----|
| Kent PSM | - | 75% |
| Schlumberger | - | 20% |
| Master, Helix | - | 5% |

Typical PWD specification of water meters (15 mm size) is as follows:

| | | |
|---------------|---|--|
| Type | - | 1. Semi-positive rotary 2. Multijet inferential |
| Flow accuracy | - | ± 2% for high and low flow rates (fast test 150 gph; slow test 5 gph) |
| Life Test | - | 360,000 gallons at 500 gph i.e. 720 hours. |

9.4 Meter Reading and Billing

In most States, meter reading and billing for domestic supplies are carried out once in two months. For commercial and industrial supplies billing is done once a month. Except for Penang State, the practice in all States is for the meter reader to read the meters and render the bills at the premises instead of using the postal service to deliver bills. Four States have commercial accounting and two States have computerised billing.

10. UNACCOUNTED FOR WATER LOSSES (UFW)

10.1 Survey

A survey on unaccounted-for water losses (UFW) was carried out on statistics available for the year 1978. The survey indicated that the overall percentage of unaccounted-for water in Peninsular Malaysia was 26.5%. An analysis of data collected on the 118 supply districts in Peninsular Malaysia indicated that unaccounted-for water ranges from 13.2% in the best district to 57.6% in the worst district. Most districts have unaccounted for water losses of 20 to 30%. For Kuala Lumpur, the capital city, the UFWs are 18% (1979); 19% (1980), 20% (1981) and 23% (1982).

10.2 Reasons for High UFW

No in-depth study has been undertaken to assess the breakdown of unaccounted-for water. Although records are kept on fire-fighting and mains bursts, the records are not sufficiently complete to enable an accurate assessment of water wasted through mains bursts or drawn for fire-fighting. It is difficult to determine the percentage of UFW attributable to leakage from pipelines, overflowing at reservoirs, illegal use and meter reading fiddling. Basing on tests carried out on meters at the consumers' requests, it is not difficult to assess generally the meter inaccuracy and errors in the system.

Explanations given by the States with UFW higher than 30% are:

- (1) Shortage of water supply and low pressure in system; hence to obtain water public open up meters and draw free water at meter positions.
- (2) Rural people without public water supply loosen air valves, sluice valves, scours to obtain water from trunk mains traversing rural areas.
- (3) Frequent seasonal mains bursts during dry season. (This applies usually to asbestos-cement pipelines).
- (4) Over-flowing at reservoirs due to defects in ball-valves or due to over-pumping.
- (5) A lot of meters not working and incorrect billing as minimum charge.
- (6) Corrosion of brass-ferrules resulting in leaks from tapping point.
- (7) Slow in attending to pipeline bursts and attending to leaks in communication pipes (between public mains and meters).

Water authorities having UFWs between 20 to 30% suspect that apart from actual leakages from pipelines, the UFW is attributable to the following major factors:

- (1) Fiddling of meters.
- (2) Overflowing at reservoirs at night.
- (3) Mains bursts and fire-fighting.
- (4) Metering errors.

11. ACTIONS TAKEN ON CONTROL OF SYSTEM

11.1 Checking Meter Reading

There is provision in all States to check the meter reading of meter readers. But staff provided is inadequate for effective control on meter reading.

11.2 Patrolling of Mains and Checking on Overflow at Reservoirs

Most trunk mains used to be checked daily by patrolmen specially appointed for the job. Due to shortage of staff and re-deployment of manpower, this practice has more or less been discontinued since the 1960s.

11.3 Replacement and Servicing of Meters

The established practice is to replace meters after every seven years using a colour coding to identify year of installation. In most States difficulty is encountered in following the 7 year replacement programme.

11.4 Waste Detection

So far only two States had carried out waste/leakage detection, that is, Kuala Lumpur and Penang. In Kuala Lumpur waste detection has been discontinued since 1960 because of staff shortage and staff transfers. For similar reasons, waste detection has also been neglected in Penang since 1975.

12. PROPOSED MEASURES FOR MORE EFFICIENT CONTROL OF SYSTEM

12.1 General measures

Major water supply authorities, Kuala Lumpur Waterworks in particular, have proposed several measures to achieve a more efficient control of the distribution system. All the States have decided to set up a waste/leakage detection section during this Fourth Malaysia Plan period (1981 - 1985) and are budgetting for the section's operating costs. Two water authorities, Penang and Kuala Lumpur are taking action immediately to resuscitate the waste/leakage detection section. Recognizing that it is easier said than done (i.e. to reduce unaccounted for water loss), the PWD Headquarters has recently issued a directive to State water authorities to institute measures for a more efficient system control, beginning with the easier and more practical measures first.

12.2 Kuala Lumpur Waterworks' Plans

The Kuala Lumpur Waterworks plans to take measures in 2 phases. These measures are:

(a) Phase I

This mainly deals with visual inspection without the use of leakage detection or other measuring and recording equipment. Proposed measures are

- (1) Inspection of reservoirs and suction tanks at night to ensure no overflow.
- (2) Patrolling of exposed pipes including appurtenances.

- (3) Liaison with Fire Department to supply records of actual fire-fighting and also fire practices so as to assess water used.
- (4) Use of Waterworks Inspectors to read big meters.
- (5) Checking servicing and calibration of all flow recorders at the treatment plants and in the distribution system.

(b) Phase II

The Phase II measures are :

- (i) In designing new reticulation systems serving new areas, introduce "waste water districts" and incorporate by-passes and provisions for installation of measuring equipment.
- (ii) Gather literature and information on waste/leakage detection and send selected staff for training in other water supply authorities.

13. PROBLEMS OF IMPLEMENTATION

Implementing measures other than waste/leakage detection will not be a big problem, given adequate manpower and funds. However, setting up a waste detection unit poses problems. Firstly, there are no staff with experience in leakage detection and those who are experienced are mostly retired. Secondly, it is difficult to get the staff to work in the leakage detection unit which works mostly at night. Thirdly, due to road congestion and lack of provision in the existing system for incorporation of waste detection meters and the like, carrying out waste detection will necessitate alteration of the system and disruption of service to the consumers.

14. CONCLUSION

Malaysia certainly welcomes the opportunity to participate in a workshop on Water Supply Leakage and Wastage Control and hopes to learn a lot from participating countries.

COUNTRY REPORT

SINGAPORE

by

Chan Chow Teing
Senior Engineer (Waste Control & Inspectorate)
Public Utilities Board,
Singapore

CONTROL OF LEAKAGE AND WATER WASTAGE IN SINGAPORE

1 INTRODUCTION

1.1 The Republic of Singapore comprises a main island and some smaller islands with a total land area of 617 sq km. The estimated population in 1982 was 2.47 million. Approximately 99.8% of the people live on the main island. For the purpose of this paper, Singapore refers to the main island.

1.2 In 1950, the population of Singapore was a little over a million and the demand for potable water was 142,000 cubic metres per day. Today, the population had gone up by 2.5 times but the water demand had increased almost 5 times. In 1982 there were more than 550,000 consumer accounts, and the average daily demand for water was approximately 746,000 cubic metres. In Singapore, 99.5% of the population are served with drinking water.

1.3 Over the past few years, the growth rate in our water demand has been more than 5% per annum. Such rate of growth represents a great strain on Singapore's limited water resources.

2 WASTAGE & LOSS OF WATER

2.1 A significant portion of our daily water demand is due to wastage and loss. In order to reduce the water demand, it is essential for us to control such wastage and loss of water.

2.2 Wastage and losses can be classified broadly into two categories, namely, that which occurs in the transmission and distribution system and that which occurs on consumers' premises.

3 MEASURES TO CURB WASTAGE AND LOSS

3.1 In order to identify accurately the extent of water losses in the system, it is important that transfer and usage of water be accurately accounted for.

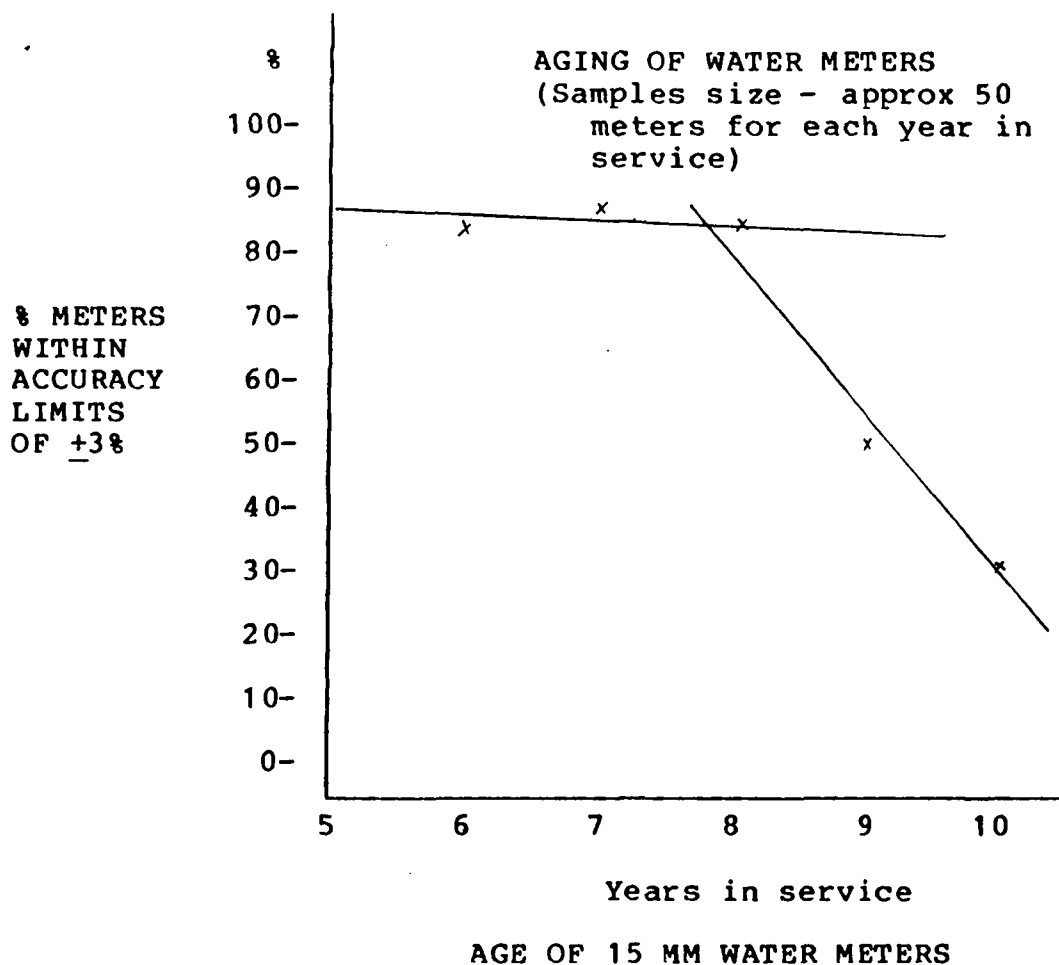
3.1.1 Recording devices measuring output of treatment works at one end and consumers' meters measuring consumption at the other end must register as accurately as possible the quantities of water passing through them.

The accuracy of the former is of particular importance as an error would grossly affect the water balance account. For this reason we carry out calibration tests on recording devices for Works Output every six months, using draw-down of clear water storage tanks in the Works. It is expected that inaccuracies will be limited to less than 3% through such calibrations.

In 1982, there are more than half a million consumer meters in use. Although consumption registered by each domestic meter may be small, inaccuracies in these meters if left unchecked can affect the total water balance account.

Results of our tests on domestic meters show that more than 80% of meters retain an accuracy of +3% up to 7 years, as shown in Graph 1.

GRAPH 1



As a result of these studies domestic meters are bulk-changed on a 7-year cycle. Approximately 57,000 meters are changed per year. The recovered meters are returned to the Board's meter workshop for reconditioning before reuse. In view of the large number of meters involved, details of meters due for bulk changing are generated by the computer.

Water consumption registered by all consumers' meters is monitored by the computer, and excessive variations in consumption patterns are picked out for investigation. An average of 4,000 cases are picked out per month.

3.2 In the transmission and distribution system, measures to curb wastage and losses are as follows:

i Losses through leakages.

Transmission mains are physically inspected twice a week by men walking along the pipeline routes. Leaks are reported early and immediate action taken to rectify the fault.

Leakage detection tests are carried out on all distribution mains 500 mm dia and below. For this purpose the distribution network is divided into 299 subregions. The tests are conducted by 3 teams of 15 men each on 2 nights every week. All the subregions are covered in 10½ months

leaving 1½ months to retest the more leak prone areas. In 1982, 146 leaks were detected. A breakdown of the leaks detected is tabulated below:

| Common Leakage Points | No of leaks | % |
|---|-------------|-------|
| Connecting pipe between main and consumer's meter | 117 | 80.1 |
| Main | 18 | 12.3 |
| Sub-Main | 8 | 5.5 |
| Valve-gland | 3 | 2.1 |
| | — | — |
| | 146 | 100.0 |
| | — | — |

It has been estimated that had the 146 leaks not been detected and stopped but allowed to continue leaking from the time it was detected until the end of the year the total cumulative wastage would have amounted to 1,020,000 m³ or 2,800 m³ per day. It may be relevant to mention that leakage detection tests yield other indirect benefits, for example it involves the operation of valves and valves inadvertently covered up by road resurfacing can be identified and uncovered - this would facilitate future isolation of mains for repairs.

The extent of loss from a leaking main depends on the length of time between the occurrence of the leak and the isolation of the main. Here public co-operation in reporting leaks is important. This co-operation is not achieved overnight but rather through continuing education starting with the young ones in schools. To facilitate public reporting of such leaks, there is a 24-hour Service and

Operations Centre, which among other functions receives and promptly investigates such reports. Prompt response in reciprocating to such reports encourages future public co-operation. To minimise time for identification, location and isolation of mains, drawings showing all mains (down to 100 mm) and valves are maintained and updated regularly. In 1982 some 1,000 reports on main leaks were received mainly from the public. In order to reduce the incidence of main leaks, there is a replacement programme for old mains, which among other considerations take into account the number of leaks in a particular main.

ii Wastage from Flushing of Mains

Dead-end mains can cause colour and odour problems due to stagnation of water. A systematic programme for flushing of mains may be less wasteful than flushing from consumers' taps. An on-going programme to connect up dead-end mains, not only overcomes the problems of colour and odour but also eliminates the need for flushing.

iii Losses Through Illegal or Unauthorised Drawoffs

There are few cases of illegal or unauthorised drawoff. In 1982 for instance, there were only 10 cases. In any case, as a deterrent, people responsible are prosecuted in court and fined between S\$250 and S\$800.

iv Wastage from Hydrants

Wherever possible, water for fire fighting is drawn from rivers or the sea instead of from the potable supplies. Where alternative sources are not available, water can be drawn from hydrants but dousing of ambers is done with a fine spray of water instead of with full jets.

3.3 A broad plan to curb wastage and loss on consumers' premises includes:

- i Education of the general public, especially school children, on the need to curb wastage. This is done through campaigns, talks, seminars, etc. There is also a conservation centre where the public can view exhibits on ways and means to curb wastage. These activities create public awareness and encourage co-operation in curbing wastage.

- ii Identification of large consumers where the scope for saving is greatest. Large consumers could be those whose water consumption exceed 75 m³ per month in the domestic sector and 1000 m³ per month in the industrial sectors. For instance, in 1982, there were 996 large industrial consumers whose total water demand is 20.7% of the total Singapore Demand.
- iii Visits to large consumers to audit their water usage and to identify areas of wastage. Consumers are advised on measures and encouraged to reduce wastage.
- iv Periodic revision of tariffs to arrest unhealthy increases in consumption.
- v Mandatory measures to curb wastage.

3.4 Areas of wastage on consumers' premises differ with different types of consumers. Generally, those who do not pay directly for the water used have a tendency to waste. Consumers can be classified broadly into three categories, namely domestic, non-manufacturing and manufacturing. In the non-manufacturing sector, large accounts are mainly those for multi-storey buildings such as hotels, commercial complexes and construction sites.

3.5 Common areas of wastage and loss on consumers' premises are leaking underground pipes and leaking fittings. Consumers are taught how to check for underground leaks and are encouraged to have all leaks repaired promptly to reduce wastage. As an incentive, domestic consumers are given a concession on their water bill, based on the lowest block in the water tariff rates, if leaks are repaired within 7 days after they are spotted. Of the 4000 odd cases, picked out by the computer monthly for investigation, some 3% are found to have underground leakages in their service pipes.

3.6 In the domestic and non-manufacturing (hotels and commercial complexes) sectors, the measures to curb wastage are as follows:

- i Installation of Water Saving Devices
 - a Flow control devices or thimbles are installed for all high rise residential apartments where pressure is excessive. Thimbles are brass discs with an orifice of 6 mm and are installed after the meter position.

At a pressure of say 10 m head of water, thimbles can reduce the flow rate by 30%. Thimbles have been installed in more than 158,000 high rise residential apartments. The total estimated reduction in consumption of all these apartments after thimbling is some 152,000 m³/month.

- b Thimbles and constant flow regulators are installed in taps and showers of multi-storey commercial buildings such as hotels and commercial complexes where water pressure is excessive. Thimbles that are installed in basin taps have an orifice of 2 mm. Constant flow regulators, which are installed at basin and shower position to limit the flow rate of basin and shower taps to not more than 8 lit/min and 12 lit/min respectively. These devices have reduced consumption in some buildings by as much as 30%. All toilets/wash-room in all public places including hotels, restaurants and cinemas are required to install self-closing delayed action taps. Their timing and

flowrates should be adjusted to not more than 3 secs and 8 lit/min respectively for basin taps and not more than 15 secs and 12 lit/min respectively for shower taps.

ii Wastage From Frequent Flushing of Water Storage Tanks in Order to Get Rid of Rust Sediment

Inspection of water storage tanks in all high rise buildings are carried out to ensure that they are adequately maintained thereby reducing the need for frequent flushing. In Singapore there are some 8,000 water tanks which are of pressed steel construction and lined with a bituminous coating. In time, the coatings crack and the tanks begin to rust. Maintenance personnel are encouraged to reline the tanks with approved materials such as H.D.P.E., M.D.P.E., G.R.P., polypropylene or rubber-based sheets or to replace the tank with those of stainless steel or GRP. For new buildings, tanks are to be of stainless steel or G.R.P. or lined with approved materials if of pressed steel.

iii Wastage in Cooling Towers

Cooling towers in multi-storey buildings which are poorly maintained or undersized can waste as much as 70% of the make-up water used. In hotels and commercial complexes, make-up water for cooling towers may account for up to 40% of the total consumption of the building. Maintenance personnel are required to ensure that their cooling towers are adequately maintained and are advised to have them replaced if undersized.

3.61 On construction sites, the measures to curb wastage and loss are as follows:

i Losses Through Leakages

Pipes and fittings at construction sites are more prone to damage and vandalism. Contractors or their site agents are required to inspect all pipes and fittings frequently and to have leaks repaired without delay.

- ii Wastage From Washing of Vehicles, Etc

Contractors are encouraged to reuse water for washing of vehicles or other miscellaneous washing where clean water is not required. Vehicles are washed on a graded platform where the water can be collected and reused. All hoses used at construction sites must be fitted with self closing devices such as spring loaded nozzles. For washing of formwork and steel bars prior to concreting, contractors are encouraged to use compressed air assisted water jet instead of just a water jet.
- iii Wastage From Curing of Concrete

Contractors are to use gunny sacks for curing of concrete instead of persistent spraying with water.
- iv Wastage in Labourers' Dormitories and Canteens

Contractors are to install water saving devices such as thimbles, constant flow regulators and self-closing delayed action taps at labourers' dormitories and canteens.

Before water supply is given to construction sites, contractors are required to give an undertaking that they will comply with the requirements to curb wastage. They are also required to provide a detailed breakdown of their water requirements. This is closely scrutinized before their application for water supply is approved.

3.7 In the manufacturing sector, broad measures to curb wastage are:

i Wastage From Cooling and Washing Processes

Industries such as 'Food and beverage' and 'Electronics' can recycle cooling water through use of cooling towers. Industries are not permitted to have a once-through cooling system. In 'Beverage' industries, water used for bottle washing can be reused - use of canned or packet beverages would eliminate the need for bottle wash water.

Industries are urged to use industrial water (treated sewage effluent) or sea water, where available, in place of potable water for purposes such as cooling.

- ii Wastage From Frequent Boiler Blow-down.
Installation of efficient pretreatment plant such as demineralisers can minimise the frequency of boiler blow-down.
Wherever possible, such as in 'Food and beverages' and 'Chemical, rubber and plastics' industries, steam recovery is encouraged to minimise make-up water.

Whilst existing industries are strongly urged to upgrade the efficiency of their water usage, water requirements of new industries, among other considerations, are carefully studied before approval is given for their setting up.

3.8 For ease of communication and enforcement of measures to curb wastage, large consumers in the manufacturing and non-manufacturing sectors are urged to appoint water controllers whose primary function is to audit water usage, identify areas of wastage and implement measures to curb wastage on their premises.

4 PROBLEMS ENCOUNTERED

4.1 As mentioned earlier, losses due to leakages in mains can be minimised by shortening the time required for isolation of mains. The problem starts with

location of valves. Drawings indicating location of mains and valves, which currently are on a 1:1000 scale, are found to be inadequate. To expedite location and identification of valves, a manual of major valve junctions has been prepared. We will need to extend the manual to cover other valves as well. Having located and identified the valves, there is the problem of effectively shutting them to isolate the main. Sometimes valves cannot be shut tight to completely stop the flow in the main - some are even damaged during operation. A programme is being prepared for maintenance and operation of valves.

4.2 Losses due to underground leakages can be minimised by shortening the time required for locating the leaks. The equipment presently used for locating leaks include Geophone, Terroscope and Son-I-kit which work basically on accoustical principles. These equipment are rather slow in locating leaks especially during the day time when there are interferences from traffic and other noises. We are looking into the use of more sensitive equipment that can expedite the location of leaks. The equipment we are currently looking into are those that work on the leak noise correlation principle.

4.3 In view of the low cost of water, large consumers, especially those in the manufacturing sector, are reluctant to invest in plant and equipment to increase efficiency of water usage. As water cost represents only a small percentage of their overall operating cost, they invariably have a tendency to compare the benefits of any equipment installed against its cost. To assist such industries, those who have made meaningful efforts to conserve water by a substantial margin will be supported with tax incentive. We are looking into a disincentive scheme against those who can reduce their water demand but refuse to do so.

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SUMMARISED COUNTRY REPORTS

SUMMARISED COUNTRY REPORTS

BRUNEI

The total population of Brunei in 1980 was approximately 200,000. The four districts are supplied by river sources (3) and a dam (1) (Tasek Dam). Some 60% of its population live in towns with public water supplies. Of the 40% of its population living in the country, some 90% are served by public water supplies. Average consumption is estimated to be 450 l/p/h or twice that of neighbouring countries. It is estimated that 90% of the services are metered. At present, passive leakage control is practised in Brunei, with leak location and repair work being undertaken on reports from the public. This is attributed to the current lack of trained staff and manpower shortages. Brunei is considering employing a firm of consulting engineers to investigate the extent of its leakage problem and dependent upon its findings implement the most appropriate leakage control policy.

FIJI

Fiji's population was estimated at 634,000 in 1980. Public water supplies mostly serve towns and settlements with populations of 1000 or more. Of the estimated 400,000 urban population, some 80% are served by a public supply, whilst in rural areas the relevant percentage is only 20%. Unaccounted for water is estimated to average 33%, with consumption averaging 150 l/p/d in towns and 100 l/p/d in rural areas. All domestic properties are metered.

Leakage detection has in the past been carried out intermittently, depending largely on the priorities of the Resident Engineers.

The Government of Fiji recognises the importance of reducing leakage and is currently drawing up a programme to implement a leakage control policy with UNDP support.

REPUBLIC OF KOREA

The Republic of Korea (ROK) has a population of 39.3 million. Some 24 million live in an urban environment with public water supplies serving about 88%. The proportion of the population in the rural environment receiving water from a public supply is only 15%. Most of its water is supplied from rivers, with reservoirs and deep wells supplying most of the rest. Water consumption is estimated to average 270 l/p/d ranging from an average of 285 l/p/d in urban to 141 l/p/d in rural situations. All properties are metered.

Leakage detection in ROK is not widely implemented and unaccounted for water is estimated to average 27% (range 16% - 40%). A recent study has shown that in Ulsan City leakage on service connections is twice that from the distribution system. ROK is receiving US\$7 million from the ADB to help finance schemes in leakage control in a number of smaller towns and one or two large cities (Seoul and Ulsan City).

SOCIALIST REPUBLIC OF VIET NAM

Hanoi Water Supply Department serves a population of 2.6 million with a total of seven service areas with 100% coverage in the city and 15% in the suburban areas. There are two main rivers (Hong and Nhue), a raw water reservoir and some 98 deep wells supplying water to the area. Urban consumption is estimated to average 70 l/p/d.

Leakage and other water losses are believed to be high, representing some 40 - 50% of the total quantity supplied. This results from the fact that some 70% of the pipes are damaged. In 1983, Hanoi Water Supply Department constructed and made alterations to some 20 km of transmission mains and distribution pipes and is carrying out some leakage and wastage investigations. However current practice can largely be described as passive control, finding and repairing leaks only when they show themselves on the road surface.