Proceedings of Symposium on An Understanding of Water Losses

The Institution of Water Engineers and Scientists

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SYMPOSIUM ON AN UNDERSTANDING OF WATER LOSSES

PROCEEDINGS OF SYMPOSIUM HELD IN LONDON, ENGLAND 1st and 2nd DECEMBER 1981

ANY CORRESPONDENCE relating to the papers appearing in this publication should be addressed to the Secretary, The Institution of Water Engineers and Scientists, 31-33 High Holborn, London WC1V 6AX, England. (Tel: 01-831 6578).

PREFACE

The provision of a cheap, plentiful and wholesome supply of water is a matter of concern, not only to all disciplines involved in the water industry, but also to the general public whose present-day standard of living is based upon the availability of water on tap 24 hours a day.

It is not surprising therefore that, to the man in the street, waste of water is synonymous with waste of money, particularly where heavy expenditure is needed for the development of new water resources. The position is exacerbated when such development is seen to affect the environment and the lives of many people.

At the present time opinions differ as to what constitutes "waste" for the word has both a legal and a vernacular meaning. Furthermore the modern term "unaccounted for water" has introduced a new concept by which some have equated lack of accurate statistics to actual leakage or undue consumption. It is certain that much more information is needed about meter accuracy and per capita use both at home and at work before the true extent of water losses and the best means of exercising economic control can be established.

The Symposium will endeavour to present information, views and facts on this important subject which may not be fully understood at present, even by people working in this specialised field. The Symposium, however, is not intended to be solely for engineers, as the range of the papers will be of interest to all those with a general involvement in the subject. The topic is of equal interest to those in other countries and it is expected that many overseas delegates will attend.

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OPENING

The Rt Hon Tom King, MP

The President, Mr. E.C. Reed, introduced the Rt Hon Tom King, MP, Minister for Local Government and Environmental Services, and invited him to open the Symposium.

Mr. King acknowledged his introduction. He had recently returned from a trade mission for water industries to the Middle East. As a nation we had lost many of our traditional markets. That made it all the more important for us to strive even harder in those fields where our skills and experience and proven technology offered the best prospects. One of those fields was undoubtedly the water industry. The work which we did on leakage control, as on many other subjects, which was important to ourselves also had a very direct potential for export.

Mr. King had been told that it lay within our grasp both technologically and economically to detect and prevent leakage of as much as ten per cent of the total quanity of water available for use. The implications of such a saving on the costs and efficiency of the industry would be considerable, not just on pumping and treatment costs but also at a time of concern over the loss of agricultural land as a result of the demand for new reservoirs. It was inevitable that anyone seeking to promote a new reservoir in the future must show that all reasonable steps had been taken to conserve resources and to reduce costs.

Mr. King then referred to the work of the Water Research Centre on new leak detection equipment. There were in addition four related topics, which applied individually or in combination were of importance when considering rising demands for water; these were metering of water supplies to consumers, research on variable flush devices for WC cisterns, new model byelaws, and achieving public understanding of the need for economy in water use.

Mr. King concluded by wishing the Institution success with its Symposium which he had been pleased to open.

1. CATCHMENT LOSSES: BUT FIRST SOME BACKGROUND

K.J.H.Saxton, MA, FICE, FIMechE, FIWES, FBIM*

The scene is set by reference to the 1974 IWES Symposium on Waste Control and to some of the principal official documents since published. What has and has not changed in the water industry's thinking is noted.

Types of catchment loss and their orders of magnitude and cost are identified. The continuing need for better quality control over measurement and data collection is stressed.

INTRODUCTION

The President's brief to me for this introductory paper was to give, "mainly a historical run-up". This made me think of the first book I can now consciously remember having read concerning the water industry. It was a history of the water supply of London, published by the Metropolitan Water Board (1), and typically put the rest of the United Kingdom water industry politely in its place. The book began with the sentence, "The supply of water to the City of London presented no grave problem down to the end of the 12th Century"! So prior to 1236, when at the request of Henry III, Gilbert Sandforde granted to the citizens of London and their successors "liberty to convey water from the town of Tyburn into the city by pipes of lead", there presumably were no problems in the United Kingdom with what we are now encouraged to describe, not as "waste", but as "transmission losses". However, the subject of water losses and leakage control is one of the oldest in the water business and Sextus Julius Frontinus, the water commissioner of Rome in 97 A.D. tells in his writings (2) of shortages of supply, lack of pressure, aqueducts which were a continual source of leakage and illegal connections to the distribution system of Rome.

THE 1974 SYMPOSIUM

My thoughts also turned to the Symposium on Waste Control which this Institution held at Reading in September 1974 and to the introduction then by Harry Giles of his paper on "The Causes and Extent of Waste and Undue Consumption" (3). Giles said that whenever water engineers forgathered the question was invariably posed, "What is your waste level and what do you mean by waste?". While resisting the temptation at this stage to add still further definitions to those produced over past decades, I will also resist answering

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the initial question posed by Stanley Barrett when he launched that 1974 Symposium, "What is Waste?".

Instead what I will do, is draw attention to the dramatic change in some of our thinking within the United Kingdom water industry since 1974. Can it really only be seven years since Barrett was saying "... demands for water are ever increasing" and that "... water lost by leakage cannot have much impact on forward planning"? (3) Admittedly, Judith Rees in her 1974 paper "Waste Control: An Economic Approach" (3) was already beginning to take us to task; she and a few others were floating the concept of demand management and of the likely benefits to be derived from the integration of resources. This was leading into the optimal provision and utilization of water supply facilities which we now favour so much. To bring us up to date it is significant that in the Monopolies and Mergers Commission Report published in June 1981 on the Severn-Trent Water Authority, and the East Worcestershire and South Staffordshire Water Companies, (4) no less than ten pages refer to water leakage and its control in relation to demand management. Amongst the Commission's conclusions is one that "... more manpower should be allocated to leakage control when the properly discounted costs of this activity are less than the value of the benefits, which should include savings in capital budget".

Ernest Young in his 1974 paper "Future Measures to Minimize the Waste of Water" (3), was telling us, "... loss of water from undertakings' distribution pipes c1750 to 1820 was thought to be about one-third of the total supply" Earlier, but on that same day in 1974, James Reid was assuring us when introducing his paper on "Design and Operation of Distribution Systems" (3) that the average losses in the Manchester area were the precise figure of 6.8%. I wonder whether anyone in this our 1981 Symposium will refer to losses in terms of one tenth of one per cent! I suspect that with present knowledge they will not and, indeed, if we accept the Recommendation 3a of the joint Department of the Environment (DoE) and National Water Council (NWC) Technical Working Group on Waste of Water (5), we will not even use "percentages of quantities supplied" for making comparisons of leakage levels. That Working Group, incidentally, had originally been set up in 1973 and after two interim reports it published its final Report in July 1980. Young and Reid were both members of the Group, under the chairmanship of Frank Ridley, and whilst being careful not to use the word "percentage" I must say that the order of magnitude most of us now have in mind is likely to be nearer that mentioned by Young, rather than that by Reid.

Others of the views expressed by those present at the 1974 Symposium can now be stated with even greater conviction. The Water Research Centre (WRC) in its Technical Report TR154 published in November 1980 on "The Results of the Experimental Programme on Leakage and Leakage Control" (6) stated that the effect of pressure on the rate of leakage is now known and has been found to be greater than theoretical considerations would suggest. Apparently, a given reduction in pressure will cause a corresponding greater reduction in leakage. Subsequent authors and speakers at this 1981 Symposium are likely to be drawing heavily upon the findings of the DoE/NWC Working Party and on the work of the WRC and so no further reference will be made at this point to these Reports.

MEASUREMENT

On the subject of measurement, Giles in 1974 was drawing attention(3) to the relative inaccuracies of meters and in the second Paper at this 1981 Symposium Field and Spencer will be dealing in detail with flow measurement.

I deliberately do not intend myself to refer in depth to the subject of the metering of domestic water supplies, but as metering and methods of charging for water inevitably bring us back to the subjects of demand management, cost/benefit and the use and misuse of water, I will just quote as food for later thought the following paragraph from the 1981 Corporate Plan of the Severn-Trent Water Authority "To 1986 and Onwards" (7):-

> "... the severely curtailed approach to capital investment would conflict further with meeting all the demands arising from incautious or uncontrolled use of water. There are two main areas to be tackled. Leakage from supply mains has been increasing steadily in recent years and insufficient resources have been available to find and stem it, even where economic to do so. Secondly, it is becoming clear that the peak rate of domestic consumption is rising markedly as a result of increasing use for garden watering. In order to secure more frugal use of water in an economic climate of low investment levels it may be necessary both to charge for garden watering and to impose selective bans if there is a real possibility of supplies falling to danger level. Both these problems require an initial increase in the use of financial and manpower resources in direct contrast to present policies."

The thinking in the water industry seems yet again to be turning full circle!

In 1974 Rees was saying (3), "... accurate data gathering could be seen as a clear prerequisite for reducing all forms of wastage in water use". She hoped the 1974 Symposium would stimulate developments in this direction. Whether the Symposium did so to any significant extent remains to be seen but there is no doubt her premise was correct. I have to admit that one of the things which surprised me when I arrived in Wales in 1974 was how little some of the Welsh Water Authority's predecessors really knew about the quantities of water moving around their undertakings. Detailed statistics to three and four significant figures had been quoted for daily consumptions and yet, in one of the smaller divisions, it was subsequently discovered that not even a single major water meter existed. In another division, the figures being quoted in official records had been derived solely from the fact that they looked about right when compared with neighbouring undertakings! Hopefully, after seven years a greater understanding exists of the overall situation, without us being misled by spurious degrees of accuracy, but there still is much scope for improvement in the measurement both of water usage and of the water leaving sources.

CATCHMENT LOSSES

The preceding paragraph has, therefore, brought us to the second and main aspect in the President's brief to me which was that I introduce the subject of catchment losses.

In the United Kingdom there is no intrinsic shortage of water. Rainfall is ample to meet all water demands for the foreseeable future; where problems do arise it is from the uneven distribution of rainfall over both time and place. The measurement of rainfall in association with the water supply industry has been taking place for approaching a century and a half. Bateman (8) certainly recorded rainfall in the Derwent Valley catchment at Bamford-cum-Hathersage in the years 1840 and 1841 and others of you may know of even earlier records. Most water authorities have been re-examining in recent years the quality of the rainfall data they have been accumulating and gauges with inaccurate records due to incorrect exposure, vandalism, or insufficient interest by observers are being discontinued. In the area of the Welsh Water Authority the number of gauges has been reduced by nearly 10 per cent in the last seven years and now averages one per 35 sq kilometres.

This reminds me of the recommendation being made in 1963 by myself and my predecessor as Engineer to the Derwent Valley Water Board, Reg Thompson (9), that after an initial ten year period a few gauges well dispersed can give a good representation of mean rainfall at all times of the year providing the number of gauges is not reduced to less than one per 39 sq kilometres (15 square miles). I wonder what Reg Thompson, if he were still alive, would have to say today about weather radar!

Run-off Data

Early in the 1960s there developed an increasing awareness of the need for run-off data and this was accelerated following the passing of the Water Resources Act 1963. For example, the Welsh Authority now has 123 river gauging stations although it must be admitted that some of the past records from these stations are still being critically examined with regard to accuracy. For some reservoirs in Wales, run-off records are available for yield calculations but for most of the smaller reservoirs the yield has been derived by first assessing the average annual rainfall, then subtracting average annual losses to get the average annual run-off and applying a regional model to obtain the yield value.

Logan Jack drew attention in 1977 (10) to the lack of published information on annual catchment losses and the difficulty of obtaining accurate data upon which to base guidelines for hydrologists on the estimation of such losses. He suggested a practical method using a technique which relies on choosing an initial value which is then adjusted to allow for elevation, exposure and afforestation. The range of annual loss figures which can be expected on Welsh catchments using this technique is illustrated by the following examples:

Location	Size	Elevation m	Exposure	Afforestation %	Losses mm
Snowdonia	small	600	N	0	360
Mid Wales	large	250	-	10	470
Mid Wales	small	450	E	70	550

Effects of Afforestation

Nearly half the rain falling on the United Kingdom returns to the atmosphere either directly by evaporation or indirectly by transpiration through plants. The development of thinking in the United Kingdom since the Second World War on the impact of afforestation on water supply interests has been interesting. In the years immediately after the War there was an awareness that increased afforestation would render the nation less vulnerable to the kind of timber shortages that had been experienced in wartime and considerable amounts of land owned by water undertakings were let to the Forestry Commission, often on 999 year leases. There was little indication at that time that forest cover on a water catchment was less suitable for run-off purposes than the open moorlands and unimproved farms. In fact, the traditional view from as far back as the previous century was that "a covering of trees and grass is very beneficial in increasing the average discharge of a river by reducing evaporation, especially in the summer months when water is most needed". (11) The issue was investigated at length by the Gathering Grounds Sub-Committee of the Central Advisory Water Committee. Their report (12), published in 1948, concluded that water undertakers should be encouraged to adopt a policy of afforestation in gathering grounds where the conditions were suitable and where the land could not be more economically used for agriculture.

In the early 1950s research in other countries was arriving at very different conclusions. For example, comparisons in Holland between four small plots of scrub, deciduous trees, coniferous trees and bare soil resulted in the conclusion that "... it was evident that conifers represented the worst kind of vegetation for a water supply catchment". (13) In the United States of America the conclusion was being reached that "... forest vegetation may exert a substantial effect upon the net precipitation reaching the soil".(14)

Following on from this, Frank Law, Engineer to the then Fylde Water Board, carried out experiments in Yorkshire to determine the effects in the uplands in Britain. Rainfall and runoff were studied in a lysimeter in a stand of Sitka Spruce at Stocks Reservoir. The results, presented to the British Association for the Advancement of Science in 1956 (15), showed that the runoff from the areas of trees was much less than would be expected from the area if it had been grass-covered. Law found that:

(i) losses in the lysimeter were 290mm/annum greater than those of the whole reservoir catchment;

(ii) interception in the winter of 1955/56 was as high as that in the summer of 1956, and inferred that -

(iii) if the whole catchment were afforested there could be a loss in reliable yield of 42% from the reservoir for water supply.

Law went on to calculate that at Stocks an acre of forestry reduced the water supply by an amount capitalised in 1956 at £200, whereas the rent per acre paid by the Forestry Commission was usually 2s.6d. per annum which could at that time be capitalised at something under £3. It is interesting to note that, of these values derived in 1956, the cost to water supply will have increased considerably in present day prices whereas forestry leases are usually for long periods and rentals are unlikely to have changed. Thus the balance now is even more to the financial detriment of water supply.

The debate arising from these results was fierce, with some arguing that Forestry Commission planting in reservoir catchments should be stopped whilst others contended that the results were not conclusive. Further research was called for, resulting in the formation of the Hydrological Research unit (now the Institute of Hydrology). The Unit was formed to study the hydrological effects of land use, particularly the differences between forest and grass. After some time spent on evaluation of sites the Plynlimon study in Wales was started in 1968, whereby the headwater catchments of the Severn (62% forested) and the Wye (1% forested) were intensively monitored. The remote nature of the catchments and the wild weather conditions resulted in a slow start to the experiments until the staffing and instrumentation problems were resolved. Very little information on the findings at Plynlimon emerged until 1975 but since then there has been considerable coverage in a wide variety of journals and at scientific meetings. Malcolm Newson in his 1979 (16) paper to this Institution tells us the conclusions are that the results of the Stocks experiments are confirmed in that trees do "use" more water than grass, i.e. less runoff occurs from afforested catchments. In addition, considerable knowledge has been gained on the processes by which this extra water loss occurs. Some of the other effects of forestry, previously believed to be beneficial, have also been shown to be detrimental to water supply - these include sediment production, water quality effects and flood amelioration. There is also evidence that fish life is adversely affected. The results(16) from the Plynlimon catchment for the years 1970-77 show losses of 849 mm/annum from the forested area of the Severn compared with 405 mm/annum from the unafforested Wye catchment, an increase of 444mm/annum due to afforestation.

The implications of the Plynlimon results for the water industry were examined in a paper published in September 1980 (17) which reached the conclusion that four things were still needed:

(i) further data to enable the extra catchment losses due to afforestation to be evaluated on a monthly, rather than an annual time scale, and for areas with rainfall between 1000 and 2000 mm/year. (Rainfall at Plynlimon is some 2400 mm/year.) The data would then be used to evaluate reduction in reservoir yields and hence the additional cost to the water industry from forestry activities.

(ii) data to enable the extra cost to be evaluated of additional water treatment due to the various effects of afforestation on water quality.

(iii) means for the effective communication of the outcome of (i) and (ii) above.

(iv) planning controlover afforestation and where appropriate financial reimbursement to the water industry.

In October 1980 the National Water Council gave written evidence, on behalf of the water industry in England and Wales to the Forestry Sub-Committee of the House of Lords Select Committee on Science and Technology drawing attention to forestry related research in the post-war years. The Council made the point that the industry regarded the massive Institute of Hydrology project at Plynlimon as conclusive in comparing average runoff from grassland and forest in wet uplands. The industry saw a need for further work on seasonal patterns of runoff to quantify the effect on water yield more precisely and of course this still remains to be done. (18)

These views of the water industry were reflected in Volume 1 of the Report of the Select Committee when this was published in December 1980 (19). Paragraph 56 of the Report referred in detail to catchment studies and said that "... in high rainfall uplands mature forest can be expected to reduce average runoff from grassland by 13-21 per cent (with 50 per cent canopy cover). More detailed work is needed to quantify the reduction in reservoir yield but this could be expected to range up to 13-21 per cent depending on the extent of reservoir development (and canopy cover) - Evidence strongly suggests that there is need for more research - on seasonal patterns of runoff to quantify yield more precisely. - The scientific case for such work is strong".

<u>Effects of Local Geology</u>

There is another form of catchment loss which I have not yet mentioned and this has been highlighted by recent work, not yet published, but carried out for the Welsh Water Authority in the Heads of the Valleys area in South Wales. The geology of the particular catchment is complex. Most of the surface rock is of the Millstone Grit series, and underlying this is the Carboniferous Limestone which in many places has been eroded so that the overlying Millstone Grit has collapsed into the holes formed by this erosion. The resulting landform is composed of a number of conical depressions of various sizes, known as swallow holes, and the study has shown that the run-off available in the surface streams is 45 per cent of the amount that would be expected if the catchment did not suffer from leakage. The value of 55 per cent losses applies equally to all months of the year and the effect of the leakage can therefore be thought of in terms of reduced effective catchment.

The major points arising from this study of catchment losses are:

(i) that the Welsh Water Authority should consider increasing its supplies by development from underground sources and that increased surface storage is inappropriate.

(ii) even though the catchment had been reservoired and used for water supply for 70 years the existing measurement facilities in the catchment were unable to indicate the resources available

(iii) within 6 months of commencing accurate catchment measurement (comprising 1 small weir, 6 raingauges and 4 water meters) the catchment resources could be identified. It is felt that this disproves the view prevalent within certain sections of the water industry that water balance studies are costly and take years to achieve results.

Minimum Acceptable Flows and Compensation Water Provision

In this paper I do not intend to dwell at length on the difficulties of implementing the concept, which arose from the Water Resources Act 1963, of minimum acceptable flows in relation to inland waters. Similarly I will leave to others the opportunity to quote examples where, in their opinion, the requirements for the provision of compensation water are excessive. Never-the-less the fact does remain that during the major drought in the United Kingdom of 1975-76, residual flows were in many cases substantially reduced and apparently with little significant damage to the environment. Thus the question must arise in some catchments as to whether the existing provisions for compensation water do constitute an excessive "loss" as far as the provision of water for supply is concerned. Another catchment loss, which sometimes occurs within the activity of the water industry itself, but which should be avoided wherever possible, is the failure at water treatment works to re-cycle the filter washwater and the supernatant water from the sludge treatment.

COST IMPLICATIONS

Running costs are ever increasing; there is an overall need to conserve energy, and with figures now being quoted of up to £200,000 per tcmd of yield as the replacement cost of source works, it is clear that very substantial sums are involved when we are thinking of water losses. The construction of additional source works can be deferred by:

(i) managing the consumers' demand for water,

(ii) reducing the amount of water unaccounted for in the distribution network, and

(iii) reducing, or at least preventing an increase in, the losses within the catchment areas of source works.

When attempting to improve our understanding of water losses we should remember that:

(i) in terms of magnitude, catchment losses can be similar to those we tend to associate more readily only with the distribution network.

(ii) the need to increase our knowledge of the movement of water within the catchment area is just as great as the need to measure the flow and usage of water in the distribution network.

(iii) in certain circumstances savings may be achieved more readily and at less cost by looking at the catchment in addition to the distribution network.

CONCLUDING REMARKS

To close this introductory paper I take us back to the Institution's 1974 Symposium at Reading and to the remarks of Ernest Young when concluding his paper at that time (3). Young said an obvious criticism of his paper was that it advocated nothing new because it had all been said before. His answer was that he hoped in 25 years time we would not have to go over the ground yet again. He felt that having identified the problems we should exert ourselves to solving them.

I make no apology for repeating much that has been said after only 7 years! In real terms we have made far too little progress in getting to grips with our problems.

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DISCUSSION

Author's Introduction

Mr Saxton, in introducing his paper, said that it was apparent that most of his fellow authors agreed that there had been positive changes in the water industry's thinking since the Institution's previous Symposium on waste in 1974. However, what seemed to be lacking was sufficient change in the industry's practice on the ground. There certainly were delays in the implementation in practical terms of many of the changes in the industry's thinking with regard to water losses.

The Planners, faced with the almost impossible task of predicting to any degree of accuracy the future demand for water services, and their operational colleagues within the industry had accepted the concept of the integrated use and optimization of resources: but the implementation of the concept of deliberate demand management now appeared likely to be shelved for some time, as recent evidence showed that limitations of finance and the current industrial recession were already having a significant effect upon demand.

Turning to the subject of catchment losses, Mr Saxton said that, as could be seen in Table 1, these could be substantial, and in terms of magnitude similar to those perhaps more readily associated with the distribution network.

TABLE I - Water losses for Typical Direct Supply Reservoir
(based on reservoirs in the Brecon Beacons)

	tcmd (%)	Decrease/ Increase yield, tcmd	Replacement Cost/ Benefit Value @ £200,000 per tcmd*
Yield if catchment not afforested	100 (100)	- 10	£2 million
Yield with existing 30% afforested catchment	90 (90)		
Statutory compensation water provision	20 (20)	+ 15	£3 million
Compensation water during drought order	5 (5)		
Water leaving headworks after provision of stat. compensation water	70 (100)		
Water into supply after typical existing "transmission loss"	45 (65)		
Existing "transmission loss"	25 (35)	+ 15	£3 million
Assumed "transmission loss" after intensive waste detection campaign	10 (15)		

* capitalised value of typical rental received by water industry for area of catchment leased for afforestation is £20,000 (£1,000 p.a.)

Discussion

W.J. JACK (Welsh Water Authority) in opening the discussion referred to a particular catchment where, not only were there a number of different types of loss affecting the supply, but also the economic effect of these losses was very great.

The Carno catchment in South Wales supplied Ebbw Vale and its surrounding area. The supply from the catchment was reduced from the maximum possible by four forms of loss:

(a) loss to underlying geological strata, as detailed in the paper

(b) reduction in run off due to land use change from sheep grazing to coniferous forest

(c) releases of water from the reservoir for compensation to the river.

(d) loss due to the difficulty in maintaining the catch water channels which brought in extra water from surrounding high ground by gravity.

Mr Jack described how the Carno supplies had to be augmented by water pumped from the Talybont and Taf Fechan reservoirs. The pumping heads associated with these transfers were 549m and 410m respectively. Thus, every drop of water lost from the Carno catchment had to be replaced by very expensive water: electricity charger associated with the Talybont transfer amounted to 36p per thousand gallons.

Carno provided one example, but there were many other supply systems where considerable savings could be made by reducing catchment losses.

H.D.M. SPEED (Newcastle and Gateshead Water Company) congratulated Mr Saxton on his comprehensive, thoughtful, and well researched paper which had focused attention on the problems of catchment afforestation, such as water quality and the losses in run-off and their corresponding financial value. Presumably account should be taken of the value of the tree crop, either to the water undertaking direct if it owned the forest, or to the nation in the case of Forestry Commission woodland. The Newcastle and Gateshead Water Company was actively pursuing a policy of commercial forestry, and current figures indicated yields of about £4700 per acre for 30 year old stands of timber. Substantial grants were obtainable for replanting and the financial yield appeared to compare very favourably with Mr Frank Law's figure of £200 for the capitalized value of one acre of catchment in 1956 in terms of its run-off yield. Mr Speed wondered if Mr Saxton knew of any current effort to compare the relative worth of tree crops and run-off. There was also the wider national interest of the need to grow trees somewhere; perhaps where new catchments were developed there was potential for harvesting a tree crop before the full yield of the catchment was needed!

Mr Saxton had referred in his introduction to the question of compensation water: although this was not waste in the strictest sense, it nevertheless constituted a loss; Mr Speed understood that at least one water authority had managed successfully to re-negotiate compensation flows downward without resort to public enquiry but with the execution of minor river works. There must be scope for useful if perhaps not substantial gains in many places. There was a tendency to think of compensation flows which were written into Acts or Orders as inviolable but many such figures had been plucked from rather thin air, perhaps before the turn of the century, without any proper basis in stream flow measurement or, for that matter, need: there must be potential for change in the light both of altered circumstances and many decades of catchment records. Mr Speed would be interested to hear further from Mr Saxton his view of the scope for such changes and their political viability.

The final point which he wanted to make concerned regulation losses: regulation was, of course, very wasteful in terms of efficient energy use but regulation losses themselves could amount to 10% or more of releases from reservoirs. This was a fairly substantial amount and he wondered if there was scope for a more flexible attitude to 'hands off flows' in periods immediately before and after regulation.

K.F. ROBERTS (Wessex Water Authority) said that for him the most important message of the paper was contained in its last 17 words 'in real terms we have made far too little progress in getting to grips with our problems' (meaning leakage). Although they might claim that their efforts since the war had contained the problem within reasonable limits, Mr Roberts suggested they should not underestimate the value of the work already done because any relaxation in waste control could lead down a slippery slope from which the recovery of the situation was difficult if not impossible: those engaged on overseas assignments associated with waterworks knew this aspect too well.

He thought that few would deny that until a few years ago, the distribution side of water service was a Cinderella activity and spending on waste detection and control was not always treated in a consistent manner. The economic situation had changed since the last symposium and in a climate when waste of any type was regarded as inefficient, the mood had changed and the priority for dealing with 'unaccounted for water' was now based more on the 'return on the expenditure' assessment. Because of this the author's replacement cost of source works in relation to waste losses was most helpful. However, this was only part of the story and Mr Roberts referred to the fact that 60% to 70% of the assets of a water service were underground and mainly in the distribution system. In his Authority, a recent move to introduce automatic pressure limitation in one area without prejudice to the standards of service to the consumers, had a profound effect on the total demand and in consequence on replacement and repairs expenditure. He wondered whether the author could give figures to complement the source works costs on page 1.7 in respect of distribution works savings so that waste expenditure could be equated to an overall cost benefit.

Mr Roberts said he was indebted to the author for his summary of the current position on catchment losses, but thought that any possible savings from changes in afforestation policy were very long term and in any case the subject required more investigation. He concluded by saying that in his view recent developments in microtechnology and telemetry had given the industry new 'weapons in their armoury' to attack the waste problem and he thought this was a challenge to the Institution's Micro-technology Group to consider the part they could play in developing new techniques.

K.F. CLARKE (Anglian Water Authority) said that he must react to the author's statement '...we have made far too little progress in getting to grips with our problems', and put forward a contrary view. The water industry had, in the last seven years: absorbed the biggest reorganization in its history; reduced its capital programme by half in real terms; reduced its staff; and coped with massive changes in demand forecasts; while at the same time maintaining, and in many aspects, improving, its high level of service. At the same time the industry had made far-sighted water use studies which had produced firm evidence of water use and unaccounted for water; carried out significant exercises to ensure that the amount of water going into supply was measured more accurately; carried out large exercises to identify where leakage was occurring and where it was cost effective to reduce it; and modified its demand forecasts significantly by assuming that leakage would be reduced, and as a result significantly slowed down its capital investment programme. Therefore the industry should be proud of what it has done, although it should not be complacent.

Finally, the author had said 'I wonder what Reg Thompson, if he was still alive, would have to say about rain radar?', and in case this was meant to be derogatory, Mr Clarke said that though rain radar did not necessarily have a role in the evaluation of quality water resources, it had a tremendous potential for helping water authorities improve the speed and efficiency of their operations.

B.H. ROFE (Rofe, Kennard and Lapworth) said that with regard to the now accepted loss of run off due to afforestation, it should be noted that this could not be regarded simply as a water loss in national terms, as the use of water for growing trees in this way was acknowledged to be an efficient process. It should be noted that there were also considerable adverse effects where trees were removed from a catchment, especially in regard to siltation and increased flood run offs.

The example given of pumped input to a catchment from a neighbouring catchment or area was an example of a growing problem induced by the theoretical requirement for a 'water grid'. The basic point of design needed emphasizing: it always cost a lot of money and energy to move water around - water was heavy stuff! In addition the process of moving water around would inevitably lead to some transmission loss. It was suggested therefore that the local source, be it groundwater or local impoundment, was of considerable merit compared with the long distance transfer (which might at first sight on economic comparison appear to be cheaper).

A further example of a situation where surface water was 'lost' to the ground was shown in the applications of the Thames Groundwater Scheme. In some areas of the Berkshire Downs there was evidence of swallow holes and fissures, and the groundwater modelling carried out had shown that there was considerably more recharge under summer conditions than would be indicated by current theories. However, the water was not in fact 'lost', as it could be effectively stored underground and pumped out when required. This led to a much cheaper overall cost of water supplied than allowing it to run off into the rivers and having to pump it back again.

Author's reply

Mr Saxton replying to the discussion wrote that the contribution by Mr Jack, which gave more detail about the Carno catchment, was must useful in drawing attention to the economic effect of the losses in this particular catchment. It gave him the opportunity to restate, what should be obvious but nevertheless was frequently missed; that a greater understanding of water losses should make it possible to give priority to those investigations likely to prove most cost-effective in reducing waste.

Mr Speed and Mr Rofe had both touched upon the commercial value to the nation of afforestation and Mr Speed had asked whether he knew of any current effort to compare the relative worth of tree crops and run off. The short answer to this was that he did not, but the subject had been raised at his request by colleagues at a seminar held in the Spring of 1979 at the Centre for Agricultural Strategy, Reading University. In February 1980 the Centre published its Report 6, 'Strategy for the UK forest industry'. Two extracts from the Report make it clear that, if as yet there was no such effort to compare the relative worth of trees and run off, there certainly was a need for it. The extracts were from page 136 of the Report,

> the state should also consider the possible disadvantages of using land for forestry such as effects on water supplies, impact upon the countryside and implications for food production. Economic analysis of these factors would be extremely complex and not all the necessary data are available.

and from page 207,

> the effect of afforestation on water collected from catchments is not clear cut. . . . Costs borne by Water Authorities will probably rise because of lower flows and variable quality of water. Costs to forestry interests will rise if special measures are needed to reduce adverse effects on yield and quality. More research is needed on the regularity, quality and amount of water yield from catchments under all types of vegetation and use: pasture, gorse, forests and scrub.
>
> This information is essential as a basis for land use and planning. Once the information is available, compromises will be necessary to allow more intensive use of the uplands.

So that it should not be lost, however, the point he was making in paragraph (iv) on page 1.6 of his own paper was that in his opinion even where afforestation was in the national interest but resulted in additional costs to the water industry, the state should make appropriate financial reimbursement to the water industry.

Mr Speed had also asked for his views on the scope for changes in the provision of compensation water and their political viability. He would not presume to comment upon 'political viability' but he certainly felt there were likely to be many cases still in existence where compensation water provisions were based upon circumstances which were no longer strictly applicable. He had in mind various categories: firstly, the requirement for compensation water from reservoirs, such as some in the Pennines, for mills and dye-works which were no longer in operation. There was also the possible redeployment of existing compensation water to produce increased quantities for abstraction. This had been achieved recently in relation to the compensation water provision from the Elan Valley reservoirs in central Wales. He had even heard colleagues discussing over many years the need or otherwise for the present compensation flow of Thames water over Teddington Weir!

Concerning Mr Speed's final point about a more flexible attitude to 'hands off flows' immediately before and after regulation, he certainly had sympathy with this particular viewpoint. He also agreed that regulation schemes were now expensive in terms of energy costs but when considered in relation to the increased yields made available by regulation, he felt regulation losses of around 10% were, on balance, still an acceptable evil.

He was certainly not being derogatory when referring in his paper to weather radar and Mr Clarke had rightly drawn attention to the considerable extent of the work already done during the past seven years to change the industry's thinking with regard to water losses. However, he was also aware that in 1981 in some divisions of water authorities it was a regrettable fact that even less effort was now being made in practical terms to detect and reduce water losses than had been the practive before the reorganization of the water industry of England and Wales in 1974. He thought it was likely that this situation also prevailed in Scotland.

Mr Roberts had referred to the replacement cost of source works which he had quoted in the paper at £200,000 per tcmd of yield. He had been interested that this figure had not been questioned at the symposium and agreed with Mr Roberts that if an appropriate figure could be determined in respect of distribution works savings it would enable waste expenditure to be equated to an overall cost benefit. He suggested that the figure for distribution works would vary from undertaking to undertaking but he hoped colleagues in the industry would make data available in the future.

2. UNDERSTANDING UNACCOUNTED-FOR WATER

By D.B. Field, BSc, MInstP*, and Dr. E.A. Spencer, BSc, FIMechE°

The unaccounted-for water (UFW) formula has been used for a variety of purposes. The paper examines the uncertainties associated with each term in the formula and combines these to determine the overall uncertainty in the figures for UFW derived. It is shown that the overall uncertainty is so large as to make the figures impractical for any use other than broad planning decisions. The paper gives examples, highlights the additional problems that arise from the use of percentage figures and outlines an improved method for estimating (UFW) from night flow rates.

1. INTRODUCTION

The phrase 'unaccounted-for water' has been introduced into the terminology of the water industry. It is defined(1) as that amount of water which is the difference between the total amount put into a supply and distribution system and the water which can be accounted for. The use of this term, unaccounted-for water (UFW), as given by the so-called unaccounted-for formula, and the values obtained, have probably caused more friction between operational engineers and planners in the water industry than any other topic. This paper discusses the constituent components from which 'unaccounted-for water' may be derived, and the problems of interpreting the results obtained. It suggests ways in which the objectives for which the term has been developed could be achieved more reliably.

2. UNACCOUNTED-FOR WATER FORMULA

The term 'unaccounted-for water' (U) is given by the equation:-

$$U = S - (M + aP)$$

where S = total water put into the supply system

M = total metered consumption

a = unmetered per capita consumption

P = population

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As it stands the formula is perfectly correct: ie unaccounted-for water equals the difference between the total amount of water put into the system and the water taken out which can be accounted for. The main problems arise from the fact that a large proportion of the water put into the system is not subsequently metered and so must be estimated and secondly there can be large uncertainties also in the values obtained for S and M. The former applies to virtually all domestic consumption and to the non-metered trade and commercial uses which is quantified as 'a' in the formula. The latter gives rise to uncertainty on differences between large numbers and the resulting figures can be notoriously erratic.

2.1 Total Quantity of Water Supplied

The total quantity of water supplied is the sum of all the inputs to the system. These may be from bore holes, treatment plants or supply reservoirs. Also if bulk supplies, which may not be regular, are taken from a neighbouring water undertaking during the accounting period they must be noted and added to the total.

It is clear that for the results to be meaningful the period over which the accounting is undertaken must be the same for all the terms in the formula. Thus, if S is taken from a measurement on a given day all the other factors in the formula should relate to that same day; if for a month then the accounting should all relate to precisely the same 28 days. Input flow data will usually be available on a daily basis and consequently can be calculated over any desired accounting period. It will be seen later that this is not true for the other terms.

The flowmeters used for measurement of source inputs into the chosen system are usually of various types and sizes. Table 1 shows the results of a questionnaire regarding meter size and type which was circulated in 1978.

TABLE 1 - Number, Size and Type of Source Meter

Meter Type	Number of Meters			
	3"-6"	7"-12"	13"-24"	>24"
Venturi	154	557	365	173
Dall Tube	73	284	223	55
Magnetic	22	40	25	32
Helix	785	348	32	11
Others	190	174	94	26

It can be seen that the large meters tend to be of the differential pressure type whereas the smaller ones are mechanical. From the figures given it can be estimated that about three-quarters of the total quantity of water measured is by differential type flowmeters. Table 2 shows results on the same questionnaire regarding bulk and district meters. It should be noted that some of the latter meters will be used for the determination of term S.

TABLE 2 - Number, Size and Type of Bulk and District Meters

Meter Type	Number of Meters			
	3"-6"	7"-12"	13"-24"	>24"
Venturi	56	166	135	76
Dall Tube	53	149	72	30
Magnetic	54	15	22	13
Helix	4538	590	31	27
Others	570	90	29	30

Provided that all flows into a supply and distribution system are measured the inaccuracies in the term S will result from errors associated with the meters used. Clearly if there are known incoming supplies which are not measured some estimate of their amount and the associated uncertainties must be made. On the other hand if there is leakage into the system its presence is likely to remain undetected. Indeed it may only be discovered if it comes from an adjoining system where a loss has been established.

TABLE 3 - Uncertainties in Measurements obtained with Various Types of Flowmeter

	Diff Press devices	Electro/ Magnetic	Mechanical Types	Other Source Meters
Accuracy when new	±1.5%	1%	2%	±2%
Effects of installation	2	2	1	2
Age effects	4	1	2	2
Effects of integrators	2-5	0.5	-	1

Estimates of the uncertainties associated with these various meters are given in Table 3. If the flowmeter has been calibrated on site then the estimate for the first two sources of uncertainty can be taken to be the uncertainty associated with the calibration method. Also it is assumed for the Table that the meters are operating within their design flow range and are installed and used with due regard to the manufacturers recommendations or the requirements laid down in the specification standards. It has to be remembered that the tendendy to put in flowmeters for a maximum demand which does not materialize can mean that the actual flows are low and hence the uncertainties in these measurements will be greatly increased.

It also has to be realized that very often flowmeters are incorporated either at a later date or at such a stage in the system design that the measurements obtained can be extremely unreliable. In such instances errors of up to 30 per cent or more could easily occur. Similarly if a sound maintenance schedule is not followed then meter inaccuracies or even complete failures can occur without the user being aware that a problem has arisen.

Taking all the effects referred to above and in the table into account the overall uncertainty in the term S is likely to be between ±3 and ±10 per cent, the former figure referring to a system which is well thought out and well run.

Higher accuracies could be achieved but would be expensive to maintain and in the light of the other uncertainties referred to later would not be justified solely for the purpose of obtaining estimates of unaccounted-for water.

2.2 Total Metered Consumption

The term M includes all metered consumption. This will include bulk amounts supplied to neighbouring authorities as well as industrial, commercial and other measured supplies. In practice it will be the term M which dictates the accounting period. This may be quarterly, half-yearly, or annual; any lesser period will necessitate a special survey being made.

Meters will normally be read four times per year although users of large quantities of water may have their meters read more frequently. The accounting period for each customer varies because meter reading is usually arranged to take place over a three month period. Consequently some consumers could start their accounting year in January, others in February and still others in March. The errors that staggered meter reading introduces will tend to even out if an annual accounting period is chosen, although they will not all relate to the same year. However large errors could be introduced if shorter accounting periods are used, particularly in areas of varying seasonal demand.

The meters used for consumption measurement are usually mechanical and of the rotary piston or helical vane type. The accuracies claimed by the manufacturers are very similar and so the uncertainties to be associated with the measured consumption recorded by the meters when new change little with the different types. They normally fall within the ±2 per cent band if operating above their nominal flowrate while at flows down from this level to their minimum flowrate the acceptable tolerance or uncertainty can increase to ±5 per cent. However their performance does deteriorate with age and this will be aggravated by the presence of debris in the water. The problems of ensuring good installation conditions with recommended upstream and downstream straight lengths of pipe to give swirl-free flow with a reasonably well-developed velocity profile also applies here. Many instances can be cited of placing flowmeters immediately downstream of tortuous bends or after valves which may be partly closed: they should not be allowed to occur.

If the number of metering points is large then the overall uncertainty on M arising from the original accuracy and the meter installation effects can be expected to be relatively small since the positive and negative errors on individual flowmeters will cancel each other. However it may be expected that there will be a tendency for under-registration on low flows.

The overall uncertainty on M in a well-managed system may be expected to lie between ±3 and ±6 per cent.

2.3 Non-Metered Consumption

This term, by definition, is not measured and must therefore be estimated. As noted earlier the bulk of non-metered consumption is made up of that required for domestic and un-metered trade and commercial use. It is intended, however, that it should include all water which is taken or used by some deliberate action accepted by the water supply authority as a recognized service. Consequently, uses such as fire-fighting, mains flushing, building water, street cleansing, public toilets, etc. should be included.

The usual way of obtaining an estimate of this total quantity is to obtain a figure for the average per capita domestic demand, based on measurements made in a sample of houses, and to add to it an allowance for trade and commercial use divided by an estimate of the population. Very often no attempt is made to carry out a local study to establish these figures: instead estimates from publicatons, other areas, etc. are used.

The difficulties of obtaining acceptable figures are obvious and need little amplification. However, a few of the more important points are listed below:

a The allowance for non-metered trade and commercial use, although perhaps inferred from the results of similar metered consumers in or outside the area, is little more than a guess.

b Population figures are difficult to obtain except from the ten-year census. If the accounting period is to be a year then the population figure required is the annual average population for that particular year and the stability of the population in the area must be checked. Even then the problem of estimating a realistic population becomes even more difficult in areas with large numbers of commutors or areas with large seasonal changes in population such as holiday resorts or tourist areas. If the accounting period is shorter than a year then clearly the uncertainty in these estimates will be very high.

c Research[2] has shown that UK type plumbing systems tend to cause low rates of flow which may not be measured by a flow meter. Figures are between 4 per cent and 16 per cent under-registration have been measured for typical domestic use sequences. The measurement of domestic use based on a sample of measurements may therefore be biased low.

d Even when a local study is made the sample of consumers measured is unlikely to be truly representative of the entire communicty. Also a consumer conscious of having his supply metered may economise on the water he uses so that the figure obtained is an underestimate.

The overall accuracy of the estimate of non-metered consumption as given by the product aP clearly cannot be determined. To enable an assessment to be made of the whole formula, however, let it be assumed that with care it is possible to determine per capita consumption, plus allowances for trade used, to an accuracy of between ±8 and ±15 per cent. Similarly let it be assumed that it is possible to determine the population to within an accuracy of ±5 per cent. The overall uncertainty on the product aP is then given by

lower estimate $\sqrt{5^2 + 8^2} = \pm 9.4\%$;

upper estimate $\sqrt{5^2 + 15^2} = 16\%$

on the general statistical basis that the square-root of the sum of the squares of the individual contributions has a high probability of being nearer the truth in a large number of sets of measurements than the direct sum of the contributions. In practice when dealing with just one particular set the overall uncertainty could be up to ±13 per cent on th basis of the former and ±20 per cent for the lattter. It seems reasonable to take a figure of ±12 per cent for the purposes of this study.

3. ACCURACY OF WATER UNACCOUNTED FOR (U)

In order to determine the effects of these combined uncertainties on the term U it is necessary to use actual figures for each factor. Thus if the uncertainties on the various terms are expressed as percentages (dS, dM etc.) the actual amounts must be calculated to determine the uncertainty ΔU on U.

$$\Delta U = [(S.dS)^2 + (M\ dM)^2 + (aP.d\ aP)^2]^{\frac{1}{2}}$$

To see the results of such estimates six hypothetical towns, based on real supply systems, have been defined in Appendix 1. For simplicity, it is assumed in the following analysis that the uncertainties associated with the measurement of each term are normally distributed around zero although in practice some of these could be biased to one side.

TABLE 4 - Uncertainty in Unaccounted for Water

Town	Uncertainty in U (%)
A	37
B	53
C	30
D	32
E	65
F	35

It can be seen from the above table that the overall error in the Unaccounted-for water as calculated by the formula is likely to be high and is as much as 65 per cent in the examples given above.

4. PURPOSE OF DETERMINING WATER UNACCOUNTED FOR

It can be deduced from examining the above sources of uncertainty that the major contributor in a system where metering has been given care and attention, is the uncertainty on aP. However the importance of this overall uncertainty will depend on the reasons why the determination of unaccounted-for water is being made.

Three primary reasons for wanting to determine unaccounted-for water are generally given. These are:

a The planning and design of future sources or extensions to the distribution system.

b Using the figures to obtain performance criteria for comparing one division, company or authority with another.

c Estimating leakage for the determination of a leakage control policy or for monitoring overall performance of a chosen leakage control method.

For the first of these, the errors associated with (U) may be quite acceptable when compared with other uncertainties associated with long term planning decisions. There is then merit in separating out metered consumption, non-metered consumption and unaccounted for water and making various assumptions about the ways in which these may change in the future. The spread of the likely demand can be gauged and presented properly in relation to all the other factors. For short term planning purposes, where the other estimates may be more accurate, the figures obtained from the formula will have to be used with much more caution unless additional studies have been made to give much greater assurance.

Using unaccounted-for water figures as a basis for comparing performance (the second reason given above) can be quite misleading. The danger of making wrong conclusions has been compounded by the tendency to express these figures as a percentage of total supplies. In Appendix 1 a series of results are obtained on the basis of the examples given in the Appendix. Neglecting for this purpose the uncertainties on each of the estimates of the various figures given for the six towns it will be seen that differences in the actual amounts of unaccounted-for water of zero to 100 per cent can be falsely presented as the same (both Town A and Town F are shown to have around 11 per cent more unaccounted-for water than Town B and Town E whereas the first two actually have the same and the second two differ by 2:1). Many such examples could be instanced but the important conclusion must be that simple comparisons are worthless.

The third reason above relates to leakage and indeed makes the assumption that unaccounted-for water is synonomous with leakage. This figure is then used as a basis for determining future leakage control policy and subsequently monitoring performance of the chosen leakage control method. In the authors opinion the only situations in which it it could be used for such purposes are, for example, in small isolated zones where meters have been calibrated. In general where such an estimate of leakage is required the method outlined in reference 1 based on the measurement of night flow rates is to be recommended. An outline of this method is given in Appendix 2.

5. CONCLUSIONS

The combination of the individual uncertainties associated with each term in the unaccounted-for water formula generally results in the overall uncertainty in the term U being so great as to render the term meaningless except perhaps for long term planning use. Clearly it is essential if the formula is used that a realistic assessment should have been made of the uncertainties associated with the particular system and the overall uncertainty must be presented with the value of U on all occasions.

Expressing unaccounted-for water, or leakage as a percentage of the total water supplied and comparing the percentages for different systems only adds to the confusion since it has been shown that such percentages can be absurdly misleading. If comparisons are to be made then the quantity of unaccounted-for water per property may be the most meaningful but even here it is still wise to examine very carefully if the figures are truly comparable.

The assumption that unaccounted-for water obtained from the formula is leakage is clearly not valid when the uncertainties associated with the constituent terms are often of the same order as the resulting U. Consequently figures for U obtained from the formula should not be used for the determination of a leakage control policy nor for the monitoring of the performance of a chosen leakage control method unless special efforts have been made to reduce the uncertainties to below the level where they would have a significant effect on the decision.

If an accounting period of less than a year is being assessed then great care is required to relate the constituent terms to the period under review and an additional source of uncertainty must be estimated to take the variations into account.

Though not without its own problems, the use of the modified formula based on the measurement of night flow rates can be expected to lead to a more reliable figure for the purpose of leakage control. The requirement to assess the uncertainties associated with the various terms in this modified formula and hence the overall uncertainty on the value of leakage obtained remains equally mandatory. Such measurements are to be encouraged for the data bank on this subject is still very inadequate while its importance as the need for reducing waste rises is clearly considerable.

REFERENCES

1. Leakage Control Policy and Practice, Department of Environment/ National Water Council. Standing Technical Committee Reports No. 26, July 1980.

2. Under-Registration of Small Semi-Positive Displacement Flow Meters when used for Domestic Demand Measurement. Field and Goodwin, WRC Technical Report TR 101, January 1979.

APPENDIX 1

Set out below (Table 5) are six hypothetical towns based on real supply systems. For the purpose of example it has been assumed that all of the terms listed are known accurately. All units are mega litres (Ml) and represent daily quantities.

TABLE 5 - Example Supply Systems

Town	Total Supply (S)	Metered Con (M)	Non-Metered (aP)	Unaccounted (U)	Number of properties
A	30	5	17	8	136,000
B	50	25	17	8	136,100
C	21	25	8	6	84,000
D	21	4.5	10.5	6	84,000
E	47	15	25	7	203,000
F	54	15	25	14	203,000

From the text of this paper it has been deduced that the uncertainties associated with each term in the unaccounted for formula are likely, in a well planned and controlled system, to be within the range shown in Table 6.

TABLE 6 - Uncertainty Associated with each Term in the Formula

Term	Uncertainty Range (%)	Mid Point (%)
S	3-10	7
M	3-6	5
aP	9-16	12

For the purpose of example the mid-point uncertainties in Table 6 are used for calculation.

In order to determine the effects of these combined uncertainties on the term U it is necessary to use actual figures for each factor. Thus if the uncertainties on the various terms are expressed as percentages (dS, dM, etc.) the actual amounts must be calculated to determine the uncertainty ΔU on U.

$$\Delta U = [(S.dS)^2 + (M.dM)^2 + (aP.\ daP)^2]^{\frac{1}{2}}$$

For simplicity, it is assumed in the following analysis that the uncertainties associated with the measurement of each term are normally distributed around zero although in practice some of these could be biased to one side.

<u>Town A</u>

$\Delta U = (30 \times 0.07)^2 + (5 \times 0.5)^2 + (17 \times 0.12)^2)^{\frac{1}{2}}$

$\Delta U = 2.94$

Uncertainty in U = ±37%

<u>Town B</u>

$\Delta U = ((50 \times 0.07)^2 + (25 \times 0.05)^2 + (17 \times 0.12)^2)^{\frac{1}{2}}$

$\Delta U = 4.24$

Uncertainty in U = ±53%

<u>Town C</u>

$\Delta U = ((21 \times 0.07)^2 + (7 \times 0.05)^2 + (8 \times 0.12)^2)^{\frac{1}{2}}$

$\Delta U = 1.79$

Uncertainty in U = ±30%

<u>Town D</u>

$\Delta U = ((21 \times 0.07)^2 + (4.5 \times 0.05)^2 + (10.5 \times 0.12)^2)^{\frac{1}{2}}$

$\Delta U = 1.95$

Uncertainty in U = ±32%

<u>Town E</u>

$\Delta U = ((47 \times 0.07)^2 (15 \times 0.05)^2 + (25 \times 0.12)^2)^{\frac{1}{2}}$

$\Delta U = 4.52$

Uncertainty in U = ±65%

<u>Town F</u>

$\Delta U = ((54 \times 0.07)^2 + (15 \times 0.05)^2 + (25 \times 0.12)^2)^{\frac{1}{2}}$

$\Delta U = 4.88$

Uncertainty in U = ±35%

In the analysis given above the uncertainties in the term U lie between 30% and 65%.

EXPRESSION OF UNACCOUNTED FOR WATER AS A PERCENTAGE OF TOTAL SUPPLY

The problems of expressing unaccounted-for water as a percentage of total supply are best illustrated by examples. For these examples the hypothetical supply systems listed above are used.

Towns A and B are identical in every respect except that B has an additional industrial estate close to the treatment works. Expressing unaccounted-for water as a percentage of total supply reveals:-

Town A	26.7%
Town B	16%

The inference is that unaccounted-for water is 10 per cent higher in A, but in fact the two are identical. At first sight, expressing leakage as a percentage of non-metered water supplied, i.e. as a percentage of S-M, would appear to solve the problem. However, towns C and D are also identical in every respect except that C offers a metering option to all consumers and as a result metered consumption is higher and hence non-metered lower.

Expressing unaccounted-for water as a percentage of non-metered water supplied, in this case results in:-

Town C	42.9%
Town D	36.4%

In this example it appears that offering the meter option in Town C has increased the unaccounted-for water by 6.3 per cent, but again the two are identical. Expressing unaccounted-for water as a percentage of non-metered water supplied is not therefore the answer.

There is another danger in expressing unaccounted-for water or indeed for that matter leakage as a percentage in that it does not accurately reflect changes in that quantity. In the example below towns E and F are identical in every way except that E has a policy of active leakage control whereas town F has a policy of passive leakage control. Consequently let it be postulated that unaccounted-for water, which includes leakage, is twice the figure in F that it is in E. Expressing these as a percentage produces:-

Town E	14.9%
Town F	25.9%

Whilst unaccounted-for water is actually 100 per cent higher in town F than E the percentage figures suggest that it is only 11 per cent higher.

It is clear from the foregoing that expressing unaccounted-for water or leakage as a percentage of total supply or non-metered water supplied reveals very little about the relative magnitudes of these figures nor does it actually accurately reflect change. The only simple method of expression, although not entirely without its problems, of which the authors are aware is to present the figures as a quantity of water per property. The results of doing this are shown in Table 7 .

TABLE 7

TOWN	A	B	C	D	E	F
No of properties	136000	136100	84000	84000	203000	203000
% UFW	26.7	16.0	42.9	36.4	14.9	25.9
UFW/property	58.8	58.8	71.4	71.4	34.5	68.9

APPENDIX 2

An Improved Method for Estimating Leakage

When the objective of assessing unaccounted for water is to obtain an estimation of leakage, a better estimate can be obtained by using the modified formula based on night flow rates.

The formula becomes:-

$$U' = S' - (M' + a'n')$$

where

S' = sum of all minimum night flow rates into the system
M' = total night flow rates of all trade and commercial users
a' = average domestic night flow rates for domestic properties
n' = number of properties supplied
U' = unaccounted for night flow rate

The magnitude of the terms in the modified formula are such that small values, subject to certain errors, are subtracted from relativly large values in order to obtain a large value. This approach is therefore inherently more accurate than the standard method.

In order to use the night flow rate formula it is necessary to perform a direct measurement on a chosen night. This consists of measuring night flow rates from all sources and service reservoirs and direct measurement of consumers who take water at high flow rates at night. Details of the measurements are given in reference 1.

When measurements of S' are made, as many sources as possible should be turned off (provided the pressure on the system is not radically changed) so as to minimise the number of measurements to be made, and increase the flow rate at the remaining sources. In some cases measurement of rate of fall of reservoir level can be used as a measure of flow rate. For the purpose of example it is assumed that the measurement of S' is less accurate than the measurement of S and the overall uncertainty is ±10%.

M' is an estimate of the total night flow rate into industrial and commercial premises, regardless of whether they are metered. It is obtained from sample measurements of different types of significant users and by estimate (or guess-work) for small users and direct measurement of large users. In this example it is assumed that the overall uncertainty in the term M' is ±50%.

A' is obtained by sample measurement and is typically less than 21/props/hr. For this example it is assumed that the overall error in the product A'M' is ±100%.

U' is the unaccounted for night flow rate. However, since most legitimate use if included in either U' or A', it is much closer to leakage than is U.

In order to assess the overall uncertainty in the term U' two of the hypothetical towns are used as example, the figures are set out below. For simplicity the units are (flow rate) Ml/day.

Town	S'	M'	a'n'	U'
A	8.1	0.6	0.3	7.2
B	10	2.5	0.3	7.2

Using the same method for calculation as used in Appendix 1 we have:-

Town A

$$U = ((8.1 \times 0.1)^2 + (0.6 \times 0.5)^2 + (0.3 \times 1.0)^2)^{\frac{1}{2}}$$

$$U = 0.91$$

Uncertainty in U' = ±8%

Town B

$$U = ((10 \times 0.1)^2 + (2.5 \times 0.5)^2 + (0.3 \times 1.0)^2)^{\frac{1}{2}}$$

$$U = 1.63$$

Uncertainty in U' = ±23%

It can be seen from the above analysis that using night flow rates in the modified unaccounted for formula gives significantly better estimates than those obtained using integrated quantities.

For certain applications it will be necessary to convert the night flow rate U' into a daily quantity. Where this is required allowances should be made for the effects of pressure on night flow rate. A method for doing this is outlined in ref 1.

DISCUSSION

Authors' introduction

In their introduction the authors said that the purpose of their paper was to demonstrate how the comparatively small uncertainties associated with each term in the unaccounted for water formula could combine to produce a relatively large overall uncertainty in the term U. Each term in the formula was discussed in turn and the causes of uncertainties examined. These were then combined, using a number of examples, to assess the overall uncertainty in the term U.

The authors said that the best way of showing the results was by pictorial representation, as in Figs 1 and 2. In these figures the height of each bar represented the magnitude of the term and the shaded portion on top of each bar represented the uncertainty associated with that term. The figures showed the fundamental difficulty of using the UFW formula and that arose because generally large terms, subject to certain errors, were being subtracted to obtain a relatively small one. Under these circumstances the overall uncertainty in the term 'U' would generally be high.

Figures 3 and 4 showed results for the same two towns, but this time based on night flow rates. Here the situation was entirely different in that small quantities, subject to certain uncertainties, were subtracted from a relatively large quantity to obtain a large quantity. The percentage uncertainty of each term was greater but the overall uncertainty in 'U' was very much less.

The authors then discussed the problems that could arise from expressing UFW, or leakage as a percentage of total supply. Using examples from Appendix 1 of their paper, they showed how an apparent difference of 11% UFW, towns A and B, actually corresponded to zero difference in the quantity of water unaccounted for, whereas an apparent difference of 11% UFW, towns E and F, corresponded to an actual difference of 100% in the quantity of water unaccounted.

In concluding, the authors said that the main objective of their paper was to demonstrate the dangers of indiscriminate use of the UFW formula. They recommended that engineers using the formula undertook the same type of analysis, as described in their paper, to ensure that the overall uncertainty in the term 'U' was sufficiently small to meet their particular requirements.

Discussion

L.R. BAYS (Bristol Waterworks Company) congratulated the authors most sincerely on the courage shown in producing this excellent paper.

For many years when water engineers were asked 'How much waste have you' the answer was 'Well we don't really know but the night line is 25% say (as an under estimate) of the net consumption but that isn't all waste'. They generally settled for a figure of 15% as that seemed to be acceptable on all official forms when applying for finance. This very vexed question on waste remained unanswered until they changed the jargon and started talking about 'unaccounted for water' and produced a new formula as the answer to their prayers. Having just become accustomed to the use of this formula the authors had the temerity in such a short space of time to destroy it.

The presentation in Appendix 1 highlighted the variations in results that could be obtained and showed that comparisons were pointless. However, odious comparisons of results would be made and erroneous conclusions drawn on the efficiency of authorities, divisions, companies etc. by those who sought to do so on the basis of such results. In the eyes of the layman unaccounted for water meant waste and by using such a formula the percentages were invariably higher than the old percentage night lines. He asked, therefore, if the authors were proposing the abandonment of calculations of unaccounted for water or were they suggesting that they should be continued with all the inherent disadvantages?

Turning to Appendix 2 of the paper a new formula was suggested, but surely the practicality of the method was limited to small areas of supply by the very nature of the calculation. The mere fact of selecting a particular night for this exercise was limiting in itself and with increasing use of night pumping for energy conservation coupled with the difficulties of either shutting off metered consumers or in reading many meters simultaneously introduced errors except in small area exercises. As an alternative he suggested a possible method which helped reduce waste as was used in the Bristol Company at the moment. This involved the formula

$$K = \frac{S - (M+NL)}{P}$$

where K = demand index in l /head/day

S = total zonal input

M = known metered trade

NL = net night line of WWM districts in zone

P = population of zone

The method was based on a distribution system where supply zones and sub zones inputs and outputs were metered and a waste water meter district network existed within a zone. Quarterly metered trade figures were used together with night line figures averaged for the quarter. It was realised, of course, that errors and inaccuracies existed but despite this they had proved extremely useful for comparison purposes and a high degree of success had been achieved by their use. This value for K must not be confused with the normal per capita demand as by using the formula it was obvious that some of the consumption S was included as the night line. However, from a high number of zones and sub zones used it was apparent that a tight zone yielded figures for K of between 80-100 l /head/day. Higher or lower figures than this indicated the need for some investigation in a particular zone or subzone.

The reasons for high figures encountered had so far fallen into one or other of the following categories:

(i) trunk main or leading main leakage
(were not on waste water meters)

(ii) reservoir overflow or leakage

(iii) meter errors

(iv) incorrect zone isolations
(usually associated with low figure in adjacent zone)

(v) insufficient knowledge of unmetered trade or commercial use.

Whichever system was used he felt that it showed that no one formula such as "unaccounted for water" should be used for so many purposes. However, any formula drew attention to the subject of meter accuracies. Would the authors advocate a common meter exchange policy across the country? If so, should this be on failure or suspected error, or on a pre-planned basis? Was there a significant difference between the performances of:

(i) new meters?

(ii) meters repaired by manufacturers?

(iii) meters repaired in house?

If comparisons were to be made on performances then this sort of information needed to be collated so that better base standards could be used in statistical information.

A.C. TWORT (Binnie & Partners) said he was concerned with the over-simplicity of the equation U = S - (M + aP) in which there was not a proper distinction between distribution losses and consumer wastage. This led to erroneous comparisons between data from different undertakings in different parts of the world. Three principal types of undertakings could be distinguished. First, there were those undertakings (in the USA for example) where domestic metering was reasonably efficient: consequently their reported unaccounted for water comprised largely distribution losses. Secondly, there were those many undertakings overseas where the principal purpose of metering was to frighten people into keeping their consumptions low, so that the accuracy and efficiency of metering took second priority and was often low. In these undertakings unaccounted for water comprised distribution losses, substantial meter under-recordings and misreadings, illicit supplies, and consumer wastage of all types. Thirdly, there was the UK and just a few other places where domestic supplies were not metered so that unaccounted for water comprised distribution losses, consumer wastage, some amount of unmetered trade consumption, and virtually no meter under-recordings or misreadings save basic metering errors which were common to all three types of undertaking.

The confused comparisons arising first resulted in an under-estimation of distribution losses and consumer wastage for many years in the UK, and then latterly had led to an over-estimation. This was because the value 'a' in the formula above had been influenced too much by the results obtained from special investigations. The value suggested for 'a' had been 110lcd. Of course, it was admittedly a mean figure for all classes of domestic consumers; but such a low value as 110lcd tended to be about the lowest found in special field investigations, where people had known they had been under observation, and had consequently been 'on their best behaviour'. The figures derived from Malvern and Mansfield also tended to be non-typical, since those towns were not modern and one noticed, for instance, such things as the low incidence of automatic washing machines there.

If field tests on a larger scale were taken over diverse waterworks there was evidence that, in every class of consumers, there were a proportion who took more than double the average of the rest. In small samples there was a tendency not to believe such high consumptions on the basis that they must represent some error of measurement or some leakage on the premises that had not been noticed, and they were therefore excluded from assessing the mean. But the evidence mounted that this is not so. Figure 5 showed typical results obtained in eight sets of careful investigations. At Istanbul there was no doubt as to the validity of the readings, since tested meters were used and no houses with obvious signs of leakage and wastage were included. The data for Egypt could also be quoted with a reasonable degree of confidence. These showed that a percentage of consumers, for one reason or another, did actually take and use more than twice the average taken by the rest. There were two principal reasons: in some households the majority of the residents were at home all day; and (a separate phenomenon) some people simply had the habit of using water more liberally than the majority.

Such 'real' figures of consumption, in the sense that they represented what actually happened reflected the real domestic demand a water authority would be obliged to meet. A water undertaking would not be able to curb the 'high' consumers; nor could it do much more than ensure that obvious signs of overflow or leakage from premises were stopped. A certain amount of unavoidable consumer wastage must be allowed for, or water undertakings would be set chasing targets that were unrealistic and uneconomic of achievement. For in-house mean domestic demand in UK, with a substantial proportion of relatively new housing, or old housing renovated to modern standards, Mr Twort felt that the figure should run something over 110ldc; probably nearer 120 to 125lcd, when unavoidable consumer wastage was included.

The figure would, of course, vary slightly from city to city according to the proportions of old and new properties. What should be added to this for 'unmetered trade' supplies in UK was a problem special to UK on which more test data were required, but the WRC estimate of an additional 20lcd seemed high.

Hence the formula would better read:

$$U = S - [M + (a + u)P]$$

where u = unavoidable consumer wastage.

And U itself should then be broken down into:

U = estimated distribution losses + consumer wastage

where the estimated distribution losses should include estimated leakage from service pipe tappings to mains.

R.H. MORGAN (Rickmansworth and Uxbridge Valley Water Company) noted that over the years many methods had been used to try to measure levels of waste; the first figures were probably based more on what was believed to be acceptable than on any scientific measurement. The unaccounted for water formula undoubtedly brought an air of respectability to the calculations and had the advantage that it was indisputably correct. However, the estimating of unmetered per capita consumptions together with the potential errors in the more directly measured items could lead to massive inaccuracies in the 'unaccounted for water', a point well illustrated in the paper. Even when the modified formula was applied to night flows the errors could be large due to the assumptions required.

Great emphasis had been placed on assessing absolute values for waste so that comparisons could be made; quoted figures generally took little account of the inherent differences that existed between areas. Absolute measurement of waste had very limited use other than for determining and checking policy on waste detection. For regular monitoring purposes relative values were much more important and success should be measured in terms of improvement within an area rather than by comparison between areas. There were always those who insisted on having statistics regardless of how useless they were and there was therefore a need to improve accuracy. In theory at least, universal metering should help although the range of figures quoted in Mr Pocock's paper (from 3% to 30% unaccounted for water in countries having universal metering) perhaps gave rise to some doubt. With increasing use of telemetry and improving techniques of data collection in future it should be possible to obtain a very much better picture of the characteristics of distribution systems, and perhaps more meaningful statistics on waste.

R.H. SMITH (Northumbrian Water Authority) commented on the accuracy of meters. He had been reminded of his earlier days when he was more frequently in contact with the ironmongery of the service. On one occasion, investigation of doubtful readings from a 6in venturi meter had revealed a 4in diameter stone in its throat.

In his Authority the problem of calibration of source meters was being tackled by salt dilution gauging. A review of the hydrometric scheme developed by the former River Authority had resulted in a reduced workload for the Hydrometric Field Offices whose duties included operation and maintenance of the rainfall and streamflow gauging stations. The resulting gap in their work programme had been filled by their being given the task of calibrating a total of 50 source and principal distribution meters. The expertise of these officers in hydrometrics fitted them well for this work. At the first location dealt with, a water treatment plant, the existence of a clear water tank had enabled the results to be checked against the volumetric measure calculated from the fall in water surface in level in the tank. The dilution gauging was within 1% of the volumetric measure but the Dall tube had been reading 8% high. Mr Smith said that the regular calibration of large meters had not been given adequate consideration by many engineers; large source and distribution meters were a most important element in water supply systems and knowledge of their accuracy was essential for the proper application of the formula.

N.H. GIMSON (North West Water Authority) said that he was surprised that although the authors of this paper and others in the symposium were rightly concerned to point out the high level of inaccuracy of estimates of water losses, they made no criticism of the very low level of accuracy of many traditional types of meters, even though that was the main cause of current statistical difficulty. The industry had not been active enough in emphasising the need for the development of better metering devices, particularly for large quantities on major trunk mains where the volume represented by a 5% or 10% inaccuracy could be very high. In Mr Gimson's opinion the industry had also not paid sufficient attention to the maintenance of major meters of the differential pressure type which tended to be 'out of sight out of mind' and malfunctioning more frequently than they should.

There had been particular difficulty on a major non-potable network incorporating a number of meters of different types and sizes. Heavy losses were suspected, but were difficult to prove, as it was rarely possible to get all meters working satisfactorily at any one time, the presence of suspended solids no doubt making breakdowns even more frequent than usual. The advent of magnetic flow meters had been thought of as the solution, but although a significant number of these had been installed there continued to be problems with breakdowns. Hopes were now resting on the possibility of ultra-sonic metering. It seemed that manufacturers and the Water Research Centre as well as the purchasers and users of large volume metering equipment should be criticised for the low level of technology in this field.

On the subject of smaller consumers' meters it was surprising to hear that positive rotary meters required swirl free flows for accuracy and he wondered how many 'option' meters were currently being installed in domestic premises in a manner which the authors had stated would lead to increased inaccuracy. This seemed to be another area where ignorance needed to be dispelled if the accuracy of estimates of water loss were to be improved, to say nothing of the need to get domestic water bills correct.

R.A. PEPPER (Sunderland and South Shields Water Company) referred to the unaccounted for water formula and to the comments and criticisms which had been made about it. The authors had restated that the formula was perfectly correct, but there was no doubt that its application had attracted adverse attention. In Mr Pepper's view the criticism lay, however, not with the simple formula itself but with the interpretation of the results obtained from it. He drew attention to the origin of the formula. It had first appeared as Appendix B in the First Report issued by the Technical Working Group on Waste of Water in September 1976. In that Appendix the many elements of water usage and loss included within the formula were identified, and whilst it was true that leakage remained the most significant element, there were many others which warranted attention. Not least amongst these was the basic one of adequacy and accuracy of metering at source works and elsewhere within the distribution system. The traditional assessment of water required for domestic purposes per capita required critical reappraisal. Assumptions made in respect of unmetered non-domestic use required examination. There were other 'unknowns' hidden within the formula.

Used as was originally intended in that First Report, the formula had served the purpose of requiring water undertakings to re-examine many hitherto unquestioned assumptions relating to the destination and use of water put into a supply and distribution system. Until all elements contributing to unaccounted for water were properly identified and examined then all associated with the water industry should be alert to the difficulties in applying the simplified formula and interpreting its results, and avoid unwise comparisons.

The formula was, of course, completely independent of time; calculations relating to intervals of one year, one month, one week, or one day might be made with equal validity, within the limits of accuracy of the data available. The authors' improved method for calculating leakage by using flow rates measured at times of minimum night demand, was essentially the same formula applied under specific conditions over a very short time scale such as was likely to eliminate or minimise the effect of some of the unknown elements of water usage from the results obtained. Some would prefer this approach.

R.N. BENNETTS (South West Water Authority) asked how the results in Table 3 had been obtained; were they determined by the study of a sample population of each meter type in the field, in the laboratory under simulated site conditions, or from manufacturers' specifications? He assumed, from the way in which the figures were presented, that the percentage inaccuracies in the table were considered as being cumulative in both directions. Apart from under-reading caused by low flow effects, mechanical meters in particular tended to 'slow down' with time, causing the uncertainties associated with age effects to be biased in the negative direction.

In the Taw District of the South West Water Authority, covering mid and north Devon and north Cornwall, aggressive waters from moorland and agricultural catchments had over the years led to the precipitation of manganese, aluminium compounds, and iron in the mains, and consumer complaints of discoloured water. A specialist air scouring vehicle and crew had been set up and was flushing and scouring mains starting at water treatment works and working towards the worst affected areas; it was hoped that this system would continue as part of regular planned maintenance outside the colder winter months and the tourist season. Consequently, non-metered consumptions in affected areas would be significantly increased when such work was in progress, and at these times it would be necessary to make an estimate of the quantities of water used. These estimated quantities would need to be deducted from unaccounted for water to exclude them from leakage calculations.

J.E. THACKRAY (Severn-Trent Water Authority) said that although he understood the criticism of the UFW formula made by the authors, these were perhaps taken too far when they said that 'the overall uncertainty is so large as to make the figures impractical for any use other than broad planning decisions'. He would put the proposition the other way round and say that in view of the cost and difficulty of obtaining and comparing nightlines for many situations, the UFW and similar formulae had an important role to play in operational and monitoring work, provided they were applied in such a way that consistency of results could be achieved over a period of time. Results obtained from the UFW and similar formulae must, however, be used with extreme caution in making comparison between areas as a basis for broad planning decisions. As an obvious but important arithmetic truism, leakage calculated by the UFW formula as 27% but with an accuracy of one-third might in practice lie anywhere between 18% and 36%. Therefore to imply, as the Monopolies & Mergers Commission had done in their recent study of one water authority and two companies, that a difference in calculated leakage between two very dissimilar areas of around 5% was important evidence of better leakage management in one area than another, was a highly suspect exercise. Nevertheless, if the errors implicit in the calculation of the 27% could be kept consistent over time for a particular area, then a change in the calculated leakage of 5% over a year would be very significant indeed for operational management, economic and engineering analysis, and strategic planning.

P.F. BULLOCK (Anglian Water Authority) wrote that all water authorities were being subjected to pressure to find quick answers to the problem of unaccounted for water. It was incumbent upon them to respond to this pressure with some urgency, but it was also important that they avoided the temptation to do the work in a superficial manner solely to provide a cosmetic 'papering over' the leaks for political purposes. It was work which must be done methodically and carefully if leakage control policies which were truly appropriate to the circumstances were to be established.

In the Anglian Water Authority a regional co-ordinator for the work, had been seconded from other duties. A pilot study had been made in one division so that the lessons learned could be applied across the region. Early work during the study indicated that the inaccuracy of the source works meters which measured the quantity of water being put into the system could be of the same order of magnitude as the possible volume of leakage. For this reason it was decided to assess unaccounted for water by measuring minimum night flows. This was being done by means of drop tests on service reservoirs and water towers using punched tape water level recorders which measured to an accuracy of one millimetre. This work was time consuming and needed careful advance planning but it had a number of additional benefits including an improved understanding by the locally responsible staff of the way in which the distribution system operated.

Having decided to base the work on the measurement of minimum night flows, it was important to be able to identify legitimate night water use insofar as this was possible. Consumers' meters which recorded large quantities in each of the drop test zones were read during the period of the test. A difficulty remained with smaller meters, in that the numbers made individual readings impracticable yet the quantities passing through them were probably not insignificant. Night readings had been made on 325 such smaller meters selected to give a reasonable spread across the various classes of metered water consumer. It was found that the average hourly rate of flow during the night for all meters included in the exercise was 25% of the average hourly rate of flow throughout the year.

Application of the results of this sample meter reading to the 186 drop test zones which had so far been measured, revealed an unaccounted for water flow rate which varied from an average of 4½ litres per property per hour to an average of 10 litres per property per hour in the Authority's seven water supply divisions. In the one area where the exercise had been carried through to the determination of the leakage control policy no change in total resources had been made. The way in which the waste inspectors worked had been changed so that a greater proportion of their time was now spent looking for leaks and a smaller proportion was spent reading waste meters.

Most water authorities were now offering a meter option to consumers. Political pressure was being exerted to allow the installation of meters within premises to minimise the installation cost. If this was done much of the advantage to the community of more widespread metering was lost because leakage from underground supply pipes was not recorded. It was essential for some upper limit to be set to the length of underground pipework not metered. Was this political pressure the first step towards water authorities becoming responsible for all underground pipework including that for which consumers were at present responsible?

The principal interest of consumers in work which was undertaken by water authorities related to the effect on water charges. The introduction of current cost accounting and financial targets encouraged authorities to incur capital expenditure and reduce operating costs. How did the authors' view the effect of this change in financial arrangements on the determination of an appropriate leakage control policy?

M.T. SETFORD (Mid Kent Water Company) wrote that some clarification of the term n' in the formula u' = s' - (M+a'n') contained in Appendix 2, was required.

In his introduction Mr Field had specifically referred to n' as the number of domestic properties which, for predominantly urban areas containing few metered connections, was obviously valid. However, when considering areas containing a relatively large proportion of metered users, many of whom might be non-industrial, the definition of property must surely change and n' should include both domestic and metered connections. (This assumed that during a night test only the large industrial users would be measured).

He accepted that as long as the authority or company using the formula were consistent with their own definition, comparisons of leakage levels could legitimately be made within that undertaking. However, if levels of leakage were compared between different undertakings (as inevitably happed within the water industry) it was possible that different definitions of the term 'property' might be used and the results would not therefore be strictly comparable.

The effect of this could be illustrated as follows:

Using Mid Kent Water Company 1981 statistics:

Total number of domestic connections = 180,327
Total number of domestic and metered connections = 193,984

If the NWC formula u' = s' - (M'+a'n') was used,

Where s' = minimum night flow rate
M' = large industrial usage (measured during night test)
a' is assumed to be 2 litres per property per hour
and n' = number of properties supplied,

Then u' is found to be 10% higher when substituting the number of domestic connections for n' compared with the alternative of incorporating both domestic and metered connections. It would be most helpful if the authors could comment on this matter.

Authors' reply to discussion

In reply to Mr Bays, the authors said that the purpose of their paper had been to demonstrate how the use of the unaccounted for water formula, and use of comparisons could lead to completely erroneous conclusions particularly when percentages were used. There were a few occasions when it was necessary to obtain the best possible estimate of leakage. Examples of these were, determination of leakage control policy and assessing, say every four or five years, the overall effectiveness of the chosen leakage control method. On these occasions the authors would urge engineers to perform the type of analysis outlined in their paper and determine for themselves whether the overall uncertainty in the figure obtained was tolerable for their particular purpose. The authors recommended that on such occasions careful consideration be given to the use of night flow rates as described in Appendix 2 of the paper. It was not always possible to use this method, but in very many systems it could, with a lot of determination and a bit of ingenuity, be applied very effectively. North West Water Authority, Anglian Water Authority, and some others had demonstrated just what could be achieved using night flow rates.

Effective application of leakage control methods such as waste metering and district metering involved the use of indicators of change. In such cases, it was unimportant if the magnitude of a particular indicator was 50% in error, provided that it would accurately indicate a significant, say 10%, change. It was, of course, also important that such indicators were not used for purposes other than assessing changes.

Turning then to the formula mentioned by Mr Bays, the authors said that three of the terms, S, M, and P in the Bristol formula were the same as those in the UFW formula, and the term K included 'a' from the UFW formula. In addition, the nett night flow, NL, had been introduced into the Bristol formula and this introduced yet another uncertainty. However, the formula used by Bristol Waterworks Company was applied to a smaller area than those envisaged by the authors, and was used on a comparative basis to detect change rather than to determine absolute values. These two factors made a considerable difference and, provided that the instruments used for measurement gave consistent performance, meaningful results should be obtained. Also the authors added that this was an interesting way of combining waste and district metering to cover the entire system. They suggested, however, that a term be included in the formula to convert nett night flow rate into an average daily flow taking pressure changes into account. A method for achieving this could be found in report number 26.

It would be unwise to generalise too far on the question of variations in the performance of meters as received and after repair at the manufacturers or in-house. The authors certainly agreed that a survey which was fairly regularly updated was required to assess performance of this kind and they would take note of the suggestion. In many instances the manufacturer could make an effective repair on a clear fault which arose after a meter had been in service. The authors had certainly been dismayed to find how high was the number of faults occurring in new meters going into service, some of which would not be discovered unless the meter was calibrated independently.

The authors said that they agreed with most of Mr Twort's comments, particularly those related to the difficulties of obtaining reliable sample measurements of domestic consumption, as discussed in Section 2.3 of their paper. Neither of the authors had been personally involved with measurements of domestic consumption, but would have expected a range of values depending upon type and age of property. The actual values recommended by the Standing Technical Committee report number 2, published in 1976, were 110 to 130l/head/day including the allowance of 0 - 20l/head/day for non-metered commercial use.

The authors said that they agreed with Mr Morgan that the important reason for obtaining an absolute value for leakage was for the initial determination of the appropriate leakage control policy. For routine implementation of most leakage control methods, relative values were much more useful for reducing or maintaining leakage at a low level. The authors would, however, recommend engineers to make an absolute measurement every four or five years to check that systematic errors in relative values were not giving false impressions.

To compare leakage in one undertaking with that in another was quite meaningless because leakage alone was not the sole criteria, the costs of producing water were very important. One would expect to find higher leakage levels in areas where the long run cost of supplying water was low and vice versa. Any monitoring system or performance assessment intended to make water undertakings aim at the same level of leakage would probably only ensure that half of the water undertakings in the UK were doing too much leakage control, while the other half were doing too little.

The authors agreed with Mr Smith that, in general, too little attention was given to the sizing, installation, and maintenance of meters. In many cases this had resulted in meters being grossly oversized for the load they were intended to measure, and significant errors caused by the configuration of the pipework within which the meter was installed. The authors were interested to learn of the in situ calibration work being undertaken and said that it was a procedure they would encourage other undertakings to adopt. They also said that it was a subject which their own organizations, NEL and WRC, were to jointly investigate to determine whether improved procedures could be developed.

In reply to Mr Gimson, the authors said that the purpose of their paper was to demonstrate how the combination of relatively small uncertainties could leak to a large uncertainty in the term 'U'. They had, however, emphasized that the figure quoted for meter accuracy applied to a reasonably well designed, installed, and maintained system. Uncertainties very much greater than those quoted could exist when the meters were incorrectly sized and installed or poorly maintained.

Turning to meter design, the authors did not agree that there was a low level of technology in the field of flow measurement. Generally, flow metering technology was high, particularly where meters had been developed for other industries. There was, however, a need to tailor some of these developments to meet the specific requirements of the water industry. This could only be achieved by producing water industry performances specifications which set down in detail what the water industry expected from flow meters used in different applications. Only then would the manufacturers have a clear idea of the industry's requirements. WRC in conjunction with NEL and the Standing Technical Committee would be developing performance specifications, the first which would cover district meters, source meters, and small revenue meters.

Obtaining flow meters to meet the specific requirements of the water industry solved only half of the problem. To obtain reliable flow measurements the meters must be properly sized, installed, and maintained. The authors agreed with Mr Gimson that there was a tendency for the industry to install meters and forget about them until they stopped indicating. If the industry wanted reliable flow measurements it would have to pay more attention to these points. Again, WRC and NEL intended to assist the industry by producing guidance notes on choosing, sizing, installing, calibrating, and maintaining meters for different applications.

Mr Gimson's comments on the lack of reliability by electro-magnetic flowmeters was disturbing since in good conditions the early problems of this type of meter had largely been overcome. Certainly their zero pressure loss advantage would be equalled by the ultrasonic flowmeters now coming into service but unless the latter were the more sophisticated multipath systems, which were quite costly, then they were in general more susceptible to the upstream velocity profile in the pipeline than the electromagnetic meter. Long reliability in service of ultrasonic meters had still to be established as would the effects of solids in suspension in the water.

Finally, the authors said that the accuracy of semi-positive displacement or rotary piston meters such as the Kent PSM or the Neptune Type 44, were not affected by inlet or outlet conditions. The accuracy of meters of the helical vane type was affected by inlet and exit conditions and was particularly adversely affected by the swirl.

The authors agreed with Mr Pepper that the UFW formula had served a useful purpose and added that it could still serve a useful purpose provided that it was used wisely. The alternative method based on night flow rate suggested by the authors, certainly used the same type of formula. However, the important message they were trying to convey was that even if the accuracy of the individual night flow rate components were very much worse than the corresponding ones for total daily quantity the overall uncertainty in the estimate of unaccounted for water could still be very much better.

In reply to Mr Bennetts, the authors said that Table 3 was based in general on laboratory tests of a number of different meters of different sizes of the particular type though note had been taken of national and international standards where these existed. They agreed that there was some oversimplification in the assumption that the uncertainties were symmetrically gausian rather than of skew distribution. In a presentation of this kind it was inevitable that there was considerable generalization. WRC and NEL were collaborating to produce a detailed assessment which would take into account the effects referred to by Mr Bennetts as well as the variations in claims and assessments coming from different sources.

Water used for mains cleaning, street cleansing, fire fighting, etc. should all be included in the formula. Normally the total annual quantity of water used for these purposes was so small compared to the total annual volume put into supply that they could be ignored. However, where mains cleaning was undertaken frequently, particularly in rural areas, or where the accounting period was short, water used for these purposes might become significant.

In reply to Mr Thackray, the authors said that first they must make it clear that obtaining night flow rate measurements over large areas was not particularly difficult nor costly as no doubt North West Water Authority or Anglian Water Authority would agree. Secondly, they had in mind that the formula, applied indiscriminately, could only be used for broad resource planning decisions as described in Section 4 of their paper. They certainly would not advocate its use for determining leakage control policy except in small well controlled areas, otherwise it was likely that an inappropriate method of leakage control would be adopted.

Using the unaccounted for formula as a monitor of change could be possible in a small well-defined area, but generally it would not provide meaningful results. If the various terms in the formula were examined it will be seen that there is no reliable way in which changes in population or per capita domestic consumption could reliably be monitored. It would be necessary, therefore, to assume those factors to be constant. Thus, rearranging the formula the monitor of change became

$$S - U = U + \text{constant}$$

They were adding a large quantity to the term U and were hoping to see a small change in U. If they assumed that the term a, P and M were constant over a period of time, the best possible case, and the term U had changed by 5%, the corresponding change they would actually monitor would be in S. Using the examples A and B in the paper, they would be looking for changes of 1.3% and 0.8% respectively. There was, therefore, no chance whatsoever of seeing the change suggested.

Turning to the last part of the question, the authors said that in Appendix 2 of their paper and in their presentation they had demonstrated how an 11% difference in UFW could actually represent zero difference (towns A and B) or 100% difference (towns E and F). Similar results could be obtained with a 5% difference. Consequently, armed with that single item of information it would be quite wrong for the Monopolies and Mergers Commission to suggest that a difference of 5% was significant, but it would be equally wrong for Mr Thackray to suggest that the 5% difference was insignificant.

The authors thanked Mr Bullock for his contribution. They said that his examples supported the points they were trying to make and they hoped other authorities would follow the excellent example set by Anglian Water Authority.

They would not be drawn on the subject of the domestic metering option, that was a topic for another conference on another day.

With regard to the effects of current cost accounting, they said that these were matters which affected financial arrangements, whereas the procedure for determining leakage control policy was based on economics. In theory, therefore, current cost accounting should not affect the use of the procedure, but it could have some effect on the practical implementation and it was a point they would all have to watch.

The authors said that they agreed with every word that Mr Setford had said and, although it did not represent a major problem or drawback, it was a constant niggling problem which must be resolved. The authors said that they had looked at simple ways of resolving the problem by specifying hereditament or number of bills sent out, but these had problems because of blocks of flats or council property. The matter had been discussed at some length at the last meeting of the Leakage Control Liaison Officers and following that meeting it had been suggested that:

A block of flats was treated as one property, i.e. one connection.

Council houses which might receive one bill were counted individually.

Properties with no water supply were excluded.

Properties on a common supply, including industrial estates, were counted individually.

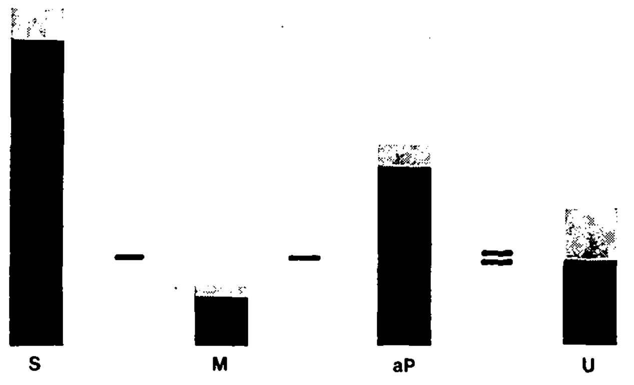

Fig. 1. Calculation of UFW for Town A based on daytime flow rates

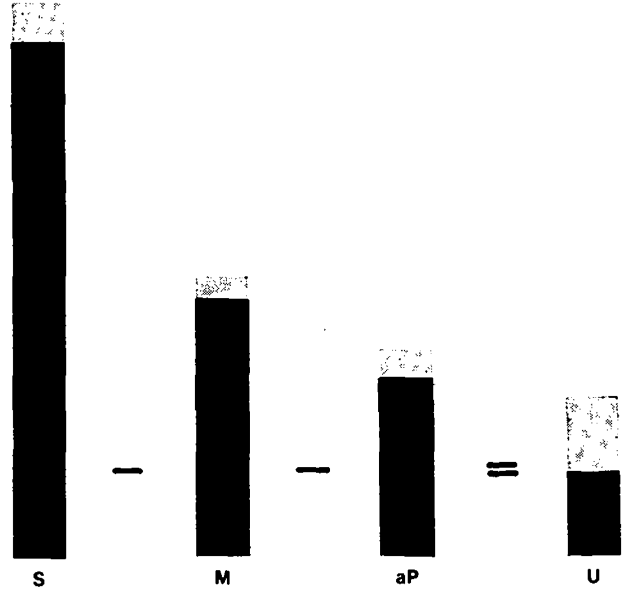

Fig. 2. Calculation of UFW for Town B based on daytime flow rates

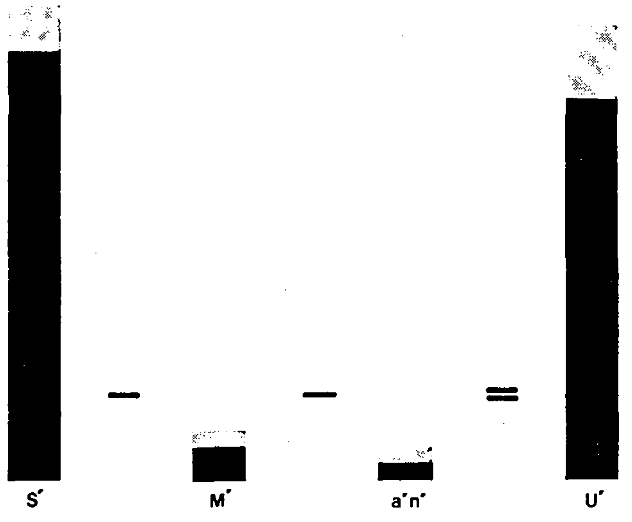

Fig. 3. Calculation of UFW for Town A based on night flow rates

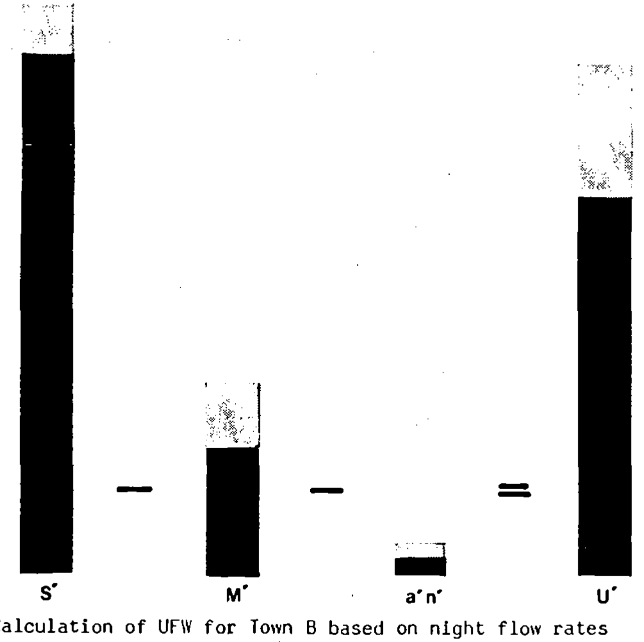

Fig. 4. Calculation of UFW for Town B based on night flow rates

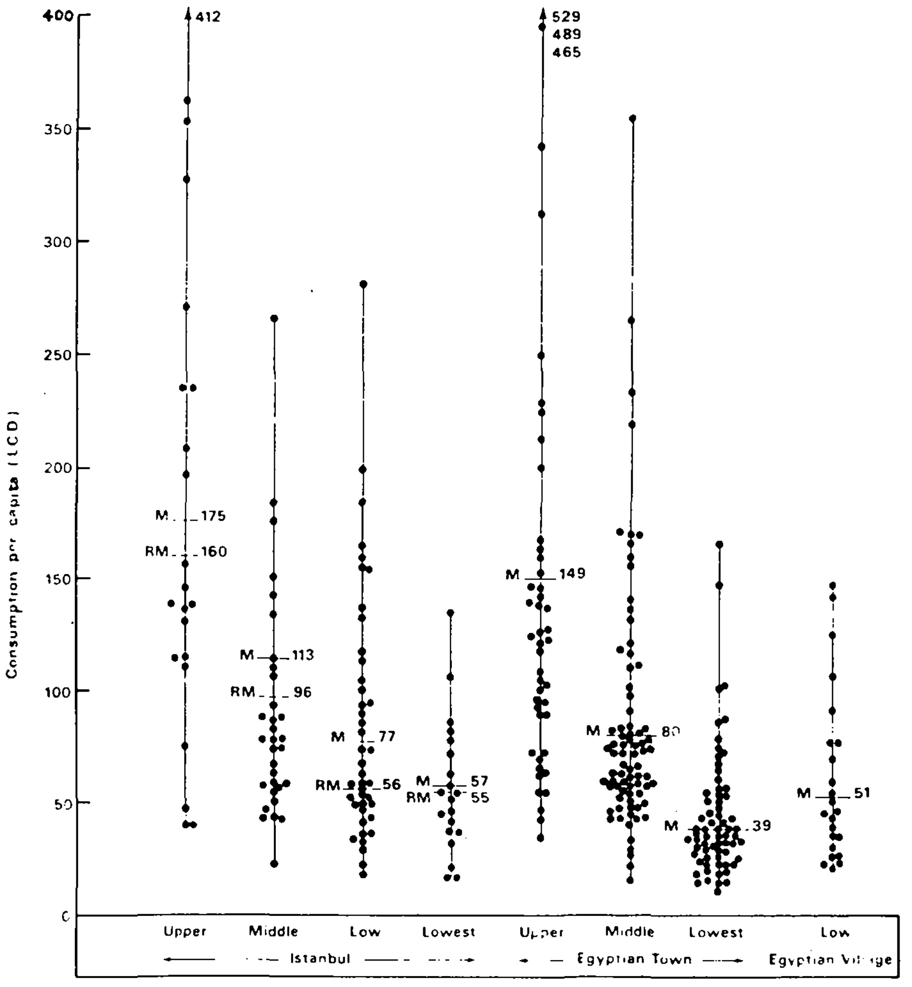

Fig. 5. Variation of household consumption within a given class of dwelling (M=mean of all results within class; RM=reduced mean which excludes households taking more than twice the mean of the others withing the class.

3. THE TRADITIONAL APPROACH TO WATER LOSSES

By J.S. Pocock, MBE, BSc, MICE, MIWES*

Our philosophy for controlling water losses has changed little over the years and it is still appropriate to apply traditional techniques. Past successes are examined and compared with present efforts to establish an economic balance between the cost of exercising control and the value of water lost.

INTRODUCTION

An oft quoted passage in Ecclesiastes is 'What has happened will happen again and what has been done will be done again, and there is nothing new under the sun'. Whilst this is indeed true of many of our present attempts to reduce 'waste' (that being the generic term for use without purpose as well as leakage) there is another later quotation from the same source - namely that 'For in much wisdom is much vexation, and the more a man knows, the more he has to suffer'. Certainly as the cost of electrical power, oil and manpower has escalated there has been a corresponding degree of vexation amongst politicians when figures of 20%-30% have been quoted for the percentage of water that leaves our source works but is not accounted for, or is not purposefully used by the customer.

The vexation is increased tenfold for the water engineer who cannot, for lack of accurate instrumentation, prove that the situation is not as bad as the 'unaccountable' figures would suggest.

Looking back through water history for a hundred and fifty years, it is possible to identify a cycle of interest in water losses; at intervals of about 30 years there have been progressive stages of analysis and invention, and it is indeed humbling to read the excellent paper given by George Deacon(1) to the Society of Arts in 1882. There have been other classical presentations and I would particularly mention papers to the Institution of Civil Engineers by William Hope(2) in 1892 and by Henry Cronin(3), Chief Engineer of the Metropolitan Water Board in 1951.

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Prevention is better than cure

The need for better materials and better standards of design was recognised at a very early stage not only for mains and services but also for the customers' installations. Thus iron mains became compulsory in London in 1820(4), and lead, copper and wrought iron for connections in 1847(5). Detailed Regulations regarding the customers' fittings and pipework were introduced in 1871(6), and it was in these Regulations that the phrase 'prevention of waste, misuse, undue consumption and contamination of water supplied by the undertaker' was introduced. We are still, in 1981, trying to reform these original objectives into yet another version of Model Water Byelaws(7), having rejected the intention of revision to Building Regulations (Water) under the Health and Safety at Work etc. Act, 1974(8).

In my earlier days as Distribution Engineer for the Metropolis, I recall few difficulties in enforcing Byelaws in a fairly autocratic way, for not only did the plumbing fraternity deem it inopportune to argue, but the time honoured tradition of shutting off supplies for waste in London meant that the threat of retribution was real.

The political climate has, of course, changed, not only because of our close involvement with the E.E.C. but also because of the emergence of powerful pressure groups in our society - water authorities are looked upon as bureaucratic organisations even when they are demonstrably democratic, and the abusive word 'quango' is hurled at any associated committee. Such pressures have refined the philosophy of controlling water losses and an example is that of consumer protection. Since the 1871(6) Regulations there have been simple rules such as a requirement that taps should withstand a test pressure of 300 p.s.i., even when working pressures were only a tiny proportion of that figure, but a peak of customer protection was reached in the 1930's when it was decreed that every single water fitting used in the Metropolis should be tested and stamped(9). There was certainly a notion of public good in some of these moves even if waste and contamination were used as the official justification, and this probably arose because of the lack of other effective legislation to protect public interests. Today, therefore, whilst withdrawing to some degree from customer interest in our pursuit of effective means for controlling water losses, we are really only narrowing the space between the goalposts because the salesman and the landlord have other restraints placed upon them.

One very real example of reversion to tradition is the argument that we do not need a byelaw to define the strength of water cylinders. There was no such regulation in 1871 and, if we did not have one today, would the occasional leak cause any significant increase in the overall level of water consumption? Is it the job of the water authority to prevent an occasional leakage of water which will, in any case, be stopped quickly owing to the serious damage that it will cause to the customer's property? Would it not be more realistic to direct our inspectors' time to tracing leakage from our apparatus and leave the need for ensuring suitability for purpose to other organisations including perhaps our Members of Parliament, who, too often, are apt to criticise the application of law that they have themselves created.

Pressure Control

Control of pressure as a means of controlling leakage was identified in the recent national report(10) as a means of controlling water losses, and it is interesting to try and trace application of this philosophy in the past. Certainly pressure control valves have for many years been used to reduce trunk main pressure to a level that is appropriate to a locality, but reference to the Third Schedule of the 1945 Act(11) shows that pressure control valves do not fit in with the statutory concept of flow by gravity from a service reservoir chosen by the undertaker. The tendency in the past, therefore, has been to discharge through valves to local reservoirs or water towers which themselves correspond with the statutory concept - furthermore the reservoir provides a means of maintaining the supply if the pressure reducing valve needs repair, and a safeguard against pressure surges if the valve sticks. It could be that present legislation should be modified to include reference to pressure reducing valves and in line boosters, both of which enable local pressures to be controlled more closely relative to ground level.

There is not a shadow of doubt that the requirement for 'in house' storage cisterns, which has been related to local legislation in the Metropolis for more than a hundred years, took account of the beneficial effect of a low and constant pressure on leakage from defective fittings, and many engineers still regard this requirement as justified on the grounds of waste control alone, even though it is clear that other very good reasons exist. There is, of course, still an equivalent option for those who advocate 'all mains' systems to also advocate the provision of pressure reducing valves outside or inside every dwelling such that a constant but adequate low pressure is applied to all fittings.

Incremental Correlation

At times of water shortage or financial restraint it is necessary to estimate changes in water demand as well as the financial consequences in order to justify either the expenditure or the likely effect of a water shortage on customers. It is very difficult to estimate changes in losses resulting from greater changes of demand that develop from year to year. Nevertheless, Mr. Cronin carried out such an exercise in 1950 when there had been a substantial increase in expenditure on waste control and that trend can be compared with recent figures for London where the effect of improvements in conditions of employment and cuts in staffing levels have led to a substantial reduction in the number of inspector hours being spent on waste control. Over the four years 1946 to 1950 the average minimum night flow fell by 13.3 m.g.d. or 3.3 m.g.d. per annum. Over the same period the average daily supply fell by 9.6 m.g.d. or 2.9 m.g.d. per annum. It was felt, at that time, that this correlation between night flow and average demand was reasonable evidence that the financial expenditure on waste control over the four year period had been justified (Table 1).

TABLE 1 - Incremental correlation.

Year	Minimum night flow m.g.d.	Average daily supply m.g.d.	Ratio of minimum night flow to average daily supply
1946	80.5	325.5	24.7%
1947	85.9	333.8	25.7%
1948	76.2	323.7	23.5%
1949	67.2	315.9	21.3%
Difference	-13.3	- 9.6	
1971	94.1	384.9	24.4%
1972	97.7	387.4	25.2%
1973	99.3	386.6	25.7%
1974	101.4	392.7	25.8%
1975	102.8	409.2	25.1%
1976	108.2	391.0	27.7%
1977	110.1	402.3	27.4%
1978	116.6	416.7	28.0%
1979	123.7	421.3	29.4%
Difference	+29.6	+36.4	

Note: The Minimum Night Flow is the flow measured by Deacon Waste Meters.

Over the last decade (1971/72-1979/80) the average minimum night flow has increased by 29.6 m.g.d. and over the same period the average daily supply has risen by 36.4 m.g.d.

Whilst the need between 1946 and 1950 was to employ usefully an increasing number of staff, the objective over the last decade has been to increase efficiency and reduce staffing levels. The effect of this in the Metropolis can be seen both in the increase in minimum night flow to average daily supply ratio and in the decrease in number of defects discovered by the Inspectors as shown in Figure 1. As can be seen in Figure 2, there has been a reduction of 38% in the Inspectors' total working hours between 1964/65 and 1979/80. If only waste related matters are considered, the reduction in manhours is nearly 43%.

If the incremental correlation between minimum night flow and average daily supply is accepted as a measure of the effectiveness of waste control, there is indeed reason for concern at the present time. The records of the former Metropolitan Water Board, continued by Thames Water, are remarkably good and it can be judged that annual effort applied to waste control in 1949/50 amounted to 357,381 manhours. In 1979/80 it had been reduced to

188,400 manhours, notwithstanding the fact that the average age of the mains network had increased from 62 years in 1949 to 82 years in 1979 (Figure 3).

Minimum night demand

This phrase does not appear in the recent DoE/NWC report(10) but it has the virtue of clarity. A reference to making such measurements appeared in 1898(12) and the technique was, as today, that of either ceasing pumping or isolating the service reservoir from the pumping station whilst observing the change of level of the service reservoir using a hook gauge between the hours of 2.00 a.m. and 5.00 a.m., and comparing this demand to the average for the day. Figures are not available for these early tests but it can be inferred from various references that leakages from both mains and service reservoirs was considered to be small, and almost half the quantity put into supply was lost or wasted from the customer's pipework which, at that time, extended to the main.

When pumps cannot be shut down and there is substantial infusion between reservoir zones it is much more difficult to measure minimum night demand, but Mr. Cronin made such trials over four days periods in 1949 and 1950 and arrived at minimum night demand ratios of 44% and 38%, respectively. These figures correspond with ratios for minimum night flow of 24% and 21% giving a difference of 20% and 17% for these two years - say 18.5% which presumably represented leakage from trunk mains and reservoirs as well as bulk use from trunk mains and metered demand that had been excluded from waste water meter areas.

Corresponding figures for the Metropolitan area today give a *minimum* night demand ratio of 51% and a minimum night flow of 31% - giving a difference of 20% which, as might be expected suggests either a slight worsening of leakage from trunk mains and reservoirs or higher trunk mains use. The figures also suggest a significant worsening of losses from the distribution system amounting to an increase of 8% in the minimum night flow ratio over a period of 30 years.

If the system for assessing acceptable economic losses as described in the DoE/NWC report(10) is applied this would correspond with an acceptable level of water losses of 16% in the Metropolitan area, leaving 15% of the minimum night flow figure to be separately accounted for.

Applying the corresponding assumption of the DoE/NWC report (10) to other Divisions of the Thames area suggests target levels of water losses between 10.5% and 12.9% with an average for the whole area of 15%.

Maintenance of reduced waste

The DoE/NWC report(10) provides a means of estimating the effort necessary to maintain an effective waste water meter system and histograms were used in that report to indicate the problem. It is interesting to find data presented in such a form by Mr. Hope in 1892(2), covering experience from about 1878.

It is difficult to compare this data with that produced by the recent working party as that of Mr. Hope is on a per capita basis and the more recent one is on the basis of households - nevertheless, assuming a current ratio of 3 persons per household, the original experience will be seen to correspond quite closely (figures 4 and 5). Mr. Hope in his address to the Institution also gave us the interesting information that 3.9 inspectors per 100,000 of the population were used originally and this was reduced to a ratio of 3.1 after 13 years. These men were probably employed on a 12 hour day six days a week with no overtime for nightwork.

The present equivalent full time waste inspector ratio in the Thames area appears to vary from about 0.9 to 3.5 per 100,000 of population.

The use of sounding sticks to locate hidden leakage is undoubtedly a very old practice; they were certainly used systematically in the mid-Victorian era (probably with wooden cups to fit against the ear) as the follow-up to step tests on metered districts. Sounding sticks are very popular and are still probably the most efficient means of locating leakage. Where sounding sticks fail there is now, of course, a very proper place for electronic devices and specialist staff.

Trunk main leakage

It is difficult to find any significant reference to leakage from trunk mains in early literature but Mr. Cronin in 1950 states that 90 miles of trunk main between 30" and 42" had been systematically tested; that the total leakage amounted to 25,580 g.p.h. and the defects causing it were subsequently, or would be, traced and rectified. He added that the results of tests tend to confirm, as was thought, that the Board's trunk mains were not in bad condition and that leakage from them was comparatively small. A similar opinion was expressed in 1885 by the engineer who subsequently became the first Chief Engineer for London. Undoubtedly, very high standards were maintained as regards the manufacture, handling, laying and jointing and testing of mains but it is difficult to correlate Mr. Cronin's figures for minimum night demand and minimum night flow without questioning his logic.

It so happens that the author carried out one of the tests on a 42" main to which he referred and, far from accepting the original figure of 100 g.p.h. leakage indicated by a ¾" meter through a hose connection to an air vent, later research suggested figures of about 2,000 g.p.h. after allowing for valve let by, there being a substantial hydraulic gradient when the section of main to be tested had been isolated.

A test for measuring leakage that allowed for valve let by had thus been developed by 1952 and it was used on scores of old mains between 3" and 42" in diameter. A paper on the subject was indeed submitted to the Institution a few years later but was not accepted for publication.

Very briefly, the technique is to observe the normal pressure, then isolate the main and observe the pressure again. If the pressure falls by more than 50% a valve, preferably a small valve, is cracked deliberately to permit controlled let by. Water is then drawn off from the main, or fed into it from a higher pressure source, and the pressure/draw off relationship is observed. Finally, the system is allowed to revert to its original status quo condition as a check on movement of valve gates. When such movement does occur it seldom happens again if the test is repeated.

The calculation to estimate leakage is somewhat complex but there are half a dozen simpler versions of the test which can be applied using nothing more than a bucket, a stopwatch and a little mental arithmetic. Accuracy is of the order of 10% when compared with directly metered leakage on mains with tight valves.

Management

At first sight there seems to be little about management that can be called traditional but closer examination of past events shows a recurring theme.

The paper by Mr. Hope in 1892(2) shows a financial analysis of the effect of waste metering that bears a close similarity to that contained in the recent DoE/NWC report(10). This early study is shown in Table 2.

There were few manpower problems in those early days but, as quoted already, Mr. Hope claimed a reduction of manpower from 3.9 to 3.1 per 100,000 of the population after a waste control system had been operating for thirteen years. A survey by the Author of the number of staff involved in waste control in the U.K. today suggested that the figure is on average 2.9 for waste control on premises and 2.1 for byelaw inspection - corresponding figures for London being 3.5 and 1.6, respectively.

As stated earlier, the present number of manhours spent on waste control in London is only about half those employed during the post war peak of such activity. There has, of course, been a recent move towards more holidays, a shorter working week, time off after night work and similar changes that have reduced work output, and it is that adverse effect that we now need to combat by reassessing our problems, establishing new financial targets and adjusting our resources in terms of money and manpower to re-establish the status quo.

Per capita consumption

One of the earliest means used to assess the effectiveness of a system of waste control was that of comparing total consumption of different towns on a per capita basis. Sometimes industrial metered consumption was separated. This is still a valid means of comparison for the diverse nature of the factors which go together to control the level of waste is such as to justify an exchange of views, not only nationally, but internationally.

During the latter half of the last century the basic problem

TABLE 2 - Financial analysis of waste water metering - Mr. Hope 1892

Town	Population 1000's	Capital cost of introducing W.W.M.'s £000's	An.revenue cost of operation of W.W.M.'s £000's	Av. daily supply before introduction of W.W.M.'s M.G.D.	Av. daily supply after application of W.W.M.'s M.G.D.	Net annual saving @ 6d. per 1000 gall. & 8% interest £000's
Bath	59	2.6	0.3	2.81	1.24	4.7
Birkenhead	93	3.1	0.5	2.35	1.59	6.3
Carlisle	41	1.0	0.1	1.75	0.77	8.9
Gloucester	37	2.0	0.2	1.18	0.57	3.2
Lambeth	342	6.0	2.4	11.28	6.27	43.6
Leamington	23	0.4	0.1	0.55	0.36	1.5
Portsmouth	111	Est. 0.2	Est.0.7	3.90	2.17	Est. 12.4
Southwark & Vauxhall	842	16.8	2.0	42.10	15.16	81.0
Widnes	21	0.4	0.1	0.24	0.17	0.5
TOTAL	1569	32.5	6.4	66.16	28.30	162.1
Total per million of population	-	20.7	4.1	42.2	18.0	103.3

was that of introducing a constant supply without increasing the total amount put into supply. Progress along that path proved to be very slow and it is only the pattern of demand since the introduction of a constant supply that is meaningful. Figure 6 details the increase in per capita consumption in London over the last 100 years.

When Mr. Cronin addressed the Joint Institutions in 1951(3) he quoted consumption in 20 towns throughout the world that had also been selected for the Presidential address to the Institute of Civil Engineers in 1900. It so happens that half of these towns were, by coincidence, selected for a similar review for the International Water Supply Association in 1980, and we thus have an interesting pattern of change over a period of nearly 80 years.

It will be observed that there is a remarkable correlation between the growth of demand in the four U.K. towns, amounting to 1½% per annum and it follows that at any time within that period an effective waste control policy would have had a significant impact on the capital programme of the organisation. A recent study of the value of water in the Thames area shows that the average marginal value based on operating costs is only 1.55 p/m^3 but this increases to an average of 5.55 p/m^3 if both the short and long term capital value is taken into account. The present metered charge is 17.05 p/m^3 but if standing charges recovered the full amount of availability related costs, the metered charge would be around 13 p/m^3.

It is apparent from these figures that the financial return derived from an increase of effort on waste control can vary widely from place to place in an authority's area, perhaps by a factor as great as 20; and the financial returns will not be the same for equal reductions of waste in metered and unmetered premises.

Another comparison was made recently for the I.W.S.A. by selecting 5 major towns in each country and plotting the total consumption in a stepped sequence such as to give a visual impression of consumption (figure 7).

This average consumption in all of the metered towns was compared with that in unmetered towns and it was found that the unmetered average was actually marginally below the metered figure. This raises a question as to whether metering itself produces any permanent reduction of demand in a modern prosperous society.

Figures have seldom been quoted from overseas for differences between total metered quantities put into supply and total quantities registered on revenue meters. This was, therefore, researched for the I.W.S.A. and results are shown in Table 4.

It seems logical that low losses from mains and reservoirs could be associated with a modern distribution network and enquiries were made as to the proportion of mains that have been laid or renewed in recent years. This is shown in Figure 8. The low level of renewals in London becomes apparent.

TABLE 3 - Water supply to towns, with reference to consumption and waste

				Average quantity supplied per head per day (excluding bulk supplies) gallons		
City	Year	Area of Supply: sq.miles	Population thousands	Domestic and unaccounted-for water	Trade	Total
Birmingham	1900	130	668	17	10	27
	1949	183	1220	20	16	36
	1978		1212	37	23	60
Glasgow	1900	68	1000	34	21	55
	1949	98	1223	40	26	66
	1978		881	81	29	110
Liverpool	1900	101	857	18	13	31
	1949	106	1097	25	17	42
	1978		860	53	24	77
London	1900	620	5900	27	8	35
	1949	540	6453	34	15	49
	1978		5710	56	13	69
Dublin	1900		290	30	7	37
	1948	250	603	31	8	39
	1978		998	44	11	55
Amsterdam	1900	17	521	-	-	19
	1949	68	840	19	9	28
	* 1978		758	27	24	51
Brussels	1906	64	705	-	-	16
	1949	116	1030	-	-	28
	1978		1311	24	10	34
Copenhagen	1900	9	358	14	5	19
	1949	29	764	23	21	44
	1978		537	39	26	65
Paris ∅						
Capetown	1914	59	152	-	-	29
	1949	79	426	27	16	43
	* 1978		750	31	18	49
Philadelphia	1900	145	1230	-	-	187
	1949	135	2052	-	-	143
	1978		1900	90	73	163

* Figures exclude unaccounted-for water

∅ Figures for Paris not included as some include non-potable water.

TABLE 4 - International data. Towns with all supplies metered.

Country	Number of towns	Unaccounted for water expressed as a % of average daily supply	
		Range	Average
Belgium	1	-	15%
Denmark	5	5%-12%	9%
France	6	13%-30%	20%
West Germany	3	3%- 6%	5%
Italy	2	-	12%
Poland	4	3%-12%	8%
Finland	4	10%-15%	13%
South Africa	4	7%-11%	9%
Spain	4	19%-28%	23%
Israel	2	8%-20%	14%
Sweden	5	7%-23%	18%
U.S.A.	4	12%-25%	18%

Notes:

1. Unaccounted for water as shown above was calculated as follows:

$$\frac{\text{Metered quantity put into supply} - \text{Quantity registered on revenue meters}}{\text{Metered quantity put into supply}}$$

2. Unaccounted for water includes:

   i) water used for street cleaning
   ii) mains flushing water
   iii) water for fire-fighting
   iv) leakage
   v) meter errors (which may be positive or negative)

CONCLUSIONS

This review of traditional methods of controlling water losses has identified techniques that have been successful at some time in the past and I am sure that Mr. Hope would be delighted to observe the close similarity between his paper of 1892(2) and the recent DoE/NWC report on 'Leakage control policy and practice'(10). The only references that would puzzle him relate to heat pulse and turbine insertion meters, and the electronic correlator. How then has good practice failed, in many respects, to maintain its momentum in recent years? It is perhaps a fact that management techniques can never stand still, for few today would seriously suggest employing staff on a 60 hour week without payment of overtime, or require men to work both day and night on consecutive days. Many other changes can be identified that cannot be reversed, and it would appear that in the sphere of water loss control technology has not advanced at a sufficient rate to compensate for loss of manpower productivity. The present understandable reluctance to employ more men on waste control does not relate to any fallacy in the techniques of the past but rather demonstrates our need for improving the productivity of those now employed. Existing bonus schemes cannot be regarded as a success and some may argue that they have actually been detrimental in so far as they relate to the speedy completion of a routine instead of to the achievement of a defined level of losses.

It may be that by using more sophisticated costing procedures we can, and should, increase the level of manpower involved in keeping with our fundamental duty to provide a reliable and wholesome supply of water at minimum cost. Manpower needs should fit into that concept but the alternative course of action is to accept, as a temporary phase, the conclusion that water losses will be higher than is economically desirable for a few years whilst new techniques of search, repair and renewal are developed. Reductions of pressure, and the introduction of restraints on demand, may provide a breathing space in which this development can take place, but in the long run it is unlikely that the basic ideas of control, both financial and technical, will change significantly from those which would have been familar to our forefathers.

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Acknowledgement

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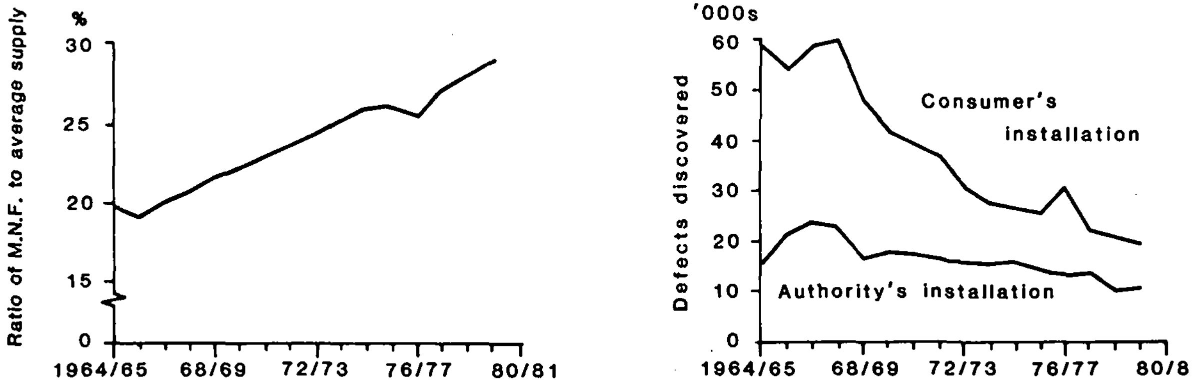

Figure 1 Long term trends relating to Minimum Night Flow

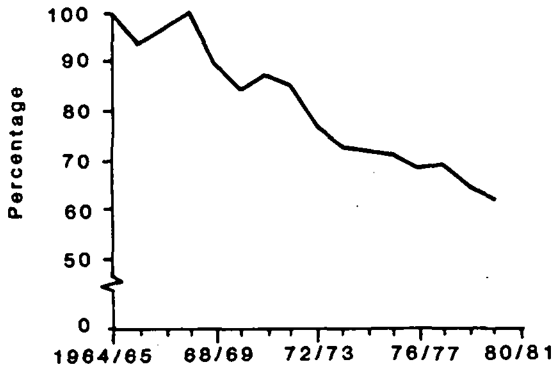

Figure 2 Inspectors working hours (1964/5 total taken as 100%)

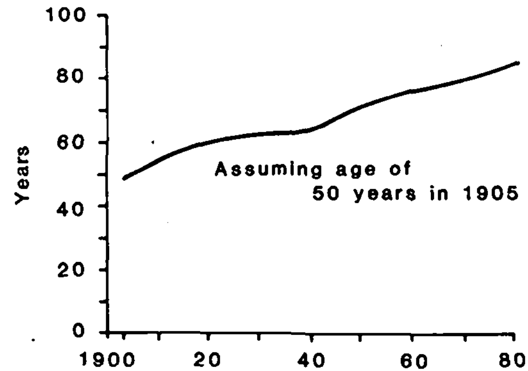

Figure 3 Average age of mains in Metropolitan Water Division

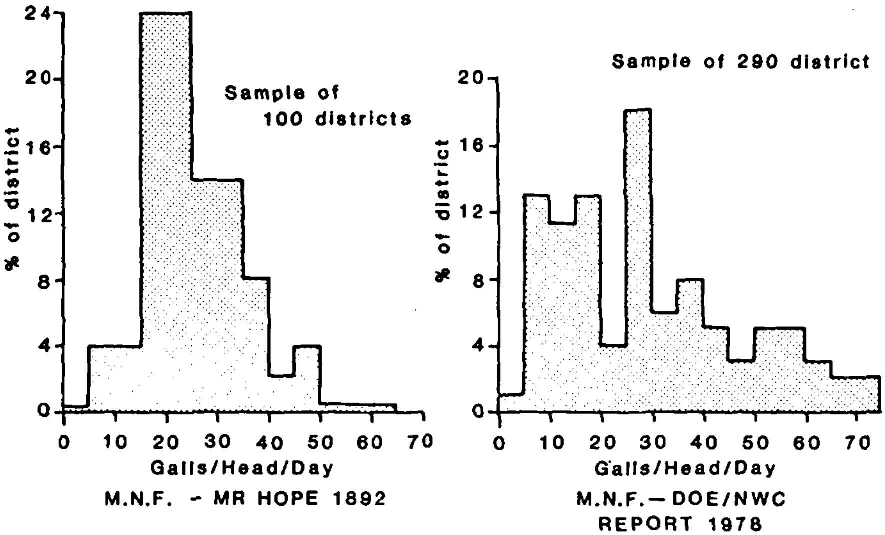

Figure 4 Minimum night flows without waste metering

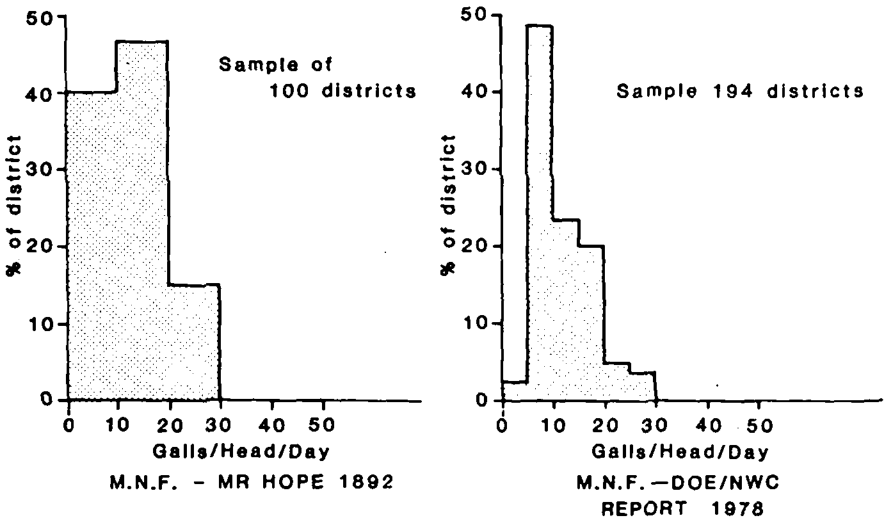

Figure 5 Minimum night flows after application of effective waste metering

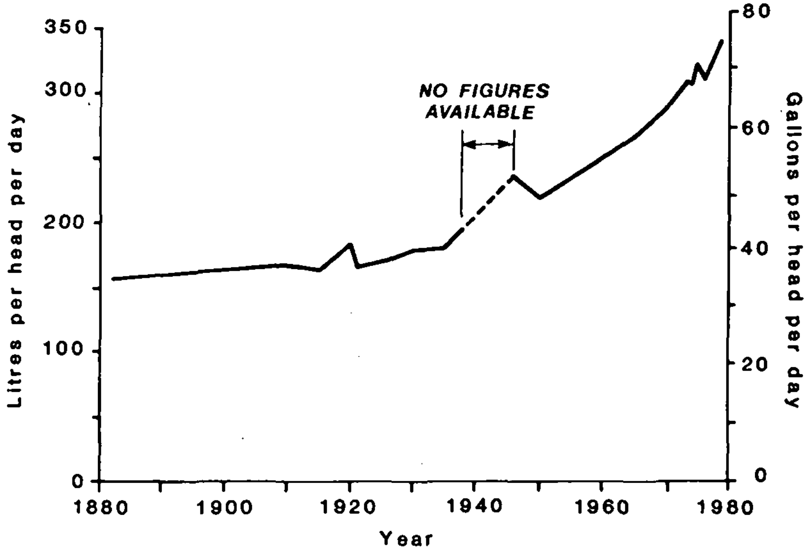

Figure 6 Metropolitan Water Division - Supply

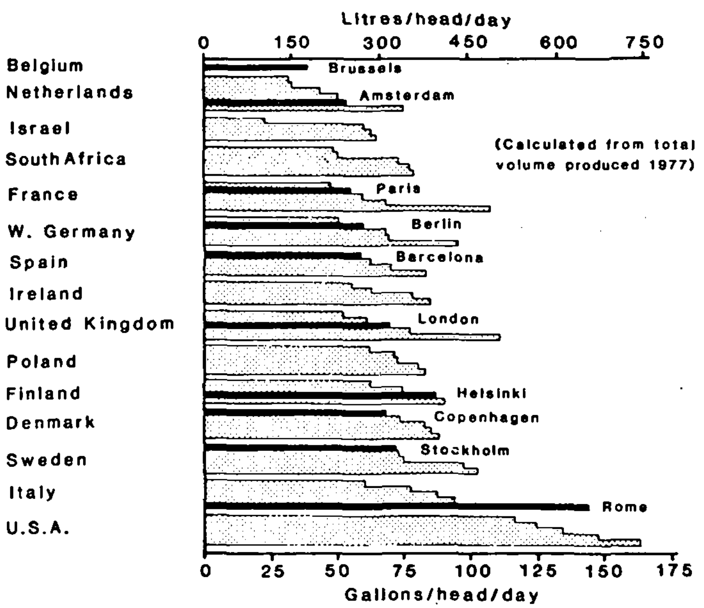

Figure 7 Average daily supply

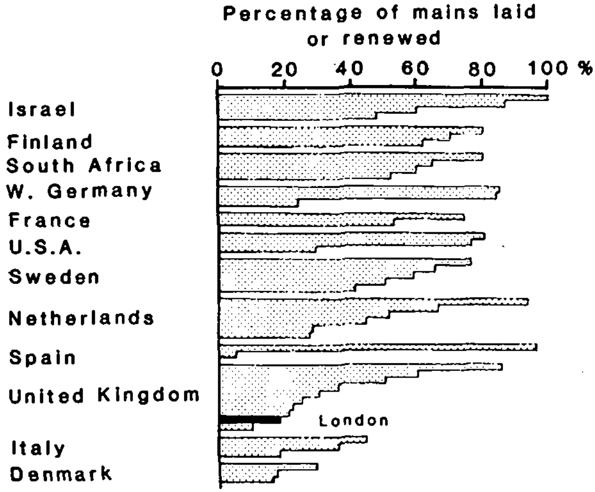

Figure 8 Percentage of 100-300mm diameter mains laid or renewed in large towns 1948-1978

DISCUSSION

Author's introduction

Mr Pocock introduced his paper by saying that the more a water engineer learnt about norms of water use and losses the more was his vexation in trying to explain the differences between those figures and the quantities of water supposedly put into supply.

It was possible to compare water supply statistics on an international scale and, he drew attention to other information published by the International Water Supply Association. This showed that water consumption in London was comparable with that elsewhere, taking account of the fact that water here was cheap and mostly unmetered, and that London was a vast, commuter, tourist, and commercial centre. Demand had increased more in the last 30 years than in the preceding 50 years but this phenomenon appeared to be typical of most other towns.

The various trends that he had identified were not necessarily examples of simple cause and effect; thus, for instance, if the average age of mains in an area was increasing it did not necessarily mean that this was the principal reason for a simultaneous increase in the ratio of MNF to average daily supply, nor indeed that the latter relationship necessarily implied an uneconomic level of water losses in part or all of that area. Little thought had, for instance, been given to the techniques and cost of finding and repairing leaks on trunk mains that were operating at the limit of their present capacity.

It was quite apparent that the subject of water losses attracted public interest about once every 30 years and in between these peaks of interest the priority for dealing with water losses took second place to other priorities and constraints that were politically fashionable at the time. For that reason he did not feel sensitive about presenting a frank paper on the traditional approach, for what they were looking at was not just water losses but the whole technical, financial, and political framework within which a water authority had to operate.

Discussion

G.F. BELL,(Newcastle and Gateshead Water Company) agreed that the general principle for controlling water losses had changed little over the years. It was the method of going about the search that concerned him; i.e. the method imposed on some undertakings by productivity scheme consultants whom he regarded as 'opportunists'. Unaccounted for water, or water that was not purposefully used by the consumer, was difficult to imagine. He had no doubt that the day would come when every branch pipe was metered, but he doubted if even that would help to determine where the water went and how it could be accounted for.

The heading 'prevention is better than cure' said it all. How often had they cut out an old iron pipe to find 3/8in metal on one side and ¾in on the other! How often had they exposed, for repair, odd-shaped castings with no spares for replacement! Standardization was undoubtedly necessary, but he wondered if Mr Pocock thought that they had gone far enough? He asked Mr Pocock how he got over the situation where an old existing main to which a new customer was to be connected, was shallower than the newly-laid supply pipe and the customer said 'but why should I have to lay my pipe with 2ft 6in of cover when your main is only 18in deep?'

Pressure control was a section which could easily, in itself, be a subject for a whole seminar. The old argument, 'in-house storage or not', still continued. He considered that in-house storage might well reduce consumption and consequently waste on a proportional basis, but the control of waste in general would be necessary and the same manpower still required to carry out the work. With regard to incremental correlation, it was difficult to estimate changes in losses resulting from greater changes in demand that developed from year to year. In the north east of England there was the recession of the traditional heavy industries and their replacement by light engineering units in other parts of the area, coupled with the resultant shift of population. Consumption had not dropped, but just in case their sums were wrong and there was much undetected waste, his company had decided to instal district meters.

They should not be misled, as Mr Pocock had pointed out under the heading Minimum Night Demand, by the inference, from figures from early tests, that leakage from mains and reservoirs was necessarily small. He had personal experience of having to strengthen the floor of a 1½ mg R/C Service Reservoir and at the same location, replace an 18in flanged pipe at the bottom of this 15ft deep structure.

He agreed with Mr Pocock that sounding sticks and the traditional approach to locating waste still had a place in our programmes. His company had purchased a Leak Noise Correlator and it was proving highly successful when a leak proved difficult to pinpoint. They should not neglect leakage from steel mains. He had personal experience of a steel sounding rod penetrating the bitumen sheathing and giving rise to corrosion. The main eventually became a sieve.

Management of waste had entered the realm of the professional and in a number of undertakings, a professionaly qualified water engineer was specializing in the prevention of waste as a top priority.

The question had been raised by Mr Pocock as to whether metering itself would produce any permanent reduction of per capita consumption in a modern prosperous society. Mr Bell considered that temporary reduction of demand might occur but only until the financial implications were analysed. Perhaps Mr Pocock would care to comment on the low level of renewals in the London area.

In conclusion, he too believed that the momentum of the previous good practice had 'flagged' in recent years. He believed that the monotony of travelling in vans and the lost contact with the general public had contributed to the loss of momentum. It would be difficult to restore, but not impossible. He thought they would all agree, however, that the basic ideas for controlling water losses were unlikely to change.

E.G. MOSS (North Surrey Water Company) said that he wished to make observations on two points in Mr Pocock's paper. Firstly about the time honoured Metropolitan Water Board tradition of turning off supplies which were wasting water. The former MWB led the field in a number of ways but this power was not available to most water undertakings. Mr Moss said that he had never worked in an undertaking with the power to disconnect for waste of water but that from time to time many engineers had faced the problem of the reluctant consumer who allowed his overflow to run to waste, often to the annoyance of a neighbour, but who despite notice and threats from the water undertaking persisted in allowing the waste to continue. He was not one of those who advocated the return of capital punishment but oh for the power of the MWB to turn off for serious leakage!

Secondly, about Mr Pocock's claim for increased labour in the location and repair of leakage. Mr Moss said he was sure that this point would be reiterated throughout the symposium. The Water Research Centre had pioneered improvements in equipment and techniques for the detection of leaks but ultimately leaks could only be located and repaired by manual effort. This was labour intensive and this point was also highlighted in the papers by Mr Ingham and Dr Rees.

Mr Moss illustrated the reduction of water consumption by application of increased man hours in waste detection by showing graphs of the consumption in gallons/head/day in the former South West Suburban Water Company between 1948 and 1958 following the introduction of systematic house to house leak detection on the pattern described in Mr Ingham's paper. The Company had reduced the average daily supply from 6.75 mgd in 1947 to a figure of less than 3.5 mgd in 1950 which did not return to the 1947 value until 1958 despite a continuing increase through the period in the number of properties supplied. The graph also showed that the defects found per year fell from over 8,000 in 1948 to around 3,000 in 1958 and demonstrated the law of diminishing returns.

He said that water undertakings were indebted to Work Study practitioners for reduction in manpower but there was nevertheless a problem in adequately rewarding waste detection teams when by increased effort the number of leaks found was progressively reduced.

B.H. ROFE (Rofe,Kennard & Lapworth) said that the paper was extremely useful in identifying a need for the continuing application and utilization of experienced teams to control water losses. The paper also identified the difficulties in maintaining the traditional approach; the reductions in staff and the restrictions on times of operation under good present employment practices.

The National Water Council Standing Technical Committee on Sewers and Water Mains had been considering this matter for some time, and Sub-Committee 1 on Hydraulic Design and Planning had established a number of areas of research to improve the present situation. These could be summarized as being requirements to identify the system. In particular it was important to be able to take continuous and repeatable measurements at different points in the system, and to this end research was being carried out at Water Research Centre on alternative meters and other instrumentation for this purpose.

Once adequate records of the system had been obtained and suitable flow and pressure measurement instruments were available, it was then possible to carry out a network analysis. The technique and application of network analysis had been known for several years but was still not applied to any full extent in existing systems. It was suggested that the main reason for this was the lack of time available to acquire the necessary information. However, on every occasion when an authority or company had made the necessary investment to establish the records of their mains and carry out flow and pressure measurements, the resulting findings from the network analysis had established savings considerably in excess of the cost of carrying out the study. Would the author comment on this?

A. HOWARTH (Asian Development Bank) stated that although he was not in a position to comment on the percentages of unaccounted for water shown in Table IV of Mr Pocock's paper (which applied to developed countries), he could provide some data and information on unaccounted for water associated with 35 or so urban water supply projects in 12 developing member countries in Asia which had been financed by ADB over the last 10 years and for which ADB had provided about $780m in loans. The ADB, when financing a project, not only appraised the specific project for which financing was requested but also required that an in-depth analysis be made of the distribution system. The reason for this was the obvious one that there was no point in providing a loan for additional supply capacity if a large percentage of the water that was to be supplied, and the water presently being supplied. was unaccounted for. In the majority of urban areas in the developing member countries of the ADB unaccounted for water prior to the introduction of comprehensive distribution control programmes had been between 40 and 50% of the water supplied to the system. With the exception of three projects, all urban water supply projects financed by the ADB have all service connections metered. In all recent projects ADB financing includes the provision of meters for both supply source works (existing and proposed) and consumers' meters. It was realized that an acceptable percentage of unaccounted for water was difficult to define and must, of necessity, vary from one water supply authority to another. However, ADB's experience to date showed that between 20 and 25% could be obtained without too much difficulty if the reduction of unaccounted for water was given the attention it deserved. If the majority of a distribution system was in relatively good order a figure of 15 to 20% had usually been adopted as a target. For those systems where an extensive programme of relaying existing pipelines and services needed to be undertaken and the system was relatively old 25% had been generally adopted as the target. Experience to date showed that for the majority of the systems the above percentages could be achieved if a comprehensive approach to the reduction of unaccounted for water had been adopted. This entailed such measures as: the provision of efficient meters throughout the system backed up by regular meter reading and maintenance of meters; routine leakage detection carried out by night flow measurements by isolating specific parts of the system; detailed surveys of consumer properties to detect illegal connections; and public information campaigns. To reduce unaccounted for water in the major cities with populations of several million appeared to be the most difficult and progress had been the slowest in reaching acceptable levels of unaccounted for water in these cities. A notable example of what could be achieved was in the case of Singapore where the percentage of unaccounted for water was about 10%. The supply system in Singapore was such that with the high marginal cost of water in Singapore it had paid the authorities to keep the percentage low. However, this authority provided a good example of what could be achieved provided a water supply authority was prepared to adopt a comprehensive programme to reduce unaccounted for water and work hard at the programme.

R.H. MORGAN (Rickmansworth and Uxbridge Valley Water Company) referred to the author's statement that the financial returns were not the same for equal reductions of waste in metered and unmetered premises, and commented that it would be a strange charging policy indeed that had a metered water rate lower than the unit cost of leakage. It followed that the reduction of waste on metered premises was almost always financially disadvantageous to the water undertaking. In view of this 'penalty' the author was requested to comment on the relative emphasis which should be placed on detection of waste in the two sectors.

Author's reply

Mr Pocock noted Mr Bell's critical reference to bonus schemes, and observed that waste control seemed to be poorly suited to bonus conditions if it merely represented speedy completion of a routine. Possible solutions were to change the present concept of bonus payments for such work or to identify waste parameters that could be regarded as evidence of proper completion, even if different levels of waste were justified in different locations. He also agreed that universal metering would be of limited value since most customers had now been offered meters in such a position that underground leakages would not be registered. On the question of standards he felt that innovations should be welcomed when materials, dimensions, and designs could be modernized together. This was what happened in the case of ductile iron, and the same principle could be adopted with regard to the medium density polythene pipes or new OSV assemblies. Mr Pocock noted with interest Mr Bell's reference to the advantages of 'in house' storage in controlling water losses and felt that poor performance of the Portsmouth type float-valve had obscured this advantage. He looked forward to its compulsory replacement by the diaphram type float valve. The low level of mains renewals in London was partly accounted for by the non-corrosive nature of the water and past good standards. A planned renewal programme introduced by the former Metropolitan Water Board had not survived present financial pressures, and renewals were seldom found to be justified on purely economic grounds.

Mr Pocock noted Mr Moss's interest in being able to shut off the supply to customers who caused waste, but pointed out that this power, which the public seemed to accept, was coupled with an absence of power to recover all costs for searching and reporting leaks on private pipework. He found it difficult to understand the efficacy of house-to-house inspection alone, unless some other factors were involved, such as a predominance of leakage on service connections, or an absence of plastic pipes.

With regard to Mr Rofe's suggestion that network analyses were self-financing, Mr Pocock agreed that this was usually so when new works were involved, but he had no evidence of financial advantage under other circumstances. Waste water meters were usually of inadequate capacity to indicate peak nodal demands, especially under summer conditions.

Mr Howarth's observations on levels of waste in the Far East were most interesting, but, as water control was a labour intensive activity, the optimum balance of effort should, presumably, differ in different countries. Some information on waste control overseas had already been collected on behalf of the International Water Supply Association.

Mr Pocock was pleased that Mr Morgan had recognized the import of his comments on the relationship between metered charges and savings from waste control. It should, however, be recognized that money was not the only factor; nearly every public enquiry was based on environmental arguments, and he doubted whether neglected waste of metered water would be accepted in court as an 'unavoidable cause' of failure to maintain statutory pressures as specified in the 1945 Water Act.

4. ALTERNATIVE WASTE CONTROL METHODS

"You never know the worth of water until the well is dry"
(attributed to Benjamin Franklin)

By F Howarth T Eng (CEI) FIPHE, FRSH, MBIM* and P Olner BSc **

This paper examines alternative waste control methods, it includes a note on the development of schemes for testing and approval of fittings, an explanation of leak correlation and various water saving devices, including design of W.C pans and gives details of experiments which have been carried out to demonstrate the effectiveness of some of the devices. The Wessex Regional Telemetry scheme is described together with results achieved and the paper concludes with a comment on how existing developments could be advanced.

INTRODUCTION

There is no mystique to waste detection, and the results achieved in waste eradication are in general proportional to the amount of effort put into planning, tracing, sounding, locating and repairing. Mr John Pocock has dealt with the traditional approach, this paper seeks to examine alternative waste control methods in the light of technological developments and the need to ensure maximum utilisation of both manpower and technical resources. Historically speaking, waste detection has been a matter for concern since waterworks were first established and throughout the 19th Century as industrial development burgeoned and towns grew, so did the wastage from water distribution systems. Reed (1) refers to an extract taken from a report in The Times newspaper for August 24th 1896. This followed a period of prolonged drought in the capital and stated "Waste goes on mainly in three ways, defective fittings, wanton carelessness and excessive use of garden hoses". The report concluded "Whatever else is done in the way of increased storage or fresh sources of supply, the constant service must be accompanied by an effectual system of waste prevention". That statement is as true today as it was in 1896. Since then, technology has moved on by leaps and bounds yet the problem of wastage from the distribution system still remains. However, there are heartening developments which enable better assessments to be made not only of how much water is being wasted but perhaps more importantly, the costs to eradicate such leakages are becoming better understood. An earlier appreciation of the whole subject was given in 1957 by Gledhill (2).

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** P Olner is Electronics & Communications Engineer Wessex Water Authority

EXAMINATION AND APPROVAL OF FITTINGS

Ingham (3) refers to the need for reminding the reader and the industry of the magnitude of the system beyond the stopcock. Whilst the numbers of fittings in the UK are probably not so numerous as the myriad grains of sand on the seashore, nevertheless we could be talking about 150 million plumbing fittings. It is therefore opportune to consider these 150 million potential points of leakage and following the adage "Prevention is better than cure", examine the facilities available for ensuring fittings in the widest sense of the word are at least approved for use and installed properly. I cannot at this stage resist the temptation to include a quotation from the Worshipful Company of Plumbers Ordinances for 1365 which stipulate that a plumber should submit himself to examination so that "The trade might not be scandalised or commonality damaged or deceived by folk who do not know their trade". These are timely words indeed and as true today as they were in 1365. This whole topic has been considered by the Water Industry over many years and arrangements for testing have ranged from very localised organisations to the more formalised system operated by the former British Waterworks Association.

UNITED KINGDOM SITUATION

The Water Act of 1973 placed certain responsibilities on Regional Water Authorities for testing and approval of water fittings and on the 26 October 1977, the National Water Council approved a scheme for the testing and approval of water fittings pursuant to the Water Act of 1973.

The objects of this scheme are to make provision throughout the United Kingdom for the assessment and testing of water fittings to ascertain whether they comply with the byelaws for preventing waste, undue consumption, misuse or contamination of water and with such other regulations as may be made from time to time, and to establish such administrative, technical and financial arrangements as may be appropriate. The organisation consists of the Management Committee and the Technical Committee which is sub-divided into a Fittings Assessment Panel (F.A.P) and a Test Criteria Panel (T.C.P). There is one other Committee, namely the Consultative and Liaison Committee, which includes not only members from the main Committee, but also outside representatives from such organisations as the British Standards Institute, National Brass Foundry Association, British Plastics Federation, Copper Tube Fittings Manufacturers Association and others etc. The functions of the Consultative and Liaison Committee are to consider any question relating to or arising from the operation of the scheme and to make recommendations thereon to the Management Committee or the Technical Committee as appropriate. The scheme came into force with effect from 1 January 1978 and the Committee has recently published a completely new version of approved water fittings. At the present time, the question of a suitable mark for National Water Council approved fittings is under consideration and it is hoped that when this has been accepted, it will be a very useful guide for inspectors in the field to enable them to speedily determine whether or not a fitting is approved. The whole concept of fittings as a source of leakage is one worthy of study and Reed (1) reported that from an international examination of the subject, 33% of total leakage was estimated to be from consumers fittings and pipes on premises. The figure is even higher in the United Kingdom, over 41%. This may be in part due to the lack of domestic meters which in the United States of America and Continent of Europe act as incentives to consumers to effect economies by promptly repairing or replacing leaking fittings, since by so doing, they can directly influence their water charge.

FOREIGN FITTINGS

The number of foreign fittings arriving on the British market appears to be increasing and whilst some are acceptable from a byelaws point of view, there are others which have not been accepted by National Water Council. It is when faced with non approved or non British standard fittings that great care is essential to prevent the initiation of a potential problem in a few years time.

LEAK CORRELATION

The latest development of a leak correlator has dramatically improved the position in tracing difficult leaks. This instrument has been developed by the Water Research Centre working in conjunction with the Electronics Industry, and whilst traditional methods are successful in many cases, it is in locating difficult leaks eg at road junctions where the correlator proves its worth. Recently, in the Wessex Water Authority several long outstanding leaks have been located and repaired, the most significant was occurring in an old portion of a seaside town. It was known a leakage had been occurring in this particular area probably for as long as three years, but repeated efforts had failed to find it. Using the correlator the leak was pinpointed to within half a metre and over the past few months, 93% of leaks located by the correlator have been within this limit. The correlator has also been used for more routine leak detection and over a period of 7 working days detected 12 leakages which accounted for 7275 l/hour. Repairs by the Authority amounted to £270 and water saved as a result of the repairs, was estimated to cost over £2000 per annum. Had the correlator not been used in this way, it would have been necessary to undertake labour intensive conventional operations which may or may not have been successful.

Method

Water escaping from a pressurised main generates a characteristic noise which travels along the pipe in both directions from the point of leakage. The level of noise will vary with the pipe size, type of fracture and pressure but the velocity will be constant. The noise is detected and converted into electrical signals by transducers placed either side of the suspected leakage up to a maximum distance between the transducers of 250 metres. The comparison is achieved by electronically delaying one of the signals and searching for similarity in the other. When the correlation is achieved, a plotter shows a typical high amplitude pulse. The time delay for this pulse to be produced is measured by means of a calibrated time trace. Cross correlation minimises the effect of noises other than the continuous leak noise so tracing can be carried out in a very high ambient noise situation which is one of the advantages of the technique which is illustrated in figs 1-4.

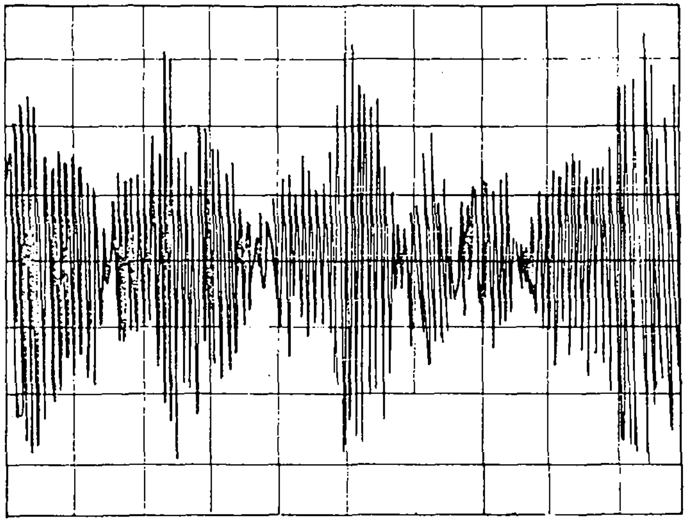


Fig 1 Typical Correlation Pulses

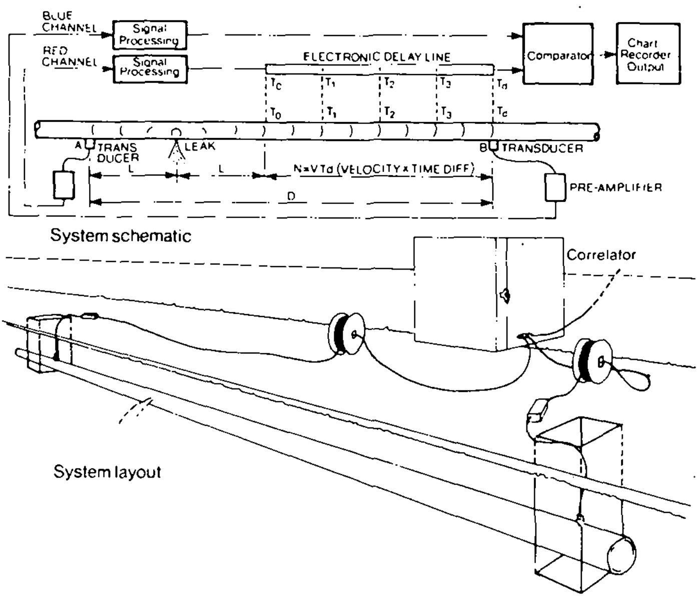


Fig 2 Typical Layout of equipment for correlation exercise

In this system the relationship between distances D and L time difference (Td) and velocity (V) is given by D=2L+(VxTd).

The time difference Td is given by the correlator and the distance D is measured out using either a conventional measuring tape or preferably a measuring wheel.

Technical Description

The processor within the correlator has three main functions:-

(1) To time shift one signal with respect to the other by using a delay line.

(2) Measure the cross correlation coefficient.

(3) To plot an output which enables the delay time to be measured when maximum correlation occurs.

The processor enables one wave form to be compared with another one but of different time shifts looking for similarity of wave shape. The point of maximum similarity is indicated by the maximum amplitude of the output plot, this is known as a delay time. If one transducer is fixed making a reference point and the second moved sequentially to other points (fittings on the main), then a family of these time delays will be obtained with different times depending on the transducer spacing referred to the source of leakage.

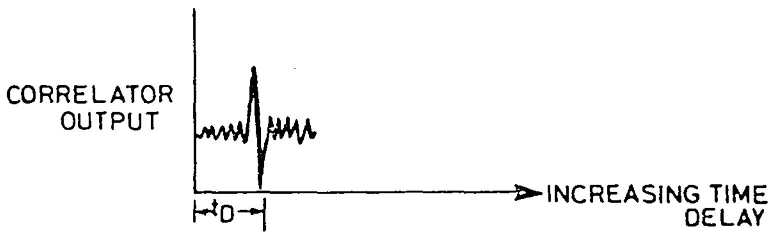


Fig 3 Typical Correlator Output

Plotting the Leak Position

Plotting the time delays obtained against the moving transducer position for each correlated pair results in a typical diagram as shown. The point of intersection of straight lines drawn through the plotted points, one straight line passing through the reference microphone position, extended to the detector position axis gives the leak position.

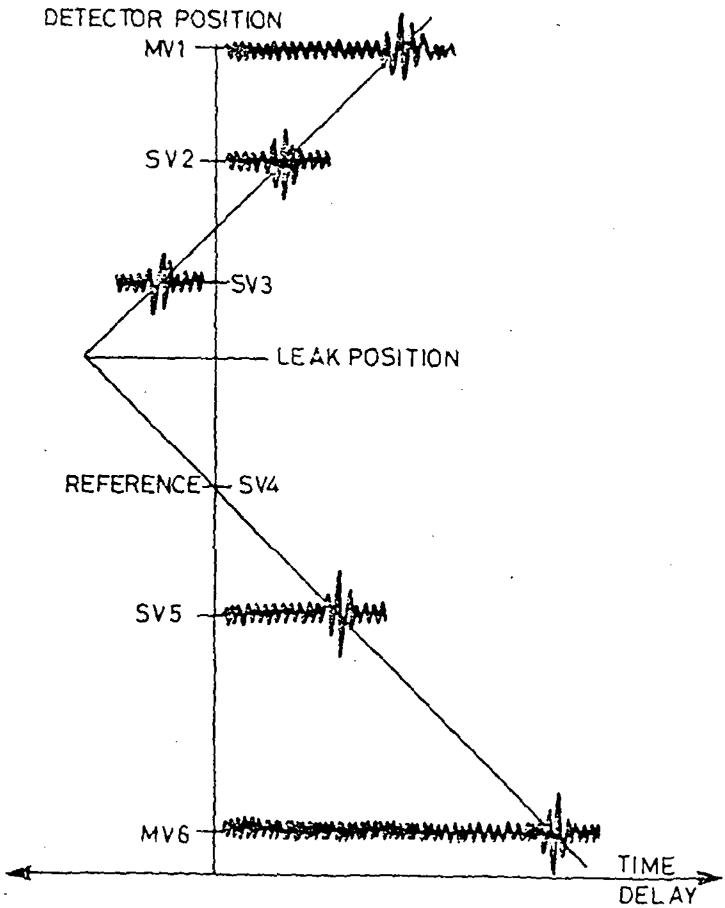


Fig 4 Plotting the leak position

W.C FLUSHING
WATER SAVING DEVICES

Although the recent byelaws permit the use of dual flush devices which allow a half or full flush at the discretion of the user by either depressing the flush control half or fully down, or by adjusting a dial indicator, there is scope for the development of variable flushing devices. Work undertaken on evaluating the amount of water saved by variable flush devices indicates there are substantial savings to be made and one such experiment is detailed later in the paper. The Building Research Establishment have developed a variable flush device from a design of Mr Skevington which will flush from a small quantity up to the full nine litres (two gallons) of normal cistern capacity.

This simple device is likely to cost in the region of £1 and already one Regional Water Authority is providing these free of charge to all households who decide to take up the metering option. This larger experiment will enable useful information to augment the existing experimental results. The device is simple yet robust and easy to install and operate. It relies for its effectiveness on breaking the siphon by introducing air after the desired flush has been achieved, thus breaking the flow of water through the siphon. The principle of variable flush devices is commended by the Monopolies Commission in their recent report on Severn Trent Water Authority.

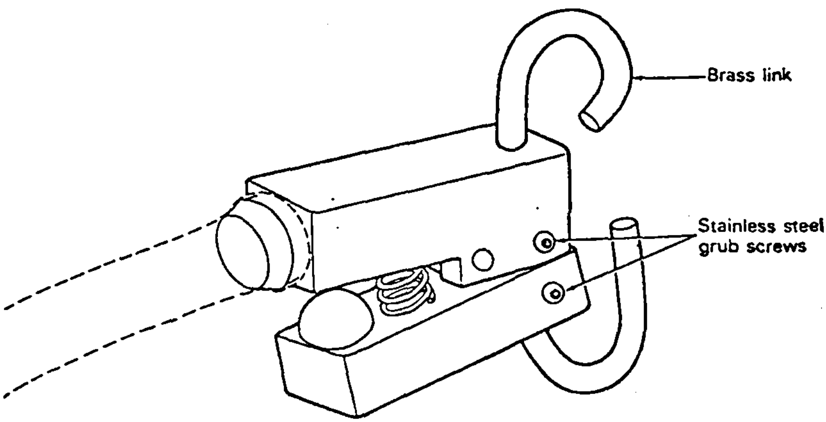


Fig 5 Skevington/BRE valve

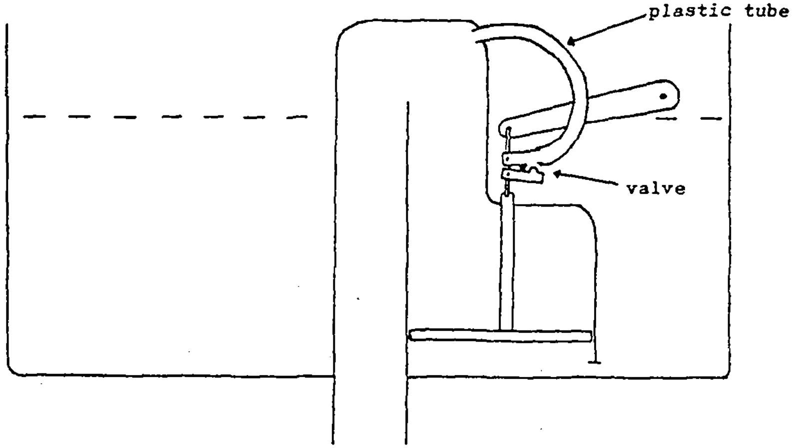


Fig 6 Section through typical converted cistern showing installation of variable flush unit

VARIABLE FLUSH STUDY - MELKSHAM

This study considered both types of devices although only the Skevington/BRE valve is illustrated in this paper. Properties were chosen using a systematic random sampling method, and then they were inspected to see if the occupants were willing to participate so the necessary components could be installed. Meters were fitted on the supply to each W.C and counters fixed to record the number of flushes to individual W.C pans. Once installations were completed, meters and counters were read weekly for a period of two months prior to the actual conversion of the W.C cisterns in order to determine the pre-experimental use of water for W.C flushing. The variable flush units were then fitted and commissioned and each householder visited after six months to see if any problems had arisen.

During the study the Building Research Establishment surveyed drains of ten of the houses using a CCTV camera, conditions of drains were noted immediately before the W.C's were converted and gradients measured. Twelve months later they were inspected once more and there was no evidence of blockages, and no drain blockages were reported by individual householders taking part in the study.

Results

About 85% of W.C cisterns in the area under review were converted to dual or variable flush operation using a simple device. Average domestic consumption worked out at about 104 litres/head/day of which approx 39% was used in W.C flushing. The study showed up to 40% of W.C flushing water could be saved amounting to about 15 litres/head/day. Since a number of cheap robust valves are available to convert W.C cisterns the possibility of using this conversion as an alternative to resource development is relevant.

IMPROVED DESIGN OF W.C PANS

Significant reductions in the amount of water needed to clear W.C pans can be achieved by improving the basic design of the pan. Already one pan has been approved by National Water Council for use in this country and this is designed to clear solids using a six litre flush. Work is currently being undertaken by BRE and others on W.C pans designed to clear using a three litre flush. It is too early yet to forecast the outcome of these experiments but early results are encouraging and particular attention is being given to the effects on the sewer system. This approach can only be a very long term solution and the short term solution lies in the use of variable flush devices. However, if the experiments demonstrate successful savings there is no reason why all new property should not be fitted with three or six litre flushing units commencing within the next few months, subject to any relaxation of existing byelaws being considered necessary.

FREE TAP & BALL VALVE REWASHERING

This service has been provided by some undertakings for many years but due to labour and transport costs, it appears in some instances to be being phased out. Whilst it is sometimes difficult and expensive to re-washer ball valves, cold direct mains taps are a fruitful source of wastage, indeed Middleton (5) noted "That there are few houses in which one or more taps do not drip and a dripping tap may mean as much as the loss of ten gallons (45 litres) of water a night, whilst the useless and pernicious waste of water in gardens for no purpose is deplored". This topic is covered in some detail by Ingham (3) and so I must not pre empt what he has to say other than to add, if it can be shown to be advantageous on cost grounds, then this can be a worthwhile exercise. However, much depends on the value of the water saved. In a simple gravity system, it may not be justifiable on cost grounds to provide a free service but a pumped system could show a very different result. However there are other benefits not solely related to cost, the presence of an inspector meeting consumers in their home is a valuable PR interface with our consumers whom we seek to serve and it also provides a facility for the inspector to see other problems, and not least it reminds the consumer that as an industry we care about wasted water. It is all part of the development of an image which in the opinion of the authors is well worth fostering.

PROVISION OF SPRAY TAPS

Spray taps are an effective way of cutting down on water use particularly in office and industrial situations. These should be incorporated along with other devices such as timing devices for urinal flushing and showers etc. Unfortunately in the domestic situation there is little inducement for economy in water use for various domestic appliances although this position may change as household metering gets under way. Washing machines, dishwashers, waste disposal units and water softeners are all potentially prolific water users and it is suggested that good housekeeping could be encouraged by issuing all approved machines with a design centre type of award indicated by a suitably designed eye catching label. This could be a selling point for the particular appliance along with and running complementary to National Water Council approval.

HOUSEHOLD METERING

The introduction of household metering has been primarily brought about on equity grounds, but it is likely to have some effect on water consumption if the take-up is significant. High peaks of summer demand would then be paid for instead of being virtually free as they have been up to now. However, it is far too early to make any quantitative forecast of what the real effect is likely to be on the demand position, although enquiry abroad does indicate that savings occur.

FLOW RESTRICTING DEVICES

A water flow restricting device for insertion in taps has been patented by one of the members of staff of Wessex Water Authority and although this device is not yet in commercial production it is indicative of the ingenuity which people are prepared to bring to the subject of water economy. Without doubt, the great drought of 1976 focused consumers attention on the subject and rising costs generally have brought home to people the need to economise.

TELEMETRY

One of the most significant recent contributions in the field of alternative methods of waste control in the Wessex Water Authority has been the development of the regional telemetry scheme. Wessex has had a telemetry system of some form for many years but it was not until 1978, that it embarked on a scheme which was designed on a regional basis. The Wessex Region is managed on a multi-functional basis and the telemetry scheme reflects this by providing facilities for:-

(a) Management of water supply resources;

(b) Management of water supply distribution;

(c) Monitoring of sewerage disposal;

(d) Flood warning;

(e) Water quality monitoring;

Initially three areas (Chippenham, Dorchester and Taunton) were included in the scheme. In each of these areas, new instrumentation, control valves and systems have and are continuing to be evaluated to enable the most advantageous developments to go forward on further expansion of the system.

The scheme has been designed on the basis that a telemetry master station is established in each area control room with communication links to remote plant from monitoring and control data. Information is displayed at each area control with similar information displayed at the appropriate divisional office and Regional Operations Centre where control facilities are also available.

During normal hours the areas control their own system and set operating patterns and limits. At the end of each working day full monitoring and control of the systems is switched to the Regional Headquarters, Bristol, where the Regional Operations Centre is manned 24 hours a day - throughout the year.

The Area Control Centre equipment is a single mini-computer configuration which controls the telemetry equipment, evaluates collected data, reports exceptions, displays on demand all primary and derived data, together with summaries and trend analysis on a half hourly and daily basis. In addition it allows remote manual and automatic control of various pumping and distribution operations in the system.

Initially, there will be up to 40 outstations (remote plant units) in each area, ranging from single point facilities at pressure measuring points to multi-range facilities at pumping stations. The distribution system is sub-divided into zones for control and monitoring purposes with remotely controlled valves regulating flow and pressure.

By providing remote monitoring and control, the Regional Telemetry Scheme gives Operations Staff an indication of potential problems which enables remedial action to be taken in good time. This means the Authority is able to provide a better service for the consumer and reduce costs by efficient pumping, pressure control and waste reduction.

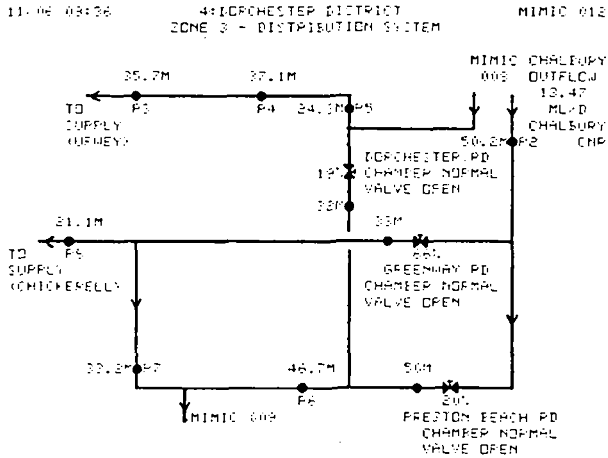
A NEW LOOK AT PRESSURE REDUCTION

Gledhill (2) stated "Excess pressure means waste" and this without doubt has been proved on countless occasions over the years. During the design stage of the regional telemetry scheme, it was decided to select a zone in both Dorchester and Taunton areas for the installation of control valves, with the object of controlling distribution pressures and waste. Network analysis was used to select the best location for the valves and also the critical locations for the installation of control (and monitoring) pressure measuring instruments. Valves were installed on the three trunk mains serving the area which in the case of Dorchester included the seaside town of Weymouth. This has a mixed distribution system, some of it dating back into early Georgian times. Inter-linking of the trunk mains within the zone is shown in Fig 7. In Taunton the zone selected was further divided into six sub zones and each sub zone provided with a single valve on the main serving that area. Each sub zone was thus isolated, see Fig 8. Different types of valve were selected for evaluation - Eccentric plug with electric actuators in Weymouth and conventional weighted (spring loaded) p.r.v's with hydraulic actuators in Taunton.

METHOD OF CONTROL

The method of pressure control adopted was "closed loop control through the telemetry computer" (fig 9).

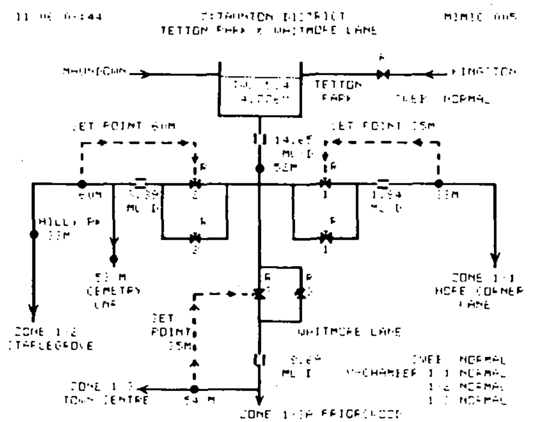
Pressure is monitored at a remote point in the distribution system and the pressure value telemetered back to the area control centre where the measured and desired values are compared. Any discrepancy between measured and desired value results in a corrective control action being telemetered to the valve site where the valve is inched, "open" or "closed". Corrective actions are issued every minute. An important feature of the system employed is the facility to make the desired value, time variable and easily modifiable by the supply engineer at the area office. Thus the desired value profile can be tuned to cater for day and night-time variations. In addition, there is a facility to have a different desired value pattern for each day of the week.



(a) Valves controlled to maintained P3 at desired value.

(b) Desired value 22m (day): 16m (night)

Fig 7 Dorchester - Inter linking of Trunk Mains



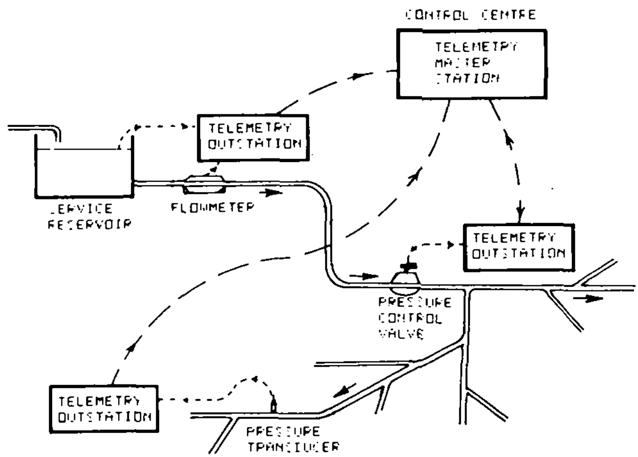
(a) Valve configuration consists of control valve with bypass.

(b) Control pressure fed back to computer and compared with desired set point value.

(c) Corrective controls sent to valve.

(d) Valve configuration [illegible] bypass valve open.

Fig 8 Taunton Sub Zone



PRESSURE CONTROL:

Closed Loop Control through the Telemetry Computer.

Fig 9 Method of Pressure Control

In the Weymouth area the pressure is maintained within 1m of the desired value. To prevent valves over-compensating (hunting) the valves are allocated a pressure band outside which they will operate ie one valve will operate for a discrepancy of 1m, two valves for a discrepancy of 2m, all three valves outside limits, 3m. The order of valve operation is easily selected by the supply engineer from the area office.

An alarm is initiated if the pressure deviates by 5% from the desired pattern.

Results

The results to date are most encouraging. The "night line" for Weymouth, which suffers from many very old and poor condition pipes and services, has been reduced from 14.4 to 6.1 litres/property/hour and the average daily consumption has been reduced by 10%. In addition, the number of burst mains has fallen by about 50%. The result has been a saving of about £9000 per annum on pumping and repair costs.

In Taunton the "night line" has shown similar reductions (57%) with the average daily demand reduced by 5.3%.

Some problems have been encountered with the valves and actuators in Taunton and alternatives are being considered. The performance of the eccentric plug valves in Weymouth has been generally satisfactory.

Alternative forms of control have also been adopted which employ closed control through local instrumentation. These are mentioned below and the second system may be employed where comprehensive telemetry facilities are not available.

(a) Pressure is monitored at a remote point in the distribution system and the pressure value relayed to the valve location and forms an input to a 2 term controller. The desired value is telemetered from the area control centre to the outstation and forms the reference input into the controller. The discrepancy between the measured and desired values initiates rectifying controls to the valve.

(b) Pressure is monitored at a remote point in the distribution system and is relayed to the valve location and forms an input into a controller. Within the controller is a programmed pattern of desired pressures for the 24 hour period. The discrepancy between measured and programmed values initiates rectifying controls to the valve.

FUTURE DEVELOPMENTS

The advancement made in computer based telemetry schemes presents a real opportunity to grasp the vexed question of Unaccounted for Water levels throughout the water industry. Could competitive business for example put up with losing 25 to 30% of its basic product. We venture to suggest this is doubtful. Telemetry gives the water engineer a ready means of adjusting the system to his requirements. For example minimum pressures at a given point can be set and the telemetry programmed to make the most economical use of sources and determine how the distribution system should run. By noting trends on various areas of the system, it is possible to deploy waste gangs to concentrate effort where the need is greatest.

Traditionally methods of waste detection have demanded paper orientated systems, but much of this can now be eliminated by the use of visual display units and disc storage. If this equipment is coupled to a map digitising system it all adds up to a most effective unit which can be controlled with minimum effort. Obviously the system will respond to what is built into the programme, and it is in the field of programming where some research would pay off. It is perhaps not too far fetched to consider waste detection, particularly in determining what is lost from the system being controlled from a central control without having to undertake labour intensive meter reading. I hasten to add this near utopian situation, where the demand is programmed into a computerised telemetry system which runs itself until it calls itself for action, is not with us yet. However it is fair to say telemetry has already shown what can be achieved and that it is a formidable ally in the fight to control waste.

Is it expensive? It all depends how you as the engineer "value" waste.

A further useful avenue to explore is the installation of variable flush devices, perhaps one way to get these brought to the attention of the public is to issue them free of charge as referred to earlier. Further development of the Leak Correlator particularly in the presentation of results is yet another area worthy of further study.

Attention should be given to meter accuracy particularly at low flows, because unaccounted for water levels in which there is a large element of metering could in reality be higher than the measurements indicate. This is a basic issue which must be resolved if we are to arrive at a uniform and reasonably reliable method for calculating amounts of unaccounted for water.

To sum up, there have been considerable advances in waste detection over the past few years, and providing resources are available to invest in a concentrated attack on leakage, the next decade and indeed up to the end of the century should enable a dramatic reduction to be achieved in reducing the amount of water running to waste.

ACKNOWLEDGEMENTS

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DISCUSSION

Authors' introduction

Mr Howarth said that the aim of the paper had been to show some areas of waste control in which advances were being made. Nationally the NWC/DoE report number 26 had directed attention to the subject and pointed a way forward. The NWC fittings approval scheme was also proving very helpful. Although fittings had to be marked by the manufacturers, inspectors still needed to possess Houdini-like characteristics to identify the appropriate markings on installed fittings, and it was to be hoped that a National Water Council mark of approval would be granted as quickly as possible. In the paper reference had been made to flushing and various other water saving devices, particularly low volume flush units, which could be fitted in new properties now if architects and builders could be persuaded to do so. Metering of households might be an alternative method of controlling waste. For example, Wessex offered an option to meter to all households from the 1 April 1981 and to date 2,000 options had been taken up out of a possible 34,000 properties, where in the opinion of the authors, the consumers would benefit. As the benefits became more widely known metering might begin to have a significant effect on water conservation, although it must be made clear that metering was introduced in the domestic sector largely on grounds of equity, and it was much too early to draw firm conclusions. With the Wessex metering packs each consumer was given two variable flush devices free of charge after deciding to take up the meter option.

One of the most significant technological developments in recent years had been the leak correlator. This machine had taken much of the estimation out of the leak detection process and put the art of leak detection on to a more scientific footing. However, the authors did not wish to minimize the excellent work which had been and continued to be done using more traditional methods. For example, wooden cupped listing sticks were still used, but for more difficult leaks the Authority now had the advantages of leak correlation. The instrument was housed in a walk-in type vehicle and was operated by one or two men. Maintenance of the correlator was undertaken by a member of the Authority's staff who had been trained by the manufacturer. The next step could well be to develop the correlator still further by making it more portable and simplifying the presentation of data, possibly in the form of a digital read-out.

To use the correlator effectively, good plans of the distribution network were vital. If the main had been offset or laid under sewers for example it was very important to work out the effective length of the main at ground level in order to obtain accurate results. The method was extremely accurate and an analysis of the last 100 leaks had shown that 60 were pinpointed accurately, 29 were within one metre of the position indicated, and the balance were within one to two metres. In fact the number of occasions when a miss was scored were very few.

Mr Saxton in his earlier paper had referred to source replacements of up to £200,000 per tcmd of yield and it was obvious very substantial sums of money would be necessary to replace decaying distribution systems. In one small area of Wessex alone over £4m would be needed to replace mains over the next few years and if these figures were extended across the country, even an optimistic calculation would show vast expenditure was necessary. Therefore in the opinion of the authors a good case could be made out for waste control particularly using alternative methods which had been developed in the light of modern technology, but calculations must be done first to see where the best return on investment can be made.

Mr Olner explained that telemetry provided the facility to monitor plant conditions and performance, and display data from that plant at a central point. In addition, schemes enabled remote actions to be carried out on the monitored plant. Thus, the generic term 'telemetry' covered telemeasurements, telesignalling, and tele-control.

To provide the ability to remotely monitor plant it had been necessary to instal new instrumentation, although a large proportion of this would have been necessary even without a sophisticated telemetry system connected to it. Electromagnetic flow meters engineered to provide high turndown ratios were installed together with electronic level measuring devices to provide high resolution and repeatable measurement of reservoir levels. These devices along with others were linked into the telemetry systems and measured data displayed on colour VDU screens.

The ability to monitor the system through telemetry and provide accurate data on variations in flows and pressures in individual distribution zones enabled areas where waste detection efforts should be concentrated to be highlighted.

To facilitate the application of telemetry to pressure regulation the distribution system had been divided into zones and subzones. Network analysis was carried out on the zones to determine:

(a) the locations where pressure measurement would be most critical;

(b) the locations where regulating valves would be most effective.

An installation in Taunton had a main feed from the service reservoir split into three subzones. Control and bypass valves were installed together with flowmeters. Within each subzone a controlling pressure monitor was installed. The distances between sites forming each of these zone systems could be many miles. All the information from each site was relayed back to the Taunton control centre. The zone pressure was compared with the desired pressure and corrective actions issued by the telemetry computer to the control valves.

A similar installation was in Weymouth part of the Dorchester Area except that here within one zone there were three valves controlling the one zone. Several pressure monitors were installed and one selected to act as the control reference. This selection was flexible and could easily be modified within the computer by the supply engineer. Figure 7 showed part of the distribution system where the measured pressure points were P6, P7, and P8; P8 being the defined control reference. Without control it was shown that the pressures were variable and at P8 the pressure at night reached 34m whilst during the day it dropped to 20m. Analysis and actual operating trials had shown that 16m was an acceptable operating pressure and consistent with meeting Wessex Standards of Service. During the day in summer months to meet the higher demand this pressure was increased to 22m. The desired 'pattern' was entered into the system by the supply engineer, the period of change from day to night operation defined and the system automatically controlling to that operating pattern. Figure 10 showed the situation before and after pressure control was applied.

The use of telemetry to operate the control procedure enabled modification to operating patterns to be incorporated easily and kept local plant equipment simple. Various other control systems were being developed and used in Wessex where there were only simple links between instruments and valve controllers. However, Mr Olner emphasised that when operating the system close to minimum acceptable pressures, monitoring over a telemetry scheme was desirable, not to say essential.

He concluded, by saying that he trusted that they had been able to demonstrate there were systems available which could reduce water losses but they were aware that in some areas the expense of detection or of control might not equate favourably with the savings achieved. With the increasing cost of water resources they must be continuously looking for improvements, and what might have only a marginal benefit now could become a significant investment for the future.

Discussion

R. HUNTINGTON (Wessex Water Authority) in opening the discussion congratulated the authors on providing a thought provoking paper ranging from basics to the sophisticated use of electronics as an aid to waste control. He suggested that for successful control of waste, all undertakings needed to choose a judicious mixture of established practices and the newer techniques now becoming available. However, no matter what systems were used, results would not be fully effective unless there was optimum staff commitment and this would not be forthcoming unless management deliberately spent time and effort on fostering and maintaining good communications and, not least, dealing with operators' worries relating to the effect of newer techniques on jobs. The authors' views on this, not least the impact on jobs and work patterns, would be appreciated.

Manpower was expensive and any method of waste control which required minimal labout must be given careful consideration: pressure control certainly fell into this category. Well tried and tested mechanical pressure reduction valves had their limitations in that they operated on the principle of providing a fixed pressure downstream of the valve, which was high enough to maintain the minimum acceptable pressure to cover peak demand periods. At all other times pressure was in excess of requirements. This limitation was not true of telemetry controlled networks in which pressures at sensitive points were relayed to a control monitor, which then transmitted a command signal to adjust valves and keep pressure at a required level. A development of this system was a 'stand alone' electronic pressure control valve, which could be installed anywhere in a distribution system without telemetry links. Such a system needed to be programmed to match an area's individual requirements and still be able to open up automatically to meet legitimate needs such as firefighting. A careful choice of valve location could result in beneficial adjustment to pressure over a wide area.

The choice of valve was important; the ideal was a valve which had an approximately linear relationship between opening and flow. The choice of potentiometer also needed care. The small additional expense resulting from the use of a good potentiometer able to match duty requirements was well worthwhile.

Wessex Water Authority had recently developed a 'stand alone' electronic control valve and had just embarked on a series of trials to ascertain its effectiveness. Early results were encouraging in that reductions of 15 to 19m were being achieved in an area during high pressure periods, with reductions in daily consumption better than 10%. Capital costs would be repaid by savings in operating costs over a period of two years.

Switching now to more basic matters, Mr Huntington said he thought he was right in saying that no mention had been made in any of the papers about pipe joints. This was rather surprising, because as far as leaks were concerned, this was the most vulnerable part of most pipelines now being laid. The use of rubber ring joints had many advantages, but were present joints likely to store up troubles for the future? He thought the answer was 'yes'. Perhaps a hundred year life could be visualized for pipe materials, but excessive leakage from rubber joints would have necessitated pipeline replacement long before the pipes themselves had reached the end of their useful life. Surely the industry should be actively engaged on urgent research aimed at developing joints which would have a life expectancy comparable to the pipes themselves. He said that consumers were deriving benefit from the good engineering of water engineers who practised their skills 30 to 100 years ago, and questioned the size of capital programmes without such an inheritance. Should present engineers show their thanks by handing down serious troubles to those who follow? Joint costs were about 1% of the overall cost of a pipelines, but it was the single most important factor affecting overall life expectancy. Doubling or trebling joint costs would have minimal impact on overall pipeline costs, but good designs could have a major impact on length of useful life. The industry should not be misled by the fashionable financial and net present value calculations which tended to be used to counter good engineering judgment. It was suggested that the problem was worthy of the Water Research Centre's attention.

Getting down to basics, it was regularly assumed that the standard toilet flush was 91 (2gall), but what percentage of toilet cisterns produced a flush in excess of this? A water level 15mm in excess of the standard resulted in flushes being about 12% in excess of the required 91. If the public could be educated to ensure that water levels in cisterns were not allowed to increase as washers bedded in, there would be a substantial saving in water usage.

Finally, he asked the authors whether they had achieved success using the leak correlator for plastic mains and what limitations, if any, they had found?

D.L. THOMAS (North West Water Authority) said that following the publication of the Standing Technical Committee Report No.26, an extensive study was undertaken in his authority to determine the current level of leakage and the most economic control method for any zone. The study started in June 1980 and took nine months. It involved considerable staff time with each of the seven dual-purpose Divisions using an average one qualified engineer assisted by waste engineers, technicians, supervisors and NTIC operatives when necessary. In the 290 supply zones covered, which varied in size from a few hundred to several thousands of properties, the physical measurement of the net night flows was undertaken involving service reservoir drop tests and extensive meter readings. Approximately 2.5m properties were included representing 85% of the total.

The results showed that of the average of 2450Ml/day supplied, some 835Ml/day (representing 34%) was lost through leakage. This figure was increasing and bearing in mind the age and condition of the system, it was unlikely that it would be possible to save the major proportions. However, it was essential that this leakage was kept to the economic minimum. It would (at present) be economical to reduce the level by some 10% of the total water supplied or 30% of the leakage. To achieve this, however, would involve an initial expenditure of £4.5m (Q2,1980 prices) to set up the control methods; the work comprising the planning and checking of new metered zones together with the installation of meters, (including extensive work on the distribution system to facilitate this), location and repair of the backlog of leaks. It was estimated that the effect on the net night flow would be to reduce the regional figure from 16.75 to 11.66l/prop/h. Ultimately, however, when considering detection costs versus costs of water saved, it was estimated that (again at Q2, 1980 prices) some £1.5m per annum could be saved on revenue budget. This figure took into account the additional manpower (estimated 60 posts) required to achieve the end results, whether that manpower be in detection or repair personnel. The latter group were of vital importance as unless they had the resources to repair the leaks, it really was pointless expending considerable effort in finding them in the first place. Table I showed the existing and predicted situations. Initially the Authority had approved an allocation of £1.1m for a two year period to concentrate on the worst (from an economic view) zones first. Subject to achievement and strict performance monitoring of results and costs, further allocations might be forthcoming. This guarded approval was caused by the concern on whether or not the empirical graph (shown on p5.4 of Mr Ingham's paper) which predicted the level to which leakage could be reduced, was applicable to the north west.

The authors had given some results of their experience in the use of the leak noise correlator. One such unit had been operating in the north west since September 1980 and after considerable teething problems was now obtaining a 70% success rate for correlation with 90% of these locating bursts within an acceptable margin. Such was the success that a further three units were being purchased. The authors' views were requested on whether the correlator should be used in all cases prior to excavation or should conventional sounding techniques be used with the correlator being used after the excavation of the first 'dry hole'.

To conclude, congratulations were due to the authors on an excellent paper and in particular the pressure control method. What was the size of the zones in Taunton and Weymouth where the method had been employed; how long did they take to set up; and how much did it cost?

Table I Leakage control in North West Water Authority (upper figure - existing situation; lower figure - possible ultimate solution)

Division	Number of properties covered by study	Total leakage, Ml/year	Average net night flow, l/property/h.	Percentage of properties subject to:				
				Passive control	Regular sounding	District metering	Waste metering	Combined metering
Northern	132,652	13,083	13.51	8	15	47	30	-
		11,378	11.75	4	-	52	14	30
Ribble	402,854	51,029	17.35	56	-	-	44	-
		23,352	8.62	1	-	39	9	51
Pennine	405,258	52,039	17.59	29	45	-	26	-
		34,682	11.72	-	6	45	4	45
Western	416,080	83,038	27.34	26	-	-	74	-
		60,721	19.99	20	-	16	-	64
Eastern	559,478	40,840	10.00	14	-	-	86	-
		44,890	10.99	2	4	90	1	3
Central	267,276	32,608	16.71	71	-	-	21	-
		15,766	8.08	1	-	63	7	29
Southern	309,667	32,213	14.25	37	25	18	18	2
		19,476	8.61	1	-	53	13	33
Regional total	2,493,265	304,850	16.75	33.14	11.46	6.59	48.55	0.26
		212,265	11.66	4.10	1.91	52.70	5.69	35.60

D. BEAL (Wessex Water Authority) commented on his Authority's experience with the leak noise correlator and described the factors that were taken into account when the decision was taken to further increase the number in use. It had enabled the productivity of the reduced numbers of waste department staff to be improved significantly as leakage was found more quickly. One man operated the correlator and coordinated the work with usually one other operator installing microphones. The investigation was normally carried out during normal working hours. Time spent on the essential work of step testing and laborious direct sounding was minimized. In this way it had been possible to reduce labour costs.

Particular consideration had been given to ensuring that the correlator was regarded as part of the normal range of techniques available to waste staff and not as complex equipment operated by specialists. A further reduction in the equipment size and simplification would in future even further improve its flexibility.

The operatives of the Waste Department had generally adopted leak noise correlation with enthusiasm and their confidence had grown with its obvious success in finding leakage when compared to conventional methods. It had been used successfully in those areas not so far covered by waste metering and in those with high ambient noise levels which prevented direct sounding from being used. It had enabled cross connections in older, poorly recorded mains networks to be rediscovered. Blanket application across extensive areas had been achieved with speed and effectiveness by quickly leapfrogging the microphones along mains. Some of those night lines which had failed to respond to numerous previous attempts by conventional methods had been rapidly improved by leak noise correlation investigation.

Increasingly the correlator was being used in those emergencies where supplies to consumers had been interrupted by a burst main that was difficult to locate. Where there was a limited supply of water available to locate the leakage, particularly in remote isolated systems or extensive rural areas, the time required to restore supplies could be protracted. The correlator could often speed up the process of elimination and as a result it could be said that the standard of service to the consumer had been significantly improved.

The Authority was evaluating carefully the cost benefit of the correlator. This process of comparison was being carried out over an extended period as it was obviously not possible to determine individually for any leak how the effectiveness of the Waste Department had been improved by use of the correlator. The technique was particularly suited to urban areas where there was abundant access to the mains through numerous valves and hydrants and where there was metal pipework which easily transmitted noise. The conditions generally applied to the older parts of the network which were usually most prone to leakage. Mr Beal reiterated the earlier speakers' comments concerning the difficulties in initially tracing and then locating leaking in PVC and asbestos cement pipes and polythene services when using a correlator.

T.J. WATSON (Severn-Trent Water Authority) said that the way in which Wessex Water Authority had applied modern telemetry techniques to reduce leakage was most interesting, especially the method concerning the control of pressure by telemetry means. The microchip really had changed everything. For the first time the water industry had the prospect of factual interrogation and control right across its distribution mains systems. In addition to treatment works, reservoirs, and pumping stations, it was now possible to obtain pressures and flows from key junctions and nodes on the mains system itself, on a continuous basis at low cost. This was the important difference because until now, pressure and flow recordings had been a matter of setting up instruments and recording charts, and manual interpretation of those charts at a later date. So many times the period chosen for the recording had missed a vital pressure or flow by a few hours; and so many times the recording needle had failed to register; and, of course, every exercise of this kind was expensive in manpower. The application of telemetry, backed up computer analysis, had to be the way forward for the water industry in waste detection.

Telemetry outstations, transmitting by cable or radio, could be established easily enough at points adjacent to an electricity supply and they could also be set up for transmission of information via public telephone systems. However, very often a junction of hydraulic importance on the water mains system was remote from both electricity and telephone links, and it was for cases like this that Severn-Trent's Avon Division had developed an electronic module system which is thought to have great potential. Fig.11 shows how this module system worked. It consisted of a portable waterproof solid-state recorder (cost approximately £400) containing four standard HP batteries, and a plug-in data module (costing about £250) also of the solid-state type. The device was connected to a rotary flow meter from which it picked up and remembered pulse signals on a time base.

Typically, flows every 10 minutes for a week or a fortnight would be recorded, at the end of which period the module was removed and brought back to the computer office. A software programme had been developed which would print out the recorded flows to show their digital value together with an analogue (histogram) which was essentially a waste meter chart. Thus, seven or fourteen days variation of flow was known in detail for every point monitored and a bank of information, available on demand, could be built up on the computer files. The Division was now at work to record pressure information in a similar manner.

This continuous data on how the distribution system behaved was important for all facets of its operation, maintenance, and development. Network analysis, growth, and change of demand, shortages, low pressure areas etc. may all be studied in addition to waste and leakage detection.

J.A. YOUNG (Wessex Water Authority) said that he was interested in Mr Watson's solid-state device for transmitting pressure and flow information. As part of the Wessex network analysis exercise they had found it necessary to develop similar equipment because of the inaccuracy and unreliability of commercially available equipment. Their first recorder was based on a standard cassette tape, but although the recorder worked perfectly satisfactorily there had been trouble with breaking and snarling of the cassette tapes, and they had now gone over to a full microchip system which could be plugged directly into the computer for analysis of results.

R.J. ELAM (Anglian Water Authority) said that there were two projects currently being undertaken in the new city of Milton Keynes which involved modern technology and would, it was hoped, produce better waste control methods.

The first related to remote meter reading. There were currently two systems being developed for the two-way transmission of data from customers' electricity, gas and water meters. The first of these used electricity mains as the communication medium: a field trial of this system would take place in 1982 in Milton Keynes and London. Water meters were currently being installed in the two Milton Keynes trial sites. The second system used telephone lines to transmit signals and would also be on trial in 1982. Although both systems were being developed around the facility for remote meter reading, one of the main benefits as far as the water industry was concerned was likely to arise from improved leak detection. Both systems could be used to rapidly detect leakage downstream of the meters by reading the meters at night. By looking for changes between these readings and the consumption on a master meter also linked into the system, distribution system leakage might also be detected much sooner than was currently possible. At the request of the National Water Council, the Water Research Centre was currently evaluating both of these systems.

The second project related to the remote control of waste meter districts. The new city of Milton Keynes had been built on a 1km grid square basis and water mains laid along the grid squares had had cables laid alongside them and routed back to the control room for the Milton Keynes area. At the control room there was already in existence a computer driven telemetry scheme providing control for pumps and reservoir levels, and the proposed scheme would provide for operation of remote control valves at node points on the grid mains system. Waste areas would be set up using a computer programme to shut down mains as in a normal step test, and flow information, provided by meters at the node points, would be monitored and recorded at the control room. It was hoped that the labour saved in the automatic shut down of mains for step tests could then be concentrated on finding leakages and, in addition, there would be the facility for continuous monitoring, should this be thought to be necessary.

S.J. GOODWIN (Water Research Centre) wrote that he was extremely interested in the use of the Wessex telemetry scheme to improve the control of pressure in the distribution system. Over the past few years the Water Research Centre, working in conjunction with the Working Group on Waste of Water had carried out a substantial amount of work on the effect of pressure reduction on net night flows. It was found that this effect was much greater than would be supposed from applying the square root law for flow through an orifice, and that by the use of a simple curve the effect of a given pressure reduction could be estimated enabling the likely benefit of that reduction to be weighed against the cost of achieving it. This work has been reported both in DoE/NWC Report No.26 'Leakage Control Policy and Practice' and in WRC Technical Report No.154. He would be interested to learn from the authors whether the reductions in leakage (net night flows) quoted in the paper fell in line with the results quoted in the above documents and also whether the additional reduction in leakage brought about by controlling pressure at a remote point rather than at the pressure reducing valve was sufficient to justify the expenditure on the equipment and communication links at that remote point.

Authors' reply to discussion

The authors agreed with Mr. Huntington that the question of joint reliability was of great importance. Already in the Wessex area there was some evidence that biological degradation of rubber joint rings had occurred. In some cases joints on mains were leaking after being laid a relatively short time in relation to the 100 years life quoted for pipelines. Some research had been undertaken by the Water Research Centre and resulting from this, manufacturers were in the process of introducing synthetic rubber rings to a special formulation which should not be subject to attack. It remained to be seen how successful these would be in service, but under experimental conditions encouraging results had been obtained. In the present financial situation it was unlikely that undertakings would be able to replace all joints on a defective system although this might be cheaper in the long term than repairing as and when the situation arose.

A good case could be made out for education through good public relations of all aspects of water economy. Whilst savings could be significant, undoubtedly a longer term return would be given by paying more attention to the amount of water needed to clear a WC pan of solids. The new 6l WC unit which was now available had much to commend it. This needed to be advertised so that architects and builders could begin to incorporate it in new property now. Water undertakings could also make it know that there were new WC pans on the market.

Although the leak correlator had proved a very useful tool in the fight against waste and new developments on this instrument were awaited with interest, the authors considered its use on plastic pipes had been rather disappointing insofar that they had only had limited success in tracing leakages on new PVC mains and service. This aspect was something which was worth following up in any development of the correlation unit.

The authors agreed with Mr. Huntington's comments on the importance of staff commitment. Operations staff working with the instrumentation technicians and engineers were and continued to be involved in the installation and maintenance of the systems. Telemetry had been viewed with suspicion but generally it had been found that by informing and involving both office staff and field operatives of what the telemetry was doing they had accepted and often welcomed its incorporation. The control rooms had become the focal point of the Areas' day time operation, with responsibility for the telemetry operations and also the radio with the ability to handle incidents, emergencies, and, most importantly, consumer queries. Operatives as well as senior staff had access to the control room, and rota systems in which more senior staff were included had helped to give all staff an involvement and appreciation of operations which were previously outside their normal duties.

Mr. Huntington's consideration on the 'stand alone' electronic control valve indicated the extensive developments being made within the Authority. In addition, control valve packages being employed in another of the divisions of Wessex Water involved the investment of £225,000 on 30 control valves with telemetry links resulting in an expected saving of 10% in energy.

The authors agreed with Mr. Thomas that there was no point in just finding leaks if resources were not available to repair them, and each area needed careful economic evaluation to see whether or not the advantages justified the cost of achievement. The approach of the North West Water Authority in concentrating effort where the need was greatest had much to commend it, but the authors considered that other parameters needed to be built into the equation: for example it might not be economic to undertake work in some areas but if the pressures in the system were very low and consumers were experiencing real supply problems there might be no alternative. Report number 26 was very useful in setting out the economic factors and considerations to be investigated before setting up a detailed method of waste detection.

In regard to correlator techniques the authors considered conventional sounding techniques should be used and correlation used for more difficult leaks, e.g. those which conventional sounding techniques had failed to reveal. Bringing in the leak correlator after the first dry hole had been discovered seemed to be a good starting point for the introduction of leak correlation and the authors would concur with this approach.

Supply zones varied in size from 14Ml/d for Dorchester to 1Ml/d for the sub-zones in Taunton. The times for implementation were in the order of two years from the placing of order to take-over of the telemetry system which included the incorporation of new techniques and automatic operation to meet the Authority's requirements. Site works involving valve and pressure monitors were installed and commissioned in parallel with the telemetry procurement. Costs for control sites ranged from £4,000 to £8,000.

The authors thanked Mr. Watson for his comments on their paper and heard with interest the developments being pursued within Severn-Trent. Wessex Water Authority had developed over the last several years pressure monitors using electronic recording that could be applied to any transducer system. Information could be recorded at 20s intervals for up to 24h or, by extending the interval, for up to a period of a week. These units were self powered using re-chargeable cells and linked to a processor system back in the office for analysis. These units were used in the network analysis from which the critical points were selected for continuous monitoring by the telemetry systems.

The information provided by Mr. Elam was of considerable interest and the authors hoped that when results were obtained these would be made available to other undertakers. The second project which involved the facility to obtain step tests and flow information by remote control was of particular interest. Wessex were proceeding in this direction and a pooling of information would be very useful.

The comments by Mr. Goodwin were appreciated and the preliminary checks of the Working Group's analysis in para. 5 showed reasonable correlation with those found in Wessex. The selection of various pressure monitors in a zone had shown that the trend of the extreme measurement point was reflected in the behaviour of the intermediate measurements points (Fig. 7). The pressure measurement local to the valve could be used for control in the event of failure of the remote monitor. The problem of using the local monitor was that the flow rate was not taken into account. The use of a remote monitor made the control algorithm simpler, with automatic compensation for flow variations.

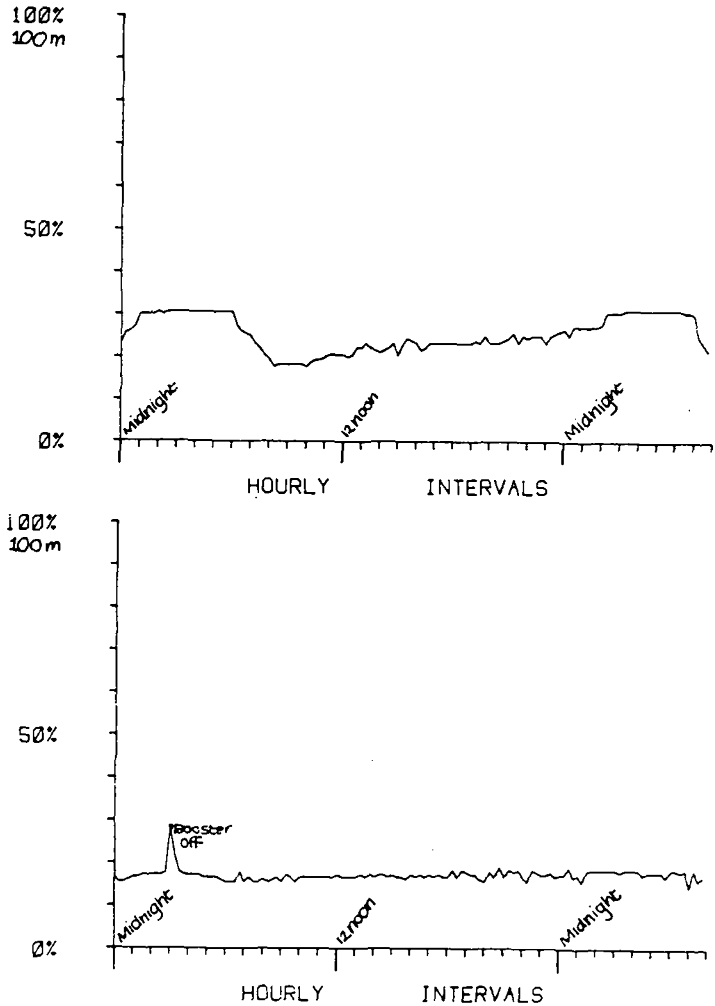
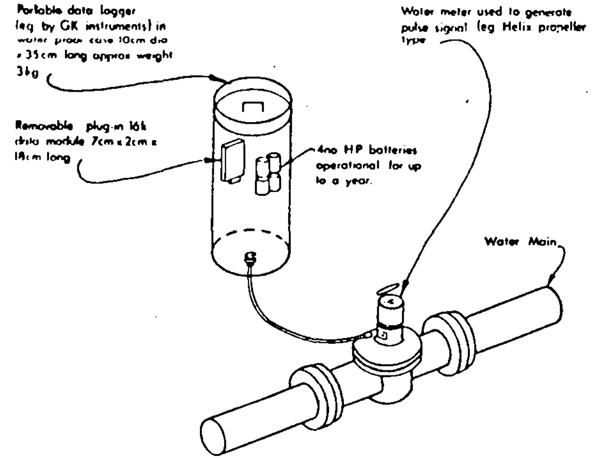
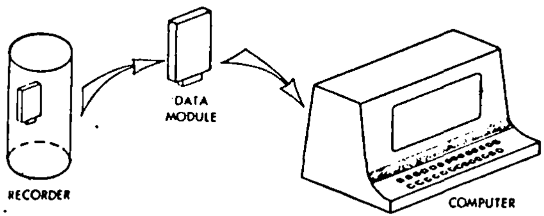


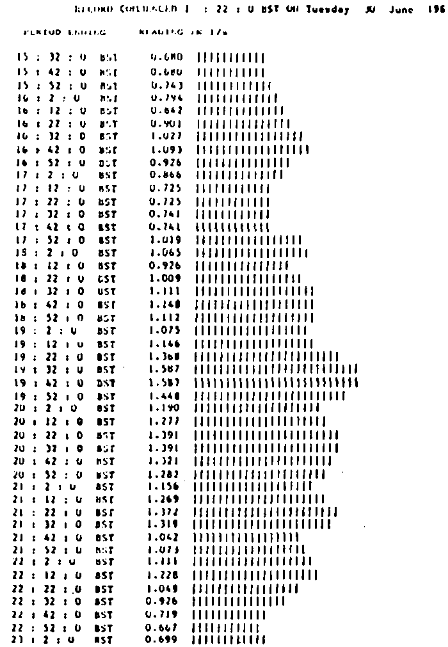
Fig. 10. Weymouth-Chalbury zone pressure before (top) and after (bottom) introduction of pressure control



SKETCH TO SHOW INSTALLATION OF DATA LOGGER TO METER & WATER MAIN



• MODULE REMOVED and INTERROGATED BY COMPUTER



EXAMPLE OF PRINT OUT FROM MODULE SHOWING TIME, DIGITAL and ANALOGUE FLOW. (FLOWS RECORDED EVERY 10mins FOR 14 DAYS DURATION ARE TYPICAL)

Fig. 11. STWA Avon Division - continuous flow records by solid state device

5. WATER LOSSES AND THE CONSUMER

By G. L. INGHAM, BSc,CEng, FICE, FIWES. *

INTRODUCTION

History

Centuries ago in England and Wales, the impact of man on the water cycle was minimal.

The consumer of water merely took from a lake, river, stream or well sufficient water for his daily needs only.

The population was small and sewage treatment and disposal was almost unknown.

Progress through the ages to the present day has now created a modern system which includes whole river basin managagement, controlled by a few, with water supplied to a vast number of people, living in approximately 18 million households. The population is now supplied with water through a pressurised distribution system which has become a form of treadmill for the industry; a system which needs constant maintenance and includes probably 150 million plumbing fittings.

Every citizen is a consumer. Waste of water or wasteful use of water by each individual consumer needs to be multiplied by a factor of 49 million to produce the national total.

The object of this paper is to remind the reader and the industry of the magnitude of the system beyond the stopcock. The water industry tends to neglect its consumers as a group and certainly as individuals. Good public relations with such a large number of consumers will surely pay handsome dividends. If all consumers can be persuaded to reduce their consumption of water by taking only the amount they genuinely require and if their co-operation and support can be gained in the never-ending task of waste control, then significant savings will be achieved.

The Monopolies and Mergers Commission Report on the Severn-Trent Water Authority, published June 1981, pointed out that "more effort should be made to control leakage, saying the Authority loses 27% of its treated water and the proportion is increasing. If even a small part can be retained, the need for costly new capital works can be delayed. Leakage control measures are labour intensive, expensive and relatively unpredictable in their effect, but are steadily more important as new water resources become more costly or environmentally damaging to exploit."

The amount saved in terms of energy, labour and chemicals will vary throughout the country, depending upon whether the supply is by gravity or

* Director and General Manager, The Sutton District Water Company.

by pumping and also depending upon the amount of water treatment necessary. In the case of The Sutton District Water Company, the value of water saved is high.

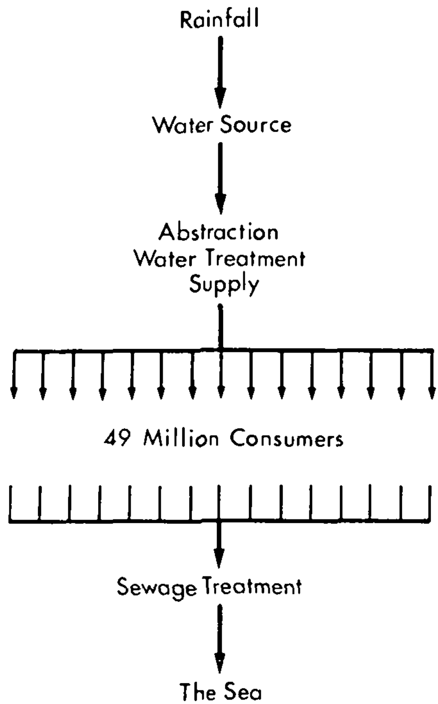


Figure 1 The present day water cycle in England and Wales

<u>Waste Control at Sutton</u>

The Sutton District Water Company obtains all its water from underground sources. Every gallon has to be pumped and repumped before reaching the consumer. In the highest distribution zone the water has to be repumped as much as four times. Water saved means a saving in energy as well as in chemicals. The cost of chemicals for water treatment is more significant at Sutton in so far as the Company has a statutory obligation to soften all water supplied.

In 1948, E.G.B. Gledhill, the Engineer & Manager of the Company, introduced an alternative method of waste control, based on differential sounding, and this is full documented in a Paper presented to the Institution in 1956, included in the Journal of the Institution, Volume 11, No. 2, March 1957.

This method of waste control has continued until the present day. The advantages claimed by Gledhill are still considered to be viable by the present Management. These are:

(a) Using differential sounding, an agreed frequency of sounding for a particular district, can be decided.

(b) Labour engaged on the detection of underground leakages is employed during normal working hours and to the best advantage.

(c) A regular and prompt contact is maintained with consumers, particularly where leakage or excessive consumption is discovered on the premises.

(d) Some of the disadvantages of waste meter control are avoided, viz. rapid operation of valves to "zone in" when possible partial emptying of mains can contribute to leakages.

(e) Stopcock casings and surface boxes are regularly examined and serviced. Broken or missing lids are replaced, casings partially filled in are cleaned out, making primary stopcocks readily available for use.

(f) Other tasks can be incorporated in the inspectors' schedule of work, reducing wasteful travelling time.

In parallel with the application of the differential sounding method of waste control, the Company operates a plumbing service which is available to all consumers.

How effective, therefore, is the Company's over-all method of waste control?

Many organisations consider that the average per capita unmetered water consumption measured in, say, litres per head per day is a good indicator. This consumption, however, varies with the standard of housing in any particular area of supply, indeed, with the general standard of affluence of the consumers. The author considers that the net night flow measured in litres per property per hour gives a better and more reliable over-all figure of the effectiveness of the applied waste control measures.

For many years, waste tests have been carried out by the Company at regularly six monthly intervals, measuring total reservoir drop with all pumping units shut down between 2 a.m. and 4 a.m.

The resultant net night flow is established and the most recent figure is indicated on the diagram in justification of the effectiveness of the service.

The results indicate that the net night flow for the whole of the Company's area of supply is 4.9 litres/property/hour. This is not unsatisfactory, although it may well be practicable to reduce the flow further.

It should be noted that the Sutton figure has been added to the extract of the D.O.E. Report.

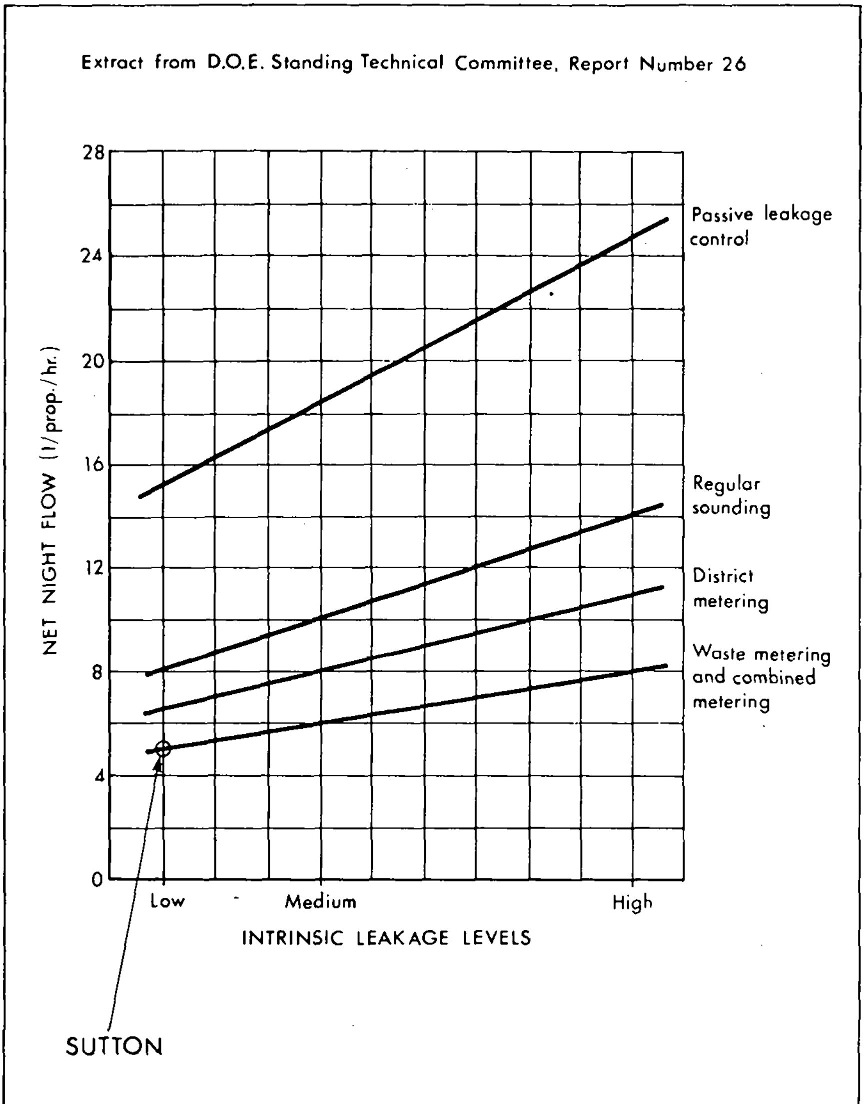


Figure 2 Net Night Flow

Sounding Procedure

For non-specialist readers who may not be familiar with the method of sounding, details are as follows:-

1. Check the surface cover of the stopcock box for damage and any variation from the general level of the footpath.

2. Check the casing for access and any blockage, and clean out where necessary.

3. Sound the stopcock, using stethoscope to check if there is a flow of water through the stopcock. If there is no sound - move on.

4. If a sound is detected, listen for a short period, say,15 seconds. A diminishing sound indicates that a ballvalve is probably closing and within a short period the sound may cease.

5. If the sound is continuous, it may be a leak or water is perhaps being used by the consumer. Move on and return in a few minutes (for instance, after taking soundings at one or two neighbouring properties). If no sound - move on.

6. If the sound persists, contact the consumer to request that all taps be closed. Continuing sound indicates a leak on service pipe.

7. Close the principal stopcock. If noise ceases, the leak is between the stopcock and the house, otherwise it is between the stopcock and the street main.

8. Note address at which the leak is occurring - move on.

The principal advantage of carrying out continuous soundings with a skilled inspector is that it is a positive "go/no go" procedure. It is a rapid and reliable method of checking for leakage on both the communication pipe and the supply pipe to the premises.

A very high proportion of service pipes do not have leaks and therefore the inspector is able to rapidly verify this, checking only for a very short period of time at each premises. Although the procedure, as detailed above, may appear lengthy and a little cumbersome, in practice, the time taken to sound at each address is approximately ½ minute, plus, say, 1½ minutes' walk between stopcocks.

As the average household is only using water for about 20-30 minutes during the day, between 8.30 a.m. and 5 p.m., the inspector only rarely sounds a stopcock when water is being used.

The Company's inspectors can sound between 200-300 premises per day, depending upon the density of the housing and the length of the frontages of the properties being checked. On average, about 1,200 underground leaks are discovered each year, plus a similar number of leaking taps and ballvalves.

Night Flow Tests - December 1980

1.	Number of domestic properties	106,382
2.	Number of mixed commercial/ domestic properties	3,364
3.	Total number unmeasured	109,746
4.	Metered supplies	2,412
5.	Total connections	112,158
6.	Estimated population	281,736

7.	Minimum flow from all service reservoirs, no pumping - 2.0 a.m. to 4.0 a.m.	183,817 g/h 834,530 l/hr
8.	Number of meters read during test (i.e. 6.7% of total)	162
9.	Average measured flow 2.0 a.m. - 4.0 a.m. from meter readings	47,967 g/h 217,770 l/hr
10.	Difference (9-7)	135,850 g/h 616,760 l/hr
11.	Assessment of minimum flow of 2,250 metered supplies not read (insufficient manpower) (assessed as 15% of daily flow)	14,380 g/h 65,285 l/hr
12.	Net night flow (10-11)	121,470 g/h 551,475 l/hr = 4.9 l/prop/hr
13.	N.B. - Allowance for unmeasured night consumption	Nil

Plumbing and Repair Service for Consumers

The plumbing and repair service offered to consumers on a repayment basis was started by the Company in the mid-1930's. In earlier years, most of the work was carried out by sub-contractors, but in 1950, the Company recruited its own plumbers and service layers to carry out this work and has continued to recruit ever since. The principle object of the scheme was to provide a better service to the consumer and to encourage renewal of old water fittings and the prompt repair (or replacement) of faulty underground supply pipes.

During periods of prolonged frosts, the Company receives many calls for assistance, especially from consumers living in older properties which have inadequate insulation and little heating. An advantage of the plumbing service is that the Company's skilled craftsmen and experienced inspectors are available to render assistance and this helps consumer relations, and reduces waste.

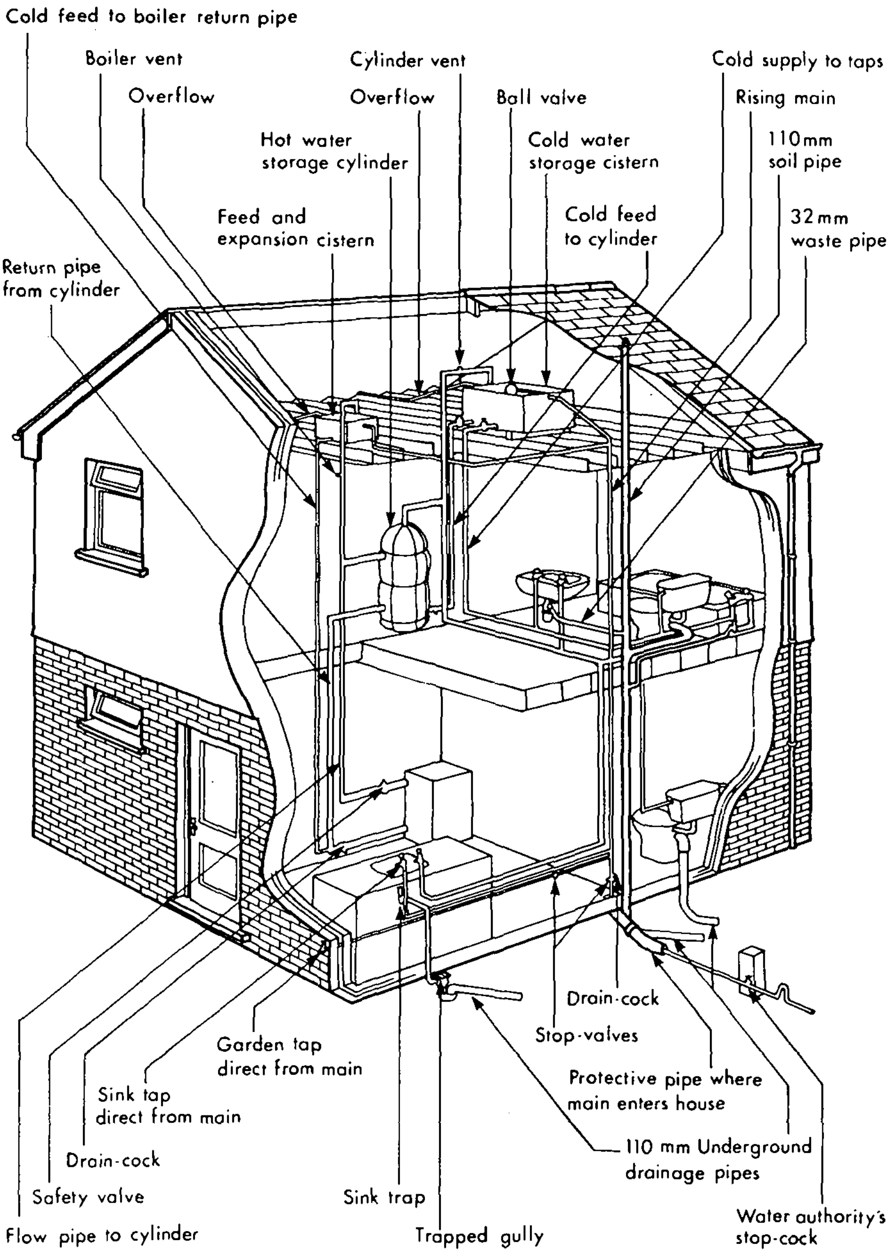


Figure 3 Plumbing in the Home

Early in 1978, for instance, over 1,000 calls for assistance were received in two weeks and each was dealt with promptly, the Company's employees often working throughout the night to cope with the volume of requests. By comparison, the other undertakings were unable to provide any service beyond the principal stopcock and were unable to assist their consumers, merely referring them to local plumbers.

In the case of elderly and infirm consumers, all charges were waived during the period of severe frost.

Priority is given to the repair and replacement of defective fittings, although larger jobs are also undertaken in order to attract skilled craftsmen to the Company's service. This additional work includes the installation of new bathrooms and heating systems, which can produce a good profit margin.

Costs and Turnover

There have been many reports, papers and formulae published in recent years about waste of water and the cost to the Authority or Company. The consumer is rarely mentioned, but it should never be forgotten that he pays for everything. It should be borne in mind that those consumers who support a repair service on a rechargeable basis also contribute to the cost of controlling waste and excessive consumption.

The turnover on rechargeable work in the Sutton area for 1980 was £273,530.

Rechargeable Work	£
Total invoices	273,530
Direct Costs - Labour and Materials	246,279
	£27,251

and this has been reasonably constant in real terms over the past few years.

The Company supplies approximately 110,000 properties (of which about 20,000 are council owned and outside the scope of the Company's repair service as all maintenance is carried out by each council).

The costs of supervision need to be deducted from the trading surplus of £27,251. The amount of supervision is relatively small and is fitted into the supervisors' routine schedule. Every effort is made for each supervisor to keep in touch with plumbers and service repairers during normal daily visits to mainlaying and mains repair jobs as well as visits to pumping stations on supply work. Thus, the cost of supervision is marginal.

It is the Company's policy to 'break even' with this service year on year, despite the problems of inflation and of reduced demand for the service during periods of recession.

Average Cost of regular sounding

Total soundings 1980	156,250	
Rate of sounding (with no delays) - number per day per inspector	210	
Number of underground leaks detected 1980	1,312	
Soundings per leak	119	
Cost per inspector per day - (8 hours @ £6.02 - Dec. 1980)	£48.16	
Cost per sounding	£0.23	
Total cost of sounding per annum, say,	£36,000	
Cost per leak discovered	£27.30	
Volume of water of equal value per leak (Energy and chemicals etc. @ 4.5p per m3)	606 m3	
If leaking for 1 year	= 133,330	g/annum
	= 365	g/day
	= 15.2	g/hour
	= 0.25	g/min.

N.B. Bonus - Any leaking taps and ballvalves discovered are rewashered.

Average Labour Costs - inspectors 1980

Basic Wage	3,934
London Weighting	435
	4,369
Overtime	1,120
Bonus	1,066
Standby	188
	6,743
Employers' E.R.C.	645
Employers' Pension Contribution	787
	8,175
Transport (van)	2,156
	10,331
Overheads @ 20%	2,063
	£12,394 per annum
Effective hours worked per annum (i.e. basic hours plus overtime, less holidays, less sickness)	2,057 hours
Cost per inspector	£6.02 per hour

THE CONSUMER

His Requirements

The term "consumer" is often applied to large groups of the population. The individual domestic consumer may have household requirements which vary considerably. By way of illustration, the range of demand, for instance, could be:-

TABLE I Sutton Consumer Demand

TYPICAL RANGE OF SUTTON CONSUMER DEMAND

Demand	Low	Medium	High
No. in Dwelling	1	3	6
Estimated Consumption (litres/day)	150 (min)	500 (av)	2,000 (max)
Estimated Total Head (metres)	100	150	250
Annual Energy Requirement (KWH/annum)	24	122	816
Annual Cost	£	£	£
Energy	0·72	3·66	24·48
Chemicals	1·80	6·00	24·10
Total	2·52	9·66	48·58

NOTE: (a) Low demand – single person, low level zone
High demand – family of 6, high level zone
(b) Energy requirement based on 60% overall efficiency at 3·0 p/unit
(c) Chemical costs assumed 15p/1,000 gallons

Thus, the cost in terms of energy and chemicals of supplying a consumer in a dwelling with high demand in high level zone can be 20 times that of a similar dwelling (of similar rateable value) with low demand, in a low level zone.

Expenditure on publicity and manpower to encourage consumers to economise in consumption is, therefore, better directed towards larger dwellings in high level zones. To date, no satisfactory, practicable method has been evolved for determining numbers of occupants.

Leakage from fittings and underground pipes varies with:-

Water pressure
Age of fittings or pipe
Quality of materials used in manufacture
Aggressiveness of mains water
Amount of use to which fitting is subjected.

It is unreasonable to expect one class of consumer, such as an elderly, single person, on a low income, to spend more than the absolute minimum on repairs to the plumbing system of a dwelling. Another consumer, such as an owner/occupier with a large family, may well be prepared to finance a new plumbing installation and repairs to underground service pipe, particularly if the householder is a D.I.Y. enthusiast.

His Expectations

The average consumer has grown to expect a supply of safe, wholesome and palatable water at his tap for 24 hours a day throughout the year. Many consumers have probably never known an occasion during their lifetime when water did not come out of the tap when turned on.

Water supply is inevitably taken for granted and economy in use is generally only practised during periods of severe drought, following publicity on a national scale.

The present method of charging for water, on the basis of rateable value of the property supplied, provides little financial inducement for the consumer to be careful in the use of water. There is also little inducement to pay for the renewal of water fittings.

Other utilities - electricity, gas, telephone - provide a repair service up to the interior of the premises at no cost to the individual consumer. Gas leaks receive rapid attention and consumers are only charged for repairs to appliances.

Apart from a few exceptions, the service provided by the water industry terminates at the primary stopcock.

CONSUMER SERVICES	ELECTRICITY	GAS	G.P.O. TELEPHONE	WATER
Free repairs to supply pipe or cable	☆	☆	☆	
Maintenance of equipment	☆	☆	☆	
Domestic metering	☆	☆	☆	(some)
High Street showrooms	☆	☆	Post Office	
Appliances readily available	☆	☆		
Credit terms available	☆	☆		
Consumer advice from supplier	☆	☆	☆	
Consumer protection associations	☆	☆		

Figure 4 Consumer Services

The electricity and gas industries have numerous showrooms, where a large variety of appliances are available to their consumers, at competitive prices, often with easy credit terms. Many of the appliances require a water supply, e.g. water heaters, washing machines, dishwashers, showers, waste disposal units.

The water industry provides no such facility.

His Household Expenditure

The Family Expenditure Survey 1979, published by H.M. Stationery Office on behalf of the Department of Employment, provides a wealth of information about private households and how they spend their money. It is based on a representative sample of about 10,000 private households in the U.K. and the following extract shows a small section of the statistics:-

TABLE II Average Household Expenditure - 1979.

Commodity or Service	Expenditure per week	
	£	%
Housing, including rates	13.72	14.6
Fuel, light, power	5.25	5.6
Food	21.83	23.2
Alcoholic drink	4.56	4.8
Tobacco	2.85	3.0
Clothing, footwear	7.79	8.3
Household goods	7.05	7.5
Other goods	7.28	7.7
Transport (including car)	13.13	13.9
Services	9.74	10.4
Miscellaneous	0.97	1.0
	£94.17	100.0 %
Water Supply - Author's Estimate	£0.60	0.6 %

The only reference to cost of water supply in the survey is included amongst general rates, rents.

The average expenditure of £7.05 per week on durable household goods includes furniture, floor coverings, soft furnishings, television, radio, gas and electrical appliances, hardware, ironmongery, etc. No reference is made to household plumbing.

Such statistics as are available suggest that the expenditure by the average household on the replacement and renewal of plumbing fittings and, thus, the prevention of waste of water, is quite minimal. It surely behoves the water industry, by good public relations and reliable service, to encourage the consumer to pay more towards this item of family expenditure.

SERVICE TO THE CONSUMER

"Free" Service

The Company has adopted a policy over the past 30 years of rewashering, free of charge, all ball valves, hot and cold taps on either mains pressure or cistern supply and also all internal stopcocks, during normal working hours, from Monday to Friday. A reduced charge is levied for work carried out in the early evening and on Saturday mornings where consumers are out at work all day during the week.

Although free of charge to the individual consumer, the cost has to be spread over the community as a whole by the general water rate, or recovered from the profits of the plumbing service:-

TABLE III Fittings Rewashered

Number of Fittings Rewashered						
Year	Cold Tap	Hot Tap	Bath Tap	Ball Valve	Total	Inside Stopcock
1971	1767	2258	1507	5953	11485	1609
1972	1760	2200	1372	5312	10644	1470
1973	1751	2050	1319	5418	10538	1443
1974	1663	2225	1398	4750	10036	1747
1975	1862	1126	2450	4205	9643	932
1976	2051	1128	2064	2947	8190	852
1977	1869	1333	1702	2878	7782	583
1978	2854	1023	1355	3802	9034	333
1979	1750	681	1484	2311	6226	1566
1980	1600	701	1483	2133	5917	1329
	10-year average				8949	

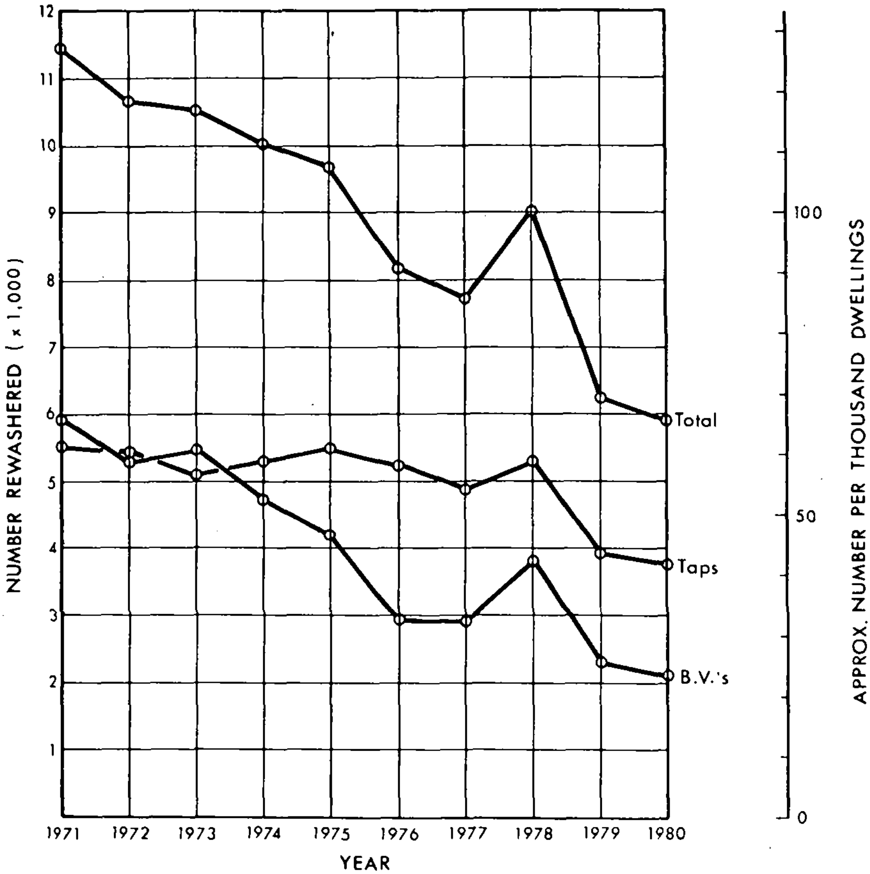


Figure 5 Fittings Rewashered

Feed-back of information from inspectors carrying out this work draws attention to the fact that a high proportion of the inspectors' time is spent in travelling to the premises, gaining access to the faulty fittings (particularly ball valves in cisterns in the roof space) cleaning up, filling in time sheets, bonus sheets, etc. Only a small proportion of time may actually be spent working on the fitting.

A breakdown of time spent at a typical rewashering job of one tap and one ball valve at one dwelling can be as follows:-

(a)	Receiving call at Depot	10 minutes
(b)	Travelling, say, 5 miles	18
(c)	Access to premises, shut off supply	5
(d)	Rewashering of sink tap	2
(e)	Gaining access to roof space and returning	10
(f)	Rewashering ball valves, including cleaning piston and re-assembling	12
(g)	Time sheets	5
(h)	Return journey	18
		80 minutes

Work on fittings - 14 minutes = 17.5%

Conversely, the 82% of time taken in travelling and gaining access, etc. can be substantially reduced by organising a number of jobs in one district at nearby addresses. The provision of suitable tools and equipment, such as light-weight ladders and portable lamps, may also reduce the time taken on the job.

The waste detection system of regular sounding helps considerably, in so far as the inspector, whilst carrying out soundings at every house in rotation, will also deal with rewashering work as the need becomes apparent on his round.

An inspector, when entering a roof space to rewasher a ball valve is required to carry a new plastic float with him. Having rewashered the ball valve, he examines the existing float. If there is any sign of weakness or corrosion, the float is automatically changed, free of charge, as the additional cost of the new float over the scrap value of the old float is often only a few pence.

In premises occupied by elderly people of limited means, the Company's policy is to change the ball valve itself, free of charge, particularly when the existing valve is old and corroded. This must be left to the discretion of the inspector, bearing in mind that with bulk purchasing, the cost of a new ball valve is only £1.50, which is equivalent to 15 minutes of the inspectors' time. When considering the alternative of charging for a new ball valve, it should be remembered that the total cost of preparing and rendering an account, and the collection of the charge, is probably £2.50.

<u>Repairs to Supply Pipes</u>

This is a vital and most important part of the Company's service to the consumer. Leaks on underground pipes can often continue for many weeks and consumers are some times reluctant to incur the expense of repairs, particularly if they have to rely on outside contractors who may not be qualified plumbers.

Amost all service pipes installed prior to 1970 in the Company's area of supply were of heavy-weight lead. Since that date, heavy-weight copper with PVC sheathing has been used. Repair work invariably includes wiping of soldered joints.

Repairs to some consumers underground supply pipes are carried out on a rechargeable basis by Company employees. A fixed price is charged for all straightforward jobs, the principal exceptions being supply pipes under reinforced concrete access roads, landscaped gardens and similar difficult situations requiring expensive reinstatement. This type of work is carried out on a cost plus basis on the cost of labour and materials.

Most consumers prefer to instruct the Company to carry out the work as there is a 5-year guarantee on workmanship. In cases where further repairs become necessary due to the overall poor condition of the supply pipe, consumers can often be persuaded to pay for the renewal of the whole service within their premises. From the consumers point of view, this eliminates further costly repair work and somewhat improves the value of the property and is an advantage in case of a future sale. From the Company's point of view, renewal of the supply pipe should eliminate leakage for many years.

Plumbing Service

The contribution made by this part of the Company's service to the reduction of waste is probably less than the contribution made by the free rewashering service and the repairs to underground pipes.

The plumbing service itself, however, provides a useful source of revenue from profits which can be directed towards subsidising other parts of the service.

Plumbing work can be extended to provide higher profits, subject to the availability of skilled labour, supervision and management time. Expansion is, of course, subject to the demand from the consumer, which is likely to be much less in times of recession.

Certain items of plumbing work are carried out on a fixed price basis to a firm specification. A significant amount of work is carried out on the basis of prepared estimates and quotations and in many cases the consumer may choose fittings and appliances from a supplier other than the Company. Some more expensive work is carried out on a cost plus basis, particularly where the additional service of craftsmen such as plasterer, carpenter or painter is required.

Full scale heating systems are installed as well as new bathrooms. This type of work has a higher profit margin and helps the craftsman plumber to maintain his skill.

Fittings and Appliances

The fittings provided and fixed by the Company are limited to those which have been specifically selected for their quality of material and construction and for their usefulness of purpose.

All fittings have to be on the National Water Council approved list and be of British manufacture wherever possible.

This selection of fittings permits the Company to retain some form of control over the quality of the fittings in its area of supply, a task which is much more difficult, if not impossible, when relying upon the application of bye-laws.

Occasionally, the Company is asked to supply only taps or ball valves for the consumer to fix himself. On these occasions, the price of the fitting, subsidised in so far as the customer is only charged on the wholesale price to encourage the use of good quality fittings and to discourage the consumer from installing lower quality goods.

The fittings provided and installed by the Company include:-

Hot and cold taps
Mixer taps
Ball valves
Shower units

The consumer rarely asks for a quotation for the supply only of an appliance, preferring to purchase such items from local suppliers or High Street shops. However, installation work on appliances is often carried out, more particularly the installation of washing machines and dishwashers.

There is considerable variation in the amount of water used by different appliances but, so far, no encouragement or financial inducement has been given to consumers to purchase those machines having a minimum water requirement.

The following extracts from the magazine "Which" of the Consumers' Association, illustrates this variation in water consumption.

TABLE IV Variation in Water Consumption using Different Appliances

Dishwashers (September 1980)

Brand	Model	Country	Target Price £	Water Consumption (H & C)	
AEG	Favorit	Germany	250	62 litres	
Beekay	GS381S	Germany	240	72	*MAX.
Bosch	M500	Germany	280	52	
Colston Ariston	LS612	Italy	220	66	
Hoover Superjet	D7016	Germany	250	70	
Indesit	116 AOG	Italy	235	47	*MIN.
Miele	G540	Germany	525	50	
Phillips	2000SLADD030/1	Germany	330	51	
Servis	400	Italy	200	62	
Zanussi	EM614	Italy	250	54	

TABLE IV continued

TABLE IV Variation in Water Consumption using Different Appliances (cont)

Washing Machines (March 1980)

Brand	Model	Country	Target Price £	Water Consumption (H & C)	
AEG	800 HC	Germany	287	120 litres	
AEG	64 SL	Germany	300	100	
Beekay	WA 7050	Ger./Ital.	160	125	
Beekay	WA 760	Ger./Ital.	486	115	
Bendix	7147 A	Italy	230	120	
Candy	Aquamatic	Italy	170	45	*MIN.
Colston	Ariston LB 515	Italy	160	160	
Eastham	Burco A977	Italy	289	150	
Hirundo	HL 9800	Italy	145	80	
Hotpoint	18380	Britain	260	110	
Hotpoint	18580	Britain	265	110	
Hotpoint	15690	Britain	275	205	*MAX.
Indesit	099AOG	Italy	?	135	
Indesit	092AOG	Italy	?	80	
Miele	W 423	Germany	581	170	
Neff	5047	Germany	529	115	
Newpol Multifill		Spain	157	75	
Philco	W45A	Italy	170	155	
Philips	555 AWB 103	Brit./France	280	155	
Servis Compact	303	Britain	235	155	
Servis Slimline	308S	Britain	250	155	
Servis Selontronic	309	Britain	345	145	
Zanussi	S2 18T	Italy	210	115	
AEG	2001	Italy	608	155	
Bendix	7348	Italy	370	100	
Colston Ariston	850XD	Italy	280	150	
Indesit	WD10	Italy	280	165	
Miele	WT 489	Italy	738	170	
Newpol	2000	Italy	235	105	

Effectiveness of Service

The provision of a consumer service can only be justified if it is cost effective. Any calculation of effectiveness should compare the existing situation with that which would obtain without the provision of the service. This is a difficult task.

By way of example, the diagram shown, Figure 2, on page 5 4, indicates a net night flow of 8 l/prop/hr for regular soundings in low leakage level areas. The Sutton figure for net night flow is 5 l/prop/hr. If the difference is a saving which could be attributable to the consumer service provided by Sutton, then: -

Water Saving	3 litres/prop/hr
Saving for 109,746 dwellings each year	(954 Ml/annum or
	(210 mg/annum
Saving on electricity and chemicals alone @ 20p per 1,000 gallons or 4.5p per cu.m @ current prices	£42,000 per annum

Even assuming there is no measurable saving of water attributable to a consumer service, the plumbing service at Sutton is provided on a rechargeable basis at no cost to the consumers in general. Indeed, a modest profit is available to the Company to be offset against operating costs. The individual consumer pays for the service in accordance with published charges. The service is provided in competition with the private plumbing sector and the consumer has the freedom of choice in the matter.

The public image of the water industry has, undoubtedly, diminished in recent years. The impact of inflation on water charges and the attention of the media is causing the public to become critical of the cost of the service provided. Any improvement in consumer service must help public relations and it is to be recommended.

Recent discussions in Parliament about the control of plumbers has highlighted concern felt by the public, particularly about unskilled operators or "cowboy" plumbers. The water industry has an opportunity to fill this void and to provide a service backed up by a guarantee of workmanship.

D.I.Y.

Work carried out on a "do-it-yourself" basis by consumers has, until recent years, had little effect upon the water industry. To-day, however, there is no doubt that the provision of plumbing fittings and materials for sale to the general public has become one of the major growth industries. A number of departmental stores and many retail outlets now provide a large selection of materials for the repair, maintenance and improvement of domestic plumbing systems.

Items are enticingly packaged and prominently displayed to attract the purchaser. A number of retailers provide instructions for the handyman and a typical leaflet is given overleaf. Some retailers give no information or assistance at all to consumers but this does not appear to affect their trade.

A significant point about plumbing work under consideration by householders is that, unlike electric and gas installations, there is very little personal danger to them if they make a mistake. Quite obviously, incorrect electrical wiring or gas connections could result in a fatal accident. The worst that could befall the installer of poor plumbing is that he may get wet or cause minor damage to decorations.

The most disturbing aspect of the large increase in D.I.Y. work is the difficulty facing water authorities and water companies in controlling the quality of the fittings and the workmanship. Whereas some fittings are marked as being of British origin or manufactured by well known British firms, much or the material on offer does not have any identification mark and does not appear to be made to British Standard Specification.

A recent investigation into the retail prices of taps and ball valves available in the Sutton area showed:

Basin Taps	Maximum Price (G.B.) £14.79 pair	Minimum Price (Italy) £6.70 pair
Ball valves	Maximum Price £4.80 each	Minimum Price £1.60 each

Examination of the six sample pairs of taps purchased showed that the quality of chrome finish of the cheaper taps was somewhat inferior to that of the more expensive fitting and the waterways were also smaller. This would tend to give a lower flow from the taps in areas of low pressure but the purchaser may not be aware of this.

The twelve ball valves purchased over the counter were very similar but the cheapest valve had an all plastic piston and was fitted with a soft washer.

Much of the advertising of plumbing materials and fittings is extremely persuasive, the following advice being given to the consumer who may be thinking of doing it himself:

(a) There is no reason why the consumer should not tackle most plumbing jobs himself if he has a few basic tools.

(b) All he needs is some knowledge of how the system works and of the correct techniques.

(c) The consumer can carry out most repairs and save himself a lot of money.

(d) He will not have to wait for an overworked plumber to come to do a simple job.

(e) He can do his own installations as well as any professional once he has gained confidence in his own abilities.

(f) He should be able to carry out many improvements which he thought were beyond his reach simply because of the prohibitive labour costs.

(g) Faults anywhere in the plumbing system can be located and repaired quite quickly.

(h) Leakages can be prevented if a few simple tasks are performed to protect against cold weather, corrosion and scale formation.

(i) The consumer can install a bath, a washing machine, a dishwasher, an immersion heater, sink, basin or shower all by himself.

(j) If he invests in his own skills the value of his home will increase.

It is hardly surprising that many house owners have been tempted and will continue to be tempted by such advice to carry out their own work. It is regrettable that the water industry plays no part in this. As far as the average consumer is concerned, the industry waits on the side lines.

It is extremely difficult to obtain statistics about the volume of work being carried out on D.I.Y. basis. Such information as is available suggests that from 10% to 40% of all plumbing repairs and improvements may be carried out by consumers themselves.

From the water industry's point of view, prompt repair or replacement of defective fittings by anyone will make a contribution towards a reduction of water losses in the home and should be given every encouragement.

STATISTICS

General

For over 40 years, the Company has kept fairly detailed statistics about the numbers and types of leaks which have been discovered on mains, valves, hydrants, service pipes and domestic plumbing fittings.

This has proved to be a useful indication of the output of the work force and the effectiveness of the waste control measures adopted by the Company. A selection of the statistics is given below, which may prove to be of use and interest to other undertakings.

TABLE V Leaks on Underground Service Pipes

	Leaks discovered and repaired during 1971-1980									
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Leaks										
Self-Evidencing	1091	1100	1078	857	548	537	525	186	411	282
Hidden	1527	1499	1402	1536	1329	889	1013	947	798	1240
Total	2618	2599	2480	2393	1877	1426	1538	1133	1209	1522
Services (x 1000)	101.6	102.1	102.6	103.3	104.4	105.3	105.9	109.1	109.9	111.1
Total Leaks per 1000 services	25.7	25.4	24.2	23.2	18.0	13.5	14.5	10.4	11.0	13.7
Soundings (x 1000)	168	116	83	168	173	110	118	137	166	156
Soundings per Leak	64	44	33	70	92	77	77	121	137	103

Rate of Flow of Leaks

Very little information is available nationally about the rate of flow of water escaping from typical leaks on service pipes and various plumbing fittings, although some information is available about the number of leaks.

During 1980, at Sutton, a random selection was made of approximately 1,000 leaking fittings and the rate of flow of each leak was measured and recorded prior to repair work being carried out. A simple method of measurement was adopted in view of the limited manpower available. This was to direct leakage into a calibrated container, timing the rate of filling by stopwatch. The range of various flow rates is indicated on page 23.

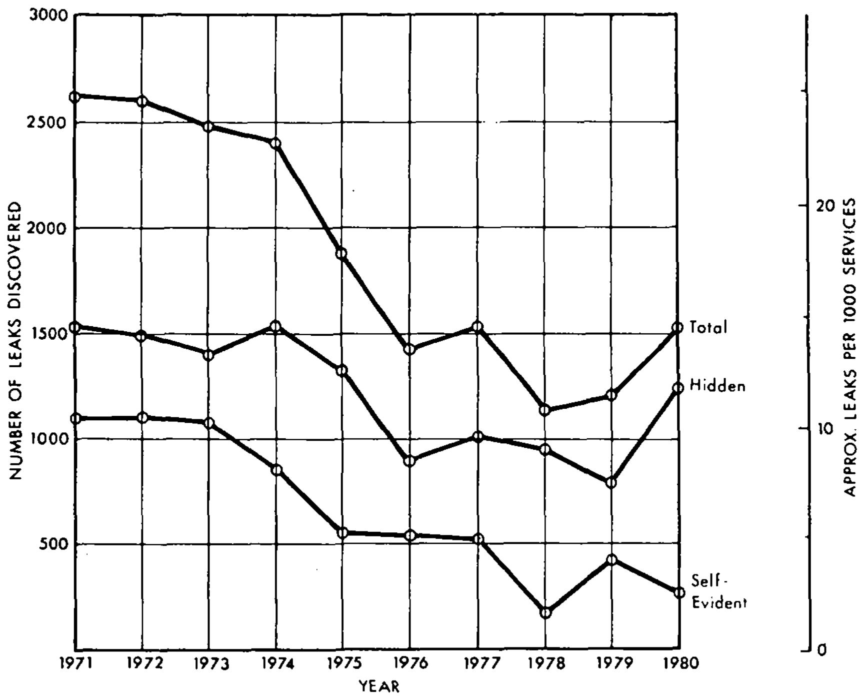


Figure 6 Number of Leaks Discovered

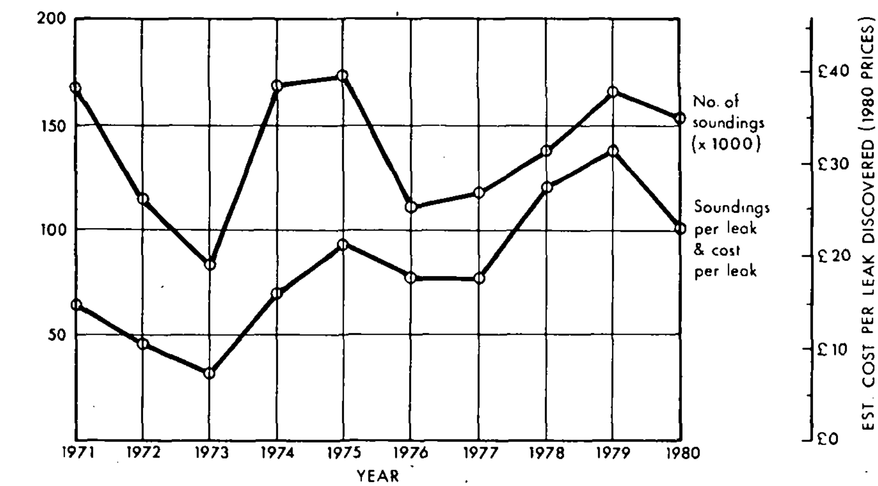


Figure 7 Cost per Leak Discovered

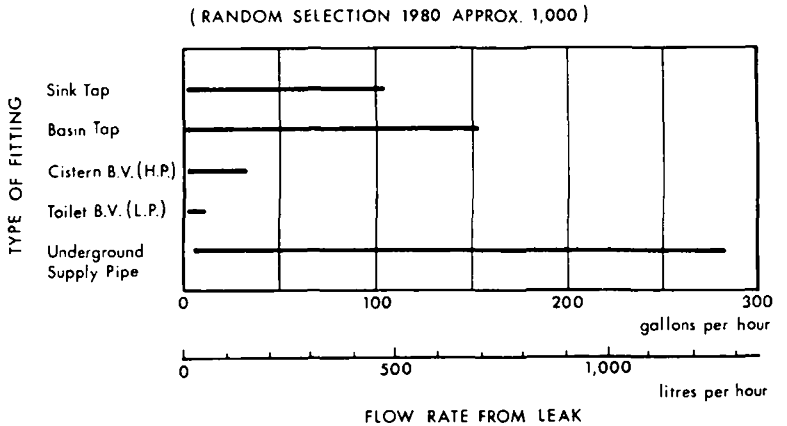


Figure 8 Range of Leakage from Various Fittings

Work by Inspectors

Detailed statistics for the year 1980 give an indication of the scope of their involvement with consumers.

TABLE VI Inspectors' Duties

	Work Detail	Number	
*	Census of Houses	73	
	Mains Shut Down	911	
*	Notice Delivered	190	
*	Meter Readings	13,679	
*	Re-inspection	7,963	
*	Soundings	156,251	
*	Supplies Turned On/Off	836	
	Attending on Jointers	1,317	Manhours
*	Attending on Plumbers	1,221	do.
	Flushing Mains	414	do.
	Starting/Stopping Pumps	417	do.
	Reservoir Security Inspection	1,726	do.
*	Water Sampling	2,044	do.
	Tracing Mains	573	do.
	Waste Tests	224	do.
	Checking Reference Wells	128	do.
	Chlorinating New Mains	47	do.
	Operating Valves	597	
*	Dealing with Consumer Requests	8,539	
*	Serving Statutory Notices	84	
*	Debt Collection	1,400	Manhours
	* Some involvement with Consumer		
	Total manhours worked per annum (including overtime)		26,464

Summary of Statistics

TABLE VII Leaks and Repairs showing the trend over 30 years.

	1950	1960	1970	1980
Visible Leaks, Service Pipes	523	1081	858	282
Hidden Leaks, Service Pipes	1705	1174	1522	1240
Total Leaks, Service Pipes	2228	2255	2380	1522
Leaks on Mains	54	60	68	93
Leaks on Valves	107	76	92	46
Leaks on Hydrants	24	34	40	17
Total Mains Leaks	185	170	200	156
New ball valves and Taps fitted	836	953	314	96
Services sounded (1000's)	223	179	176	156
No. of Services (1000's)	62.9	87.3	100.3	111.1
Length of Mains (Km)	788	837	880	940
Total Leaks per 1000 services	35.4	25.8	23.7	13.7
Mains Leaks per 100 Km.	23.5	20.3	22.7	16.6

EXTENSION TO SERVICE

Display Centre and Showroom

Consideration is being given at Sutton to extend the service provided. Arrangements are in hand to provide a modern showroom and display centre at the Company's Depot at Gander Green Lane, Cheam, where consumers who choose to may inspect various items and, if they wish, place an order with the Company for installation work to be carried out. Such items will include taps and fittings; shower units; bathroom and toilet equipment; kitchen equipment; water heaters; dishwashers; waste disposal units; water softeners.

Although the variety of appliances on show will be limited, it is intended to have a full range of literature available for alternate models which will be readily available from the Company's main supplier.

The showroom will be staffed by retired plumbers and supervisors on the basis of a part-time salary, plus commission. The Company intends to offer practical advice to the D.I.Y. enthusiast, to enable him to discuss practical problems with a registered plumber on the premises of the showrooms on Fridays and Saturdays. The consumer will be able to fully examine fittings and for a small fee, practise making joints and assembling fittings under the watchful eye of a plumber.

Credit Facilities

One of the principal obstacles which inhibits consumers who may be considering the renewal of plumbing fittings is the high cost of good quality goods and the high cost of skilled labour. It is very much in the interest of the industry to encourage the prompt replacement of defective fittings. The provision of attractive credit facilities at reasonable rates of interest may well achieve this object. Using modern computer techniques, credit facilities need not be expensive to the supplier. If linked in with the collection of water charges there may well be an improvement in cash flow and a reduction in the amount of time involved in collecting water charges from those consumers who usually pay late.

THE FUTURE

Domestic Metering

There seems little doubt that all domestic consumers will soon be offered the option of a measured supply by all water authorities and water companies. A number of consumers will probably opt to have a meter installed. This will provide an incentive for those consumers to be more careful in the use of water and to have regard to the amount of water required by various appliances which they may purchase in the future.

If a meter is located at the boundary of the property there will be a much greater incentive for metered consumers to pay more attention to leakage from their underground supply pipe, if necessary by reading their meter at frequent intervals. Thus, if a consumer notices a high reading and suspects a leakage is occurring, it can be reported in good time and reduce the size of the bill he would otherwise receive. If a meter is located inside the dwelling, waste due to leakage from the supply pipe will not be measured. The position will continue as at present, whereby the consumer, although under a legal obligation to repair the leak, is not liable to pay for the water which is wasted prior to the carrying out of repairs.

Whichever location is decided upon, the installation of an out-reader is to be recommended, placed in a convenient position so as to be easily read by the consumer. The out-reader may draw attention to the volume of water regularly consumed and also to wastage.

Those authorities and companies who have a firm preference for the location to be at the boundary may wish to consider subsidising the cost to the consumer to encourage consumers to opt for a meter and be responsible for the cost of water wasted from leaking supply pipes.

Subsidies

Bearing in mind the cost in terms of energy and chemicals of wasted water, the question needs to be asked whether or not the water supply undertaking should subsidise certain parts of a consumer service in the same manner as the existing subsidy is applied to the provision of a free re-washering service.

Subsidies, selectively applied to the service, will encourage consumers to promptly attend to the repair or renewal of fittings before leakage becomes significant and also to select appliances which use less water. The subsidies should be applied to all consumers, including those on a metered supply and particularly to consumers having a limited income and to whom the minimum price of an appliance is of paramount importance. Calculation of the amount of subsidy is not at all easy and will depend upon a number of parameters which will vary in each undertaking.

It is questionable as to whether water authorities and companies have the legal right to use income from ratepayers in general to subsidise a particular section or class of consumer, i.e., those who purchase an appliance or have plumbing work carried out on their premises. If the amount of the subsidy is taken from profits of the consumer plumbing service and not from general water rate the right to apply this money is stronger and less liable to be challenged.

Advertising

The only recent advertising campaign of any significance carried out by the water industry in recent years was during the 1976 drought. This campaign has been covered by the National Water Council Report, entitled "The 1975/76 Drought", dated April 1977, which drew attention to the remarkable scale of voluntary saving of water achieved by consumers who heeded the appeals and publicity over a sustained period. The Report summarises many aspects of the "Save It" campaign and the methods of advertising, including posters, leaflets, stickers, billposters, children's "T" shirts, press advertising, radio "jingles" and T.V. "spots".

Obviously, the warm and dry weather, together with the news value of the drought to the media on television, radio and newspapers, gave considerable assistance to the water industry. There is little doubt that the impact of such publicity during a spell of cold, wet weather would have been less.

TABLE VIII Opinion Survey covering 7,3000 people showing effectiveness of Advertising

Advertising Medium	Public Recall	Advertising Medium	Public Recall
Television	81-90%	National Radio	4%
National Press	29-30%	Magazines	2-3%
Posters	26-33%	Local Radio	2-4%
Local Papers	13-16%	Other	12%
Notices at Work	7%		

The general conclusion of the National Water Council's Report was that peak voluntary savings approached 30% consumption and that long standing savings at lower levels were achieved.

The effectiveness of advertising has been widely confirmed in many industries. The relatively high expense of advertising nationally suggests that to be cost effective, a campaign directed at water consumers should employ local media, particularly local newspapers, together with the existing general communication via the postal service when supplying authorities send out bills and accounts.

Consumer Relations

Any consumer seeking information about other utility services, such as electricity, gas, telephone, post office, bus, train etc. can approach a number of departments, offices or showrooms, to make his request. If, however, he needs advice about his water supply or plumbing, or appliances using water in his house, he is likely to be much less successful if he approaches the water industry. Even if he has suffered from a minor domestic catastrophy, such as flooding within the house due to a burst pipe or other flow, he may well have difficulty in obtaining any advice except from the local plumber, who may or may not be qualified to give advice.

Although the water industry responds promptly to complaints about water quality or about water pressure (or no supply at all) most other problems facing the consumer on his own property and beyond the principal stopcock, tend to be neglected by the water supply authority. There is a need for some form of local advice centre to be set up to deal with consumer complaints and provide sound technical advice to those seeking it. The improvement in public relations could be significant. The most economical way, initially, would be to include such centres at existing offices or depots or works.

CONCLUSION

It is suggested that the attitude which the water industry should adopt towards its consumers is best summarised by the following (of unknown origin):

" The Consumer

Is the most important person in any business

Is not dependent on us - we are dependent on him

Is not an interruption of our work - he is the purpose of it

Is a part of our business - not an outsider

Is a person who brings us his requirements - it is our job to satisfy those requirements

Is deserving of the most courteous and attentive treatment we can give him

Is the life blood of this and every other business "

ACKNOWLEDGMENTS

The author would like to render his appreciation to The Sutton District Water Company for the support given in producing this Paper. The opinions expressed are, however, his own, and do not necessarily coincide with those of the Company.

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DISCUSSION

Author's introduction

Mr Ingham introduced his paper with a reminder that, with very few exceptions, the consumer paid for everything: not only all the interest and depreciation on capital and all the energy and chemicals consumed, but also the wages and salaries of everyone employed in the water industry. All citizens were consumers throughout their lifetimes, and if their requirements and expectations were not understood fully, water losses could not be understood fully either.

To supply the consumer the UK water industry had created a vast pressurized distribution system which transported potable water to a wide range of probably 150 million plumbing fittings and a few million appliances, all potential sources of leaks and wasteful consumption. This distribution system required constant maintenance up to each of its extremities.

It was the part of this system beyond the principal stopcock that he had drawn attention to in the paper, with the aim of highlighting the magnitude of the problem and opportunity which was there to be grasped. The UK water industry tended to neglect its 49 million costumers as individuals. Good public relations with such a large number would surely pay handsome dividends. If all consumers could be persuaded to reduce their consumption of water by taking only the amount they genuinely required, and if their co-operation and support could be gained in the never-ending task of waste control, significant savings could be achieved.

For many years The Sutton District Water Company had operated a plumbing system for its consumers. The principal aim was to provide a better service by replacing worn fittings at the expense of the individual consumer, and not the general ratepayer. The total turnover of this service in 1980 was £273,500: it was the Company's policy for this service to break even. The total service to the consumer provided by the Company was, Mr Ingham considered, the minimum which should be offered to consumers throughout the UK. A 'free' rewashering service, although free to the individual, was a charge on the whole community, using expensive skilled labour. Any reduction in travelling time, and in the time required to gain access to fittings produced valuable savings and increased efficiency. The constant object of the service should be to maximize the number of jobs done in a small area on a daily basis. The plumbing service was principally justifiable in the long term by the number of fittings renewed rather than by the modest profit which was achieved. Repairs to underground supply pipes were the most vital part of the service, and consumers seemed to find the fixed price of £63 (1981) quite attractive. Horror stories of 'cowboy' plumbers charging up to £250 were not uncommon.

The Company's consumers had recently been offered the option of domestic metering. The Company had a strong preference for placing domestic meters at the boundary of consumers' premises, the advantage being that the consumers would then pay for all future waste for leakage from their underground supply pipes. A fee of £15 for an initial survey of the premises was waived if the consumer agreed forthwith to the meter being fitted at the boundary. A fixed price of £90 was charged, and the consumer was offered interest-free credit terms: payment of £15 each half year over three years. So far, the Company had a 95% success rate in persuading consumers to pay for the meter on the boundary.

The Company was particularly interested in offering an outreader facility to all metered consumers, both domestic and commercial, on a repayment basis, to reduce call-back problems and to overcome the possible inconvenience to consumers of having their meters at the boundaries of their properties. Many outreader systems on the market were not satisfactory in that they would not operate under flooded conditions, i.e. if the meter pit flooded with surface water, or if the meter head filled with mains water from a leaking gland (even on a meter installed in dry conditions in a building) then some outreaders would not function. The problem appeared to lie with the switching device or the magnet in the meter head. While waiting for the outcome of further research in the industry they had developed a simple system which would operate under water. The test rig had been operating successfully under water for some months. The outreader would indicate to $0.01m^3$, say 2 gallons. This could be very useful for those consumers who were interested in avoiding waste and wished to read their meters regularly. The device was designed to be installed in an existing meter in situ in about five minutes.

Discussion

J.A. CRICHTON (Strathclyde Regional Council) in opening the discussion indicated that he had found the paper fascinating because he was in tune with the Sutton Company's philosophy of total service to the consumer. Here was described a deliberate and systematic approach to the ideal situation. He doubted, however, whether the same level of service could be achieved elsewhere - certainly not by local authorities; and RWAs and most other companies would think hard before tackling the problem of consumer waste by offering what appeared to be a subsidised replacement and repair service.

The solution of the problem of waste lay in speedy repair. Mr Crichton had some experience in densely populated areas where a reasonably efficient waste detection organization using ordinary methods of night sounding and meter runs and step tests, was in use. He ventured to say that detection itself of consumer waste was relatively simple and that anyone tackling the problem with purpose had a fair idea of where losses were located, but waste eradication could be achieved only if detection was followed quickly by repair. He wondered how many authorities had that ability and indeed how many effected repairs to their own apparatus as quickly as they might.

Comparison was made between the type of housing predominating in Sutton District and that of densely populated urban areas of flatted accommodation particularly where housing was rented rather than owner occupied. It was likely that there would be resistance to a move by a water authority to set up a repair organization in competition with local business. Was there opposition in Sutton when the present organization was founded?

Mr Ingham's summary of consumer expectations on page 5.11 met with almost wholehearted approval - almost, because a number of authorities readily advised consumers in detail about installation problems and did become involved to some extent, inside the house. The most rewarding assistance an authority could give, short of providing a total plumbing service, was free rewashering. The consumer relationship which developed helps to create the image of 'your friendly water man', and more importantly, gave the 'friendly water man' the opportunity to look at all of the installation and thus spot badly executed DIY repairs, unsatisfactory fittings, and leaks from other apparatus.

Encouragement of DIY plumbing should not be supported wholeheartedly because the preponderance of tenements and flatted dwellings in some areas brought specific problems. Mr Crichton mentioned the damage caused to other houses because of badly executed DIY repairs to existing plumbing, and on balance he thought that encouragement should be limited to brand new installations and perhaps to total replacement.

Lastly, Mr Ingham's thoughts about the value of advertising to promote economy were questioned. The 1976 drought campaign was successful only because consumers saw for themselves the need to economise. Without specific motivation, appeals for savings were, in the main, ignored.

G.S. MILLION (Thames Water Authority) said that Mr Ingham appeared to reject the orthodox approach to waste control, which had recently been restated by the Technical Working Group on Waste of Water. They had recommended waste metering where the cost of water was high, as it was in Sutton. Mr Ingham's approach provided a fascinating comparison. The figures from the night flow test were remarkable: a net night flow of 4.9 l/property/h. Mr Million asked whether anyone else had made comparable measurements and, if so, what were their results? His authority had found it very difficult to measure night flows in the way recommended by the Technical Working Group. He then drew attention to the average daily quantities supplied per head in each Division and Water Company area in the Thames WA region (which he thought was reasonably representative for this purpose). In 1978 Sutton District's figure was the lowest in the region, but that might perhaps be explained by differences in metered use, unmeasured commercial use, commuters, tourists, and so on. What was remarkable was that since 1978 the supply per head had gone up in all areas except the Sutton District, where it had gone down. Mr Million thought that that could not simply be luck: in his view it showed that there was something in the Sutton approach and he congratulated Mr Ingham on his paper.

R.J. SLATER (The Mid-Kent Water Company) congratulated Mr Ingham and supported the general attitudes and practices of the Sutton District Water Company in relation to its consumers. He said that this was a philosophy which The Mid-Kent Water Company had endeavoured to adopt, although being predominantly rural, they were very different in character as the following statistics showed:

	Sutton	Mid Kent
Properties	110,000	193,800
Area, km^2	100	2,056
Properties/km^2	1,100	94
Mains, km	940	2,500
Properties/km main	117	55
No. of Sources	8	32

Mr Slater emphasized that they had a very different attitude to waste detection, having decided as a matter of policy in the middle 1950s to instal district and waste meters rather than extend soundings as advanced by

Mr Ingham's predecessor, Mr E.G.B. Gledhill. Despite the fact that at present about 80% of all properties could be covered by waste meters. Mid Kent's unaccounted for waste appeared to be slightly higher than that for Sutton. Although Mr Ingham had superimposed his Company's performance on the DoE leakage graph, it appears that he had not followed implicitly the formula for assessing the net night flow, but, on his basis, the Mid Kent figure would be about halfway up the combined metering curve. In view of the different approaches, Mr Slater gave a few figures comparing activities and results which he felt might be of interest:

	Sutton	Mid Kent
Mains leaks	156	725
Service pipe leaks	1,522	8,299
Total leaks	1,678	9,024
Waste Meter charts	-	474
Step Tests	-	144
Soundings	156,000	92,000
Leaks found	1,515	6,027
Soundings per leak	103	15.3
Leaks per 100km main	16.6	20.7
Leaks per 1,000 services	13.7	42.8
Cost per leak found	£27.3	£14.7*

*includes all revenue costs of operating waste meters.

He mentioned in particular that the cost of finding leaks last year in Mid Kent was £14.70 compared with £27.30 in Sutton. He suggested that this could be due partly to the fact that the rate at which service pipe leaks occurred appeared to be three times that for the Sutton area.

Mid Kent offered a free washering service and in 1980/81 dealt with 11,879 taps. He mentioned that the Company also provided a general plumbing service which was well used by consumers. He was not able to differentiate between repairs and new work, but the total of invoices for last year was £540,000. He also supported the idea of water fitting shops but with one eye on sales would suggest lady demonstrators rather than retired plumbers!

M.T. SETFORD (The Mid Kent Water Company) wrote that in the paper (p.5.6) Mr Ingham had detailed the results of a night flow test carried out within his Company in 1980. Under Item 11, an assessment of metered supplies was made using 15% of daily flow as an approximation. It would be interesting to know how this assessment had been derived as it did have a significant effect on the result.

Mr Setford also made a general point regarding the use of the DoE/NWC chart referred to on p.5.4. He felt it was important to remember that the chart was compiled using the results of over 500 field trials carried out by the NWC in predominantly urban areas, consequently any undertaking that was predominantly rural might be misled when using the chart if they compared their performance with what might appear to be national averages.

Author's reply

Mr Ingham, in replying to Mr Crichton, said that the plumbing service provided at Sutton was not subsidised out of the water rate. To introduce a service one should start slowly and make a profit, then reinvest the profit back into the service. A further, but most significant point, was than even if the service did not make a profit, labour costs were still paid for by consumers who used the service and not the ratepayer in general.

There had been almost no opposition from local plumbers, even during times of recession, as most of the work carried out by the Company had a low profit margin. Furthermore, collection of charges for this type of work was difficult for small plumbers who often relied on regular cash flow.

The cost of detection of leaks had to be paid for by all ratepayers but they benefitted from the savings in costs of energy and chemicals which would otherwise be wasted.

Response to advertising would probably vary in different regions throughout the country. Perhaps the only solution in this very emotive problem would be to try a modest publicity campaign and then assess results before proceeding further.

Mr Million's contribution was very much appreciated by the author, in particular, his chart showing the average daily quantity supplied per head in each Division and Water Company in the Thames Water Authority area. Comparisons within the south east of England were probably more viable than comparisons on a national basis. Although there were a considerable number of different parameters which affected consumption per head of population, the figures supported the effectiveness of the waste control methods applied at Sutton.

The author valued Mr Slater's contribution and the useful statistics he provided. The comparison between Sutton and Mid Kent supported the philosophy that waste occurred from mains and services and not from the area of supply. Although Mid Kent has a statutory area 20 times the size of Sutton, the length of main per property was only twice that of Sutton. The statistics given by Mr Slater emphasized the number of leaks per 100km of main at Mid Kent was only 25% higher than at Sutton. The figure for leaks per thousand services was 212% higher.

Inevitably, the higher the number of leaks per thousand services in a distribution system, the cheaper it was to find them. This illustrated the problem facing all authorities and companies, whatever the method of waste control employed: to optimize the rate of detection of leaks so that the cost coincided with the saving in terms of energy and chemicals. The savings due to postponement of capital expenditure on new resources needed to be included in the calculation but would vary significantly between one undertaking and another.

In reply to Mr Setford, Mr Ingham said that the assessments of the minimum night consumption of metered supplies shown in item 11 on p.5.6 was an approximation. It was unlikely that the problem would ever be solved completely.

Throughout the year, minimum consumption of metered consumers had been monitored, particularly between 2 and 4 am. Flow recorders were installed each night on approximately a dozen premises and moved to a different group of premises the following night. This built up a statistical record which included all metered consumers following a period of six months to a year. The minimum night flow of each premises was expressed as a percentage of the annual average daily flow, this flow being readily available from computer records. Examination of the statistics had confirmed that

$$\frac{\text{minimum metered night consumption}}{\text{average daily metered consumption}} = 15\%$$

was a reasonable approximation for the total metered supplies in the Company's area of supply.

A further advantage of this approach was that those consumers whose premises showed a high night flow were made fully aware of this by the company's inspectors, and often discovered leakage, which could be rectified, thus helping consumer relations.

6. THE SITUATION IN BELGIUM

By Ir. J. Dirickx* and Ir. R. Depamelaere**

INTRODUCTION

In 1945, the Belgian City of Ghent recorded water losses of more than 40 per cent. By 1955 this figure had been reduced to 25 per cent, to 15 per cent by 1962 and to 12 per cent by 1980.

This example shows clearly what results can be obtained provided that the motivation is sound and that a thorough approach to the problem is adopted.

The water services of Ghent have always been "leak detection-minded" and a former Inspector-Director, Mr. R. Despiegelaere, earned an international reputation in the field of waste detection. Indeed, he was General Rapporteur on subject No. 6, "Use of electronic apparatus in waterworks practice with special reference to waste detection", at the IWSA Congress in London in 1955, when he presented an excellent paper (1) which still remains of current interest and which undoubtedly merits rereading.

Mr. Despiegelaere and his co-workers also designed the Aqua-Visual leak-detector, the excellent performances of which were mentioned in an article in the Institution's Journal in 1955 (2).

THE ORGANIZATION OF THE WATER SUPPLY IN BELGIUM

In Belgium, responsibility for water supply rests with the municipalities and it is up to the local authorities to choose their own ways of supplying their residents with drinking water. A great many municipalities have set up "Intermunicipal Companies", which are responsible for specialized technical activities such as the supply and distribution of potable water.

The most important examples of these companies are:-

- B.I.W. (Brusselse Intercommunale Watermaatschappij - Brussels Waterworks), which, with a yearly distribution of $110.10^6 m^3$ of potable water, supplies the 19 municipalities of Brussels capital and 52 other municipalities.
- The A.W.W. (Antwerpse Waterwerken - Antwerp Waterworks) which, with a yearly distribution of $125.10^6 m^3$ of water, supplies the City of Antwerp and 13 suburbs.

These companies, together with the N.M.W. (Nationale Maatschappij der Waterleidingen - National Waterworks) which has a yearly distribution of $160.10^6 m^3$ of water, are the three largest in the country; they also provide significant bulk supplies of water outside their own areas.

The N.M.W. was founded in 1913 to provide water supply services in areas not covered by the municipalities.

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In addition to the above mentioned units, which together supply about 70 per cent of the drinking water in Belgium, there are some other important companies:-

- P.I.D.P.A. (Provinciale en Intercommunale Drinkwatermaatschappij der Provincie Antwerpen - Provincial and Intermunicipal Drinking Water Company of the Province of Antwerp);
- T.M.V.W. (Tussengemeentelijke Maatschappij der Vlaanderen voor Waterbedeling - Intermunicipal Water Supply Company for Flanders);
- C.I.E.A.L.E. (Compagnie Intercommunale des Eaux de l'Agglomération Liégoise et Extensions - Intermunicipal Water Supply Company for the conurbations of Liège and its extensions).

Each of these companies supplies in a year between 30.10^6 and $40.10^6 m^3$ of water which, together with the cities of Ghent and Liege, represents a further 20 per cent of the total demand for Belgium. The remaining 10 per cent is supplied by about 200 smaller companies.

All the water supply companies belong to the public sector. The municipalities, Provinces, and State are their only shareholders.

In order to obtain information for inclusion in this paper a questionnaire was sent to each of the above-mentioned water supply companies, with the exception of Liège and CIEALE.

Figure 1 shows the supply zones of these six companies. It should be noted that their yearly supply of water is not necessarily proportional to the area of the supply zones because of the different densities of population and industry and because of the quantities supplied by some companies outside their actual supply zones. This applies especially to Antwerp and Brussels.

It should also be observed that all Belgian water supply companies have metered supplies, with the exception of the A.W.W., where the domestice consumers have a free choice between invoicing after registration via water meter or payment of a fixed charge, calculated according to the number of sanitary appliances in the house. By the end of 1980, 17 per cent of the consumers had opted for metered supplies, and this follows a trend which is increasing.

HISTORY OF THE DEVELOPMENT OF LEAKAGE CONTROL IN BELGIUM

N.M.W. (National Waterworks)

This company checks both the registered and the unregistered consumptions. The latter figure includes, besides water losses, also water used for fire-fighting and public cleansing-services, etc. An exact figure for water losses cannot easily be given. Some figures are given below in m^3 per head and per year:-

	Registered consumption	Unregistered consumption
1975	106	35
1979	111	39

The Company has subdivided its supply area into zones which include between 5 000 and 10 000 communication pipes. The consumption of these zones is registered fortnightly.

If the consumption shows a striking rise compared to the corresponding period in previous years, the night flow (registered between 0 and 4 hr) of the zone is measured during the weekend and checked. The night flow of all zones is registered at least once a year. The apparatus used records both the immediate and the total flow. If the minimum immediate flow in a rural area, expressed in l/service pipe/hr, is found to exceed 5, the zone where leakages are thought to exist is located by shutting off sectors.

A.W.W. (Antwerp Waterworks)

Until 1952, only the listening stick was used by the Antwerp Waterworks. The Company then designed its own acoustic listening device which remained in use until 1956. From then until 1961, the Aqua-Visual leak detection referred to above was used. From 1961 until the present time an acoustic apparatus (Testpatex, from Sewerin, Germany) has been found to give satisfactory results.

In addition, another piece of apparatus has been in use since 1978 which measures the differential temperature of the road surface. The experiences gained with this apparatus are mentioned below.

Between 1946 and 1956 a systematic leakage detection programme was undertaken, especially in the older parts of the city (the A.W.W. has been in existence since 1881). The work was necessary because the distribution system had suffered heavily as a result of damage sustained during the Second World War. Leaks were detected in the day-time and located by night.

After 1959 no systematic leakage control programme was carried out. The work was considered to be no longer viable, since most of the important leakages had been repaired and because a large-scale programme of replacement of the worst affected mains had been started in 1950. Nevertheless, after every winter a systematic leakage detection procedure is still carried out on the oldest mains.

A system for the examination of all consumers' pipes and water fittings is operated by the Company. The workforce comprises a team of eight men, and each household is inspected once during a ten-year period.

Since there are no water towers in its supply area and the pressure in the distribution system is regulated by varying the revolutions of the centrifugal pumps in the main pumping station, the Company is easily able to control the pressure. For many years the pressure has been reduced from 3.2 to 3 bar between the hours of 10 p.m. and 6 a.m. This arrangement saves energy costs, and reduces water losses and the chance of bursts.

In the case of fires, the pressure can be increased at the request of the fire service.

B.I.W. (Brussels Waterworks)

Because of the rapid expansion of the Belgian capital and the absence of local water catchments, this Company has, since its foundation in 1891, been confronted with the problem of water shortages so that ideas like "economical use" and "fight wastage of water" were propagated from the very beginning, and the population has been educated to that effect.

The water catchments and the entrances towards the municipalities-partners are equipped with water-meters, the information from which is processed and checked in a dispatching centre.

It should also be mentioned that, due to the undulating nature of the supply area, it is divided into four pressure zones which sometimes involves the placing of several meters at the entrances of one municipality. All flows are recorded weekly so that the data can be compared to the results of the previous week and possible abnormalities detected.

Whenever irregularities occur, measurements of the minimum night flow are made. This is done systematically in order to locate the suspected zone, and a leak detection survey is then carried out with sounding apparatus.

When the quarterly charges are submitted to the municipalities, the quantities involved are compared to those of the previous years. Once a year the water volumes supplied to each municipality are compared with the sum of its consumers' meters so that figures relating to leakage can be calculated. At the same time these figures are compared with the figures of the previous year.

Since 1950, teams have sounded the distribution network regularly and the complete system is checked every two years. Since the end of the 1950s more accurate water meters have been installed.

P.I.D.P.A. (Provincial and Intermunicipal Company of the Province of Antwerp)

This Company supplies drinking water to an extensive and rural region. The supply area is divided into 12 sectors, each either with its own water catchment or linked to the mains of another company. Water meters are installed which register the net consumption per sector.

These quantities are compared yearly to the total quantities supplied to the consumer. This difference, which remains limited to 15.5 per cent of the available quantities, is considered acceptable. The Company considers that the creation of a special service for systematic leakage control is not justified, since the distribution network is extremely extensive and relatively few mains are located under roads so that possible leakages can easily be noticed and located. The cost of the leakage detection service would be higher than the value of the water saved and the damages caused.

T.M.V.W. (Intermunicipal Water Supply Company for Flanders)

In order to detect leak noises, only the listening stick was originally used; this was subsequently replaced by a simple stethoscope. By the end of the 1950s, a leakage detection apparatus which incorporated an amplifier and a special recorder-microphone was taken into service. Later the efficiency of the apparatus was markedly improved by using frequency-filters.

For the systematic control of certain municipal networks, specialized firms were used initially. At first, the leak detector was used only at night but since 1980 good results have also been obtained during the daytime.

The total supply via municipal main water-meter is compared, on a yearly basis, to the quantities delivered to the customers' water meters. The consumers' evolution indicated by the municipal main meter, is also followed and interpreted.

When important water losses are suspected, the night flows are checked and the affected zone is divided into sections. In order to find the exact location, a leak detector (Aquaphon) is used. A systematic leak detection programme is not operated.

Ghent Waterworks

The remarkable results obtained by this Company, referred to in the introduction to the paper, are due, on the one hand, to the change-over to velocity and volume-meters (which give better results) and, on the other hand, to the introduction of a systematic control of the distribution system with the aid of leak detectors. It was this Company which developed the Aqua-Visual leak detector (2). Nowadays the network is divided into leakage-zones which, according to their importance, are tested every two years or yearly.

REASONS FOR THE PRESENT LEVEL OF LEAKAGE CONTROL

Almost all authors of articles on leakage control refer to the important financial consequences of non-leakage detection:-

- higher exploitation cost (more raw water, chemical products, and energy);
- higher investments (because larger production plants and mains become necessary);
- eventually earlier investments for new sources;
- damage to roads, mains, cellars, foundations of houses etc.

Although the Belgian water supply companies who were involved in the survey undertaken to gather information for this paper were undoubtedly aware of these considerations, the efforts made to detect and repair leakages are very dissimilar, as the above historical survey has shown.

Some companies are conscious that all water losses should be avoided and that efforts to this end are worthwhile. The city of Ghent is convinced that the total cost of its leakage control corresponds with a leakage of only 1 per cent. Other companies find it more difficult to estimate the profits of leakage control and prefer rather the equilibrium which they deem to have obtained.

The PIDPA Company is the only one which doubts the value of a leak detection service, for reasons which have already been given.

POINTS OF LEAKAGE

The figures supplied during the survey show that the percentage of water lost by leakage is considered to lie between 12 and 26 per cent of the total distributed water. These water losses are divided as follows:-

	%
leakage from service reservoir	0 - 1
" " water-towers	0 - 1
" " trunk mains	1 - 3
" " distribution mains	3 - 7
" " service pipes	2 - 3.5
" " customers' pipes on premises	0.5 - 1.5
errors of measurement	1 - 8
unauthorized and unknown use	1 - 1.5
others	0 - 4

Excluding the leakages due to the damages inflicted on mains by works executed by third parties, the most important factors causing leakages are, in declining order - age of mains, traffic, ground movement, defects in materials and joints and corrosion.

In his 1981 lecture to the Technological University at Delft, Mr. E.C. Reed (3) pointed out the phenomenon of an increasing number of bursts after a severe winter (1963) and a warm summer (1976). The A.W.W. Company has had the identical experiences, but especially after a severe winter. The increase in the number of bursts after a warm summer has been far less striking.

It is regarded, in Belgium, as good practice to repair leakages as soon as they are discovered, and it is assumed that this is also the view of engineers in other countries. In Belgium many companies have special repair groups who are on duty at night and during the week-ends and public holidays, so that leakages can be dealt with immediately.

The practice of the renovation of mains is rarely applied in Belgium. A few years ago, the Antwerp company renovated an old Ø 500 mm cast iron main at a cost of about one-half the price of a new main. Encrustations were removed from the main with scrapers and cement mortar was then centrifuged onto the leaned pipe wall.

P.I.D.P.A. was also interested in this method of renovating one of its mains but was unable subsequently to obtain such competitive quotations for the work.

As a general rule one may assume that, except under difficult working conditions, the replacement of a main under Ø 300 mm in size seems to be less expensive than renovating it.

Amongst Belgian water supply companies it seems to be a generally accepted policy to have the complete replacement of mains carried out when road construction or repair works are being undertaken. Obviously, the high cost of repair works to roadways is a reason for this.

Since 1977 the A.W.W. has used special forms (Fig. 2) for the registration of bursts and leakages in the distribution network. These forms are designed to gather as much information as possible concerning the leakages, and they are completed by the workmen who repair the leak. There are selected answers in each column of the form, and the appropriate one has to be ringed. After each form has been checked by the "ganger" for completeness and accuracy, the information is fed into a computer. The stored data can then be used for a variety of purposes e.g. to draft a replacement programme for pipes; for an examination of the causes of the bursts; for an appreciation of materials used; and possibly for an assessment of probable future leaks.

WATER-METERS

The experience of the City of Ghent has shown that the remarkable decrease of the figures for leakages was due, apart from a systematic leakage control programme, to the replacement of the existing water-meters by more accurate apparatus.

The T.M.V.W. estimates that at the present time some 8 per cent of its leakages are due to errors in the flow measurements.

On 16th February 1977 a Royal Decree was published in Belgium which defined the regulations for cold water-meters, the working of which is based on a direct mechanical system using measurement-chambers with movable walls or on the velocity of the water on the rotation of a movable organ. They are therefore called volume or velocity water meters.

When drafting this Royal Decree, the Council Directive 75/33/EEC of the European Economic Community dated 17th December 1974 concerning the mutual adaptation of the legislation of the Member States regarding cold water meters was taken into account.

This Decree came into force on 1st May 1977; however, the water supply companies have a period of 12 years in which to conform to these new regulations.

It will be seen from the following table, which forms part of the Decree, that the zone Q_{min}-Q_t is very small while the zone Q_t-Q_{max} is very large. The greatest acceptable mistake in the lower zone from Q_{min} till Q_t is 5 per cent at the first gauge and 10 per cent when in operation. The greatest acceptable mistake in the higher zone from Q_t till Q_{max} is 2 per cent at the first gauge and 4 per cent when in operation.

Class	Q_n	
	$< 15\ m^3/h$	$> 15\ m^3/h$
Class A		
Value of Q_{min}	0.04 Q_n	0.08 Q_n
Value of Q_t	0.10 Q_n	0.30 Q_n
Class B		
Value of Q_{min}	0.02 Q_n	0.03 Q_n
Value of Q_t	0.08 Q_n	0.20 Q_n
Class C		
Value of Q_{min}	0.01 Q_n	0.006 Q_n
Value of Q_t	0.015 Q_n	0.015 Q_n

Taking into account the fact that $Q_{max} = 2\ Q_n$, the mistake is reduced to max. 4 per cent for 85 per cent of the range of load in Class A, for 90 per cent in Class B and for 92.5 per cent in Class C.

Most water-meters in the cutomers' premises are small capacity volume-meters or large capacity velocity-meters of the Woltman-type.

The water leaving the treatment works is usually measured in the trunk-mains by venturi-meters. However, in some of the newer applications, electro-magnetic flow meters are used. The accuracy of the two meters is 3 and 1.5 per cent respectively.

APPARATUS USED BY THE A.W.W.

The most commonly used device is the old type of ear stick or listening stick. By preference one listens using the ebonite ball which is located in the fire-hydrant where the sound intensity is much stronger than it would be on a valve either in the distribution main or on a communication pipe (main stop-cock).

With the aid of this ear stick, the zone in which the leakage has occurred is determined as near as possible. Next, the Testpatex (from Sewerin) leak detector is used. In this piece of apparatus a feeler is placed on the ground and an amplifier is used to give both an acoustic and a visual signal. The best results are obtained when the apparatus is used on paving stones and cobbles. The detector is less accurate when used on concrete and asphalt and its worst applications are on loose earth.

The reduction in efficiency when used on concrete and asphalt surfaces is probably due to the presence of hollows caused by subsidence under the road surface which helps to deaden the leak noises. Paving stones might have sagged. The fact that detection is better on covered roads than on loose earth is probably due to the improved conduction of the cover so that, at a certain distance from the leakage, the signal would be much clearer when the road is covered.

It has been found that leak noises can suddenly stop in winter. A possible explanation for this could be the fact that the frost causes the leaked water to collect around the leak, so deadening the noise.

It is commonly known that leakage detection is easier on small diameter pipes which are under high pressure. The Testpatex cannot be used under conditions of heavy traffic or when it rains. It can replace the ear stick by placing other feelers directly on fire-hydrants, valves and main stop-cocks.

Combined with and in addition to these listening devices, an apparatus "Instatherm" was taken into service in 1978. It is shaped like a revolver and when pointed to the ground it measures the infra-red radiation of the soil. The apparatus is very sensitive and indicates every variation of temperature.

If there is a reasonable difference between the temperature of the soil and the water in the distribution main, and if there is a leak and the water reaches the underside of the road surface it will be recorded by the meter. However, the apparatus also registers, depending on the depth, electricity cables and sewers. The apparatus is extremely sensitive, so much so that it will detect, in sunshine, the slightly higher temperature of a spot in a road surface which is darker in colour than the surrounding area. With frost and snow the efficiency is rather questionable.

The use of these apparatus requires much experience on the part of the personnel and a great deal of common sense if the right conclusions are to be reached.

NEW APPARATUS

Although the above-mentioned apparatus, used by skilled and dedicated personnel, give reasonable satisfaction, many negative experiences are registered which leave many "dry holes".

The Leak Noise Correlator (L.N.C.) which has been developed by the Water Research Centre (W.R.C.) in England and Plessey undoubtedly represents an enormous step forward in the field of leak detection. In Belgium, much was expected of this apparatus and in December 1980 tests were carried out on it in the cities of Antwerp, Ghent, and Charleroi. Early reports indicated that in Antwerp and Charleroi the L.N.C. succeeded in locating the exact spot of the leakages, where other apparatus had failed to do so.

In 1981 an article by two engineers from the Compagnie Générale des Eaux in Paris (4) described the DF 02 leak detector and gave details of some test results. This piece of apparatus is also based on the principle of the acoustic correlation, as developed by the W.R.C., but it was supplied by the French firm of Metravib, which specializes in the field of vibrations and sound. The article pointed out two essential differences with the L.N.C.:

(1) The use of a "Multi-point correlator" which determines the correlation factor of 400 delay-values simultaneously.

(2) The possibility of selecting the frequency band with separate high and low frequency filters.

In addition, the delay-time and the distance are directly visual on the apparatus. The following table gives the comparative results of leakage detection in the Paris suburbs both following the classical method and with the DF 02.

Appreciation of the results	Classical method	Correlation method
good	41%	82%
difficult	18%	2%
bad	41%	16%

In their article the authors point out that the percentages in this table have only a relative value and that both systems are complementary. By their joint use, almost all the leakages could be traced.

During June 1981 a leak in the distribution system of the Antwerp Waterworks which had defied detection using the Company's own methods was quickly located with the help of the Metravib apparatus.

It is reported that Metravib intends to change the apparatus so that the signals from the pre-amplifiers on the transducers will be transmitted by radio signal to the comparator.

FUTURE POLICY OF LEAKAGE LOCATION

The replies to the questionnaire circulated in connection with this paper indicate that most of the water supply companies in Belgium are satisfied with their existing policies, and that at present only some of them plan to increase the manpower devoted to leakage detection. Nevertheless, it is likely that as the new acoustic-based equipment receives more publicity there will be a renewed interest in the whole approach to the subject.

However, it must not be forgotten that even with the help gained from the new apparatus, leakages in plastic pipes are difficult to detect, and this fact will affect the views of those companies which use this material extensively.

All efforts to improve efficiency in leak detection, particularly with the aid of more sophisticated apparatus, must be encouraged. But it must be remembered that even the best equipment will only give good results if it is operated by a skilled and properly motivated workforce. Great importance must therefore be attached to the selection and training processes of such personnel.

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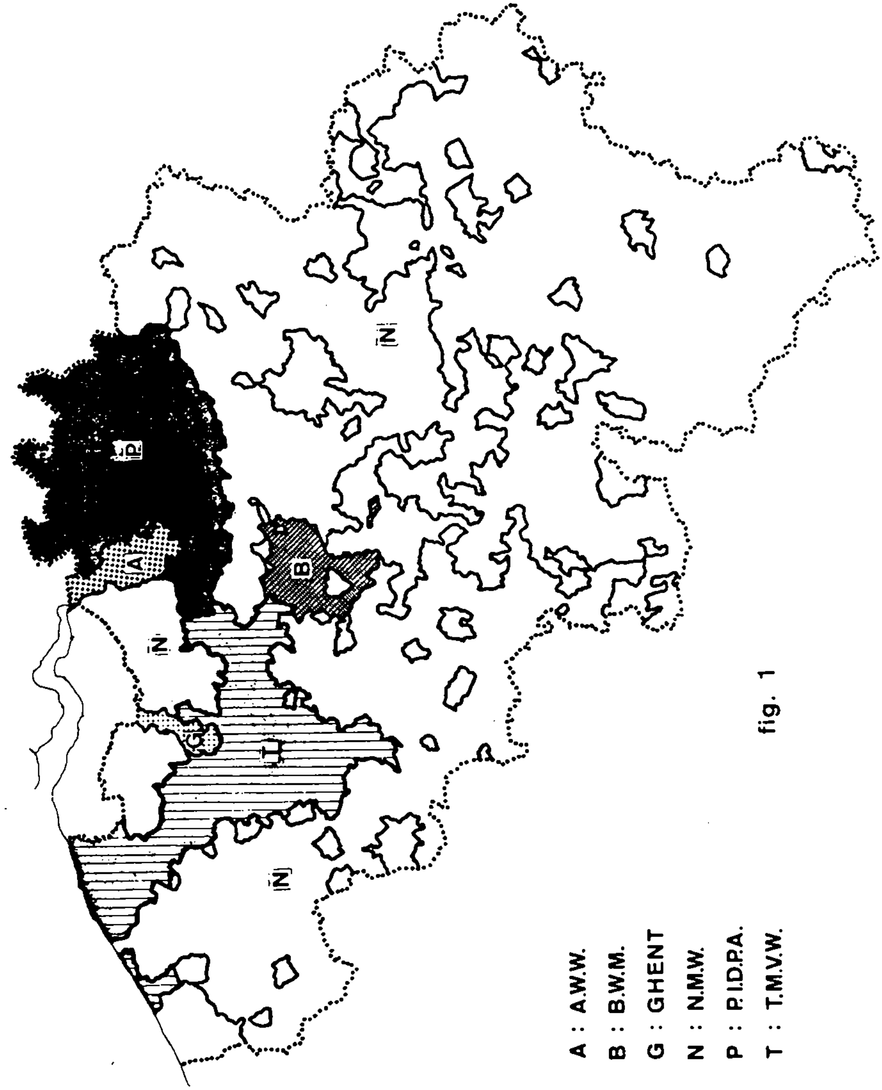

fig. 1

A W W
Technische Dienst

BREUK - LEK DISTRIBUTIENET

(niet te gebruiken voor defekten aan afsluiters - brandmonden - aansluitingen)

GEM		CODE 1 2	STRAAT	CODE 3 4 5 6	NR 7 8 9 10
DATUM DEFEKT	11 12 13 14 15 16		STAMNUMMER KOPMAN	17 18 19 20	

21 - 24 DIAMETER		25 MATERIAAL		26 LIGGING		27 VERKEER OP DE RIJWEG		28 AARD VAN DEFEKT		29 SCHADEGEVAL ?	
80	450 ong	1	AC	1	Rijweg - asfalt	1	Druk	1	Dwarse breuk	1	Neen
100	500 norm	2	GG	2	Rijweg - beton	2	Niet druk	2	Langse breuk of scheur	2	Ja
125	500 ong	3	GN	3	Rijweg - kassei of klinkers			3	Schelpbreuk		
150	600	4	Staal	4	Rijweg - zonder verharding			4	Lek		
175	700	5	Sid. cem. bonna	5	Voetpad - geen inrit			5	Korrosie		
200	800	6	Sid. cem. socea	6	Voetpad - inrit						
225	900	7	Voorg. beton Sentab	7	Zinker						
250	1000	8	Voorg. beton Socoman	8	In leidingenkoker						
300	1100			9	Andere bijzondere ligging						
400	1200										
0000		0		0		0		0		0	

30 - 31 BIJZONDERE SITUATIE DER LEIDING		32 - 33 PLAATS VAN HET DEFEKT				34 HERSTELLING		35 Vorst in grond ?		36 Bijzondere vaststelling	
01	Geen bijzondere situatie	01	Geen bijzondere plaats	16	Sid. cem. mof loodverbinding	1	Dwarse breuk : herstellings mof	1	Neen	1	Neen
02	Onder tram of treinspoor	02	Aan huisaansl. rechtstr. geboord	17	Sid. cem. mof lasverbinding	2	Dwarse breuk vervanging van defekt stuk	2	Ja	2	Ja
03	Leiding door riool	03	Aan huisaansl. met zadelstuk of aanboorz.	18	Uitbouwstuk Vlinderafsl						te vermelden in speciaal vak onderaan
04	Leiding juist boven andere leiding zonder kontakt	04	Aan verankering	19	Johnson - voeg	3	Herstelling loodmof				
05	Leiding juist onder andere leiding zonder kontakt	05	Aan verbinding met bijzonder stuk	20	Loden flensdichting	4	Geen dwarse breuk vervanging van defekt stuk				
06	Onze leiding rust op andere leiding	06	Defekt aan bijzonder stuk zelf	21	Rubberen flensdichting						
07	Andere leiding rust op onze leiding	07	Universeelflens	22	Sentab - rubber	5	Herstellings - mof bonna				
08	Leiding op geringe diepte	08	Loodmof	23	Socoman - rubber	6	Andere methode				
09	Leiding op grote diepte	09	Aantasting rubber	24	GN - rubber express - voeg (serie 1)						
10	Slechte ondergrond (puin e.d.)	10	Selftite - koppeling	25	Buiswand doorgeroest						
11	Leiding rust op hard voorwerp	11	Komeet-koppeling	26	GN - verbinding met inwendige verankering						
12	Defekt in trekvast gedeelte	12	Gibault - oud model	27	Flens zelf gescheurd						
13	Buiswand aangetast door ondergrond	13	Gibault - nieuw model	28	Bouten van flensverbinding losgekomen						
14	Leiding in schede	14	Herstellingsmof	29	Andere bijzondere plaats						
15	Buis in slechte staat	15	GN - rubber distributie leiding								
16	Andere										
00		00				0		0		0	

IN TE VULLEN DOOR BUREEL		
Jaartal Plaatsing leiding	Temperatuur Water	Temperatuur Aan de grond
37 38	39 40	+/- 41 42
		ΔT₁ 43 44
		ΔT₂ 45 46

BIJZONDERE VASTSTELLINGEN
(in te vullen door kopman)

fig. 2

1533 18C

Translation of Fig. 2.

BURST FORM — DISTRIBUTION NETWORK

(not to be used for damage to stopcocks - fire hydrants - service pipes)

1, 2 LOCALITY 3-6 STREET 7-10 HOUSE NUMBER
11-16 DATE FORM COMPLETED 17-20 GANGER'S WORK NUMBER

21-24 DIAMETER

25 MATERIAL
1 asbestos
2 ductile iron
3 steel
4 reinforced concrete with steel core (type 1)
5 reinforced concrete with steel core (type 2)
6 prestressed concrete (type 1)
7 prestressed concrete (type 2)

26 LOCATION
1 under road (asphalt)
2 under road (concrete)
3 under road (cobbles)
4 under road (unmetalled)
5 under pavement (not under garage entrance)
6 under pavement (under garage entrance)
7 under small watercourse
8 in conduit
9 other

27 TRAFFIC CONDITIONS
1 heavy
2 light

28 KIND OF BURST
1 radial
2 longitudinal
3 'shell' burst
4 small hole
5 corrosion

29 ANY DAMAGE CAUSED BY LEAK?
1 no
2 yes

30-31 SPECIAL LOCATION OF PIPE
01 no special location
02 under railway or tramway
03 through sewer (with sleeve)
04 over another pipe without contact
05 under another pipe without contact
06 resting on another pipe
07 another pipe resting on it
08 shallower than usual
09 deeper than usual
10 bad backfill
11 resting on hard object
12 defect in rigid pipe (not loose coupling)
13 soil corrosion
14 within a sleeve pipe
15 badly corroded
16 other

32-33 SPECIAL LOCATION OF BURST
01 no special location
02 screwed junction with service pipe
03 saddle junction with service pipe
04 anchorage point
05 junction with special connection (valve, standpipe, etc.)
06 defective special connection
07 flanged joint
08 lead joint
09 rubber sealing ring
10 'Selftite' coupling (asbestos cement)
11 'Cornete' coupling (asbestos cement)
12 'Gibault' (Victaulic) coupling - old
13 'Gibault' (Victaulic) coupling - new
14 sleeve coupling
15 ductile iron sealing
16 reinforced concrete with steel core (lead seals)
17 reinforced concrete with steel core (welded seals)

Continued ...

continued

18 expansion joint for use with valve
19 Johnson coupling
20 lead flange coupling
21 rubber flange coupling
22 rubber seals 'Sentab' type
23 rubber seals 'Socoman' type
24 ductile iron rubber express couplings
27 flange damage
28 flange bolts damaged
29 other
(25 and 26 no longer applicable)

34 REPAIR METHOD
1 radial burst - sleeved
2 radial burst - replacement of special connection
3 repair of lead joint
4 no radial burst - replacement of pipe length
5 repair kit for special type of pipe
6 other

35 Frozen ground?
1 no
2 yes

36 Special circumstances (not covered elsewhere on form)
1 no
2 yes (space provided for comments)

FOR OFFICE USE

Year pipe installed   Water temperature   Ground temperature

DISCUSSION

Authors' introduction

Ir Depamelaere introduced the paper on behalf of both authors by saying that Antwerp Waterworks (AWW) had always supplied water without metering the quantities. It was the only company in Belgium to do so, as it was their opinion that the supply of drinking water should be regarded as providing a service rather than as supplying a product.

Domestic consumers were charged a fixed tariff based on the number and type of plumbing fittings on their premises (i.e. the more fittings and the more water they used the higher the tariff). A consumer's fittings were examined by an AWW inspector, and a proposed tariff for that consumer calculated. If the consumer rejected the proposed tariff a water meter was installed, and the consumer charged on the basis of his consumption, plus a standing charge. For an average family in Antwerp, paying the fixed tariff, the charge for water represented less than 1% of the lowest yearly income. If general metering were introduced charges would have to rise by about 10%.

Industrial consumers were charged on the basis that they could take water at night for 50% of the day time tariff. This led to a considerable reduction in the maximum demand imposed upon the water company. In 1955 when the system was introduced the maximum flow was 1.6 times the average flow. By 1970 by which time the development of the industrial zone had almost ceased this figure had dropped to 1.15.

The AWW attached great importance to informing their consumers of the importance of economical water use. Various means, including visits to the company's works by members of the public, exhibitions, and slogans on the company's stationery had been used. In recent years the company had adopted a policy of equalizing the amounts paid by domestic consumers on the metered and fixed tariff systems. This had resulted in reductions of up to 10% in the amounts payable by fixed tariff customers. When these reductions were made it was emphasized that this was a result of water savings made during the previous year.

The first technical regulations for interior plumbing (the equivalent of byelaws) had been introduced in Antwerp in 1955. A team of eight inspectors was employed in checking the plumbing on consumers' premises to see that the technical regulations were observed and that the number of fittings agreed with the number given in the contract between the consumer and the AWW from which the fixed tariff was calculated. This operation was self-financing: the increased revenue from the extra fittings found covered the costs of the inspection.

The Belgian water supply companies all belonged to an association (called Navewa in Dutch and Anseau in French) which existed to defend their interests. In the interests of the consumer Navewa had introduced a label which was attached to water fittings which met Navewa's regulations. At present these were limited to preventing pollution in the consumers plumbing or the distribution system by flowbacks, but the idea of fighting water waste by denying approval to fittings which used excessive amounts of water was slowly gaining ground.

Discussion

G.W. KNEEN (Welsh Water Authority) congratulated the authors on their paper. The zoning of distribution areas for the purpose of waste control had been noted with interest and, in particular the size of the zones adopted by the NWW. Zones of between 5,000 and 10,000 communication pipes had been found to be impracticably large in Wales and in consequence areas containing between 1,000 to 5,000 connections had been adopted as meter zones. The importance attached to the development of electronic listening devices by several Belgian water undertakings had also been noted with interest, as had been the comments regarding the difficulties experienced in locating leakages from plastic pipes. It would be most useful to have information regarding any improvement which had been achieved by the use of electronic listening devices in connection with waste detection on plastic systems.

The seasonal increase in pipe fractures was noted. Similar seasonal variations were experienced in the Welsh Region. A midwinter increase in the incidence of burst mains was particularly noticeable in areas overlying mine workings but in limited areas there was evidence of an autumnal increase in fractures. It was assumed that this was due to a change in the underground water table but factual information was difficult to obtain. A better understanding of these aspects might enable mains to be laid which were less prone to leakage from fracture.

Although it was accepted that inaccurate meters were misleading, it was difficult to understand how this increased actual leakage. It would be appreciated if this point could be explained.

It was disappointing to note that the renovation of old mains of less than 500mm was rarely undertaken. In Wales the renovation of smaller mains had been undertaken with considerable success. Technical experience of the scraping and lining of underground pipes was indicating that, particularly where mortar lining was used, the strength and watertightness of systems was increased at a much smaller expenditure than that required for renewal.

W.J.F. RAY (Thames Water Authority) commented that the paper was of considerable interest in its description of the Belgian situation regarding water losses, and particularly the reported reduction in the losses in Ghent from 40 to 12%. As the leak detection system used in London was understood to be similar to that used in Ghent, it was interesting to compare the reported losses for Ghent with the figure of 20-38% given for 'unaccounted' water in London in a recent internal report on water losses. It would be helpful if the authors would quantify the manhours employed on waste control in Ghent for comparison with the current 188,000 manhours per annum engaged on this for the 6m population of London.

With reference to the renovation of mains, the authors had stated that renovation of mains was rare in Belgium, that cleaning and cement mortar lining costs were approximately 50% of the cost of a new main of 500mm diameter, and that renewal of mains of under 300mm diameter was the cheapest option. Mr Ray inquired if the authors regarded cement mortar lining as constituting full renovation and to what extent did they believe this lining provided a permanent seal against leakage. He considered full renovation as the process of relining with a smaller diameter pipe or with an internal coating having significant hoop strength. For example, insertion of HDPE pipe or glass fibre reinforced mortar lining; another option was the 'Insituform' process, in current use for sewer relining. The authors were therefore asked to comment on the extent to which this type of renovation was being pursued in Belgium. There was also the problem of repairing leaks and of remaking service connections onto relined pipes without excessive excavation. Here the possibility of vacuum excavation and of remote insertion of ferrules was under study by Thames Water Authority.

In conclusion, the authors were asked if they had any information on the incidence of leakage in mains related to their age. There was recent evidence that there might be increased leakage from newer thinner walled ductile pipe, possibly due to corrosion pitting.

R.A. PEPPER (Sunderland and South Shields Water Company) complimented and thanked the authors for describing the problems of leakage control in Belgium and the techniques of leak detection currently in use there. Descriptions of the experiences of others were always valuable. The authors had referred to the difficulty of detecting leakage in plastic pipes, and he drew attention to a technique currently being used with success within his own Company. The technique involved the insertion of a small radio transmitter in a foam swab which was then pushed through a suspect plastic main by controlled flows of water. Simultaneously an operator with a radio receiver walked along the surface of the ground following the transmitter. The point where the transmitter stopped, or showed a marked reduction in forward progress, indicated the location of a break in the main. The technique had been used successfully with plastic pipes ranging in size from 10in down to 4in diameter.

G. WOOLTORTON (Welsh Water Authority) said that he would like to hear more of how the leakage detection work was organized in Belgium. In general, within the Welsh Water Authority the work of leakage detection was carried out by manual operatives who were paid a bonus linked to their performance. Several methods of assessing performance had been devised on which bonus payments were currently being made but none were entirely satisfactory. For example, some men were paid more, the more leaks they located, while others had their bonus linked to the quantity of leakage in the areas in which they were employed (i.e. the greater the leakage the smaller the bonus). It had also been confirmed within the Welsh region that a large proportion of the time of 'waste inspectors' was spent on duties unrelated to waste detection such as dealing with consumer's complaints. The initial assessment therefore which was carried out in Wales to ascertain the level of activity and cost of waste detection was very misleading. It was found that in practice very little time was being spent on waste detection, despite the fact that on paper the Authority had a good number of waste inspectors. Waste detection in many areas had been relegated to a low priority and was only carried out if time permitted. The Authority had adopted a policy two years ago which would ensure ultimately that these weaknesses were overcome. Waste inspectors would be employed on waste detection full-time in future and the bonus incentive schemes would be rationalized to provide better motivation.

Mr Wooltorton asked the authors to give details of how waste detection work was carried out in Belgium. Were the waste inspectors manual workers or staff and were any financial inducements paid? What were the number of workers employed full-time on leakage detection work, and what was this when expressed in terms of manpower related to population or connections? Was it possible to give the level of leakage in the urban AWW area with the more rural PIDPA in comparable terms?

T.R. ELLSON (Southern Water Authority) asked for more details of the arrangements for industrial consumers to take water at cheaper rates at night. Presumably time solenoid valves were used.

I.V. YOUNG (Southern Water Authority) asked if the authors had made an analysis of their data on mains bursts and leaks. Had any correlations between bursts and environmental and constructional factors been established?

Authors' reply

The authors thanked all the speakers, both for their questions and for the information they provided. In reply to Mr Kneen they said that the NMW had found no particular problems with waste control zones of between 5,000 and 10,000 connections.

The AWW had no plastic mains in its distribution system, so they had no practical experience in leakage detection on such pipes. The other Belgian water supply companies who used this material, confirmed the difficulties which arose when detecting leakages in plastic pipes. It was to be regretted that even the LNC and the French Metravib-apparatus offered no solution to that problem.

With regard to meter accuracy, it was obvious that, if, as a result of introducing new water meters, the quantity of unaccounted for water diminished, only the errors of measurement decreased and not the actual leakage.

They were surprised to learn that in the UK the renovation cost for pipes up to a diameter of 300mm only amounted to one-third of the renewal cost, and regretted not being able to obtain such favourable conditions from Belgian contractors. They hoped that this situation would change in the near future.

Replying to Mr Ray, they said that within its supply area, Ghent had 263,980 inhabitants and about 84,000 connections, in a 912km distribution system. Registered water consumption was 12,141,725m^3 in 1981, and 3,420 manhours were spent on leak detection. Antwerp employed two waste inspectors for 142,000 subscribers representing a population of 600,000. Water losses were estimated at slightly more than 12%. In the rural areas covered by the PIDPA losses were estimated at 15.5%.

The most important advantages of cement mortar lining were the improvement of the flow characteristics and the prevention of new incrustation. As the cement mortar lining also improved the strength of the pipe, it would also influence positively the prevention of new leakages, although it could not stop up existing leaks.

As previously stated, renovation was rare in Belgium, because of the unfavourable price, but whenever it was done, cement mortar lining was applied. HDPE-pipe or glass fibre reinforced mortar linings had not been used.

So far, ductile iron pipes had posed no corrosion problems at all. Their resistance to corrosion seemed to be at least as good as that of grey cast iron pipes. The wall thicknesses of the ductile iron pipes which were used in Belgium were as follows(without the thickness of the cement mortar lining):

diameter, mm	wall thickness (excluding lining), mm
100	6.1
150	6.3
200	6.4
300	7.2

The relationship between bursts and the age of distribution mains could be established by the AWW as follows:

Year	total number of bursts (a)	percentage of (a) for circumferential burst (b)	percentage of (b) for grey-cast-iron pipes (c)	percentage of (c) for mains laid before 1940 (d)
1978	151	95%	80%	72%
1979	186	92%	87%	61%
1980	173	87%	71%	82%
1981	223	93%	73%	61%

The authors thanked Mr Pepper for the information on detecting leakages in plastic pipes. The use of a radio transmitter in a foam swab was known in Belgium, as it was applied to locate the swab when cleaning larger mains. The successful use for leak detection of the fact that the swab stopped or proceeded slowly as soon as a burst was encountered was previously unknown to them.

Mr Wooltorton had mentioned the payment of bonuses to waste inspectors. In the Belgian water industry, no bonuses linked to performance were paid. This applied to all activities and functions, not only to leakage detection. Generally speaking, they considered that the system of bonuses presented more disadvantages than advantages.

In response to Mr Ellson's request, the authors gave the following information. For peak flows up to 40m^3/h, mechanical equipment consisting of a volumetric meter and a flow limiter was used. The latter consisted of a regulating valve, the outlet of which was regulated by the combined action of a spring and a membrane acting on the control rod. By adjusting the tension of the spring it was possible to limit the peak flow. A pulse emittor was installed on the meter mechanism. This activated a pulse counter which was switched on at the beginning, and off at the end, of the night tariff period by a time switch. The electric power required to operate the system had to be supplied by the consumer. Failure to do so resulted in all water consumed being charged at the daytime tariff.

For consumers whose peak flow exceeded 40m^3/h an electro-mechanical system was used. (The highest peak flow encountered in 1980 was 920m^3/h). A pollux water meter, equipped with a 'polypuls' head, a magnetic coupling, and a rotating counter was installed. The polypuls head contained an oscillator, the impulse frequency of which was determined by the rotational speed of the water meter turbine, i.e. by the flow. These impulses were converted to a dc current (0-20mA) proportional to the flow. The polypuls head also contained a microswitch, operated by a cam on the drive shaft of the counter to open and close once per revolution of the shaft. The dc current from the convertor was fed to the contact points of the switch and the resulting electrical pulses counted by a time switch operated counter.

A flow recorder and a two-step on/off controller with minimum and maximum contacts were connected in serious with the dc circuit. This operated a butterfly valve installed on the consumers' premises to control the flow within preset limits. Once again the electric supply had to be supplied by the consumer, but a backup system incorporating a battery and a clockwork mechanism were installed in case the current failed.

In reply to Mr Young, they said that a recent study of the correlation between bursts and other factors had been carried out but it was too early to draw any definite conclusions. The results were as follows:

Correlation between bursts and traffic

Year	Number of bursts (a)	Percentage of (a) for bursts in roadways (b)	Percentage of (b) for bursts in busy streets (c)
1978	151	67	50
1979	186	74	46
1980	173	66	42
1981	223	67	42

Correlation between bursts and temperature

1. Water temperature (Surface-water)

Year	Number of bursts (a)	Percentage of (a) for bursts at a water-temp. $\leq 4^{o}C$ (b)	Percentage of (a) for bursts at a water-temp. $\leq 5^{o}C$ (c)	Percentage of (a) for burst of a water-temp. $\leq 7^{o}C$ (d)
1978	151	21	43	60
1979	186	52	56	64
1980	173	28	36	56
1981	223	41	50	60

2. Ground temperature (minimum temperature of the air at ground level)

Year	Number of bursts (a)	Percentage of (a) for bursts at a ground temp. $< -1^{o}C$ (b)	Percentage of (b) for bursts on an increas ing part of the temp. curve (c)	Percentage of (b) for bursts at peaks or valleys of the temp. curve (d)	Percentage of (b) for bursts on a decreasing part of the temp. curve (c)
1978	151	38	?	?	?
1979	186	58	38	50	12
1980	173	31	41	47	12
1981	223	55	32	39	29

7. AN ECONOMIC APPROACH TO WASTE CONTROL: A SECOND LOOK.

Dr Judith A.Rees, BSc(Econ), MPhil*

The usual economic approach to efficiency losses within the water industry, with its emphasis on allocative losses will be questioned. Losses which arise from leakage, failure to develop transfer networks and the use of an unduly high quality and/or quantity of supply for specific purposes will then be considered. It will be argued that although suppliers are now paying more attention to measures which increase the efficiency in use of existing resources, considerable scope still exists to reduce water and financial losses within the industry.

INTRODUCTION

It will no doubt be a relief to all that this paper will not be a conventional theoretical treatment of wastage within the water industry, but will attempt to take a pragmatic approach, recognising the practical constraints under which decision makers within the industry must operate. As in the paper presented at your 1974 Symposium, (1) a broad definition of the term losses will be taken, with 4 distinct types of loss discussed. First, there are the obvious physical losses which occur through leakage from the distribution system and from fittings within a consumer's property. Second, losses occur from the failure to develop transfer networks to allow the yield from each supply source to be utilised to best advantage. These losses are particularly important at present given the excess capacity which exists in some areas. Third, losses can arise from the use of an unduly high quality and/or quantity of supply for specific purposes. And finally, losses occur from the misallocation of water between competing uses and users and from the misallocation (or premature commitment) of productive resources (land, labour and capital) to water services when they could be used more productively elsewhere in the economy. Although the premature investment of resources in water provision may be an important source of loss, the usual economic approach of assuming that it can be corrected by merely changing the pricing policies of the industry is rejected here.

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PRICING POLICIES AND ALLOCATIVE EFFICIENCY

With few exceptions studies on the water industry in the economics literature have concentrated on the last type of loss, being concerned with the efficiency with which available water was allocated between consumers and with which productive resources were allocated to investments in new supply capacity. Economic losses were judged to occur if these allocations diverged from the 'Pareto' optimal distribution of resources*. Discussion has in fact been narrowed still further because marginal cost pricing was seen as the mechanism theoretically capable of producing an optimal allocation of resources. Therefore, the attention of economists has been heavily focussed on the pricing policy question. A plethora of papers now exist which basically rediscover the wheel by reiterating yet again the theoretically optimal pricing and investment rules; most of them adding little to the now classic statement on water economics produced in 1960 by Hirschliefer et al (3). By now practitioners in the industry must be thoroughly bored with economists telling them how far their pricing practices diverge from the 'optima' as defined by welfare economic theory. In Britain, it was, and remains, extremely easy to show that prices are set nowhere near marginal costs and to infer that allocative efficiency losses must therefore occur both in the patterns of water use and in capacity development programmes. Such losses are inevitable in an industry in which the traditional practice of historical cost accounting is only now being buried after a long and painful struggle for survival. They are also inevitable because of 60% of the product is still supplied at an effective unit price of zero (ie: all unmeasured supplies). However, the recognition that pricing policies are not optimal and that resource misallocations may be presumed to occur doesn't take us very far in suggesting practical ways of promoting efficiency in the industry. In my view further theoretical debate on pricing is largely irrelevant to present day decision-making within the water industry and only serves to divert attention from areas in which much greater efficiency improvements could be made.. Rejection of the conventional economic approach is based on four key arguments.

First, it has to be recognised that no amount of tinkering with the pricing arrangements will produce any significant improvements in allocative efficiency until meters are installed in most properties. The decision to introduce universal metering will, of course, be taken primarily on political grounds although economists can help inform the decision-making process by contributing to the assessment of the economic viability of the measure. The basis for such an assessment cannot be the notional advantages of introducing theoretically optimal pricing practices but the concrete capital investment savings which arise from reduced consumption and leakage losses. In calculating the possible demand reductions, it would be more convincing, and ultimately more realistic, to assume that metered prices are

*'Pareto' optimisation is concerned with the allocation of national resources between all their possible uses. Resource allocations are said to be efficient if it is impossible to reallocate them to make some consumers better off without simultaneously making others worse off. A Pareto improvement in efficiency occurs when a change produces gains that exceed the value of any accompanying losses, in which case the gainers could compensate the losers and still be better off than before (2).

set at average current accounting costs, rather than to imagine that marginal cost prices (always assuming that there is agreement about what these are) will be employed.

The relevance of further discussion on marginal cost pricing and Pareto optimality must also be questioned because it is now widely recognised that the rules for optimality are "derived from a model of the economy which is a poor approximation to reality" (4). As extensive debates in the recent welfare economics literature have shown, marginal cost pricing will fail to produce an optimal allocation of national resources if 'inefficient' conditions prevail in other sectors of the economy. The existence of monopolistic or imperfectly competitive firms, highly unionised labour, non-marginal cost pricing in other sectors of the economy, and firms or individuals who do not react in the prescribedly rational way to the prices set inevitably means that 'inefficient' conditions are widespread. As these 'deviant' elements will be signalling inaccurate information to water suppliers and users it is argued that it is necessary to counter the inaccuracies by developing 'second best' pricing rules, with prices diverging from marginal cost. In order to establish what the 'corrected' prices would need to be the water industry would have to develop an enormous data base on the way prices for its inputs, complementary products and substitutes deviate from marginal costs. It is understandable that such arguments have been received with a singular lack of sympathy by those actually responsible for establishing prices for public sector goods and services. The cost of collecting the required information would almost inevitably greatly outweigh any allocative efficiency benefits which may result. In the real world it is impossible to define in concrete terms what the optimal allocative pattern would be or to devise implementable rules to achieve it were it ever to be defined. It is, therefore, suggested that little of any practical value will emerge from discussions on 'second best' charging schemes "the reasons for which are concealed in what could be regarded as theoretical 'mumbo-jumbo'" (5).

A third reason for questioning the relevance of the Pareto allocation approach lies in its treatment, or rather non-treatment, of the income distribution issue. In terms of Paretion value judgements it would not matter if the introduction of an optimal pricing system benefitted rich households at the expense of the relatively poor; an efficient resource allocation could produce a highly uneven distribution of wealth. The fact that income distribution is not irrelevant to decision-makers in the water industry is evident in the legislation and in discussions concerning option metering. The 1973 Water Act, for example, requires the RWA's to develop pricing structures which do not 'unduly discriminate' between consumer classes. In part this provision was justified on equity grounds; although just four years later a completely different and contradictory concept of distributional equity was employed to rationalise the Water Charges Equalisation Act (1977), which introduced inter-regional cross-subsidies. Similarly, the National Water Council and the RWA's have supported option metering because 'it provides a remedy for the greatest inequities of the present system' (6). One strongly suspects that in practice avoidance of possible litigation is the strongest motive behind the sudden popularity of the metering option, as it 'avoids the risk of accusations that refusing this option to households constitutes undue discrimination'. However, whatever the motives, the fact remains that water authorities cannot, either legally or politically, ignore the way their charges affect the real incomes of different consumer groups. For example, any attempt to withdraw the subsidies paid directly and indirectly (via charge equalisation within Severn-Trent) to Welsh consumers, and to introduce a marginal cost pricing system, which imposes full supply costs, would be politically foolhardy at the present time. By and large people disadvantaged by current pricing practices are poorly aware of the subsidies they effectively pay to others and therefore rarely protest. How many consumers in recently valued properties, realise that the decision to discontinue the re-rating process in effect condemns them to continually subsidise other water users? Given that one of the unwritten but important objectives of water suppliers is to minimise flack from the public (7), it is in their interest to change existing pricing practices as little as possible; major changes inevitably generate public opposition.

The final reason for rejecting the conventional allocative efficiency approach to losses and wastage within the water industry, is that it is implicitly based on the assumption that optimal pricing and investment rules will ensure that suppliers operate efficiently. However, such rules can only produce an optimal allocation of resources if it is assumed that suppliers are already employing least-cost methods of producing a given level of output (technological efficiency) and are supplying an appropriate type of product (product choice efficiency). For example, if a supplier was adhering to an optimal pricing system, but could produce the same amount of water using less labour and capital, the resulting resource allocation could not be optimal, as it would be possible to release productive resources for use elsewhere in the economy without penalising water users. Whereas, in a competitive situation, it might be assumed that individual manufactures would seek to operate at minimum cost levels in order to ensure their continued profitability, no such assumption can be made about an industry in which neither competition nor the profit motive exist. Nor can it be taken as axiomatic that consumer preferences will ensure that suppliers provide an appropriate product, either in terms of supply quality or service reliability. It will be argued here that the industry is neither technologically or product choice efficient and that attempts to reduce these sources of loss are likely to produce greater and more speedy financial returns than efforts to revise pricing policies to conform to a notionally 'optimal' system.

LEAKAGE LOSSES

Since the 1974 'Symposium on Waste Control', the public statements made by personnel in the water industry suggest that a major change in attitudes towards leakage losses has taken place. However, whether this change has been translated into a major revision of practices remains debateable. Undoubtedly in the early 1970 s a large number of water engineers were unwilling to admit that significant losses occurred and I was taken severely to task for suggesting that losses of 30% of total supply were common. Moreover, many took the view that greater expenditure on detection and repair was uncalled for since it could make no difference to the size or timing of investment programmes. Delegates at the 1974 Symposium were somewhat schizophrenic on the matter. Many agreed with Mr Barrett's thesis that "waste in this country is far from being unreasonable and probably as small, if not smaller, than elsewhere in the world" (8), but in discussions from the floor we were treated to a competition for the worst leak story.

Today, it has been largely accepted that 'unaccounted for' water represents about a quarter of total water supplied in the United Kingdom. While there is still some disagreement about the effect of inaccurate statistics on this loss figure, most people now recognise that loss levels are high enough to warrant serious attention. The fact that both the Water Research Centre and the National Water Council have recently investigated leakage is significant in itself. With the acceptance that loss levels are too high to simply ignore, the relevant question now is what level of expenditure on detection and repair is appropriate in any given area at any given time. As I said in the 1974 paper the theoretical economic answer to this is clear; expenditure should occur until the cost of saving a further unit of water equals the additional cost of supplying an extra unit. This rule implies two things. First, the object of the exercise is not to minimise leakage loss for its own sake, but to ensure that effective supplies are provided at the least cost. It is only rational to spend additional money on saving water if the costs involved are lower than those of producing the water in the first place. And second, the appropriate level of expenditure will vary from place to place, since the cost of producing water varies spatially.

Ideally, the method of waste control employed should be determined by the level of expenditure which the application of the rule implies. In practice, however, the problem is complicated by the fact that it is not possible to gradually increase the level of expenditure to get a neat balance between the unit cost of control and the unit cost of supply. This arises because the leakage control cost curve is highly stepped (figure 1). Moreover, authorities become wedded to one type of waste control technology and cannot easily change methods as the value of the saved water changes over time. While it may be possible to introduce a new waste control method in line with any major increase in the unit cost of supply production, it is clearly impracticable to dismantle a control system if the value of the saved water falls. Such falls are likely to occur immediately after a major extension to capacity has taken place, when only operating costs are saved by the reduction in effective demand. These difficulties mean that the theoretical rule cannot be followed blindly, but it is still of great value in showing the direction which changes in practice should take.

The DOE/NWC publication 'Leakage Control Policy and Practice' provides a good common-sense first approach to operationalising the economic rule in practice. The approach outlined here basically only differs in emphasis. In calculating the appropriate level of expenditure on control, it may be useful to think in terms of five distinct stages.

1. Measure existing losses from different parts of the system, service reservoirs, trunk mains, distribution network, and consumers' fittings. For the first three the manual gives what to a non-engineer appears a comprehensive review of available measurement techniques, but discussion on the last is conspicuously absent.

2. Calculate the unit cost of leakage or the unit value of the water potentially saved. At this stage the calculation should consider the long-term future savings which arise from the way loss reduction lowers the effective demand trend over time. These savings include two distinct elements, reduced operating costs (basically pumping and treatment) and the value of the resources saved by deferring investment. At this stage it is worth stressing that the reduction in the demand trend produced by the introduction of new control methods is a permanent feature; therefore more than the next increment to capacity may be deferred (figure 2). This may not be important if the next increment involves a massive extention to capacity, since the discounted present value of the deferred investment in subsequent increases in capacity will be negligible. However, it is relevant when a series of relatively small-scale extensions to facilities is planned.

3. Choose the appropriate long-term methods of control for each supply area. The term methods is deliberately put into the plural here, because for each of the four sources of loss an appropriate control method must be chosen. After listing the possible control measures, the unit cost of saving water using each method should be calculated. If this cost exceeds the water value established in stage 2, the method must clearly be rejected and when no method of tackling a particular loss problem proves economic the simple alternative of doing nothing remains. It seems possible, for example, that the costs involved in house to house inspection of consumers' fittings will outweigh the resultant savings. Perhaps, it is also worth saying that if an existing control practice fails to meet the viability test, it would be economically rational to phase out its use over time. When more than one method of reducing losses from a particular source are viable, the one showing the greatest net savings should be selected.

4. Calculate the total value of the water saved by employing the appropriate control techniques for different districts within the supply area. It is not realistic to suggest that the appropriate long-term method of control can be immediately and simultaneously employed in all parts of a supply area; equipment must be bought and installed and manpower trained or redeployed. Therefore, there is a need to find some way of guiding the sequencing of introduction to maximise the value of the control effort. The total value of the water saved in any specific district in any one year will depend on three main factors; current variable cost of supply per cubic metre; loss levels now experienced in that area; and the extent to which the existing supply system has spare capacity (this will determine whether the deferred capital expenditure saving is a relevant short-term consideration). It makes economic sense to concentrate the introduction of the improved control technology into areas where the total value of the water saved is greatest. Gradually over the years the system can then be extended down the descending order of total savings until the whole area is covered. A gradual and sequential approach minimises the capital availability and manpower problems involved in increasing the waste control effort.

5. Calculate the intensity of effort required at different time periods in different areas. For most control methods there is not just one level of effort at which the control system could be run. The time interval between soundings, the frequency of reading and inspecting meters, and the speed with which the detected leaks are repaired can all be varied. Not only will the desired intensity of effort vary between districts, determined by the same factors as in step 4, but it will also vary over time. As it is highly unlikely that the same intensity will be required in each area at the same time, it becomes a question of redeploying manpower to concentrate on areas where the value of the saved water is greatest. Hanke, in a recent paper in Water Engineering and Management (9) has suggested that a benefit-cost model can be used to determine the appropriate level of effort. Such a model could be used in two stages. First it can help determine the appropriate intensity of effort required in the longer term assuming that additional manpower can be recruited. Second, it can help re-allocate a given fixed level of manpower in the short-run to districts where the net benefits from waste control are at a maximum. Basically, it is not a question of choosing a control method and applying it so that it becomes fossilised in routine, but of maintaining operational flexibility to maximise the cost savings.

The figures presented in the DOE/NWC manual clearly suggest that for many parts of the country a more active waste control policy would be economically viable. Why then do sub-optimal methods remain in use?

The most usually given answer is that it is the fault of the Government's informal imposition of manpower ceilings. Certainly no one will deny that leak detection and repair is a highly labour-intensive activity, but to blame the lack of implementation solely on manpower needs is not entirely convincing. In the first place, the better sequencing of effort and the redeployment of labour between areas, which was discussed earlier, will help minimise the manpower implications of a more forceful waste control policy. Secondly, virtually all organisations have 'manpower slack' which could be reduced without affecting the level or quality of work done. The fact that such slack still remains in the water industry is suggested by the Monopolies Commission report on the Severn-Trent (10). It reported cases of job-finding to improve incentive payments and to avoid the need to reduce manning levels and also rather politely commented that "staffing at Headquarters appears to be high". Obviously it would be extremely naive to believe that such problems are unique to Severn-Trent.

Finally, it is clearly counter-productive to cut labour or to refuse to take on additional workers when this merely increases capital expenditure and energy or treatment costs. Certainly it is extremely difficult to justify maintaining leakage control efforts at present levels when "rising transmission losses are a major component of supply requirement growth over the next ten years and ... the capital programme on water resources and distribution ... dwarfs the Authority's estimate of the costs of holding leakage at its current level" (11). It is perhaps worth pointing out that the Government is also keen to curb public sector capital expenditure, therefore, unless major gains can be achieved in the efficiency with which existing resources are deployed, then the industry is going to offend against Government policy one way or the other. In these circumstances I can do no better than to quote a key sentence from the Monopolies Commission report "more manpower should be allocated to leakage control when the properly discounted costs of this activity are less than the value of the benefits, which should include savings in the capital budget" (p190).

One strongly suspects that the manpower issue blinds us to the underlying reason for non-implementation and that is the real prevailing attitudes within the industry. Although these are changing slowly, suppliers still place far too much emphasis on capacity extension rather than on methods designed to maximise the use of existing facilities. By and large engineers are trained to construct capacity, not to ensure that the need for it is minimised. At the 1974 Symposium waste control was rightly dubbed the 'Cinderella of the supply function': has its position really changed since then? One engineer recently told me that if an engineer is assigned to waste control he knows he's a failure; surely that is the real root of the problem.

TRANSFER NETWORK LOSSES

Undoubtedly the creation of the regional water authorities has promoted a much greater degree of system integration and has significantly reduced the 'losses' which arise under the single demand centre development pattern. The regionally integrated system has two main advantages. First, it increases the security of supply to each centre while avoiding the need for each supply source to be developed with large safety margins. There is in other words, a 'pooling of risks' over a region which should allow the regional safety margins to be lowered. Second, the total level of surplus capacity developed throughout a region, at any one point in time, is much reduced, since transfers can occur from surplus to deficit areas. This is particularly important in the water case where it has been the practice to develop supply increments in very large discrete steps and ahead of requirements.

The economic advantages of integrated networks and supply transfers has largely been accepted within each RWA, and it is clear that on formation most of them saw it as a priority task to assess the potential benefits from redeploying available resources. Many notable examples could be cited of the effects of such redeployment exercises on capital expenditure programmes. However, the logic of the pro-integration arguments does not appear to have been accepted so readily when the question of inter-authority transfers a arises. A number of authorities appear to value autonomy over the potential cost savings from transfers. Kielder, for example, remains isolated from the Yorkshire supply system and Rutland Water lies largely unused while the development of Carsington trundles ahead. Of course it is recognised that difficulties will inevitably be encountered in agreeing transfer terms, but perhaps the application of a little commonsense economics may help here. Recipient authorities must clearly pay the connection cost plus all the operating costs related to their consumption. That provides the base-line figure. These costs should then be compared with all the savings associated with deferred expenditure in their own areas. It would pay the receiving RWA to offer a sum up to the difference between these two figures in order to secure a cheaper supply. In the same way it would be economically rational for the 'donor' RWA to accept <u>any</u> contribution towards the capital costs of the project. Is it too much to suggest that in cases where authorities fail to agree on the proportion of the cost savings to be received by each that the Department of the Environment or the NWC should have the power to enforce an equitable division? It is not, of course, the intention here to argue for large scale transfer schemes, but to urge that opportunities for inter-regional transfers are taken when this reduces the net cost of supply.

LOSSES FROM UNDULY HIGH QUALITY OR QUANTITY OF SUPPLY

It has long been my view that significant opportunities to increase the efficiency in use of existing capacity exist by attempting to reduce the quantity of potable, often expensively treated, water currently being used for purposes which could be adequately served from lower quality sources. As Mr. Wijntjes(12) pointed out at the 1974 Symposium, in most industrial societies only between 10-25% of water is used for functions requiring high purity standards and yet the overall quality of municipal supplies is dictated by such uses. Theoretically it would be possible to reduce the non-essential use of high quality water by developing dual quality systems and encouraging greater re-use. Although some engineers have recognised the potential of such measures, it is still true to say that very few systematic appraisals have been conducted of the costs and benefits involved in the adoption of such alternative supply strategies.

The development of dual quality systems has been resisted on three main grounds; potential health hazards, possible adverse public reaction and the cost of duplicating the distribution system. Rejection of the possibilities without analysis is, however, commonplace. The likelihood of any adverse effects on health is minimal since the non-potable quality would be basically disinfected and occasional inadvertent use would be harmless; the fact that dual systems are operating elsewhere in the world without health problems is evidence in itself. Moreover recent work by Baumann and Dworkin (13) amongst others, has suggested that the costs of system duplication have been overestimated and that they can be significantly less than those incurred in constructing capacity and treating potable supplies.

Is it unfair to suggest that the real barrier to the introduction of a non-potable service arises because it is simply not part of the water engineer's conventional package of supply options? While it is unlikely that widespread adoption of dual quality systems will prove economic, undoubtedly cases do exist where breaking away from the assumption that all urban supplies must be potable can produce marked financial savings. Two Australian examples will illustrate this point. First, in New South Wales six small towns, all of which had 1971 populations below 4000, have introduced a two-quality service for all domestic consumers. Local river water was cheap to tap but prohibitively costly to treat to potable standard, and since up to 50% of supplies was used outside the home, chiefly for garden watering, savings on treatment costs greatly outweighed expenditure on a second 'outdoor' distribution system. No health problems or adverse public reactions have been reported. Despite the financial success of these projects, which arose largely through local initiatives, no attempt has been made by the responsible authority, the State's Public Works Department, to incorporate an assessment of dual supply potential in their routine evaluation of capacity extension schemes in similar country towns (14).

The second example is taken from North West Tasmania where plans were being developed for an integrated regional supply project, which would improve supply security and give fully treated water to all consumers for the first time (15). In their original scheme, the consultant engineers assumed that all non-domestic users at present receiving piped supplies would receive fully treated water when available. This proved to be a costly and unnecessary assumption. Firms not requiring potable supplies, or with already installed private treatment plants, accounted for 75% of total current peak demand for industrial water in the region. Once the question of a two quality service had been raised it proved remarkably simple to devise low cost distribution methods to serve the bulk of them. In one case, a large cement manufacturer agreed to take over the old untreated municipal source when higher quality supplies for the town became available; only minor works severing connections between the two systems were required. In another area it proved possible to omit a treatment plant at one reservoir, reserving its supply for firms clustered together on an industrial estate; the net capital cost savings, after some realignment of the distribution network and the addition of a small domestic quality pipeline into the estate, was $Aus 800,000 (1975 prices), to which must be added the costs of operating the treatment works. Further examples occurred throughout the region where industrial users and extensive areas of playing fields or parks could be served with non-treated supplies at minimal cost. It is interesting to note that neither the municipal authorities nor the firms concerned had ever been asked to consider the dual quality question; the problem was not one of political or public acceptability merely one of acceptance of traditional modes of operation. While these examples contain circumstances which are particular to Australia, it would be surprising if similar cost saving opportunities did not arise in Britain.

The potential for re-using water has similarly been neglected. Re-use can occur within the consumers' property or could occur throughout a supply system through the renovation and re-use of waste waters. In-property re-use already takes place within industry, but zero unit domestic water prices make it uneconomic for householders to even consider private installation of, for example, storage tanks to allow used bath water to be recycled for toilet flushing. Although the industry could require that once-through systems were not installed in new houses, no such initiatives appear to have been taken. As viable schemes are operating in Sweden and elsewhere, it would seem desirable that at least some economic viability tests were initiated.

Re-use of waste water at the municipal level has rarely been seriously considered in Britain, although the potential has been long recognised in the United States. In 1972 the US National Water Commission (16) recommended that the use of renovated waste water "should occupy a prominent spot in future planning for overall water resources utilisation". Once again, resistance to re-use occurs because of possible health risks, treatment costs and the likely public reaction. However, it has been claimed that in the United States the health risks are a non-problem since the quality of treated waste water would undoubtedly be significantly higher than the tap water presently available in many communities (17, 18).

The economic viability of re-use will clearly vary from area to area, depending on the cost of conventional supplies and on the level of sewage treatment needed pre-discharge to meet local river quality standards. Wherever advanced treatment is already required for pollution control reasons, the additional expenditure involved in further treatment to allow re-use could be significantly less than collecting, transporting and treating raw water. It has already been shown that re-use is a relatively inexpensive supply option in parts of the United States (19).

As yet we know little about the acceptability to the public of re-used water. As Johnson (20) has said "it would appear that water managers know very little of consumer responses concerning renovated waste water, but generally consider the public would not accept it". However, a recent survey in Denver, Colorado, has shown that 85% of the respondents expressed a willingness to drink treated waste water. If this evidence is more widely applicable may it not be the case that the key factor limiting serious consideration of the re-use option is not public reaction but the perceptions of water managers?

It has long been clear that many water fittings and water-using consumer durables use far more water than is necessary. As the price mechanism cannot operate in the domestic sector to encourage householders to install water efficient equipment, the only way this 'loss' can be reduced is for the water industry to take a much more positive approach to the problem. Some efforts have been made to calculate the viability of introducing dual flush toilets but so far these have not been translated into action. Just as it is economically rational to concentrate leakage detection efforts in areas where the value of the saved water is highest, so the possibility of installing variable flush toilets in such high cost areas should be actively pursued. To date, there is relatively little evidence that serious attempts are being made to promote the use of other water-efficient fittings or to press for development of low water using consumer durables.

CONCLUSIONS

In 1974 I accused the water industry of taking a supply-fix approach; using capacity development to meet all foreseeable demands and neglecting methods designed to improve the efficient use of existing supplies. Undoubtedly since that time attitudes appear to have changed, waste control is at least discussed as a viable alternative to immediate supply extension, intra-regional transfers have cut the need for capacity development, and some RWA's at least have accepted that small scale staged capacity extension is a preferable option to committing huge capital sums to inflexible large-scale schemes. The fact that premature capacity development has occurred in the past is difficult to deny; Kielder and Rutland Water will remain expensive boating lakes for some time to come. The question is have attitudes changed enough to ensure that such costly mistakes are not made in the future when and if the economy recovers. Certainly the suspicion remains that one of the conclusions of the Monopolies Commission report on Severn-Trent would apply to most if not all the RWA's. "We are, however, concerned about the low priority given to cost-saving investment and that, given a capital expenditure programme of around £90 million per year, the Authority has not yet developed a comprehensive strategic planning process which clearly demonstrates that the overall level of investment is economically justified." It would appear that considerable scope still exists to reduce water losses and to give water and cost-saving measures their due place in the water planning and management process.

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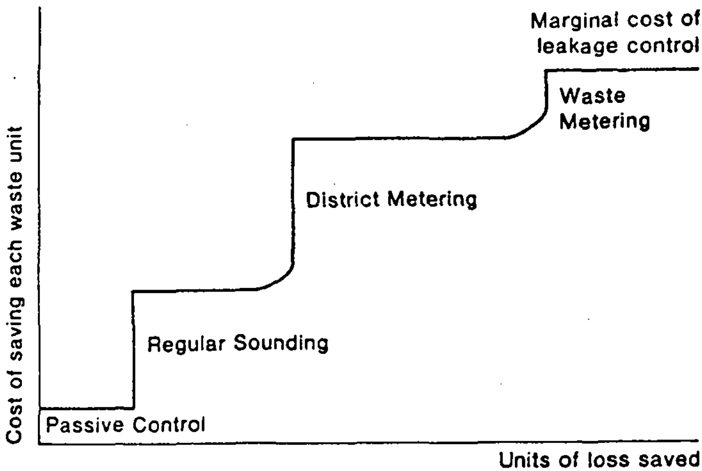
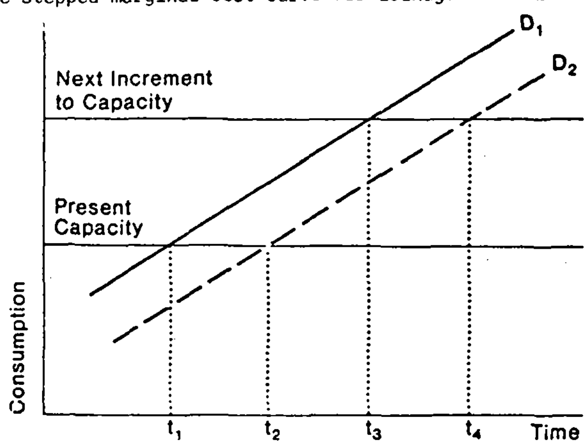


Fig. 1. The stepped marginal cost curve for leakage control



D_1 :- Growth in consumption assuming a low level of detection and repair

D_2 :- Growth in consumption assuming a high level of detection and repair

$t_1 - t_2$:- First Period over which Investment deferred

$t_3 - t_4$:- Second Period over which Investment deferred

Fig. 2. Demand reductions and deferred capacity development

DISCUSSION

Author's introduction

Dr Rees in introducing her paper commented that she was pleased and honoured to be invited to address the Institution for a second time and to be able to pursue the question of waste or loss control once again.

Previous contributors to the Symposium had concentrated on physical water losses arising within the consumer's property, through pipeline leakage, and from the incomplete use of catchment potential. But it had to be stressed that such physical losses were of concern not for their own sake but because their existence suggested that it might be possible to reduce the resource inputs currently expended on the production and distribution of water supplies. The objective of loss management was not to save water per se, but to save land, labour, and capital resources, and it therefore followed that it was not economically rational to pursue any loss management policies unless the resulting resource savings exceeded the control costs.

In the paper a broad view had been taken of the nature of water losses to include economic losses which could occur when productive resources were not used to best advantage. However, no attempt had been made to reiterate the theoretical arguments substantiating the likely existence of three forms of economic loss which had been discussed at some length in the paper presented at the 1974 Symposium. Given that water prices were not, and for the unmetered sector could not be, set at marginal supply costs, the presumption must be that economic losses were still occurring through the use of excess quantities of water, premature investment in capacity, and the misallocation of supplies between consumers. However, further discussion at this time on such allocative efficiency losses served no useful purpose, being largely irrelevant to present-day decision-making within the water industry. Reduction of this type of loss depended on the introduction of universal metering and appropriate unit pricing policies, and only when, or if, this took place would further discussion be anything other than academic. It had also to be pointed out that optional metering would do little to improve the situation, particularly as some at least of the schemes appeared to have been designed to encourage people to refuse the option! As with all other waste control measures metering and 'optimal' pricing would only be justifiable if the resulting resource savings exceeded the costs involved; on present evidence this condition did not appear to be satisfied in most parts of Britain at the present time.

Moreover, as it had been pointed out in the paper the relevance of further debate on allocative efficiency losses must also be questioned since their very existence and the rules for allocative optimality were derived from a model of the economy which was a poor approximation to reality. It was now well known that the introduction of theoretically optimal pricing practices would not produce an efficient allocation of resources if 'inefficient' conditions occurred elsewhere in the economy. Nor would it necessarily produce prices or income distributions which conformed or conventional or politically acceptable notions of equity. It had been argued that economists had paid far too much attention to allocative efficiency and had neglected the assessment of the 'technological' and 'product choice' efficiency of the water industry. Such neglect was all the more surprising since allocative optimality could only be achieved if the industry was employing least-cost production methods.

It would be difficult for suppliers to claim that they were already least-cost producers and most would acknowledge that scope existed to increase the efficiency with which existing resources were utilized. It seemed probable that efforts to increase efficiency in use would yield much greater and more immediate returns than any attempts to introduce notionally optimal pricing systems. In the paper, it had been suggested that economies could possibly be achieved in four areas: the reduction of distribution losses, extended inter and intra-regional transfers, the use of appropriate supply qualities, and the efficiency of water-using consumer durables.

On the surface a major attitude change towards distribution losses had taken place over the last decade. The days when engineers were reluctant to admit that significant losses were occurring had largely gone. Although perhaps something of this old reluctance could be detected in Mr Pocock's paper when he commented that 'The vexation is increased tenfold for the water engineer who cannot prove that the situation is not as bad as the "unaccountable" figures would suggest.' However, it was difficult to avoid the nagging doubt that although numerous expressions of concern over losses existed on paper as yet these had not been translated into much effective action.

In any discussion on leakage it was crucial to remember that the objective of control was not to minimize physical losses but to curb losses to a point where the control costs equalled the value of the water saved. Although from an engineer's point of view it was probably easier to think in terms of achieving low night flow readings, there appeared to be a danger that some set night flow figure would become enshrined as good engineering practice. Such a mechanistic approach to the loss problem would miss the objective of the control exercise which was to save resources. For example, Mr Ingham had been congratulated on achieving a net night flow figure of 4.9l/property/h, but the key question was what did this figure mean in terms of the cost incurred per unit of savings. As both the cost of control and the value of the water saved varied over a region, it was clear that no one set minimum night flow figure would be appropriate for all areas.

It was common for water engineers and managers to argue that leakage losses could not be cut at the present time because of government pressure to reduce manpower levels. Anyone working in the university sector was only too aware of the problems involved in manpower cuts, but two lessons had been learnt from that experience. First, in any organization there was likely to be some manpower slack and scope for redeployment. Second, cuts would be counterproductive in departments which brought in high fee paying students or research funds. It was extremely doubtful whether the water industry could claim to be free of 'labour slack', and it must be uneconomic to cut manpower in an area when this merely acted to increase capital expenditure, and energy or treatment costs. It was difficult to justify a situation where an Authority was planning to spend £90 million a year when 50% of the likely demand growth in the area was due to projected increases in 'unaccounted for' water.

There was no need to go over the transfer and excess capacity issue again here, it had already been well aired by Pearce (21). Many water engineers had expressed annoyance with this article and disputed its accuracy. But it was difficult to deny that expensive over-investment had occurred and that, at least in the Kielder case, the idea of transferring surplusses had floundered on the failure of the two supply authorities to agree on cost-sharing. It was not enough to claim that current supply surpluses were merely the result of unforeseen falls in demand, nor was it axiomatic that in future the RWAs would take every economic opportunity to transfer surpluses.

On the questions of alternative supply qualities and low water-using consumer fittings and durables, it was not known whether any of the proposed measures would produce resource savings. But it was argued that the industry should take a more innovative approach and at least seriously test whether opportunities for economy existed. Unless suppliers took a more aggressive approach, making serious attempts to promote the use of more water-efficient fittings and supply systems, the public could not be expected to appreciate the true costs of their supplies.

Discussion

J.E. THACKRAY (Severn-Trent Water Authority) said that he was honoured to have been asked to open the discussion on this particular paper. Before reading it he had asked for the comments of two engineers and two economists. Being initially qualified as an engineer but now practising in the fields of water economics and charging, he had found their different perceptions and reactions most illuminating and he invited the comments of Dr Rees and the audience on them. Both of the engineers said that they had found the paper exhilarating and provocative: the economists were both disparaging and said that it was misdirected and that it had been heard many times before. This led to the obvious questions which had to be answered in this discussion. How far had the engineers understood and made use of the economists' methods and messages since 1974; and how far since 1974 had the economists been able to improve their factual base and take economics from the textbook and lecture theatre into the practical situations of the water industry?

Taking the author's headings in the paper, her first analysis concerned 'Pricing Policies and Allocative Efficiency'. Here it seemed that she had fallen into the classic trap laid for all economists, that of moving from the undeniable fact that money motivated people seriously, to implying that people were only seriously motivated by money: '..... (allocative efficiency losses) are inevitable because over 60% of the product is still supplied at an effective unit price of zero (i.e. all unmeasured supplies) ..... it has to be recognised that no amount of tinkering with pricing arrangements will produce any significant improvements in allocative efficiency until meters are installed in most properties'. In fact careful studies by the author's colleagues had shown that in Malvern, the only place in UK where water supply was almost universally metered, there was no measurable price elasticity in water use at UK consumption levels. Further, the 'meter consciousness effect' measuring the persistent difference in use for measured to unmeasured groups of customers was rather less than 10% (22). These facts were themselves hardly surprising in view of the degree of respect in UK for careful living and for the law, as well as for what money could buy; and the very small percentage of the average household budget formed by water costs. In fact 'the installation of water meters in most properties' had itself been shown to be a serious potential misallocation of resources (23). In economic terms the water authorities were right, in Mr Thackray's view, to allow householders to use their own money to meet the extra costs of metering over and above those of the much simpler rateable value based unmeasured system, but not to contemplate universal metering. Although mandatory metering in a few small areas for the sake of the 10% saving might seem theoretically attractive, the legal and operational difficulties of running it alongside optional metering might well raise its costs and practical difficulty beyond a viable economic and technical level, except in isolated rural situations. There was the possibility that selective mandatory metering of household use, including substantial garden watering, might prove technically feasible and economic when it became practical to implement peak load/seasonal charging for these and agricultural customers.

The author's second analysis concerned her fairly orthodox approach to leakage control economics. Mr Thackray complimented her on stressing the need for defining appropriate methods and levels of leakage control for different areas and for the same area at different times. The problem here was to find reliable data to make these definitions and to monitor the application and success of a policy based on them. Investigation had shown that data were extremely scarce, throughout the world, on the precise costs of different levels of control, ranging from dealing only with reported leaks showing above ground (passive control) through the various available stages of inspection and correction to achieve the maximum practicable tightness in an underground system. As the complement to its previous studies of household and industrial water use (22, 24) Severn-Trent had some while ago embarked upon just such a study which would enable it to develop the type of finely articulated policy which Dr Rees described, in about two years time. In three years time he hoped that the full results would be published for discussion. One of the first facts to come out of the study was the relatively high proportion of properties with defective stop taps belonging to the supply undertaking, up to 24% in some of the areas surveyed. Dr Rees was, however, wrong to imply that the Monopolies Commission had uncovered something new at Severn-Trent. Its comments in this area were taken from internal reports made within the Authority as part of the process of defining the massive inherited task of co-ordinating and rationalizing the diverse leakage control policies of its predecessors in a situation where the Authority was forecasting an entirely new set of demand profiles following the studies already referred to in Ref. 22 and 24.

In referring to her third issue of 'Transfer Network Losses', Dr Rees was sadly out of date. In practice the economic viability of major water authority transfers has generally been seriously undermined by the recently lowered water authority forecasts of demand growth. The initial costs of interbasin transfer links on a large scale were very high and these propositions tended to be uneconomic unless use of the links moved rapidly to a high level and was then held there. In particular, the case for a Rutland Water link to defer or avoid the need for the Carsington Reservoir had been analysed exhaustively at Public Inquiries and had not only been rejected by the two Authorities on economic grounds, but also by the Government following the report of an Independent Assessor.

'Losses from Unduly High Quality or Quantity of Supply' was the author's fourth heading. Here Mr Thackray was surprised that the author had not referred to the major system of lower quality use in UK. This was by licensed direct use of river and groundwater, particularly by industry. In the Severn-Trent region this exceeded use of the piped supply by a ratio of 3 to 2 even after deducting through cooling use for power generation in bulk. The basic costs of such sources, of good quality and reliable yield, were less than 10% of the costs of piped supply. Alternative piped supply systems of different reliability and quality were rarely economic, because two-thirds of the cost of piped systems were in the pipes themselves, and savings on source costs were rapidly offset.

The two Australian examples were interesting if one had that type of climate and socio-economic situation, but were only relevant to westernized and very affluent communities living in an arid region.

Although UK water fittings were already among the most economical and cost effective in the world, the author was right to point to the need to further efforts here. The Wessex Water Authority was pioneering the use of dual and variable flush WCs, and other Water Authorities and, he hoped, manufacturers, were eagerly awaiting the results of this experience with a view to making significant progress in this area. For manufacturers, this would be of great value in export markets.

In conclusion he thanked Dr Rees for rightly focussing attention on the point that in most regions a rounded approach to the definition of losses was essential, and for producing a paper where she had had the courage to make sweeping and provocative assertions in order to stimulate discussion. As with the various recommendations of the Monopolies Commission, he would counsel that readers should consider carefully the economics of the proposals themselves as well as their theoretical attractiveness, before taking them past the research and development stage to full scale implementation.

H. SPEIGHT (Southern Water Authority) in congratulating Dr Rees on a stimulating and provocative paper, said that he ought, perhaps, to reassure her that there was now a better understanding of the respective roles of the water engineer and the economist: a big change in thinking over the past fifteen years. He had referred to that period because it marked the time when, on the British water supply scene, there were more than a few flutterings in the dovecotes whenever long cherished and jealously guarded notions of what was in the consumer's best interests were challenged by anyone with less than a quarter of a century's experience of actually supplying water. Not only were they now more tolerant of those in other disciplines who challenged them to look at what they were doing and to justify it but they even acknowledged that this needed to be done. It might be, however, that the industry was now in some danger of providing employment, in what was essentially a field of technological enterprise, for rather more economists and consultants and efficiency auditors and government accountants than for engineers and scientists ... but that was another matter and not to be pursued at this time.

Mr Speight said that he believed that Dr Rees was right in saying that engineers tended to see the construction of additional capacity as a traditional solution while turning aside from minimizing the need for such additions. Although the statement was generally true, however, it was only a partial assessment of a complex situation. Contemporary pressures from Government via the Monopolies Commission Report, and the stone-turnings which had followed its publication, advocated the desirability of minimizing the need. They overlooked some of the practicalities of a situation, however, in which the theories need to be applied in practice rather than displayed on the printed page.

Governments might advocate measures to lead consumers to use less water, but were they prepared to give the water suppliers the virtually dictatorial powers to enforce that advocacy? Byelaw powers now existed to enforce the installation of dual flush devices under specified conditions, but what sort of an interference would it be in the daily life of the citizen if the industry stipulated that no more once-through-systems were to be installed (as Dr Rees advocated). What sort of interference would arise if the industry attempted to decree that showers must serve the same purpose as baths and that spray taps would henceforth be compulsory on all but the kitchen sink? One could be cynical and suggest that progress in this direction might be quicker were the advocacy to arise from the manufacturers of suitable appliances than from within the water industry itself!

Mr Speight said that he could not let the opportunity pass of referring to the implicit acceptance by Dr Rees of the universal relevance and accuracy of the voluminous contents of the Monopolies Commission Report. Accepting that there would always be room within any organization to cut costs, it did not necessarily follow that the medicine now being so freely prescribed would effect a cure in all cases, or that practicalities were not at least as relevant as philosophies. For instance, Dr Rees had inferred that leakage control was a once and for all operation in terms of securing a given effect. In practice the water saved by the initial adoption of particular methods would remain saved for only so long as it was practicable to mount the effort to prevent the situation reverting to its former state. There was a reference in the paper to a failure to develop effective transfer systems within the industry (and possibly a call for the resurrection of a Water Resources Board with teeth). In an imperfect world, however, it might be necessary to continue to live with surplus resource capacity for a variety of economic, political, and practical reasons.

Finally, Mr Speight pointed out that Dr Rees referred to re-use; implying, he felt, the direct reclamation of water from effluent discharges and possibly overlooking the fact that, in the contemporary scene, significant abstractions were supported by effluent discharges made upstream. Re-use by a less direct mechanism, but re-use nonetheless (and not made without misgivings in some quarters) but re-use in a manner recognizing both the costs of alternative developments and practical limitations.

K.F. CLARKE (Anglian Water Authority) said that Dr Rees, and economists like Robert Smith of the Water Resources Board and Paul Herrington of Leicester University, had made an impact on the water industry out of proportion to their numbers, and as a result, the industry had made tremendous strides. Therefore, it was pleasing to see that the author had acknowledged that progress had been made. On the other hand, it was disappointing that there were no firm suggestions for the next seven years; and, more importantly, some of the assertions made by the author were based on incorrect information.

The author's comment that progress on reducing waste was slow because engineers were 'trained to construct capacity' showed how out of touch with the industry she was. The industry had made dramatic advances in the last seven years, in quantifying and identifying waste, in spite of considerable traumas such as a massive reorganization. Today's water engineer tended to have less to do with reinforced concrete and more to do with Performance Aims, Performance Indicators, Levels of Service, Management Accountancy Systems, Management Information Systems, etc., all of which were aimed at making the industry more efficient.

The author's remarks that Rutland Water was an expensive boating lake must be vigorously refuted. Rutland Water was not 'largely unused'. It was commissioned in 1977 and since then had supplied 33,000 M gallons. Today, only four years after commissioning, it supplied over half its 'parliamentary' yield, and as such it supported the whole fabric of existence in an area stretching from Milton Keynes to Grimsby and from Northampton to Skegness, including supporting the growth of three New Towns.

A decision to construct Carsington Reservoir was made only after a searching inquiry, and the author could be assured that even if water from Rutland Water was supplied at zero cost, the Severn-Trent Water Authority's programme for resource development, including Carsington Reservoir, would still be cheaper. Inter-Authority transfers were never forgotten and would be recommended if economically viable. Mr Clarke said that he had a professional interest in recommending them if they were viable because he had helped draft the Water Resources Board's final report which recommended them.

Dr Rees had recommended dual systems: in fact, large dual systems did already exist, an example was one in South Humberside. Also there was another dual system, because in a peak week in a dry year, about 50% of the water used in the Anglian WA region was abstracted directly by the consumer from the water resource system, and that system was enhanced when appropriate. On the subject of re-use, there was large potential and this was being realised. In the year 2001, about 30% of the surface water used in the Anglian WA region will have been used before.

Finally, if the author would like to visit the Anglian WA, she would be shown some of the achievements of the last seven years, some of which had resulted from the influence of the small group of economists like her.

J.B. BUKY (World Bank) said that the pricing considerations given in the paper highlighted the single major omission in each of the excellent papers presented during the symposium, namely the question of loss of revenue to the water undertaking caused by losses of any form. Since under the British system, domestic consumers were not (yet) charged directly for the amount of water consumed such omission was understandable. Nevertheless, since industrial and public consumers were metered, loss of revenue due to under registration of meters ought to be a concern. In the United States, Brazil, Singapore, and other places such meters (over 2in diameter connections) were often recalibrated every 3-6 months to avoid such revenue losses. The revenue issue should also be considered by the British water industry because of the leading role of its consultants and members in water supply in the developing countries. One of the World Bank's primary requirements in considering financial support for water supply projects was the financial viability of the borrowing entity. By far the most common form of charging for the supply of water was the use of metered tariffs and it was therefore a vital financial issue to keep unaccounted for water (UFW) to the economically possible minimum. The financial viability was not merely a 'sound business' requirement. If the estimated 2,300 million people who will require water supply services during the next ten years were to be satisfied, a major part of the required funds would have to be generated internally by the water supply sector through appropriate charging systems. Efficient control of UFW was a major consideration in every World Bank supported water supply project and there was a constant search for improved methods. The British water industry through various channels and specifically through this Institution should play a major part in this search and the World Bank's water sector staff would welcome a closer cooperation with the Institution to further this. The leak detection practices and technologies described during this symposium would be vitally important in many developing countries but the commonly 'quoted' 50-60% UFW figures could not all be considered leakage. It was therefore most important that what were often called 'administrative losses' be given adequate consideration. In many cases successful reduction of such 'losses' through improved 'accounting' might determine that only the most simple and routine leak detection programmes were justified economically.

J.A. YOUNG (Wessex Water Authority) said that he was grateful to Dr Rees for her paper, not only for what it said but for what it hadn't said. It was a relief to be spared the usual marginal cost arguments. In a world where charges were set by a combination of brute force, ignorance, and legalized brigandage, the immaculate conception of charges for the water industry was becoming rather an outworn cliche.

As well as ensuring non-discrimination between classes of consumers under Section 30 of the 1973 Act, tempering the wind to the shorn lamb of the lower income groups, water authorities must meet their Performance Aims, manpower targets, keep within capital ceilings and external financing limits, realize the required rate of return on assets, only spend capital on revenue saving schemes, adopt inflation accounting, review their asset lives, be scrutinized by the Department of the Environment in the wake of the Monopolies and Mergers Report on Severn-Trent, and by accountants appointed by the Government before going firm on budgets and charges. The overall result of these inconsistent, ad hoc, mutually contradictory expediencies was that at the end of the day charges would be rather higher than they would have been if water authorities had been left completely to their own devices.

Mr Young then said that her breath of fresh air was needed to sweep away any complacency. Things were moving and they didn't now write 10% as their percentage of unaccounted for water when asked to provide this information. There was now a standard method of calculating unaccounted for water in accordance with the Leakage Control Policy & Practice Document, but as long as domestic consumption was largely unmetered, unaccounted for water would perforce have to be an estimate, although an increasingly accurate one. They were also beginning to calculate the value of water saved in different areas so that limited manpower could be directed in the best direction as far as waste detection was concerned. Mr Young said that he didn't know how Dr Rees's suggestion that the headquarters staff at Severn-Trent should be remustered as waste inspectors, had gone down there, but it would not be the first time that his headquarters staff had been sent out at night to carry out comprehensive waste detection tests!

Mr Young said that he did not share Dr Rees's views about duplicate distribution systems for potable and other qualities of water, except in special cases. There was a real problem with the risk of contamination by cross-connections and of course by far the highest proportion of fixed costs, 60% or more, was in underground assets, both from a capital and revenue point of view, and it was very uneconomic to duplicate these unless there were very special circumstances. However, effluent was being re-used.

Mr Young said that if he drank the glass of water in front of him it would have been through, he believed, at least five sewage works on its route down to the Thames, until it was treated for water distribution. At Bristol, Wessex supplied treated sewage effluent to industry and both effluent and electricity to the refuse destructor, and they had been trying ever since 1974 to get a joint scheme off the ground with the County Council to utilise the waste heat from the refuse destructor to add to the 6MW Wessex already generated at Avonmouth from sludge gas; and at the Westbury cement works, sewage affluent was being used for slurry transport and town refuse to heat the kiln.

As far as domestic water economy was concerned, all new installations had to be dual flush and with the Wessex meter pack for the domestic meter option, two free variable flush cistern conversion kits were provided, which would reduce average domestic consumption by 17%. It was disappointing to find that a large number of people interested enough to opt for a domestic meter were not even bothering to get their plumber to install these variable flush kits, and Wessex were about to embark an additional publicity on this aspect. In spite of the hysteria about water charges, price elasticity still seemed to be very low for water.

Wessex were also using the variable flush kits on Exmoor as a resource option to husband spring supplies which fell to a low level in the summer when the area was full of visitors. Mr Young agreed, however, that much more action was needed to produce economical water appliances, such as washing machines, and it would be a good idea if there was a water economy label available from the National Water Council, on machines which were economical in water use.

R.H. SMITH (Northumbrian Water Authority) said that the Technical Working Group on Waste of Water had indicated its credentials in economics by recommending its winding up; it had thus become the first standing technical committee to apply for voluntary severance! He thanked Dr Rees for another paper that had the effect of putting members on their mettle but he believed that important advances had been made since Dr Rees's paper of 1974; a codified procedure, in the form of the Final Report of the Technical Working Group on Waste of Water was now available and it had been shown to be acceptable to both economists and to engineers.

Mr Smith said that he was very pleased to note Dr Rees's approval of the commonsense economic method used in 'Leakage Control Policy and Practice'. One point worthy of emphasis was that in taking into account limitations in the accuracy of the constituent elements, it recognized that there may be more than one method of control that was economic for any particular system. The less easily quantifiable factors must then be assessed and the manager's judgement exercised on political, financial, and operational matters before one method of control could be determined. As an example he had worked the figures, put forward earlier in Mr Ingham's paper, into the Working Group's method using only the unit operating cost and had found that regular sounding (the current method) and district metering were shown to be economic options. Figures for the unit capital cost were not available but, although the absolute figures changed when a notional unit capital cost of 1 penny per cubic metre was added to the unit operating cost, both regular sounding and district metering were still shown to be economic. Mr Smith said that he was sure that he knew what Mr Ingham's choice would be.

Dr Rees had referred to the absence of reference to leakage from consumers fittings in the Working Group's report. Significant leakage from consumers apparatus was specifically referred to and would, of course, be picked up during inspections of districts. Because inspections for waste within buildings was so intimately tied up with inspections for contamination, misuse, undue consumption, reverberation in pipes, etc. it had been decided by the Group that to go into detail would cloud the main thrust of its work and it had been agreed with the Chairman of the Standing Technical Committee on Water Regulations that his committee would deal with waste inside buildings. Mr Smith believed that this had been a correct decision.

House-to-house inspections had also been referred to by Dr Rees and Mr Smith said that these (amounting to checking taps and ball valves for leakage) had been abandoned many years ago by the Durham County Water Board in favour of a freely available rewashering service. The latter had proved to be cheap to run, reduced leakage and maintained good consumer relations.

S.J. GOODWIN (Water Research Centre) wrote that a number of authors had referred to NWC Report No.26 'Leakage Control Policy and Practice' and the author herself had commended it as a 'good commonsense first approach to operationalising the economic rule in practice'. The symposium would be incomplete without mention of the importance of that report and the substantial effect it had made on the water industry since publication eighteen months ago.

It had long been accepted that economics should play a major part in determining leakage control expenditure and many theories had been proposed over the years. Report 26 provided for the first time a practical procedure for determining leakage control policy which included not just the economic considerations but the practical factors and constraints also. This was most probably the first report of its kind which had been found acceptable by engineers, economists, planners, and accountants. This procedure was shown in Fig. 3 It is applicable universally, to all parts of a supply and distribution system and to all systems regardless of the fact that an active leakage control policy was in operation.

The need for accurate estimation of leakage levels was paramount to avoid the choice of an inappropriate method of control. David Field and Tony Spencer had persuasively shown that this meant measurement of net night flows using perhaps a reservoir drop test and although these measurements involve some effort, this was but a drop in the service reservoir compared to the effort and expenditure which would be incurred in future years on the chosen method of control. They had heard in the discussion that NWWA had performed such measurements for 290 zones covering 85% of the properties in their region. This was no mean feat and several other authorities had so far achieved more than 60% coverage. Significant progress had been made in the calculation of the unit cost of leakage, and he estimated that to date these costs had been derived for approximately two-thirds of England and Wales.

His final point concerned the question Dr Rees asked in the paper - If active waste (leakage) control policies were economically viable, why did sub-optimal methods remain in use? The simple answer was time. Since publication of the report in July 1980 substantial progress had been made in implementing its recommendations and several authorities had reached the stage where they had determined the appropriate policies in a large part of their regions. In the coming few years they would be applying themselves to the much more difficult, expensive, and labour intensive tasks of implementing those policies.

R.W. RILEY (Binnie & Partners) in a written contribution commented on the third type of loss discussed by Dr Rees in her challenging and provocative paper. That was the provision of an unduly high quality of supply.

In Hong Kong in 1962, severe drought conditions led to the reduction of the water supply to four hours every fourth day, which naturally caused everyone to make arrangements for water re-use on an individual basis. Salt water flushing systems were already being provided for new housing projects and, as an emergency measure, additional salt water flushing mains were laid above ground on footpaths. The salt water flushing system had continued to expand since then and was now provided as a matter of course in all areas of new development. The Hong Kong Water Authority also had a programme for converting potable water flushing facilities to salt water in areas of existing development, and a condition of any new lease of Government land in urban areas was that pipework shall be provided in all buildings for separate salt water flushing whether this was currently available or not.

In his opening remarks the Minister had referred to the major works currently being carried out on both the sewerage and water supply systems in Baghdad. The Water Supply Administration of Baghdad had undertaken to replace virtually the entire treated water distribution system of the city and also to construct a new raw water network for garden watering. Work on pipes of 400mm dia. and above was proceeding concurrently for both projects with a target of completion in thirty months. For pipes smaller than 400mm dia. construction of the raw water system would probably follow completion of the treated water network which was planned for the end of 1984. Each network involved about 5,000km of pipelines varying between 1600mm and 100mm dia.

The schemes in Hong Kong and Baghdad might be taken as confirmation of the views on dual quality systems put forward by Dr Rees but Mr Riley sounded a warning. In theory it was an excellent idea but the practicalities of laying a complete new system in a major city were rather different as Baghdad was now finding to its cost in the dislocation of traffic and of most other services. Some of the problems could be overcome with a much larger time scale for construction but he thought that the construction of a totally new system, as implied by a changeover from a single to a dual standard of supply, was unrealistic for an existing city of any significance except in very special circumstances such as those which prevailed in Hong Kong.

Dr Rees had quoted a series of papers edited by Baumann and Dworkin as suggesting that the costs of system duplication had been overestimated but the paper quoted made it clear that it referred primarily to new systems while it was also considered that dual systems may be appropriate for new communities or new areas. The paper quoted went on to state that ' ... if an existing municipal system is to be replaced more or less in its entirety by a dual system, the cost might be unrealistic'. A different paper in the series quoted the result of a major study to evaluate a dual supply system for a new community of 10,000 persons at Denver, Colorado, which was rejected in favour of a single supply system. It was also interesting to note that the paper quoted by Dr Rees went on to discuss metering dual quality systems and suggested that: 'Perhaps it might not be necessary to have separate meters for each type of water for each use. It may turn out that only the potable supply should be metered or perhaps even that metering might not be needed at all.'

J. DIRICKX (Antwerpse Waterwerken) in a written contribution commented on the provision of dual supply systems, and said that the examples given in the paper were not relevant to western industrialized countries. A study in Belgium had shown that 15% of water used in houses had to be of the highest quality, and a further 58% could be of a slightly lesser quality, but had to be hygenically harmless, so that the cost of producing it was almost the same as for the highest quality water. Thus, 73% of consumption must, in effect, be drinking water.

It was found that the provision of a dual supply system would increase the cost of water to consumers by a factor of three or four. Furthermore it was felt that the introduction of dual supplies could encourage consumers to use the lower quality water more lavishly, thus increasing overall consumption.

J.S. POCOCK (Thames Water Authority) wrote that he thought that Dr Rees had misunderstood the reason for vexation by engineers who had, perforce, operated through traditional methods. The vexation did not arise from a reluctance to accept change but from the fact that water supply systems were often inherited; if one found them old and inadequate for present needs it was difficult, and might be impossible, to do anything about it. Thus many excellent systems were designed on the principle of producing, treating, and pumping huge quantities of water at low cost but this objective did not always include accountability for quantities put into supply in different geographical areas. Such systems used scale and pumping head to maximum effect and, at the time of construction, saved capital expenditure as well as reducing subsequent repair and replacement costs on plant, meters, reservoirs, and gravity networks. The penalty today was poor accountability within the considerable tolerances of accuracy identified by Dr Spencer and Mr Field. Dr Rees had only added to his vexation and he would ask her to consider what value she was prepared to put on achieving arithmetic accountability within wide bands of possible inaccuracy that were little understood by the public.

J. CLAXTON-SMITH (Yorkshire Water Authority) wrote that he thought that the comment in the paper about the unwritten sub-objectives of water suppliers being one of minimizing flak had, in part, been carried through to the symposium. They had listened carefully, but he suspected they really did not understand water losses, because they have been given no hard data on water usage. He took up one theme to which Dr Rees had drawn attention; the need to get some more manpower allocated to leakage detection and control. He drew attention to Bones's Discovery: unlimited manpower could solve any problem except what to do with the manpower, an example of which might be: if one man could dig a hole in an hour why couldn't sixty men dig a hole in a minute?

He suggested that it was not manpower, per se, that was required but the ability and willingness to manage the human resource. This broke down into two basic factors; the technical requirements, and the motivational aspects of the management task. Here they were talking of leakage detection and control as a real task for a water engineer.

It may be appropriate to ponder the managerial role of the task of leak detection and control in the 24 hour/day, 7 days/week water industry. Leak detection seemed to involve more than its fair share of what were termed 'unsocial hours'. It would seem inappropriate for manpower to be allocated to this task without the necessary leadership. It was worth noting that normal management working hours only gave 25% cover. Would Dr Rees care to comment on the managerial-manpower relationship in instituting change to reduce water loss.

Author's reply

Many important issues had been raised in the discussion session and it had clearly not been possible to do justice to all of them in a manageable length reply. However, an attempt had been made to identify and answer the key issues, some of which had been raised in common by several discussors.

First of all, Dr Rees felt that she had to reply to Mr Thackray's comments on the different reactions to the paper from engineers and economists. It was no surprise that the economists should be 'disparaging' since the first part of the paper had critizied the relevance of the conventional theoretical economic approach to efficiency within the water industry. However, it would be difficult for them to deny that the main thrust of the academic contribution to water economics had concentrated on allocative efficiency issues and that this approach had limited relevance, given the highly abstract model upon which it was based. Moreover, this emphasis had undoubtedly led to a neglect of other areas of study which could have much more practical significance for suppliers operating under real world economic and political conditions. As Mr Young had said, even in industries where unit pricing was possible charges were not set according to 'optimizing' criteria, and it was clearly necessary for attention to be turned from the 'immaculate conception of charges' to areas where real efficiency gains could be made. An example of what could be achieved when economists and engineers sat down together to deal with an issue of practical importance was clearly seen, as Mr Smith and Mr Goodwin had pointed out, in the report of the 'Technical Working Group on Waste of Water'.

No attempt had been made to claim that the points made in the paper were new; in fact it was a truism to say that very few really original thoughts had ever been produced, progress was more likely to come from the understanding of old messages and their application to different situations. It was pleasing to note that the engineers found the paper 'exhilarating and provocative'; it was, of course, written with them in mind. Perhaps the different reactions served to illustrate the gulf which still existed between the views of the engineers and the economists. A gulf which was also shown in quite a different context by Mr Speight's statement that water supply was essentially a technological enterprise. This was very much a physical science view. To most social scientists the industry's problems were not perceived of as being technical in nature, but included issues such as what the appropriate levels of service defined in economic, social, and political terms?, how should supply costs be allocated between consumers?, what were the distributional consequences of operating the water industry as a business rather than a public service?, what measures could be adopted to improve the efficiency of resource use?, and how far should suppliers be accountable to the public they serve? While technical skills clearly had a role to play, 'technology fix' solutions were not always feasible or indeed appropriate and could not answer these key questions. Indeed another discussor, Mr Clarke, had argued that already the job of the water engineer had less to do with engineering skills and more to do with economics, accounting, and man management.

Turning to the pricing policy and allocative efficiency issue raised by Mr Thackray, it must be made quite clear that the paper did not advocate universal metering, in fact rather the reverse. There was no doubt that it would indeed be a misallocation of resources to invest in metering, or in any other 'waste' control measure, if the costs involved exceeded the resource savings. This was particularly so in the metering and pricing case as many of the theoretical allocative efficiency gains were unlikely to materialise under real world conditions. However, it must be pointed out that the evidence cited by Mr Thackray on the effect of metering was rather contradictory. If there was indeed a consistent 10% difference between metered and unmetered consumers this implied that some price response was present when prices rose from zero to current unit price levels. Studies conducted in one town were an extremely narrow data base from which to make definite conclusions on the price elasticity of demand for water in Britain. This was particularly so when the study period was one of rapid price inflation, with little or no real rise in water prices, and when consumers in low rateable value properties, which in earlier analyses had been the most price sensitive group, and been effectively removed from the study by the introduction of fixed minimum annual charges.

A number of discussors had taken up the comments in the paper on leakage control, although it was interesting to note a certain amount of disagreement about the attention given to waste control by water engineers. Whereas Mr Speight broadly agreed 'that engineers tended to see the construction of additional capacity as a traditional solution while turning aside from minimizing the need for such additions', Mr Clarke had argued that such remarks reflected out of date information on the industry! The fact that such disagreements occurred rather spoke for itself. The view was still held that while without doubt the industry had made tremendous strides over the last seven years, waste control still had not achieved equal status with supply construction in attempts to increase supplies. It was still comparatively rare for investment appraisal exercises to include leakage control measures alongside alternative capacity development schemes.

In the paper it had never been implied that the Monopolies Commission had uncovered something new in discussing 'unaccounted' water in Severn-Trent, it could hardly do so since in broad terms the issues raised by their report had been discussed in the Institution's own 1974 Symposium. The fact that there was nothing new in the findings on leakage also implied that the industry could not, as Mr Goodwin had suggested, hide behind time as the reason explaining why more progress in waste control had not been made. While it was, of course, true that the DoE/NWC report had only been published in July 1980, as long ago as 1967 a president of this Institution had argued that the 'unaccounted loss ... in the majority of undertakings would be not less than one-third of the total daily consumption ... It is obvious therefore that there is room for considerable improvement in consumption per head per day' (25). Long before 1967 engineers such as E. Gledhill had argued that more attention must be paid to leakage control. Surely lack of will not lack of time had been the chief factor inhibiting progress. Finally on the leakage question, while accepting Mr Pocock's point that given the industry's historical legacy it was frequently difficult to achieve supply accountability, as Mr Goodwin had said accurate estimation of leakage levels was crucial and the costs of measurement were minor compared to the costs of control.

It had been a relief to hear that large scale reservoirs such as Rutland Water were not 'largely unused', although it was difficult to judge how that fact squared with the considerably lowered forecasts of demand growth. Would it be indiscreet to ask whether this meant that other older reservoirs or pumping stations were now used less intensively? If indeed these reservoirs were needed then surely the RWAs should improve their public visability and be prepared to refute statements such as 'The Anglian Water Authority says it may start to use some of the huge potential yield of Rutland Water's - 250 million litres per day - in about five years time'(21) made in a journal not noted for journalistic inaccuracies. Mr Thackray's statement that large scale interbasin transfer links tended to be uneconomic was accepted, in fact this was probably true of most large scale supply extension schemes. It had not been the intention of the paper to imply that in future planning the large reservoir with transfer links would be a viable option, but to suggest that in situations where vast surpluses existed, and would exist for some considerable time, transfers could be a more environmentally sensitive and a cheaper option for the economy as a whole than the development of new reservoirs to serve deficiency zones.

On the question of appropriate supply quality, it was, of course, accepted that private abstraction represented a major 'lower' quality supply source and did involve considerable re-use. However, having said that it remained true that few systematic appraisals had been conducted on the potential viability of planned dual supply and re-use. In no way was it implied in the paper that dual supply systems should be introduced everywhere, with construction teams tearing up the urban fabric to lay another set of pipes. In fact it was explicitly stated that it was unlikely that the widespread adoption of the system would prove economic, but in the absence of analysis it remains to be seen whether small scale projects serving industrial estates, recreation complexes or even domestic consumers in new or renewed housing areas would similarly be uneconomic. It must be said that by no stretch of the imagination could Northwest Tasmania be regarded as an arid region, it was temperate with a climate not dissimilar to parts of southern England, albeit with summers!

All that had been attempted in the paper was to suggest that a more innovative approach could be taken by the RWAs, in at least thinking about their 'accepted practices' and testing alternative supply strategies. The work being conducted by Wessex was to be welcomed and it was to be hoped that other authorities would follow their example.

Finally, it must be said that there was every sympathy with Mr Young's obviously heart felt plea concerning central governments various and often inconsistent demands. It had always been difficult to see how the achievement of any test discount rate or in more modern terms the required rate of return, could be a meaningful efficiency criteria for a monopoly industry which raised much of its revenue from rates rather than unit charges.

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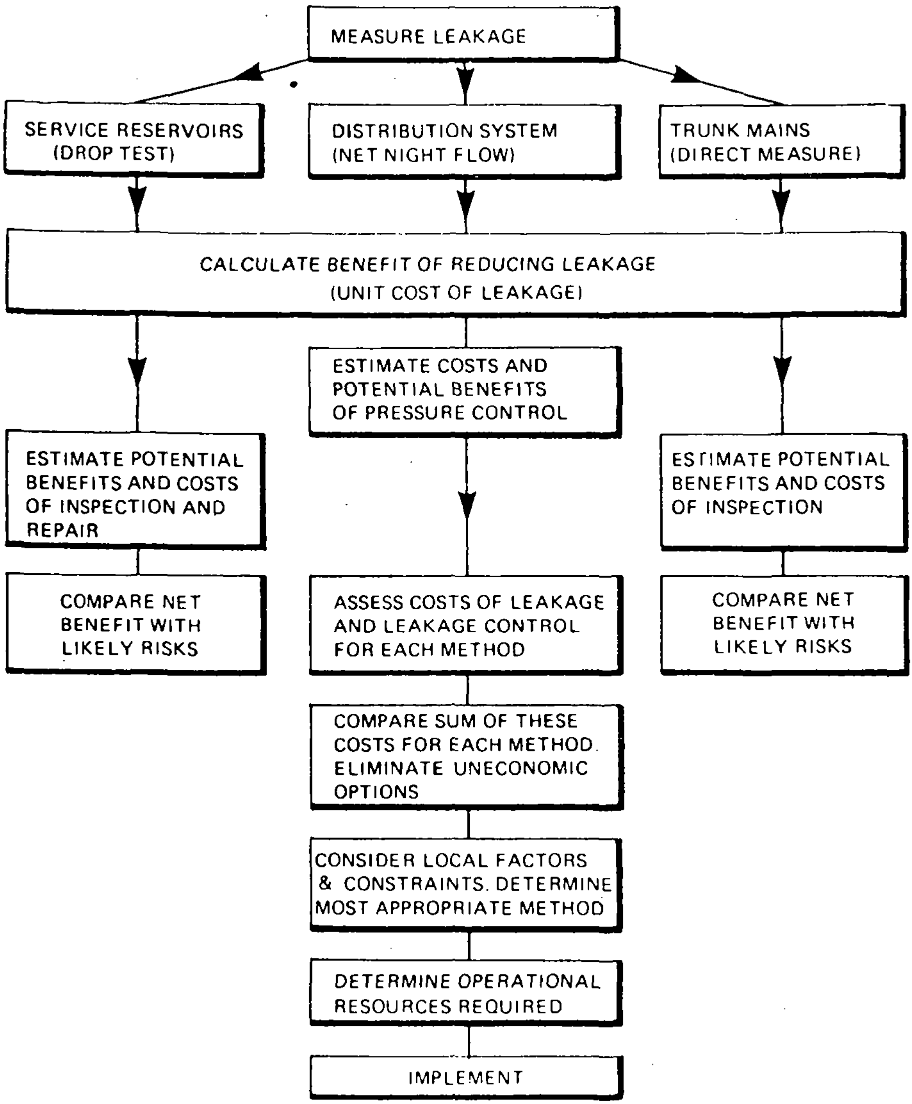

Fig. 3. Flow diagram for the determination of leakage control policy

8. THE GOVERNMENT'S VIEW ON THE LOSS AND WASTE OF WATER

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INTRODUCTION

The duties and obligations of statutory water undertakers are laid down in various Water and Local Acts. Their collective purpose is to secure that adequate supply is maintained within undertakers' areas; there are prescribed circumstances in which these duties may be relaxed, such as periods of severe drought.

In turn, the Water Acts impose a duty upon Secretaries of State to promote and secure effective execution of a national policy for water. Thus the affairs of the water industry, particularly its efficiency, are of concern to Ministers. For this reason the extent of water loss interests not only the consumer (who ultimately pays all costs) and the undertaker (who has a duty to maintain the service) but also Ministers (who are answerable to Parliament for their sponsorship). In carrying out the duties imposed by the Acts, Ministers have regard not only to the interests of consumers (the costs they have to bear and the standard of services they receive) but also to the many problems to be overcome by water industry management.

THE IMPLICATIONS OF LEAKAGE AND UNDUE CONSUMPTION

Stated at its simplest, the total daily supply of water is the sum of water taken and properly used in consumers' services plus the water lost through leakage and undue consumption. Put another way, the ratio between the amount of water properly used and the total put into supply can be considered a form of "use factor". It is self-evident that the water industry should aim for a high use factor as this implies not only minimal loss from leakage but also careful use of water by its consumers. Although these statements can be labelled as obvious or trite, they contain the fundamentals associated with an understanding of water losses. For every gallon properly used by consumers, a fraction of a gallon has undoubtedly been lost (by leakage, waste or undue consumption) on the premises and another fraction of a gallon as a consequence of leakage from the mains.

In one respect, the use factor is a measure of "efficiency", but the word efficiency can mean different things. A high transmission efficiency (low leakage rate) might be attained only at disproportionate cost. Optimum efficiency must have regard to costs as well as benefits. In judging the efficiency of his water undertaker, the consumer looks at the size of his bill as well as at the reliability and quality of his supply.

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By reducing leakage from the mains and persuading consumers to make proper use of water they receive we delay the need to expand the undertaker's supply capability. This, in turn, conserves the land, manpower, materials and capital needed for construction of works to abstract or store water and to treat and transport it. The implications for operating cost, in terms of use of energy, chemicals and manpower, are self-evident. Clearly, Government has an interest in any issue which may place a demand on land, manpower, materials and capital, for these, in the final analysis, are national resources.

Within the constraints on public expenditure necessarily imposed on the water industry, Ministers look to each undertaker to exercise sensible economic practices in establishing appropriate and acceptable use factors (efficiencies, or whatever term might be used).

WATER LOSSES IN THE CONTEXT OF NEW RESOURCE DEVELOPMENT

Prudence dictates that the needs of the future should be provided for in good time. But an over-cautious approach can lead to premature expenditure on new water resources, or to provision of sourceworks larger than those required to meet needs forseeable within a reasonable planning horizon. Thus, in deciding when to seek powers to construct new sourceworks, and in determining the size they should be, an undertaker must strike a balance between the need to secure adequate supplies in good time and for a finite period, and the need to conserve national resources, using the definition already outlined.

The procedures to be followed in promotion of new sourceworks are laid down by statute. Ministers have the duty to make the final decision and to balance the opposing interests that are invariably involved. In doing this they cannot neglect to have regard to the influences that present and future water losses within the command area have on the immediate need for new sourceworks or on the size they should be. In considering this matter they will wish to be informed of the economic balance between the cost of reducing water loss and the value of the water saved.

ACCIDENTAL ESCAPES OF WATER

Mains bursts can be spectacular and may involve loss of substantial volumes of water. They are daily occurrences the incidence of which is only likely to be reduced in the long-term as mains replacement proceeds and as standards of design and construction improve. Closer control of mains pressure, made possible by modern sensing and control equipment, may offer some prospect of improvement as the technology develops.

Repair of bursts and steps taken to reduce their incidence are, in general, matters of detailed operational control for the undertaker. The aggregate effect of accidental escapes of water is most unlikely to prejudice an undertaker's ability to maintain supply in the long-term, but insufficient attention to upkeep and replacement could influence its cost. Thus, in the extreme, neglect of the distribution system could be said to prejudice the effective execution of the undertaker's duty to supply and could be of interest to Ministers.

FIELD OF CONSIDERATION OF WATER LOSS

It is convenient to consider water loss under five headings:

Losses from reservoirs

Water loss within undertakers' supply and distribution systems.

Effects of domestic metering on water loss.

Control of waste and use of water by means of water byelaws.

Publicity for economy in the use and avoidance of waste of water.

LOSSES FROM RESERVOIRS

Evaporation, seepage, and compensation water represent losses which the water supply engineer regrets. Conservation of water includes the construction of impounding reservoirs free from seepage and, in some cases, measures to control evaporation. In another respect, loss of water which might otherwise have been available could occur as a consequence of afforestation.

Water undertakers are generally under an obligation to discharge compensation water from impounding reservoirs. The determination of compensation water for any particular reservoir involves considerations of diverse factors such as the character and flow of the receiving river or stream, particularly as to whether the compensation flow should be continuous or in accordance with an agreed formula or rule linking river flow and the calendar.

Other interests need to be taken into account, such as the requirements for fisheries, agriculture and industry, other water undertakers, protection of rights of riparian landowners and the minimum flows required to secure public health interests. In making decisions on applications for licences to impound or abstract and in fixing the amount of compensation release it is necessary to balance these competing and conflicting interests; this task frequently falls to Ministers.

Ministers are also concerned whenever orders under the Drought Act are applied for by undertakers for the purpose of temporary relief from compensation water conditions. Reconciliation of the various interests in these circumstances is most difficult.

WATER LOSSES WITHIN UNDERTAKERS' SUPPLY AND DISTRIBUTION SYSTEMS

Composed of elements as diverse as service reservoirs and pipelines, constructed from materials often prone to corrosion, aged anything up to 100 years or more, subjected to loads often not contemplated when constructed and, most especially, usually located below ground out of sight, it is not surprising that leakages occur almost anywhere throughout a water supply system.

The current level of leakage in any area is often dictated by standards of manufacture, design and workmanship employed 50 or more years ago, not only on distribution mains, but also on pipework, fittings and appliances within consumers' premises. Moreover, the level of leakage in any area is dependent upon ground conditions and on the attitudes of management within the undertaking towards waste control. If left unchecked, the level of leakage will rise to a level which could necessitate premature construction of new resource works, extension of treatment capacity and reinforcement of distribution mains.

All this is self-evident but needs to be said. What could, or should, be done the DoE/NWC Working Group on the Waste of Water has made clear in its report "Leakage, Control Policy and Practice" (1). The Establishment of this Group followed recognition of the need for work on the subject, arising from the Institution's Symposium on Waste Control in 1974 (2). As one of the authors said at that time:

> "The benefits obtained from waste control which include the value of water saved as well as the value attached to the postponement of capital expenditure on new works should be expressed in cash terms to be set against expenditure, so that conscious decisions can be made whether or not additional (or lesser) expenditure on waste control is justified. In this manner, each water authority would determine how much effort by each division should be put into preventing waste; they will need to establish what saving in water occurs for each pound spent. This appraisal will in many cases be very difficult to carry out but some attempt to do so must be made. What makes the problem so intractable is the fact that we need to know more about the extent of waste of water. We do not know just how much leakage is taking place or where it is occurring."

Much of this rings true today but we have advanced since then in that the recommendations in the DoE/NWC report provide valuable tools by means of which the industry can tackle the problem, decide the amount of effort that should be devoted to it and identify areas likely to yield the best return.

There is some evidence that the present national aggregate level of leakage (inclusive of that from consumers' underground supply pipes) may amount to some 20% of the total volume put into supply. It is thought that it would not be economic to attempt to reduce loss to below 12%. On this basis there could be a potential saving of some 8% to be won by a radical re-appraisal of leakage control. The scale of the problem in England is immense, concerning some 140,000 miles of mains and 18 million service pipes. But unpublished information obtained by the Working Group indicated that the possible annual net savings on account of reduction of leakage from distribution systems might be very significant.

Clearly, this is a matter relevant to the effective execution of water undertakers' duty to supply, and one, therefore, in which Government is entitled to take an interest. Ministers have endorsed the recommendations of the Report of the Working Group. In doing so they have recognised that increased effort on leakage control has manpower implications but have expressed the hope that some at least of the extra effort required may be diverted from less important tasks.

Accounts of progress in implementing the Report recommendations emphasise the lack of factual data, particularly on current leakage rates. This aside, in some areas there has been encouraging progress since publication of the Report. Impressive results have been achieved rapidly and with relatively minimum effort by pressure reduction linked to telemetry. This suggests that, because unnecessarily high distribution mains pressures, particularly at night, contribute significantly to water loss, consideration should be given to the possibility that action along these lines might prove cost-effective in other areas. Aside from reducing water loss and, perhaps, lessening the incidence of bursts, pressure reduction could produce other unquantifiable benefits to consumers, including reduced wear and tear on their fittings.

It is for the water industry to demonstrate that all reasonable and economic measures are being vigorously pursued to reduce needless loss of water from their distribution systems. Unless they do so they will find it difficult to urge the consumer to take steps to conserve water within his premises or to justify stern water byelaws, likely to have cost implications for the water user, aimed at preventing waste or undue consumption. They will also find it difficult to justify the use of national resources to expand their supply capacity.

EFFECTS OF DOMESTIC METERING ON WATER LOSS

The water industry, following publication of its report (3), has recommended that optional metering for domestic services should be permitted. Those taking up the offer would have a real incentive to keep their installations in good repair and to consider installing water-saving fittings and appliances, such as high efficiency showers and conversion of single-flush WC cisterns to dual-flush or variable-flush. However, reduction in the use and waste of water would not necessarily result in all cases. For example, metered water bills could lead to a greater use of water where fixed charges for the use of hoses for garden watering no longer apply.

Because water economy is beneficial not only to the individual metered consumer but also to the water industry and thereby to its customers collectively, it would be sensible for the water industry to make available to consumers advice on how they can maximise their benefits from being metered.

CONTROL OF WASTE AND USE OF WATER BY MEANS OF WATER BYELAWS

It is for the water industry to take all reasonable and cost effective measures to reduce needless loss of water as a consequence of leakage from supply and distribution systems. These measures apply generally up to the junctions of undertakers' communication pipes and consumers' supply pipes. Beyond undertakers' stopvalves, reliance for reducing loss of water must primarily be placed on making and enforcing water byelaws for the prevention of waste and undue consumption. The practice of detection and service of notice requiring repairs to be undertaken on consumers' premises is to be preferred to that of prosecution for actual waste. Prosecution is regarded as a mechanism of last resort and this view is supported by the Department.

It is convenient to consider under four headings the way water loss within consumers' installations can be controlled by water byelaws:

Prevention of waste of water

Prevention of undue consumption

Enforcement of byelaws

New Model Water Byelaws

Byelaws for the purpose of preventing waste of water

Measures prescribed in byelaws for the prevention of waste of water (and, for that matter, prevention of undue consumption) have implications for expenditure by property owners. Expenditure incurred by the water undertaker on mains leakage location and control should yield a substantial rate of return, benefitting all consumers in the form of reduction in general scale of water charges (or smaller increases than would otherwise be the case). In contrast, expenditure incurred by individual non-metered property owners on conservation yields them no direct return.

For this reason, byelaw requirements aimed at preventing waste of water need to be capable of being shown to be appropriate and the minimum necessary. As an example, byelaws aimed at producing high standards for underground pipework might well be justified on the grounds that leakages on these pipes are usually long running before detection, resulting in aggregate in a substantial proportion of the total loss of water. In contrast, byelaw requirements aimed at preventing leakage from piepwork and fittings above ground could be difficult to justify if they aimed at ensuring, as with underground pipework, that leakage should never occur.

By their very nature, byelaws as a code of plumbing practice are no substitute for sound design and good workmanship. Nor are they appropriate for securing services which are fit for the purpose. These aspects are best dealt with by those whose business it is to provide such advice, be they designers, manufacturers or installers.

It is the view of the Department that there should be as wide a choice as possible in the selection and use of water fittings. Although it is accepted that cheap products might well fail, involving the owner/occupier in expense in premature repair or replacement, the view is taken that it is not for Government to prescribe the life expectancy of a draw-off tap or a float operated valve. On a related matter, it is felt that the decision whether to provide a free or subsidised tap or valve re-washering service is one that should rest with each undertaker in the light of local circumstances.

The question has been asked whether byelaws aimed at preventing waste of water should apply equally in areas where the unit values of water differ significantly. The Department's view is that all installations at the time they are first connected to the mains should be to a byelaw prescribed minimum standard commensurate with the expected life of the building served. This assumes that fittings and appliances will receive appropriate maintenance, repair and renewal as and when necessary. The control exercised by the undertaker on leakage and waste in consumers systems subsequent to their connection to the mains should be proportionate to the value placed on water saved. Thus the starting position in all new installations should be similar but the degree of intensity of ensuring repairs are carried out at a given time may vary from area to area.

Byelaws aimed at prevention of bursting of pipes and fittings as a consequence of freezing benefit both the undertakers and the occupants of buildings. Experience has shown that poorly protected installations are at serious risk during prolonged low temperature conditions. Whilst draining pipework to avoid freezing in unoccupied or unheated buildings is widely practised, frequent draining down to waste should be discouraged; one way of doing so would be to reduce the need by ensuring that the installation is adequately protected against freezing. This is an area where codes of good practice could materially assist both undertakers and the public at large.

Byelaws for the purpose of preventing undue consumption of water

Because compulsory metering of domestic services is not in prospect, at least for the forseeable future, there is need for water byelaws not simply to prevent loss of water as a consequence of leakage, but also to control water use wherever that can be achieved without detriment to the level of service. An important example of this is the control of water used in WC flushing. In past years, byelaws prescribed the maximum flush (in England, 2 gallons) following Regulation Number 21 of the regulations made under the Metropolis Water Act 1871. This was a milestone in water byelaws history; it was many years before manufacturers were able to produce an acceptable design but there is no doubt that this requirement - which has been perpetuated throughout over 100 years of byelaws - has done more to reduce undue consumption than any other single byelaw. (4)

Since 1976, byelaws made by water undertakers have, at the suggestion of the Department, included a requirement for domestic WC cisterns serving pans of the washdown type to be of the "dual-flush" variety. It was not considered feasible to apply this new requirement retrospectively to the millions of existing WC pans. Apart from the logistics implicit in such a requirement, there were doubts concerning the economics inherent in the conversion of cisterns to dual-flush. Whilst the cost of a new dual-flush cistern is only marginally greater than that of its single-flush equivalent, the cost of conversion of an existing cistern is substantial compared with the prospective saving, ie the value of water which otherwise would be lost.

The DoE/NWC Standing Technical Committee (STCWR) has been asked to draft the technical requirements for a new Model Water Byelaws. This Model will take much further the matter of water economy in WC flushing. Proposals before the STCWR include:

requirements which would permit variable-flush as an alternative to dual-flush for WC pans of the washdown type;

the basic requirement for a low volume single-flush WC cistern and pan (possibly of the order of 4 to 5 litres);

extension of the requirement to all premises, domestic and non-domestic;

a measure of retrospective application by applying the requirements to replacements or renewals of cisterns or pans; and

extension of requirements to WC pans of all types.

Other important areas where byelaws could further control undue consumption include retrospectively applying controls on filling rates to urinal flushing cisterns and the setting of low rates of water use in domestic clothes and dishwashing machines.

Enforcement of water byelaws

There is little point in making byelaws unless they can be enforced. But enforcement carries with it implications for expenditure and manpower; thus it is essential to include in byelaws only those requirements which can be justified and which can be enforced at reasonable cost. The STCWR has been asked to prepare a report on byelaw enforcement, giving consideration also to manpower and training needs. The Department hopes that the resulting report from the Committee will enable the whole structure of byelaws and their enforcement to be overhauled in the light of present-day needs.

New model water byelaws

The role of the Department in preventing waste and undue consumption of water in consumer's installations is achieved by means of Model Water Byelaws which undertakers are encouraged to adopt as a draft when making their own Byelaws. The present Model was published in 1966 and is now out of date technically. The STCWR has been asked to draft technical requirements for a new Model. The Department intends to publish these for public comment together with the STCWR recommendations for guidance on interpretation and on ways in which the Byelaws might be satisfied.

PUBLICITY FOR ECONOMY IN THE USE AND AVOIDANCE OF WASTE OF WATER

Consumers' attention should be drawn to the advantages for them in practising water conservation within their own premises. Publicity could be given to means of promoting water economy by making available to designers, installers and consumers information on measures they could take to secure savings, with consequent benefits in overall water use. For non-metered services, information might be made available on the extent of savings in energy use associated with use of showers instead of baths, by the reduction of lengths of uninsulated hot water pipes and from timely replacement of worn washers in hot water taps. In addition, for metered services, advice could cover likely savings and other benefits consequent upon conversion of WC cisterns from single-flush to dual-flush, from selective choice based on the hot water requirements of clothes and dish-washing machines, from installing controls of urinal flushing operations and so on. It is suggested that the industry should study the cost-effectiveness of publicity of the type described.

CONCLUDING REMARKS

It is self-evident that one of the major benefits arising from an effective campaign to reduce loss (and waste) of water arises from the deferment of capital expenditure on provision of new source, treatment and distribution capacity. But this can only be achieved if sufficient manpower is continuously devoted to work in the areas of leakage control and Byelaw inspection. Within the financial and manpower constraints under which the water industry operates, much of the necessary extra effort must come from re-direction from less important or less urgent tasks.

Whilst legislation, economic methodologies, waste detection techniques and equipment collectively provide the framework for the control of waste and loss of water, the success of any policy ultimately rests on the knowledge, experience and continued enthusiasm of the men on the ground. Each leak located is a minor skirmish won in the war against waste but the price is continuous, dogged and patient application by fully trained personnel.

In this unglamorous war, for that is what it is, the lead must come from management and senior engineers. Providing they are sufficiently determined, there is no doubt that standards will not only improve but will be sustained. In this, the Department will continue to support the water industry because at the end of the day, we all serve the public at large.

ACKNOWLEDGEMENTS

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DISCUSSION

Authors' introduction

In introducing the paper, Mr Musgrave said that the interest of Government in water loss was centred on the effect it had on the cost of water supplied and on the efficiency of water undertakers. Delegates had heard what Tom King, the Minister, had said about this in opening the Symposium, but even before they had heard his remarks they would have known only too well how keen the present Government was to take all measures possible to ensure a slim, cost-effective industry.

To prevent any misconception, it was necessary to say again that the water industry had not been 'picked upon' or singled out for special treatment in the drive to improve efficiency. Government pressure to improve performance and cost-effectiveness extended throughout the public sector and the financial climate was forcing the private sector to put its own house in order too. Delegates might not all agree with the methods that had been employed in seeking these objectives, but they had to agree that the goals were desirable ones at which to aim. All concerned within the water industry would agree that they should play their part in this country's economic recovery by doing all they could to hold water charges as low as possible without too great an adverse effect upon standards of service.

The Minister's speech, and the paper, showed how all this related to the subject matter of the Symposium. As the authors saw it, there were no short cuts to reducing water loss. It was a case of fighting many skirmishes on many fronts; there was no single set piece battle which, if won, would solve all the problems. They felt, however, that there were perhaps two main areas of activity which might produce worthwhile results. These were the reduction of leakage in distribution systems and the reduction of the quantity of water used for WC flushing. Beyond that it was a case of paying attention to a host of minor ways in which leakage and wastage could be reduced.

Ministers' interest in this subject was not likely to go away. They were firmly seized of the importance of the subject and had asked for regular progress reports. Ministers' pressures on civil servants were likely to lead to pressures on the water industry. The Department had already set in motion an initiative covering most of the areas included in the paper and Ministers had asked for a progress report.

Mr Young said that consumers' underground supply pipes had been identified as a major source of potentially long-running leakage. Could the problem be lessened were undertakers to have powers to supply and lay pipework from their communication pipe to the consumers' house (at the expense of the builder/consumer)? Undertakers could put in pipes which were fit for the purpose, with lives compatible with the building served.

The paper emphasized the importance attached to reducing water used in WC flushing. The Department's long-term goal was to establish the safe lowest limit of water used in a single flush - that might be as little as 5 or even 4l. Work at the BRE would provide data upon which decisions could be based.

In discussion on an earlier paper, Mr Pepper had put up a spirited defence of the use of the 'unaccounted for water' formula. Despite its apparent shortcomings, the formula was useful for monitoring progress in particular areas or districts from time to time. Although they supported the concept that percentages should not be used to describe 'waste', the authors admitted that it did have attractions and that they had used it in their paper.

Concerning the use by installers of good quality water fittings and the way in which the NWC's application to the Department of Trade for a Registered Trade Mark might assist in this, the Department hoped to issue a consultation paper in the near future about a proposal that powers should be taken to enable Ministers to regulate which types or categories of water fittings should appear on the Council's list of tested and approved fittings.

Discussion

W.F. RIDLEY (Northumbrian Water Authority) opened the discussion by thanking the authors for their interesting paper, and said he would comment separately on the loss of water by water undertakers and on the losses due to excessive use or waste from consumer premises, because the Report of the Technical Working Group on Waste of Water had restricted itself to the definition of a leakage control policy as far as the consumer's stop valve. It had left matters on the consumer's premises to be dealt with by the Standing Technical Committee on Water Regulations.

The Technical Working Group had recommended that every water undertaking should determine the appropriate leakage control methods and the anticipated net benefits arising from these methods and that Liaison

Officers should report annually on progress through WRC to the NWC and to the DoE. It did seem, therefore, that the Minister's opening comment at the Symposium that 'a lot of water could be saved' was bad news to those people who hoped that things would go on as before and that no positive action need be taken on leakage control. The Minister's statement, that 'evidence of water loss figures would be required when new resources were being promoted' was now more meaningful than it might have been in the past, because the method of obtaining the evidence was detailed in Report 26. Mr Ridley thought that the industry probably had no option but to proceed with a logical examination of the cost and volume of water losses from supply systems and he expected that most members of the Institution would, on reflection, accept this as the professional thing to do.

He noted the authors' hopes that the manpower required to introduce proper systems under Report 26, might be diverted from other tasks. This would not always be easy because it was essential for success that the personnel employed on waste reduction were keen, qualified, and dedicated. He observed that it was particularly encouraging therefore that details of a middle way had been given the previous day at the Symposium; that was the use of advance technology to assist in waste reduction, not only for its own good sake, but also for the new dynamic it could bring to the personnel engaged in loss reduction.

Mr Ridley then dealt with the authors' comments on byelaws and noted that the authors intended to continue to avoid specifying fitness for purpose. He questioned whether or not this was a tenable long-term position, insofar as successive Governments seemed to be forced into extending consumer protection. For instance, from next April, water authorities would be required to pay compensation to persons injuriously affected by burst mains, even when they were not responsible for the burst. Was it not therefore only a matter of time before liability for faulty fittings installed in 'innocent' consumers' premises had to be rectified by water undertakers? This would be particularly so, if non-traditional methods of plumbing were permitted by byelaws.

There had been comments made during the Symposium suggesting that the metering of domestic consumers would save waste. He noted that there was no evidence of excessive water use by unmetered consumers, nor that the average water consumption in Great Britain by domestic consumers was greater than in those cities in Europe where water was metered. Because current cost accounting would now raise charges virtually in line with inflation, he felt that all water undertakers should continue to be very sensitive to the consumer's real wishes, and that they should not press for compulsory metering, or worse still, support the imposition of retrospective byelaws to reduce consumption in consumers' premises.

M.J. ROUSE (Water Research Centre) said that the paper provided an excellent appreciation of the relationship between the Government and the water utilities in respect to water supply losses. He had two comments on the paper and there were two other important issues which he believed required debate.

He started with the comments on the paper. Firstly, the authors had mentioned the importance of pressure control in relation to the availability of modern telemetry systems. He agreed that the modern communication systems did allow much more effective control of pressures but he would also stress that control of pressure by individual PRVs could be very effective and it would be wrong not to adopt pressure control in areas where telemetry was not envisaged. Results produced from pressure control exercises using PRVs could be equivalent to those being realised with telemetry-based control. Secondly, the authors had said that it was not the responsibility of the Government to prescribe the standards of plumbing fittings and equipment. Who then should be responsible for protecting the consumer against the installation of fittings which were going to create problems in the house?

He then turned to the two important issues involving Government which were not included in the paper. The first one was the civil liability of statutory water undertakers for escapes of water (this was Clause 6 of the 1981 Water Act) which made the water utilities liable for any damage or loss resulting from the escape of water from the distribution system. This must be a very important issue in relation to water main maintenance policy and to the amount of money and effort which should be applied to it. The second important issue which he believed ought to be mentioned was the recently published White Paper in relation to the use of heavier lorries on the roads in this country following the Armitage Report. It was clear that very little was known about the effects of traffic loading on underground services especially in respect to the dynamic effects of different numbers of axles and the effect of such impact loading on deteriorating roads. He believed that far more work needed to be done in understanding traffic loading before the decision was taken to risk creating a high increase in the maintenance costs of underground services. The water industry should regard this issue as being very important, particularly when considered in conjunction with the civil liability issue.

G.L. DAVIES (Southern Water Authority) said that his presence at the Symposium was an example of the change of attitude towards waste control now sweeping the water industry. Ten years ago he was building a dam but today the management of waste control was among his duties. The economic criterion for sound waste control had been clearly stated, namely that it was worth spending more on waste control if the cost was less than the value of water saved. It all seemed beautifully pure and simple but unfortunately, this was not so because of the uncertain returns from waste control. Two factors distinguished waste control from other conventional source works as potential resources. Waste control was unpredictable in effect and required persistent effort. Proper monitoring, performance appraisal, and review were essential, which incidentally added to the cost, and targets should be amended in the light of experience.

This was the approach in his own authority where Waste Reduction Programmes tailored to the circumstances of each water division had been developed. One factor which he had found was that although waste control might be economically viable, there was a financial difficulty in that the heavy cost of the repair backlog in the early years preceded the reductions in operating costs. In view of the Government's requirement for water authorities to demonstrate that all reasonable and economic measures for waste control were being vigorously pursued, he asked whether the Government would be prepared to relax revenue expenditure controls to allow for the cost of the repair backlog. In addition, he asked whether the Government would be understanding in applying manpower limits when water authorities, having cut their manpower and redeployed others, required limited additional staff for proper leakage control.

G.S. MILLION (Thames Water Authority) gave an example of the cost to the consumer of controlling waste on his premises. He had paid £27 to repair a defective ball valve which was leaking, by his estimate, 80l/day or $30m^3$/year. Was the repair economic? Water was sold to metered customers in the Thames WA region at about $17p/m^3$ but when it came to expenditure on waste control, where they were essentially buying water, water authorities seemed reluctant to value the water lost at much more than the operating cost - less than $2p/m^3$ in Thames' case. Even when the capital costs (of works deferred) were included, bringing the value to about $6p/m^3$, Mr Million's repair was scarcely cheaper than the alternative of letting the water run to waste for ever. He hoped that water undertakings would spent as much on waste control on their own apparatus as they required their customers to spend on theirs.

S. ALDRIDGE (Severn-Trent Water Authority) expressed his concern that all the problems of those engaged in tackling the problem of water losses were being frustrated by the financial regime under which the water authorities now had to work. The new financial framework imposed by Government did not help in the economic allocation of resources, in fact it discriminated against increases in revenue expenditure and favoured capital solutions. He referred to the impact of performance aims and the effect of the recently introduced current cost accounting principles adopted to determine income requirements by water authorities. Since they had been introduced, performance aims had been expressed in unit costs for operating expenditure only, comprising labour and other costs. The achievement of performance aims required these unit costs to be reduced in real terms over a period of three years. Consequently, enormous pressure had been created to reduce manpower and other operating costs, the same costs which were required to improve leakage control. Until the costs of capital were included in performance aims, this discriminatory pressure would inevitably continue and Mr Aldridge asked Mr Musgrave and the Department of the Environment to consider ways in which this anomaly could be corrected as quickly as possible.

Regarding the new current cost accounting regime, the income requirements of the water authorities were now determined in a way which produced no real impact on charges from new capital expenditure. This was a feature which militated against leakage detection by operational action, as the impact on income requirements, and hence charges, of solving leakage problems by capital expenditure was minimal. The increased operating costs required to avoid or defer the capital expenditure would be added directly to the income requirement and make the achievement of performance aims more difficult. The effective substitution of a financial target percentage of 1½% in place of the interest charges on capital, which previously had to be found from charges, was not creating the right discipline and in Mr Aldridge's view, should therefore be reviewed by the DoE.

A.A. REDHEAD (Anglian Water Authority) thanked the authors for their paper and went on to echo the view that there seemed to be a lack of factual information relating to the present leakage levels throughout the country. In an attempt to rectify this matter the Anglian Water Authority had set about a programme of reservoir/water tower drop tests to reveal the true leakage levels. The leakage in the Norwich Water Division was 4.01 per property per hour when taken as a property weighted average over the whole Division.

In evaluating the marginal costs, and hence the cost of leakage, the capital deferment costs had been ignored in a first stage approach to the problem. The cost of this level of leakage to the Division was £176,000 per annum and represents a cost of £1 per property per annum.

He concluded by suggesting that the success of the Symposium should be judged by the ability of those present to go out into the field and get to grips with the problem of leakage.

J. CLAXTON-SMITH (Yorkshire Water Authority) in a written contribution referred to the authors' statement (p8.6) that 'reliance for reducing loss of water must primarily be placed on making and enforcing water byelaws for the prevention of waste and undue consumption'. In relation to this area beyond the stop valves would the authors care to state what water usage occurred. Did they have to rely on data from Istanbul and Egyptian villages? Of this usage would the authors care to be a little bit more forthcoming as to what they mean by undue consumption, with particular reference to subjective nature of the description 'undue'.

He had been surprised in listening to the papers and discussions that only one person had indicated that an end route for the water leakage they had been discussing, was that of the water authority sewers. Would the authors care to comment on their perception of the implications of the water authorities cycling water from their mains to their sewers and their sewage treatment plants?

Authors' reply

The authors, in response to Mr Ridley's reference to the Minister's remarks on the need for evidence of water loss to be available when new resources were being promoted in future, said that ascertaining and evaluating water losses (or as they preferred it, establishing the transmission efficiency) was, after all, only good-housekeeping. It was only common sense to prepare sound cases for new resources and to be able to demonstrate that all reasonable measures had been taken in good time to postpone the need for expensive new works.

Manpower devoted to evaluation of leakage and waste of water needed to be sufficient in number but more importantly, to be dedicated men. They needed to see that their efforts were appreciated by management, it was essential that this work should not be categorized in the mind of staff as a repository for men who no-one else wanted. The continued development of advanced technology to assist the location of leaks was essential. The rewards to designers/manufacturers should be such as would promote this work.

Mr Ridley had asked whether it would be only a matter of time before liability for faulty fittings installed on 'innocent' consumers' premises had to be rectified by undertakers. That was an interesting question bound up in part with safety and in other respects with damage to property. If and when safe operation of domestic plumbing installations merited control by regulation of the activities of designers/installers, provision existed in the Health and Safety at Work etc. Act 1974 Part III. Responsibility for damage to property caused by the failure to install suitable fittings, or to maintain them, lay with builders and owners. Public opinion had not reached the stage where regulations prescribing performance, life expectancy, and so on were likely to be demanded, with the concomitant acceptance of probably significantly increased costs for consumers and others in business (such as designers, builders, and plumbers). However, the water industry almost certainly had a common law duty if not a moral one towards its customers. Thus, full information on the quality of water (particularly its corrosivity in relation to certain materials) needed to be available to the public. Any change brought about by undertakers in water quality put into supply carried with it liability and obligations. These could not be avoided simply by creating criminal offences (i.e. byelaw prohibitions).

Mr Ridley was right to point to the uncertainties which at present surrounded the relationship between domestic water use and metering. The Department would want to see much clearer evidence on the likely reductions in water use before recommending compulsory metering as a cost-effective form of demand management. Similarly an important principle underlying the Department's approach to byelaws was that any change should be supported by evidence of cost-effectiveness. In that way the consumers' interests could be taken into account in both byelaws and metering. The role of current cost accounting was to act as a first step in confronting consumers with the real costs of water services and thereby to enable consumers charged by measure to begin correctly and directly to communicate their real wishes.

Mr Rouse had asked who should be responsible for protecting the consumer against fittings likely to create problems in the home. Questions of regulations concerning safety had been dealt with in the reponse to Mr Ridley's contribution. It was worthwhile quoting the words of Mr Finsberg, Under Secretary of State for the Environment, in a House of Commons debate on 'Plumbing' on 10 April 1981. He had said:

> Finally, we should not forget why, despite all the adverse publicity, people are still prepared to employ cowboy firms. The reason, quite simply, is money. The cowboys offer cheap prices, in return for which they use inferior material and produce a dubious standard of workmanship. The customer has a clear choice. He may go to a reputable plumber - perhaps one registered with the Institute of Plumbing - who will charge him a fair price for the work done, or he may prefer to take the risk of employing a cowboy, whose work may be substandard. If he takes that risk he may regret such a decision, which, for the sake of a few pounds, may rebound on him later.

Concerning the civil liability of undertakers for escapes of water from their distribution systems, it should not be forgotten that water authorities acted, in effect, for each and every member of the public; all costs and benefits of their operations fell to the public. There was no reason why the new law should affect in any way the efficient operation of competently managed systems. Under Section 6 of the Water Act 1981 (which, incidentally, came into force on 1 April 1982) water undertakers in England and Wales were liable in most cases where damage was caused by escapes of water from mains or communication pipes. It was, however, doubtful whether this would turn out to be as important an issue in relation to water mains maintenance policy and expenditure as Mr Rouse had suggested. The fact was that, given the usual location of water mains, most damage from bursts was likely to be caused to streets and, to a lesser extent, to the gardens of houses abutting them. It was, therefore, undertakers' equipment buried in streets (e.g. gas and electricity installations) and the fabric of the streets themselves which was most likely to suffer damage, and in these cases, liability would continue to be governed by the Public Utilities Street Works Act 1950. The cost to undertakers of Section 6 could not be predicted with any precision at this stage. The industry had suggested it might be of the order of £8-10 million per year for England and Wales; the Department's view was that it was unlikely that the new provisions would have a major impact on individual undertakers' water mains maintenance policy.

The cost of maintaining underground services depended on a number of inter-related factors of which distributed traffic loading was only one. Other important considerations were the effect of excavations for adjacent services, weather conditions (especially low temperatures), and the age and condition of the particular underground services.

Although Mr Rouse was right to raise the question of the effect of increased traffic loading, it was known that such effects were mainly dependent on axle loading rather than vehicle weight. The proposals in the White Paper would increase axle loading by only 3% above current levels and therefore the effect on underground services was unlikely to be great. The authors agreed that more work needed to be done on the overall effect of dynamic traffic loading on highway pavements and the underlying buried services in order that such imposed maintenance costs could be properly allocated to those road users responsible.

Mr Davies seemed to be asking whether DoE, in setting performance aims, would take into account the extra operating costs involved in undertaking leakage control. The future form of performance aims would be discussed with the industry but on the whole, the answer was 'yes', provided that the waste control policy had been adequately appraised. It was surprising that Mr Davies should emphasize the delay between incurring repair costs and obtaining operating cost savings. Examples in the joint DoE/NWC report on Leakage Control Policy and Practice (and elsewhere) suggested that the payback period in terms of operating cost savings was only a year or so.

On the question of manpower, the Department did not apply manpower limits as such, although it was encouraging authorities to reduce manning levels and monitoring their progress in this. It was up to individual authorities to state their priorities for manpower deployment, though there was clearly a case for additional staff in cost-saving areas such as leakage control (as the Monopolies and Mergers Commission had recommended in its report on Severn-Trent) provided that downward trends in overall numbers were maintained.

Mr Million had put his finger on a most interesting point in contrasting the cost incurred in maintaining plumbing systems in good repair, with the benefits derived by the person paying for the work to be carried out. In other parts of the world, the decision whether or not to repair a fitting was left to the metered consumer who balanced cost of repair against cost of water wasted; a charge based on realistic marginal costs soon pursuaded consumers to take action. But in a society where the marginal cost was zero, legislation was needed to 'persuade' owners/occupiers to keep their plumbing in a good state of repair. They had this legislation in this country but undertakers were understandably reluctant to prosecute: fines up to £400 were possible. There was no doubt that high charges were often incurred by the public for the repair of tap washers and float-operated valves. That could not be avoided when the justifiable cost of a plumber simply turning out to visit a house could be at least £15. That situation did not apply everywhere; some undertakers offered a free or subsidised service.

Mr Aldridge had questioned the principle of setting performance aims based only on operating costs. That, he claimed, distorted decisions on the choice between capital and current spending. That was a question to be considered for the future of performance aims, which would be discussed with the industry. There were other controls on capital expenditure, for example, through capital allocations, and there was a problem in finding costs related to the actual use of capital; depreciation over standard lives did not so relate. Adequate investment appraisal could be seen as the counterpart control for capital spending of performance aims in revenue expenditure. Regarding financial targets, the Department accepted that the system of financial targets at present in operation (until 1983/4) did not apply a correct financial discipline on new capital expenditure. That was a complex question which the Department would shortly be discussing in detail with the water industry; it was to be hoped that Mr Aldridge's constructive approach would be supported by the industry as a whole. In the meantime the industry would be well advised to be guided by the economic methodology underlying the NWC's Report No 26 rather than by the current financial incentives.

The authors thanked Mr. Redhead for his account of the way Anglian Water Authority had established current leakage levels. He had reported a leakage level of 41/property/h, average over his Division. The authors were tempted to compare this figure with the notional average net supply to dwellings - say three persons at 110l/day. For a total of 330l supplied, using Mr. Redhead's figure, 4 times 24 or 96 litres had been lost in supply; conclusion, his leakage was 22%! The only safe conclusion to be drawn was that there appeared to be scope for improvement, possibly to reach an eventual target level of 2.5l/property/h, i.e. a leakage rate of about 12% However, each case should be considered on its merits.

Mr Claxton-Smith had asked the authors to state what water usage occurred beyond the (undertakers) stopvalves. In the absence of universal metering, they had to rely on data produced by others from field studies and assessments, which could be little more than guesstimates. The Working Group on Waste of Water had suggested that average domestic water use lay between 110 and 130l/person/day. So much depended upon the size of the family unit, the facilities available, and the life-style; garden watering could exert significant effects on generalized statistics. However, the object behind the authors' statement on the making and enforcement of byelaws was to emphasize that there were ways in which water economy could be improved, for example, a requirement for 61 WC cisterns in place of 91 cisterns.

The authors would not wish to hazard a guess regarding the proportion of sewer infiltration which was derived from mains leakage. Sewer infiltration might be likened to the problem of mains leakage in that both were undesirable in principle. But there were economic limits below which true water-tightness was unjustifiable.

SUMMING UP

J.L. VAN DER POST (Chief Executive, Water Research Centre) said that his lasting impression of the Symposium was a collection of people all deciding "It's all been said already". Much the same ground was covered by the Symposium of 1974.

Mr Pocock had drawn attention to papers published in 1892 and, to what he recognized as, a thirty year cycle in the apparent importance of water losses. Mr van der Post said that he had been asked during the conference, did he think they were moving in the right direction. Well, were they moving at all? While many speakers had indicated that there had not been all that much change, the papers did show some important new departures.

It was a pity that the Symposium did not review the NWC/DoE Report 26 'Leakage Control Policy in Practice' which was published a year ago. All the British authors, except one, mentioned the report, so a summary of the recommendations and some discussion of their implementation would have been helpful; above all, a review of those arrangements which were being made to implement the recommendations, and a review of progress, would have been extremely interesting. He doubted whether any future seminar on this subject will maintain that it had all been said before.

The papers, by Mr Saxton and Dr. Rees put the problem in perspective. Each in their own way showed that water losses were only part of the problem which must be considered. Mr Saxton had given the engineer's view that water losses were only part of the spectrum: one must consider losses from pumping, other energy losses, and unnecessary consumption; and together with other speakers he had pointed out how important it was to avoid unnecessary expenditure of all sorts. Dr. Rees had taken an economist's point of view and expressed it more forcefully; she was concerned with the loss of money. Together they had emphasized that what they should be worried about was the optimum use of resources. One lesser point in Mr Saxton's paper deserved more comment. It had also been mentioned by Mr Rofe in the discussion. This was the effect of afforestation on upland catchments; trees reduced the amount of water flowing into the reservoirs. As Mr Rofe had said, they must have trees. Whether it was economic to have them in this location was perhaps uncertain; but at some future date, the marginal cost of trees would have to be compared with the marginal cost of water in the reservoir. However, the scientific evidence was not all that conclusive. Measurements in the catchments indicated that there was some reduction in run off. However, he thought it was now accepted that there was rather more uncertainty in the results than was originally thought; and results in other catchments might give different answers. He was all for trees, and he was all for water, but for reasons which he would bring out at the end of this summing up, not at all keen on increasing the amount of cross-charging between public services. There were cases where cross-charging had had a depressing effect on decision making, particularly in the distribution activities of the nationalized industries.

Mr Field and Dr Spencer had brought home the difficulties of a simple formula for unaccounted for water. The problems were complex and the uncertainties very much greater than one might expect at first. This paper highlighted the difficulties of using the formula and implied some important lessons when thinking for the future. They could use the calculations not only to find out how uncertain they were, but they could know that uncertainty to six places of decimals.

In Mr Pocock's paper there were two really important points which should be emphasized again and again. The first was the perceived view of the costs (1p per cubic metre to 17p per cubic metre). People responsible for controlling leakage might only see a part of the financial structure. They saw the cost of pumping, not the cost of repairs, i.e. they only saw the costs of their own operations. It was only when the problems reached such a level that the effects reach higher management, that any action was taken; and this was the reason for the thirty year cycle. His second point was made by Fig. 3 which showed the age of water mains. It was clear that the average age of water mains was increasing in spite of all the new investment; and these assets were being used long after the end of their depreciated life. This was causing considerable concern.

There was also one point in Mr Pocock's paper which he didn't accept. There was no intrinsic connection between pressure control and storage, except that different types and location of storage required different control and pressures. They should not reject pressure control just because they had a particular storage problem. There was a form of pressure control to fit it. The gas industry had shown that demand activated governing would work where there was little or no storage capacity downstream of the governor.

That point brought him to the paper by Mr Howarth and Mr Olner where there was a first class exposition of pressure control. They had taken advantage of telemetry, but the system could be worked in other ways, if necessary. Their figure of reduction in average daily demand of between 5 and 10% was the most convincing case for pressure control: additional benefits were the reduced numbers of bursts and hence maintenance. He hoped that before too long Wessex WA would publish an economic appraisal of the whole operation. The paper also described the use of the correlator which was a significant advance.

It was refreshing at this point to have the paper by Mr Ingham which reminded them that the reason for their existence was that their customers needed water. The emphasis on the advantages to the consumer of going in for the best procedures was salutary and was an illustration of how small organizations could pioneer things quickly in ways which might be difficult for larger undertakings.

The paper by Ir Dirickx and Ir Depamelaere gave a fascinating view of how these problems were dealt with overseas. One of the most important functions of the Institution was to keep the industry looking outward. Contact and joint activities with Undertakings overseas had a most important part to play. The paper had a particular interest for those who looked for the effect, or rather the non-effect of tariffs on leakage, and gave a delightful description of the up-to-date practice on the Continent.

Dr. Rees' paper was a lively discussion about the optimum use of resources. In the complex community they lived in, recourse to this argument was perhaps the water undertakings' most useful tool for maintaining their position. The paper recognized that undertakings had to live in a world which was not wholly logical, and beset by political and public pressures. Dr. Rees had held up a mirror in which they could see themselves. If they did not like the reflection, perhaps they should do something about it. Water Authority speakers showed plainly that they had sound arguments about the further construction of reservoirs, and inter-Authority transfers were sometimes rather less than optimum. One could wish that one point had been made more forcibly. One could not leave a transfer pipeline unused. Whereas oil and gas could be stored in pipelines, surface water could only be stored on the surface, or its quality deteriorates. But Dr. Rees' argument was not for any particular practice but for an economic examination of the alternatives before making decisions. She had also commented that engineers were biased towards large construction works rather than maintenance activities. This was an important point and he would deal with it again later.

One of the most pertinent comments had come from Mr Buky of the World Bank. He reminded that while they are discussing the optimization of an ample supply of water and luxurious sanitation the majority of the world had little of either; that a tremendous part of the resources of Third World countries was often tied up in collecting water, or wasted by disease from inadequate sanitation. This was a concerted argument for the optimum use of resources by water undertakers in Britain. Their major exportable resource was skill, and expertise. If they could run their undertakings expertly and economically then they had more expertise available which could be used in the Third World. He hoped the economists would agree that this was an optimum thing to do.

The paper by Mr Musgrave and Mr Young gave 'Big Brother's' view. It showed the conflicting pressures on those who made regulations. It was immensely encouraging that they should put forward the use of the procedures in Report 26. It was disappointing that the water industry was not in a position to give a sensible report on the progress made in implementing them.

Mr van der Post then summarized the important points which had arisen, as follows:

1) There was a procedure available for the economic control of losses. It would indicate quite clearly when action should be taken on leakage and what economic benefits would accrue; and also under what conditions there would be no benefits. In these circumstances, there was no longer any excuse for not implementing a proper leakage control policy - and ignoring the issue was not a policy. Discussions of the problem should be more concerned with how much progress had been made. Hopefully, in a few years time the Institution would hold another such seminar at which they could look back on some years of significant progress and some substantial financial benefits.

2) The industry should stop its continual discussion around leakage control and get on with implementing the recommendations contained in report 26. The directors of operations of water authorities and DoE had already recognized the need for this and as a result had set up a Committee of Liaison Officers to report on the implementation of report 26.

3) Report 26 was the first and only report on leakage control which was acceptable to both engineers and economists.

4) District metering had been shown to be a cost effective method of leakage control in most UK distribution systems and WRC were currently investigating ways of improving the technique and developing a performance specification for district meters. The cost and effectiveness of linking

a metering system with telemetry was also being investigated.

5) The leak noise correlator had proved to be a successful tool for location. To date 75 instruments had been sold and nearly all purchasers were getting consistent results.

Finally, he injected a view of his own. The image which engineers had of themselves was all important. Dr. Rees had suggested, not without justification, that while a plaque could be put up commemorating the construction of a water works, or of a reservoir, there were no prizes for completing even several thousand holes in the road. Unfortunately this syndrome was not confined to just the engineers in the industry or even to their industry. It affected in some way or another all those who sat on Committees, or Authorities, or Boards, or Councils.

How could they get out of this trap? Mr Pocock had showed clearly how easy it was for operations engineers to see only part of the cost. The same was true of their counterparts in other industries. Arguments about liabilities for costs between utilities and highway authorities had sometimes been used as a convenient hedge and sometimes as a reason for getting round budget restrictions. They always led to delays. They did not raise the sights of distribution engineers. Did they improve the service? It was vital that engineers should know not just their own operating costs but the full picture of their undertaking's activities and then perhaps there would be a prize for filling in a hole in the road.

Another reason why leakage needed to be taken seriously was that thirty year cycles were too long for the complexities of the 1980s and 90s. As noted earlier, water mains were ageing; water undertakings are coming under increasing pressure from the Government and other utilities to keep them in better order. The Water Act of 1979 conferred absolute liability on undertakings for dealing with water mains and its enforcement for April 1982 would be a most serious matter. There would have to be very much better attention to leakage.

Finally, there was a suspicion, so far it was no more than a suspicion, that the life of water-pipes laid since the war might be significantly shorter than that of pre-war pipes. In that case, they would find all their water pipes were wearing out together in a very few years. This might not happen but as long as there was any risk, it was another compelling reason why they must have the means of controlling leakage, not only as a possible operation in their repertoire but as a well-rehearsed and currently-operating part of their everyday function.