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Symposium on Waste Control: its importance in the planning and management of water supply systems

The Institution of Water Engineers

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Symposium on Waste Control:

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Proceedings of Symposium held at the
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PREFACE

IT HAS BEEN estimated that the consumption of water in England and Wales will double in the period up to the year 2000. This arises not only from the needs of an expanding population and industry but also from an estimated increase in consumption per head of the population. It is hardly practicable, even if it were desirable, permanently to limit the rise in consumption by restricting the amount of water available to domestic consumers and to industry, even though such action might be necessary in emergency.

There is however one form of consumption which can be restricted without detriment to anyone—waste. "Waste" for the purposes of this Symposium includes all forms of waste wherever and however it is caused. It embraces, for example, on the one hand leaks in trunk mains and on the other undue consumption (extravagant use) on consumers' premises.

Although a reduction in losses of water through waste will not in the long term reduce the total of new capital works required it could extend the time for their provision through better use of existing resources. It could therefore be of significance not only by postponing expenditure on new source works but also be reducing the loss of energy associated with pumping over a long period of time.

It could perhaps be argued that, where supplies of water are plentiful, the reduction of waste may cost more than the "value" of the water saved. On all counts and particularly on economic grounds it is however undesirable that any natural resource should be used wastefully. Although, therefore, reference is made at the beginning of this note specifically to the position in England and Wales, the subject of this Symposium is of importance to other countries in the United Kingdom and overseas.

The Symposium was opened by Mr. Denis Howell, MP, Minister of State, Department of the Environment.

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1. WHAT IS WASTE AND WHY IT SHOULD BE CONTROLLED

By S. G. Barrett, cbe, msc, fice (*Fellow*)*

What is Waste? In the context of water supply I suppose that every practising engineer (and inspector) knows quite clearly in his own mind what waste means and although he may apply his own personalized shades of meaning he broadly conceives waste to mean that amount of water which is lost by leakage from his mains and communication pipes systems and also pitylessly allowed to "run to waste" in houses, factories and other premises—water, that is to say, which has been collected, treated and conveyed with infinite care and professional pride. The Oxford English Dictionary succeeds in being a little more expansive in attempting to define waste but is not at variance with the narrower concept given above. These mighty and fascinating tomes introduces such other considerations as waste being related to that which cannot be utilized for the designed purpose, which is a residue, which is left over and which is spoiled**. In our special and immediate interest we note that our byelaws are made and applied for the purpose of preventing not only waste but the undue consumption and misuse of water, there being, thus, distinctions to be drawn from the three elements of the byelaw's purpose. Let us go a little further in our exploration of the meaning of the word waste and in doing so get our minds just that bit more muddled than is really necessary to accomplish the object of this paper. Let us look at the matter from the point of view of hydrologists—and that means ourselves wearing different hats. Assuming that the earth keeps on behaving much as it has done in the recent geological past, the action of the hydrological cycle will ensure an infinite repetition of the blessing of fresh supplies notwithstanding the profligacy with which we despoil our terrestial water and it will defy all our attempts to waste water irrespective of how we define the word waste. Water is not a wasting asset like Arab oil but in regular supply (in these islands at least) to within deducible limits. To avoid involving ourselves in a preposterous exercise in semantics, suffice it to say that although we do not need to argue with ourselves as to what we are doing when we practise measures to minimize the output from our works it will be necessary for those who follow me on the rostrum at this symposium to have some clear idea and to inform us of what they mean when they are delivering themselves of their views and propositions on the topics which they have selected to debate with us. It is possibly expected of me as part of my remit to set limits on the definition of waste for my fellow participants to follow but this I must regretfully decline to do on the grounds of impracticability and of imposing undue restrictions on ensuing discussion notwithstanding that I have, earlier in my career, attempted this exercise. Scrutiny of the programme of the symposium reveals clearly, however, that our subject is at least two sided; on the one—waste, on the other—undue consumption, and these two sides do not greatly differ from the broad attitude of my hypothetical practising engineer in operating his undertaking, namely, his dislike of loss (i.e. the quantitative difference between what he puts into his system and what comes out) and the inexcusable drawing off, irrespective of

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** The amount of water spoiled by the pollution of our rivers dwarfs the waste from water undertakings into insignificance.

amount, of a valuable commodity or carelessly or viciously permitting its discharge, to no useful ends, from the totality of the water supply system. Loss of water in the form of leakage from mains and pipes is inevitable, so far as my experience goes, because bursts and breaks are always occurring for a variety of reasons or for no apparent reason whatsoever, and it would be a modern miracle to identify them and repair each of them as it takes place. E. G. B. Gledhill in his remarkable paper published in 1957 concluded that bursts break out with a rough degree of regularity so that with a cyclical leak finding operation bursts are breaking out behind the team at the same rate as in front. This phenomen happily keeps the waste inspector in full employment even if it tends to be disheartening to the engineer, and must be accepted as a fact of life. By careful and diligent investigation and search and prompt remedial action the amount of this loss can be kept within reasonable limits perhaps down to acceptable or economic limits beyond which the engineer would not be prepared to exert the energies of his staff or spend his employer's money. Night lines obtained from waste water meter installations establish such limits at the same time giving positive satisfaction to the engineer in having something to look at on a chart which he can compare with previous experiences thus to measure results against the amount of effort expended. Of course, if he has confidence in the manner in which his inspectorate staff perform their sounding duties and if the system of sounding is good in respect both of the frequency of investigation he carries out and of the equipment he uses, he can rest at night undisturbed by fear that excessive losses are occurring and derive happiness in the thought that he has not put his employers to the expense of putting in waste water meters throughout the reticulation. I have no dislike for these appliances, on the contrary I believe that there should be provision for their installation where extensions are presently being made to the system so that during the youth and middle age of mains and pipes quick checks can be made to ascertain if leakage is occurring at such a rate as to justify more detailed investigation. In the old parts of the system it is probable, if not certain, that bursts are occurring so frequently that regular control procedures are required and it is hardly necessary for a meter to impart that information; in any case the meter can only indicate crudely the vicinity of the leakage, the sources have to be pin pointed by other means. Whatever method is adopted to minimize loss of water from the underground system the engineer is the final judge as to the worthwhileness of his operations and the assessment of this has exercised the minds of many eminent authors in the past and we look forward to the guidance Judith Rees can give us on this subject. If, from a variety of financial and other considerations, we can set an economic limit on the minimum loss we strive to maintain, so we can imagine an absolute maximum loss of water from the system provided that (*a*) all leakage eventually shows itself on the surface of the land or elsewhere, and (*b*) upon being given visual indication of their occurrence the defective apparatus is immediately repaired. The loss is then the quantity of water escaping from defects between the instant of breakout to the instant of shut-off for repair—a very variable interval indeed. Nevertheless, under these hypotheses the maximum constant loss can be roughly quantified. It will be noted under the first hypothesis, that the most certain way of finding all leaks is to let them reveal themselves, then having ascertained, however imperfectly, the measure of maximum loss a comparison can be made between the cost of detecting leaks before they evince themselves and the value attached to lost water. To embark upon a calculation of this kind is neither practicable nor profitable and is not to be recommended since it does not take into account the penalties associated with hidden dangers caused by a laisser faire attitude to underground leakage—such as cavities beneath road surfaces—and actions in the Courts for negligently failing to prevent damage to person and property. In any event, there cannot be many places, even in the clay sub soil areas, where some leakage water does not find its way downwards or into sewers, nevertheless, I find it difficult to believe the statements often made to the effect that in certain water supply systems, mostly situated overseas, as much as 50 per cent of the input is lost by leakage unless it is shown that the sub soil is so permeable as to provide an excellent site for ground water recharge. Using purified sewage and trying twice as hard, it would seem possible to develop a perfect recirculatory system. The prime cause of excessive (as gauged by any standard) waste by leakage from underground apparatus is, in my opinion, due to a disregard of ample evidence or indications that defects have occurred and subsequently delay in carrying out repairs. Some losses are tiny in themselves and therefore exceedingly difficult to detect but if occurring in sufficient numbers might aggregate to a sizeable quantity. An old friend and former President of the Institution once suggested the possibility that if the joints in the mains system were leaking a few drops a day the total loss thus aggregated would amount to an appreciable proportion of the total input. Trying out this conjecture, I find that in Newcastle upon Tyne every joint would need to leak at the rate of something near 8 drops per minute to lead to a loss of $\frac{1}{4}$ mgd or substantially less than 1 per cent of the input. No doubt some joints are leaking at this rate, some indeed very much more but I am convinced that taking the system as a whole the undetectable leakage by drops from pipe joints does not amount to the figure given above. The drop theory of lost water does not seem to amount to much. Having embarked on arithmetic exercise can we gain some idea of the shape of the global loss over England and Wales? We are told that the daily water usage is roughly 3 000 mgd, if the loss is 10 per cent we are losing 300 mgd which would be the yield of one and a half Kielder reservoirs—if ever the North East of England gets one Kielder. It means also that for each person there is less than 6 gal/day going to waste which is equivalent to, in most parts of the country, 3 flushes of a lavatory cistern. Many engineers may think 10 per cent unavoidable loss, from mains or pipes, unrealistic. Even double that percentage does not, in my opinion, mean that we should get wildly excited about the matter nor does it mean that we should be complacent. Elsewhere I have pointed out that the need to tighten the waste prevention belt becomes critical when somebody is going short or going to be short of water, whether in the home, the factory or the river. With the river in full flow, the reservoirs overflowing, the aquifers fully charged and the mains fully pressurised then loss of water from the underground system is likely to have, at that instant, a relatively low position in an engineer's order of priorities. Whenever any of these situations changes there follows an added emphasis to conserve water supplies and prevent waste. It is, however, barely conceivable that in any normal British Water Undertaking the reduction of lost water from a point above to point equal to an economical limit will do more than defer the harnessing of new resources beyond a few years since demands for water are ever increasing and surplus effective resources are being eroded year by year. The time necessary to promote new schemes and construct them is now so extensive that the hidden reserve of recoverable system water lost by leakage (assuming that the amount is not extravagantly above an economical limit) cannot have much impact on forward planning.

The traditional British practice of waste detection relative to water mains and services i.e. the discovery of leaks, is to carry out regular and cyclical inspections of the system. In some parts of the United States—I can only speak for the places I have visited—this does not seem to be the way at all; it appears to be customary in those parts to carry out intensive blitzes at pre-determined intervals and, after doing all necessary repairs thereby brought to light, leave the system alone until the next attack. I recall during a discussion on waste detection the manager of a water utility in one of the Eastern States told me that his invariable practice was to engage a number of high school undergraduates to sound his system for leaks during the summer vacation. It is not unusual for American water utilities to place contracts with specialist firms, some using the Cole's pitometer on trunk mains, to mop-up the leakage. In the last few years there has appeared in U.S.A. a magic van of electronic equipment (at the time of writing this is, I believe, undergoing tests in our country) which will pin-point minute leaks under the heavily paved Broadway notwithstanding the mighty roar of New York's traffic. This equipment, so it is claimed, will very quickly sweep an area clean of leakage and after doing so the contractors will come back later when called upon and do the same again. Assuming complete effectiveness and that this equipment can do in say one month what takes waste inspectors twelve months to do, the question posed is whether or not, in terms of water running to waste, it is more economical to have a theoretically bottle-tight system for one month and for the remainder of the year to have leaks breaking out and not being discovered or, alternatively, to find, on average, one twelfth of the leaks each month by traditional methods. The answer lies not in the discovery of leaks but in the repair of them; when leak discovery and repair are concerted activities following a cyclical pattern it follows that in say a 12 month cycle one twelfth of the leaks are repaired each month; with a given quantum of labour the volume of repair work performed would be the same whether taken from waste inspectors' monthly returns or from a long list of incidents generated from the instant electronic survey. So it is difficult to find any virtue in being able to sweep the same areas twelve times as often for waste. In New York last year Maurice Randall and I reported to I.W.S.A. that the Newcastle and Gateshead Water Company spent £77,000 in 1971 operating a Prevention of Waste Department and I was eagerly offered the use of this electronic equipment for half that amount with the firm promise that every leakage in the underground system would then be found. This claim contrasts rather sharply with the estimated cost of finding leaks, at £250 each, using the electronic equipment developed by the Water Research Association and reported on in 1969—perhaps my American acquaintance had over-estimated the value of the dollar against the pound! Those of my generation may remember the high hopes of infallibility we credited to the ill-fated and onomatopoeic Pongophone.

So much, then, for losses from the mains and services network; let us turn our attention to what I prefer to describe as misspent water in our homes and factories. The average per capita consumption in England and Wales works out at something approaching 55 ghd based on a total output of about 3 000 mgd (as officially recorded) for a population of around 50 million persons making some allowance for system losses. Of this perhaps 36 ghd is unmetered consumption. Our American friends are wont to ask "How do you keep your consumption so low?" bearing in mind that their consumption is anything up to 4 times as much as ours. By way of reply I have put the question "How do you manage to keep your consumption so high?" Professor Abel Wolman in a public address he gave last year to the American Water Works Association, reviewing American Waterworks practice in the past decade or so, touched on this disparity of water demand and concluded that the British "envied us our baths". He later privately assured me that he had indulged in one of his characteristic flights of artistic hyperbole. Nevertheless, there is a grain of truth in his statement; people in America are inclined to cool off under showers pretty frequently in their hot and humid summers. Not all domestic supply of that country goes through meters but the great majority does and those cities where open supply was traditional are rapidly changing over and installing meters. There is little doubt in the American engineers' minds that payment for water in accordance with measured quantity supplied does act as a curb on consumption even though, from where we stand, it seems singularly to have failed to have reduced demands to anything approaching the level in our country. It was put to me once that the rugged individualists in the U.S.A. were not going to be dictated to in regard to their usage of water whether by precept or the cost mechanism and, that this being so, meters acted to ensure a fairer and more equitable means of charging for the water used in their homes than the free for all conditions of open supply. If, as economic principles incline us to believe, the consumer becomes more careful in his use of water when he pays for it by measured quantities it will obviously be much easier to reduce consumption by any given percentage on a consumption of 150 ghd than on 55 ghd. It is not necessary to discuss the costs of meter installations and maintenance in comparison with savings thereby to be achieved—very few British water engineers consider universal metering to be a paying proposition for the present and, at least, the next decade. Nor does one need to mention the sociological effect of rationing water to the poor; this was given a thorough airing in Parliament during the debate on the 1973 Water Bill; none of us really believes that the poor need suffer as a result from attaching meters to their premises. The cost of the basic commodity i.e. cold water in the supply pipe, is less likely to act as the economic brake than the cost of heating it for the domestic purposes consonant with rising standards of living. If the intention underlying any suggestion that the fixing of meters is to prevent or minimize the lavish, extravagant or excessive consumption of water by a direct attack upon the pocket of the user—and this seems to be the popular view—then we ought first of all to know what we mean by lavish, extravagant and excessive use. Who is going to dictate that two baths a day or one a day or one a week or one a month is wasteful? I am sure that my wife would compel me to forego some of my personal luxuries to pay for the water needed for her dish-washing machine if it ever became a choice of spending money on this or on those. Of course payment related to the amount of water used will bring about a constraint on the use of water but "Mother, is it worth it?" I cannot believe it is worth it even in these depressed times or will be more worthwhile in the more affluent days of the future. If we did meter all premises we would ultimately lose a great deal of interest in the way the householder uses the water we supply and in the conditions of the fittings installed in the house*. The attitude of our American and Continental colleagues is—"they pay for the water, it's not our job to tell them how they should use it". I have talked much longer than I intended on this matter of metering—let's leave it where it is with a footnote of my personal view. I shall need a great deal of persuasion that the idea of putting in meters to stop wasteful use or to produce reduction in use of water can really be justified. I believe, on the other hand, that charging for water by measurement of volume used is fundamentally rational, can be put on a basis fair to all strata of society, could lead to a number of advantages in the production of charging schemes and in the operation of undertakings, but these benefits are luxuries we can presently ill afford.

Let us now in lighter mood try to put together what we know about household water usage. When we get home the kids are being or have been bathed, we have a wash and clean our teeth (probably under a running tap), we eat our meal during the preparation of which water has been evaporated and the surplus poured down the sink, we find ourselves involved with the washing-up unless we are cunning enough to have brought work home or are fortunate enough to have a dish-washer; our wife puts the kids' dirty clothes in the washing machine (a pound or two using 4 or 5 gal of water), we flush the toilet a few times during the evening, in the summer time we might water the garden or clean the car either by bucket or hosepipe; when bedtime comes we might have a bath or merely use the wash basin. Next morning there is further use of the toilet and the bathroom by all the family for washing or bathing and teeth cleaning, breakfast, washing up again hopefully after we have departed leaving the domestic staff behind to put the house in order. What happens now we can only conjecture. Floors have to be washed (there are not so many of these uncarpeted nowadays) windows and other household impedimentia cleaned by water, the front path occasionally sluiced and brushed, the toilet flushed periodically and possibly

* Although statutory provisions relating to waste prevention (including application of byelaws) act equally on the supply of water for non-domestic as to domestic purposes, it is often accepted that the meter, where fixed, is an effective byelaw enforcement agent. It is probably true to say that a greater proportion of water is misspent in metered industrial premises than in our homes. To monitor water used in factories would be a difficult—and unpopular—exercise.

used, inexcusably and infrequently, to transport a pinch or two of fluff, meals prepared, clothes washed and so on. If that is anything like a typical day for a typical family in this day and age it is difficult to say that we have used water wantonly or capriciously even though we must allow that had we tried hard we could have economised somewhat. An inhabitant in a developing country might well be appalled at our excessive use of water—he being provided with only a gallon or two a day to subsist on—if we had done without the 30 gal we used in our bath it would not have given him 30 gal more. Would a typical American family use more or less? In my experience I would say about the same except that probably in the sticky weather each adult would have immersed his body, either under a shower or in a tub, at least once and often twice in the day and that the sprinklers would have been dousing the lawn for a few hours most days in the summer months. But are we a typical British family? If not we are tempted to divide the population into social classes which really means that some are richer and some are poorer than ourselves, or that some are more and some less sensitive and intelligent and that these different people react according to class in predictably different ways when confronted by a British Standard bib tap. This is nonsense, it is inconceivable that more than a minute proportion of our citizens, irrespective of class, creed or colour, deliberately turns on taps or unnecessarily flush closets for the avowed purpose of wasting water. It is no great joy to the ordinary person to hear water running down the sink or toilet or out of the warning pipe. In fact as a nation we have been surprisingly conscious of the value of piped water to our homes and the desirability of conserving it. Carelessness and thoughtlessness in the use of appliances can never be ruled out and each and every one of us could, if put to it, use less water without detriment to our comfort and standard of living but in my view the savings thereby to be achieved in this imperfect world would not amount to very much.

How then, it might be asked, can substantial savings be made? The answer is, of course, that they are already being made in large measure; if water engineers were not adopting a serious conservation practice by leak detection, byelaw enforcement, regular inspections of properties, general awareness of the waste problem and ensuring the early repair of defects, the loss and waste, misuse and undue consumption of water would be prodigious. The fact that the amount of "waste" in this country is far from being unreasonable and probably as small, if not smaller, than anywhere else in the world has not come about by accident. There is a long history attached to the struggle against waste. The mid-nineteenth century water legislation empowered undertakers to make regulations to minimize waste in premises—some undertakers obtained statutory powers to test fittings—others did so without any legislative sanction. Some undertakers set up departments specifically to prevent waste before the turn of the century. In Newcastle a Prevention of Waste Department was established in 1895 when the domestic consumption was estimated at 25 ghd; after 5 years this consumption was said to have been reduced to 22 ghd and after 21 years to 17 ghd. In other big cities similar action was being taken but it is sad to recount that this was not the general experience among the several hundred waterworks operating prior to 1960. Whitehall found it necessary to step in by setting up a Departmental Committee into waste—its causes and prevention—leading to the requisition that appears on Form K.20 that waste surveillance is a condition precedent to obtaining loan sanction for the construction of works. The model byelaws, published before the last war and followed by the subsequent editions of the byelaws, the powers and duties in respect of waste prevention contained in the 1945 Water Act, the tremendous work of the Standing Committee on Water Regulations, the proceedings of the Institution and the research of the W.R.A.—all these have played their part in raising the standard of waste control.

In the circumstances of the new water services industry in which new and wider vistas will be opened up to the engineer, he must be careful not to turn his back on the pioneer work of his predecessors. He should, by the precept and example of his staff, by exercises in public relations and by the service his undertaking renders the consumers enlighten and educate everyone concerned that to squander a processed commodity such as water is just bad business; bad for individuals and for the nation as a whole. This, in short, is why waste should be controlled and it can be controlled even if it cannot be eradicated.

It is with gratification that I observe that the seminar is not solely concerned to investigate the extent and effects of waste but that a number of learned authors are to express their views on the cause of waste and they will, it is to be expected, take us along paths leading to the necessary improvements in materials and workmanship and possibly the education of our customers so that our systems will not need so much peripheral money spent upon them during the course of their normal working lives. On the face of it, it seems patently wrong for a medium sized water undertaking to spend something more than 4 per cent of its income in controlling waste. On the other hand it might be proved that 4 per cent per annum adds up to less than the added cost of putting in a copper bottomed system originally. With inflation, taxation and the other horrors of the modern world—I presume, however, to doubt it.

To conclude, I was asked by our Secretary to write this paper to set the scene for the symposium; if I have succeeded in doing that there can be no one more surprised than myself. Advancing years tend to make one pompous, self opinionated and disdainful of the views of others. When this paper is being read I pray the gentle reader to be aware of these human frailties and be at peace with himself in the knowledge that the author will not take offence if there is any disagreement with the views expressed.

AUTHOR'S INTRODUCTION

Mr. H. D. M. Speed (Newcastle and Gateshead Water Company), in introducing Mr. Barrett's paper, conveyed the author's apologies for his absence and his good wishes for the success of the Symposium.

Mr. Barrett drew a vital distinction between water which was wasted by leakage from the distribution system and water which was consumed unnecessarily. To deal with the former, a system of leakage detection and repair was needed; the second problem was less straightforward. Several questions must be answered. Was the domestic user more wasteful than the industrial consumer? Since the industrial user was likely already to be metered, had payment by measured quantity had any effect? Were we to hope that future increases in cost would make him more economical of water? At best this was a negative approach and in his own view a much more positive attitude should be taken. How much money should be spent on purely educational public relations? However, until we knew the answers to the questions already posed we could not make the most economical allocation of resources.

Mr. Barrett had reservations about waste metering; he himself did not believe that it offered a panacea for leakage control. Dangers existed in spending too much time in maintaining and reading instruments and insufficient on maintenance of the distribution system. When waste meters indicated that excessive flows were occurring it was still necessary to *find* the leaks. In Newcastle, much other work was done during the twice-yearly sounding of the mains, including turning of valves and checking of packings, operation of stopcocks, checking for and replacement of missing case lids, ensuring that hydrants were drop-tight, rewashering of consumers' appliances, etc. Very important was the aspect of consumer relations; the Company's inspectors were seen to be in the area and to be giving active attention to the apparatus. The cost of running the department

Avoidable Waste—that waste in excess of the unavoidable waste.
Leaks—an individual uncontrolled escape of water from any part of the system which may or may not be detectable by normal methods. This definition departs from that given by Gledhill (1957), which was "A leak means a hidden leak on a buried pipe which can be detected by an experienced man using standard equipment".

MEASUREMENT OF WASTE LEVELS

Numerous methods are currently used in the water industry to describe waste levels. Most of the methods in common use employ the parameter "percentage waste" to describe the waste level and, since this is capable of being calculated in a variety of ways any inter-unit comparison of waste levels is difficult.

Any method used to present waste levels should be:—

(*a*) simple to use,
(*b*) independent of local factors, e.g. trade consumption, annual variation in consumption,
(*c*) consistent and capable of permitting comparisons to be made, either historically or with other districts (or towns, undertakers, etc.).

Two methods are available to describe waste levels:—

(1) The minimum night flow into an area is measured, and an allowance made for nocturnal trade and domestic consumption; the remainder is deduced to be waste.
(2) By inference from a knowledge of total demand and trade consumption for an area and by assuming a value for domestic consumption for the area.

As a preamble to considering methods of presenting waste levels it should be remembered that waste levels cannot be determined with great accuracy because of the various assumptions that need to be made in their calculation. Also, the reduction of waste levels, which can more readily be determined, is more important than the determination of a precise waste level.

In a paper published in 1900 the New River Company claimed an annual saving of 719 566 475 gal by the introduction of waste water meters. This order of precision cannot be justified simply on considerations of meter accuracy, let alone the assumptions which must be made.

Two basic methods exist for calculating waste levels:—

(i) Waste as a ratio of some parameter of total flow.
(ii) Waste expressed as the average waste per service in unit time.

Before any discussion can take place on the advantages or disadvantages of the various approaches some consideration should be given to trade consumption and the problems of correlating actual waste levels with measured waste levels.

Trade Consumption

Two points must be considered when examining the effect of trade consumption on waste levels:—

(1) The variability of trade consumption with time.
(2) Trade usage may not entail any substantial leakage in the distribution system compared with an equivalent amount used for domestic purposes.

As the trade demands for any area are unique to that area and can vary both seasonally and throughout the working week, careful consideration must be given to their inclusion when defining waste levels. If trade consumption is included in any assessment of waste levels the percentage waste levels may appear to be low and levels obtained in this way do not allow for a satisfactory means of comparison with other areas or historically with that same area.

Consider also the different characteristics of a trade supply from an equivalent supply for domestic purposes. A 1 mgd (4 544 m^3/d) supply to a factory may only require a small length of main from the existing distribution system and the water supply, once accounted for by the factory water meter, has no further effect on any calculations of waste levels.

A similar supply for domestic purposes may supply 10 000 houses and would require the following for its distribution, all of which are capable of being the source of waste:—

50–100 miles of mains
60 000 taps
20 000 ball valves
600 sluice valves
600 hydrants
also service reservoirs, pressure-reducing valves, etc.

Relationship of Actual Waste to Measured Waste

Rarely is waste measured directly but rather it is inferred from other measurements, normally by measurement of the night flow into an area. However, Phillips (1972) obtained details of actual domestic consumption from readings on the system of universal domestic meters. Having a knowledge of trade consumption he was able to calculate that 31·5 per cent of water supply to the system was unaccounted. Jenking (1973) obtained similar results at the Fylde Water Board.

In the majority of cases it is considered that the waste in an area is that water entering a district by night, less any water used for nocturnal trade or domestic consumption, plus any water used to make up storage. Domestic consumption at night is very small and can usually be ignored. The examination of waste meter charts reveals that only isolated discreet usage occurs and this is borne out by Webster (1972) in his investigation into the usage of water in high blocks of flats. Nocturnal trade consumption can be measured or assessed for any given district.

However, having made allowance for both nocturnal domestic and trade demands, can one assume that the water entering the district is the true waste level of the area?

Several important factors govern the difference between actual waste levels in a district in normal reticulation and those levels measured by waste metering.

(*a*) In normal reticulations there are usually several feeds into the area compared with the single meter feed during waste metering. This will affect
- (i) the pattern of pressure contours;
- (ii) the pressure, which will normally be higher at night; also the pressure drop through the meter installation.

(*b*) The pressures and pattern of pressure contours at night are influenced by the low night flows due to waste and nocturnal consumption. Day time consumption will superimpose a different flow pattern on the system, with a consequential altered pattern of pressure contours.

(*c*) The mains pressures at the inlets will vary during the day due to differing demands from the district and other areas being served by the mains system, unless the inlets are immediately downstream of pressure-controlling devices.

The effects will be unique for any system in any given time. Work has not been carried out to investigate the relationship between actual and measured waste for an area, although it would be possible to establish a mathematical or analogue model which could be used to examine any given situation. However, the work involved would be considerable with comparatively marginal benefits.

In the absence of any real information it is normally assumed that

$$\text{Total daily waste} = 24 \times (\text{night waste level}).$$

METHODS OF MEASURING WASTE LEVELS

Percentage Waste.—This is the most commonly used method of expressing waste levels and, at first sight, is the most straightforward and simple.

$$\text{i.e. percentage waste} = \frac{\text{waste} \times 100}{\text{water supplied}}$$

Unfortunately, various approaches to the use of this method exist in the water industry. Trade consumption may or may not be deducted from the total (in some cases only metered trade is deducted, in others an assessment is made for unmetered trade and consumption). A further complication exists in cases where engineers define a target minimum night flow for an area, and only that part of the minimum night flow in excess of the target minimum night flow is assumed to be waste for the purposes of calculating the percentage waste.

The different approaches outlined above have made it impossible to obtain a comparison of quoted figures, unless other information is available.

A method reported by Clerke (1949) is to quote waste levels as a ratio of maximum day flow to minimum night flow. Clerke said that the ratio would be between 12:1 and 15:1 in a good domestic area. However, it is not a method in current use and would appear to have little to recommend it.

Waste/service/hour.—This is a method which has several advantages:—

(i) It is independent of consumption, either trade or domestic, and is not affected by any variations in them.
(ii) It does not depend upon a knowledge of average or peak flows into the district under consideration.
(iii) Comparison with other districts is simplified and inter-undertaking comparisons become meaningful.

Inter-unit comparison will depend upon the density of services/mile of main being similar as in normal urban areas. Rural areas and areas with high rise blocks of flats present the two extreme cases and some adjustment will be necessary to permit comparisons between dissimilar districts.

ACCEPTABLE LEVELS OF WASTE CONTROL

Leakage may be considered to fall in one of three categories:—

Category I
Very small leaks, e.g. sweating joints on mains and services, dripping taps, etc., which are not detectable by normal techniques (although a dripping tap can be seen but may not be repaired).

Category II
Medium-size leaks which are of a size to make an appreciable contribution to general waste levels in a district, but which are not apparent except by detailed inspection, or, in some cases, by more sophisticated techniques, e.g. nitrous oxide leak location.

Category III
Large leaks which make their presence known by various mechanisms, e.g. water breaking surface, bulk meter readings, loss of pressure, noise in houses, etc.

Generally, Category III leaks will be reported and repaired independently of any waste control measures.

Category II will contain some leaks which can be located by waste control measures and be subsequently repaired.

However, it may not be considered economic to locate and repair some leaks in Category II and those in Category I would only be detected by exposing all mains and services.

Therefore it would seem that the wastage level below which it is uneconomic to locate and repair waste will be made up of Category I and some of Category II.

Gledhill (1957) carried out tests on nine mainly domestic districts containing a total of about 20 000 people. Each district was proved to be clear of leaks by sounding on one day, the minimum night flow was measured, and the following day the district was again sounded to ensure that leaks had not broken out during the test. Each district was tested at least three times. The average values of the minimum night flow level was about 0·27 gal/household/hr (0·025 m^3/d/household) which can be attributed to Category I. It is interesting to note that the minimum night flow recorded for one district was 0·12 gal/household/hr (0·073 m^3/d/household) on one occasion.

Controlled experiments in several undertakings suggest that a level of 0·25 gal/household /hr (0·03 m^3/d/household) is the minimum level to which waste could be reduced. In new estates it is likely that these figures could be bettered for a short time after commissioning but would rise with time to more usual levels.

Therefore, it is unlikely that this figure would be economically sensible as a target for waste control. The general experience of those who carry out routine waste control is that waste levels of less than ½ gal/household/hr (0·05 m^3/d/household) cannot be economically achieved. The use of this figure assumes an average district, or rather an average density of services per mile of mains. In districts where the normal density may not occur, e.g. rural areas or urban areas with a large number of high-lift flats, some weighting must be used to normalize the waste levels. Woodward (1968) at East Devon Water Board weighted his results by allowing 0·1 gal/yd/day (0·12 m^3/d) of mains and 10 gal/household/day (0·04 m^3/d/household) which is in close agreement with ½ gal/household/h quoted above.

Although the generally accepted optimum target level for waste control is ½ gal/household/hr, this figure can vary with particular circumstances:—

Pressure—high pressures would normally raise the level of economic waste control as a given dripping joint can be expected to leak more under a high pressure than under a low pressure.

General waste levels—in areas where waste levels are generally high it would not be sensible to reduce the waste in a few districts to ½ gal/household/hr, when waste levels in surrounding districts may be as high as 3 to 4 gal/household/hr (0·33 to 0·41 m^3/d/household) due to more easily traceable leaks.

Value of waste water—furthermore the value which the undertaking accords to the water wasted will have considerable effect on the limit of economic waste recovery, e.g. where the safe yields of all available supplies are being reached or where water is expensively bought by bulk supply the economic limit of waste control will be vastly different from that where water is abundantly available from a cheap source.

The new Regional Water Authorities will undoubtedly be concerned with the amount of, and the value of, waste when establishing strategic resource planning and examining new means of charging for water.

It appears therefore that leakage in the order of ½ gal/household/hr (0·05 m^3/d/household) may contain, in part, leakage of a magnitude such as can be located and repaired, although generally it will not be considered economic to locate and repair that leakage. Waste levels of ½–1 gal/household/hr represents the range to which it is considered economically possible to reduce waste levels and that higher levels may be considered excessive.

WASTE LEVELS IN THE UNITED KINGDOM

The various methods used to determine waste levels coupled with a natural reluctance to appear inefficient makes it difficult to obtain waste levels for individual authorities. However, it is difficult to disagree with the authoritative statement made by Hobbs (1967) in his Presidential Address to this Institution:—

"The overall consumption per head of water undertakings in Britain averages perhaps 50 gal/day, 'all in'—trade and domestic. Of this amount it is likely that the unaccounted loss based on minimum night flow from reservoirs in the majority of undertakings would be not less than one-third of the total daily consumption, largely accounted for by leaking mains, services, and fittings. It is obvious therefore that there is room for considerable improvement in consumption per head per day".

An investigation by the author into the waste levels in various areas with little trade consumption revealed minimum night flows of ½–4 gal/household/hr (0·05 to 0·40 m^3/d/household, which represents a waste of approximately 16–60 per cent based on a figure of 65 gal (295 l) actual usage of water/household/day. Waste levels in excess of 4 gal/household/hr (0·40 m^3/d/household) have been reported elsewhere.

A brief examination of published statistics (Water Engineer's Handbook 1973) of trade and domestic consumption (which latter figure includes waste) for individual undertakers confirms Hobbs's estimate, if one assumes a per capita daily domestic consumption of 20–25 gal (91 to 114 l).

FACTORS AFFECTING WASTE

Waste control is usually considered as being the location and repair of leaks, but an undertaker's policies and its approach to certain problems may considerably reduce the amount of water lost from the system (or misused) even before routine waste control measures are employed.

Gledhill (1957) stated that the factors having a direct bearing on waste in the area of the Sutton District Water Company, in order of importance, were:—

(1) high pressures,
(2) corrosive soils,
(3) poor quality of fittings and material, bad workmanship,
(4) movement of soils caused by changes of temperature and moisture content, and by subsidence,
(5) shock and water hammer, especially due to the opening and closing of valves,
(6) effects of traffic,
(7) corrosive waters,
(8) extent of free service given by water undertakings with regard to rewashering,
(9) age of services and mains.

The McNaughton Report (Ministry of Health 1949) gives the following examples of methods for reducing waste:—

(*a*) avoidance of unnecessarily high pressures,
(*b*) insistence of good workmanship and materials through stricter enforcement of byelaws and by the use of British Standards,
(*c*) use of care in laying, bedding, protecting and testing pipes and services,
(*d*) taking of precautions against corrosion,
(*e*) introduction or extension of domestic repair facilities,
(*f*) need for testing and stamping fittings,
(*g*) regular overhaul of automatic flushing cisterns.

Gledhill's findings are generally applicable to the industry although local variations in the order of importance may occur and potential methods of reducing the waste of water may be self evident if these points are examined.

Similar factors to the two lists above can also be found in the "Manual of British Water Engineering Practice". Improvements in materials, methods and technology play a large part in achieving a reduction in waste, especially in the long term.

One factor, which has a deleterious effect on waste, but is rarely tackled in a positive manner, is that of high distribution pressures. The lack of enthusiasm may be due to several reasons, operational difficulties, including the problems of maintaining pressure-reducing valves, the belief that the high pressure is part of the service to the consumer or simply being unaware of the very large increase in waste that can occur due to very small changes in pressure.

High pressure has three effects on waste:—

(i) For any given leak the leakage rate will increase with pressure.
(ii) The incidence of leaks will increase with pressure.
(iii) There may be some increase in consumption (with certain uses of water where the usage depends upon a fixed opening of a fitment coupled with a fixed time of use, e.g. washing hands under a running tap (by definition it is not strictly waste).

There have been various reports of the effects of pressure upon waste control. Bain (1957) reported that a district served through a pressure-reducing valve with a fixed

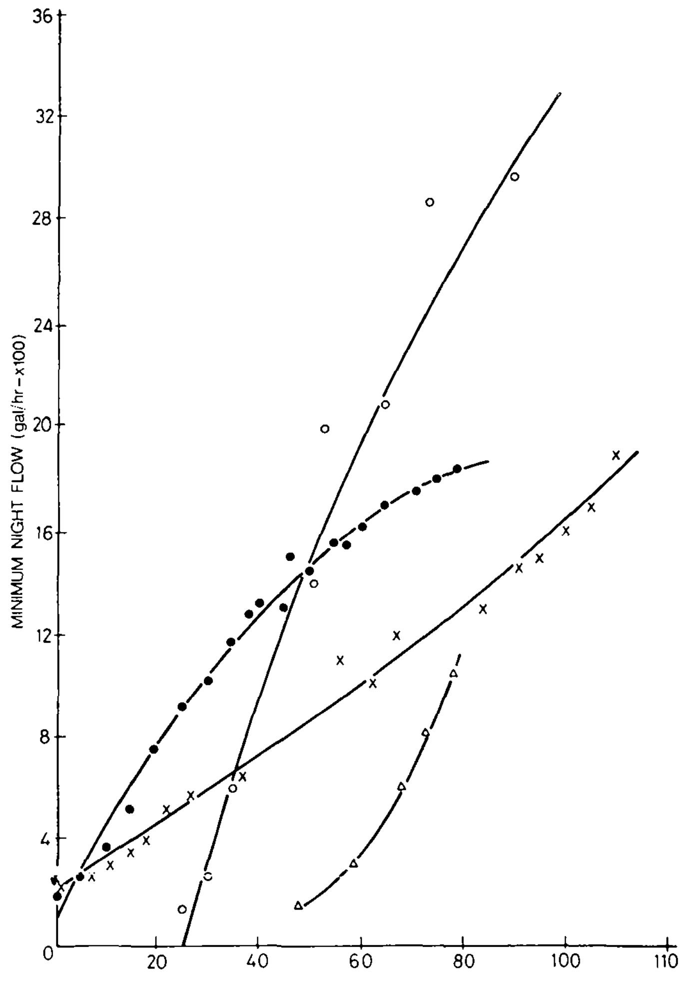

Fig. 1. Curves of minimum night flow v main pressure at waste meter

downstream pressure of 45 lb/in^2 (3·1 kg/cm^2) had a minimum night flow of 850 gal/hr (3·9 m^3/d) which increased to 2000 gal/hr (9·1 m^3/d) when the valve was by-passed so that the pressure rose to 85 lb/in^2 (5·9 kg/cm^2) The MNF returned to 850 gal/hr when the supply was again passed through the pressure-reducing valve.

Baxter (1952) stated that a reduction of pressure from 200 to 100 ft (61 to 30 m) in a district resulted in a reduction in consumption of 5 gal/head/day (0·2 m^3/head/day). Babbit and Doland (1962) noted that a pressure increase from 25 to 45 lb/in^2 (1·7 to 3·1 kg/cm^2) resulted in consumption increases up to 30 per cent.

The author carried out a simple experiment on four waste meter districts to examine the effects of pressure on waste. During a night test on a district the mains pressure upstream of the meter was reduced and readings of the minimum night flow obtained for the reduced pressures and these are shown in Fig. 1. It was considered that the scatter of some points above the general trend of the curve may be due to readings being taken at the time of some consumption in the district. (A filling cistern, for instance, can raise the flow by 100–150 gal/hr (0·5 to 0·7 m^3/d).

It can be seen that a small reduction in pressure can result in quite considerable reductions in waste levels. For example, in one district a reduction of pressure of 20 lb/in^2 (1·4 kg/cm^2) resulted in a drop of 1100 gal/hr (110 m^3/d).

The pressure/waste relationship did not follow the square root law in any of the four districts, although the square root relationship is often quoted in these circumstances. The topography of the district and the location of the meter will all play a part in deciding the characteristics of the relationship.

Various attempts have been made to achieve reduction in waste levels by pressure control, including that by Davies (1972) in part of the area of the Mid Cheshire Water Board. Two electrically operated 12 in diameter valves controlled by time switches were used. At 7.00 p.m. one valve was closed, which concentrated the flow from reservoirs into three instead of the normal four trunk mains, thereby increasing the pressure losses. The second valve, closing at 23.00 hr forced water (via a pressure-reducing valve) through two trunk mains thereby achieving a total reduction of pressure of 40 ft (12 m).

Careful investigation revealed a saving of 0·12 mgd (27 m^3/d) at an estimated annual saving of £2000, based on current production costs. Davies considered that the "pay-off" would be even more significant in the future when the undertaking will be working near its marginal limits and when the purchase price of water from a neighbour to replace that wastage will cost £4000 per year. The cost of valves, etc. was £1500 and he estimated that the benefit/cost ratio could be as high as 3–1 in any year and as large as 30–1 in the long term.

Whilst this particular application is limited to certain specific applications it shows that savings from this approach to waste control can be both measurable and impressive.

WHERE DOES WASTE OCCUR?

Within the industry exists a considerable amount of detailed knowledge of practical observations on waste and waste control, of useful trials and experiments, and of noteworthy incidents all of whose publication would be of widespread benefit. Much of this body of knowledge is not readily available, certainly not in a standard format, despite the efforts of the Institution of Water Engineers (1966) in recommending a standard method of recording leaks which has, unfortunately, since the publication of the report, been little used.

The variability in the causes of waste and the methods of controlling waste make it almost impossible to give definite statements on leakage rates and running times for various categories of leaks. The two extreme cases could be an instantly repaired dripping

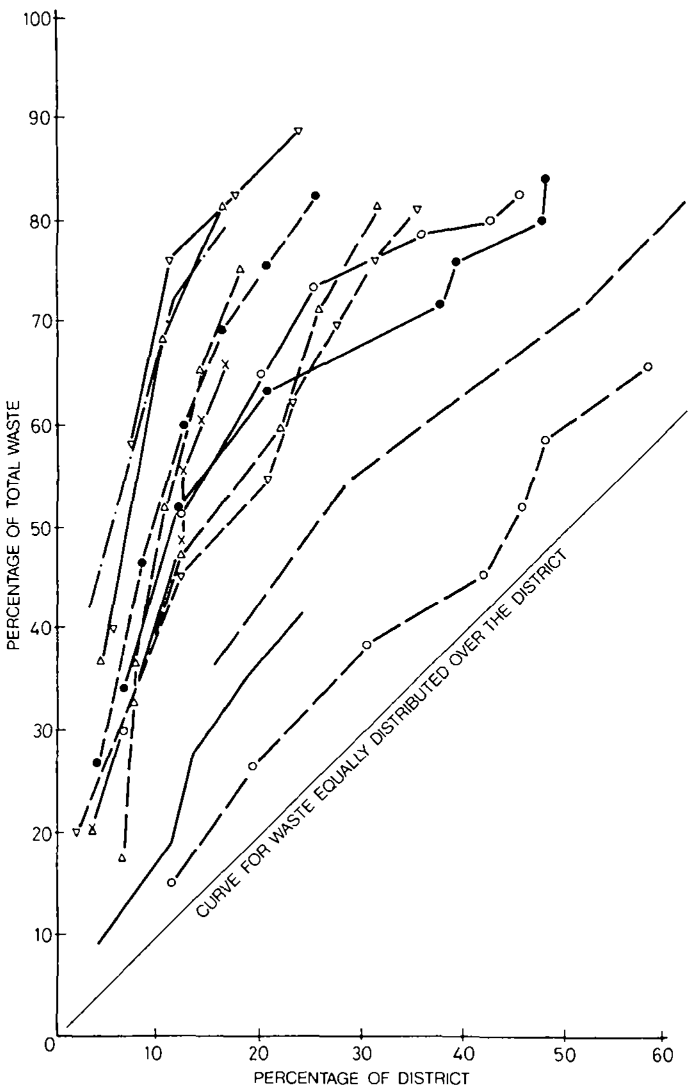

Fig. 2. Curves of percentage total waste v percentage of district

tap and a leak on a large trunk main which leaks at a rate in excess of ¼ mgd (1136 m^3/d) for many years.

Although waste occurs throughout the distribution system and from a variety of causes it does not have a uniform spatial distribution. An examination by the author of the distribution of waste over several waste meter districts suggests that the distribution is of the Pareto form. The results of the investigation are given in Figs. 2 and 3 which show the distribution of total waste and unacceptable waste respectively.

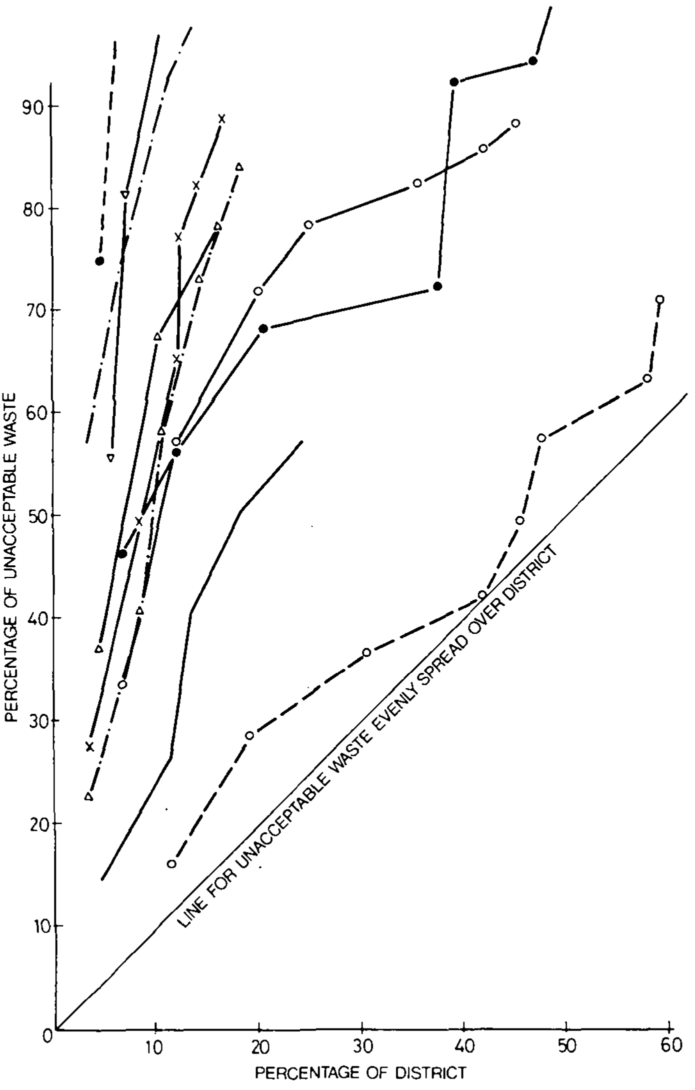

Fig. 3. Curves of percentage unacceptable waste v percentage of district

Although waste and wasteful use both have a similar effect on the depletion of an undertaker's resources their differing nature makes it advisable to consider them as two separate subjects in this discussion.

Waste

Leakage which occurs in elevated service reservoirs and tanks is easily noticed and the subsequent repair may not present too many problems, but the waste which can occur from buried service reservoirs is usually much more difficult to detect, locate and repair. Much of this leakage is through hairline cracks in the concrete walls which may close completely when the reservoir is emptied down for examination and only open under static water pressure. Unless there is a risk of the leakage causing instability to the struc-structure or of infiltration of polluted ground water these small leaks may be allowed to run unrepaired.

Leakage from mains will be from various mechanisms ranging from a total fracture of the mains to a weeping joint. Trunk mains may present somewhat different problems to those of the smaller distribution mains because the latter are normally inspected and monitored by waste control and distribution control measures. This may not apply to trunk mains which are sometimes not monitored by meters, or even where meters are used any discrepancy in the system's mass balance can be attributed to meter error. It is interesting to consider that on a pipeline metered at either end and with no intermediate draw-offs between meters an error of 5 per cent on each meter, but in opposite directions, could result in a 4000 gph (18·2 m^3/d) leak being undetected for a nominal 1 mgd (4544 m^3/d) flow through the main because a mass balance could be achieved between meters and errors in excess of 5 per cent are not at all uncommon in large meters.

Leakage from the smaller diameter distribution mains will be generally for similar reasons as for trunk mains, although the greater number of fitments, ferrules, etc., will increase the leak potential of the smaller mains. A recent investigation by Bacon *et al* (1973) into the failure of mains in sample areas of the Metropolitan Water Board showed that the fracture pattern in the larger mains was largely longitudinal and for smaller mains was transverse.

The leakage from service pipes is generally in excess of that from mains and, according to Gledhill, the leakage from communication pipes exceeds that from supply pipes in the ratio of between 3:1 and 5:1.

The waste which occurs in domestic premises will normally be that from fittings, e.g. taps, ball valves and consumers' stopcocks, although other failure mechanisms play their part.

The waste from trade consumers' premises is more variable in its nature because of the complexity of the water systems. The detection, location and repair of this waste will also be far more difficult than on domestic consumers' premises and generally larger running times will occur.

The reader's attention is drawn to that part of Gledhill's paper in which he evaluates the causes of leakage and associated leakage rates in the various parts of the distribution system of the Sutton District Water Company.

A detailed analysis of the sources of all leaks found and repaired in the course of systematic waste control in 1972 in the area of the West Hampshire Water Company are

TABLE I. INCIDENCE OF LEAKS IN THE AREA OF THE WEST HAMPSHIRE WATER COMPANY IN 1972

Mains			
Bursts	35	Sluice valves (glands)	320
Leaks on joints	21	Fire hydrants (glands, etc.)	164
Leaks on small G.I. mains	50		
Miscellaneous	21		
Service Pipes			
Communication pipes	325	Supply pipes	611
Ferrules	13	Garden stopcocks	9
Company stopcocks	160	Consumers' stopcocks	2393
Meters	104		
Ball valves	1884	Taps	4001
Storage and central heating	31		

shown in Table I. Whilst these results can be said to be reasonably typical it will be found that comparing them with another undertaker will show various anomalies because of the inherent variability of waste.

This variation will be because of the various factors which change even between districts in the same locality—pressures, type of soil, traffic density, historical policy regarding fittings, etc.

WASTEFUL USE

Wasteful use, by virtue of its definition, occurs mainly on consumers' premises. On domestic premises wasteful use occurs in many ways. The maximum length of spur pipes on hot water systems is laid down in the byelaws to prevent excessive amounts of cold water being run off as hot water is drawn to the outlet, but in many cases these spur lengths are longer than recommended. A somewhat similar problem occurs when the water standing in the pipes obtains an unpleasant characteristic of taste, odour or colour and the fitment is run for a considerable period to clear the pipe. Whilst not strictly within the category of wasteful use it should be mentioned that dual-flush cisterns are being introduced in an effort to reduce the amount of water used to flush toilets, although evidence exists that suggests the introduction of these cisterns initially causes an increase in consumption until the consumers become educated in their use.

The habits born of long custom of carrying out such household tasks as preparing vegetables under a running tap can be responsible for considerable wasteful use of water, and it is difficult to foresee any change in these habits at the present time.

The wasteful use of water by trade consumers is more complicated because of the larger number of ways it can occur and the various financial implications that may influence the consumer's approach to the wasteful use of water.

Three of the factors that may affect the attitude of trade consumers are:—

(1) The method of charging for water, i.e. by meter or by a fixed charge based on rateable value.
(2) The percentage of the cost of water used to the total operating cost of the enterprise.
(3) The cost of reducing the wasteful use of water.

After the formation of the North West Norfolk Water Board a survey was carried out into the consumption of unmetered trade consumers. The effect of charging certain consumers by meter was a substantial increase in revenue and/or a drop in wasteful use of water. In one instance a local sports ground had previously paid £12.48 per annum, this increased to £293 in the first year of metering but dropped to £108 by the end of the second year. A fish and chip shop similarly metered had equivalent annual amounts of £8.77, £107, and £54.

In many cases water from the public supply is used as a straight through cooling water or for washing or processing where the water could be recycled. The McNaughton Report mentioned a trade consumer who had achieved a 70 per cent reduction in water use by recirculation of the water.

Automatic flushing cisterns are well known as being wasteful in the use of water and, where allowed to run in an uncontrolled manner, many discharge in excess of 60 gal/hr continuously. Disk valves can be used to limit the discharge to an adequate 8 gal/hr and use is now being made of solenoid valves controlled by a time clock to limit the operation of the cistern to those hours when the toilets are in use.

Local authorities may wastefully use water in the operation of sewer flushes, either by excessive use or when used in such a way that the flush is ineffective. Some engineers do not regard favourably the practice of fire brigades of excessively flushing out their hydrants.

Water undertakers are not entirely without blame when operating their distribution system. The now rare practice of operating small diameter bleeds from the dead end of distribution mains is both ineffective and can be a health hazard.

In mains cleansing programmes a considerable quantity of water is wastefully, and often ineffectively used where the practice is to operate a continuous programme of flushing end hydrants at low velocities for a long period. The replacement of this method by a systematic programme of flushing or swabbing would achieve better results and use considerably less water.

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DISCUSSION

AUTHOR'S INTRODUCTION

Mr. H. J. Giles, in introducing the paper, said whenever water engineers foregathered the question was invariably posed "What is your waste level and what do you mean by waste?" Waste was an emotive word, having the connotation of inefficiency and ineffectiveness, and answers to the question were often misleading and misinterpreted.

In presenting the paper he chose to define certain terms, realizing that these definitions might not be universally acceptable. It was interesting to speculate that the usual way of describing waste levels could be calculated by several methods, all presenting quite different waste levels for the same circumstances.

Consider the situation of an area supplied with 100 units of water, made up of 40, 30, and 30 units attributable to domestic consumption, trade consumption and unaccounted for water, respectively.

(1) When waste was described as a percentage of the total supply the waste level =

$$\frac{30}{(40 + 30 + 30)} \times 100 = 30 \text{ per cent.}$$

(2) Where trade consumption was ignored on the grounds that once accounted for by meters it had no further effect on waste, then waste level $= \frac{30}{(40 + 30)} = 42{\cdot}9$ per cent.

NB- Similar results would be obtained for (1) when trade consumption fell off during weekends, strikes, etc.

(3) Where a target minimum night flow was determined (say 15 units) and waste was considered to be that unaccounted for water in excess of the target figure,

$$\text{Waste level} = \frac{(30 - 15) \times 100}{(40 + 30 + 30)} = 15 \text{ per cent.}$$

This large range of waste levels for the same circumstances had led to difficulties in making comparisons between undertakers etc. Another area of disagreement concerned the amount of the minimum night flow that could be attributed to nocturnal domestic consumption, because by so allocating a large proportion of the MNF the waste levels could be considerably reduced. This could be considered to be zero in most cases, as the domestic usage of water at night was normally limited to the occasional WC flush and could be seen by examining waste meter charts where indivdual flushes of WCs could be determined. This was confirmed by Webster (1972) who, over a period monitored every incidence of usage from each of seven outlets in 18 flats.

If we were to obtain some common understanding of waste and the problems of its control, we should establish some simple method of defining waste levels. The simplest and most logical would be to define levels as waste per unit of distribution, e.g. waste/household/hour. This was an unambiguous method which was not affected by the actual consumption levels and was thereby independent of trade and seasonal variations. It also permitted a comparison between streets, districts, towns, and counties.

One criticism of the method was that it relied upon a constant density of services. Some investigations were necessary to derive weighting factors to take into account rural mains with a low density of services and also areas with a high density of population such as areas with high-lift blocks of flats.

One of the causes of high waste levels was excessive pressures in the distribution system. In many cases high pressures could not be avoided, or only at great expense, but often pressures were provided at a high level in the belief that it was a service to the consumer. An approach to pressure control that would result in some reduction in waste levels was to maintain pressures at a level just above that at which complaints would arise. Pressure control was often shunned because of the cost of installing and maintaining pressure-reducing valves. He had referred in the paper (p. 16) to the "Delwyn Davies approach", which resulted in measurable savings from a quite simple control system.

One area of distribution control that could lead to excessive water running to waste undetected for long periods was in the accuracy or otherwise of bulk meters. Errors in large meters could be high, and might occur for a multitude of reasons. Even meters recently calibrated in a test rig to acceptable standards might become inaccurate when installed. Any discrepancies in a mass balance between meters could be attributed to several causes, but even a good mass balance could mask large losses from the system (p. 19). Large meters, once installed, should be calibrated *in situ*, either volumetrically, by salt dilution, or by other reliable and accurate methods.

He had welcomed the opportunity to present the paper, since he felt sure that there was a wealth of information available, merely waiting to be collected, collated, and presented. It was, therefore, with a feeling of dismay that having made various approaches, he had realized that while the information existed, it was not readily available, nor was it in any consistent form for analysis. It was disappointing to learn that the efforts of Research Panel No. 1 of this Institution (1966) in preparing a leakage request form had been ignored, even by those organizations who had taken part in the initial investigations. A potential spin-off from the present Symposium might be a decision for this Institution to take the lead in persuading engineers to make use of a standard recording system. The extreme variability of waste ranging from a dripping tap repaired within the day to a 10 000 gph leak allowed to run unchecked for 40 years, coupled with the multitude of causes and approaches to waste control, made it difficult to make firm statements on leakage rates and running times. Therefore the paper was written to provide a backcloth against which participants could describe their own experiences.

Finally, he reaffirmed the statements concerning waste levels in this country which were contained in the paper. Waste levels were such that about one-third of all treated water never reached the consumer. It was inconceivable that this level would be reduced to nothing, but as the costs of supplying water rose, it was essential that waste levels were reduced to an acceptable figure in the order of $\frac{1}{2}$–1 gal/household/hr.

Verbal Discussion

Mr. K. J. Reynolds (Lee Valley Water Company), in opening the discussion, said that waste was an emotive word and we now had a moral obligation reinforcing the economic need to evaluate and reduce waste to a minimum. In former times we were exhorted to "waste not, want not", although that applied to food rather than water. Having passed through what will, perhaps, become known as the "profligate age" of the 1960s and early 1970s, we must ensure that no commodity was wasted, including water.

Referring to p. 11 of the paper, the effect of pressure difference at night compared with day could produce a marked difference between indicated and actual waste. A further factor was the slow filling of cold water cisterns between normal top water level and overflow level. This was not waste, but like the previous factor served to inflate the apparent loss. Could the author comment, please?

On p. 12 it was stated that "Category III large leaks which make their presence known etc.". This was a dangerous assumption. Large leaks could go undetected for long periods, amounting sometimes to years if means existed for the dispersal of the leaking water. He referred to one instance where a railway's depot was supplied from a well which had received its supply for years via an enormous leak due to the substantial failure of a 48 in diameter lead joint! Finding one such leak (probably exceeding 1 mgd) could be equivalent to years of patient and costly searching in the normal reticulation system. Trunk mains (where such leaks could most readily occur) merited much closer systematic waste investigation than was normal practice. He invited the author's view on this assertion.

On p. 14 the causes of waste were listed in the order of importance given by Gledhill (1957). This order might no longer be correct. Many here must know how expensive and difficult it was to obtain the services of a plumber to rewasher a tap. In this situation the provision of a free rewashering service must rank higher in the order of priority.

On p. 15, the author commented on the effect of pressure on the degree of waste and he felt that in pressure reduction and control lay, perhaps, the most effective means of waste reduction.

The author suggested that waste on trade consumers' premises was difficult to detect and locate. This was not generally the case, as routine checks of the quarterly meter readings would often serve to detect waste and the strong economic factor usually spurred the consumer to considerable effort to locate waste when he was warned that it could be occurring!

Mr. J. R. M. Kearsey (Bristol Waterworks Company) said that it was not possible to measure waste but only the minimum night line. Having measured the minimum night line various factors could be applied to produce varying figures for waste. The minimum night line included such constituents as wasteful consumption, acceptable waste, domestic consumption, unmeasured consumption, instrument errors, unacceptable waste, and measured trade consumption. Generally, the factors of unacceptable waste and measured trade were likely to be the largest. In assessing waste it was, therefore, of great importance to be able accurately to assess trade. At least six methods seemed to be in common use in the water industry for assessing trade consumption at night as follows:

(*a*) To ignore trade. This method was often adopted in areas with a large number of small trade consumers but was unrealistic and gave misleading results.

(*b*) To take a fixed estimated figure. Unless trade consumers had fixed trade consumptions this method was unacceptable.

(*c*) To shut trade supplies off individually for say 5–10 min. and hence to record the reduction in night line. One limitation of this method was the "sensitivity" rather than "accuracy" of a waste water meter. Tests on a new waste water meter indicated that for flows between $\frac{1}{3}$ and $\frac{1}{2}$ full-scale readings a change of flow of 150 gph was required on a 6 in meter and 75 gph for a 4 in meter in order to give any noticeable movement of the pen.

(*d*) To shut off trade supplies cumulatively for say 3–4 hr. Whereas this overcame the sensitivity problem, it could create consumer relation problems. The method was advocated by Mr. Reid in his paper. Perhaps, as waste control assumed a growing importance, legislation should be considered whereby night isolations and inspections should be included in the categories of work when it was not necessary to give advance warning of an interruption of supply.

(*e*) To read all trade meters sometime before and after the night isolation or inspection. This method assumed that the average flow was the actual flow during the time that the minimum night flow was being recorded or the night inspection carried out. This method was the one recommended by W.R.A. in TP 109. Generally, the method would over-estimate trade flows as it was likely that storage would be filling during the early hours of the night and might be filled at the time that the reading was being made.

(*f*) To read meters over a short period during the isolation or inspection and to assume that this figure was constant during the whole isolation or inspection.

On p. 10 the author stated that an advantage of the index of waste per service per hour was that it was independent of trade. Whereas this index was used at Bristol he himself could not agree that it was necessarily independent of trade consumption unless night trade was accurately assessed.

Mr. J. N. M. Hutton (Hydrotronic (Jersey) Ltd.) said that the author used figures which related to the UK and it might be of interest to quote the following loss figures which he himself had encountered abroad:

(1) A town in Italy where the engineer was particularly keen on waste control, and where the difference between the measured output at source and the total of all metered supplies left an unaccounted for loss of only 11·12 per cent. Incidentally, virtually everything was metered. A leak detection survey revealed 3·8 per cent of the loss which left 7·32 per cent to be accounted for by use in fire-fighting, inevitable small leakages, meter error, etc.

(2) In other places the production which was not accounted for by known consumption usually came within the range of 20–40 per cent, which tended to confirm the author's findings. However, there had been an occasion when the leakage found had exceeded that which was thought to be missing. Again confirming the author's comments regarding meter inaccuracies of 28 per cent.

(3) The largest single find to date had been a leak of 4 mgd.

Mr. R. B. Tabor (Thames Water Authority) referred to the three categories of waste mentioned on p. 12. He agreed that sweating joints on mains would be found only by the costly business of systematic stripping of joints, but it should not be assumed that dripping taps were not worth repairing. The free rewashering service offered by some undertakers made the consumer water conscious and, therefore, more likely to report other sources of waste.

There were probably five or more taps in every home. Within the past year or so a random survey was carried out in the area of the Metropolitan Water Board and it was found that on pressures up to about 180 ft head taps were found to be dripping between rates of 1 to 5 gal/hr. If one assumed an average of 2 gal/hr. per leaking tap and one home in 20 had one dripping tap this was nearly $2\frac{1}{2}$ mgd in London, which represented over 0·5 per cent of its average daily supply.

It was difficult to average the cost of a rewashering service, as often an inspector would be able to rewasher several taps in one house and at other times he would have to arrange a single tap rewashering in the course of routine inspection work. During 1971/72 about 20 000 taps were rewashered in the London area; it was estimated that at present-day wage rates this would cost about £10 000. If these taps had been left unattended and allowed to leak for just about six weeks the cost of the water lost thereby would have equalled the cost of rewashering.

It was apparent therefore that there could be economic justification for this service, apart from any psychological benefits. It was agreed that category II (p. 12) leaks made up the bulk of waste, and for this reason none in this group should be regarded as uneconomic to repair because category II leaks could develop into category I leaks and even these, contrary to the suggestion, did not always make their presence known.

He asked on what grounds the author could justify the use of the term "acceptable waste", particularly in the context of training waterworks employees and with the risk that such an idea could be communicated to the general public.

Mr. R. A. Pepper (Sunderland and South Shields Water Company) referred to the definitions in the early part of the paper and suggested alternatives which would be more descriptive or would, by choice of suitable words, subtly change people's attitudes.

In particular he suggested "that water which leaked away from mains, pipes, and fittings other than through a controlled outlet" should be called exactly what it was, namely, "leakage" rather than "waste". He did not like the term "unavoidable waste", in that it was a negative expression tempting people into doing nothing about it. Instead he suggested "acceptable" or "tolerable waste" for that which would be uneconomic to trace and repair. "Unaccounted loss" should be used for that loss which could not be explained. Such terms were more likely to attract critical attention.

Mr. R. H. Smith (Northumbrian Water Authority) said that there was plenty of room for improvement in the design of fittings. Late the previous evening he had found one of the spring-loaded hot-water taps in the University's residential block running full-bore to waste!

On p. 14 the author had stated that the figure for domestic consumption in the Water Engineers' Handbook, 1973, included waste. He himself suggested that the figure for trade consumption in the same handbook also included waste, using commonly accepted definitions of waste or the definition of waste postulated by the author at the beginning of his paper.

Earlier speakers had referred to examples of large leaks which had been discovered. His own contribution, although not huge in volume accounted for a large proportion of the demand from its source. It was on a trunk main feeding a small town with a population of about 10 000. A large leak was known to exist from knowledge of the minimum night flow and the total daily demand. A leak which accounted for about 40 per cent of the previous total daily demand was discovered, completely by accident, discharging directly into a subjacent sewer.

Mr. A. C. Twort (Binnie and Partners) said that he was interested in the author's remark that "pressure/waste relationship did not follow the square root law", as he himself had found similarly when trying to locate the level of a service reservoir leak. Could it perhaps be a reflection of the fact that one was not dealing with a single leak but several or perhaps many?

AUTHOR'S REPLY TO DISCUSSION

Mr. H. J. Giles, in reply to the discussion, wrote that Mr. Reynolds had referred to the effect of cold water cisterns filling during the night. Generally, this would appear to manifest itself as a steady fall in the minimum night flow until about 03.30 hr, and might be as much as 150 gal/hr for a waste meter district containing 1000 properties. It was unlikely to be the difference in normal top water level and overflow level, as suggested by Mr. Reynolds, but to some quite small increase in level which was necessary to cause the ball valve to close against the higher night pressures.

He agreed that careful monitoring of the trunk mains could lead to the finding of the very large leaks, and, in some circumstances might be more effective in reducing waste than systematic waste investigation of districts.

Waste control was essentially an optimization process with the aim of minimizing the ratio: water saved/cost of saving that water

Unfortunately, there were real difficulties in monitoring the large trunk mains systems where often large leaks could occur and run undetected for long periods. In his introduction he had mentioned the difficulty in obtaining a mass balance on simple metered systems because of the errors in the meters. In old trunk mains systems the presence of small, often unrecorded, take-off points, passing valves, and faulty or non-functioning meters made the detection of excessive leakage difficult to determine. Possibly, a better definition of category I leakage (p. 12) would be "large leaks which made their presence known by various mechanisms, e.g. water breaking surface, bulk meter recordings, or loss of pressure, noise in houses, etc., or which had an escape pathway which enabled the leak to run undetected."

He hesitated to suggest any change in the order of the factors listed by Gledhill (1957), as his list was based specifically on the area of the Sutton District Water Company. Other lists had been compiled of factors which varied to some extent in the order of importance of the factors. However, he was not entirely convinced that the provision of a free rewashering service ranked high in the priority, as the leakage from dripping taps was proportionately quite small, and the efforts of the waste control personnel in repairing those dripping taps could be better utilized in locating larger leaks. This was an extension of the philosophy propounded by Mr. Reynolds when he suggested that the repair of large leaks on trunk mains was a better use of effort than systematic waste control.

Waste on trade consumers' premises might be easy to detect by a comparison of quarterly metered consumption in cases where the demand was reasonably constant with time. A gradual increase in waste might simply be put down to an increase in actual consumption or to changes in process or methods of operation when a resulting variation in normal useage could easily mask wastage especially where supply to the consumer was from several metered sources.

Mr. Kearsey set out the problems caused by trade consumption in determining waste levels from knowledge of the minimum night flows into a district. It was difficult to recommend any one of the six methods he described as being the best for all situations, but the approach which had much to recommend it was denoted in section (*f*), i.e. to read meters over a short period during isolation or inspection and to assume that this figure was constant during the whole isolation or inspection. Where all the meters could be read in rapid succession at the beginning of the test and re-read again as soon as was possible afterwards then the trade consumption calculated during this period should represent the trade consumption during that period of time.

Only in the cases of large rapidly changing trade demands would it be necessary to monitor individual meters more carefully. Also, the selection of such meters would normally be made from the local knowledge of the waterworks staff.

It was interesting to read of the low levels of wastage in an Italian town, described by Mr. Hutton, but it was unfortunate that the presentation of waste levels as a percentage did not allow any comparison with levels obtained elsewhere. Mr. Hutton's comments on meter errors and a leak of 4 mgd served to confirm the need for systematic waste control to be based on the total system and not on individual districts.

Mr. Pepper's suggestion that "waste" would be better named "leakage" had considerable merit, but when formulating the definitions given in the paper he had considered that it would be best to use those expressions which were currently used and understood by the industry. He himself was not entirely satisfied with the term "unavoidable waste", although it could be presumed to be accurate in that it described that leakage which could not be avoided, i.e. that which would occur in any distribution system with the passage of time and which did not respond to normal methods for its location. The alternatives suggested by Mr. Pepper might have some merit in attracting critical attention, although he was not entirely confident that this was so. However, he would welcome the use of any suitable expression if it was sufficiently emotive to cause those people in charge of distribution systems to reduce the level of wastage.

He agreed with Mr. Smith that the figures for trade consumption in the Water Engineer's Handbook would also include waste (and also wasteful use). It could be argued that as this water had passed through a controllable outlet, i.e. the meter, it did not represent waste from the system especially as revenue would be derived from it. This might not necessarily be the correct or long term approach to this problem.

Mr. Tabor described probable reduction in waste levels that could be achieved by the provision of a tap rewashering service in the London area. The savings appeared to be related to the charges for metered consumption rather than to the marginal cost of supply. Although these savings might appear to be worthwhile and most certainly the provision of this service was a good public relations exercise, it was necessary to ask "what annual saving of water could have been achieved if the stated sum of £10,000 had been used to carry out further systematic waste control?" Only if the saving of water by systematic waste control had been less than that obtained by the rewashering service could this service be justified, unless some proportion of the cost of the service was allocated to consumer relations and not to waste control.

Category II leaks might form the bulk of waste where the monitoring system could pick up large trunk main leaks, although there were circumstances where the existence of Category II leaks were known but the particular circumstances precluded them from being located and repaired. Typical of these situations were leakages which might occur in lengths of main buried under a heavily reinforced concrete road with continuous heavy traffic movement. In situations such as these, where location and repair of the leak was difficult and extremely expensive, the engineer might deem it uneconomic to locate and repair the leakage.

In response to Mr. Twort's question regarding the non-observance of the square root law in relationship between pressure and waste, leakage would normally occur from several leaks all of which might exhibit different characteristics as described below:

(1) The pressure at the leak would not necessarily be that at the point at which the pressure was measured because of the difference in levels and also friction head losses in the pipes.

(2) The leak orifice, normally assumed to be constant in size, might vary with pressure.

(3) Some leaks might not occur until a certain threshold pressure was reached e.g. longitudinal cracks in UPVC pipes.

The following description of a simple case might explain the varying results displayed in Fig. 1, p. 15.

Consider a district in waste meter reticulation, within the waste meter at the lowest point in the district, and with a population of leaks L_1, L_2, - - -L_j - -L_n all obeying a simple orifice formula.

If leak L_1 was at a height H_j above the meter location and the friction head loss during the period of the minimum night flow was F_j, it could be assumed that the leakage W_j from the leak could be expressed as:

$$W_j = K_j \text{ (pressure at the leak)}^{\frac{1}{2}}$$
$$= K_j (P - H_j - R_j)^{\frac{1}{2}}$$

Where K_j was a constant for the leak L_j and where P was the pressure at the meter, then:

$$\text{M.N.F.} = \sum_{1}^{n} K_j (P - H_j - R_j)^{\frac{1}{2}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (a)$$

In the case where the meter was at the highest point in the district the expression would become:

$$\text{M.N.F.} - \sum_{1}^{n} K_j (P + H_j - R_j)^{\frac{1}{2}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (b)$$

It could be readily seen that the square root law did not fit this model except in the case of flat districts with accompanying low friction losses, or if the peculiar circumstances of the district were such that $H_j = R_j$ for each leak.

Where the meter was at the lowest point of the district, case (*a*), it could be seen that the M.N.F. could approach zero although mains pressure existed at the meter. In case (*b*), where the meter was at the highest point in the district, it was possible for this to flow with the district although the mains pressure at the meter was zero. Both of these cases were recorded, as could be seen by examining Fig. 1, p. 15.

In practice, the situation was normally a combination of both cases, with the possibility that the leaks did not always obey the theoretical pressure discharge relationship.

In the case of the leaking service reservoir, it was possible that there might have been one or more leaks, and it was likely that leaks were cracks in the walls which would not only alter with pressure but which had extremely variable pressure/discharge relationships.

3. WASTE WATER AND UNDUE CONSUMPTION IN THE NETHERLANDS

By Ir. W. C. Wijntjes*

CONTENTS

INTRODUCTION

It is only a few decades ago that in most water undertakers in the Netherlands the production of drinking water was restricted to a simple and consequently cheap treatment of the "raw material" in order to produce a fresh, reliable, and tasty final product.

Owing to the increasing demand, good drinking water has become hard to find, so that one has to rely more and more on surface water. The process has to become more complex. In the case of those undertakers who rely entirely on surface-derived sources, they must wage an unceasing battle against pollution. Future plans for the provision of water supply clearly show the marks of this struggle. Extensive reservoirs will be required, often located far from the supply areas, so that long and expensive aqueducts and trunk mains will be necessary. A large investment programme will also be needed for the plants to treat this water. Accordingly, water charges must rise—drinking water is becoming expensive.

The choice of subject matter for the present symposium—waste—is therefore particularly timely, since it is one area in which there is scope for economy, perhaps even innovation. This paper is intended to outline the present situation in the Netherlands.

WASTE AND UNDUE CONSUMPTION

What do we actually mean by "waste"—Waste of water? In fact, it is impossible to get rid of water, to destroy it: it remains in the hydrological cycle. Water is displaceable, it can be changed into another state, it can be combined temporarily with other matter, but it cannot be "lost". The total quantity is constant, in contrast to other resources such as oil or coal.

What we really mean when we refer to waste of water is waste of money. What we are asking is whether the conditions under which the water undertaker operates are really optimal. What is perhaps as important is that we should not only look at the waste of *quantity*, but also at the waste of *quality*.

* Chief Engineer, Head of the Water Distribution Department of the Dune Waterworks of the Hague.

QUANTITATIVE ASPECTS

In order to calculate the financial savings from the quantity viewpoint it is necessary first to see in what way the amount of water distributed at present might be reduced. Two subjects require attention:—

(1) The water meter—as a means of reducing consumption and/or checking leakage.
(2) The extent to which potable water is "inappropriately" used.

METERING

The household consumption of water in the Netherlands is one of the lowest in Europe Two factors contribute to this:—

(*a*) The influence of the work of KIWA, the Netherlands institute for testing and research in the water industry.
(*b*) The water meter.

The application of water metering has increased greatly in recent years. However, there are still some undertakers who have not introduced metering, including the two largest—Rotterdam and Amsterdam. The Netherlands therefore provides a useful opportunity for a comparison survey of metered and unmetered consumption. The results of such a survey (undertaken in 1967) are shown in Fig. 1.

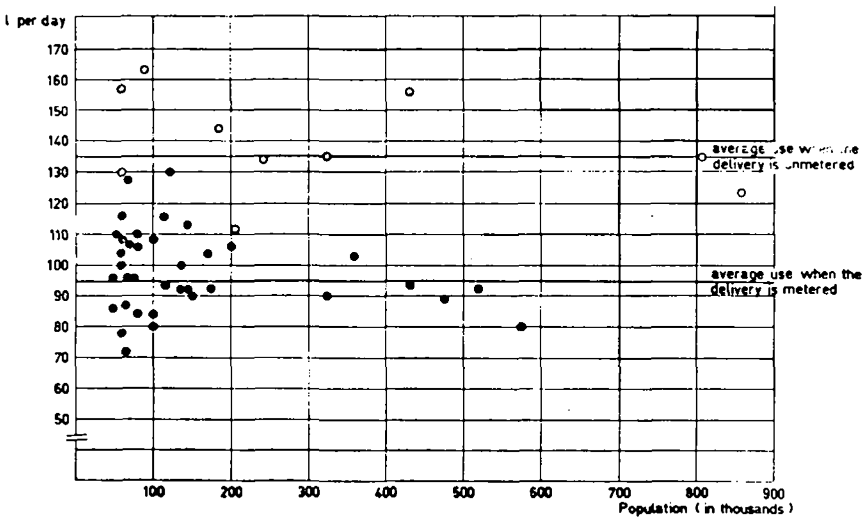

Fig. 1. Water consumption per capita in areas of supply with a population larger than 50 000 (1967)

○ = Unmetered delivery (⩾ more than 60 per cent of the dwellings have no meter)
● = Metered delivery (⩾ more than 60 per cent of the dwellings have meters)

The survey was confined to those undertakers who supplied a population larger than 50 000. Each point on the graph (Fig. 1) represents one undertaker. There is a clear difference (of about 40 per cent) in the average per capita demand in the metered and unmetered areas. The results compare favourably with those obtained in other countries, particularly Sweden and Israel. A separate survey undertaken in Rotterdam (unmetered) and The Hague (metered) showed the difference in demand to be even greater (about 50 per cent).

The results show that there is a dramatic and lasting effect when metering is introduced. This is confirmed by the records of The Hague undertaking, where the water meter was introduced in 1900, because of the shortage of water. Only in 1965 did the per capita consumption in this undertaking reach the level it had risen to in 1900 (Fig. 2).

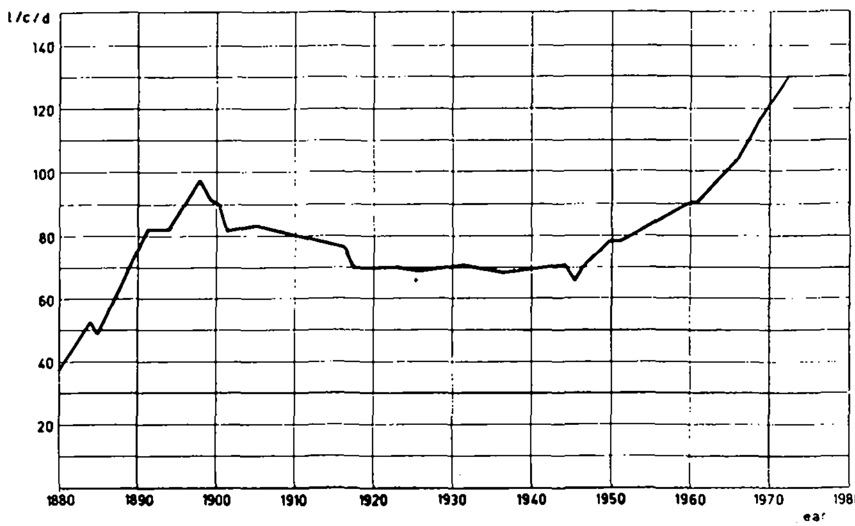

Fig. 2. Water consumption in the Hague

One of the important conditions concerning metering is that the accounts must be settled by the individual consumer, and not by the landlord. It has been found that central metering of a large number of dwellings is of relatively little value. In some countries where this condition is not applied, consumptions are much larger than those in the Netherlands. However, in Brussels, where metering is also applied on an individual basis, consumption figures are low. The explanation is to be found in human nature—why should you economize with water if your neighbour is to pay part of the bill?

In the case of individual metering, it has also been found that early attention is given to the repair of leaks.

In cases where hot-water supplies are provided on a central basis to a number of houses it is, of course, not possible for the water undertaker to apply the concept of individual metering. Though in the Netherlands there are few houses connected to a central system and consequently no well-founded ruling is available, the general impression is that this arrangement leads to a doubling of the water consumption, compared with an individual cold and hot-water supply.

WATER PRICE AND METER RATES

It is generally accepted in the Netherlands that:—

The influence of the present-day price with regard to the use of water is of less importance.
This influence in the case that the level of the water price will raise will only be effective in metered areas.

When metering is introduced, and consumers are confronted for the first time with a "water price", there is a surprising fall in consumption. This is known as the "metering effect". If, after the introduction of metering, there is a subsequent increase in charges there is, however, no corresponding fall in consumption. In other words, the fall in consumption is related only to the initial introduction of metering.

LOSS OF WATER AND LEAKAGE

There is still some confusion concerning the meaning of "waste" and "leakage", particularly if meters are used.

With a leakage in a drinking-water installation, a part of which can be registered by a meter, the consumer has to pay for water which he did not use. Fig. 3, p. 33, shows the water distribution of an undertaker who has introduced partial metering. The left-hand side of the diagram may be used for totally metered undertakers and the right-hand side for totally unmetered undertakers. The principal definitions used in the diagram are as follows:—

The financial (not accounted for) loss is the amount of water which an undertaker does not get paid for. In the metered undertaking it consists of the total of the loss of conveyance, the leakage that is not indicated by the water meters, and the consumption that is not indicated by the meters. In an unmetered undertaking, it comprises the total of the loss of conveyance and the leakage in installations.

The total leakage is the amount of waste water from leaks in aqueducts, mains and service pipes, in the accompanying apparatus, and in the associated plumbing installations.

OCCURRENCES OF LEAKS

Leaks may occur in aqueducts, mains, service pipes, and in plumbing installations. Important, from the quantity viewpoint, is the so-called "running-time" or duration of leaks. This, expressed in the number of days, is the time between when the leak starts and when the loss of water from the leak is stopped. The running-time depends upon a number of factors, e.g. pipe material, aggressivity of the soil, depth of pipe underground, groundwater level, etc. In the Netherlands, where in many cases a high groundwater level exists, breakages in mains occur spontaneously and the running-time is usually some days. The corrosion of mains as well as the leaks in service pipes result in longer running times.

An extensive survey has been undertaken by KIWA into leaks in service pipes. This showed the yearly leaks per 100 000 in service pipes to be broken down to pipe materials as follows:—

Lead	850
Copper	170
Steel	570
PVC	525
Polythene	425

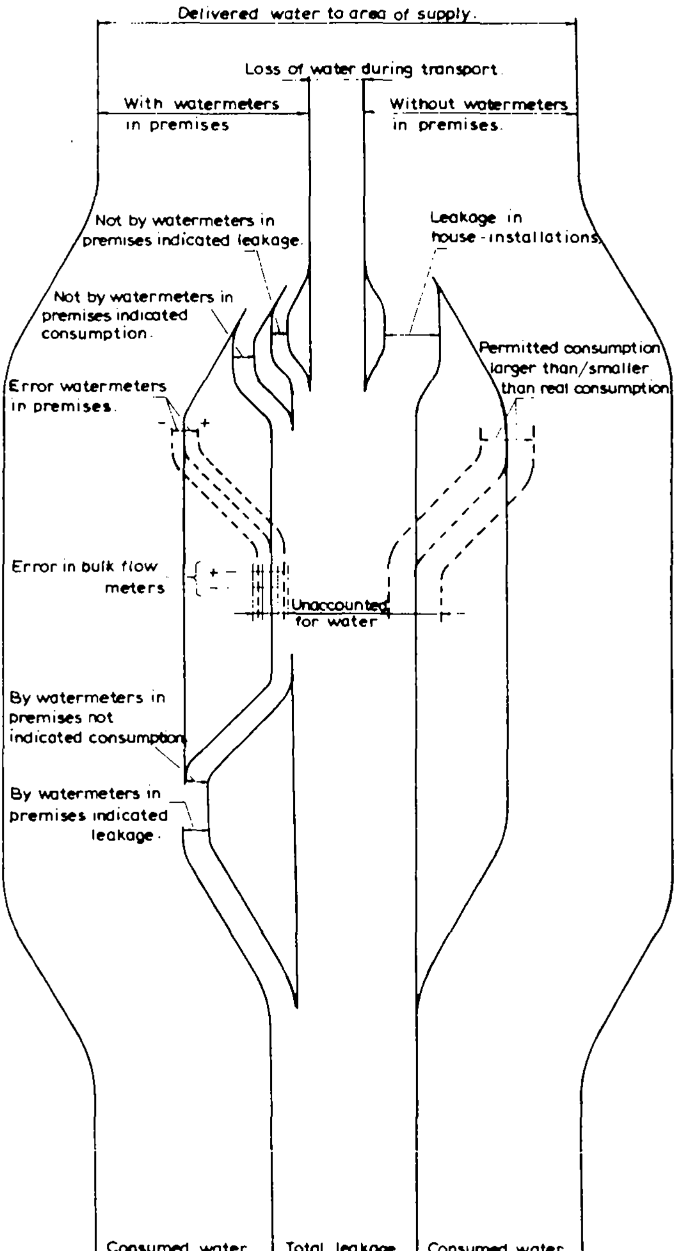

Fig. 3. Water division of partially metered waterworks

In urban areas the number of leaks amounted to 3 to 7 per 1000 service pipes; in rural areas, where the length of the service pipes was generally greater, the figure was 7 to 11. It was also shown that the greatest number of leaks in service pipes was found to start in the summer months. Most leaks occurred in lead pipes and the smaller number in copper pipes. At the present time in the Netherlands there are approximately an equal number of copper and plastic service pipes in commission.

CALCULATION OF LEAKAGE IN SERVICE PIPES

To estimate the total leakage in a distribution system an estimate is needed of (*a*) the average number of leaks, and (*b*) the running-time of each leak.

KIWA undertook a series of experiments in this connexion. A number of pipes, with a small hole in each, were laid in a field. The results showed that the average running-time of a leak may be about 400 days, and that the average leakage amounts to about 70 l/hr. It would also appear that in the case of steel and plastic pipes, the running-time for a leak would be considerably longer.

Other points to come to light as a result of the experiments were that the amount of water loss from leaks in lead pipes increased considerably towards the end of the running-time and that a leakage must generally be greater than 1 m^3/hr before its existence was likely to be discovered.

It was felt, however, that the survey was too small to enable general conclusions to be drawn.

LEAKAGES IN DRINKING WATER INSTALLATIONS

Leakages in drinking water installations appear principally in underground parts of house installations and in defective apparatus. With one exception, little research has been undertaken into this kind of leakage, by water undertakers in the Netherlands. However, it would appear that the number of defects of this type is declining. This is principally due to new house building and to the influence of the work of the KIWA organization in connexion with the testing of waterworks equipment and materials used in these installations.

The leakage in an installation can be estimated by relating the minimum night flow to the transport losses in the distribution system and the normal consumption in the night hours. The following values are used in the Netherlands:—

(i) In a dwelling provided with a water meter, the leakage not indicated by the meter can be estimated on an average at about 0·1 l/capita/hr; the leakage that is indicated by the meter can be estimated at the same rate.

(ii) In dwellings not provided with a meter, the leakage rate depends very much on the age of the installation and on whether or not the installation is inspected regularly. If it is regularly inspected the leakage would possibly amount to 0·4 l/capita/hr. In unmetered areas of supply, however, values as high as 1·5 l/capita/hr have been discovered.

THE LEAKAGE RATE

The leakage rate in a water supply undertaking is generally expressed as a percentage of the total output. Because it is technically possible to deliver larger quantities over the distribution systems—the "output" of a distribution system is rather low—this comparison is not necessarily correct. Further methods of expressing the figure are in the length of the mains system or in the wet surface of the mains.

In the author's view these also are incorrect. Most leaks are found in service pipes and drinking water installations. Therefore, the best approximation is given by expressing the leakage per service pipe.

WASTE CONTROL

Waste control should also be concentrated on two aspects—the inspection of the drinking water installations, and of the service pipes.

If the drinking water installations are not metered, "spot checks" should be made. Where individual metering is practised, the meter provides a good means of control. In those premises where consumption rates are found to deviate from the normal, inspections should be carried out.

This raises the question of how often inspections should be made. When the average running-time of a leak is short, there is no point in searching for the leak. The "benefit" arising from the leak detection service will hardly increase if the time of inspection exceeds the average running-time of the leaks. For the present, therefore, it is obvious that the rate of inspections by the leak detection service should be at most equal to the average running-time of the leaks. Whether it is preferable to shorten the time of inspections is a point solely related to economics.

Varying the time of the detection service can provide useful information on the running-times of leaks.

ECONOMY

From the economical point of view, the problem has to be divided into two parts:—

(1) The costs of leak detection, related to the amount of water to be saved.

(2) The financial gain to be allotted to the prospective decrease in loss of water.

In determining the costs, one is faced with a series of complicated technical questions. Thus, it is necessary to have some notion of the total number of leaks present, the frequency of the occurrence of new leaks, the average running-time of the leaks, the loss of water per leak per unit of time dependent upon the age of the leak, and the place where the leak is to be expected (in domestic piping, service-pipes, mains, etc.)

When these questions have been satisfactorily answered, the relationship between the average costs of leak detection and the estimated savings in water can be determined.

Regarding (2), one is inclined, when solving this problem, to be led by arithmetical data regarding the cost-price of the water. The objective, however, is "By what amount are the total costs of water supply reduced if the leakages decrease by one cubic meter?" When a company's turnover decreases, some costs will remain constant and others will increase more or less proportionally. Only in the latter case will a decrease in leakage result in a saving of money.

Costs are related to the following factors:—

(*a*) power consumption in the operation of the distribution system;

(*b*) chemicals to be added at the treatment stage;

(*c*) filter cleaning;

(*d*) water purchased in bulk.

Other costs are usually fixed and can be divided into staff and capital expenditure. The reduction of leakages will contribute almost nothing to savings in staff expenditure. The capital burden does not allow of reduction because the investments made are irrevocable. In addition to the proportionally variable savings which, according to Dutch standards, are not large (some pennies per m^3) savings should not be found, therefore, in present production means but in those still to be acquired. If a cut in leakage results in essential investments being deferred, the savings in costs can be considerable.

A remarkable exception to this rule is made by the undertakers who buy water from a third party. Here the cost price of the water must be considered to belong to the proportional variable cost. It is remarkable that in an area where for this reason one is engaged in leak detection, this handwork loses its meaning as soon as the purchasing-trade has made a fusion with the producing-trade. Nevertheless, it may be observed that leak detection is a more profitable business with non-metered services than with metered services. On the whole we do not look for leaks in the Netherlands on economic grounds.

LEGAL ASPECTS

In the Netherlands there is no legal obligation for water undertakers to operate leak detection. It is not unthinkable that there are circumstances leading to the conclusion that an undertaker has to unfold activities in this area and so on ground of the principle of carefulness. If the situation in an undertaking is such that frequently leaks appear in the mains and that consequently damage and/or annoyance to consumers and/or a third party is caused, the carefulness demands that the water company does the needful. And systematic leak detection may belong to it. On the other hand it cannot be denied that a water undertaker cannot guarantee that pipe breakage will not occur. So there should be a certain relationship between care for the maintenance and control directed against the prevention of damage and the frequency of pipe breakage.

In practice the only proper solution is that the water undertakers insure against financial consequences of contractual and legal responsibility.

UNDUE CONSUMPTION

Very little attention has been paid in the past by Dutch water undertakers to the question of undue consumption of water. Perhaps one reason for this is because a large proportion of supplies are metered.

A conscious attempt to prevent undue consumption could lead to a change in the pattern of water use which might be unacceptable to consumers. Therefore, it would be essential, first, to define what is meant by the term in relation to existing water use (e.g. can the washing be done using less water, but maintaining the same standard). It must also be decided whether one attempts to prevent undue consumption by "compulsion" or by "education" or persuasion. The author favours the latter approach.

A number of factors influence the amount of water consumption, of which the following are highlighted:—

(i) *Central Hot Water Supply Systems*.—As mentioned earlier, consumption in private houses having a central hot water supply system amounts to double the figure for the same type of houses provided with individual hot water systems and separate meters. What is the main reason for this? With the recent discovery of large supplies of natural gas in the North Sea, the promotion of gas-using appliances was accelerated. At the same time, charges in the tariffs for gas for small and larger users were introduced, e.g. a hundred houses with a central hot water supply system were treated as one large consumer. In this way, the householders received a considerable reduction in their gas charges. This was a surprising development, as there was no apparent advantage as far as the gas company was concerned. An off-shoot of this action was an increase in the consumption of water.

(ii) *The Pollution of Surface Water Act.*—Some years ago the Pollution of Surface Water Act came into operation. The water undertakers had been confronted, up to that time, with "parabolically" running consumption developments. Since the law came into force, consumption of water by industry has remained static and in some cases it has even decreased.

The average yearly supply of water by the undertakers in the Netherlands has remained fairly constant in recent years. The reason for this is related to the introduction of the above-mentioned law. Under this Act a charge is made to factories disposing waste waters. An important parameter in this connexion is the quantity of water which is discharged.

Since the introduction of the law the water consumption by industry has been carefully watched and all possibilities have been examined in order to try to reduce it. The increasing cost of industrial water is shown in Fig. 4. This represents the costs of water for a number of factories belonging to one manufacturer of electronic equipment.

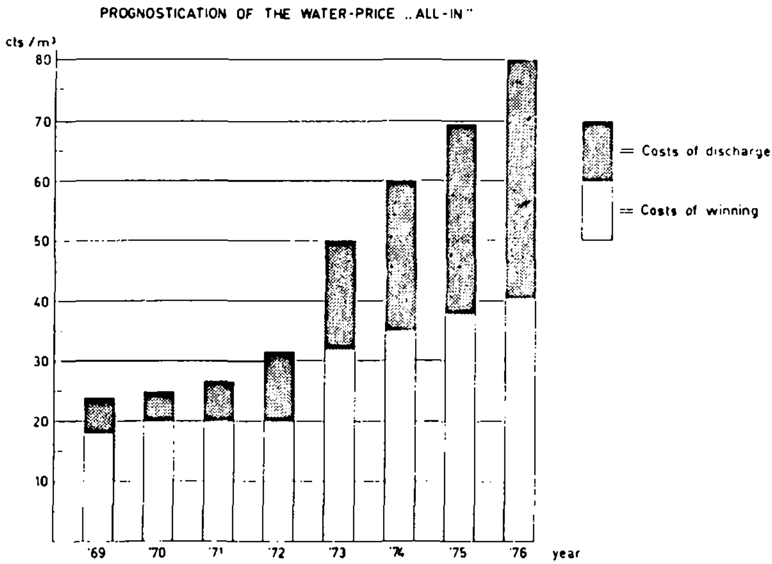

Fig. 4. Costs of industrial water

SAVINGS IN WATER CONSUMPTION

It is felt that the Netherlands is entering a new era in regard to water consumption, i.e. that of water conservation. In due course detailed information will become available on the changing pattern of consumption. In the meantime, it is only possible to make a preliminary study of that information which is already available from some selected examples.

INDUSTRIAL USE

The charges for potable water supplied to industry have always been low. Even a decade ago these charges were below those for domestic consumers. However, the industrial charges often had a political background but because the consumptions involved were not too large the reduced charges did not then give cause for concern.

In recent years, the situation has changed dramatically. Industrial demands have risen rapidly, so much so that charges had to be made economic. The resulting increases had little effect in reducing demand.

However, with the introduction of the new law on the pollution of surface water, industrialists have been assiduously looking at water-saving methods. Three examples are quoted:—

(1) The General Union of Industries in the Netherlands has asked its members to consider the economic aspects of water conservation. Particular reference is made to cooling water.

Such water used in closed condensers, which is subject to only a limited rise in temperature, is not unduly polluted. In these circumstances consideration should be given to the re-use of the water. There are two possibilities:—

(*a*) The use of cooling towers.

(*b*) The use of the cooling water as "trading-water". In these circumstances the water must be acceptable for the required purpose, both in relation to quality and temperature.

The Union has also advised its members to look into the possibility of alternative methods of applying cooling.

(2) The second example is that of an industrial complex with an annual water consumption of 12 to 15 $\times$ $10^6 m^3$, of which 60 to 70 per cent is used for cooling purposes. By the introduction of thermostatically controlled pressure-reducing valves in the boiler-houses and engine room, a saving of about 10 per cent in cooling water consumption was achieved.

(3) The third example concerns a new brewery, planned before the introduction of the new law, which included provision for an annual water consumption of about 10 $\times$ $10^6 m^3$. The use of a computer for the water system led to a decrease in water consumption of about 7 $\times$ $10^6 m^3$ per annum. In addition, the use of the computer also gave savings in other aspects of the work of the brewery.

THE DOMESTIC CISTERN

One of the most important water-using apparatuses in a household is the W.C. The per capita consumption in the Netherlands for W.C. flushing is about 40 l/day.

KIWA have undertaken an extensive series of tests over recent years into flushing cisterns and W.C. pans. The hydraulic design of the W.C. pan is particularly important, The use of cisterns with bottom valves was for some time forbidden in the Netherlands. because leakage from such valves can proceed unnoticed. However, research work by KIWA has shown that, by the use of better packing material, the operation of the bottom valve can be made more reliable. Consequently, many of these valves are now in use.

The hydraulic design of the bottom valve offers greater scope for economy of water than the siphonic cistern traditionally in use in the Netherlands. However, it is felt that very little further economy of water from toilet flushing can be expected with the apparatus now used.

GARDEN WATERING

Because of climatic conditions in the Netherlands, the amount of water used for garden watering forms only a small percentage of the yearly demand. However, such demand usually occurs at peak load times.

With the increased prosperity of the population, coupled with reduced working hours, it is expected that there will be a growing interest in gardening as a hobby. This possibility has been considered by a KIWA Committee, which has advised the water undertakers to give the following advice to consumers:—

> "Lawn sprinkler systems should provide 25–30 mm of water in a period of 1 to 2 hours. In order to promote a sound roots system watering should be confined to one application every 4 to 7 days. Excessive watering weakens the grass."

It is perhaps relevant to refer to a research study on garden watering of about 11 000 premises undertaken by the Johns Hopkins University, in Baltimore, U.S.A. It was found that on warm days the average quantity of water applied to lawns was 5 mm. A striking discovery of the survey was that the consumption in unmetered premises was about three times as high as in metered dwellings.

DOMESTIC WATER HEATERS

Increasing attention is being paid by members of the public to the layout of kitchens and bathrooms. As well as demands for greater convenience and comfort, there is a growing tendency to site "ugly" items such as hot water tanks in inconspicuous places such as lofts. This creates problems of wastage of water, as outlined by an inquiry undertaken by about 15 water undertakers in the Western Netherlands. In cases where hot water heaters were sited outside the kitchen, it was found that on using the tap about 7·5 l of water were run to waste before the temperature reached a satisfactory 60°C. There were examples of wastages as high as 25 to 30 l per use of the tap.

There was also a corresponding wastage of time on the part of the householder, who had to wait as long as 2 min before the water had reached the appropriate temperature. However, this did not seem to cause concern, as 60 per cent of the householders expressed satisfaction with the situation.

It is expected that the results of this survey will lead to further inquiries throughout the country.

Not only are large quantities of water wasted, but there is a corresponding wastage of energy. More attention must be paid to the insulation of hot water pipes and more specific regulations will need to be applied.

UNDUE CONSUMPTION - QUALITY ASPECTS

Potable water is used for many purposes but the quality of all the water supplied must be of the highest standard. This was less of a problem in the past when the quality of the raw water was high, and only minimum treatment was necessary. Today, however, the situation is different and enormous investment is necessary in order to produce a potable water from an increasingly deteriorating raw source.

In view of the high cost of providing potable water, there is in the Netherlands a demand for dual supplies. This would, of course, necessitate a separate distribution system for the "second class" water, the initial cost of which must be offset against any savings in cost. Also to be considered is the question of public safety, which is of paramount importance.

Shortage of space does not permit a detailed discussion here of the merits of such a system, but any consideration of the suggestion must bear in mind the following:—

(i) Water consumption in the Netherlands will undoubtedly increase considerably. However, it is etimated that by the year 2000 the amount of water actually used for "drinking" purposes will amount to only about 0·2 per cent of the total quantity supplied.

(ii) Because the growth in consumption will take place in the "non-drinking water" categories, the useful effect of the investments will considerably decrease.

(iii) In large industrial complexes, consideration should be given to the introduction of a grid system of dual supplies.

(iv) In view of item (i) the provision of dual supplies for households becomes an increasingly attractive proposition. Initially, the introduction of such a system would probably be confined to new towns and large housing developments. The application to existing installations is far more complex and would create many difficult problems.

(v) Potable water distribution by bottle, even on a small scale, would be most expensive.

Finally, it must be said that as industrial water consumption continues to grow and becomes an ever-increasingly important part of the total supplies of potable water, the advantages of the introduction of a system of dual supplies becomes more and more attractive. In fact, there are already examples in the Netherlands where dual supplies to large industrial complexes are working satisfactorily. A research study undertaken in Basle, Switzerland, showed that 40 per cent of the total quantity of water supplied to industry might be of an inferior quality.

GROUND WATER

In the Netherlands the situation concerning groundwater is far from satisfactory. There are, in fact, legal commitments regulating groundwater abstractions by water undertakers, but industrial consumers are able to use these resources as they wish. In a country where groundwater is scarce, this arrangement is illogical.

At present water undertakers must look to surface water to meet their increasing demands, whereas industry makes use of excellent quality groundwater for cooling purposes. A rearrangement of the legal basis for the abstraction of groundwater must surely come, perhaps coupled with the right to charge industry for the groundwater which it uses.

CONCLUSION

The problem of the "wastage" of water in the Netherlands has been studied over a period of many years, and a certain measure of success has been achieved. However, with regard to "undue consumption" of water, we are on the threshold of a new era. Much deliberation will be needed and many obstacles will need to be overcome, not least of which will be the difficulty of persuading the general public of the urgency and extent of the problems. This will mean a changing rôle for the water engineer.

DISCUSSION

Author's Introduction

Ir. W. C. Wijntjes, in introducing his paper, said that the Symposium enabled the differences in practice in England and the rest of Europe to be discussed.

Fig. 1, p. 30, showed the clear difference in per capita consumption between metered and unmetered water undertakers in the Netherlands. In Holland there were still a number of companies who had not adopted metering, but during the last decade many had changed to total metering.

Metering undoubtedly reduced consumption. This did not mean, however, that consequently we should change over to metering completely! A number of other factors were involved. If, for instance, a company had a large number of industrial consumers, a saving of about 33 per cent in household consumption as a result of metering might only amount to a saving of 10 per cent in total consumption.

Another difficulty associated with total metering was the method of supply adopted in parts of the Netherlands. In some blocks of flats all the kitchens were supplied from one vertical riser pipe; another pipe supplied all the toilets, and so on. The introduction of individual metering in such circumstances presented formidable problems.

As mentioned in the paper, extensive research had already been undertaken in the Netherlands into the causes of leakages, and it had been concluded that corrosion of the (metal) service pipes was the most important contributory factor. Fractures in older lead service pipes were also important. Research was urgently required into plastic pipes and further investigation was needed into the related factors of leakage, i.e. ground and air temperatures, rainfall, electrostatic conditions, and frost. It had already been established from an inquiry conducted at The Hague waterworks that there was a connexion between the number of leaks detected and the time of the year.

Verbal Discussion

Mr. F. J. Machon (Water Research Centre), in opening the discussion, said that the paper described the situation regarding wastage control in the Netherlands as it was, and as the author expected it to be. The paper also constituted a useful statement of the case for controlling waste by inspection primarily, rather than primarily by measurement using waste meters. It was useful to have the papers by Mr. Wijntjes and Mr. Giles following each other, since they took opposing views.

At the joint KIWA/WRC Conference on Drinking Water Distribution Techniques, held in the Netherlands in June, it became apparent that there were differences of opinion as to which principle of waste control should be used. He himself had the impression that the water engineers from the UK favoured waste meters and that those from other countries used routine inspection.

Water engineers were used to finding differences of practice in different countries. The explanation could often be seen to lay in differences of circumstances or of history, and the author gave an example which perhaps touched on both of these, when he explained that mains leakage appeared on the ground surface because in Holland the water table was high. But it seemed that this effect would depend upon the rate of leakage, as well as the nature of the ground cover, and the hydraulic conductivity of the soil, and that significant leakage at less than the critical rate might still occur unnoticed, as leakage did in the UK. This would be easily determined by experiment, but perhaps that had already been done. Possibly the explanation lay rather in his reference to the shortness of time during which the control of wastage had become important in Holland. Might it be that a procedure which tolerated a certain level of mains leakage was appropriate a few years ago, but perhaps was due for reconsideration now?

This paper clearly made the point that the time that leaks were allowed to run must be minimized. It was equally clear that the productivity of the leak repair effort would be greatest if it was directed to the largest of the leaks which existed at any time. These two characteristics should be looked for in any waste control system, and it seemed that the procedure described by Mr. Wijntjes did not have these characteristics, whilst that described by Mr. Giles did.

The data presented on p. 30 were particularly helpful, but again revealed significant differences between us. Mr. Wijntjes said "If, after the introduction of metering there is subsequent increase in charges there is, however, no corresponding fall in consumption". Phillips (1972)* demonstrated that the water demand at Malvern had been sensitive to price. His data were used by Smith (1974)** who derived from it a realistic figure for the Price Elasticity of Demand—the economist's unit for measuring the sensitivity.

Again, there were no doubt good reasons for these apparent differences. Economics was notorious as a science which suffered from incomplete data, but it was now necessary to know what these reasons might be.

Finally, he referred to a point made by Mr. Wijntjes with which all would probably agree, that "when consumers are confronted for the first time with a water price, there is a surprising fall in consumption". He asked if, when consumers realised that they were buying water by the gallon, they become more demanding, as customers in general were? Were they more keen to get their money's worth in terms of quality, pressure, and freedom from interruptions to supply?

Mr. J. S. Shinner (East Surrey Water Company) said that the author attributed the low consumption per capita in Holland to the influence of KIWA and to metering. He himself suggested a third and possibly a fourth factor, district pressures and population density. His own undertaking supplied a fairly hilly area; inevitably some zones were supplied at high pressures and leakage was greater than in a relatively flat country. Probably the population density might also be relatively low with consequent greater difficulties of inspection.

The paper mentioned investigations into the occurrence of leaks, and showed a comparison of the numbers of leaks occurring in different pipe materials. He had used the I.W.E. leakage enquiry form to do some similar work on three occasions, taking a sample of some 300–350 leaks for each analysis. The results obtained over a period of about seven years helped in the assessment of waste inspection problems, the behaviour of different pipe materials in different situations, and other factors. Furthermore, the data could be sorted to show the effect of combinations of factors, e.g. lead pipe and old age or iron pipes in a clay soil.

It was stated that most leaks occurred in service pipes. In his own case whilst this might be true numerically, it had been shown by a controlled experiment in a residential area of about 550 houses that the quantity of water leaking from the mains greatly exceeded the leakage from consumers' services and water lost on the premises. A single experiment in one part of one undertaking could not be taken as conclusive but was a useful indicator for that particular undertaking.

Mention was made in the paper of inspection of consumer's installations. Consumers could be encouraged to report leaks on the premises by having a free repair service available to them. His own undertaking rewashered about 20 000 taps and ball valves each year,

* Reference is given on p. 21.

** Smith, R. J. 1974 *Journ. I.W.E.*, vol. 28, No. 1, p. 47.

involving some 10 000 man-hours of work, and it was felt that this was a worth while operation.

Regarding economy, the author compared the cost of waste suppression with the cost of supplying water. Regardless of the type or size of a water undertaking, the effort expended on waste work would vary over a long period. When surplus source water was available the effort tended to be diminished, but when the construction of new works to meet demands became imminent, the effort would be intensified.

All agreed that there was some wasteful use in industry, and the author suggested some possible remedies. He himself wondered whether at some time in the future water might be supplied on a rising price tariff, i.e. the higher the consumption the higher the unit rate. Would the author comment?

The peak loading on the system due to garden watering was of general concern. He liked the advice offered by KIWA regarding intermittent high intensity use of water for gardens. Did the author feel that this could be further developed into a rota system, thus reducing the peak impact on the system?

Mr. R. B. Tabor (Thames Water Authority) said that the author had referred to the dramatic and lasting effect of consumption in Holland after the introduction of the water meter in 1900. He wondered what other influences might have been at work, as Fig. 2 showed a sharp reduction in consumption prior to 1900.

It was interesting to note also the steep rise in consumption from 1945 onwards. In London there had been a rise in consumption over the same period, but at a lower rate. It was true that the consumption per head in the London area was rather more than that shown for The Hague, but during the period 1945 to 1973 whereas The Hague consumption increased by 100 per cent, the MWB consumption had increased by less than 30 per cent. Bearing in mind that in London trade supplies were metered, he asked for the author's observations.

Was the author able to advance any theory regarding the high number of leakages in service pipes, which he stated began during the summer months in the Netherlands, particularly in lead pipes (p. 34)? Did he consider that there might be some ground movement brought about by differential temperatures between ground and air and the possible effect of the high water table?

He agreed that waste of quality was wrong (both morally and economically), but in a congested area like London the provision of dual supplies via clean and "dirty" water mains was impracticable and regarded as a contamination hazard. It was more important to see that the industrial user circulated water supplied to him for non-potable purposes as much as possible. Furthermore, it was important to ensure that the materials used in contact with potable water were such as to be not only non-toxic but proof against creating unpleasant tastes which could be a cause of water being run to waste by the consumer.

Mr. D. A. Gill (Water Research Centre) said that some of the differences between the average water usage in unmetered and metered areas as shown in Fig. 1 could be ascribed to different methods of assessing usage in the two types of area. Could the author give some details of the accounting methods?

Was any information available as to the types of failure within the five different pipe materials used for service pipes in the Netherlands?

Mr. B. A. O. Hewett (Southern Water Authority) asked the author to elaborate further on the operation of the Pollution of Surface Water Act in the Netherlands, particularly with regard to pricing policy. The charges for the supply of water and the right to discharge had apparently been very effective in forcing industry to use water more efficiently. This policy would reduce the rate of capital expenditure on new water reclamation works as well as additional water resources.

Regarding Fig. 1, had the author any information on changes in domestic usage which could account for at least part of the dramatic difference of 40 to 50 per cent in demand between metered and unmetered supplies? Such information, obtained perhaps by social workers rather than engineers, might be useful in the publicity campaigns used periodically in the UK to try to reduce domestic consumption. Did the figures mean that all Dutchmen were clean, but some were cleaner than others?

AUTHOR'S REPLY TO DISCUSSION

Ir. W. C. Wijntjes, in reply to Mr. Machon's contribution, wrote that in the Netherlands it was not the usual practice to look for leakages in mains. Because the ground-water level in the country was generally high leaks in mains were usually discovered almost immediately. Less importance was attached to leak detection as such, but it was perhaps significant that the unmetered undertakers usually had some form of leak detection service, but that the metered companies did not.

His own opinions concerning the correlation between metering and water consumption were based on his experiences gained in Holland. These were endorsed by the evidence given in Fig. 1. of the paper. However, it was difficult to say in answer to Mr. Machon's final question whether a Dutch consumer became more demanding when his supplies were metered, and to make comparisons with his English counterpart. Much depended on how water-conscious the Englishman was.

Mr. Shinner supposed that higher pressures led to higher consumptions. His own findings did not lead to clear conclusions. Some undertakers found no difference, whereas others believed that as much as 10 per cent more water was used with higher pressures. However, he would make two observations. Firstly, a consumer became accustomed to a regular pressure and operated the taps accordingly. Of course, pressure variations made no difference when a bath or bucket was being filled.

Secondly, pressure was closely related to the running-time of leaks. Greater pressure obviously meant greater losses of water, but it also probably meant that the leakage was discovered sooner.

Concerning the possibility of water being supplied on a rising price tariff, this had been raised more than once in Holland. However, it did not necessarily follow that because a factory consumed large quantities of water it was being wasteful with that water. It did not seem right therefore to penalize such a user.

The rota system of garden sprinkling had been tried in the Netherlands, with moderate success.

In reply to Mr. Tabor, the increase in consumption after 1945 was general throughout Holland. This was probably due to higher industrial demands and to increases in water use by consumers in baths, showers, etc.

He could not explain why more leakages were discovered in the summer than during the winter months.

Concerning Mr. Gill's reference to Fig. 1 of the paper, the data used in the illustration originated from a national committee set up to predict likely future water demands. The information was collected by questionaire from the undertakers.

Mr. Hewett also asked for further information about the significant differences between metered and unmetered consumptions. These had never been examined scientifically. He himself felt that the principal difference in the case of unmetered supplies could be attributed to leakages; if these did not cause nuisance, they were seldom repaired.

Concerning Mr. Hewett's final comment, he thought that rather than being a question of clean or cleaner, it was probably a case of the difference between lazy and quick.

4. WASTE CONTROL IN THE WATER INDUSTRY: AN ECONOMIC APPROACH

By Judith A. Rees, BSC(ECON), MPHIL*

CONTENTS

INTRODUCTION

Traditionally, Public Water requirements have been met through the construction of increasingly large supply capacity, irrespective of the costs and benefits involved. The only criterion for deciding whether new investment is required being that future peak needs exceed present potential supply. Costs are introduced into the investment analysis only when choosing between alternative schemes or strategies (Water Resources Board 1974)**. Few, if any, attempts have been made to relate the costs of the chosen project to the benefits derived from extra supply. It is always assumed that the value of additional water must exceed the construction costs; such an attitude being typified by the statement that "Water is cheap at any price" (Warford 1966).

Capacity development has usually taken place well ahead of needs, since managers have valued security highly, being extremely averse to the risk of supply shortfall. Such behaviour is understandable since the penalties for failing to provide enough water can be great, whereas the costs of overcapacity are so widely spread as to go largely unnoticed. This traditional "supply" or "requirements fix" approach is by no means confined to Britain; similar situations have been reported in Canada (Grima 1972), United States (Hanke and Davis 1972) and even in Israel (Kantor 1971). There appears to have been widespread neglect of methods designed to improve the efficient use of existing supplies, and still less has there been consideration of the possibilities of managing demands for water as an alternative to supply extension. Such neglect is still very much in evidence, although there has been increased official interest in promoting greater efficiency in the operation of supply networks. This trend is shown in the recent reorganization of the industry and in the Water Resources Boards' national development plan, as both emphasize the integration and transferability of supply. Similarly, the increasing financial costs and political problems involved in new construction schemes have made engineers much more aware of the savings from controlling leakages from distribution systems (Giles 1973). However, welcome though these changes are, it is argued that they go only a small way to ensure the optimal provision and utilization of water supply facilities.

The key to such optimization is the control of all forms of physical and economic wastage of resources occurring in the industry. To the economist the term resource wastage

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** An alphabetical list of references is given on p. 54.

has a more embracing meaning than that normally employed in water provision. In addition to the traditional view of waste as losses of potential supply through pipeline leakage, evaporation, or the contamination of sources, there are four other meanings of the word. Firstly, it can be used when an unduly high quality of water is taken for any purpose. Secondly, it can be applied to denote excessive use, where water is used until its value to the consumer is less than the cost of providing it. Closely related to this is the third meaning of waste, when the productive resources of land, labour and capital are prematurely employed to provide supply facilities. Finally, it can refer to the situation where existing supplies of water are not allocated to their most productive uses. In this paper each of these types of wastage will be discussed and their management implications considered.

WASTE IN DISTRIBUTION

The most important losses from a supply network will occur through pipeline leakage, although in summer evaporation from water surfaces is also significant. In this section discussion will concentrate on leakage control, but the same type of analysis can also be applied to the decision as to whether it is economically feasible to reduce evaporation from reservoirs by using mono-molecular layers (Frenkiel 1965).

Some water undertakers have recently increased expenditure on waste prevention, but leakages remain generally high. At a minimum they account for 21 per cent of unmetered supplies, a figure derived from official returns made to the Department of the Environment (Herrington 1972), but as few authorities care to admit leakages greater than those accepted as "good engineering practice" (Twort 1963), the returns are known to be biased downwards. Authoritative sources claim that losses of 30 per cent of total supply are common, especially where marked relative relief necessitates the maintenance of high pressures. Given such wastage levels a more systematic and economically rational approach must be taken to the question of what level of expenditure on detection is appropriate in any time period. 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.

A hypothetical, smoothed, marginal cost curve for leakage control is illustrated in Fig. 1. Although the exact shape of this curve will vary spatially and is likely to comprise of irregular cost steps, in general it will have an exponential form. When a detection service is first implemented the cost of saving each unit of waste will be relatively low (unit "*a*" costing only *o–x* pence). However, as leakage levels decline so the costs of saving further units will escalate (unit "*b*" costing *o–y* pence). Given this type of

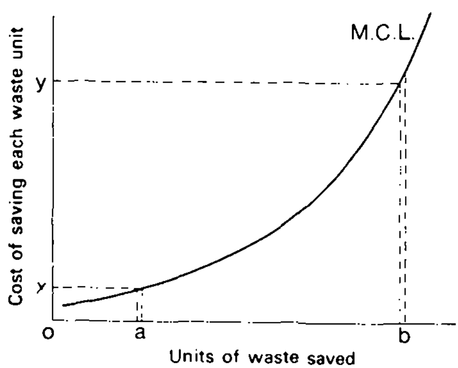

Fig. 1. A marginal cost curve for leakage control

marginal cost curve, it is virtually certain that some leakage will be economically desirable, there being no justification for using still more labour and capital resources to eliminate leaks when the resource costs exceed the resulting benefits.

The value of the water saved will depend on whether a supply network is operating below its reliable capacity, or whether new facilities are needed. In the first case the savings will be confined to the *variable* costs of supply, comprising in the main of pumping and treatment expenses. All fixed costs, including interest on borrowed capital, must be ignored as they remain the same irrespective of the quantity of water used. These marginal variable costs will normally be lower than present average costs, and will not increase markedly as output is expanded, until the reliable yield of existing capacity is neared. However, in the second case, the savings from leak detection will be much greater as the costs of constructing new capacity must be considered. It is clearly not worth investing in new facilities if an effective supply increase (or an apparent decline in demand) can be achieved at less cost by increasing the waste control effort. Invariably long-run marginal supply costs are higher than present average costs, although they will vary considerably over the country. At a minimum they will be approximately 25p per 1000 gal (4550 l), but in some areas, in particular Essex, Northamptonshire, and Oxfordshire, they may well rise to between 40–60p (Batchelor 1970). Even these figures are deflated since they omit any social or environmental losses resulting from reservoir construction.

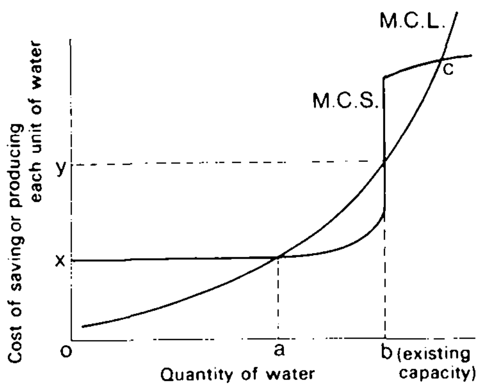

Fig. 2. The optimal level of waste detection in the short and long runs

o – b : **Existing water capacity**
M.C.L. : **Marginal cost of saving units of water by leakage control**
M.C.S. : **Marginal cost of providing extra units of supply**

As Fig. 2 shows the savings to result from waste detection remain low until the limits to present capacity (*o–b*) are neared. While capacity is not fully utilized the leakage detection and repair effort should continue only until *o–a* units of water have been saved. If savings are less than this the authority could lower its total costs by continuing expenditure on detection, since M.C.S. is above M.C.L., but it becomes uneconomic to save any of the units *a–b*. In this short-run situation, when only variable supply costs are saved, a relatively low level of waste detection activity will be optimal. However, this is not so in the longer term. Once the extra supply costs, including investment expenditure, exceed *o–y*, it becomes rational once again to increase the waste control effort, only at point *c*, does further expenditure on leak detection become unjustified. Very few authorities are yet pursuing their control activities to this long-run optimal level, thus leaving considerable scope for improvements.

Any major decrease in leakage levels has the important economic advantage of postponing the need for investment in new capacity. In Fig. 3, the apparent reduction in water demands allows investment to be deferred between t^1 and t^2, and releases resources of land, labour and capital for use in other more productive ways. These advantages are long-lived since the demand trend is permanently lowered, therefore at any future point in time a lower level of supply capacity is required. Any savings from postponing investment are particularly vital in our present economic circumstances, with the shortage and high cost of capital. Some engineers have claimed that more expenditure on leakage control would have little economic return as capital works will only be deferred for 2–3 years (Randall and Barrett 1972), but this takes a very conservative view of the possible savings. Moreover, it is not an argument for curtailing the waste detection effort since this must be related to the marginal value of the water saved, and not the capital saved by the postponement of investment.

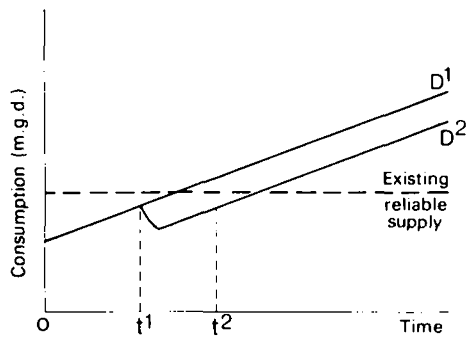

Fig. 3. Shifts in the demand trend line through leakage control

D^1 = **Growth in consumption assuming a low level of waste detection**
D^2 = **Growth in consumption with waste control occurring until the marginal cost of detection equals the long-run marginal cost of supply**
t^1 = **Time at which detection effort is intensified**
$t^1 - t^2$ = **Period over which new investment can be deferred**

WASTE BY USING AN INAPPROPRIATE WATER QUALITY

Limited supplies of potable water are being squandered on uses such as industrial processing or toilet flushing which could be adequately served from lower quality sources. There are, basically, two methods available for decreasing this form of wastage. Firstly, separate piped systems of potable and non-potable supplies could be provided, and secondly, water reuse could be encouraged within factories and households. Neither of these ideas are new but what is now required is a systematic investigation of the costs and benefits involved in their implementation.

While piped non-potable supplies are provided for a few large industrial consumers, potential health dangers and high distribution costs have generally militated against widespread dual supply provision. However, recent evidence has suggested that the extra distribution costs may not be great and therefore that significant economic gains could arise from substituting non-potable for potable water in some uses (Maney and Hamann 1965; Water Resources Board 1972). Okun (1972) reports that provision of a dual water system in new urban developments increases the distribution costs by only 20 per cent, and in areas of high population densities the cost increment would be even lower if reclaimed sewerage was used as the non-potable supply. Clearly, any economic analysis on the benefits of dual systems over conventional supplies will be similar to that employed in the previous section. Once again the extra supply costs must be compared with the savings to result from a lowering of demand for potable water, and these savings will be most significant when present supply capacity is being used fully. It must be stressed that any cost comparisons between the two systems must be made on the basis of the *extra* or marginal costs of developing capacity and not on average accounting costs.

Water reuse within factories and homes also offers considerable scope for reducing the wasteful use of high quality supplies. Such techniques are already employed by industrialists in areas where water costs outweigh recycling expenses (Rees 1969); but in Britain similar opportunities have been neglected in the domestic demand sector, where for example bath water could be stored for toilet flushing or car washing. In fact the policy of charging domestic consumers on rateable value gives no incentive to install reuse equipment, since charges are not related to the level of consumption. Unless potable water is priced per unit it will inevitably be used for all household purposes which must involve wastage if a lower quality would have been adequate, and if the costs of reuse are below those of providing the extra high quality supplies.

WASTE AS EXCESSIVE WATER USE

Before considering this and subsequent forms of waste a distinction must be drawn between the terms "demands" and "requirements", which to the economist have distinct and specific meanings. Demand refers to the quantity of a good which a consumer is prepared to take at a particular price, for virtually every good this quantity rises as price falls. Consumers indicate the value of a good by the price which they are willing to pay for it. In the case of water, when only a little is provided consumers will be prepared to pay highly for it and will reserve it for such high value uses as drinking and basic hygiene ("*x*" position, Fig. 4). As more becomes available it will be used for progressively less valued uses until with very plentiful supplies consumers may allow it to run to waste and will be prepared to pay nothing for further supplies (position "y"). Therefore, the price charged for water will be an important variable in determining demand. On the other hand, "requirements" carry the implication that a certain quantity will be used irrespective of the price charged.

Waste in the economic sense of excess usage occurs when the costs of providing water exceeds its value to the user. This arises whenever the price consumers pay for their

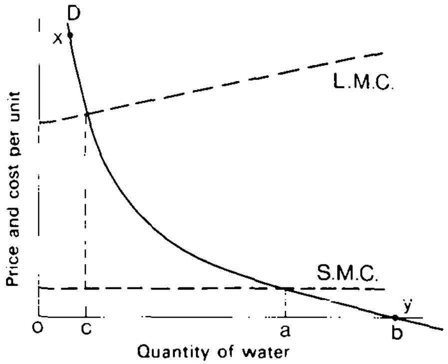

Fig. 4. Excessive water use levels

D = **Demand curve for water**
L.M.C. = **Long-run marginal cost of supplying water, including a capital cost element**
S.M.C. = **Short-run marginal cost of supplying water, including only the variable costs**

marginal unit of consumption lies below the costs incurred in supplying that unit. A number of areas in water provision can be identified where the pricing system encourages such wastage, the most notable being municipal supply for domestic and commercial users. These consumers pay for a service rather than a commodity. The unit charge for water is in reality zero, since their annual flat rate payment remains the same irrespective of the quantity used. Under these conditions water is used until its marginal value is also zero. There is no incentive to avoid waste by such simple expedients as replacing worn washers or turning off taps during operations like rinsing clothes; still less is there any encouragement to economize by purchasing water-saving equipment such as showers or dual-flush toilets. The crucial point is that consumers are allowed to neglect the facts that water is not a free good, and can only be provided at a cost.

Excessive usage becomes particularly important when new supply capacity must be developed to meet demands at zero prices (Fig. 4). When existing capacity is under-utilized no reason exists to restrict consumption below "*a*", since consumers are prepared to pay all the variable costs (S.M.C.) involved. But any supply of *a–b* units is economically unjustified and wasteful since they cost the authority more than they are valued by the consumer.

In the long-run, however, water supply costs become much higher than the variable pumping and treatment expenses, as the expenditure on new capital investment must be included (L.M.C.). Long-run marginal costs will normally increase as the quantity supplied increases, as the most economic sources are usually tapped first. Therefore, when new facilities are developed to meet demands at a zero unit price, the level of wastage increases to *c–b* units. In fact, the individual user has no means of controlling his wasteful use as new capacity provision does not increase his unit charge but raises his flat rate payment; refusal to pay the increase deprives him of all water not just the low value units.

Economists argue that the only satisfactory way to remove excessive, wasteful water use is to institute an efficient pricing policy. For this to be possible householders must be metered and charged on a quantity taken basis. This subject will be returned to later as this measure can also decrease other forms of wastage.

Excessively high and wasteful water usage may also be occurring for the removal of effluent and sewerage. Numerous writers (Kneese and Bower 1968) have pointed out that dischargers must be made to consider the full social costs imposed by their disposal in order to ensure that streams are used optimally for the removal of water-borne residuals. If disposals are not priced,there is a grave danger that too much effluent will be produced in relation to the damage caused to downstream users. Only when dischargers are asked to pay the full social or "opportunity" costs will it be possible for them to make rational choices about the types of production processes or waste recycling equipment to install. In Britain manufacturers, farmers, and municipal sewerage authorities pay nothing when discharging waste directly into streams. Invariably, therefore, downstream users subsidize in some way the removal of effluents. Although every disposal is now subject to consent standards, this control is designed to reduce or prevent pollution *per se*, rather than attempting to achieve optimal water use. There is, of course, no guarantee that the standards set avoid the wasteful use of streams for effluent and sewerage removal.

WASTE AS PREMATURE INVESTMENT IN CAPACITY

This form of waste is closely related to that discussed previously, although the emphasis here is not on the wastage of water itself, but of the productive resources (land, labour, and capital) which are required to develop new supply capacity. Such resources will be expended prematurely and non-optimally if water supply extensions are provided before consumers are willing to pay the long-run marginal costs of supply. Wasteful capacity development has recently become a vital issue as storage construction costs are escalating, and pressure from amenity and agricultural groups is decreasing the political acceptability of new reservoir sites. Given this climate of opinion there appears little justification for expanding facilities when the costs involved exceed the value of the additional water to the consumers.

In order to minimize the premature development of capacity, the economist once again would advocate the use of the price mechanism, as it is seen as a means by which consumers indicate their preference for particular goods and services. Theoretically the optimal pricing system would be based on marginal costs. While existing supply facilities are underutilized the unit price for water should only reflect the variable costs involved in increasing water use (P_1 in Fig. 5), but as full capacity is approached the price must be raised markedly to P_2 in order to cover investment costs. When consumers are willing to pay these long-run supply costs (L.M.C.) capacity extension is justified, but until this time the price rise would have the effect of controlling demands within available supplies. If the price remained at P_1, then consumer demands in year 13 would be considerably inflated up to *o–y* units and supply extensions based on them would be premature and wasteful. Considerable financial gains could be generated by postponing investment in water facilities and using the released resources to produce goods more highly valued by the consumer.

Nowhere in the water industry is there even an approximation to these optimal pricing conditions, managers have rarely considered using the price mechanism as an aid to their investment decision-making. To the accountants, engineers, and administrators responsible for price setting, a price is seen solely as a means of generating enough revenue to balance the books; it neither enters into their estimation of future demands, nor into calculations on the appropriate level of future supplies. Of course, as economists will readily admit, marginal cost pricing is not appropriate in all situations, for example where

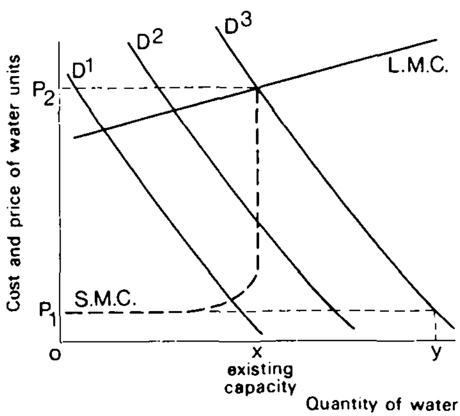

Fig. 5. **Pricing policy and capacity extension**

D^1, D^2, D^3 = Demand curves for water at different periods of time, say D^1 = in year 5, D^2 in year 9, D^3 in year 13. This movement outwards over time is typical as people become more affluent and are willing to take more quantities of the good at all price levels

S.M.C. = Short-run marginal cost curve or running cost curve. This will be low and will not increase until the limits of existing capacity are neared, when it will rise steeply becoming vertical at full capacity

L.M.C. = Costs of adding additional storage facilities true marginal costs are incalculable, or the costs of administering the system outweigh any advantages. However, there are cases where at least a movement towards a more economic policy could produce marked resource savings, the clearest of these being in municipal supply provision.

Any premature development of capacity for this demand sector is particularly crucial as it is envisaged that the bulk of new large-scale supply extension projects will continue to be designed to serve municipal needs. There are, however, two reasons for suspecting that such premature development of capacity is taking place. Firstly, as has already been seen, domestic consumers pay a zero unit price, and therefore demand excessively high quantities of water in relation to the supply costs involved. The flat rate payment system effectively ensures that unmetered households have to pay for any new schemes however small are the marginal gains in utility. Secondly, although industrialists are metered and charged a positive unit price, this is usually set below the long-run marginal cost of supply (Fig. 5). Industrial charges are relatively low because they are calculated on the basis of running costs plus the historic accounting costs of developed capacity. However, past costs are invariably less than those incurred in building new facilities, since long-standing equipment has been depreciated in the accounts and interest charges on borrowed capital were considerably lower than those ruling today. As capacity is always extended to meet demands at zero or deflated prices there is a strong probability that scarce resources are being wastefully diverted into municipal water provision.

WASTE BY THE MISALLOCATION OF WATER BETWEEN USERS

Wastage in this sense does not involve any easily identifiable physical losses, but arises if available supplies of a resource are not used to best advantage; in other words it involves a loss of potential benefits. Water would be distributed non-optimally between competing uses, *if it were possible to reallocate any units and increase their productivity in use.*

Yet again the economist advocates use of the price mechanism to ensure that water is used to maximum productivity and waste is restricted. To achieve an optimal distribution of water between consumers two pricing conditions must be fulfilled. First, each group of consumers must pay the full marginal costs of their supply, the rationale for which has been discussed earlier. Second, within each user category in a given district the price must be set equal for all consumers. The reasoning behind this second rule is illustrated in Fig. 6, which shows the demand curves for two consumers that can be supplied at the same marginal cost.

If it is assumed that consumer A is unmetered, paying a zero unit price, he will continue to demand water until it has no value to him and *o–z* units are taken. In contrast, B is charged 20p per 4550 l and therefore demands a correspondingly smaller quantity of water. Transferring some water (*y–z*) from A to B and adjusting the prices charged accordingly, will cause A to suffer only a small loss in benefit from being unable to use the water (shown by the dotted screen area). On the other hand B will gain considerably from receiving the same number of water units, as is again shown by the screened area, since he values them much more highly. This transfer process will continue to increase the total benefit derived from a fixed quantity of water until both consumers pay the same price P. When this situation is reached any further reallocation would cause A's loss to be greater than B's gain (shown by the fact that hachured area *abcd* is greater than *efgh*).

By instituting both these pricing rules every consumer would use water until its value to them equalled the cost of supply, and it would be impossible to increase the total benefits derived from a fixed quantity of water by reallocating it between consumers.

In the real world, however, there are many situations in which the costs of implementing an optimal pricing system would outweigh any benefits; no economist would recommend its introduction in such circumstances. For example, the recommendation that every consumer category pays the marginal supply costs particular to it may involve prohibitively high administrative expenses, if carried to extremes, as such costs will vary slightly between many tiny groups. Nevertheless, price differentiation between major user categories may well be viable, and undoubtedly there are cases where important net benefits could result from using the price mechanism to allocate supplies.

One such case is in the distribution of privately abstracted water, where it is possible to identify two major non-optimal features in the present allocation policy. The first of these arises because the abstraction charges are merely an expedient to obtain the revenue required for an exogenously assessed water resources budget; the licences themselves rather than any charges are regarded as the mechanism for allocating available resources. These licences are issued on a "first come, first served basis" and this becomes crucial whenever abstraction rights reach the reliable yield of supply sources, as for example has already occurred in the Colne Valley and parts of Essex. Under such scarcity conditions an absolute prohibition on the issue of new licenses is operated while established licence-holders are completely protected. Reallocation of the unused portion of any entitlement rarely, if ever, occurs despite the fact that this commonly exceeds 30 per cent of the licenced quantity. Still less has the possibility been considered of depriving a licence-holder of water which he actually uses if a more productive use exists elsewhere.

The second non-optimal aspect of present policy occurs because supplies of abstraction water are normally only expanded for municipal purposes, although the extension costs are recouped from all abstractors. Therefore some element of cross-subsidization between consumer groups must occur. For example, the construction of Empingham reservoir is expected to produce a tenfold increase in the standard licence charge levied on *all* abstractors, whereas the benefits are largely confined to municipal supply users in five urban centres (Rees 1971).

Another water demand sector in which the benefits from redistributing supplies between consumers could exceed the administrative costs, is that of municipal supply. As householders pay a zero unit price while industrialists are charged a positive value, the likelihood exists that water is misallocated between the two groups in the way shown in Fig. 6. In fact the level of misallocation may be compounded as the costs of supplying industrialists in bulk are usually lower than those of serving many scattered households. Theoretically, the redistribution of marginal water units from domestic to industrial users must increase the total benefits derived from their use.

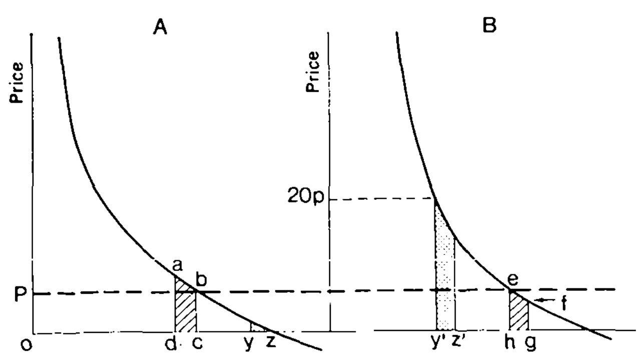

Fig. 6. Pricing for benefit maximization

DOMESTIC WATER METERING AND WASTAGE REDUCTION

The greatest difficulty involved in decreasing any of the economic forms of wastage is that the introduction of optimal pricing conditions necessitates the metering of domestic consumers. In Britain to-day, the most pertinent argument for the continued rejection of this measure is that householders are only slightly responsive to price changes, in which case the costs of metering would exceed the benefits. However, recent work has indicated that there may be situations in which demand responsiveness *is* high enough to make metering an economic proposition (Batchelor 1973; Rees, 1973).

Empirical research in Malvern U.D.C. (Rees 1971) suggests that in 1969 metered households, paying 20p per 1000 gal, demanded approximately 24 per cent less water than did non-metered consumers elsewhere, and further small demand reductions occurred as price increased. Some indication of metering viability in Britain may be obtained from the Malvern data, although clear dangers exist in such an extrapolation exercise. Metering benefits were found to vary considerably over the country in response to differences in domestic consumption levels, degrees of demand responsiveness to price changes, capacity costs and metering costs. Therefore greater net benefits are likely to result from a gradual and selective metering programme rather than universal implementation.

As it is considerably cheaper to install meters into new properties, the measure will probably first become viable for areas of new urban development, in particular new towns. In fact it appears highly likely on the basis of the Malvern data that the benefits from introducing unit pricing for *new* properties will outweigh the costs in any part of the country where the marginal supply costs exceed 40p per 4550 l. Even in lower supply cost areas this measure may be economic where household consumption levels are high, as for example in South West England. The greater cost of metering *existing* property will delay the onset of viability until the marginal capacity costs rise to between 50 and 60p per 4550 l. Although the calculations on which these conclusions are based are crude, the Malvern results do suggest that metering should be considered seriously, and that further work on consumer response to pricing be undertaken as a matter of some urgency.

CONCLUSION

Where water is cheap and other resources are scarce water can be liberally applied for all uses, and waste detection or usage control measures can be held at minimal levels. However, there are few parts of this country where such profligate use is justifiable, and it therefore is essential that attempts to control wasteful uses of water are adopted, where appropriate, as an alternative to automatic supply extension. All types of waste reduction must be considered, and the combined effects could greatly reduce the apparent demand for the resource. Water is not a free good, and need not be abundantly supplied for all purposes, it should be in short supply for all wasteful and uneconomic uses.

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DISCUSSION

AUTHOR'S INTRODUCTION

Mrs. Judith Rees, in introducing the paper, said that Mr. Wijntjes had already very correctly pointed out that when discussing waste in the water industry we were not really talking about waste of water, but about waste of money. In fact, we were essentially concerned with the suboptimal use of productive resources (land, labour, and capital) and with the loss of potential benefits from water use; both of which could be translated, albeit with difficulty, into money terms. All of the types of waste discussed in the paper fell into one of these two basic categories.

When wastage was viewed in this broad fashion no single or easy answer to the question of how to reduce it would be found. Nor was it likely that analysis and solution of the wastage problems would be satisfactorily accomplished using the expertise available within any *one* discipline. There appeared to be at least five types of solution—technological, administrative, legal, attitudinal, and economic—which could all contribute to the reduction of productive losses within the water industry. However, taken alone each of these would yield only a very partial answer to the total waste problem.

Technical solutions were clearly of critical importance in reducing the distribution losses made by supply authorities. Not only could technological innovations reduce the quantity of waste generated, through such measures as the development of more resistant piping materials or pressure-reduction techniques, but once leaks had occurred improvements in flow monitoring and detection equipment would be important in reducing the level of actual loss. Similarly, one factor influencing the possiblity of lowering the wastage which occurred through the use of potable water for purposes not requiring this high quality would be the development of improved low-cost recycling facilities or dual supply systems. However, even in reducing these two forms of wastage the technologist could not provide all the answers, there being a large step between the physical availability of waste control techniques and their acceptance and installation.

Administrative changes might also be valuable in facilitating the reduction of certain types of loss. For example, the establishment of the RWAs should allow the greater integration of supply networks and the transfer of supplies over large areas, so reducing the premature expenditure of productive resources on supply facilities which were operating well below capacity. To keep this form of wastage to a minimum it would, however, also be necessary, as the Water Resources Board had pointed out in its National Plan (1974), to ensure that the administrative and financial difficulties involved in inter-RWA transfers were speedily resolved.

Mr. Tabor had pointed out that legislation had long been used in attempts to minimize distribution losses, and undue consumption or misuse of water on the consumers' premises. In addition, the licencing system established for abstraction water and for sewage and effluent disposal went some way to reduce waste in the sense of excess usage. Although, as it was stated in the paper, the licencing system had not yet been used to its full potential to reduce the loss in productivity through the misallocation of water between users.

Changing public attitudes, particularly through the recognition of the true costs of water provision, could also play an important role in wastage reduction, but attitude changes amongst water engineers themselves would also be crucial. Although the fact that the Institution had chosen this topic for a Symposium was a heartening sign, it was disturbing to encounter the view here that an engineer placed in the waste detection section of an authority felt he had failed, and that waste reduction was still the "Cinderella" part of the industry. From the tenor of the discussion it seemed clear that some change in attitude towards waste was still necessary and that Mr. Barrett might have been somewhat over-optimistic when he wrote that "substantial savings . . . are already being made in large measure" and that "the amount of waste in this country is far from unreasonable".

However, if improvements were made in all these areas a waste problem would still remain, in the sense that resources might still not be utilized in an economically efficient manner. A further prerequisite for the introduction of an optimal waste control programme was the use of some economic measure to indicate first, when different types of resource wastage were occurring, and second, when waste control was costing more than the benefits it brought.

The economist would advocate the use of two very basic tools to aid the decision-maker on both these issues. These were the analysis of cost in marginal or incremental terms, and the use of the price mechanism as an allocative device. The two were closely related since supply costs calculated by marginal analysis were ideally the basis for price setting, if the price mechanism was to produce an optimal allocation of resources between users.

When discussing improving the control of waste we were clearly concerned with the future, with assessing the viability of introducing measures in order to postpone or even permanently stop the development of different new sources of supply. As we were interested in comparing costs and benefits all of which would occur in the future, analysis in historic or past accounting cost terms must be irrelevant to this issue. Although calculations based on costs not yet incurred would inevitably be made under conditions of uncertainty, this was surely preferable to the situation where the use of historic costs could result in higher-than-optimal wastage levels. This could arise as past accounting costs per unit of water output were invariably lower than the marginal cost of developing new storage facilities. Not only was capacity frequently constructed at lower unit costs in the past, as the most physically suitable locations or the sites nearest the demand centres were developed first, but also interest rates were much lower and long-standing capacity had been much depreciated or even written-off in the books of account.

The use of such deflated costs had two unfortunate results; firstly, the advantages to be derived from leakage control or the development of dual quality supply systems was underestimated; secondly, when these costs were used as the basis for water prices waste, in the senses of excess water usage and the premature expansion of capacity, was increased. Marginal cost measures not only gave the decision-maker a better idea of the optimal level of his leakage detection effort, but also helped him see when the other cases of wastage might be present.

Undoubtedly, incremental costs were much more difficult to calculate than those derived by the traditional method of cost calculation. In particular, difficulties arose due to uncertainty about future factor prices and technological innovations, and due to the fact that capacity was usually developed in large discrete lumps, well spaced over time. However, despite these difficulties it seemed essential that efforts were made to improve marginal cost estimates for the water industry in order to provide at least some rough forward-looking cost data, which must be preferable to precise, but irrelevant, historical information.

The use of the price mechanism could also produce clear improvements to the wastage situation. In fact, it was a crucial element in controlling three types of waste, namely, excessive usage, premature capacity expansion, and the suboptimal allocation of water between users. Clearly, the chief concern of engineers or managers responsible for price setting would be to raise sufficient revenue to maintain operations, but to regard price solely in this light was to miss the following three functions attributed to it by economists:

TABLE I. A Cross-sectional Study of all U.S. Municipal Water Use, 1954 (consumption in U.K. ghd)*

Settlement Population size	Proportion of production metered 0–50%	50–95%	95–99%	over 99%
5000–9999	152	103	102	99
10 000–24 999	157	107	100	106
25 000–49 999	174	109	102	107
50 000–100 000	162	114	102	100
over 100 000	142	129	124	114
All Municipalities	145	122	117	109

* Taken from Porges, R. 1957 *Water and Sewage Works*, "Factors influencing per capita consumption".

TABLE II. Consumption in 12 Major Dutch Towns*

Town	% residences metered	Domestic consumption plus leakage per capita, in U.K. ghd
Haalem	100	54
Leiden	100	54
Delft	100	53
Enschede	100	51
Den Haag	95	51
Hengelo	88	60
Nijmegen	83	61
Arnhem	61	62
Rotterdam	12½	73
Amsterdam	0	77
Groningen	0	93
Zwolle	0	96

* Taken from Warford, J. J. 1967 Unpublished PhD thesis, "The economics of water supply".

(1) to allocate water between consumers in the best possible way; (2) to aid the investment decision-making of managers; and (3) to influence the behaviour of individual consumers to keep water demands and supply in balance.

It must be stressed that price could not perform any of these functions unless supplies were metered and consumers were asked to pay for what they actually used. This would necessitate quite profound changes in the method of payment, not only for water but also for sewage and effluent disposal. No one would advocate making such changes unless the resultant benefits exceeded the costs involved. But, any rejection of the use of the price mechanism should be on the basis of factual knowledge about the results of its use, rather than on the basis of assertion, belief or even habit.

On the controversial subject of domestic metering considerable evidence had been gathered in other countries, for example, Holland and the United States, most of which pointed to the view that consumers did respond markedly to the pricing situation. [At this point the author showed slides of two sets of figures, which are reproduced as Tables I and II.]

More British studies were badly needed to supplement the evidence available from Malvern, and from the pioneering metering experiment conducted by Jenking (1973)*. A valuable first step would be to gather data on actual household consumption in areas other than Malvern, to allow comparison between households in priced and non-priced situations. At present any such comparison was extremely problematic, since domestic usage had to be assessed from the total supplies to the system, less metered consumption, and clearly a crucial source of error could be the allowance made in the estimates for distribution losses. The 24 per cent figure given in the paper for the difference between consumption in Malvern and elsewhere, was very dependent on the 30 per cent of unmetered usage allowed for pipeline leakage. If leakage rates were in fact higher than this the viability of domestic metering would be reduced, but the necessity of introducing an increased leakage detection effort would be greatly increased. Accurate data gathering could be seen as a clear prerequisite for reducing all forms of wastage in water use, and it was to be hoped that the Symposium would stimulate developments in this direction.

Verbal Discussion

Mr. D. E. Burgess (East Worcestershire Waterworks Company), in opening the discussion, referred to the words of the late Lord Keynes, "economics is a method rather than a doctrine, an apparatus of the mind, a technique of thinking which helps its possessor to draw correct conclusions".

In this short paper the author had helped us to take a major step forward towards this goal. It was regrettable that water engineers did not have this "apparatus of the mind" when they were starting to invest in waste detection and control.

Referring to the section of the paper on Waste In Distribution (p. 46), he agreed with the theoretical economic answer that expenditure should not occur until the cost of saving a further unit of water equalled the additional cost of supplying an extra unit.

However, there were reasons why in some parts of the industry we could not put this into practice, because of difficulties in getting manpower in competition with the other industries. Manpower was a limited resource and some tasks such as laying mains to new houses were more important than saving waste, so the point at which expenditure was stopped was somewhere below the equalization point; nevertheless, one should be aware of the full economic picture on which to make the decisions.

Referring to Fig. 2, the optimal level of waste detection in the short and long runs, in the longer term it was implied in the paper that one should increase the waste control

* Jenking, R. C. 1973 Fylde Water Board, "Fylde metering, a research study".

effort after expenditure was carried out on new works. However, one would wish to prevent more waste prior to capital investment in order to defer that investment, i.e. further expenditure should occur before *b*, to delay *b* (in time). When the capital investment had been made on new works, then savings would be confined to *variable* costs of supply only. Once we had the new capacity at *b*, the *marginal* cost of water, MCS in Fig. 2, could be back at level *X*, or even lower, and not increase as shown in Fig. 2. New works were usually more efficient in terms of pumping and treatment costs (i.e. the variable costs) than the older works.

Finally, he suggested that the marginal cost of saving units of waste was not in reality a smooth upward curve in the long term. For each new housing estate or new town one should start at the origin. Fig. 2 could be confusing with short-term savings and long-term supply. He would have thought that long-term analyses involving capital expenditure should be considered separately from the marginal cost analysis.

Mr. R. A. Pepper (Sunderland and South Shields Water Company) commented on the author's suggestion that domestic metering would result in a reduction in consumption or extravagant use. The paper suggested that under the rating method of charging the effective unit price of water was zero and there was no incentive to save water. The logical extension of this argument was that consumers would not bother to turn off their taps at all, let alone replace worn washers. But the domestic consumer did normally adopt a "waste not want not" attitude: he accepted that water was a "valuable" commodity despite its low (? zero) price. Would any realistic metered unit charge lead to significant reduction? Even with domestic metering John Citizen would use the quantity of water to which he had been accustomed, pay his bill albeit with a grumble,—and demand a wage increase—rather than change his living standards.

Yet the paper by Mr. Wijntjes indicated that consumption was reduced, as did evidence from Malvern. What was the explanation? The water industry often took the domestic per capita consumption as about 35 ghd made up of (*a*) genuine consumption, (*b*) leakage in the domestic installation, and (*c*) leakage in the water undertaking's system. The installation of meters showed that the genuine consumption plus leakage in the domestic installation amounted to about 25 ghd (and this accorded with similar figures found by others who had made investigations in the distribution system without domestic metering). Could it be that metering demonstrated that a significant amount of leakage was from the water undertaking's own apparatus?

The application of tariffs so that water was directed to the "most productive use" was the most far-reaching and contentious aspect of the financial methods of minimizing the waste of the country's assets. What was the "most productive use" and in whose judgement was the assessment made? Could this not lead to an auction situation whereby John Citizen who didn't make beer, or paper, or steel (and therefore presumably had very little "productive use" for water) was simply outbid for the available supplies? Was it valid to reduce demand by pricing high to the point of changing our life style? This would indeed be a major shift in the presently accepted supply and charging philosophies.

Nevertheless, further investigation on the response by the consumer to a pricing mechanism would be interesting, as would more work on consumer psychology and response to public relations and education. The average consumer was not now concerned only with the price of water when the question of development of new resources was being discussed: and he still expected a service from the water undertaking. Other factors were involved which were rarely reduced to monetary terms.

In short, the user demanded what he thought he needed, apparently regardless of price. However when he was made aware of the value of water by such traditional methods as publicity, inspection, and consumer service, he avoided deliberately squandering it. The industry could foster this attitude further so as to persuade the consumer to *demand* only what he really *required.*

The water industry must use all possible means to minimize waste and must (being responsible for the consumer's money), in addition to using all available technical means understand and apply the parameters of economic cost effectiveness to which the author drew attention.

Mr. R. N. Tebbutt (Severn-Trent Water Authority) asked about the waste of resources in general rather than the waste of water in particular. A distribution system was designed to meet the peak demand imposed on it by the consumers. This could be two or in some cases three times the average demand so that larger diameter pipes and greater capacity pumps had to be used than those just to meet the average demand.

Until domestic consumers were metered it was unlikely that their consumption pattern could be influenced, but it might be possible to encourage metered consumers to reduce their peak demands by using a different method of charging. He had in mind something similar to the method used by electricity boards in charging their industrial consumers where the consumer had to state his peak load and was charged at one rate if that peak was not reached and at a higher rate if it was exceeded.

In short, could the pricing mechanism be used to reduce the peak demand on the distribution system?

Mr. E. F. Young (Department of the Environment) said that we had heard that domestic metering in the UK could cost over £500 million. This figure was misleading, being based on 14 million meters multiplied by £40 per meter—the £40 being part meter installation and part maintenance and reading. Even if it were feasible to meter 14 million services, the work would need to be carried out over 20 years and the present value of the total cost would be in the order of £200 million.

As to whether or not domestic metering would be justified on economic grounds would depend upon the initial metering effect (which might be only a 10 per cent reduction in water take) as well as the elasticity of demand. We needed to know much more about these factors. The DOE had a completely open mind on the subject of domestic metering. It was a matter for water authorities to consider, but to help them the DOE was hopeful of producing a computer model whereby water authorities might enter their own criteria for each management division (or area) and to establish, on paper, whether metering would be a paying proposition.

This model could be adapted to assess cost/benefit aspects of measures to control waste of water. The essential criteria would include quantity saved and capacity saved per unit of expenditure. The DGWE Working Group on Waste of Water would no doubt be considering in due course how feasible this method was. It pointed to the need not simply for leaks to be repaired but account to be taken of the rate of leakage saved so that in the course of time accumulated totals of water and capacity savings could be determined.

Mr. J. Reid (North West Water Authority) agreed with the inference that engineers in general were not sufficiently cost conscious.

When one considered the economic approach to waste control one must look further than was suggested in the paper, i.e. "if one has sufficient water available the waste involvement should be small".

The detection of leakage was necessary at all times, irrespective of the adequacy of the existing supplies, as, apart from the obvious advantage of saving water, one might be called upon to prove that one had not been negligent in pursuing waste which had resulted in court action being taken against the undertaking because of the collapse of a roadway, a footpath, flooding, etc.

He recalled one instance which involved a motor cyclist skidding on ice which formed on the roadway from a leaking main. The undertaking was able to substantiate to the satisfaction of the court that the mains system was regularly monitored for leakage and, being able to show that in this instance the waste meter for the area had been operated the day prior to the accident and no substantial leakage was present, enabled the outcome of the court action to be far more satisfactory to the undertaking than might have been if systematic waste detection had not been undertaken.

Mr. R. N. Balmer (Severn-Trent Water Authority) was unhappy about the comment made that the unit charge for water was zero. The consumer did link the use of water with its cost, as a result of press coverage of the cost of new projects and the payment of the water rate. The water had to him a "perceived" cost. In addition, we could say that the use of hot water was effectively metered due to the charges for heating which could be 8–10 times the cost of water.

We would get much further in discussions on the benefits or shortcomings of domestic metering if we recognized that water was not one, but several different commodities. For the sake of brevity these could be divided into two groups. Firstly, water was used for life support, personal and household hygiene. These were "internal" uses and any attempt to apply commercial criteria to them was likely to arouse much political and social resistance.

The second group were mainly "external" uses and might almost be considered as luxury items. They included car washing, irrigating the garden, and supplying swimming or paddling pools. These could be metered and perhaps should be made senstitive to the price mechanism.

WRITTEN DISCUSSION

Mr. J. A. Andu (Western Nigeria Water Corporation) wrote that one important conclusion drawn from the papers was that water engineers were getting worried about the wastage of water. This was a happy omen. The problem had been identified—it was how waste could be eliminated or reduced which now confronted water authorities.

He fully shared the view put forward by Mrs Rees that water engineers were partly responsible for the wastage to which fully treated water was put. We were worried when we felt that our production capacity was being fully utilized and then planned grandiose projects which would double the existing capacity.

The appetitite of man was insatiable—the more he had the more he wanted. He did not intend to give a catalogue of the abuses to which treated water was subjected. Mr. Barrett had already done this very humorously.

We were all aware that the use of water by the public should be controlled in order to minimize wasteful use, but were we afraid to exercise this control because we wanted to keep our jobs?

Although legislation could do much in the prevention of waste the most effective way of curtailing it was by adequate public education and enlightenment. The public had to be made aware of the capital and maintenance costs of their water undertakings. They should be told how much was lost through wasteful use and other forms of waste. Prevention of waste or leakage should also form an important part of all new schemes at the design stage.

In the Western State of Nigeria the enlistment of public co-operation had helped considerably to minimize waste. Even at their own expense consumers reported burst pipes.

At times of scarcity they had even made anonymous telephone calls to report neighbours for garden watering.

Mr. R. Y. Bromell (Severn-Trent Water Authority) wrote that the preface to the papers contained the premise that undue consumption (extravagant use) on consumers' premises could be restricted without detriment to anyone. However, it should be recognized that to reduce water consumption would lead naturally to an increase in the strength of sewage which might be more difficult to treat.

In England and Wales the new Regional Water Authorities were multi-functional and had a responsibility for both water supply and sewage disposal. Due consideration must be given to all the possible consequences of the economic sanctions proposed by the author.

Mr. H. J. Giles (National Water Council) wrote that the paper was particularly valuable, coming as it did at a time when increasing attention would be paid to defining the needs and requirements of the consumer in order that the best use could be made of the common purse available to provide a service to that consumer.

However, the author had simplified the situation regarding the Marginal Cost of Supply as a criterion for determining waste level effort. Whilst the MCS of this next source might be the criterion at the macro level, and indeed evidence existed that this should be increased by some figure for the marginal cost of sewage as much of the leakage into the ground found its way into sewers. Some consideration should be given to the criterion at the micro or individual district level.

At the district level, the marginal cost of distribution might be the criterion to determine the waste control effort. Excessive levels of waste could cause pressure reductions, failure of supply, and insufficiency of storage. In these instances, waste control effort might be considered against the distribution of the construction of service reservoirs, re-inforcing mains or booster stations, etc.

Mr. D. A. Gill (Water Research Centre) wrote that in his opening remarks, the Minister had said that "water in plentiful supply is a basic right". He questioned the use of the word "plentiful". In devising water charging schemes to minimize water wastage we tended to think in terms of the present domestic water meter with quarterly reading and billing on a volumetric basis. In many water authority areas however the need for expenditure was triggered by peak demands, for example the Friday evening summer garden watering load.

Alternative schemes could be devised for domestic properties. For example, all the domestic draw-offs could be taken from inhouse storage which was fed from the mains by a low rate constant flow device. The peaky domestic and garden watering demands would then be taken from the inhouse stored water and the authorities would only "see" a nearly constant demand. The householder could be charged according to the size of the flow device installed. Alternatively, a peak-flow-rate turbine-type of meter could be installed and the householder charged on a flat rate according to house size or number of people in the house on the electoral roll plus a charge for maximum rate over a chosen period. There could be other schemes.

What did the economics of water supply look like when you thought about alternatives to the quarterly volumetric system? In this country water wasted was not really lost to the system. What we did lose was the "quality" of treated water, energy for pumping, and installed pipeline capacity that was wastefully operated.

Mr. J. N. M. Hutton (Hydrotronic (Jersey) Ltd) wrote that when considering universal metering it must be remembered that whilst there might well be an initial reduction in consumption, this gain would soon be lost because the water bill would still be a relatively small one and the novelty of trying to minimize it would soon wear off. He knew this to be true because as a water engineer he took a keen interest in his water meter when he lived in an area where all supplies were metered. His efforts made very little difference and caused too much inconvenience to the rest of the family.

The present excellent waste control in the U.K. would undoubtedly deteriorate because the need to look out for leakage on the consumer's side of the meter would lose its importance. In fact, the economist would find it desirable for income to be maximized by having any spare capacity go through the consumer's meters. Consumers who had the misfortune to have a leak on their side of the meter would be faced with the most frightening bills which in the lower income families would be ruinous. He knew this to be so because he had had experience of such a happening. Fortunately, the bills were usually waived, but this was just as unfair as the present system.

He was not against metering, only universal metering.

Mr. F. J. Machon (Water Research Centre) wrote that it was encouraging to have the author's support for the principle which they had for long tried to promote from the Medmenham Laboratory—that economic analysis could give a working indication of the most profitable level of expenditure on the control of waste from a distribution system. There was evidence that in a number of cases the waste control system used might not be the most economical, or that the level of effort might be uneconomically low. A treatment of this aspect was included in the training course prepared for the Water Supply Industry Training Board in 1969, but he did not have the impression that that part of it had had any large effect upon the industry.

However, in addition to waste in distribution, the author went on to consider four other types of situation where resources might be used in ways which were not optimal from the economic point of view: (1) *unduly* high quality of water; (2) *excessive* use of water; (3) *premature* deployment of resources; and (4) failure to allocate supplies to their *most productive* uses.

The author classed all five types of economic inefficiency together as "waste".

He himself did not, of course, disagree with the economic principles of this analysis, but the author might be wrong to group waste in distribution with the other four.

The water quality we used, the quantity we used, the allocation between users, and the risks we accepted in providing for estimated future demands, were not economic decisions. Any evidence the economist could put up was no doubt welcome, and no doubt the author's points would be so strongly taken by some delegates that their future decisions would take them into account, but these were parts of the performance objectives of the water systems, and they were decided on political grounds, not economic.

This was not so for the control of wastage from distribution. Given that the service provided gave satisfaction, then there was a clear duty to provide it without any waste which added to the cost.

He hoped that no-one who perceived the present impracticability of applying economic principles to all the cases the author gave would be tempted to reject the argument for applying it to waste control for distribution.

Mr. B. Rydz (Severn-Trent Water Authority) wrote that he sympathized with the sentiments underlying the author's approach to charging and investment appraisal. We needed reminding from time to time that the purpose of levying charges was to manage demand and thus to allocate resources effectively. Balancing the books was not even a separate purpose: it was merely one aspect of this process. We needed to take money out of peoples pockets to adjust the demand for commodities as a whole and therefore we balanced the books instead of printing money. And in detail we must always be prepared to use the structure of charges to help us give customers as a whole the best buy for their money.

But, he feared that there was currently a danger of economists' overkill. For some years now economists had stood in the pulpit and lectured us about principles; and in return accountants and engineers had reminded them of their day-to-day problems. One or two phrases in the author's paper (for instance, the opening sentence and paragraph on p. 51 beginning "Nowhere in the water industry . . .") continued this shock treatment and thus emphasized the gulf to be bridged. But bridge building was under way in several places—for instance, in the committee meeting under Mr. Jukes' chairmanship —and he thought we should be concentrating on devising practical ways of reflecting commonsense economic principles in the process of compromise which led to a pricing policy.

The provisions for abstraction charging in the 1963 Act, for instance, were a brave step towards the creation of a market in water resources use. Not all river authorities interpreted them in this spirit, but he believed that the author's strictures on p. 53 were not entirely deserved. In some areas licence-holders did reduce their demands as charges rose; and some authorities embarked on major schemes to augment resources, of which the costs were to fall on water resources account, as the author herself noted. This established a new market at a higher price level and might well drive some users out. There was, indeed, a contradiction between the two complaints about non-optimal policy on p. 53; the increase in the licence charge on all abstractors was the means to the re-allocation of licence holdings for which the author asked. Whether the burden of Empingham costs would fall on the wrong shoulders must depend on the relative factors in the charging scheme. But he himself believed that in general the point made by the author was the reverse of the truth. Because new resource needs had been calculated by reference to public water supply deficiencies other users (that was to say, secondary users of resource increments, such as industrial abstractors in the lower reaches of rivers) had very often had a cheap ride at their expense.

If the author examined the ways in which water managers had considered their options she would find that marginal or incremental costs had more often than not played their proper role. Marginal cost charging was quite a different matter, however, and its problems had had much attention recently. They included the problem of assessing marginal costs, but no less the problem of defining marginal uses. Unless the water industry was free to run unbalanced accounts over long periods, or was instructed to run surpluses in order to pay taxation or finance its future needs, marginal cost charging could do no more than reallocate current costs between the customers. For this purpose one must both define and measure those fractions of use on which marginal charges should fall. Only industry was metered, and he had not yet heard an economist suggest a formula for allocating industrial charges on a rising incremental scale which was likely to be acceptable. The same point was made by Mr. Wijntjes in answering a question put to him.

AUTHOR'S REPLY TO DISCUSSION

Mrs. Judith Rees, replying to the discussion, wrote that Mr. Burgess was very right to remind us that economics was merely a method of thinking about problems. It should be stressed that it was only one such method, and that it could not claim to be able to provide all the answers. However, in the past water managers had concentrated on the approaches of the engineer and health inspector and had largely omitted from consideration the economic view of the issues. Undoubtedly, the traditional methods of thought were crucial in the sanitary revolution which transformed unsanitary and uncertain water supplies into the high quality and abundant service we now enjoyed. But in Britain, at least, this stage in the industry's development was over and it was time, to quote Gilbert White*, "that the

* White, G. F. 1966 Preface in National Academy of Sciences—National Research Council, Washington D.C., U.S.A., Committee on Water, "Alternatives in water management".

management of water resources had evolved to a stage where planning should center upon the needs of the people rather than of water per se". It was in the assessment of these needs that, as Mr. Giles had pointed out, the economic approach could be a useful one for the water manager to add to his set of analytical techniques.

In the context of a changing water industry, if the economist was guilty of "sermonizing", let us hope that by now he was preaching to the converted. She could not agree more with Mr. Rydz when he stressed the need to concentrate on practical methods of applying economic principles to the particular problems of water supply. No one supposed that the theoretically optimal costing or pricing procedures would be perfectly appropriate in the real world. Mr. Burgess and others had rightly shown that basic difficulties, such as manpower shortage, might limit their applicability in some circumstances, while in other cases their use might be limited by overriding decisions made on political or social grounds. What was important, however, was that some movement was made towards implementing a more economic approach in order to increase the productivity in use of all scarce resources employed in providing the water facilities.

Most of the specific questions raised in the contributions referred to two central issues—marginal cost analysis and metering.

Marginal Cost Analysis.—It was first necessary to correct the impression which Mr. Burgess had gained from the paper that she had advocated increasing the waste control effort after new capacity had been developed. This was certainly not the impression which was intended. It would clearly be illogical since the major advantage to be derived from an improved leakage detection service was to postpone the need for new investment in supply facilities. Therefore, it was essential that, as demands for water neared the limits of existing capacity, the detection effort was increased to the point that the M.C.L. equalled the long-run M.C.S.

Mr. Burgess also appeared to be confused by the nature of the marginal supply cost curve portrayed in Fig. 2, p. 47. Clearly, the curve would not return to level x once capacity had been developed as it now included the costs of the supply extension. It must be remembered that a long-run cost curve was merely the sum of many short-run curves, and it would have a stepped form, with cost steps occurring when new investments were made. While it was true that running costs might be reduced below x after new facilities were developed, this was not the same thing as saying that the long-run marginal cost curve would do likewise.

Mr. Giles had suggested that the marginal cost of distribution should be the criterion to determine the waste control effort. This was obviously a valid point, in fact in most economic analyses distribution costs would be included in the M.C.S. curves; pumping and other running costs being included in the short-run curve, and any change to the distribution network, service reservoirs, or booster stations being part of the log-run curve. In no way was it intended to imply that the long-run curve only included the costs of building extra storage facilities—it should include the costs of all extensions or changes to the system.

Water Metering.—A number of contributors had made contentions on the question of the effect of metering on the behaviour of the domestic water user. Mr. Pepper did not state the evidence to support his view that the "user demanded what he thought he needed, apparently regardless of price" and it was certainly not valid for Mr. Hutton to assert that in general consumers would only respond for a short time to the pricing situation on the basis of the behaviour of his own family. Extrapolation from one household was even more dubious than her own assertion (by extrapolation from consumers in Malvern) that longer-term response would occur. She reiterated that what was required was solid evidence on the matter. The work, mentioned by Mr. Young, at the D.O.E. was therefore particularly to be welcomed, as were the metering experiments proposed by a number of the RWAs. Very few people would advocate the immediate introduction of universal metering; it would be far too costly and in some cases wasteful. What was needed was some knowledge of the areas in, or conditions under, which metering would be most viable. For example, it was highly unlikely that it would ever be economically sensible to instal meters into very old slum property, in which the water-consuming potential was low and whose life was expected to be short.

Mr. Pepper suggested that the logical extension of the argument that the rating charging system gave no incentive to save water was that consumers would deliberately allow gross wastage to occur. Surely this was not the logical implication, rather, just as there would be no deliberate attempt to save water there would also be no deliberate effort to waste it. Likewise, in the section of the paper which considered waste by excessive water use, there was no suggestion that people were extravagent with or flagrantly misused water, merely that they demanded excessive quantities in relation to the costs of supply and the benefits derived from that supply.

There would appear to be little evidence to support Mr. Hutton's view that the "present excellent waste control in the U.K. would undoubtedly deteriorate", because the introduction of meters would decrease the authorities effort to detect leaks on the consumers' premises. On the contrary, the fact that consumers were paying for each unit of supply should surely mean that they reported all leaks or defective washers much more rapidly than under present conditions. Further, from the discussion at the Symposium it must be questioned whether in many areas the detection service could be termed "excellent". Although it was quite true that large leaks on the consumers property could result in huge water bills, this problem was by no means an insurmountable one; indeed, it had been solved in all now metered areas. If the consumer promptly reported the loss, or if it was undetectable until abnormally high usage figures were found, the bill was usually simply reduced to the household's average consumption in previous time periods.

The question of peak demands was raised by a number of contributors. Metering could certainly be used to help reduce the peak problem, but to be most effective the meter would need to be much more sophisticated than those commonly used; meters capable of recording peak flows were technically feasible but were likely to be uneconomic. However, ordinary meters combined with an incremental charging scheme might go some way to solving the problem. (Referring to incremental schemes, it was surprising to learn that Mr. Rydz had not heard such schemes advocated for industrial users, they were in fact commonly put forward for all goods for which the marginal supply costs were increasing.)

As Mr. Gill had pointed out, metering might not be the most effective or cheapest way to manage demands, particularly those occurring at the peak, and he suggested a number of alternative measures. Certainly, there was nothing sacrosanct about metering, although it did allow the introduction of an optimal pricing policy. What was perhaps so valuable in this type of debate was that attention was drawn to the whole question of managing, or controlling demands, rather than just accepting increases as exogenous and inevitable. More work was clearly needed to test the effectiveness of measures, such as those proposed by Mr. Gill, and to compare these in cost-benefit terms both with present practice and with metering.

Finally, she agreed entirely with the remarks made by Mr. Bromell, about the possible effects of a reduction in consumption on the strength of sewage. Some work to calculate the costs involved in such a strengthening had been completed in the United States, but as was so correctly pointed out, due consideration must be given to all the consequences of metering in any analyses to be undertaken in Britain.

5. WASTE PREVENTION LEGISLATION: ITS ADEQUACY AND ENFORCEMENT

By R. B. TABOR, MICE (*Member*)*

CONTENTS

EARLY HISTORY OF LEGISLATION

METHODS OF WASTE CONTROL vary according to the opinions of water engineers. No doubt this will be evident from other papers and discussion at this Symposium, but nevertheless such methods are limited by practical considerations.

Legislation for waste control, however, certainly prior to the Water Act 1945 varied from one undertaking to another according to their own private Acts. It is to be hoped therefore that it will be appreciated if this paper tends to dwell more on the Metropolitan Water Board's (M.W.B.) area than elsewhere as it is therein that the author's interest in waste control in one form or another has been over a number of years.

The Romans were noted for their plumbing but it is doubtful if they were deeply concerned with waste prevention. It would be interesting to know the earliest date when the conservation of water was considered to warrant the attention of the law, but it is apparent that from the beginning of the 19th Century there were various direct and indirect references in private acts.

Section 58 of the Kent Waterworks Act 1809 states that:

> "To prevent as much as possible the wilful and negligent Waste of Water, be it therefore enacted that each and every Person supplied with Water by the said Company of Proprietors shall, and he, she, and they is and are hereby required to provide a proper Cistern or Cisterns of Lead, Brick or Wood or other Materials, to receive and hold such Quantity of Water as shall be by him or them deemed sufficient for his, her or their Consumption and he, she, or they is and are hereby required to provide a Ball and Stopcock and to affix or cause to be affixed the same to the Pipe conducting the Water from the Main Pipe belonging to the said Company of Proprietors to such Cistern or Cisterns for the Purpose of preventing the Water running into such Cistern or Cisterns from running to waste when the same shall be full:"

This Clause went on to specify that in the event of non-compliance by the persons supplied "It shall and may be lawful for the Company . . . to cut and turn off the Water . . . until such Cistern or Cisterns and Ball or Stopcock shall be provided and such Ball or Stopcock added in Manner aforesaid".

This power was transferred to the Metropolitan Water Board, which was formed under the Metropolis Water Act 1902. In 1916 a legal opinion was obtained regarding the meaning of "proper cistern" and it was stated that "no cistern can be proper which is not *inter-alia* of adequate size".

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Important factors which emerge from this part of the 1809 Act are that:—

(1) The provision of adequate storage is a means of preventing waste and from this one assumes that the introduction of constant low pressure on the house fittings is the reason.

(2) An automatic water level control is necessary to prevent overflow waste.

(3) Contrary to current thinking the adequacy of storage capacity was regarded as a matter for the consumer to decide.

In effect this meant that although storage would provide a reserve in the event of mains failure, the extent of insurance rested with the consumer and the chief function of the cistern seemed to be to introduce a break-pressure device to reduce waste. There is a present-day school of thought that apart from helping the consumer directly, provision of large quantities of storage in premises minimizes mains flow fluctuation and thereby reduces one of the factors which contribute to failures in water mains.

Other powers to require provision of storage cisterns were transferred to the Metropolitan Water Board from the private Acts of 1852 relevant to the New River Company, West Middlesex Waterworks Company, Grand Junction Waterworks Company, Southwark and Vauxhall Water Company, Chelsea Waterworks Company and also from the 1853 Act relative to the East London Waterworks Company. The relevant clauses in these Acts did not specify the reason as did the Kent Act, but did require the provision of "An efficient ballcock or other like apparatus"—so, clearly there was the intention of waste prevention.

A major step in the rationalization in requirements for waste prevention in the Metropolitan area was made with the passing of the Metropolis Water Act 1871. Section 17 of that Act required that every water company thereby affected should make regulations "For the purpose for which regulations may be made under the authority of Section 26 of the Metropolis Water Act of 1852 and that the provision of that Section shall apply also to the preventing of undue consumption or contamination of water".

The significance of this clause is that the Metropolis Water Act 1852 (Section 26) gave permissive powers for regulations to be made subject to Board of Trade approval for the prevention of waste and misuse and also to prescribe the size, nature and materials of cocks, pipes and cisterns, whereas the 1871 Act made it mandatory that such powers should be implemented and extended to include prevention of *undue consumption and contamination.* Nevertheless, it must not be overlooked that at the same time powers were retained from the Waterworks Clauses Act 1863 which, in effect, stated that any water company's special Acts should include powers for the withdrawal of supply for failure by a consumer to prevent "Waste, misuse, undue consumption or contamination of water" and it is under this original authority and the 1871 Act that supplies can be withdrawn from premises within the Metropolitan Water Board part of the Thames Water Authority.

The regulations which came into being under the Metropolis Water Act 1871 consisted of 33 clauses and 19 of these were in whole or part directly or indirectly concerned with the prevention of waste in its widest sense. Furthermore, it is fair to say that these regulations were the foundation on which not only were formulated the Metropolitan Water Board byelaws but the original model byelaws published in 1900.

There are certain clauses which are worth bearing in mind in the light of modern thinking:—

Clause 2 is a brief specification for lead pipes.
Clause 3 permits only lead pipe to be laid in contact with the ground.
Clause 8 specifies jointing methods.
Clause 10 provides for protection against frost.
Clause 12 requires the provision of an inside stop valve.
Clause 13 requires cisterns to be water-tight and provided with a ball-valve.
Clauses 14 and 15 deal with the provision and siting of warning pipes.

Clause 18 requires that draw-off taps shall be only of the screw-down kind and shall be sound and suitable.
Clause 19 specifies that taps on stand-pipes shall be of the "waste preventer" type.
Clause 21 introduced the "water waste preventer" with a flush limited to a maximum of 2 gal.
Clause 22 applied similar requirements to urinals but with a limit of one gallon flush.
Clauses 25 and 26 referred to the requirements for baths and apart from prevention of contamination called for the provision of water-tight plugs and that overflows were to act as warning pipes.
Clause 31 laid down a penalty not exceeding £5 for every offence against the regulations.

Other clauses similar to present-day byelaws were for the combined prevention of waste and contamination, e.g. no pipe to be laid through sewers or ash pits, etc.

These "1871 Regulations" were applied to the various London water companies and subsequently the Metropolitan Water Board right through to the operation of the M.W.B. byelaws in 1935 which were made under the authority of the Metropolitan Water Board Act 1932.

EVOLUTION OF LEGISLATION—1932 ONWARDS

The byelaws referred to above were patterned on the model byelaws which had been reissued about 1928 but, as stated earlier, with the 1871 Regulations very much forming the "backbone". However, there was one particularly important addition—the Metropolitan Water Board Act 1932 gave powers to that Board to test fittings and consequently controlled the quality and thereby the risk of waste from any water-using apparatus supplied with water by the Board. In those years between 1935 when the Metropolitan Water Board first commenced testings and the outbreak of the Second World War in September 1939, every tap, stopcock and flushing cistern installed in the Board's area was first submitted to one or other of two testing houses set up at and nearby the Authority's headquarters in Clerkenwell. The number of fittings examined was about two million per annum. Inevitably, with the implementation of the testing powers the immediate rush of submissions built up into what may well have been described as a "brass mountain".

The War put an end to all this but afterwards testing on a more limited scale was reinstated in what remained of the testing station following bomb damage and with what staff were available. This has continued to the present day with the exception of examination of most prototype apparatus which now is usually referred to the "B.W.A." part of the National Water Council. This change in Metropolitan Water Board policy took place within the last 12 months after the setting up of a Technical Advisory group responsible to the B.W.A. Approvals Board.

The current "bulk" testing is carried out mainly on fittings for use on fire supplies which are required by agreement to be stamped "M.W.B.", and also on all fittings to be taken into stock for use by the Metropolitan Water Division. In addition, architects, consultants and builders often specify that water fittings shall bear the M.W.B. mark. In spite of the arrangements with the National Water Council it it still deemed advisable to examine certain types of fittings, e.g. surgeons taps, which are known to be more prone to waste than others but which are required for special duties where it would be considered unreasonable to object to their installation.

It may be thought that with the gradual introduction of quality control by British Standard specification there is less need for the testing of fittings by water authorities or, for that matter, by the National Water Council but there are some factors to be considered:

(*a*) The byelaws require certain apparatus to comply with relevant British Standards but do not require them to be "kite" marked. Where no kite mark is applied a fitting may or may not be to British Standard and the water authority inspector may be unable to judge its suitability.

(*b*) Some fittings are not as yet covered by British Standards.

(*c*) Current byelaws state that "any requirement in these byelaws that a water fitting shall comply with a British Standard shall . . . be construed as requiring compliance with that Standard only in so far as the Standard relates to the size, nature, materials, strength and workmanship of that fitting; and . . . be deemed to be satisfied notwithstanding that the fitting does not comply with that Standard in so far as it relates to those matters, if the fitting is not less efficient and suitable in relation to the purpose for which these byelaws are made than a fitting which does comply with that Standard in so far as it relates to those matters". Part 2 of the relevant byelaw goes on to state that where requirements of a British Standard relating to the size, nature, strength, etc., conflict with a specific requirement of the byelaws then the requirement of the byelaws shall prevail.

Although the 1932 Act gave powers to the Metropolitan Water Board to make byelaws for the prevention of waste, misuse, undue consumption and contamination of water, it was 13 years later that similar powers were given to any water authority under Section 17 of the Water Act 1945.

It is useful to note here also that Part XIII of the 3rd Schedule of the 1945 Act contains the following provisions which are relevant to the control of waste:—

Section 61—Power to test water fittings.
Section 62—Power to enter premises to detect waste or misue of water.
Section 63—Power to repair supply pipes.
Section 64—Power to impose penalty for waste of water, etc., by non-repair of defective fittings.
Section 65—The imposition of penalty for misue of water.
Section 66—The imposition of penalty for fraudulent use of water.
Section 70—Meters to be fixed to measure water or detect waste.

Section 60 of the 3rd Schedule of the 1945 Act contains power to require provision of storage cisterns but only in premises not entitled to a constant supply and in houses to which water is required to be delivered at a height greater than 35 ft below the draw-off level of the service reservoir. The precise meaning of the latter is a little obscure, but in any event it is evident that the 1945 Act did not recognize the need for storage as a means of waste prevention but only as a limited safeguard to the consumer in the event of unreliability of supply. It will be seen that this is the exact opposite to what were considered to be the needs for storage in the mid-19th Century.

This situation is perpetuated by the Water Act 1973 which, under Section 66 of the 8th Schedule, applies Part XIII of the 3rd Schedule of the 1945 Act (with the exception of Section 61 relevant to testing of fittings) to all water authorities. The testing of fittings is provided for in the 1973 Act under Section 4 (5) (*d*) which lays the following duty up on the National Water Council ". . . with a view to the establishemnt throughout the United Kingdom of a scheme for the testing and approval of water fittings for ascertaining whether they comply with regulations and byelaws for preventing the waste, misuse or contamination of water to consult with statutory Water Companies in England and Wales, Regional Water Boards and Water Development Boards in Scotland, the Ministry of Development in Northern Ireland, the Greater London Council and such associations of manufacturers, professional associations, Local Authority associations, trade unions and other organizations as the Council think appropriate."

Clause 4 (6) states "If the Council establish any such scheme as is mentioned in Subsection (5) (*d*) above they shall secure that the scheme is administered by a Committee of the Council which includes among its members persons representing the interests of Regional Water Boards and Water Development Boards in Scotland and of the Ministry of Development in Northern Ireland".

It will be evident from this that although the onus on the National Water Council is first to consult, it then has to decide if testing is necessary. At the time of going to press certain initiating moves have been taken towards consultation. In the meantime the National Water Council have asked that the British Waterworks Association testing procedure shall continue as an interim measure and this is in fact operating under the guidance of what is now called the National Water Council Approvals Board with the assistance of the National Water Council's Advisory Group whose members have been asked to continue as previously.

If, as is evident from the 1973 Act, the water authorities are to lose powers for testing for themselves, it is to be hoped that the National Water Council will decide in favour of not only continuing but expanding the testing function in conjunction with water authorities and manufacturers' associations.

This brings the story up to date regarding national policy on waste legislation, but it has been recognized by the Department of the Environment that some water undertakers might have difficulty immediately after 1st April 1974 in meeting some of the requirements of the 1973 Act, particularly with regard to Parts VII and IX transferred from the 3rd Schedule of the 1945 Act in respect of statutory heights of supply. However, the old Metropolitan Water Board had additional problems in so far that under the various Acts referred to earlier they had powers to require storage cisterns and to withdraw supply as a penalty for non-compliance with the regulations. After discussions with the Department of the Environment a ministerial order was made under Section 254 of the Local Government Act of 1972 (as applied and amended by the 1973 Water Act) to exempt the "M.W.B" area of the Thames Water Authority from Parts VII and IX of the 3rd Schedule of the 1945 Act and also to permit the previous Local law to continue with regard to storage and penalities.

The power to test fittings is retained temporarily at least during the life of the current Metropolitan Water Board byelaws.

THE VARIOUS FACETS OF "WASTE"

The definition of "waste" can vary according to circumstances, and may be a matter of opinion. Legislative documents over the years have recognized the various facets of "waste" as waste, misuse and undue consumption. More recently the byelaws have included references to "reverberation" and "erroneous measurement". It is assumed that these terms must be related to the likely loss of water as it is generally understood that at present the water byelaws do not have any environmental connotations outside the general scope of waste and contamination.

It is suggested therefore that the following definitions should be considered in reference to the various aspects in current legislation:—

(i) *Waste.*—is that water which issues from any mains or water fittings as a result of any defect, maladjustment or poor design of such main or water fitting.

(ii) *Undue Consumption.*—is water which by design is lost in excess of the amount necessary for the efficient operation of a water-using apparatus.

(iii) *Misuse.*—is water used for a purpose which does not legitimately need the use of water and could be satisfied by the use of some other medium; or a purpose which is permissible only by licence but for which no such licence has been obtained (this would include use of garden hoses after restrictions have been applied in drought conditions).

All the foregoing constitute loss of water which is avoidable and for the purpose of this Symposium could come under the general heading of "Waste".

The byelaws fall into various categories:—

Those which clearly prohibit waste.
Those which are concerned with both waste and contamination.
Those which may be interpreted as prohibiting waste.

When it is appreciated that every fitting under ground which is subject to failure is thereby automatically subject to contamination and a fitting above ground which fails by corrosion may also cause contamination it is not surprising that there are not many byelaws which come within the Group 1 category. These are considered to be as follows:

Byelaw 10—Protection against frost.
Byelaw 14—Provision of support.
Byelaw 15(*b*)—Depth of pipe underground.
Byelaws 24 & 25—Provision of stopvalves.
Byelaw 26—Provision of drain cocks.
Byelaw 27—Provision of self-closing taps.
Byelaw 36—Storage cisterns to be watertight.
Byelaw 39—Provision of ball valve.
Byelaw 40—Provision of warning pipe.
Byelaw 42—Restriction of length of deadleg hot water pipes.
Byelaw 52—Provision of bath plugs and restriction on washing troughs.
Byelaws 57 and 58—Restriction of quantity of flush and design of flushing cisterns.

Of the foreging byelaws only Nos. 14, 26, and 42 do not have their ancestry in the 1871 Regulations and there are other byelaws which exist for the prevention of both waste and contamination which also derive from the same Regulations.

PROBLEMS OF ENFORCEMENT

It is not proposed to deal here with these dual-purpose byelaws but to refer to some of the 3rd category which are either unclear in their relationship to waste and/or have proved to difficult to administer in practice.

Byelaw 12—requires fittings to be "readily accessible" for operation or repair. The interpretation of readily accessible will depend on whether one is representing the water undertaker or is alternatively an architect concerned with the aesthetics of the environment; a hospital governor worried about dirt collecting behind pipes or an ordinary "Mum" determined to ensure that young Johnny cannot get into the cupboard on the landing and drown in the prefrabricated plumbing unit. This serves to show some of the quite cogent arguments that a water engineer has to face. The important thing to remember is that if waste occurs it can be seen either by overflow or at an outlet from a duct and that shutting off the supply does not first entail tearing down the wallpaper or searching for a 15 in screwdriver to get at the appropriate stopcock. It is appreciated than the actual repair may involve spoiling decorations, but it should not bring about a weakening of the structural fabric of the building.

Byelaw 19—has caused some misunderstanding in that it permits medium weight tube for a distributing pipe but requires heavy tubes for pump deliveries from storage unless part of a closed fire fighting system. There is apparently intended to be some correlation between pressure resistance and corrosion, but this does not bear much investigation when it is realized that the distributing pipe from a high level storage cistern can be under a head little short of that in the booster pipe supplying it. It is not easy to convince plumbing designers of the justification of such discrepancies and in specific cases it might be difficult to press in a court of law within the general terms of the function of the byelaws.

Byelaw 24—which has been referred to already in the 1st category is now quite different from its predecessors in that its scope has been widened and presents particular difficulty of enforcement in cases of conversion of houses into separately rated flats where a common access point is not available. Furthermore, because of byelaw No. 4, it is retrospective.

Byelaws 29 *and* 30—which refer to draw-off taps and stop valves have proved to be not so much ambiguous as inadequate and, with the introduction of plastics stop valves and draw-off taps, somewhat out of date. The inadequacy of byelaw 29 is shown by the fact that its only requirement is that every draw-off tap which is not of the ordinary screw-down pattern shall be of corrosion-resisting material (up to 2 in size) and capable of withstanding a pressure of 300 lb/sq in. A similar alternative is applied in byelaw 30 in relation to stop valves to which neither BS 1010 nor 1218 apply.

Although a draw-off tap may not be of the ordinary screw-down design nevertheless it will have to rely upon some form of operating mechanism and this will need to be capable of withstanding the same rigours in service as the old-fashioned kitchen bib.

A gate valve is not of the ordinary screw-down pattern and yet there is no specification in the byelaws for spindle diameter, body thickness, and seating contact area in relation to such valves. Although in practice BS 1952 is often used by water engineers as a reference in this respect, it is not entirely logical insofar that all but the highest classes of this Standard only call for spindle diameter, metal thickness and test pressure below those of BS 1010. This is particularly significant insofar that experience and tests have shown that under certain conditions gate valves can require considerable forces to be applied to ensure watertightness. It is for this reason that the Metropolitan Water Board only permitted gate valves on outlets from storage cisterns where generally the head loss through a screw-down valve might be of some importance. Even this is a problem which could be overcome by the use of modern angle-type screw-down stop valves.

Byelaw 44—is one which when introduced was clearly intended to prevent the waste which would ensue after the failure of a washer and/or copper float operating in hot water. It is possible nowadays for such fittings to be manufactured in stainless steel with highgrade heat-resistant washers. There are situations in hot water systems where the introduction of a hot water cistern controlled by a ball valve can be of distinct advantage in meeting the requirements of byelaw 53 which is essentially an anticontamination byelaw. Approaches have been made to the Department of the Environment with regard to this matter, and it is hoped that due note will be taken when the next set of model byelaws is being drafted.

Byelaw 59—requires a water user to give at least seven days notice to the water undertaker before:—

(1) Fitting or altering any fitting except as a repair or renewal.
(2) Backfilling over a pipe to carry water supplied by the undertaker.
(3) Using water from a domestic supply for certain listed non-domestic purposes.

This is a particularly important byelaw but difficult to enforce with a limited inspection staff. Further reference is made to this later.

In addition to the problems of enforcement which arise from failure to convince a consumer regarding the correct interpretation of a byelaw, there are some practical difficulties which result from incidents of waste as opposed to apparatus "likely to lead to waste".

It is imperative that before serving notice for waste that the water authority's inspector is absolutely certain that a leak is within the consumer's area of liability. Having established this, the kind of situations which arise are:—

(*a*) There is evidence of one or more small leaks (probably underground) which are difficult to locate. The consumer is not prepared to spend money on searching for the leak and asks the water authority for assistance in tracing its location. If this assistance is refused there is a danger that the authority is considered to be indifferent and its image is thereby damaged. If, on the other hand, the request is accepted there is a danger of a compensation claim being made for the cost of unnecessary excavation if the authority's inspector gives misleading information. These circumstances can be aggravated where there is expensive paving, plants or interior decorations involved.

(*b*) Where there is common supply to more than one premises there may be difficulty in getting the agreement of all parties to search for and repair the leak. There is often an added complication in such cases where there is difficulty of access to all the premises at the same time.

(*c*) There may be a dispute between an occupier and a landlord as to the liability for repair of leaking pipes particularly where the landlord is the water ratepayer but receives the equivalent of water rate as part of the tenant's rent. Such cases, and indeed other situations, can be worsened by the difficulty of communication between an absentee landlord and the occupant of the property where the waste is taking place.

(*d*) Problems have arisen due to the inertia of some large estate managers, and this includes public authorities who may have staff shortages or difficulties with contractors.

Cases have occurred where waste has been indicated by a green growth or stain on the wall or ground below a warning pipe. However, it is not always clear whether or not there has been a past defect now remedied or whether there is a current defect which is intermittent. Such a situation would call for a carefully worded letter to the consumer suggesting that if he has not recently carried out a repair there is evidence that there is a fitting on his property which is likely to lead to waste.

PENALTIES AND THEIR EFFECTIVENESS

Where there is clear evidence of waste the average water ratepayer on being confronted with a statutory notice will make a repair as soon as he can get a plumber, and no doubt there are many more repairs carried out by consumers which never reach the knowledge of the authority. However, the kind of situations referred to above make it imperative that the water authority has an effective legal means of enforcement.

Recourse to the courts and imposition of fines can be an expensive and lengthy procedure and when dealing with an obdurate consumer his knowledge that this is the limit of the authority's power considerably weakens the latter's position.

The Metropolitan Water Board throughout its life found the "ultimate deterrent" of the threat of a withdrawal of supply to be most effective. Such a power must be used with a sense of responsibility and no doubt the awareness of the need for extreme caution has restricted the number of "cut-off" orders issued. It has been realized however that paramount effect is derived from the threat rather than the action. Nevertheless, the carrying out of the cut-off procedure to finality, albeit on rare occasions, serves to prove to the would-be operators of brinkmanship that the authority's concern with waste prevention is no idle thought.

The old M.W.B. procedure in dealing with confirmed waste on premises was as follows:

(i) The inspector serves notice in person on the occupier to repair or renew a defective fitting. If the occupier is not the water ratepayer a copy of the notice is posted to the ratepayer. This notice allows a number of days, depending on the seriousness of the waste, before which the inspector will revisit expecting to find the work done.

(ii) If the work is not done the inspector's copy of the notice is sent to headquarters so that a suitable letter can be forwarded to the ratepayer.

(iii) This process is repeated as necessary and eventually, determined by an assessment of the seriousness of the situation, a further letter is sent to the ratepayer warning him that unless a repair is made without further delay consideration will be give to the possibility of withdrawing the supply.

(iv) If this proves ineffective a final letter is sent to the ratepayer with copies to the occupier (if different) and to the local medical officer of health stating a time and date, usually seven days hence, when the supply will be withdrawn if it is found at that time that waste has not been stopped.

It should be added that throughout this procedure care is taken to ascertain that there has been no change in the responsible ratepayer. Furthermore, the social conditions of the occupants are taken into consideration and if it is known from the outset that there is a young family or sickness in the house or that there are a number of premises on one supply which would be affected by the "cut-off", such a cut-off order would not be issued without either legal advice or the authority of the appropriate Committee of the Board. Under present reorganization, this would be referred to the divisional manager.

It will be seen therefore that every effort is made that the authority shall be seen to be considerate of all the social effects of the action of withdrawing a water supply. This is particularly important where the ratepayer is not on the premises. In these cases the M.W.B. have occasionally allowed occupiers to fill up buckets, etc., from a temporary standpipe at fixed times. Although this might be thought to weaken the authority's position, it relieves the hardship on an innocent occupant without removing the onus on the landlord ratepayer in the eyes of the local medical officer of health.

Statistics with regard to waste notices issued and cut-off procedures over a period of years are set out in the Appendix, p. 77.

POWERS TO REPAIR CONSUMERS' APPARATUS

Under Section 71 of the Metropolitan Water Board (Various Powers) Act 1907 authority was given to the Metropolitan Water Board to enter premises and execute repairs where a waste arising from a defective supply pipe had occurred and subsequently to recover the cost. It was also a condition of this authority that 24 hr notice must be given to the consumer. There are other somewhat similar powers included in the 1945 Water Act under Section 35 which authorizes the supply or repair of fittings on the request of the person to whom the water undertaker supplies water. This person may be either the occupier or an owner and charges may be recoverable as civil debts.

The Metropolitan Water Board very rarely invoked Section 71 of the Various Powers Act 1907. It is understood that the reason was that it was considered that in addition to anticipated difficulty in recovering costs there was a likelihood of compensation claims being received in respect of damage to consumer's property.

Nevertheless, for many years the Metropolitan Water Board operated a tap rewashering service free of charge but, again, because of the risk of compensation claims the service was restricted to draw-off taps and ball valves in storage cisterns which could be isolated readily. Ball valves in flushing cisterns were not included in the scheme, again because of the potential danger of damage to chinaware in the bathroom or toilet.

During 1971 enquiries were made of other water authorities in the United Kingdom as to whether or not they conducted any form of assistance to consumers and if so the extent and success of such schemes. Some 59 replies were received and although more than 50 per cent of these quoted a tap rewashering service in operation, and a somewhat less percentage carried out repairs after due notice had been given, very few operated any form of general plumbing on private premises. Notwithstanding the somewhat discouraging experience of other authorities the Metropolitan Water Board decided to go ahead with what was to be called a "plumbing assistance" service.

Accordingly, with the knowledge and agreement of the various plumbing trades organizations and unions a scheme was drawn up to provide a certain amount of help to consumers on whom notice had been served to carry out repairs to stop waste or make alterations to comply with byelaws and who could provide genuine evidence that they were having difficulty in obtaining the services of a private contractor.

This decision had been brought about by the growing knowledge that such cases appear to be on the increase and it was coincident that at this time due to a change in the Board's own work pattern a number of their own registered plumbers would be available to carry out the work. Nevertheless, it was deemed to be wise not to publicize the proposals, but to deal with cases on their merits as they arose and in order to obtain information with regard to costs the scheme was applied initially to minor repairs required in the Board's own dwellings allocated to certain grades of staff.

This service has been in operation and at the time of writing only a few cases of private consumers have been included. One of the difficulties which obtain is that crafts other than that of a plumber are often required and up until now it has been the intention to restrict the service to the plumbing skill only. However, it is hoped that in due time the provision of this form of assistance in hardship cases will improve the image of what is now an even larger monopoly undertaking than previously and encourage the waste consciousness of the general public. There have been one or two instances where it has been an advantage for the M.W.B. to assist the G.L.C. or one of the local boroughs where the local authority were having difficulty and as a result continued delays would have had adverse publicity in the media for all concerned.

In spite of all the difficulties it would seem that there is a case for the water undertaker being prepared to carry out work of this nature, particularly where the alternative is protracted correspondence and the cost of legal procedure in addition to the waste of water which may be continuing throughout. If such schemes are to be adopted however there is a need for the appropriate staff to carry out the work.

THE EFFECT OF STREET LEGISLATION

There are certain aspects of the Public Utilities Street Works Act 1950 which have a bearing on the control of waste, not the least of which is the general requirement that all undertakers shall give due notice to each other before carrying out street works. By this legislation a water authority can have the opportunity to ensure that during other undertakers' work their own apparatus is properly supported and does not suffer damage. A further benefit is obtained by the water authority which may carry out repairs as an emergency without prior notice and which therefore enables the necessary steps to be taken to search for and stop waste occurring under the public highway without undue delay.

THE FUTURE

It is not this author's wish to go over ground which may be covered by others who will be discussing future measures to minimize waste of water. However, there are some points of view which it is hoped will be borne in mind by those responsible for the framing of future legislation either directly or indirectly related to waste control. The following are some suggestions:—

(1) Particular attention should be given to a revision of those byelaws referred to earlier which are described as being either ambiguous or inadequate.

(2) Regulations which may come into existence as a result of the "Health and Safety at Work, etc.", Bill now before Parliament should provide for clauses dealing with "fitness for purpose" in relation to water fittings. Whilst such clauses would be primarily intended to safeguard the consumer against the effects of buying poor quality articles, it would have the indirect result of preventing waste of water from fittings over which the current byelaws have insufficient powers.

(3) Due consideration is given to any new legislation for street works or codes of practice related thereto for improved methods of backfill and surface reinstatement. It should be explained here that in 1970 in conjunction with the City University a research programme was initiated by the M.W.B. into the causes of failure of cast iron mains. This research has been continuing since that time and several technical reports have been published. Although it would be wrong to pre-empt any final conclusions, indications are that one of the causes of fracture are ground forces aggravated by the effects of temperature and traffic loading. It is apparent that when all the information is available there is likely to be a need for a means of insulating underground pipes from these external forces.

(4) It is understood that in parts of Europe plumbing is allowed to be carried out only by qualified plumbers who have been licenced by the water authority. It is considered that there may be much to be said in favour of such an arrangement and it would seem likely that this would receive the support of the plumbing trade's associations. There may be special circumstances where contractors employ non-registered plumbers who are nevertheless skilled in certain aspects of plumbing related to modern techniques who could be licenced by the water authority subject to them having proved themselves knowledgeable and capable of carrying out work to meet the appropriate legislation. It can be seen possible also that in the event of a "do-it-yourself" enthusiast making his own alterations this would be acceptable subject to sufficiently frequent inspection of his work by a qualified representative of the water undertaker.

CONCLUSION

With the reorganization of the water industry it is envisaged that eventually legislation for waste prevention will be consistent throughout the United Kindgom but it is to be hoped that the equivalent of those laws which, over many years have been proven to be effective, will be retained.

It is reasonable to assume that one of the immediate benefits of the recent changes in the water industry will be the streamlining of communication and exchange of information and ideas. It is intended therefore to take advantage of this facility in order to make comparisons between the past legislative procedures in the various pre-April 1974 water undertakings, at least within the Thames Water Authority area.

Whilst it is too early to include such information in this paper it may be possible to make a general statement on this aspect at the Symposium.

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APPENDIX

RELATIONSHIP BETWEEN NOTICES ISSUED TO RATEPAYERS TO STOP WASTE AND THE NUMBER OF SUPPLIES WITHDRAWN FOR FAILURE TO COMPLY WITH NOTICE

Year	Notices to stop waste	Orders to withdraw supply issued	"Cut-off" orders actioned	Additional cases referred to Committee	Committee Authority to withdraw actioned
1946–47	Not recorded	1 556	37	Not recorded	Not recorded
1947–48		1 527	77		
1948–49		2 966	111		
1949–50		1 921	107		
1950–51		1 535	100		
1951–52		1 051	79		
1952–53		986	87		
1953–54		892	72		
1954–55	29 579	667	76		
1955–56	31 892	703	87		
1956–57	26 502	713	92	95	29
1957–58	23 215	517	61	35	5
1958–59	19 815	442	61	12	6
1959–60	18 703	474	104	4	3
1960–61	14 888	241	40	6	1
1961–62	15 991	266	41	6	1
1962–63	16 616	185	27	4	0
1963–64	17 890	348	52	3	1
1964–65	13 369	213	36	6	4
1965–66	12 629	111	26	6	6
1966–67	12 205	126	33	4	2
1967–68	12 235	168	50	2	1
1968–69	10 081	190	51	3	2
1969–70	10 133	132	41	8	5
1970–71	10 153	79	19	10	0
1971–72	9 780	128	49	8	6
1972–73	9 302	118	27	3	0
1973–74	9 520	102	25	0	0

DISCUSSION

AUTHOR'S INTRODUCTION

Mr. R. B. Tabor said that in the conclusion to the paper he had referred to the possibility of making a statement on the various legislative procedures, at least within the Thames Water Authority. He thanked the divisional managers who had forwarded considerable data on all aspects of waste control methods within their areas. The information was still coming in and being analysed but in limiting his remarks to legislation it seemed that most of the water undertakings which existed in the Thames region prior to April this year had byelaws which, with one or two special variations, were based on the Model Water Byelaws. The dates of expiry varied from this year up to 1980. Mostly, the penalties for non-compliance with the byelaws were limited to fines under the authority of the 1945 Act. The former Metropolitan Water Board area was alone in having power to withdraw supply for non-compliance with byelaws, although the old authorities in some parts of the region had powers under special Acts to cut off supplies to empty and inaccessible premises, where waste was occurring or was suspected.

The preparation of the paper had inevitably involved a number of his staff and one had recently presented him with a small book entitled "Rules and regulations for waste department", which had been issued by the New River Company to their inspectors and which was still in use by inspectors employed by the Metropolitan Water Board after it was formed in 1904. Apart from giving details of working hours and conditions at that time, a large section of the book gave instructions on how to issue notices, what to look for in inspecting houses, and how to carry out sounding procedures, all of which were as relevant today as they were in 1897 when the book was published. The booklet demonstrated how, although the aims now were the same as they were at the end of the last century, the attitude to people had changed, particularly during the past 15 or 20 years.

Even in the early 1950s when he had first become involved in what might be called the management side of waste and quality control, very few people questioned the authority's rights to reject water fittings. Now all this had changed. Although for years licence had been given to anglers to enter some of the works, the public was now allowed to wander over the tops of covered reservoirs and yachtsmen to demonstrate their skill on storage reservoirs. Subject to proper control, this was good for public relations, but when it came to what and how water fittings were to be used in the home and factory—surely water engineers should not have to argue the pros and cons of every requirement and justify every action. He was not advocating rigidity in outlook or restriction on general progress and design, but there were situations when not only did we appear to lack authority to back our fears for waste and contamination, but often we were powerless to save consumers from their own folly or the persuasions of an attractive gimmick.

Water engineers were not irresponsible persons who would willingly see a manufacturer fold up under the restrictive effect of detailed specification—but we should be trusted to act with impartiality and due consideration of individuals provided that we had a clear mandate to carry out our duty.

Obviously, the engineer had a first loyalty to his employer—the water undertaking—but the undertaker had a duty to its employer—the public. What did one do if a consumer installed a fitting or plumbing system from which he was in danger of blowing himself up? Did one have to say that waste of water was likely to occur thereby in order to prevent him using it?

For this reason, he had hopes that we might derive a better form of control from the Health and Safety at Work Act, when it became available. But let us make no mistake, if water engineers were to have more authority over the quality of plumbing, it carried with it an even greater responsibility than we had at present and a need for specially trained personnel to act on our behalf.

VERBAL DISCUSSION

Mr. A. G. Durling (Thames Water Authority), in opening the discussion, referred to the section of the paper dealing with penalties and their effectiveness (p. 74). The author had outlined the procedure of the former M.W.B. in applying the sanction of withdrawal of supply for failure to comply with a waste notice in what was considered to be a reasonable period of time.

It was stated that in an increasing number of cases, mainly due to changing social conditions, the time taken to put into effect the actual withdrawal of a supply to prevent waste became increasingly longer. Undoubtedly a number of the delegates faced a similar problem.

Did the author consider that there were any changes in procedure that could be adopted universally which might achieve speedier repair of defects by consumers?

Mr. K. B. Clarke (East Anglian Water Company) said that it was useful to have the author's review of the evolution of waste prevention legislation as it affected one water undertaking, the largest in this country, from the beginning of the nineteenth century. It was especially useful in that it highlighted the way in which waste prevention had become less and less local over the years. With the passing of time the same regulations came to apply to all parts of London and some of them to all parts of the country. He wondered whether the author would like to add to his list for the future the standardizing of byelaws and fittings approval, not only within this country but in the whole Common Market.

One of the great problems met in byelaw enforcement was the variety of interpretation. This variety often existed within different areas of the same undertaking, where different inspectors had different preferences. It certainly continued to exist at present between one undertaking and the next. What would the author's attitude be to a national plumbing inspectorate?

The Appendix to the paper (p. 77) raised a number of questions. Why, for instance, was the number of notices issued fairly steady after falling to a third over the first 15 years of the figures? Did this indicate better plumbing or worse inspection? It would be useful if the number of inspections made could also be included in the table. The number of cut-offs carried out seemed almost constant. Could the author comment on this?

Mr. E. F. Young (Department of the Environment) referred to the ambiguity or inadequacy of byelaws. It was first of all up to ourselves, as engineers, to be clear concerning what was needed. We must express ourselves in such a way that those concerned with legal drafting understood what we meant. Perhaps we ought to produce the equivalent of an "interpretation" handbook beforehand. Criticism of present byelaws had been levied on all sides at the Symposium; perhaps we ought to start fresh again. This course of action was one he would welcome but it would not be easy.

The Health and Safety at Work etc Act 1974 contained powers whereby "fitness for purpose" might be prescribed for any water fitting or appliance. Once again, it would be necessary to be clear concerning what was required and the inferences from "fitness for purpose" regulations would need to be carefully considered. Who would test and approve fittings and appliances, how and where would "fitness for purpose" be defined, and to what extent would water authorities wish to become involved in the work?

The Back-siphonage Report contained a recommendation that the subject of licensing or registration of plumbers should be studied by a DOE committee set up for the purpose. He did not know whether or not this recommendation would be accepted.

Regarding street works, the need for legislation rather than a new or improved Code of Practice was a matter for consideration. Before legislation was considered, it devolved on the industry to show that a CP was not appropriate. He also asked who would enforce the proposed legislation?

Finally, he asked the author for his views on (*a*) the use of flushing valves, and (*b*) bottom valves instead of siphons in flushing cisterns as mentioned by Mr. Wijntjes (p. 38 of paper No. 3).

Mr. D. A. Gill (Water Research Centre) said that in the W.R.A. Technical Paper TP. 82, "Report on the investigation of back-siphonage risks in domestic properties, Winter 1970–71" it was noted that of nearly 1 300 properties surveyed, of those that were less than five years old, 36 per cent had some feature in the plumbing system that contravened the byelaws. Of those properties five to 15 years old, 63 per cent had some contravention and of those over 15 years old 84 per cent had some contravention.

Had the author any opinion as to how we should maintain initial standards and the costs of doing this, or should we considerably simplify the byelaws so that householders wanted to maintain them?

Mrs. J. A. Rees (London School of Economics) said that she had expected the paper to be a discussion on the adequacy of the existing legislation designed to control all forms of wastage of water. (This expectation might, of course, merely reflect her position outside the water industry). It was, therefore, with some surprise that she found that both the paper and subsequent discussion had dealt exclusively with byelaws which aimed to minimize only one source of water loss, namely that on the consumer's premises. While the consumers might indeed be responsible for significant levels of wastage, she had rather gathered from this morning's proceedings that in terms of the gallonage of water lost the most important sources of leakage were the water undertaking's own mains and service pipes.

Would the author say firstly, what, if any, legislation existed which required the water supplier to implement waste detection measures, and secondly, whether he felt any such legislation was necessary?

Mr. J. Seatory (Sunderland and South Shields Water Company) said that the discussion so far had been concerned with domestic premises. He asked for the author's views on the inspection of all consumers' premises including industrial, commercial, and hospital installations. In many cases undertakings took the view that once water had been sold through a meter they need take no further interest in the effective use of such water or in preventing waste or unnecessary use.

Mr. H. J. Giles (National Water Council) said that an undertaking in the South West used the following approach to deal with the problem of leakage on the property of consumers who failed to carry out the necessary repairs despite repeated notices. The undertaking was reluctant to effect repairs with their own work force because they considered that there was a risk of their claim for repair costs being countered by a claim by the consumer for damage, real or imaginary, caused by the undertaking's workmen whilst on the consumers property.

Authority was given by the Board to the engineer that after notice of intention had been given, the engineer could sever the supply at the boundary and erect a stand pipe. In this way a supply to the property was maintained but resulted in considerable inconvenience to the consumer.

In all the incidents where this procedure was considered, the warning of intention always persuaded the consumer to carry out the necessary repairs. He invited the author's views on this approach.

Mr. B. E. Coleman (Mid-Kent Water Company) said the procedure outlined by the author for dealing with defects in consumers' premises appeared in some cases to lead to long delays and consequent further wastage of water. The Mid-Kent Company relied on statutory powers so that under certain circumstances repairs could be carried out without obtaining prior instructions from the consumer. In other cases, "waste notices" were served on the consumer requiring action to be taken in 48 hr. On the reverse side of the "waste notice" there was a preprinted form on which the consumer could advise the Company on the action he had taken or request the Company to carry out the necessary repairs.

The Company provided a plumbing service and felt that apart from fulfilling a vital function in enabling defects to be dealt with promptly, it helped to bring the Company in greater contact with its consumers and also provided the inspectorate staff, who were all qualified plumbers, with an added interest in their work. There was no significant difficulty in recovering the costs of the service. He understood that at one time the old Metropolitan Water Board was considering the setting up of a plumbing service and asked the author if this had been done and with what results.

Ir. W. C. Wijntjes (Dune Waterworks of the Hague) referred to the legal aspects of the installation activites in the Netherlands. For 40 years a uniform regulation of recognition for plumbers had been in existence in Holland.

In 1971 the regulations for plumbers were changed in that the Union of Owners of Water Companies acknowledged only registered installers. Such installers were obliged to notify the Companies of work they were about to undertake. In cases where this was not done, measures might be taken against the plumber, and in the last extreme registration might be withdrawn.

The new system had a number of evident advantages:

(1) The consumer used only competent workmen for the modification, extension, or maintenance of plumbing installations.

(2) The registered plumber had to take into account the regulations given to him.

(3) The Water Company was responsible for the proper control of the installation.

(4) The Water Company was kept well informed about poor apparatus, defective materials, etc.

Author's Reply to Discussion

Mr. R. B. Tabor, replying to the discussion, wrote that if by "universally" Mr. Durling referred to procedure throughout the United Kingdom, then he himself would like to see the power to withdraw a supply available to all water authorities in the same manner as for the former M.W.B. Only then could a universal procedure be adopted, taking proper account of the rights of the individual.

Mr. Durling, who was engineer in charge of waste control, Metropolitan Water Division of the Thames Water Authority, had his sights aimed closer to home ground. Here, as explained in the paper, in recent years we had been increasingly conscious of a need to avoid the "big brother" attitude and hence thereby had perhaps been over-cautious in the administration of the "cut-off" procedure.

If waste was bad enough to warrant the cut-off penalty, the effect should be applied much sooner than in recent times. Initially we might issue more cut-off notices but he doubted if the number of withdrawals actioned would increase dramatically. In parallel with this we should be prepared to assist in cases of hardship and explore all possible means of educating the public in the need for saving water. Although some of his M.W.D. colleagues might not agree he thought more use should be made of explanatory notices placed strategically near mainlaying works; this was particularly important when water appeared to be wasted during sterilization procedures.

In reply to Mr. Clarke, dealing first with the question of standardization of byelaws and fittings approval, Model Byelaws already existed on which water undertakers should design their own but of necessity there would be differences required by local soil and water properties.

Regarding standardization across the common market, we knew that there were general moves in this direction already but apart from the differences between the plumbing systems in the U.K. and the remainder of Europe which affected the basic design performance of taps, he understood also that there were differences in the requirements between the other countries in Europe.

Mr. Clarke's point about variation in interpretation of byelaws within different parts of one water undertaking was really a matter of management control and inspectorate training. Interpretation on site should be standardized by instruction and where there was any difficulty this should be referred to head office, preferably to one man who should ensure uniformity of attitude. He felt that a national plumbing inspectorate was impracticable as the day-to-day control should be vested in the relevant water authority; by this he meant at divisional level, and not at regional level. This did not prevent regional and national establishment of general principles.

Replying to Mr. Clarke's last question, it was necessary to explain that during the decade after the Second World War there was a waste purge in the M.W.B. area and the dramatic effect of this could be seen by the drop in what in those was called the night flow factor from 85·9 mgd in 1947 to 62·3 mgd in 1953. Once the general public "got the message", the need for waste notices reduced, but it was necessary also to take account of a loss of 120 inspectorate personnel between 1958 and 1973, which represented over 30 per cent of the original staff, with a resultant loss of impetus in the effect of the campaign. Simultaneously, there had been a considerable replacement and refurbishing of old property which must have removed a potential source of waste. Notwithstanding this the daily flows had increased since 1956 and night flows had shown a significant rise since 1965. One assumed that this symposium provided the opportunity to exchange ideas on how to combat this phenomenon.

In commenting on Mr. Clarke's suggestion that a list of the number of inspections would be useful he referred him to column two in the Appendix, p. 77, which showed the number of notices served. This was a fair indication of the number of inspections for waste although it did not include the cases where the occupier agreed to repair on a verbal request. In the M.W.D. areas, most of the visits for waste detection were a sounding follow-up of waste water meter runs and were not on a routine house-to-house inspection.

He was interested in Mr. Young's comment that the Back-siphonage Report contained a recommendation that the question of licensing of plumbers should be studied by a DOE Committee. Regarding his question as to who would test and approve fittings under powers of the Health and Safety Work Act, 1974, he hoped that this would be under the overall control of The National Water Council by making use of facilities which already existed within some Regional Authorities although paying due regard to agreed uniform test criteria. In reply to Mr. Young's question on his views of flushing valves and "drop" valves, both were regarded as apparatus likely to lead to waste of water. Flushing valves depended for their operation on the clear waterway of minute orifices which were readily blocked by particiles of grit or scale particularly in hard water areas. A number of different makes of flushing valve had been examined and tested by the M.W.B. over a period of years and none had been found to satisfy all the requirements for acceptance. The main objection had been inconsistency of flush capacity and timing and the ease with which a continuous discharge could be obtained. Furthermore, flushing valves did not normally incorporate any warning device of malfunction.

Drop valve flushing cisterns were disallowed in the M.W.B. area many years ago on the basis that the valve frequently failed to reseat satisfactorily with a result that water could continually dribble through the flush pipe down the pan either undetected or without the obvious need to repair. It was also possible with such fittings to arrange a continuous flush if desired.

Mr. Gill's statistics quoted from the W.R.A. Technical Paper TP.82 brought into focus a problem which most water engineers concerned with byelaws regarded as a cause for concern but felt unable to rectify.

It was evident that all properties should be inspected at least once in five years, although a number of the 36 per cent quoted as having an irregularity might well have incorporated that irregularity almost as long as the property had been built. In the London area the intention was to inspect all new houses before the supply was turned on but quite often consumers bought and installed equipment such as washing machines and shower fittings after they had been in occupation for say 6–12 months. To make inspections of every single dwelling at intervals of five years or less was not practicable with the present staff situation, at least in the London area.

A more efficient and economical way of ensuring compliance with many of the byelaws could be obtained if powers existed for the control of the type and quality of fittings which might be sold to the consumer. Such powers coupled with the requirement that all plumbers should be licenced would remove much of the need for frequent inspection of domestic properties. However, regular inspections at intervals of say one or two years should be made of all industrial premises where plumbing systems could be changed at frequent intervals to meet changing requirements of the user.

Referring to the contribution from Mrs. Rees, it was probable that most water engineers could quote at least one instance of a hidden leakage from a water main continuing at a high rate for a long period before being discovered. When a number of such instances were brought together in discussion it was perhaps not surprising that Mrs. Rees gained the impression that the water undertaking was the main culprit with regard to waste of water. However, this was not necessarily the case. Until we could prove otherwise it was likely that in terms of gallonage the loss from undertakings mains might be in some cases equal to that from consumers installations. It was true that the byelaws might appear to be directed against the consumer, but he himself had always insisted that his own undertaking should comply with its own byelaws.

In reply to Mrs. Rees' second question, he was not sure that any further legislation was necessary to require the water supplier to implement waste detection. Under the reorganized water industry particularly, there would be a more consistent watch over waste control than previously, and it was evident from this symposium that there was a genuine desire on the part of all to arrive at uniform methods of assessing waste. Also, it had to be remembered that in the event of any water undertaking wishing to obtain authority to spend money on new works it had to provide evidence that all other appropriate measures had been taken to conserve water so that the ultimate control of the purse strings guided the water authority into the direction of limitation of waste both within its own reticulation as well as the installations of its consumers.

Regarding Mr. Seatory's contribution, all premises should be inspected at regular intervals but as stated in the reply to Mr. Gill, this was often not practicable. In the "M.W.B." part of the Thames Water Authority there were no special inspectorate gangs who spent most of their time looking for irregularities in the plumbing systems of metered industrial premises and hospitals. Contrary to the impression Mr. Seatory had of some undertakings, he himself held the view that the installation of a meter did not entitle the consumer to waste water although he agreed that users might feel that once paid for water could be dissipated as they wished. This was one of the arguments against the opinion that meters reduced waste; but they did assist the undertaker in his waste detection methods.

He was not sure what powers were enjoyed by the undertaking referred to by Mr. Giles but when we withdrew a supply for non-compliance with M.W.B. byelaws we did so by shutting the outside stopvalve or fixing one if none existed. Often where the ratepayer was not on the premises and there was the possibility of hardship to the occupier, a standpipe was erected on a nearby street hydrant for set periods. He himself preferred this method to severing the service pipe and erecting a standpipe at the boundary.

He agreed with Mr. Giles that any threat of withdrawal of supply was the most effective means of obtaining action on the part of a recalcitrant ratepayer, and thought this was proved by the figures in the Appendix to the paper, p. 77.

Regarding Mr. Coleman's point concerning the time taken to persuade consumers to repair defects in plumbing systems, as mentioned earlier efforts were now being made to speed up the procedure by deleting one or two of the stages in correspondence. But a large authority had to be mindful of the need to be seen to be fair and reasonable.

Mr. Coleman was right in his understanding that the old M.W.B. considered the setting up of a plumbing service. In fact this was done and was at present operated by the Metropolitan Water Division on a restricted scale because of the small number of plumbers available and in order to obtain experience and evidence of costs involved. Most repairs were at present limited to those needed on the Authority's own property, but some cases had arisen where it had been found advantageous to use the plumbing service to assist a consumer having difficulty in obtaining a private plumber. It was interesting to note that Mr. Coleman's Authority had had no significant difficulty in recovering the costs of such a service. Even if expanded it was not the intention of the M.W.B. that assistance should be given other than in cases of extreme difficulty either on the part of the consumer in obtaining alternative facilities or where an innocent occupier might suffer undue hardship.

It was particularly interesting to note Mr. Wijntjes' statement on the restriction in the Netherlands of plumbing work to plumbers licenced by the water authority. As stated on p. 76, he himself would welcome a similar system in the U.K. and Mr. Young had referred to the Back-siphonage Committee's recommendation on this subject. It was to be hoped that the D.O.E. would agree to set up the proposed study group and that its members would take note of the experience of water authorities such as Mr. Wijntjes' in arriving at their conclusions.

6. TESTING AND CONTROL OF QUALITY OF FITTINGS

By R. Y. Bromell, FICE (*Fellow*)*

CONTENTS

INTRODUCTION

This paper was written early in 1974 and sets out to describe methods of testing water fittings before the reorganization of the water supply industry and the demise of the British Waterworks Association. British and European standards are considered together with the principles of quality control and assurance. It discusses the future and the possible development of the testing of water fittings in the UK.

LEGISLATION

Statutory powers to test fittings are to be found in Section 61 of the Third Schedule of the Water Act 1945, which follows Section 133 of the Public Health Act 1936. It is the shortest section in the 1945 Act and as such it deserves to be quoted in full:—

"The undertakers may test any water fittings used in connexion with water supplied by them".

Elsewhere in the Act water fittings are defined as including pipes (other than mains), taps, cocks, valves, ferrules, meters, cisterns, baths, waterclosets, soilpans and other similar apparatus used in connexion with the supply and use of water.

Section 17 of the 1945 Act allows water undertakings to make byelaws for preventing waste, undue consumption, misuse or contamination of water supplied. Byelaws generally follow the Model Water Byelaws published by the former Ministry of Housing and Local Government, but with some variations to take account of local circumstances. Undertakers wishing to deviate from the Model Water Byelaws or to prohibit the use of certain materials are required to submit evidence of premature deterioration. British Standards are quoted extensively in byelaws, but compliance with a British Standard is limited to size, nature, materials, strength and workmanship.

STANDING COMMITTEE ON WATER REGULATIONS

The Standing Committee on Water Regulations was created in 1919 from the Incorporated Joint Committee set up in 1903. The origins, therefore, of the Standing Committee go back further than the formation of the British Waterworks Association (BWA) itself. In 1970 the Committee decided that as the work undertaken had increased steadily over many years, the Association should be asked to approve a restructuring programme having the primary objective of the redeployment of resources so as not merely to maintain the work at a high standard but also to enable it to meet the demands being made for a greater degree of uniformity throughout the country in the acceptance of water fittings and the application of byelaws. As a secondary objective it sought to create the condi-

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tions in which it would be able to help manufacturers to improve their export potential by means of improvements in the systems of type-testing and quality control.

As a result three new Boards were set up to facilitate the work of the Standing Committee which retained overall control of their activities. The most important, certainly by virtue of the volume of work handled, is the Approvals Board (BWAAB) which meets every month. It is serviced by a small skilled staff based on the BWA Testing Station at Staines, where most of the examination and testing of fittings is carried out. Members of the Board handle and examine the fittings in the testing station, consider the reports of tests, and evaluate the findings. In this work they are assisted by an Advisory Group of technical officers drawn from the distribution staffs of some of the larger water undertakings. From time to time the Standing Committee publishes lists of fittings that have passed the examination and the tests and have been accepted by the BWAAB.

Complementary to BWAAB is the Quality Control Board (BWAQCB) responsible for the supervision and control of fittings which purport to comply with BS 1010 (taps) and BS 1212 (ballvalves). The British Standards Institution (BSI) and the BWA are owners of registered certification trade marks that can be used only by manufacturers licensed under the certification mark scheme operated jointly by BSI and BWA. The presence of these marks on or in relation to a product is an assurance that the goods have been produced to comply with the requirements of the British Standard under a system of supervision, control, and testing operated during manufacture and including periodical inspection at the manufacturers works in accordance with the certification mark scheme.

There has been some criticism of these schemes from manufacturers on the grounds that fees are paid for licensed fittings but a fitting falling outside the scheme is accepted by the BWA under Byelaw 2(1) (*b*) provided that the fitting is not less efficient and suitable in relation to the purposes for which the byelaws are made and consequently the requirement that the fitting shall comply with a British Standard will be deemed to be satisfied, notwithstanding that the fitting does not actually comply with that standard.

The Byelaws Advisory Board (BWABAB) completes the trio and advises member water undertakings on the application and interpretation of the Model Water Byelaws.

Application has been made to the Department of Trade and Industry for a certification trade mark scheme for taps and stopvalves which do not purport to comply with BS 1010 but which meet the requirements of the Model Byelaws. It is a requirement of the granting of such a trade mark that tests and the criteria upon which fittings will be accepted or rejected must be approved by the Department and published in detail. The principles behind the application for a certification trade mark scheme should go a long way towards meeting the objection raised by UK manufacturers regarding fittings which at present cannot be rejected.

The success of the Standing Committee in testing and examining fittings over the years may be measured by the large number of water undertakings that have given up the testing and stamping of water fittings and have closed down their own local testing stations.

An essential part of the work of the Standing Committee is the representation by either members or officers on BSI Committees and other bodies engaged on the preparation, metrication, or revision of standards not only for water fittings but also in connexion with the many activities that impinge on public water supplies.

BWA TESTING STATION

Four years ago the BWA Testing Station moved out of central London into conveniently situated premises at the South West Surburban Water Company, now the North Surrey Water Company, at Staines in Middlesex. There had been a steady increase in the number of fittings submitted for examination and the opportunity was taken to design and develop specific test rigs to meet the new requirements following the reorganization of the work of the Standing Committee.

A slave testing machine is used mainly for the durance testing of bibtaps, pillar taps, and mixer units. Up to four fittings can be mounted on the rig, which opens and closes them at a constant speed of 40 cycles per min. Assuming that a tap is used 40 times a day this test would be equivalent to a life of nearly 70 years. Each tap can be supplied with either cold water at mains pressure or hot water from an experimental pressurized water heater. An extension to the machine can be used to impart a reciprocating motion to the swivelling outlet of mixer taps or with modification it can be used for endurance testing of ballvalves. It is usual to test prototypes in this way so that potential design weaknesses may be revealed, but it is equally important to examine first-run production models which may vary considerably from the one-off prototype that has been handmade with loving care by skilled craftsmen. The accelerated-life test is limited in that some materials may be subject to corrosion to a greater or lesser degree; other materials may have a life dependent on time or both time and temperature, and the probability of failure may be related to environmental conditions.

In accordance with statutory requirements pipes are tested hydraulically to twice working pressure while draw-off taps, stopvalves and ballvalves are tested to 20 bar (300 lb/in^2), but this is regarded as little more than a check for porosity. To determine the strength of a fitting it must be subjected to greater pressures—up to bursting point—which has the advantage of drawing attention to the type of failure that may be expected and to the weaker components in its design.

Transient changes in pressure produced in a pipe system when the fluid flowing within the system is accelerated or decelerated by some means such as the operation of a valve can result in reverberation in pipes or "water hammer". The shape and amplitude of any pressure wave generated depends upon a number of factors including the initial velocity of the water in the system, the rate of closure of the valve, the configuration and length of the pipework, and the physical attributes of the material from which the pipes are manufactured. A number of rigs were tried having differing water pressures and different geometry. The valve was shut manually as quickly as possible and the resultant rise in pressure could be indicated on a dead-beat bourdon gauge. After some trial and error two types of rigs are now available. The first is designed to determine the concussiveness of screw-down taps and valves when the fitting is closed at a specified rate against a specified flow of water through a test pipe; the magnitude of the pressure rise as the tap closes is recorded on an ultra-violet oscillograph. The second rig is used to assess the effect of pressure peaks on a fitting under test which is tee'd into a pipe in which the flow of water is interrupted by a concussive solenoid valve. The magnitude of the pressure peak and wave form is similarly recorded on an ultra-violet oscillograph.

Not all the work is undertaken directly in the testing station—it would be uneconomic. Certain of the more difficult chemical and bacteriological examinations are undertaken by specialist laboratories acting as consultants or research organizations. It is policy to go to wherever the best available advice may be found.

Metals corrode to a greater or lesser extent which can lead to a waste of water, either from local attack resulting in leakage or from general attack which can lead to mechanical failure. Corrosion may lead to discolouration of the water in extreme cases or even make it toxic. Stainless steels can be subject to attack in high chloride waters and may fail due to stress-corrosion cracking in the presence of high temperatures.

The dezincification of duplex brass fittings is a well known phenomenon in the presence of waters containing a high ratio of chlorides to temporary hardness, but the full extent of the problem is not precisely known. The British Non-Ferrous Metals Research Association regularly advises the BWA on such matters.

Plastic materials are subject to stringent tests for toxicity which are carried out by specialist laboratories. Polyethylene raw materials in the 1950s were not sufficiently stabilized before extrusion. Consequently, oxidation products were formed on the surface of the pipe wall and it was possible for these to become soluble in water. The resultant taste was noticeable for some time, particularly when water was drawn first thing in the morning. PVC requires the addition of stabilizers and some of the most effective and economic are compounds of lead which has caused some concern. Apparently, during the extrusion of the pipe a small amount of lead is precipitated and can diffuse from the pipe wall. Some countries prohibited the use of lead stabilizers in the production of water pipes. Recently concern has been expressed regarding deterioration in the quality of water stored in cisterns manufactured from certain plastic materials.

BRITISH STANDARD SPECIFICATIONS

Standards describe a level of attainment but the scope can vary considerably. Certain standards specify all materials and detail most of the dimensions, leaving little room for imagination on the part of the manufacturer. BS 1010 Draw-off Taps and Stopvalves for Water Services (Screw-down Pattern) was first published in 1959 and is now known as Part 1. It contained a large number of clauses with many drawings complete with several pages of tables of dimensions. Such was the tight specification that over the last 15 years amendment slips have appeared regularly each year. Almost every clause has been altered at least once; a number of drawings and tables have been added; and it has grown a list of contents at the beginning, four appendixes at the end, and is double its original size.

BS 1010 Part 2, 1972, follows a similar pattern, in metric units. The drafting committee considered that the dimensions given were essential to ensure the production of a sound article with a reasonably long life. At the same time it was hoped that these details could be applied to the component parts of a variety of designs.

Quality assurance is dealt with as a subject later, but for BS 1010 it is simply a question of inspection by attributes; each dimension is classified by gauging as either acceptable or defective. After assembly every tap must show no sign of leaking when subjected to the statutory hydraulic pressure test of 20 bar (300 lb/sq in) or a pneumatic test of 5 bar carried out under water.

Other British Standards follow the same pattern. BS 1212 Ballvalves, Part 1, Piston Type are required to be capable of shutting off against water pressures of 3, 7 or 14 bar depending on whether rated for low, medium or high pressure in addition to the statutory 20 bar static hydraulic test. A bending test is specified to ascertain the mechanical strength of the lever. BS 1212 Ballvalves, Part 2, Diaphragm Type (Brass body) has test requirements for adequacy of flow and every ballvalve must be capable of delivering at least 6 l/min when operating under a head of 1m of water. Concern has been expressed in many quarters regarding the dangers of back-siphonage, and a ballvalve when subjected to a vacuum of 0·945 bar (710 mm Hg) for 1 min must not draw-back water from the cistern.

Slavish adherence to dimensional standards has tended to inhibit both new design and improvement in many products. For some time there has been support to reduce the amount of detailed dimensions to outline and fixing dimensions and to specify tests covering the physical qualities of the product. Such performance standards are generally adopted on the Continent, are much briefer and can be written sometimes on a single sheet of paper.

A draft performance standard for draw-off taps to replace BS 1010 has been under discussion. A start was made four years ago and despite general agreement on all but a few details it was abandoned by the manufacturers in favour of the metrication of BS 1010. It is understood that moves are afoot to draft performance requirements for both brass and plastic draw-off fittings based on work that is being carried out for European standards.

EUROPEAN STANDARDS

Draft European standards for taps and stopvalves founded on performance criteria are being prepared by the Comite European de Normalisation (CEN) and representatives from the BWA, the National Brassfoundry Association, and the British Plastics Federation attend these meetings. It is proposed to publish the standards in parts:—

Part I — Dimensional characteristics
Part II — Water tightness and pressure resistance characteristics
Part III— Hydraulic and acoustic characteristics
Part IV— Mechanical endurance characteristics
Part V — Physical and chemical characteristics

Part I for ½ in mixer taps (PrEN 27 and PrEN 28) and for ½ in vertically mounted taps (PrEN 29) were made available for public comment in the UK in April 1973. The dimensions specified are those necessary to allow for interchangeability and suitability for use but difficulty arose because of the necessity to delineate fittings in order to illustrate dimensions. As a result a note has been inserted in the draft which will draw the readers attention to the outlines which should in no way prejudge the various solutions likely to be adopted. The final shape of the tapware is left entirely to the initiative of the manufacturer.

There are advantages in publishing a standard in parts, particularly in the flexibility of drafting and the speed of publication. Amendments and revision are simplified and redrafting is made much easier. However, care must be taken when bringing together the different parts and to keep the publication up-to-date as a whole. It must be stressed that reference to a European standard will be a reference to each and every part of that standard. Until all the parts have been published reference to the standard will be meaningless and cannot constitute a precedent for conformity to the standard itself. It is to be hoped that manufacturers will recognize this situation and will use the parts as published independently to begin design work and development with a view to bringing a conforming product onto the market with the least delay after the series of parts is complete.

The first meeting of the drafting committee for draw-off taps was held in April 1968 and progress has been necessarily slow. The UK is in a rather difficult position because of our unique cistern-fed hot water systems that require draw-off fittings to have large waterways in order to provide adequate rates of flow under pressures as low as 0·1 bar. The result is that British fittings tend to be large and heavy compared with their continental counterparts. However, the method of isolating the incoming supply pipe from the hot water system by means of an air-gap is under review by a committee studying the problems of back-siphonage. Perhaps the continental type of mains-fed hot water system that is prohibited under the present Model Water Byelaws may be permitted in the UK at some time in the future.

A typical problem facing the drafting committee was to attempt to find acceptance of a test for water-tightness of taps. The UK and Switzerland have statutory tests of 20 bar and 25 bar respectively, but most countries wanted 16 bar while one country would have been satisfied with a test of 10 bar. The solution would appear to be to select 16 bar as a minimum but to require a further test to be carried out at the mandatory pressure when fittings are to be used in the UK and Switzerland.

Consideration has been given to a performance requirement to determine the resistance to dezincification. In Sweden dezincification of brass fittings is recognized as a serious cause of trouble in plumbing systems, particularly in hot water systems where water has a high proportion of chloride to bicarbonate. Trouble usually takes the form of sticking or breaking of valve spindles, but leakage through the walls of fittings, blockage by the products of corrosion and damage to valve seatings are also experienced. The Swedish Building Standard for Sanitary Installations includes provision for valves and fittings in water systems to be of dezincification resistant material. The test used by the National Board of Planning which is the authority responsible for accepting materials as resistant to dezincification is immersion in a 1 per cent solution of cupric chloride at 70—80°C for 150 h.

There has been some criticism that such a test is premature, particularly for a standard which has to be acceptable for widely different conditions. Although a good correlation has been found between the test results and the behaviour of modified alpha/beta brasses containing tin and aluminium, a marked difference may be found between the behaviour of an alloy in an acid water and the behaviour of the same alloy in an alkaline water. A number of dezincification tests are undergoing evaluation in one way or another at the present time, and it is to be hoped that in due course a suitable method of testing will receive universal acceptance.

CONTROL OF QUALITY

Quality is something that most suppliers would claim to achieve; indeed it may well be true otherwise they would not remain in business for very long. It has been described in the past as "an attitude of mind", and although such sentiments are admirable this is an oversimplification of the problem. Modern industry grows rapidly more complex. Greater financial control, and the cost of development and maintenance of modern equipment requires the integration of design, production and marketing to ensure the quality of the product demanded by the purchaser. This had led to a new concept of quality control to assist in the programming and the co-ordination of efforts of each and every part of an organization.

In the same way and for the same reasons quality assurance has developed from the simple provision of proof of evidence of quality control to embrace all the activities concerned with the attainment of quality. Few modern manufacturing concerns are sufficiently self-contained to the extent that a product is manufactured from raw materials to an end product on a single site. It is evident that all materials bought-in must conform to the requirements specified, and controls must be exercised effectively to monitor work and processes at the sub-contractors plant. If necessary the plant must be kept under a system of routine surveillance.

When entering into a contract the purchaser must ensure that his requirements are detailed and explicit. The type of inspection, the frequency of visits and the methods of sampling will need to be agreed in advance. Defect of failure analysis, the rejection or remedial action that may be taken, and the control of non-conforming materials must be decided before commencing production. Documentation must be settled, notices and acceptance paperwork are all part of a proper procedure to be agreed. It is important for the purchaser to recognize the simple fact that the manufacturer has to strike a balance between the cost of quality assurance in terms of scrap and necessary replacements against the probability of rejection on test, the failure on inspection or the loss of goodwill and ultimately the loss of customers in attempting to market defective products.

HARMONIZATION OF REGULATIONS

In the UK the water undertakers make the byelaws subject to confirmation by the Secretary of State, and carry out interpretation and enforcement without recourse to central government. In Europe matters are arranged differently. Ministers generally have powers to issue, interpret and enforce regulations that are binding on both the water supply authority and the consumer. Such a fundamental difference in procedure would lead to difficulties in any attempt to rationalize the situation. A Tripartite Working Group consisting of representatives from France, Germany and the UK has been established with the objective of harmonizing water regulations. This Group was set up independently of the EEC and much progress has been made. However, a time may come when the rest of the community will want to join in the proceedings and it is hoped that the groundwork carried out will prove to be a sound foundation on which to build future work. Complementary to this work an investigation is being carried out into the contamination of water supplies.

But, it is not enough solely to harmonize regulations and a sub-group of representatives from each of the three test institutes (CSTB—DVGW—BWA) has been set up to agree test requirements and a common system of approval procedures. The Netherlands testing station KIWA has been invited to join in these talks. In particular the sub-group is concerned with detailing tests for both mechanical devices and non-mechanical conditions to prevent back-siphonage. Basically tests fall into three categories (1) the examination of physical properties and performance, (2) the situation test to simulate adverse working conditions, and (3) the accelerated-life test. Testing of water fittings on the continent is different from the work carried out by the BWA. For example, in Stuttgart water meters are tested and calibrated while at Champs-sur-Marne near Paris work is carried out into the acoustic characteristics of water fittings. Many of the continental tests are to satisfy fitness for purpose requirements.

THE FUTURE

What changes can we expect in the future? It seems likely that the Department of the Environment Back-siphonage Committee will present its report and make recommendations soon. Such recommendations could be controversial and excite much debate. If changes are to be made these would almost inevitably result in modifications to the Model Water Byelaws. As the last edition was published in 1966 no doubt the opportunity would be taken to introduce metrication and to bring the document up-to-date in other ways. At the same time the effect of any possible agreement towards harmonization of regulations between the Tripartite or the EEC countries should be considered to avoid later amendments.

The Water Act 1973, has led to the formation of the National Water Council charged with the duty to consult interested parties with a view to the establishment of a scheme for testing and approval of water fittings for ascertaining whether they comply with regulations and byelaws. Regional water authorities have been set up and on 1st April 1974 took over the responsibility for water supply functions, including powers to make byelaws and to test fittings from the present water boards and municipal water undertakers in England and Wales. In order to keep the transitional period as short as possible it seems probable that the present approvals schemes or something very much on the same lines will continue at least for the time being, so as to give the new organization an opportunity to consider any changes that might be necessary both from the point of view of water reorganization and in the light of the experience gained by the BWA over the last few years.

The present arrangements of carrying out most of the testing at Staines but letting out the specialist work has been satisfactory in the past. However, the work load is increasing steadily and undoubtedly the time has come to evaluate the need for all testing to be carried out on the same site, except perhaps for the most unusual requirements. This would entail an enlargement of the present accommodation and with the restrictions of the present location it could mean that new premises might have to be found. Such a step should not deter such a move if it would ensure that all the physical, mechanical, chemical, metallurgical, bacteriological and microbiological examinations could be made on the same premises together with the administration and secretarial support services. Space should be made available for a further expansion of the facilities to include, for example, an acoustics laboratory.

It should not be thought that the introduction of European standards and uniform regulations would lead to a decline of national testing facilities. The existing testing stations could continue and in addition make a substantial contribution towards the formation of an international secretariat charged with the duty of co-ordinating test methods, agreeing test procedures, and forming a centralized system of records. One can imagine that a fitting manufactured in the UK would be tested here in accordance with agreed international requirements and if found satisfactory would be accepted for use on a provisional basis for a period of two to five years depending upon the type of fitting and the materials used in manufacture. Test results would be passed to other countries taking part in the scheme. From time to time during the provisional period an examination of fittings in service or on field trials would add information and at the end of that period a dossier of performance would have been built up which, if satisfactory, would lead to the final certificate. Failure or unsatisfactory performance would result in withdrawal of the provisional approval.

This still leaves the vexed question of fitness for purpose. Legislation entitles a purchaser to be supplied with goods as fit for the purpose for which goods of that kind are normally bought. If a purchaser finds that the goods are not satisfactory then the responsibility rests with the retailer to put matters right. Consumers are often completely unaware that water byelaws are not concerned with fitness for purpose except where such matters can be shown to lead to waste, misuse, or contamination of water. This has led to some criticism, but undertakers have no alternative but to make byelaws that follow the relatively narrow terms of the Ministry Model. The time has come for water undertakers to be given powers to protect the consumer and to ensure that water fittings when purchased are efficient, reliable and fit for their intended use.

ACKNOWLEDGMENTS

The permission of Coventry Corporation to prepare this contribution is gratefully acknowledged. Much of the background has been taken from the paper by John Bath*, Engineering Services Officer, British Waterworks Association, to whom the author is particularly indebted.

The contents of this paper represent the views of the author, and these are not necessarily the views of his employing Authority.

DISCUSSION

AUTHOR'S INTRODUCTION

Mr. R. Y. Bromell, in introducing the paper, said that it had been written before the reorganization of the water industry, and therefore there were certain matters that needed to be brought up to date.

* Bath, J. S. W. 1974 *Journ. I.W.E.*, vol. 28, no. 2, March, p. 77, "Water fittings: their quality, reliability and performance", 1973 Winter Meeting paper.

In the Articles of the British Waterworks Association, the functions of the Standing Committee were set out as the exercise of the powers and authorities of the Association with reference to the design, manufacture, examination and certification of fittings, applications and materials employed in connexion with the supply and distribution of water. When first constituted, the Standing Committee was comprised of representatives from not only the Association (i.e. Municipal Authorities and Water Boards in England, Scotland, and Wales), but also from the

Water Companies Association
Institution of Water Engineers
Royal Institute of British Architects
Worshipful Company of Plumbers
Institute of Plumbers
Royal Sanitary Institute.

The names of some of those noble Institutions might have changed, but that representation in the broad sense had continued from the earliest days.

Co-opted members had included representatives from the

National Brassfoundry Association
British Plastics Federation
British Standards Institution
British Gas Corporation
British Non-Ferrous Metals Association
British Electrical Development Association.

The objective had been to obtain a wide selection of interests concerned in maintaining the quality of fittings coupled with expert advice on related matters. Those members gave much of their time and the most valuable assistance in the work of the Standing Committee.

Alas, the Standing Committee was no more, it passed peacefully away on 31st March 1974 as a result of reorganization. It had taken with it into oblivion the Quality Control Board and the Byelaws Advisory Board. But fortunately the Approvals Board had been asked by the National Water Council to carry on its work until such time that the Council had implemented the consultation procedure and had decided upon a new scheme of approval.

Forty years had passed since the Ministry of Health first produced a standard for taps that had been used by the BWA in its "Swan" trade mark scheme, in which licences were granted to manufacturers operating under a system of quality control. That was the forerunner of a kite-mark licencing scheme operated jointly by the BSI and BWA for BS 1010 taps which started in 1949 and indeed continued to-day.

Last year BS 1010 Part 2 had been issued in metric units and over the last few months a draft performance standard for draw-off taps with metal bodies had been issued by BSI for public comment and this had been followed by a similar draft for taps with plastic bodies. The drafts had been produced by the National Brassfoundry Association and the British Plastics Federation, respectively, and each had been arranged in five sections which coincided with the format that was likely to be adopted for the corresponding European Standard.

A fundamental basis of the drafts was the elimination of unduly restrictive dimensions and the inclusion of adequate performance requirements. This was in accord with the Department of Trade and Industry's view that more restrictive forms of specification discouraged designers from trying to improve their products. Certain dimensional requirements necessary for interchangeability had been retained.

It was interesting to note that all dimensions were expressed in metric terms except for connecting pipe threads which had been retained in imperial sizes (ISO/R 228) so as to conform with current European practice. As a result taps would continue to be designated in nominal sizes of ½ and ¾.

BS 1010 called for a hydraulic seat test of 20 bar *or* a pneumatic seat test of 5 bar under water and a hydraulic body test of 5 bar *or* a pneumatic body test of 1 bar under water. The proposed performance standard was far more comprehensive. Tests proposed were:—

Underseat	20 bar for 60 sec hydraulic
and	6 bar for 20 sec pneumatic
Body test	4 bar for 60 sec hydraulic
and	2 bar for 20 sec pneumatic

O ring seals were to be tested pneumatically for 20 sec at 0·2 bar; the mechanical strength test was of 25 bar for 60 sec.

It was anticipated that an operating mechanism test, a backnut and shank torque test, an anti-rotational test, a body bending test and cycling tests would be included in the standard. Flow and jet concentration tests would probably be specified in some detail.

The National Water Council was charged with the duty to consult interested parties with a view to producing a scheme for the testing and approval of water fittings that complied with the regulations and byelaws. The Standing Committee had made its views known to the NWC on the type of organization that should be set up, and it was thought that it would be a pity if the past experience of members in the operation of such schemes was not exploited to the full.

The heart of any approvals scheme should be the testing station and the officers who ran it. Four years ago the BWA testing station moved to new premises at Staines and took on additional staff. This had been necessary because of the increase in work-load. Unfortunately, the number of fittings examined was still increasing, but to make matters worse additional tests had become necessary. For example, the continued introduction of new plastic materials which required extensive and lengthy test procedures had caused delays in the approval of certain fittings over the last few months. Many tests on toxicity of materials required special techniques that could not be carried out at Staines. Instead, the work had to be passed out to specialist laboratories. This was not really satisfactory, but at present and until additional facilities could be provided, there was simply no alternative.

There was now a strong argument for all examinations except the most unusual to be undertaken on the same site together with the library, administration, and secretarial support services.

There was no doubt that the fittings testing station at Staines had carried out first-class work under difficult circumstances, but if the satisfactory testing and examination of fittings was to continue, an extension of the facilities was essential and that, coupled with the experience of the personnel employed, would keep the National Water Council in the forefront of fittings testing.

Finally, he raised the question of water fittings being fit for the purpose for which they were required. The model water byelaws were quite clear in that they were not concerned with fitness for purpose, except where such matters could be shown to lead to waste, misuse, or contamination of water.

Water engineers in the United Kingdom would not be surprised but it would undoubtedly alarm many consumers to learn that a tap could be approved but the flow-rate could be quite inadequate for normal purposes. This could indirectly lead to waste. We were all aware of the slow running bath tap which had been left unattended, and then forgotten with disastrous results! If others would not take action, then the time had come for the water supply industry to press for adequate powers to protect the consumer and to ensure that water fittings when purchased were efficient, reliable, and fit for their intended use.

VERBAL DISCUSSION

Mr. J. S. W. Bath (National Water Council), said he was particularly glad to open the discussion because much of the background to the paper had been taken from one which he himself had given at the I.W.E. Winter Meeting in 1973. For this reason it would not be appropriate to put questions to the author, and instead he proposed to amplify some of the points in the paper in the light of recent events.

The paper summarized concisely the whole field of testing and quality assurance of water fittings. These activities could only be carried out against clear statements of requirements, which included performance and quality. At present some of the requirements were stated in legal terms in the Model Water Byelaws, and he looked forward to the eventual introduction of technical regulations which could be made under the Health and Safety at Work Act.

He had hoped to be able to announce progress in the consultations which the NWC was obliged to have with interested bodies with a view to introducing a national scheme for testing water fittings. Owing to the pressure of more urgent business, the Council had not yet been able to issue a consultation paper, but one was expected shortly. The recipients of this document would require some time to consider the replies and formulate its testing scheme, so the interim arrangements whereby the original BWA Approvals Board was asked to continue its work were likely to go on for some time.

Referring to the effect which certain materials could have on the quality of water in contact with them, apart from chemical effects, this could take the form of growth of microbiological organisms which obtained their nourishment from the material in contact with the water. While these growths were not harmful to health, they often took the form of suspended matter in the water or led to unpleasant tastes or odours, which could give cause to complaint by consumers. For this reason they were classed as contamination, and it was decided that no fitting could be considered for acceptance until microbiological tests on the materials had given a satisfactory result. This had caused a serious interruption to the work of the Approvals Board, since the tests took a long time to perform, and very few laboratories were capable of undertaking them. The extent of this interruption could be seen from the number of fittings involved. Out of 250 awaiting test or under test, only ten did not require microbiological testing.

The effect on manufacturers of long delays in the testing of their fittings could also be serious, since some might be tempted to bypass the Council's approval, with the result that the Approvals Board would lose control over the quality and performance of these fittings. Short-term arrangements were therefore being made for the necessary tests to be done as a matter of urgency and proposals were being put forward to set up a laboratory under the direct control of the NWC to deal with these tests in the long term.

Mr. C. A. Serpell (Sunderland and South Shields Water Company) said that when references were made to testing, it was important to differentiate between prototype testing for approval of a fitting as complying with the byelaws, and quality assurance testing. The latter could either take the form of random tests in association with an agreed certification scheme, or it could consist of the bulk testing and stamping by the water undertaker of all fittings used in its area. Bulk testing was generally considered to be unnecessary and in recent years had in most instances been abandoned.

The author had referred to the need for new premises to accommodate all the different types of examinations which were now required. This called for expert knowledge in a variety of fields and, while it might not be practicable for all the examinations to be carried out in one place, it was suggested that the Water Research Centre might well be in a position to help in achieving a greater concentration of the testing work.

In the quality assurance field there was a need for the joint certification scheme for BS 1010 and BS 1212 fittings to be extended to include many other fittings and appliances. The problem was further accentuated by the growing integration with Europe, where the continental practice of metering domestic water supplies could reflect a somewhat different attitude towards waste.

The author had referred to the report of the Department of the Environment Back-siphonage Committee of which publication was expected shortly. Should the findings of the Back-siphonage Committee result in the increased use of mechanical devices for the prevention of back-siphonage, the manufacture of such devices would also need to be accompanied by adequate quality assurance procedures.

He agreed with the author on the desirability of future legislation making provision for fitness of purpose. Both flow rates and the acoustic properties of fittings should be included with those which should be the subject of control.

Finally, he referred to the statement by Mr. Barrett in his paper to the effect that loss of water in the form of leakages from mains and pipes was inevitable. While that could be said to be largely true of distribution systems at the present time, he himself contended that, with modern expertise and with proper testing and control, it should be possible to provide installations from which loss by leakage was greatly reduced.

Mr. B. Rydz (Severn-Trent Water Authority) asked for the author's comment on the performance of the flushing valve in terms of water economy and protection of the supply from contamination. It was extensively used outside this country and potentially offered a greater benefit that the dual flush cistern. Was he aware of the existence of any properly conducted comparisons of performance?

Mr. R. B. Tabor (Thames Water Authority) said that wherever microbiological testing was carried out it was bound to require long periods of test, extending into weeks or even months, although he understood that some of the unsuitable materials would reveal their growth potential quickly. In order to save time it was possible, in some cases, to run microbiological tests simultaneously with mechanical tests but this was a matter of judgment for the testing officer as the failure on one test might affect the design or material used to meet the other test.

He agreed with the author's conclusion that water undertakers should be given powers to protect the consumer and to ensure that water fittings were reliable and fit for their intended use. Water byelaws were often criticized for making life difficult for the architect and plumber but equally such Byelaws were criticized by consumers for their weakness in being inadequate to prevent the sale of apparatus which proved to be unreliable or alternatively difficult to repair in the event of normal wear and tear.

Mr. B. E. Coleman (Mid-Kent Water Company) referred to a case where details of a water fitting which had been approved by the BWA had been circulated to members of his staff. The reaction from those with plumbing experience was one of extreme concern as they felt there were certain inherent defects, particularly with regard to subsequent maintenance. Did the Approvals Board take the question of maintenance into account before giving approval?

A number of water fittings were on the market which had not been approved by the BWA. On several occasions recently he had found it necessary to draw the attention of consumers to the fact that water fittings, particularly mixer taps, and instantaneous electric water heaters in combination with shower units, did not comply with the Byelaws and would have to be removed or altered. Obviously, the consumers had been disappointed and had been put to considerable expense in rectifying the situation. This obviously did not help the maintenance of good relations with consumers, although in two cases he had managed to persuade the suppliers to change the fittings to those of an approved type.

Had thought been given to the institution of some licensing system for suppliers and manufacturers in order to provide the public with some degree of protection?

WRITTEN DISCUSSION

Mr. R. N. Balmer (Severn-Trent Water Authority) wrote that one way to explain growth in household consumption was by linking it to the acquisition of additional water-using appliances such as washing machines and dishwashers, or to factors which created new water uses such as the possession of cars. As a result, consumption for any household was likely to follow a trend line looking rather like an uneven set of stairs. Indeed it was thought that the growth of domestic consumption during the 1960s had been caused largely by the greater use of washing machines, the increased number of cars washed, and an increase in garden size.

In view of the industry's powers under the 1945 Water Act to prevent undue consumption *there did seem a case for seeking powers at national level to monitor and perhaps limit the* quantity of water new domestic appliances were allowed to use.

If, for example, a dual flush or Liljendahl type of WC was marketed using less than half the water required by a conventional unit, a saving of about 5 gal/head/d or about 6000 gal/household/year could be achieved. At a total cost for water of say 40p/1000 gal (supply plus reclamation), the present worth value of the water saved would be £24 discounted at 10 per cent or £48 discounted at 5 per cent. In other words it would be in the nation's interest to introduce byelaws to change to this new type of WC, so long as any increase in its cost was less than the value of the water saved.

AUTHOR'S REPLY TO DISCUSSION

Mr. R. Y. Bromell, in reply to the discussion, wrote that he was particularly grateful to Mr. Bath for his valuable contribution in amplification of many of the matters raised. Sufficient evidence had been produced to substantiate the urgent need to extend the facilities at the Staines Testing Station and he hoped that the National Water Council would heed the warning that the long delays in testing could encourage manufacturers to attempt to by-pass the approval scheme.

He was glad that Mr. Serpell had suggested that the Water Research Centre might be able to assist in relieving the testing station of some of the specialist examinations that had become necessary in recent years. Reference had been made to the back-siphonage report, which could result in an increase in the use of mechanical anti-siphon devices which he agreed must be subject to adequate quality assurance measures.

In reply to Mr. Rydz's question on the use of flushing valves, his personal experience was limited to two specific instances. First, a manufacturer had asked his authority to carry out tests on a sample and it was found that despite specialist attention it was impossible to set the valve so that it complied with the flow requirements of BS 1125 more than once in every three operations. In the second case he was staying in a well known continental hotel and flushed the lavatory immediately before leaving his bedroom. On returning eight hours later he found the flushing valve jammed open and continuing to discharge at the maximum flow rate! Throughout his stay that particular valve could be shut only by pulling hard and long on the operating mechanism!

He agreed with Mr. Tabor that the problem with microbiological testing was the time necessary to clear some materials. He was pleased that Mr. Tabor and other speakers had supported his contention that powers should be given to water undertakers to protect the consumer and ensure that fittings were fit for the purpose for which they had been purchased.

He assured Mr. Coleman that the Approvals Board gave consideration to the question of maintenance of fittings and in the practical consideration of repairs. If any water authority was unhappy with the approval of a particular fitting, then he hoped that it would take the matter up with the Board without delay. Unfortunately, the feed-back from authorities and users was not very great. The Approvals Board would welcome constructive criticism and a greater interest in the work of the Board. A licensing system for suppliers and manufacturers was not really practicable; after all, the licensing of plumbers had been promoted on more than one occasion but never achieved.

He agreed with Mr. Balmer's suggestion that the increase in domestic consumption was due primarily to the acquisition of additional appliances such as washing machines. The figures given on financial savings as a result of fitting dual-flush cisterns were interesting, but there were other factors to be considered. Elsewhere he had made the point that the prevention of waste and the reduction in consumption of water that found its way to sewage treatment plants if carried to extremes would result ultimately in an increase in the strength of domestic sewage, which in itself could result in increased costs for treatment.

7. WASTE PREVENTION: THE DESIGN AND OPERATION OF DISTRIBUTION SYSTEMS

By J. Reid, MIMECHE (*Member*)*

CONTENTS

INTRODUCTION

Forecasts of increasing demand for water are familiar to most people. We are informed that the demand for water will double by the end of the century and that unless the construction of new storage reservoirs and river abstraction schemes is started immediately, to be followed by estuary development in the early 1980s, water shortage will develop.

The basis of future forecasts is given in the Water Resources Board Report (1973)** and reference is made in detail to possible differences in growth demands between specific methods of forecasting. It is, however, queried if future forecasts should be treated solely in this manner as it does not take into account any determined approach towards reducing demand.

It is too readily accepted that with industrial demand showing a sustained upward trend and the country-wide large-scale housing redevelopment programme providing modern facilities to ever-increasing numbers of the population, there is bound to be an acceleration in the growth of demand. Whilst a levelling-off in demand cannot be foreseen, it now appears that the rate of increase in population is stabilizing. It would be wrong, therefore, to accept that an increase in demand comparable with that of the previous decade is inevitable.

A positive approach to reducing demand should be energetically pursued by attacking the enormity of waste wherever it occurs. In this context, waste is defined as "water which is not effectively used".

Returns from water supply undertakers giving their estimates of waste vary widely up to a maximum of 40 per cent per annum, which suggests that the average loss may be of the order of 20–25 per cent. Such a level of waste represents about £30 million value of saleable water when compared with the annual capital expenditure of approximately £150 million on all public water supply projects.

If an infinitely small proportion of the cost of future capital works were devoted to research and the implementation on a national scale of proved methods of minimizing waste, the future demand for water could be considerably reduced and capital expenditure deferred.

Waste control in water supply units ranges from the *laissez-faire* appproach, where only reported leaks causing inconvenience are repaired, to the sophisticated approach using continuously monitored telemetering schemes. Details of the various methods

* Manager, Liverpool Water Supply Unit, North West Water Authority.

** References are given on p. 115.

employed in this country have been described by Giles (1973). However, for the purpose of this symposium the present paper is concerned with:—

(1) *Waste Metering*—the most common systematic approach to the problem which generally covers distribution mains up to about 8 in (200 mm) in diameter.
(2) *Systems Monitoring*—which covers all mains including trunks but which lacks the sophistication necessary to define sufficiently the location where leakage is occurring.
(3) *Pressure Reduction*—as a complementary method of reducing waste.

WASTE DETECTION

METERS

Waste detection by house to house inspection and sounding of fittings on mains, communication pipes, and supply pipes was in the past the prime method of locating hidden wastage of water, and this method is still the only one pursued today by some water supply units. The system is inevitably inefficient and labour intensive as it does not permit concentration on areas where known waste is occurring.

A far more efficient method is by the use of "waste meters", although in fact they cannot measure actual waste, but waste plus known or estimated consumption in a mains system. Waste meters, being essentially flow meters, are not required to record the quantity passed over any period of time but to produce a diagram or record of the changing rates of flow in a main. This system optimizes the use of available skill in districts where wastage of water is known to be taking place.

The general requirements of a good waste meter are:—

(*a*) It should be possible to read low flow rates with accuracy.
(*b*) A large flow range is required because low flow readings are of vital importance. Also, meters must be able to register and pass higher flow rates under normal distribution conditions.
(*c*) The meter mechanism should be simple and trouble-free in operation under damp conditions.
(*d*) The head loss should be low at maximum flow rates.
(*e*) The meter should be easily read from ground level and suitable for installation in underground meter pits.
(*f*) The meter should be compact to enable it to be housed in a small chamber without excessive head room.

The choice of size of waste meter depends upon many factors, but a major point is the size of the area which can be readily "set-up". Another factor is that the meter is of sufficient size to pass all the water required into the area.

As in most cases where large numbers of an item are involved, standardization is a desirable feature. As far as the Manchester water supply unit is concerned the 3 in (76 mm) diameter waste meter is used as standard. This can record flows from 50–10 000 gph (225–45 000 lph) or a 1:200 range and can be used on mains up to 8 in (200 mm) diameter. The head loss at maximum flow is only about 3 ft (1 m).

There are two main types of waste meters in use:—

(i) The Deacon—cone and disk-type meters
(ii) The Kent—gate-type meter

the details of which are already known.

In large water supply units house to house inspections would take too long before any given area could be re-inspected. Waste meters are therefore regularly operated to provide records of the probable waste by districts, over the whole area, so that waste inspectors and night sounders can be directly employed following up waste where it exists. Also, as meters are running by night any underground waste is more clearly indicated than is possible by sounding, irrespective of the sophistication of the apparatus.

Waste meters provide actual rates of flow by night, which mostly represents waste, as opposed to bulk meters which record total consumption. This enables a reliable percentage waste figure to be obtained. Such figures are necessary to judge the effectiveness of waste prevention methods in the distribution system and also for comparison between one distribution area and another.

Meter Installation

The operation of waste water meters is a combined operation by waste inspectors and watermen (turncocks), and each must appreciate the others efforts. The installation of meters is also a combined effort on the part of the engineer responsible for waste prevention, the district engineer in whose area the meter is fixed, and the supply engineer.

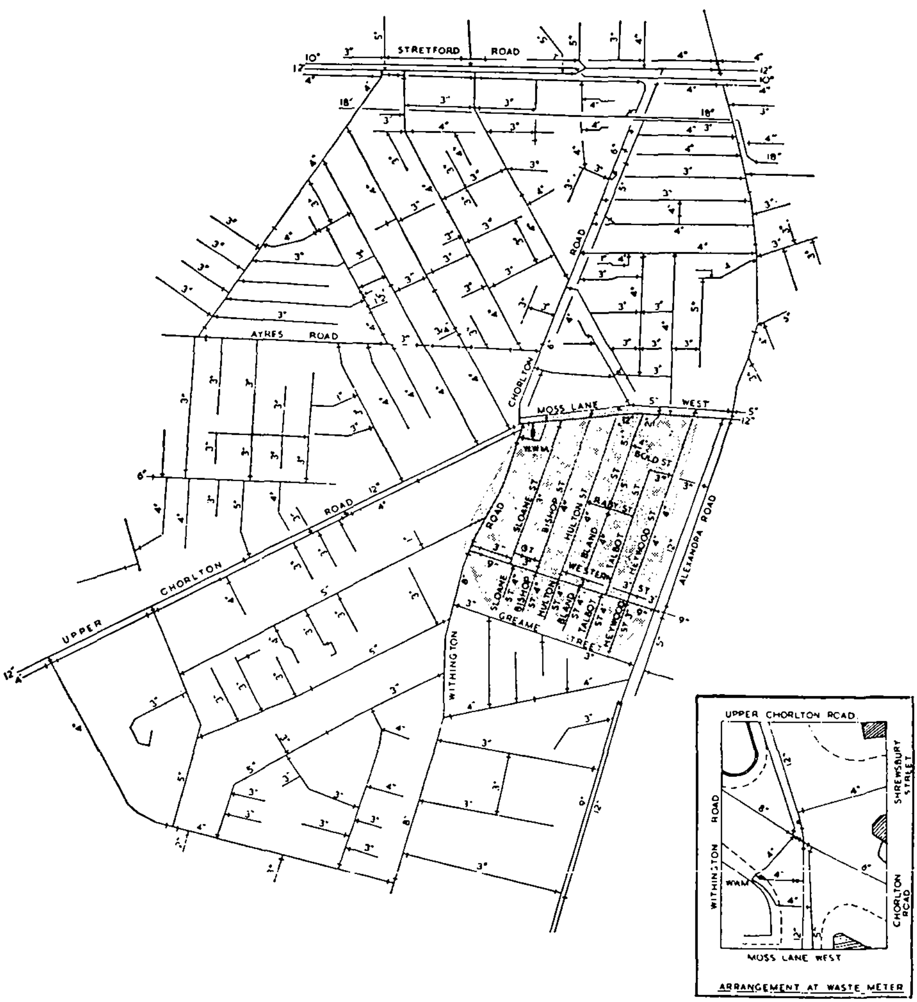


Fig. 1. Waste water meter plan of districts C23/1-3 and C28/1-4

Waste water meters are required to be installed at suitable points in a distribution network so that day and night flows (in gal/hr) can be recorded for a given reticulation of mains and services, now referred to as a waste water meter district.

Likely installation points are investigated by taking out trial holes in the footpaths or verges to find a suitable point to install a meter, usually where a large service or trunk main is connected to feed several mains radiating from a road crossing (Fig. 1). This is not always an easy matter, especially in an urban environment.

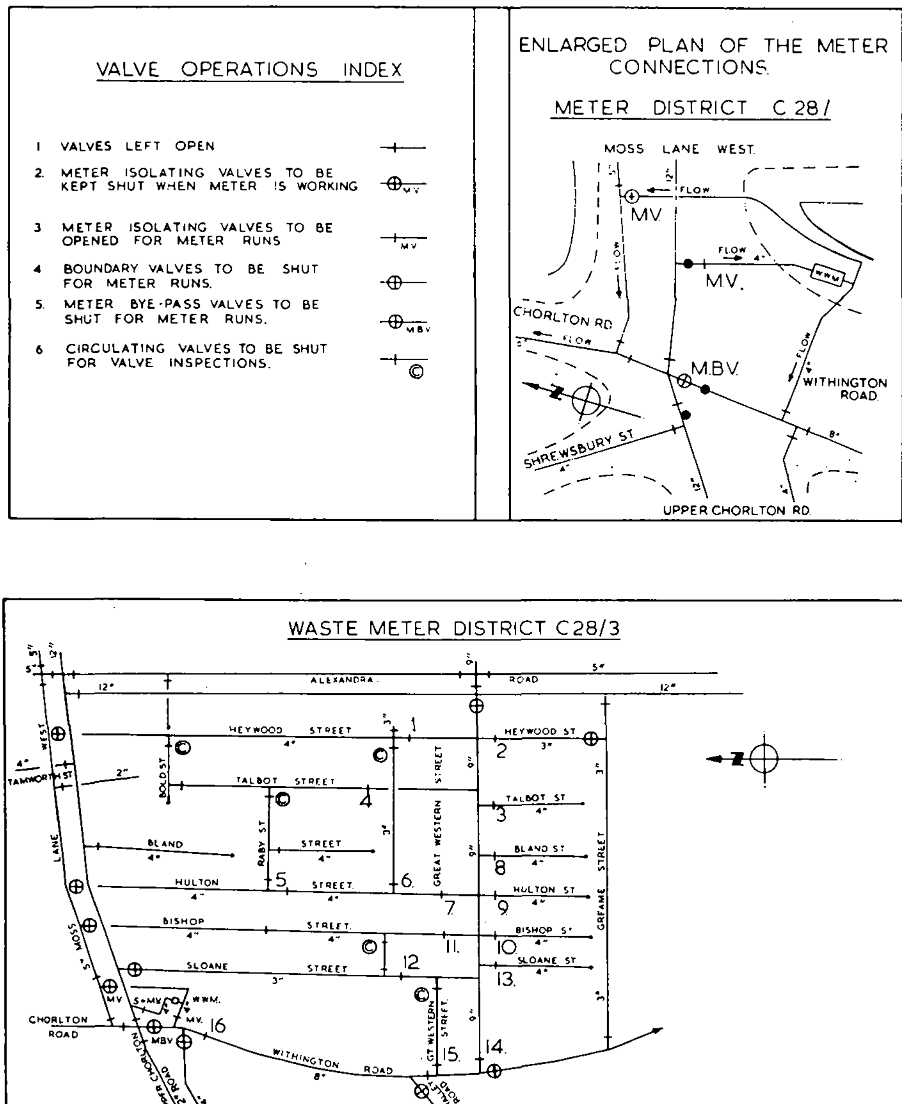


Fig. 2. Operational plan of waste water meter district C28/3

As an alternative to installing a waste meter in an underground pit, a meter can be housed in a mobile trailer (Water Research Association 1967) and connected to the mains system by flexible hose via a specially installed valve and hydrant arrangement. Whilst this eliminates the difficulty of locating a suitable position for an underground chamber and reduces the capital cost involved in installing a large number of meters in an area, the future operation of the meter area is more complicated by having to arrange transportation of the mobile unit to site each time the area is operated. In many instances it will require supervision of the unit because of vandalism and the vulnerability of the flexible hoses to damage.

The operation of this type of waste meter is undoubtedly less convenient than by fixed meter and would, in the long term, prove to be more costly because of the recurring wage charges. Also, a large number of crews and mobile units would be required at short notice after a frost period to obtain the maximum number of runs in the shortest possible time in order to locate underground defects.

Having selected such a meter point the next step is to plan a meter district, bearing in mind the type of domestic property and trade requirements, age, and size of mains and maximum pressures available. Meter districts should not overlap two or more watermen's districts because of the need for them to be called out for night runs on the meter. Each site should be selected so that the adjoining meter districts fit in to cover the whole of the mains network in due course.

Another factor that may have to be considered in a heavily built up area is the carrying capacities of the mains which under normal conditions, with all street valves open, permit water to enter the district from all parts to meet a sudden increase in demand. In Manchester, because storage for either domestic or trade use is not compulsory (although in the case of the latter much persuasion is practised) higher mains pressures are generally required and meter districts are therefore smaller than would be the case if storage on all premises were available.

It is therefore necessary to set-up each proposed meter district by trial isolation, by closing selected street valves, and feeding the district through one main which would be metered by the proposed waste water meter and then to carry out a pressure survey. From the results of the pressure survey it can be decided whether or not the district can be supplied through the proposed waste meter without causing distress to consumers.

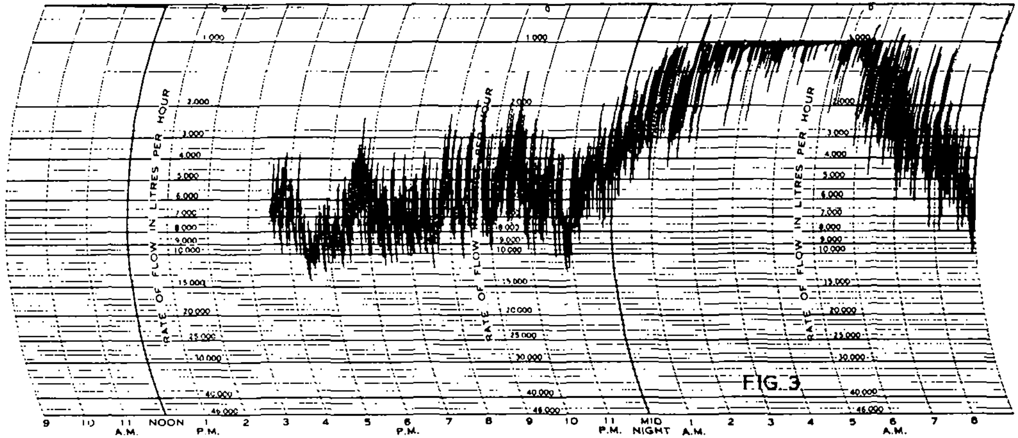
It is most important that the valves selected to be shut (known as boundary valves), are thoroughly tested to see that they are not "letting by", since a boundary valve which does not shut off properly may either let water into or out of the set-up district. Any boundary valve which lets-by must be repaired to ensure that accurate tests are obtained.

It is only after a detailed exercise of this nature that one can truly say that all the intricacies of a distribution system which has been built up over 100 years are known. All unknown cross-connexions, "left-handed" valves, etc., come to light during the survey and have to be rectified before the waste water area can be effectively set-up and operated.

The area shown in Fig. 1 was first planned as a "five-way meter", but pressure surveys showed that owing to trade consumption and the poor condition of the mains, a larger number of smaller meter districts than that originally planned were required similar to the one shaded and also enlarged in Fig. 2. The original districts gave inadequate pressure at the extremities of the areas; also the flows would have been above the maximum rating of 10 000 gph (45 000 lph) for a 3 in (76 mm) diameter waste water meter.

Finally, the meter is installed complete with isolating valves and cross-connexions, additional valves, and link-ups having been carried out on the meter districts as required.

The preparation of plans for each individual meter district is essential for the use of operating personnel, office records and the fire authority reference. The plans are not drawn to scale, as certain parts are distorted to make the detail clearer. The symbols used



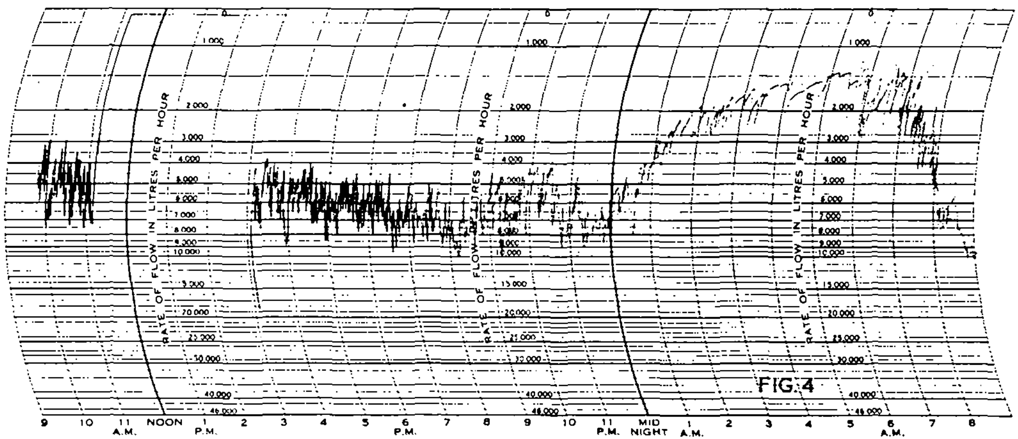


Fig. 3. Waste water meter chart—domestic area. Fig. 4. Waste water meter chart—industrial area

for valve operations are to assist the watermen to identify the particular valves in the street, apart from the numbered valves which are the waste prevention inspector's chief concern during a night valve inspection.

The numbering of plans is of considerable importance for easy reference. Manchester has adopted a system of a letter prefix followed by two numbers. The waste water district (Fig. 2) is numbered C28/3; C denotes that the meter is in the central distribution area; 28 denotes that the meter is in waterman district No. 28; and 3 denotes that it is No. 3 district of this area.

Setting up Districts

Having installed the waste water meter, it is necessary to establish the minimum night-flow characteristic for each district. This is done by means of a number of "open readings" using a 24 hr chart on the meter drum. Day and night flows are therefore incorporated in each single chart.

During the day, in a purely domestic district, the total consumption is the sum of many intermittent draw-offs, resulting in an oscillating or shaded record caused by the pen continually rising and falling over a small flow range (Fig. 3).

In a district where consumption is mostly industrial the draw-offs are usually few but large and last a long time. Consequently, the chart records are peaked or stepped (Fig. 4).

In all cases, however, the loss of water through defective fittings, pipes, etc., for all practical purposes is constant and increases the chart reading by a fixed amount.

From about 11.00 p.m. onwards the water consumption in a district decreases rapidly until a steady flow is normally reached between 1 and 5 a.m. This is the minimum night flow (MNF). In an industrial area the MNF is not as straight as in a domestic area and the lowest recorded flow may have to be obtained with the co-operation of the industry in the district by arranging for a shut down of supplies at a predetermined time for a period of, say, 15 min. This often can be arranged to coincide with a meal break or some other mutually convenient time.

Some districts contain premises which are supplied from storage cisterns, e.g. tower blocks. The refilling of these may continue for most of the night especially if the cisterns are large, the service pipes small and the pressure low. Even these can be treated as one would treat trade supply and arrange for shut-off for a predetermined period during the test.

In an average domestic district containing no large cisterns or only those in tower blocks, the night flows settle down to a fairly constant value and experienced personnel can quickly interpret charts picking out the districts which require further investigation.

When a new district is set up for the first time an initial chart is obtained and the MNF is noted. The district is then subjected to an intensive inspection for leakage on mains and services by the night sounders and supply pipes and internal fittings of each premises by day waste inspectors. During the whole of this intensive investigation the meter is continually operated so that the leakages, as they are located and repaired, can be seen to reduce the nightline. When the nightline is reduced to within the range of 150–250 gph (680–1140 lph) for a domestic area of about 750–1000 houses or flat units, the MNF is then considered from long experience to be the best which can be obtained. This flow represents both the undetectable leakage and the legitimate night usage and is in the order of ¼ gal/household/hr. All MNF above the target line is considered to be detectable waste.

Judging the seriousness of waste is not easy in a trade or combined domestic and trade district, as there may be legitimate consumption of water throughout the night. One has to find out the size of this consumption by enquiry at the trade premises. This is a relatively simple matter if the establishments are separately metered for revenue purposes. If the trade premises do not use water on certain nights the waste water meter records for these nights should be comparable with a domestic district. Positive isolation of trade premises is the only certain way of ascertaining the true result.

The comparison of MNF for a number of districts indicates that for a purely domestic district the ratio can be as low as 1:10 and in a combined domestic/trade district between 1:5 and 1:8.

Operation of Districts

The Manchester Water Supply Unit distribution area of supply covers an area of 262 sq miles (67858 ha) and contains about 2800 miles (4500 km) of mains which supply a population of 1·24 million in an estimated 424 000 houses or flats. Of the total area 88·1 per cent is waste metered through 228 meter installations comprising 597 waste meter districts.

Initially, waste meters were operated on a bi-monthly schedule but as their numbers increased this became more difficult, without substantially increasing the waste prevention staff. After a comprehensive work study operation in 1968 it was decided to run meters on a three monthly schedule. One-half of the meter districts are now planned to be run during the first month, the remainder in the second month. The third month is then available for running the meters which for some operational reason were not run as per planned schedule. This also allows time for any re-runs or special investigation to be carried out without interrupting the normal planned schedule.

Experience over many years has shown this to be a reasonable cycle of operations, although it is appreciated that waste could be gradually increasing on each district during a period of three months before it is rechecked and corrective action taken. Areas which have a bad history for leakages such as those affected by mining operations, etc., are operated more frequently. Such areas are also given special attention by the night sounders in an effort to keep the leakage within acceptable limits.

To maintain effective control over the large numbers of meter districts individual graph records of MNF obtained on each test are plotted. This enables any tendency for an upward drift in the MNF to be noted and the cause investigated. The increase may be the result of some legitimate usage or it may be undetected waste. If the latter, it is followed up by either the night sounders or by the day waste inspectors.

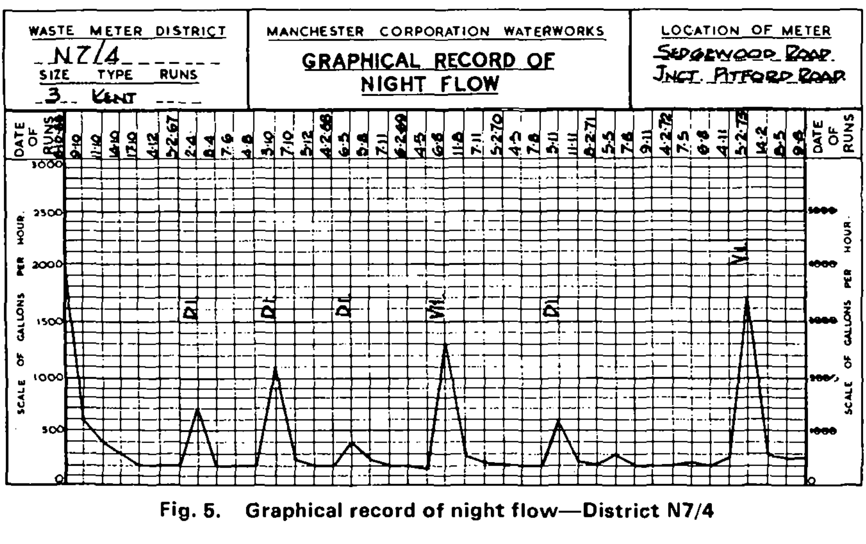


Fig. 5. Graphical record of night flow—District N7/4

A typical graphical record card from the first run on a newly set up district in October 1966 until August 1973 is illustrated in Fig. 5. This area (N7/4) represents 471 houses, 186 flats, and 80 aged persons dwellings. It consists of 2·9 miles (4·6 km) of main varying in diameter from 6 to 3 in (150–76 mm). The district covers an area of 33·5 acres (13·5 ha) and had a population of 2219 in January 1966.

When the first run was made, the MNF indicated a flow of 1900 gph (8600 lph) but this by intensive night and day investigation was reduced to about 200 gph (900 lph) in a period of 11 days. The delay was due to scheduling the repairs into the work programme and arranging for private leakages to be carried out by local plumbers. Over a period of about seven years there have been six occasions only on which it was necessary to investigate this district by either day inspection or night valve inspection and on each occasion the flow was reduced to an acceptable limit within a few days. It is acknowledged, however, that as the period prior to the run which indicated the rise in night flow was some three months, leakage could have been taking place over the whole of this period. This however unreasonably assumes that the leakage occurred the day following the previous run. On balance, in the meter districts on which leakage occurs and requires subsequent investigation it is a reasonable assumption that the high level of waste occurs for an average period of six weeks before detection and repair.

It will no doubt be noted, using this average frequency of leakage that on about every working day of the year Manchester carries out two day or night inspections and it is on this factor that the work force is balanced.

Percentage Waste and Cost of Waste Prevention

One of the major factors which makes it difficult to compare one undertaker's waste prevention performance with another is that there is no agreed method or standard of measurement. Manchester, for instance, exclude trunk mains (approximately 320 miles (514 km) within the distribution system) and aqueducts from their calculations as these are outside the scope of the present waste metering system. In calculating the 6·8 per cent waste figure the waste in each district is assessed by taking the difference in the minimum night line between that which was achieved after intensive waste detection on the setting up of the new waste meter district and which is accepted as a combination of undetectable leakage and legitimate night usage, and the current minimum night line for the district. It is interesting to note that if the whole of the water indicated by minimum night line was considered to be waste, the figure would be 11·9 per cent.

Although only 88·1 per cent of the area is covered by waste meters, the remainder is subjected to metering from small service reservoirs, small pumping zones, etc. Whilst a precise figure cannot be given for leakage in these areas, any variation in demand is quickly noted and the areas are subjected to waste inspection by either day or night inspectors. For the purpose of calculation of a waste figure the areas concerned are assumed to have a pro rata rate of leakage to that of the waste meter districts.

After the work study of the waste prevention section's activities and the introduction of a bonus incentive scheme to all inspector staff in 1968, the section has operated on a highly efficient basis and comprises:

Chief assistant engineer

1 No. Administrative assistant
2 No. Clerical assistants
1 No. Clerk/typist

1 No. Chief waste prevention inspector
1 No. Assistant waste prevention inspector
26 No. Waste prevention inspectors
6 No. Night sounders

Three light vans are used wholly by the section, these being engaged approximately half time on the fixing and removal of waste meter charts and the remainder of their time on general waste follow-up in areas not adequately served by public transport.

The cost of waste prevention is difficult to measure, as there are few water supply units which engage staff exclusively on waste prevention duties. Many waste prevention inspectors are, for instance, also required to undertake other duties such as meter reading and no doubt there are those who would suggest that even this may be considered to be a waste prevention exercise. Also, should the costs of mains repair gangs excavating and searching for a leakage be charged to waste prevention? How much of the general staffs' time receiving and dealing with telephone and personal calls from members of the public concerning waste should be charged? The list which we could consider and no doubt make a case for part charging to waste prevention is almost endless. Comparison between water supply units as to their relative costs of waste prevention is therefore difficult.

The Manchester water supply unit, however, does operate a section whose exclusive duty is that of waste prevention and the overall cost of salaries and wages including bonus, etc., is readily costed. This, suitably adjusted to include vehicles and other operational costs, totalled some £82 000 in 1972–3 and represented about 1 per cent of annual revenue.

SYSTEMS MONITORING

Waste Detection by Continuous Metering and Water Accounting

Most existing methods of waste detection rely upon some form of spot check. This is so whether it is leakage that is being traced by means of night sounding or district metering, or extravagant use, by means of inspection of consumers' fittings and factory processes. The results of such methods, interpreted in the light of particular circumstances, are an effective means of reducing leakage and undue consumption. There are, however, a number of disadvantages.

There is inevitably a time lag between the start of any leakage or of any extravagant use of water and its detection, as it is normally possible to inspect each district or major consumer only at intervals of weeks if not months. Without any sure knowledge that leakage or misuse is occurring in any particular area inspections have to be made even though there might well be none. It is difficult to use these established means of inspection on the trunk main system within an undertaking. Most trunk mains cannot be taken out of service at frequent intervals for any necessary testing, and reliance must necessarily be placed upon metering flows under normal operating conditions. Even if bulk meters exist at each end of a trunk main, meter errors can be such that all but the very largest of leaks is completely masked.

In any defined portion of an area of supply the formula $S = O + M + C + R + L$ must apply where S is the sum of all of the inputs into the zone, O is the sum of all the outflows from the zone, M the sum of all the metered supplies, C the sum of all the unmetered demands, R the increase of stock in any service reservoir within the zone, and L is the leakage from the apparatus within the zone.

Extravagant use of water by a metered consumer would be included in the figure M but is capable of being monitored from time to time and hopefully can be reduced progressively. Likewise, misuse of water by the domestic consumer is included in the figure C but can be minimized through public relations, education, and inspection methods.

The detection of leakage from mains fittings is a problem which has for long concerned the water industry. It follows, however, that if it were possible to measure all the parameters S, O, M, C, and R for any part of the undertaker's area of supply, then the leakage

L is known. It is in this context that continuous metering and water accounting can prove helpful.

Water meters can be inaccurate, especially if they are badly maintained. For any one zone taken in isolation, the value derived for L might be highly suspect but there is no ready means of testing its validity. If, however, a number of adjacent but sensibly similar zones are metered simultaneously, then many meter readings can be used in both the positive and the negative senses, and any substantial meter error shows in highly improbable comparisons being derived. The concept of overall meter balancing precludes the unquestioning acceptance of suspect values and rational explanations must be found.

The task of acquiring large numbers of meter readings is a formidable one. Many water supply units however are now developing central control systems, and it is commonly the case that all quantities being put into supply from source works are measured and transmitted to the central point as a matter of routine. Major bulk transfers from one zone to another are also frequently metered with integrated quantities being available either locally or at the central control point. Reservoir stocks are likewise normally closely monitored. In many cases such figures are available at short intervals of time (typically at 1 hr or ½ hr). Even if no attempt is made to measure quantities M and C, nevertheless a continual calculation of L from the modified formula $L = S - O - R$ can still give a useful guide to the overall demand (including leakage) within each definable zone and can indicate whether there is any substantial change in demand pattern meriting further detailed examination. Such zones might extend for many square miles and indeed could be as large as many of the pre-1974 water undertakers. As a first check on demand fluctuations, such derived figures can in themselves be most enlightening and useful. One water supply company regularly uses such figures, particularly during frost conditions, to monitor the advance of a thaw. However, if the zone concerned is too large then the use of any values of L derived becomes limited. The existence of high demand is known but the location of the demand is not sufficiently defined. The same concept can be applied to smaller zones of perhaps only a few hundred houses, a small village, or even a length of principal trunk main.

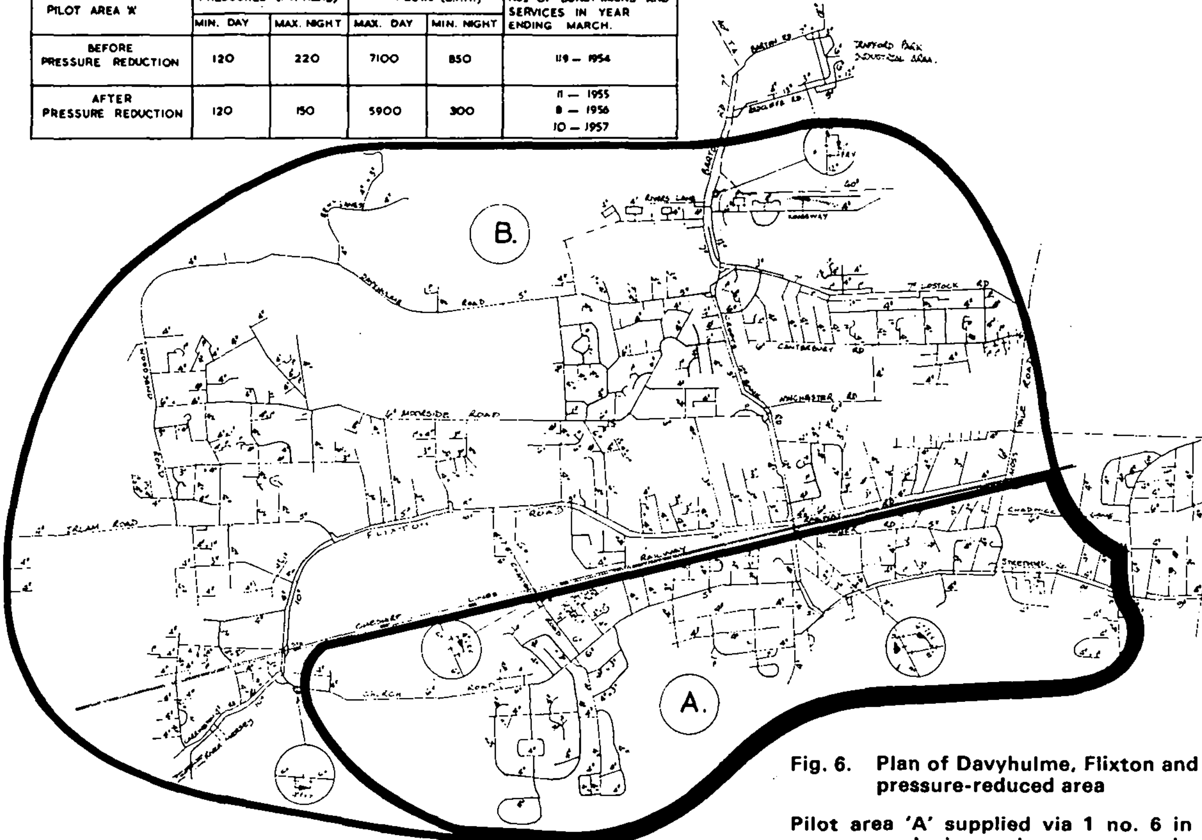
If values for M can be obtained, part of the demand is directly accounted for. This will mean that trade meters of the larger consumers will have to be read much more frequently than the typical three monthly interval. In the case of smaller industrial consumers, however, quarterly figures might be averaged to give an acceptable approximation of consumption over smaller intervals of time. Values for C could be assessed according to the type and condition of housing within a zone and the observed domestic demand pattern.

The more frequently the formula can be applied, the more closely the zone is monitored. In practice a time interval must be chosen which can relate to manpower availability, to the type of area concerned, and to the ability of the undertaking to process the many meter readings. An interval of a week or a month might be considered reasonable. As experience is gained refinements can be made to the assumed values of C. In some cases values of M will be found to be highly suspect and might warrant detailed investigation. Faulty meters might be indicated if the values for L for adjacent zones are widely dissimilar without other valid explanation.

By monitoring those zones with an apparently high L over a number of computation cycles and by eliminating many influencing factors, it becomes possible to reach the point at which it can be fairly assumed that there is a significant genuine leakage, at which stage the conventional methods of leak detection in the field can be adopted.

Continuous metering and water accounting requires a considerable amount of meter reader time, clerical effort and (if available) computer programming and run time. But it does ensure that inspectors and mains repair squads are used only in those areas where

PILOT AREA 'A'	PRESSURES (FT. HEAD)		FLOWS (G.P.H.)		No's OF BURST MAINS AND SERVICES IN YEAR ENDING MARCH.
	MIN. DAY	MAX. NIGHT	MAX. DAY	MIN. NIGHT	
BEFORE PRESSURE REDUCTION	120	220	7100	850	119 – 1954
AFTER PRESSURE REDUCTION	120	150	5900	300	11 – 1955 8 – 1956 10 – 1957



Pilot pressure reduced area marked 'A'
Final pressure reduced area marked 'B'

Fig. 6. Plan of Davyhulme, Flixton and Urmston pressure-reduced area

Pilot area 'A' supplied via 1 no. 6 in and 2 no. 4 in pressure-reducing valves commencing March 1954; whole area 'A' and 'B' supplied via 1 no. 12 in pressure-reducing valve commencing August 1959

they are likely to find significant leakage, and avoids the largely unproductive work involved in random blanket searches of an area of supply.

One water supply company has been developing this form of continuous metering and water accounting for some months and makes use of central control telemetered information, weekly meter readings for the larger consumers, quarterly meter readings for the smaller industries, and available capacity on its computer. The whole of the area of supply is divided into some 160 separate zones. The values of L for each of the individual zones are produced and compared week by week. Refinements are made progressively which tend to make L values more realistic in absolute terms, and ideally L should tend to zero as leakage is found and eliminated.

Experience to date has already demonstrated that significant leakage exists within the system, including the trunk mains, where no loss had hitherto been suspected. One individual, and unsuspected, loss of the order of 0·3 mgd from a drawn joint on a trunk main has been found and another leak of similar magnitude is suspected and is being traced. Leakages of this magnitude can soon justify the expenditure incurred on acquiring and processing the necessary data, and could begin to have a significant influence on the timing of developing additional resources.

REDUCTION OF WASTE BY USE OF PRESSURE-REDUCING VALVES

Urban Areas

In many distribution systems, particularly those deriving supplies from upland gravity sources, there are low lying zones where pressures may be excessively high. Such areas will usually exhibit characteristics of relatively high per capita day consumption and high minimum night flow lines. Additionally, the incidence of bursts and leakages will be higher than in areas subjected to lesser pressures.

This is particularly true of areas where supply pipes and plumbing are predominantly of lead, probably in excess of 40 years old.

Both consumptions and incidence of bursts are directly related to pressure levels.

Unnecessarily high consumptions will arise under high pressure conditions merely by lhe inability of a user to control the flow to the required amount. Ball valves frequently teak, particularly under night head conditions, and defective taps will waste more. Auto-flush cisterns will operate more frequently than necessary, and the amount passed by any undetected underground leakage will be correspondingly higher.

The incidence of bursts and high consumptions can be dramatically reduced in suitable areas by the installation of pressure-reducing valves, set at such outlet pressure levels as to be consistent with maintenance of adequate supplies at the highest points of the zone. There are other associated benefits such as reduction in noise levels in pipework and cisterns and reduction, or elimination, of reverberation and concussion in plumbing systems.

In many instances pressure-reducing valves can be so adjusted that their effect is merely to trim the high night pressures to approximately the same level as daytime pressures, which remain virtually unchanged.

An investigation was carried out in 1954 in a pilot area shown 'A' in Fig. 6. This particular area had unusual characteristics in the magnitude of the night/day pressure range which was basically a reflection of the Thirlmere aqueduct supply conditions at that time.

Spring-loaded-type pressure-reducing valves were fitted on to three feeds into the area. These valves are designed for conditions of widely varying inlet pressures and flows, but are capable of delivering substantially constant outlet pressures. The valves are opened by adjusting the spring load and are closed by reduced pressure acting against the top piston

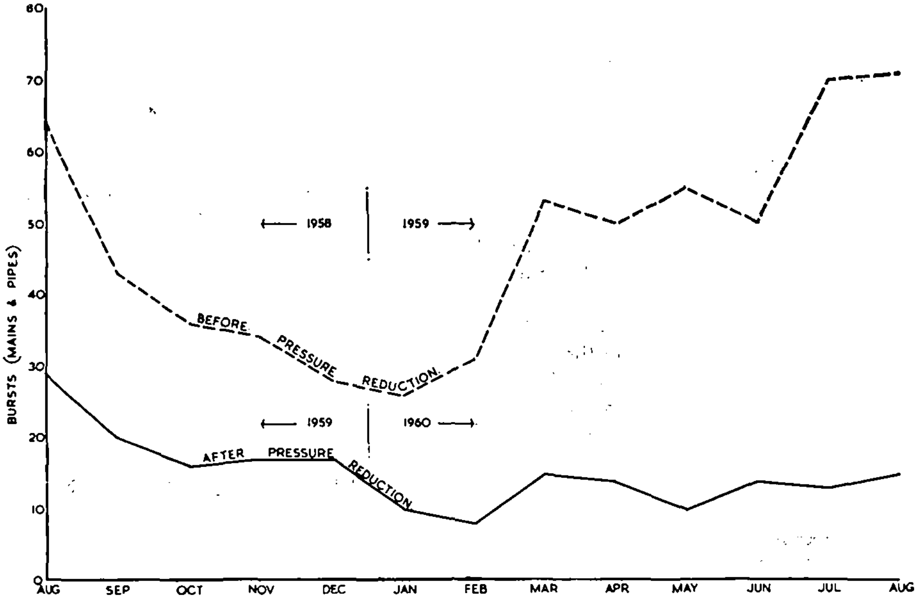


Fig. 7. Urmston, Flixton and Davyhulme 12 in pressure-reducing valve zone—comparison of incidence of bursts before and after pressure reduction

so that under working conditions the balance of those two forces determines the amount of valve opening for the required reduced pressure and flow. The main valve is counterbalanced by a second piston which ensures that the pressure setting at "no flow" is

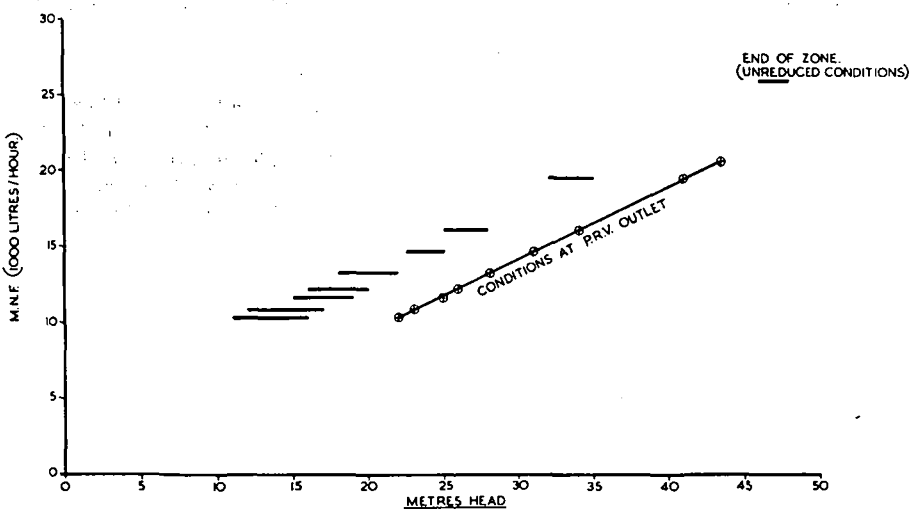


Fig. 8. Effect of pressure reduction in 28 per cent demolished redevelopment zone

unaffected by inlet pressure changes. Presure regulation is claimed to be within ±3 per cent of the setting.

In the year prior to pressure reduction in the pilot zone, bursts on Corporation mains and services totalled 119. After pressure reduction, for a three-year period the aggregate of all bursts was 29.

Flows into the area as recorded on waste water meters were reduced by about 17 per cent during the day and by 65 per cent at night. This was achieved without any deterioration in day time pressures but merely as a result of trimming excessive night heads.

In 1959 pilot area 'A' was incorporated into a much larger area fed through a single 12 in pressure-reducing valve of the weight-loaded type. The three original valves were removed. Prior to commissioning of the 12 in valve the aggregate number of Corporation repairable bursts annually within the combined area 'A' and 'B' was 611. After commissioning of the valve, during the following year, the aggregate number of bursts fell to 198. Fig. 7 shows the comparative effect on a monthly basis.

Assuming that the reduction in numbers of bursts as a direct result of the installation of the valve was about 400, the saving in repair costs alone during the first year is estimated to have been about £8000. Although analyses of bursts in subsequent years were unfortunately not carried out, the area ceased to be troublesome from this time.

A further factor which was not evaluated but which would also be relevant is the number of bursts on private pipes maintainable by the owners. The effect in this sector was no doubt equally significant.

The full area 'A' and 'B' of Fig. 6 was fully metered through 27 waste meter districts. The aggregate minimum night flow of the 27 districts before pressure control was 7050 gal/hr (9 l/sec) and after pressure reduction the minimum was reduced to 4850 gal/hr (6 l/sec) or by about 31 per cent.

Redevelopment Areas

Most large authorities involved in the redevelopment of slum areas are faced with the problem of continuous waste during the redevelopment period. Full redevelopment of an area from the time of declaration, through the various stages of demolition to a completely new housing system can occupy as long as three years.

It is normally not possible for the water authority to cut off the mains reticulation system at the outset by sealing at the site boundaries, because of the need to maintain supplies to occupied properties awaiting demolition, necessitating the maintenance of mains which would otherwise be terminated.

Inevitably, extensive waste must occur, usually from open-ended redundant services, vandalism, and theft of lead piping from empty premises. In such circumstances it is not economically viable to repair or cut off individual services or common pipes if within a few months the whole area will be abandoned. However, in view of the massive waste which is involved if no action is taken, redevelopment areas must receive special attention from the waste inspection service. In the year 1972–73 a total of 5329 redundant services were sealed at open ends on redevelopment sites in Manchester.

A number of sites in various stages of redevelopment were selected in an attempt to form an appreciation of the pattern of waste as measured through existing or temporarily installed waste meters. The results indicated that waste levels peaked when an area was less than 50 per cent demolished, gradually falling away to acceptable levels only when fully redeveloped. At the worst stage as much as 80 per cent of the water entering the area was found to be going to waste. The results in the areas tested are shown in Table I, p. 114.

TABLE I. REDEVELOPMENT AREAS: ZONE FLOWS AT VARIOUS STAGES OF DEVELOPMENT

Redevelopment area	Stage of demolition	Average daily flow, l/hr	MNF, l/hr	Flow ratio night/day
Hillier Street	CPO	32 000	10 000	1–3·2
Lees Street	CPO	34 000	7500	1–4·5
Princess Street	CPO	40 000	26 000	1–1·5
Palmerston Street . .	CPO	48 000	29 000	1–1·6
Oldham Street	28% demolished	32 000	26 000	1–1·2
Middlewood Street . .	50% „	20 000	14 000	1–1·4
Middlewood Street . .	60% „	23 000	15 900	1–1·4
Grey Street	95% „	26 000	3000	1–8·7
Brunswick Street . .	Development complete	23 000	2000	1–11·5
Norcott Walk	„	13 000	1000	1–13·0
Sedgewood Road (*a*) . .	„	28 000	2300	1–12·2
Sedgewood Road (*b*) . .	„	31 000	2000	1–15·5
Jackson Crescent . .	„	24 000	1900	1–12·6

CPO indicates Compulsory Purchase Order pronounced—Properties substantially vacated but no demolition.

It was decided to investigate the effect of fixing a pressure-reducing valve at a redevelopment site perimeter operated in series with a Kent waste water meter to establish what reduction in waste was possible whilst maintaining minimum supplies to occupied properties. The area under examination was about 28 per cent demolished at the time and was 21·4 acres (8·65 ha) in area. Prior to the commissioning of the valve it was established by waste meter that the minimum night flow into the area was 6700 gal/hr (30 500 l/hr) at an inlet pressure varying between 151 and 158 ft head (46 and 48 m).

After installation of the pressure-reducing valve the pressure was gradually decreased in steps of about 10 ft (3 m) head and then in decrements of 5 ft (1·5 m) head, a waste meter run being carried out on each occasion. It was found that the minimum acceptable end of zone pressure consistent with maintenance of supplies was 36 to 53 ft head (11 to 16 m). At this pressure the minimum night flow was reduced to 2290 gph (10 500 l/hr), representing a reduction of about 65 per cent. The effect of the progressive pressure reduction is indicated in Fig. 8.

The exercise indicated the very high levels of waste occurring in redevelopment areas and clearly showed that its extent depended primarily on the stage of redevelopment reached, the pressure supplied into the zone, and the period occupied for full redevelopment to be completed.

At the time of the tests, about 1780 acres (720 ha) of land within the City were in various stages of redevelopment. The aggregate waste in these areas through the whole cycle from compulsory purchase to full redevelopment is clearly of large proportions, but it can be significantly reduced by the use of the pressure-reducing valves wherever surplus pressure is available.

In the final analysis it is fortunate that the situation is eventually self-rectifying.

CONCLUSIONS

The introduction of a waste-water scheme represents perhaps one of the greatest economies a water authority can make. This is so whether the scheme is large and comprehensive, as in the case of large urban areas, or comprises a few meters for checking district consumption, as for a scattered rural area.

The initial cost of the meters and their installation is negligible when compared with the value of the water saved during the course of a few years.

Where large water supply units are concerned the advantages of combining both a waste water scheme and a system for monitoring trunk mains is obvious—such a combination would provide comprehensive waste control over the whole of the unit.

Trained staff are of course necessary to get the best out of any waste prevention scheme, both for its operation and for record keeping. Such facilities which are now offered under the National Water Council go a long way to fulfilling the staff requirements for training.

ACKNOWLEDGMENTS

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DISCUSSION

Author's Introduction

Mr. J. Reid, in introducing the paper, said that it was exactly 100 years ago that George Frederick Deacon—the Liverpool water engineer—gave a paper on waste systems to the Institution of Civil Engineers during their session 1874/75. It would, therefore, be seen that concern regarding waste and the methods that could be used to combat it was uppermost in the minds of the engineer of that day.

They, however, obviously considered waste of water to be a much more serious offence than we do to-day. This was illustrated by a clause in an Act of that date which inflicted a £5 penalty for the "wilful waste of water". This represented about £100 at to-day's costs!

Just to acquaint you with some facts from that paper of 100 years ago, Liverpool's consumption of water, exclusive of trade, in an area of some 60 sq miles where there was a constant supply laid on was quoted as 33·5 ghd. Deacon went on to give details of the outcome of setting up his first waste metered area in Liverpool serving some 7800 people. This indicated that between 1.00 and 4.00 a.m., the period of minimum flow, the consumption was 29·4 ghd. From this he deduced that this was waste and that the *actual* consumption was only in the region of 4 ghd.

Reference was made by Frederick La Trobe Bateman, another eminent Engineer who designed and built many waterworks—notably that of Manchester—who also attended the meeting and quoted Manchester's consumption at that time as being 35 ghd and Norwich's as 40 ghd (both figures being exclusive of trade consumption).

After a waste prevention drive, presumably by a house-to-house inspection as meters had not been installed outside Liverpool, the domestic demand by both cities was reputed to have been reduced to 14 ghd.

The water engineer for Glasgow (a Mr. Gale) was quoted as saying that his minimum night flow from Loch Katrine was 22 mgd. After an intensive waste detection and prevention drive, the consumption was reduced to 13 mgd.

The present author was not suggesting that the same saving on domestic consumption could be achieved to-day, but he earnestly felt that a worthwhile saving was undoubtedly possible, and he referred to the Minister's opening remarks when he said that a curtailment in the waste of water of 10 per cent would save £400 million a year.

Waste detection and prevention work was, unfortunately, a "Cinderella" in that the majority of water units did not have inspectors who specialized in this type of work. It was accepted that, where inspectors carried out several jobs within their broad banding grade and there was pressure for one reason or another to short-circuit the work-load, the job which was sacrificed was inariably that of waste detection and prevention.

This was an attitude which had grown up and was one which must be stopped by rigorous action by management if we were to achieve an overall acceptable waste figure. Mr. Speed, in his opening remarks to Mr. Barrett's paper, stated that specialist waste inspectors were essential.

There were ways of saving water other than by the direct pursuit of waste from leakages. He had illustrated in the paper savings both in water and in financial terms which could be achieved by reducing the pressure in a distribution system to the accepted minimum.

In gravity supply areas the pressure could vary widely from day to night due to demand on the system, and a worthwhile saving could be achieved by reducing the high night pressure to that of the day.

Another source of waste with which we were all familiar was that which occurred during large-scale redevelopment in towns and cities. From test meters on such sites the consumption per head per day was reduced to about 20–22 gal after redevelopment.

In conclusion, he reiterated his earlier comment that a large reduction in water now being wasted through leakage could be saved by management continuing to drive home that waste detection and elimination was something which mattered and which could not be discarded whenever staff difficulties, holidays, etc., occurred.

[The author showed a number of slides in introducing his paper, but these have not been reproduced.]

Verbal Discussion

Mr. F. Whitehead (North West Water Authority), in opening the discussion, said that previous speakers had questioned the basis of calculation of a percentage waste figure and had rightly pointed out that it all depended on what was established as a reference datum in the first place. The author stated that the minimum night flow lines in Manchester were initially established after correction of all discovered waste. Flows above this line were then regarded as detectable waste and flows below were assumed to be legitimate usage.

It should be made clear that if on any subsequent run, a lower MNF line were to be obtained, this would become the new datum and so revision of MNF lines was a continuous process. However, it must be accepted that conventional waste metering had limitations inasmuch as it was not normally possible to include trunk or semi-trunk mains say above 8 in diameter.

The second part of the paper dealing with systems monitoring appeared to offer hope of "bridging the gap", although he personally had some reservations as to its validity in a very large and complex zone supplying millions of gallons per day, bearing in mind the notorious inaccuracies of large bulk meters and the difficulties of ever achieving 100 per cent meter accuracy and therefore balance. Perhaps the author would amplify.

He had been particularly impressed by the pressure-reduction method of minimizing waste. A further area had recently been set up in Manchester comprising some 3·3 sq miles of typical urban development of about 15 000 properties. This area was now fed via five 6 in pressure-reducing valves, which had effectively reduced pressures by about 150 ft head, leaving residual pressures varying between 140 and 160 ft head. Although the zone had been operational for only the past fortnight, the initial effects had been most encouraging. Prior to pressure reduction, the area averaged 24 bursts per month, including both mains and communication pipes. Since pressure reduction only four Authority bursts had occurred. The number of private leakages reported had reduced from an average of 20 per week to only one in the first week of pressure reduction.

There had not yet been sufficient time to evaluate the effect on zone consumptions and waste, but the full picture would emerge as routine waste meter runs continued.

The cost of installation of the PRVs was in the region of £2500, which would be rapidly recovered in repair savings quite apart from the consumption saving expected. The savings in the private sector would no doubt be equally significant.

Pressure reduction as a method of controlling consumptions and waste would be increasingly adopted by all distribution engineers having zones where pressures were in excess of requirements, and in this context he suggested that 100 ft head was adequate for all normal purposes. He realized that this could be heresy to some industrialists who might at present enjoy Class I conditions for their sprinkler installations, but there was no duty on a water authority to provide or continue supplies at pressures in excess of normal domestic needs, particularly when it was very costly to do so. He asked for the author's comments on this point.

Mr. A. Edkins (North West Water Authority) said that one method of waste monitoring not mentioned in the paper which he himself had operated had been in the form of annual area check. In this instance a waste system was being installed but not all waste districts had been completed. It was in an area where all supplies were obtained from boreholes. On a certain Saturday night each year all pumping stations were shut down around midnight and all zone valves were closed. The water levels in all water towers and service reservoirs were measured at half hourly intervals from 1 to 4 a.m. on Sunday morning. From this minimum flows were obtained for each of the distribution zones and over a period of years useful trends could be established. Whilst this was no real substitute for the proper waste detection system, it could highlight problem zones and provide help to monitor waste detection works in the early years of a system. It also helped to indicate the areas where waste work could be usefully carried out. He invited the author's comments.

He referred to p. 103 of the paper and the question of supervision of waste trailers. In West Suffolk, which was basically a rural area, he was worried about the prospect of vandalism on waste trailers. However, in eight years in that area it was not to prove a problem.

On p. 105 comments were made about the times available for waste runs. Unfortunately, with the modern trend of living, times when runs could effectively be made were getting shorter.

On p. 107 one felt the author was apologizing for the delay in getting bursts repaired in 11 days! He should be congratulated in getting them completed so quickly. He agreed with earlier comments that we should consider building up our own work force to enable us to carry out minor repairs. He asked for the author's views on a suggestion put to him recently that the RWA should undertake improvement work and also open a water shop!

Finally, he endorsed the views expressed in earlier papers regarding waste detection staff. One would only get the best out of such teams if they were engaged on waste detection work full time.

Mr. J. A. Tyldesley (Severn-Trent Water Authority) referred to the author's suggestion (p. 99) that the average loss due to waste throughout the country might be of the order of 20 to 25 per cent, which emphasized how good the Manchester figure of 6·8 per cent really was—but it had required a great deal of effort over many years.

It was quite clear from all that had been said by earlier speakers that there was no standard way in which waste was defined. Even when defined, as demonstrated by Mr. Giles, it was generally difficult physically, or almost impossible, to arrive at a proper figure.

The DOE had asked in their annual return for the "estimated percentage of total supply lost by leakage". The quarterly return of the business statistics office asked for "the estimated wastage from public mains as a percentage of the quantity supplied to the consumers". This was a different requirement on two counts and he wondered if they really wanted the figure requested. In any case he could not give them a figure and this got him involved in correspondence. He gave them the measured night line between 1 and 2 a.m., corrected both by the readings of the larger metered consumers and by changes in service reservoir levels. This came to about 37 per cent of the average daily quantity supplied at the time of the test. The test, which involved a lot of men, was repeated every six months. He used to think that his area's waste was perhaps 20 to 25 per cent without any facts to prove it, except the 37 per cent figure mentioned earlier. It was just not possible to measure the legitimate domestic use in the early hours or the other flows including urinal flushing at pubs and all the small metered trade supplies.

He hoped that the waste figures already given to official bodies would not be used in any economic exercises until the people using the figures appreciated the difficulties and acknowledged that many of the figures might be a long way from the truth, and perhaps no more than wishful thinking.

It would be helpful if the Symposium and the deliberations of the Working Party could produce a definition of waste based on the net night line, with working rules that all could follow without excessive expenditure. This would enable fresh figures of waste to be obtained by the new water authorities or divisions on a uniform basis. It might then be possible to have the legislation making it a duty to supply these figures, which Mrs. Rees asked about in her question, to prove that one's house was in reasonable order or otherwise.

Mr. D. E. Burgess (East Worcestershire Waterworks Company) said that he agreed with much that the author had said about systems monitoring, and that some form of metering was necessary in order to measure the performance of waste prevention effort.

We were in an age of change and rapid technological improvements. The author mentioned the time lag between the start of leakage and its detection, because of the interval between inspections, and then referred to Sunderland and South Shields Company's continuous metering system.

With a proper computer-based tele-control system, based on monitoring unmanned source stations and reservoirs, it was possible to know instantaneously at any time at the press of a button, the demand in the area or zone. There was such a system functioning at East Worcestershire—still subject to further development—but installed primarily to *control* and monitor unmanned source stations, boosters, reservoirs and, in addition, to compute the most economical arrangement of taking electricity from the grid or Diesel alternators, given variations in cost of electricity and fuel and different supply conditions. The measurement of daily and instantaneous zone demands was a spin off and the system for monitoring waste was not yet complete. Eventually, it was hoped to have the district meters and the major trade consumers incorporated in the telemetry scheme.

One of the problems with a waste metering system as described in the paper was that one could never be sure what the absolute level of waste was, particularly in old urban areas, where closed valves let by. The closing of valves to permit one point of entry for water through a waste meter changed conditions by reducing pressures, thus reducing waste, and encouraged water to pass valves from the surrounding and higher pressure areas, thus reducing the measured minimum night flow. That system was not being tested under normal operating conditions.

Now if the system was monitored with district meters linked back to a tele-control centre, one could measure the minimum night flow in each district under normal conditions. Allowance could be made for trade use, etc., as required, in the manner described in the paper.

This system reduced the manpower requirement and would be an attractive proposition to those undertakers who could not get manpower because of competition from more lucrative industries.

The advantage of instantaneous reading was that even with zones with a minimum night flow of 8000 gph, it was possible to detect a 3 in burst virtually as it occurred. This was of particular value when a burst occurred under the river Avon.

Whereas conventional waste metering had its place and would be complementary to the scheme described, anyone about to install a waste monitoring scheme should first consider the modern equipment available and the social implications on employees working unsocial hours.

Mr. E. A. S. Gadsby (South Staffordshire Waterworks Company) said that the author had struck a nerve in referring to single remaining properties standing during the demolition phase of an area redevelopment scheme. This had been a regular sight in Birmingham and the Black Country, particularly during the 1960s. More recently there had been a trend towards refurbishing of older properties causing a greater draw on already ageing mains instead of providing the opportunity for mains system renewal derived from redevelopment.

For a number of reasons, including the life extension of mains in the above circumstances, his own undertaking were currently scraping and relining certain cast iron mains with concrete or bitumen where the barrel was sound enough to justify such action.

It was difficult to evaluate the contribution this work was having in reducing waste, although the incidence of bursts in these areas had dropped, despite, in some cases, higher pressures. Did the author have any evidence of the reduction of waste, from leaks or bursts, as a result of his experience with scraping and relining old mains?

Mr. H. J. Giles (National Water Council) referred to the impressive savings resulting from the use of pressure reducing valves in Manchester. However, improvements could be made to the normal method of operation of PRVs where there was a short control loop so that the valve control was maintained at a fixed level pressure immediately downstream of the valve.

Fig. 9, below, showed the simple case of a district supplied through a single feed, which was controlled by a PRV with a short control loop. The valve was adjusted so that the control pressure *b* immediately at the valve was such that the pressure gradient through this system at the time of maximum demand provided an adequate pressure *d* at the critical point in the system. At the time of minimum flow the pressure at the valve would be maintained but reduced headlosses in the system would allow the pressures to rise to a pressure gradient *bc*. One possible improvement to this system would be to use a control loop from the critical point to the valve, thereby allowing the outlet pressure at the critical point *c* to remain constant. This was shown in the lower part of Fig. 9.

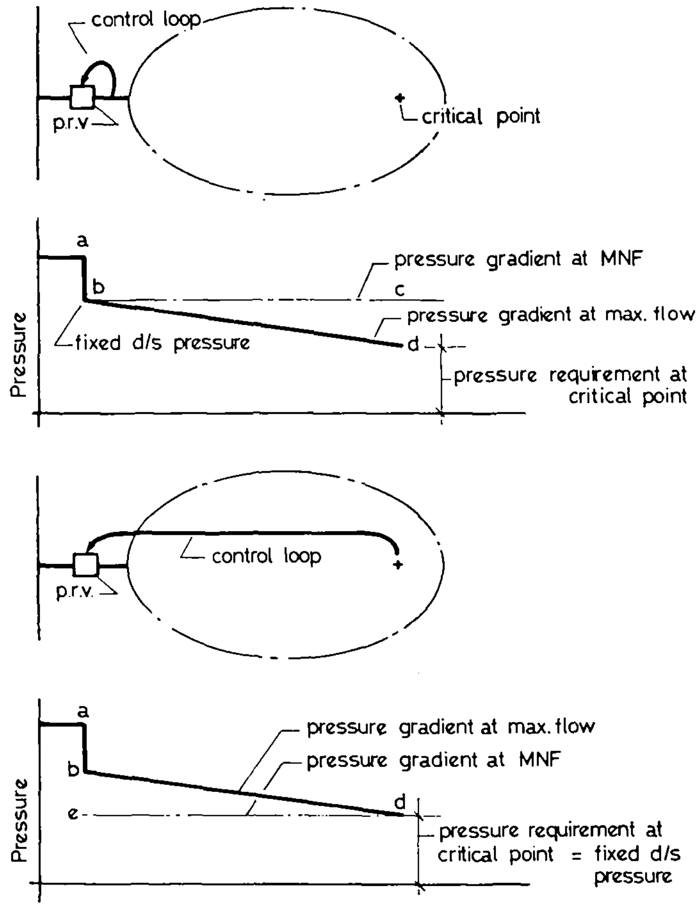

Fig. 9. Normal and suggested operation of PRVs

The pressure gradient *bd* at the time of maximum flow would be similar to that in the previous situation, but at the time of minimum flow the pressure gradient would become *de*. The effect of this would be a reduction in pressure throughout the system as could be seen by comparing line *bc* in the upper part of Fig. 9 with line *de* in the lower portion of the illustration. Such an approach would be more complex in practice as there might be several critical points and several feeds to the district, but the use of telemetry and an analogue control mechanism could make this a possible approach to pressure control especially in new installations.

Mr. J. N. M. Hutton (Hydrotronic (Jersey) Ltd.) referred to the large areas of redevelopment where the mains network had to remain charged to supply only a few properties. He had recently encountered this problem and found that one way of dealing with the risk of leakage going undetected was to restrict the flow of water into the area. This was done by closing the boundary valves and supplying the area through a small diameter bypass round one or two of the valves. The bypass was sized just large enough to supply the normal demand of the few properties still in use and therefore if leakage developed to any appreciable extent the drop in pressure would be reported quickly by the consumers.

Mr. S. J. Phipps (Severn-Trent Water Authority) said that leak detection in the end was always a "man" operation and not a "mechanical" one, no matter how sophisticated the techniques became. The result of even the simplest operation to the majority of personnel involved appeared negative. There was no physical or visual sign of achievement.

Whilst the NWC training division could give basic training, the good inspector would take years to acquire the correct attitude of mind.

Had the author considered at any time the labour implications involved in a drastic curtailment of waste detection operations as a short-term measure, followed by an attempt to re-establish an efficient waste inspection section? Furthermore, did the author consider "the man before the job"?

Mr. P. Hothersall (Anglian Water Authority) endorsed the previous speaker's views concerning the necessity for training of waste inspectors. It was necessary to predetermine the level of waste detection activity for any particular undertaking, and adhere to this level fairly closely; it was impracticable to switch a waste detection programme on and off.

He asked for the author's views on the desirability of appointing plumbing inspectors as distinct from normal waste inspectors. Large commercial organizations which now operated in this field made it desirable for plumbing inspectors to be of technician standard if they were to be in a position to speak authoritatively on plumbing installations and assert the requisite authority.

Mr. R. C. Stoddart (Sunderland and South Shields Water Company), who was responsible for the continuous metering and water accounting system referred to by the author, highlighted some of the philosophy behind the scheme. The basic principle was that of knowing as far as practicable the destination and use of all water produced.

The use of a computer permitted all meter readings available, regardless of department of origin or of the purpose for which they were taken initially, to be processed on a routine basis without any staff involvement to produce a print-out every week giving for all areas of the Company (including trunk mains) the quantity supplied, the apparent consumption per head, and the estimated leakage. The print-out made it clear where there was significant leakage and, equally important, where there was no leakage of consequence. It was at this stage that waste location in the field took over, with the knowledge that somewhere in the area being tackled there was serious leakage.

Estimated leakage was calculated by taking consumption per head in the best areas (about 25 gpd) and assuming other areas should be no worse. This method had the advantage of assessing leakage directly every week instead of by occasional night consumption checks.

The most important feature of such a scheme was that the whole system, back to source meters (about 1500 miles of main from 42 in downwards in the Company's case), must be divided into areas large or small so that the total of the quantities supplied to areas equalled the total input to the system. The total of the estimated leakages was the total input less metered consumption and less domestic at 25 ghd. No leakage could vanish because of actual or assumed meter error or leaking valves—it was merely re-distributed between areas.

The value of this procedure to the Company had now been proved with two unsuspected leaks on trunk mains, totalling $\frac{3}{4}$ mgd, to its credit, in addition to numerous smaller leaks.

From a study of his Company's figures, his view was that more than three-quarters of undetected leakage escaped from mains and that true domestic consumption was less than 25 ghd. How far these conclusions were applicable to other areas was open to conjecture, but some of the facts and figures given by earlier speakers indicated that there might be less difference between undertakings than was sometimes supposed.

Author's Reply to Discussion

Mr. J. Reid, replying to the discussion, wrote that Mr. Whitehead's question on systems monitoring and its application to large complex areas had been answered by the contributions from Mr. Burgess and Mr. Stoddart.

Pressure-reduction, as had been suggested in the paper, could have a considerable effect on fire protection equipment in buildings, i.e. sprinkler systems, hose reels, and hydrants. Whilst there was no duty on a water authority to supply or maintain pressures for such purposes, the legal duty being defined in Part IX of the Third Schedule of the Water Act, i.e. to suply at such a pressure to reach the top story of every building that could be commanded by a *nominated reservoir,* there was undoubtedly a normal obligation to notify consumers of any permanent reduction and to offer to advise them on any difficulty which could arise. He suggested that the period of notice should be as long as possible, and not less than six months.

Concerning the contribution from Mr. Edkins, the shortening of the time during which waste meters could be effectively run on a night test was just a fact of modern life, which we must accept. The best time for night runs varied from area to area, and the keen waste inspector quickly appreciated this and adjusted his running times accordingly.

He assumed that the water towers and service reservoirs to which Mr. Edkins referred were relatively small and without reliable meters capable of registering low flows. In such cases he recommended the use of low-loss-type meters on a bypass. These meters were suitable for the fitting of direct attachment recorders, and he had successfully used this arrangement previously. Whilst it did not give the accuracy of a waste meter, it would provide reliable night-to-day ratios for statistical and waste-estimating purposes.

Regarding the extension of activities into undertaking private work or managing a "water shop", he could only say that the powers of a water authority to undertake work on private installations were governed by various Acts, private or otherwise, under which it operated.

He was in favour of undertaking certain private work by direct labour, as it ensured both speed of operation and quality control. However, one would first have to consult trade councils and craft unions to see if there was any opposition to undertakers entering this field. He did not favour entering the retail business for the sale of the complete range of water and sanitary fittings, at least not until the new water authorities consolidated their present commitments.

He heartily endorsed Mr. Tyldesley's plea for a national standard to define and evaluate the extent of waste. We would then be comparing like with like, thereby establishing comparative standards of waste efficiency between authorities. This point could well be taken up by the working group on waste of water which was now meeting under the auspices of the DOE.

Mr. Burgess's contribution partly answered Mr. Whitehead's question on the validity of systems monitoring for large zones. However, systems monitoring was limited by its capacity of locating many separate minor leakages which largely made up the whole. Waste meters covered flow ranges of 1: 200 and, therefore, small isolated leakages of the order of a few gallons per minute could be detected and located.

The reference to the change in pressure characteristics caused by the setting up of a waste meter area was small and could be ignored under low night flow conditions. Also, any zone valve inadvertently left open or passing would give a positive indication on the waste chart.

He felt that systems monitoring should complement waste metering rather than replace it.

The scraping of mains and their *in situ* lining with cement mortar, referred to by Mr. Gadsby, had a significant effect on the reduction of leakage through the sealing effect it had on leaking joints. This particularly related to steel pipes, both large and small diameter, where pin-holes were sealed during lining. He himself had used concrete lining of large diameter steel mains for the specific purpose of eliminating leakage, with 100 per cent success. In such cases he recommended a two-pass lining of about $\frac{5}{8}$ in thickness in total.

It had also been noticed that most large-diameter cast iron mains which had been lined for hydraulic reasons appeared to have been reinforced to the extent that failures by way of fracture became very infrequent.

Regarding Mr. Hutton's contribution, the shutting down of unnecessary feeds into a redevelopment area was a positive and fairly standard method of controlling the extent of waste. One must be careful, however, not to reduce the supply to the extent that fire hydrants were starved of water other than with the full approval of the fire authority who might be able to make alternative arrangements for a supply for fire-fighting purposes.

He had only recently carried out precisely the action which Mr. Phipps had indicated—that of curtailing the activities of a waste section which was operating on very indifferent lines for a period whilst all the waste inspectors were sent on specially arranged training courses. These courses were arranged with the NWC training division, for his own staff only, and were highly concentrated as far as work content was concerned to cover the specific needs of the Liverpool Water Supply Unit.

Not every man, even with training, had the temperament to become an efficient waste inspector. Careful selection was necessary, followed by selective training. Then, after many years of experience the waste inspector could achieve a high degree of job satisfaction in tracing and eliminating waste and become an effective member of a team.

Mr. Stoddart's comments also answered Mr. Whitehead's question on systems monitoring. The former's estimate of 25 ghd for domestic consumption was borne out by long-term figures obtained in two separate metered districts in Manchester comprising populations of 1647 and 1152. The figures obtained were 24·2 and 25·16 ghd, respectively. Both districts were newly mained and known to be leakage free.

Mr. Giles's contribution offered an interesting variation in the method of controlling PRV outlet pressures to preserve a constant critical terminal pressure irrespective of rate of flow and head losses in the system. However, he suggested that we were ever sophisticating the operation of a simple and relatively trouble-free system by the introduction of telemetry.

Control should be simple, reliable, maintenance-free and independent as far as possible of extraneous factors. If a distribution system was in good order friction losses would not be a major consideration when assessed against the pressure reduction intended.

He agreed with Mr. Hothersall that it was impracticable to switch a waste detection programme on and off. Furthermore, it was most undesirable to do so; much of the value of a waste system depended on regular statistical information built up over the years.

Many small authorities, for reasons of economy, employed dual-purpose plumbing-waste inspectors. Each was a specialist field requiring individual attention, and the best results were obtained if these functions were separated. This comment was also made by Mr. Speed in his introduction of Mr. Barrett's paper.

He thoroughly supported the view that plumbing inspectors should be of a technician standard. In these days of rapidly expanding technology it was most important that a plumbing inspector (he himself preferred the term installation inspector) should be available to converse authoritatively with both plumbers and mechanical services consultants.

8. ADVANCES IN WASTE DETECTION TECHNIQUES AND EQUIPMENT

By R. A. Chisholm, MEng, AFRAeS (*Member*)*

CONTENTS

INTRODUCTION

Waste control has been a topic of work at the Water Research Association (WRA)** for many years. Work has been carried out in the laboratory and field on leak detection equipment and in the field on waste detection operations. In recent years, the effort has been directed largely at field operations through demonstration of procedures and equipment with assistance given to member undertakings who were setting up or extending waste control departments.

The technique of nitrous oxide tracing of leaks was fully developed by the WRA and then made available commercially a few years ago. An acoustic method of leak location was also developed at the laboratories some four years ago, and field trials proved its potential success and accuracy. However at that time, for technical and economic reasons the project was shelved. Work in this area is expected to begin again in the immediate future.

Transportable waste meters have been used for many years by a number of water undertakers in Britain. An advance achieved in this area was the introduction by the WRA of the trailer-mounted mobile waste meter. The advance was particularly significant in the operational rather than the technical sense. Many undertakers who had previously carried out little or no waste control became interested in this comparatively cheap method and began to use it for routine waste control investigations. Equipment based on the WRA design is now available commercially.

These techniques of leak detection together with the waste detection equipment are described more fully in this paper and represent the main advances brought about by the WRA in recent years.

The opportunity is taken in this paper to identify some other techniques and equipment which are available commercially. Generally, this type of equipment has changed little over the years except to improve accuracy by taking advantage of technological developments in fields such as electronics. Reference is made to these techniques where they have formed part of the WRA's experience.

One important aspect of pinpointing leaks in a water main is the need to know exactly where the main is. For this reason, reference is made briefly to the various types of mains locators available where these are also obtainable from leak location equipment manufacturers.

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** The Water Research Association was absorbed into the Water Research Centre on 1st April 1974.

WASTE METERS

The information given here on commercially available waste meters is for completeness, rather than to represent advances in technology. However, there is little doubt that the wider, regular use of flow monitoring equipment to identify the presence of leak flows has been a positive contribution. It has increased effectiveness in the use of waste detection staff and in this sense can certainly be considered an advance. An essential requirement of a waste detection system is to find leaks quickly and to identify the most important (i.e. biggest). This is best met by the flow monitoring approach, used on a regular basis, and involving established procedures associated with district metering.

Kent Meter

This meter works on the principle of a weighted gate, which is deflected from the vertical by water flowing through the meter. An increase in deflexion of the gate results from an increase in flow. The deflexion is transmitted through a linkage to a pen which records the flow rate on a moving chart driven by a clock.

The meter is currently manufactured in sizes from 3 in (75 mm) to 12 in (300 mm) with maximum flow rates of 10 000 gph (46 m^3/hr) to 100 000 gph (450 m^3/hr), respectively. Minimum flows of about 1/300 of the maximum flow can be measured. Prices of this meter vary from about £210 complete for the 3 in model to £550 for the 12 in size.

This meter was used on the trailer-mounted meter system developed by the WRA.

Deacon Meter

In this meter, water passes downwards through a diverging cone and flows around a central moving disk. The movement of the disk is controlled by a counterweight and activates a recording pen which marks a moving chart driven by a clock. This meter is available in sizes from 3 in (75 mm) to 10 in (250 mm) with maximum flow rates of 10 000 gph (45 m^3/hr) to 45 000 (205 m^3/hr). The price of this instrument currently ranges from about £240 for the 3 in meter to £550 for a 10 in, exclusive of VAT. Portable meters are available.

Mobile Meter

In this section the mobile meter developed by the WRA is described, although variations of this type have been made using Kent or Deacon meters, on trailers or mounted in caravans.

The established procedure in the UK is to use waste meters permanently installed in pits with the meter on a bypass to the main feeding a waste district. Recently there has been an increasing use of mobile meter systems for both routine waste metering and for initial investigation and design of waste districts before deciding on siting of permanent meters.

The mobile waste meter is connected into the water supply system to a waste district by using fire hydrants and fire hoses. With this arrangement and with the use of a valve on the main between two hydrants, a temporary bypass system can be set up which enables the waste district to be metered through a conventional waste meter without the expense of providing a permanent installation.

Whilst the initial cost of a trailer-mounted meter may exceed the cost of a single permanent installation, one mobile meter can provide facilities for waste metering several districts instead of having one permanent meter for each waste district. Hence, the total cost incurred on metering a certain number of districts can be considerably reduced.

It is sometimes necessary to install additional valves and/or hydrants to facilitate the setting up of the mobile meter installation. Even taking account of this cost the use of a mobile meter can still show considerable savings over permanent installations.

Situations where mobile equipment is used to advantage are:—

(1) For initial waste control, in anticipation of a long-term installation programme of permanent meters being carried out.

(2) To determine the optimum location for permanent installations.

(3) Where permanent installations are not practicable because of poor drainage conditions resulting in flooded meter pits or difficulties of services precluding the siting of a meter pit.

(4) In rural areas with long lengths of main feeding only a few houses.

(5) To sub-divide areas monitored by a large waste meter or bulk meter.

(6) For ancillary use for on-site measurement of flows, e.g. when chlorinating mains or dosing them for control of animal infestation.

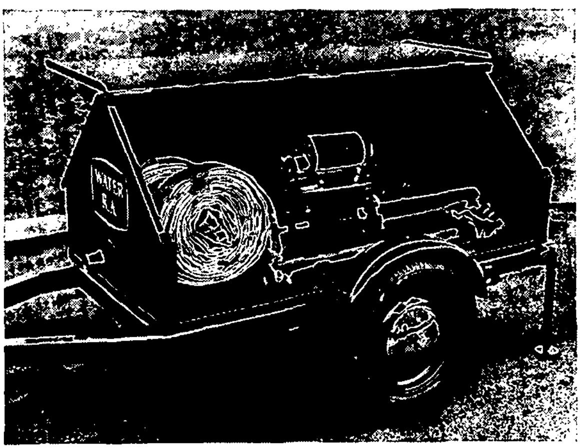

Fig. 1. **WRA mobile waste meter trailer**

The WRA mobile meter (Fig. 1) is rigidly mounted in a trailer and must be level before use on site. A trailer-mounted system has numerous advantages. The equipment can be towed by light vehicles, and if necessary can be handled and set up by one man. Ancillary equipment such as hoses can be carried within the trailer. A trailer is reasonably tamper proof and it is usually possible to leave it unattended. However, in areas where vandalism is a problem it may be necessary to engage a night watchman. The size of the equipment is such that it presents little traffic hazard and can easily be parked on a grass verge, or pavement. The cost of the trailer unit is not excessive, about £400 to £500 including meter and depending on the degree of design complexity. The trailer can often be built up from existing equipment.

When choosing sites for mobile meters it is important to bear the following points in mind:—

(a) The site should be chosen so that it causes little inconvenience to pedestrians and road users.

(*b*) There should be ready access to two hydrants which have a valve between them. The ideal distance between the hydrants is about 30 ft (9 m), although up to 430 ft (131 m) has been used by the WRA.

(*c*) Sites which would involve hoses laid across main roads should be avoided. It may be acceptable to have hoses across minor roads with the hoses protected by ramps and warning signs. Where hoses have to be laid across footpaths or driveways, ramps, warning signs and lights should be provided.

(*d*) The site chosen should be such that one or two operators can manoeuvre the equipment into position; a steep slope or a muddy area would be unsuitable.

(*e*) There are obvious advantages to be gained from working in a place lit by all-night street lighting.

(*f*) In areas with a high incidence of vandalism, the equipment should be positioned so that it remains within the public view. Preferably, waterworks staff should be in attendance throughout the operation.

(*g*) It may be necessary to install a new hydrant and/or valve where metering is to be carried out regularly at the site. Convenience of setting up should be considered when positioning the new hydrant.

(*h*) Where a hydrant with a loose jumper is used downstream of the meter it will be necessary to remove the hydrant jumper and to control the hydrant with a valve in the standpipe.

(*i*) Ball hydrants are not suitable for the purpose of waste metering because of the problems of hygiene leakage, and reverse flow.

When using mobile waste meters, care must be taken to avoid contaminating the mains through fire hydrants. This contamination could arise from unsterile equipment or from the bowls of fire hydrants. The following precautions are recommended:—

(*i*) Hoses which:

are new
have been in store
have been contaminated

should be flushed through, filled with water containing not less than 20 mg/l of chlorine and flushed out after a minimum period of 2 hr.

(*ii*) When hoses are not in use, the ends should be capped or the two end couplings joined.

(*iii*) Couplings joining two hoses should be raised on blocks to prevent possible contamination from puddles and soil.

(*iv*) The couplings on the trailer should be capped when not in use.

(*v*) The standpipes should be kept clean and preferably capped when not in use.

(*vi*) Hydrants should be flushed out until they run clean. Attach the standpipe and pour about half a pint of chloros* down it. Crack open the hydrant sufficient to fill the standpipe. Allow to stand for 15 to 20 min and then flush out.

A major problem in setting up the equipment for the first time is the choice of meter position and hose lengths. It is best to avoid the difficulty of having to "snake" hoses, since under full mains pressure the hoses cannot accept curves of much less than 5 ft (1·5 m) radius. This problem is minimized by having available hoses of different lengths or, where hydrants have to be installed, by positioning hydrants to suit the hose lengths.

Site procedure is as follows:—

(1) Set up any road signs necessary for the protection of the men working on the equipment.

(2) Disinfect the hydrants and standpipes as detailed earlier. During the disinfection contact time, operations (3) to (8) can be carried out.

(3) Pace out the area and decide on hose lengths and meter positions.

(4) Position the meter trailer.

(5) Connect up the hoses to the meter and standpipes. Lay the hoses along the ground in the positions at which they will be used, adjusting the standpipe swivel joints accordingly.

* Proprietary disinfectant containing sodium hypochlorite.

(6) Check the hose positions with regard to pedestrians and road users and check that the hoses do not curve more sharply than a 5 ft (1·5 m) radius. Adjust the meter position and hose lengths as necessary.

(7) Adjust the meter on levelling jacks, first at the rear to level the trailer laterally, and finally by means of the jockey wheel. If the meter is set up on soft ground, the jacks should have pads placed beneath them.

(8) Adjust pen to zero on meter chart.

(9) Remove the hoses and flush the hydrant bowls to waste to complete disinfection.

(10) Replace the hoses and pressurize the system by cracking open both hydrants, and releasing air from the system at the meter airbleed. The hydrants can now be closed.

(11) The system is now ready for use. Boundary valves isolating the waste district are closed. The system can then be operated by fully opening the hydrants and closing the valve that bypasses the meter.

If the site has been used for mobile waste metering before, or if the hydrants have been installed specifically for the purpose of waste metering, steps (3) and (6) are omitted.

When the above system has been set up for the first time and proved satisfactory, there will be a considerable saving in time on future occasions if a sketch is made of the layout (Fig. 2).

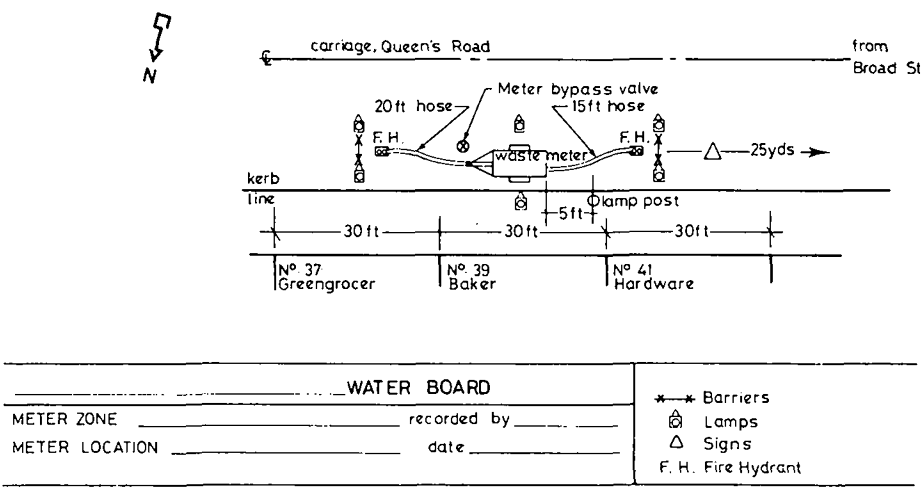

Fig. 2. Waste meter site record

LEAK DETECTION EQUIPMENT

The water industry generally uses acoustic methods to pinpoint the location of leaks, using such equipment as "listening sticks", stethoscopes, electronic amplifiers and so on. Reference to such equipment is made later but, due to the fact that it is not always successful, alternative methods have been developed by the WRA.

Nitrous Oxide (N_2O)

This method involves the use of a water soluble tracer which is injected under pressure into a main and detected as it escapes at points of leakage. A tracer suitable for water supply systems was identified as nitrous oxide, with advantages given below, and the WRA developed special portable equipment to be used in association with this technique.

A tracer for suitable water supply systems must be soluble but non-reactive with the water and, if reasonable sensitivity is to be achieved, it must also be readily detected in small quantities. Furthermore, it must be non-toxic, chemically inert, tasteless and odourless. These requirements rule out or restrict the use of some halogens or radioactive tracers although these can be used to detect leaks in sewers and raw water pipelines.

Nitrous oxide has the required properties because it is unreactive at ordinary temperatures, does not decompose in water and does not promote corrosion. It is not expensive and is readily available in cylinders from commercial suppliers. It has a strong absorption for infra-red radiation which means that an infra-red gas analyzer can be used to test for the gas. In this way, concentrations as low as a few parts per million in air can be readily found. It has a particular advantage in that the detection equipment can be made virtually independent of other gases which may be present and, since nitrous oxide is synthetic, there is no natural background concentration of gas to interfere with the effectiveness of this technique.

Operational Requirements.—The operation is simpler if the main under test is taken out of commission, although this is not imperative. Ideally, as with most other leak location techniques, the position of the main should be known. Bar holes must be made along its length, preferably at joint positions or every 10–15 ft. Water must be supplied to the main, and disposed of if it is not to be subsequently supplied to consumers. The main must be pressurized to a figure not exceeding 180 lb/sq in (1240 kN/m^2) at the dosing point, as this would exceed the feed pressure of the dosing equipment.

Provision must be made to measure the flow rate of water in the main, preferably at the dosing end. When the measurement is made at the downstream end, an allowance should be made for the amount of water lost through leakage.

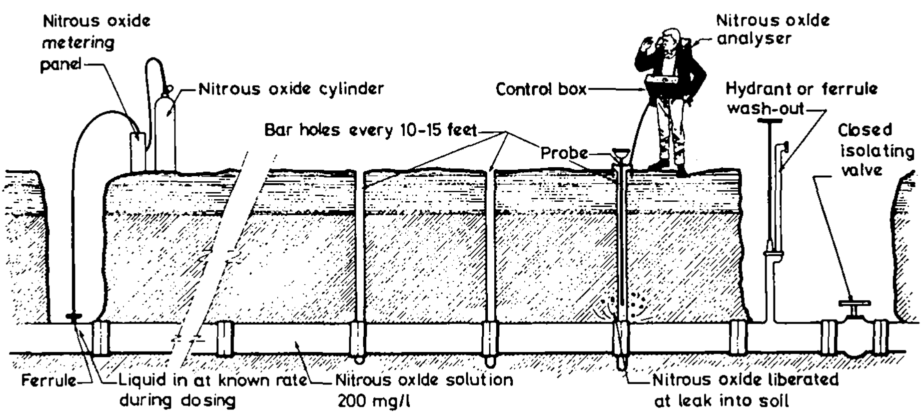

Fig. 3. General arrangement of nitrous oxide leak detection method

Procedure (Fig. 3).—Starting with a main charged with water, nitrous oxide is injected at a higher pressure than mains pressure so that it dissolves in the water. The nitrous oxide is injected at a known rate through a ferrule or similar fitting. The water in the main is allowed to flow under pressure at a measured rate until the whole length of main to be investigated contains water that has been dosed with nitrous oxide.

The outlet is then closed and the mains pressure increased to the test pressure. When the water containing nitrous oxide leaks out of the main, it returns to atmospheric pressure and the gas comes out of solution. Bar holes are made at intervals along the line of the main, a probe is inserted into each hole in turn and the air in the bar hole is tested for the presence of nitrous oxide.

Nitrous oxide is normally dosed into the mains through a dosing unit so that the water contains 100 to 200 mg/l. The choice of the actual amount of nitrous oxide dosed will depend mainly upon the size of leaks and the length of time before the bar holes are checked for nitrous oxide. This is usually a matter of experience. For example, for small leaks (as in newly laid mains with weeping joints) the main would probably be dosed with 200 mg/l and allowed to stand overnight while being kept at the test pressure.

Where the rate of flow of water through the main at the dosing point is known, it is simple to calculate the amount of gas required, since a concentration of 100 mg/l is given by 1 lb N_2O/hr for 1000 gal water/hr.

The dosing unit can provide a maximum throughout of 20 lb/hr N_2O (0·0025 kg/sec) corresponding to 20 000 gal/hr (25 l/sec) of water for 100 mg/l and gas can be drawn from four cylinders simultaneously.

The nitrous oxide can be taken as a gas from the cylinder up to a rate of 2 lb/hr (0·00025 kg/sec) when the cylinder is the correct way up. At a greater rate than this the cylinder can freeze up. Using four cylinders simultaneously, the maximum dosing rate will be 8 lb/hr (0·001 kg/sec). Where larger dosing rates are necessary it can be taken as a liquid from an inverted cylinder to the maximum panel capacity of 20 lb/hr (0·0025 kg/sec). When this happens, a heat exchanger in the dosing unit requires a separate supply of water—3 gal/min (0·225 l/sec)—to provide a supply of heat to change the liquid into gas for dosing. This water can be taken from the suspect main, but must then be from upstream of the gas injection point to avoid contamination by nitrous oxide of the surrounding atmosphere.

When it is calculated that dosed water is approaching the end of the main, samples of water should be tested for nitrous oxide.

Certain precautions are necessary when using this leak detection system:—

(*a*) Air valves close to the dosing point should be closed to prevent the escape of nitrous oxide which may not have gone completely into solution at that point.

(*b*) If the nitrous oxide is injected at a hydrant, the frost valve should not be allowed to leak.

(*c*) Care should be taken that dosed water being discharged at the downstream end cannot run back down the pipe trench, as this can lead to erroneous results.

(*d*) The outlet should be turned off when the main is charged, and the system allowed to stand under sufficient pressure to cause leakage.
Injection of gas should be continued at a low rate to ensure incoming water is dosed, otherwise leaks close to the dosing point may be missed.

(*e*) Bar holes should be spaced to coincide with joints and possibly at mid-pipe, or at intervals of 10 to 15 ft (3 to 4·5 m) where joint positions are not known. The bar holes should be immediately adjacent to the pipe and taken down to invert level.

(*f*) When a sample of nitrous oxide has been through the equipment, the equipment should be cleared before proceeding with another sample by removing the probe from the bar hole and running the pump until the instrument reads zero.

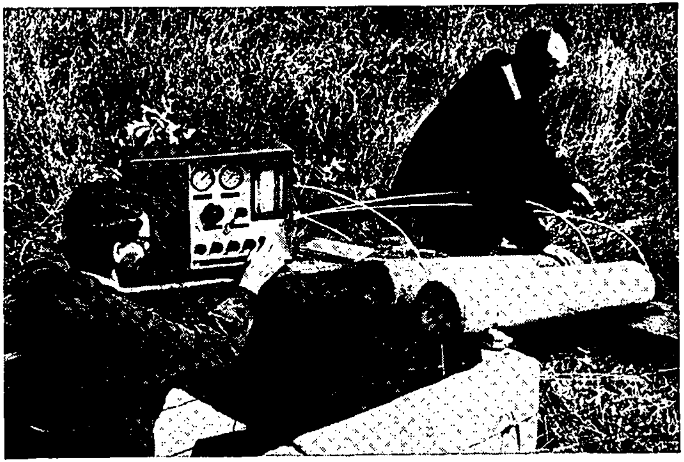

Fig. 4. Nitrous oxide—dosing and detection operations

Results of a nitrous oxide survey may be interpreted as follows:—

Where adjacent bar holes give indications of nitrous oxide, the leak will normally be at or near the point of maximum reading.

Where similar readings are obtained on a slope, the leak will be normally located at the highest point.

In hard stratified clays and shales, the presence of nitrous oxide may only give a general location of the leak. This is also true in the presence of man-made channels, such as drains, or PO ducts.

Nitrous oxide has proved particularly suitable for leak location in the following situations:—

New mains of any size which have failed to pass the pressure test during commissioning.

Large mains with relatively small rates of leakage.

Long country mains with few draw-off points where the main is laid in grass verges, through fields, or along roads with few other services present.

Fig. 4 shows the dosing and probing equipment in use during WRA field trials. After the successful development of this technique it was taken over on a commercial basis, and is available as a service from E. W. Avent Ltd., New Malden, Surrey.

Detection and Dosing Equipment.—Equipment for detection of nitrous oxide is in three units—a probe, control unit, and gas detector. In addition, there is the dosing unit to control the input of nitrous oxide; this is shown schematically in Fig. 5. The sampling probe is used to withdraw a sample of air from a bar hole in the ground, and to feed it into the gas analyzer. The bar holes from which the samples are taken may be several feet deep and frequently contain mud and water. The probe was designed so that, even when it was thrust to the bottom of a bar hole, it would be unlikely to block or to carry water over into the analyzer.

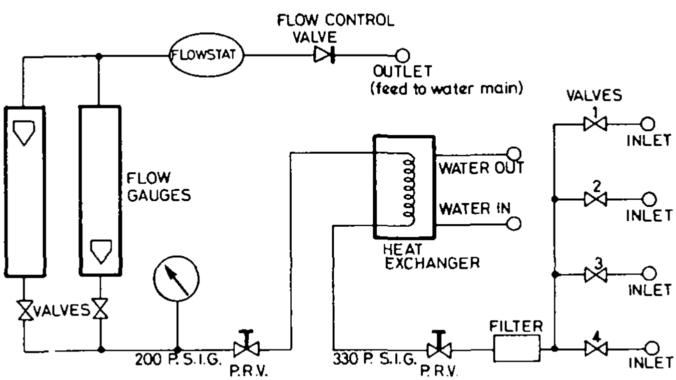

Fig. 5. Schematic diagram of nitrous oxide dosing unit

The probe is illustrated in Fig. 6. The cap is pressed down to form a gas tight seal at the edge of the bar hole so that a closed system is set up, consisting of the bar hole itself, the extension tube which passes into it, the control unit and pump, the analyzer, and the connecting tubes. Operation of the pump in the control unit forces air and other gases in this system to circulate, the direction being such that the flow is down the extension tube into the bottom of the bar hole.

If water or soft mud is present in the bottom of the bar hole the extension tube will dip into it, but blockage of this tube, and carry-over of mud and water into the rest of the system will normally be prevented by the action of the pump. At the same time, any nitrous oxide dissolved in the water will be progressively purged out of solution by the stream of air from the extension tube, and so be fed into the analyzer. Because the circulatory system forms a closed loop, the small amounts of nitrous oxide which may be present initially in the bar hole are retained within the system and not lost to the atmosphere. Maximum sampling senstivity is therefore obtained.

The extension tube is terminated by a short length of removable perforated tube. This permits additional lengths of tube to be added when deep bar holes have to be sampled, and also facilitates cleaning after particularly arduous service. The connexion to the control unit is supported by a transparent perspex section so that a visual check may be kept on the flow to the analyzer and appropriate action taken in the unlikely event of water appearing at this point. There is also an electronic circuit which operates a warning

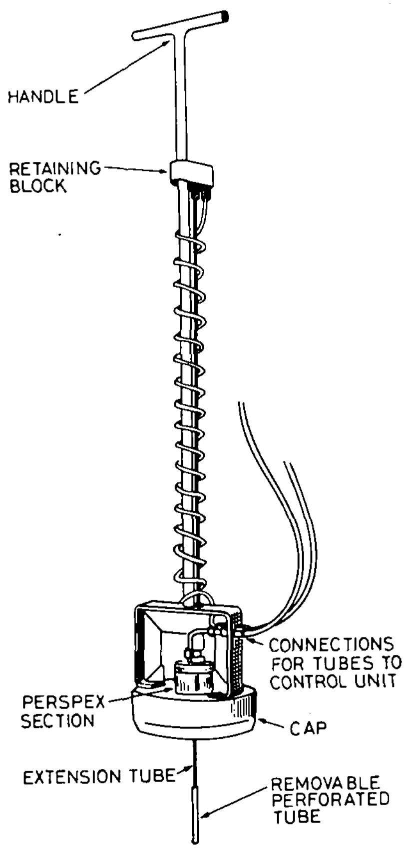

Fig. 6. The sampling probe

The extension tube is passed down into the bar hole by sliding the retaining block along the handle. The coiled flexible nylon tube joins the upper end of the extension tube to a union connected, via another length of flexible tube, to the control unit. The pneumatic circuit is completed by a second flexible tube which connects the perspex section to the control unit

light and switches off the pump if water carries over from the probe towards the analyzer. A cap insert, made of closed cell expanded plastics material, is sometimes necessary since it enables a gas-tight seal to be made between the cap and a hard ground surface.

The gas detector analyzes the samples drawn by the probe from the bar holes, and records on a meter on the control unit the concentration of nitrous oxide. The detector was developed commercially from a conventional laboratory type of infra-red gas analyzer, altered to meet the special needs of this application. This has involved slight modification to the equipment to improve its ruggedness and portability, and the development of appropriate control circuitry. The alterations needed to improve the ruggedness and portability of the analyzer were developed commercially to WRA specification, but the development of the control unit and its associated circuitry was carried out in the WRA laboratories.

A schematic diagram of the detector is given in Fig. 7. An electrically heated nichrome filament provides the radiation, which takes two paths: one through the reference cell and the other through the sample cell. The reference cell contains dry air, and the sample cell forms part of the closed loop system which includes the probe and bar hole.

Below the reference and sample cells is mounted the detector unit. This is a pneumatic device consisting of two chambers separated by a very thin membrane. It is so positioned that radiation passing through the reference cell enters one chamber, while radiation passing through the sample cell enters the other. The two chambers contain nitrous oxide gas which absorbs the incoming radiation. This means that the temperature, and hence the pressure within each chamber, depends upon the amount of radiation fed into it. A very small leak connects the chambers to provide for the maintenance of pressure equilibrium across the membrane during slow ambient temperature changes but this leak

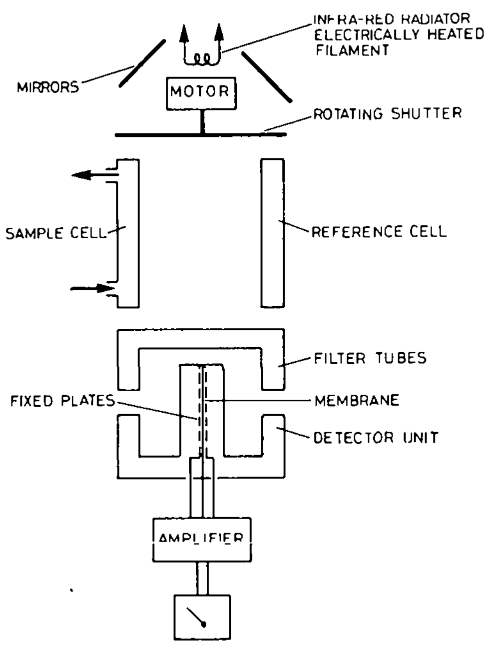

Fig. 7. Schematic diagram of the nitrous oxide detector

presents a high impedence to sudden pressure changes which may be set up by the intermittent incoming radiation.

When there is no nitrous oxide in the sampling cell, both detector chambers receive the same amount of radiation. The pressure fluctuations will therefore be the same and in phase in each chamber, and no deflexion of the membrane will occur. Nitrous oxide in the sampling cell will reduce the radiation flux entering one chamber, so that the pressure fluctuations in each chamber will not be the same, and the membrane will move to and fro. The membrane is in close proximity to a fixed plate and the two form a small electrical capacitor. Movement of the membrane can therefore be detected electronically and displayed on a meter calibrated in relation to the concentration of nitrous oxide.

Filter tubes, mounted immediately above the detector, are provided to eliminate spurious responses caused by high concentrations of infra-red sensitive gases (other than nitrous oxide) which may be present in the sampling cell. The interfering gas or gases whose effects are to be eliminated are put into the filter tube, and the appearance of these gases in the sampling cell cannot then alter the radiation flux reaching the detector. In this case, a 50 per cent v/v mixture of methane and carbon dioxide is used.

The analyzer itself is mounted in a large case, which is fitted with a frame and harness so that it can be carried on the operator's back, and the smaller case is the control unit which clips on to the harness over the operator's chest (Fig. 4). In addition to the control circuitry, the small case contains the recording meter, the power supplies, and the pump which drives the air round the sampling loop.

Correlation Technique (LINDA)

Acoustic methods of leak location such as "listening sticks" or microphone amplifier equipment often suffer from the defect that sound can be affected in transfer from its source at the leak.

Before its final "indication", a leak sound may suffer attenuation of certain of its frequencies through the soil cover to a water main. The detection equipment at the ground surface, such as a microphone pick-up or "listening stick" may only respond to certain frequencies. Furthermore, extraneous noise in the area of the leak location exercise may be of a significantly higher level than the leak sound signal.

Consequently, the final indication of sound may bear little direct relationship to the leak sound origin. A technique for removing interference effects was developed at the WRA a few years ago, which effectively identified a signal related just to the leak sound.

The procedure involved recording signals on tape from up to 16 microphone pick-ups. These pick-ups were positioned where possible on valves, hydrants, and stop-cocks in order to have direct contact with the leaking main, over a distance of about 1000 ft. Signals were fed to a 16-channel tape recorder housed in a site caravan.

The sounds, of a random type, contain frequency bands relating to leak noise and extraneous transient noises. In particular, they all contain an identifiable feature of the leak noise. The difference in times at which this feature passes the recording points (microphone positions) is a function of the position of the leak relative to them. After recording on site, the tapes were processed at the WRA laboratories on correlation equipment. This equipment compared the several recordings in pairs, and in identifying the leak feature on each, effectively removed the interference of noises not associated with the leaks. Using photographic records of the "pair correlograms", it was possible with graphical methods to plot the time taken for the leak signal to reach each pick-up against the position of the pick-up. The position of the leak could then be pinpointed by simple geometry (Fig. 8).

Field trials of the equipment at a number of water undertakers showed that the

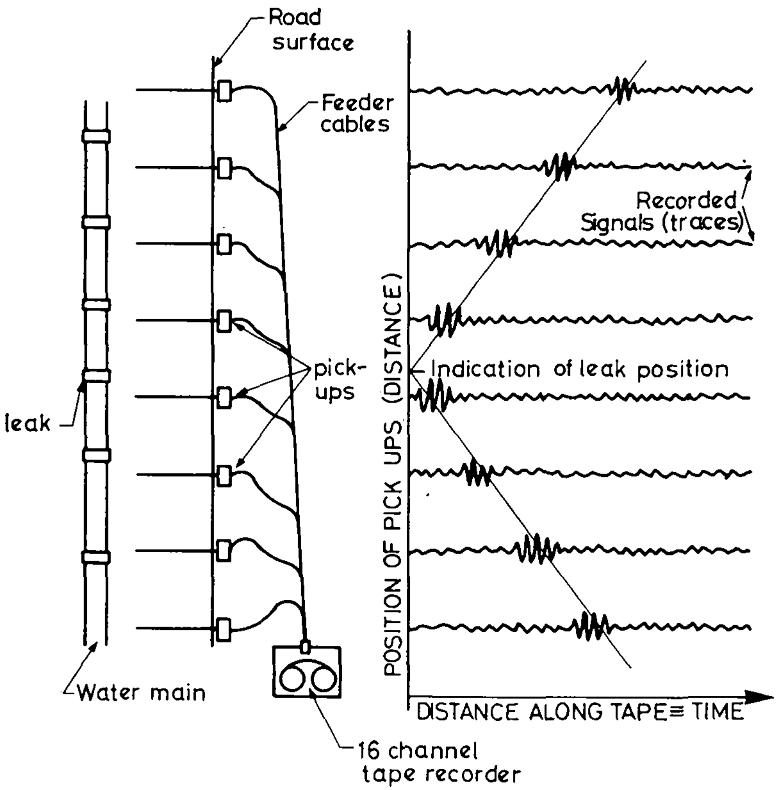

Fig. 8. Correlation technique for leak detection

Each recorded trace is made up of two components:—

(*a*) extraneous noise, individual to the particular pick-up, and

(*b*) a signal from the leak which appears on all traces, but with a time-shift as the signal travels from the leak source to each pick-up.

Matching of the signals is carried out in the experimental equipment by an electronic correlator. This will identify the leak signal from each pick-up, even though extraneous noise may be greater. The sensitivity of the method is thus greatly enhanced over conventional equipment.

Plotting the lines of best match, one trace with another as shown above, will indicate the leakage position along the water main.

equipment could pinpoint leaks to within one or two feet and on many occasions within a few inches. This applied to leaks which could be heard by stethoscope but where their position could not otherwise be found.

The equipment was developed intially to supplement existing methods of leak detection which are usually successful in about 80 per cent of leakage situations. The equipment was costly in terms of both capital and development and was offered to the water industry on a service basis at a cost of £200 per leak. This was done to determine whether a sufficient market existed for its further development from laboratory equipment proven in the field into a form suitable for regular and perhaps commercial field application. The response at that time (4 years ago) was insufficient to warrant further expenditure, so the project was shelved and is not available at present for leak detection.

In view of recent technical advances in electronic equipment, it is possible that the size and cost of similar equipment might now be reduced. A complete reappraisal of the subject of leak detection is now under review at the WRA.

COMMERCIAL EQUIPMENT

Portable Amplifiers.—There is a variety of commercial equipment available for leak detection and only those depending on "sound" location are mentioned here. The equipment usually consists of a microphone pick-up feeding an amplifier, and it is in the design of pick-up and amplifier circuit that the major differences arise. In all cases these are in a portable form, powered by batteries. A summary of the equipment is given here with manufacturers or agents addresses.

(*a*) **Terroscope** (Abbot Birks Company Ltd., East Portway, Andover, Hants). This equipment comprises a diaphragm microphone feeding an amplifier. Leak sound indication is made on a meter or through sound in headphones. This equipment has been available to the industry for many years, and in its present form incorporates plug-in printed circuits and transistors. These minimize the "internal noise" of the equipment. A 12-position frequency filter is available to facilitate selective amplification of various leak frequency bands.
It is available as a combined pipe tracer and leak locator, or leak locator only.

(*b*) **Zuurbier** (Clay Lane West, Doncaster).
This equipment again comprises a microphone pick-up and amplifier; two types of pick-up are available. One is a rod which is used for listening for leak sounds at points where direct contact is made with the pipe. The other is a microphone which is used to detect leak sounds transferred through soil above the pipe. The receiver is an audio-amplifier and has two outputs. One drives a meter and the other a set of headphones. This receiver also contains a filter switch to enable extraneous sound to be attenuated.
Pipe location equipment is also available from this company.

(*c*) **Fisher 'M. Scope'** (Available from E. Pass and Company Ltd., Holland St., Denton, Manchester).
This American equipment comprises a variety of leak location, pipe tracing, and valve box tracing facilities. The leak detection equipment incorporates a crystal microphone with amplifier. Various methods of microphone attachment are available, enabling direct contact with mains fittings, probe rods to contact a main, and plates for indirect sounding on ground surface where it is not possible to contact the main directly. A particular feature claimed by the manufacturers is the ability to "tune out" unwanted noise in both the leak detection and pipe location modes of operation.

(*d*) **'Metrotech'** (Available from Lee Engineering Ltd., Ashley House, Ashley Road, Walton-on-Thames)
This again is of American origin. It is of similar design and construction to the M. Scope equipment It comprises a microphone pick-up and amplifier with indicating meter and headphones. The electronic circuit is solid state, which minimizes internal signal distortion and component noise and the facilities are again incorporated for selectively filtering out of various frequency bands by both switching and tuning. Pipe tracing equipment is also available.

The WRA has had experience of using these various types of equipment when working with water undertakers. This has shown that the degree of success of leak detection depends to a large extent on the waste inspector's familiarity with the equipment. While the inclusion of a frequency band filter or tuning device is of value in many circumstances, it also has the disadvantage that if the frequency band of the leak happens to coincide with the frequency band of the interfering noises, then a filter will also reduce the leak sound signal.

A problem sometimes found with these leak detection methods was the effect on the microphone pick-up of strong winds. Noise generated in these circumstances could often compeltely mask all sounds, including that of the leak.

Hydrotronic (P.O. Box 75, Normandy House, St. Helier, Jersey).—Hydrotronic equipment for leak location as seen in the UK is based upon detection and amplification of a leak sound using a microphone pick-up. The sound signal is fed through frequency analysis equipment which monitors the predominant frequency bands identified in the leak sound.

The equipment is thus essentially similar in principle to other acoustic leak detection equipment. It has the added facility, through frequency analysis, of identifying predominant frequencies in the detected sound.

The Hydrotronic equipment is housed in a van and the service is offered on a contract basis with staff manning the mobile units. The equipment array includes a frequency analyzer with ten frequency bands covering the nominal range 40 Hz to 10 kHz. Analysis of the sound frequency components within these bands is shown by intensity of indicator lights, analogue meters and digital voltmeters. The sound detected by the pick-up is amplified and the output displayed on an oscilloscope. The sound is also heard through a loudspeaker on some units.

Detection of leaks is carried out by traversing a length of main setting down the pick-up on available sounding points (valves, hydrants, etc.) or directly onto the main, using a rod to penetrate ground cover. The presence of a leak is identified, in an initial "blanket" survey, by strong intensity of one or more indicator lights. Once the blanket survey is complete, further readings are taken from points nearest to the suspected leak. At this stage the apparatus is then switched to the frequency band showing maximum signal level. Fine tuning is made within this band to identify the frequency which produces maximum amplitude on the indicating equipment.

The pick-up is placed on other points along the main and a comparison of amplitude of the selected frequency with distance is made. By this means, the leak is pinpointed at a position of maximum amplitude for the predominant signal frequency.

Although the Hydrotronic equipment depends on leak sounding principles in much the same way as a "listening stick" or microphone amplifier system, it appears to have advantages of sensitivity through greater amplification with the ability to tune in to the predominant frequency present in the detection system.

Pilot tests at certain undertakings in the UK using the Hydrotronic equipment have produced inconclusive results as to its superiority over other methods for leak detection. The pilot tests involved comparisons using Hydrotronic as a "blanket" type of leak survey compared with conventional waste metering techniques and leak location. It was concluded at one undertaking that the apparatus had a distinct benefit in areas where, for various reasons, it had not previously been possible to operate waste water meters regularly. It was equally concluded that the use of the equipment on a routine basis could not be carried out frequently enough to show cost benefit improvements in relation to regular waste metering.

This confirms policies put forward previously by the WRA that a systematic waste control procedure involving the use of waste meters to locate and ultimately pinpoint leakage will always be more effective than procedures of routine sounding.

CONCLUSION

In recent years a significant advance in waste detection has been demonstrated with the more widespread application of control procedures by many water undertakers. The advance has been not only in carrying out the work but in the methods employed. The wider introduction of systematic waste control by flow monitoring prior to localized leak detection has improved the efficiency of use of staff and equipment. A contribution to this has been made by the WRA through promotion of such waste control procedures and, more specifically, with the introduction of the mobile waste meter.

In the field of leak location, considerable advances in equipment and technology have been made, especially in processes for finding leaks which could not be found by conventional methods. The significance of these improvements has been less marked, largely due to the increased costs of development and equipment. However, it is important to realise that "difficult" leaks are often themselves expensive, in terms of delays in commissioning new mains, risks to property and so on. Therefore, the speed with which "expensive", but accurate leak detection procedures are used can result in an effective saving, compared to the use of conventional methods.

Once this concept of cost effectiveness of leak location procedures is recognized, it is likely that development and acceptance of new methods will proceed at a faster pace.

ACKNOWLEDGMENT

The author wishes to thank the Director of the Water Research Centre for permission to publish this paper.

DISCUSSION

Author's Introduction

Mr. R. A. Chisholm, in introducing the paper, said that when he had been invited to present it, it was on behalf of the Water Research Association (now the Water Research Centre) in relation to its work on the subject of waste control and leak detection. He therefore thanked the WRC for the subsequent assistance in providing material for this presentation, and also his new employers, the Severn-Trent Water Authority, for permission to attend the symposium.

The problem of identifying advances in waste detection and equipment was referred to by the Minister in his opening remarks when he said "There is nothing new in the idea of waste detection", and referred to reports dating back to 1947. We had also heard various other historical references to the subject during the discussions, not least to the fact that Mr. Deacon reported on the use of his waste meter just 100 years ago. Looking at a drawing of the meter as it then was and comparing it with the current version, he noted "the advance" achieved in to-day's meter was that water now flowed downward instead of up. Otherwise the design seemed little changed.

Even after 100 years we were still arguing the merits or otherwise of waste meters, so the information in his own paper relating to WRC work going back something less than ten years could, he felt, be considered quite recent.

The paper was in two parts; the first referred to waste meters, in particular the mobile waste meter used and demonstrated by the WRC to several water undertakers; the second dealt with the topic of leak detection, and made special mention of two techniques developed by the WRC.

Most engineers were familiar with the technique of waste metering but there still seemed some doubt as to whether it should be used in preference to leak location only. He believed that for efficient use of that valuable resource—manpower—the case for waste metering was simple, but positive.

Curves of distribution of waste in a waste district, plotted for some 20 water undertakers visited during the WRC investigation, were shown in Fig. 9, opposite. The results showed that 75 per cent of the total waste occurred in proportions of the districts varying from 40 to 20 per cent. Thus, any system which nominally assumed an *even* distribution

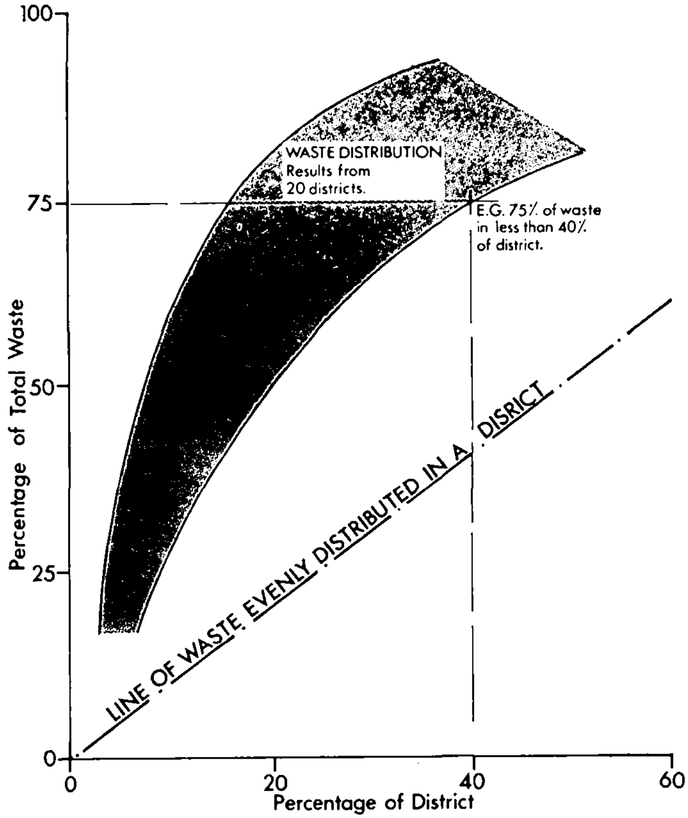

Fig. 9. Waste distribution: results of field observations

of waste (e.g. routine leak sounding) might result in wastage of about $\frac{1}{2}$ to $\frac{3}{4}$ of staff time.

These figures demonstrated the advantage of using waste detection meters to monitor night flows in waste districts, followed by subsequent localized identification of streets in which disproportionate flows were taking place. It was important to distinguish between the use of meters in this way, and the water balance method of comparing bulk meter flows with domestic metering information. The topic of universal domestic metering had been mentioned on a number of occasions. The use of domestic meters in a water balance was unlikely to give an accurate indication of level and location of wastage and this could not therefore be claimed as a benefit of universal metering. Considerable errors could arise both in bulk meters and domestic meters. For example, the WRC had experience of *in situ* bulk meter calibration exercises where errors were often around 30 per cent. Consequently, claims elsewhere in the world of a water balance showing wastage levels of only a few percent must be viewed with some degree of doubt.

With special reference to the mobile meter, a certain amount of criticism had been levelled at it during the symposium, but equally it had received some praise. Where a water authority had some years' experience of setting up and operating waste districts the benefits of a mobile meter might be less apparent. However, it had been the experience of the WRC that its use was particularly valuable for initial waste control investigations and certain other purposes identified in the main body of the paper. It had also shown itself to be of considerable benefit in setting up and regularly operating waste control procedures in developing countries.

Moving on to the subject of leak detection, the two methods developed at WRC (nitrous oxide and correlation) were described in the paper. It was important to point out that both techniques had proved to be very successful in finding leaks that could not be found by other methods. Thus, the methods supplemented existing techniques, and extended the potential available to water authorities for reducing wastage. In view of this potential, it was disappointing to note that the nitrous oxide method, now available commercially, had been used more in hydraulic testing for the gas and oil industries than in the water industry. Regarding the correlation technique, then as indicated in the paper, the response four years ago to a proposal to introduce this on a service basis was poor but the matter was being reappraised at the WRC.

As a very recent "advance", the potential use of distribution system telemetry as an aid to monitoring waste levels should be mentioned. Two examples of this were currently in hand, one at Milton Keynes and the other at the East Worcestershire Waterworks Company. With such systems it should prove possible to identify areas in which abnormal flows were occurring. It would be interesting to see how the application of these schemes developed in relation to waste control. The practical outcome must depend on the "sensitivity" of such techniques, i.e. to what levels, and locations, could waste be identified. Could they replace waste metering procedures, or would it still be necessary to investigate certain areas in detail with a waste meter before leak location was implemented? Perhaps mobile meters would replace permanent installations in these circumstances, since waste metering in any one area might only prove necessary on infrequent occasions.

Finally, he said that the symposium itself represented an advance of some importance, since it would appear that a national meeting had not been held for about 100 years! He hoped that the frequency of "waste inspection" on a national basis would increase in future.

VERBAL DISCUSSION

Mr. D. A. Gill (Water Research Centre), in opening the discussion, said that in considering whether an acoustic leak detector would be successful in any particular situation it was important to remember that a very small leak would make no noise, neither would a very big leak because the whole system pressure would drop locally. A medium-sized leak would make a noise by one or other of two mechanisms. If the water table around the leak was low then the acoustic energy would come from the break-up of the jet of water on the backfill and the sound would be a characteristic low rumbling noise. If the water table was high and the leak was actually playing under water then the characteristic sound would come from cavitation noise, a hiss, as high pressure water moved suddenly into the low pressure area. Therefore, the same leak would change its noise type as the water surrounding it rose. An understanding of these mechanisms was useful in appreciating the limitations of the acoustic methods.

Several speakers had mentioned the difficulties of finding leakage on trunk mains. Over the last year or so the WRC had developed the chemical dilution method for *in situ* calibrating large meters. This method was accurate to 1 per cent and therefore a double chemical dilution—one at each end of a length of trunk main—would provide the most accurate method we had available for determining leakage quantities. Certainly this method would have a considerable advantage over the method of using two *in situ* meters because we had found that meters commonly had errors up to 10 per cent and a 30 per cent error was not unknown.

Related to Mr. Reid's water accounting method, David Elford of the WRC Operational Research Division, had done some work on an idea of using successive network analysis which might replace the night step testing method. One analysis found the pipeline resistances in the network. Then successive network analyses were carried out assuming that the pipe resistances remained unchanged. To get a balance the water demands at the nodes of the network had to be disturbed from the figures based on numbers of houses connected near the nodes. Analysis of the metered demands in Malvern indicated that the domestic consumption of groups of say 4000 houses were quite stable. Therefore, a large increase above the assumed value at one node would indicate leakage occurring near that node.

Finally, he suggested that the Institution should set up a study group of engineers and scientists who were personally interested in trying out new leakage detecting equipment. All the water authorities would regard waste control as important, but equally important, it is necessary to find enthusiasts who would willingly stay up all night kicking electronic devices into life.

Mr. M. F. Avent (E. W. Avent Ltd) said that the paper was particularly valuable in outlining the technical equipment that should be used to seek out leakage, particularly on mains, surely one of the major aims of the symposium.

Unfortunately, the early part of the conference had concentrated on consumer waste, from ball cocks to swimming pools; delegates had also spent much time on the expensive red herring of possible domestic metering, while continuing to ignore the numerically infrequent but quantitatively major problem of mains leakage. Only isolated references were made to remarkable specific figures, including one burst of 4 mgd, which had remained undiscovered for many years. More factual evidence was given by Mr. Shinner (p. 42), which indicated that the largest volume of water was lost through mains leakage. Again, Mr. Reid had referred to a slum clearance area of Manchester where a relaid mains system had resulted in a considerable reduction in consumption. More noteworthy was the fact that the original high consumption had dropped very little after demolition had cleared all but a few public houses!

It appeared that specific investigation as opposed to generalised enquiries indicated that the technology required in finding mains leakage was a vital part in the battle for waste control. No bye-laws insisted that the water industry prevented waste in its own system but the alternative to rigid leakage control was enormous capital expenditure on domestic metering or capital works. He congratulated the WRC for spearheading this drive, but asked how often their equipment was used?

Mr. J. N. M. Hutton (Hydrotronic (Jersey) Ltd) referred to the reference in the paper to his firm's equipment. Mention was made to the use of a "microphone pick-up". He had recently been assured by the electronic engineer who designed, developed and built the equipment, that a more accurate description would be "vibration pick-up." Of course, the title given to each part of the equipment was not really important; it was the leak finding capacity that counted. During the past 14 months he had seen the equipment working successfully in finding leaks of all sizes, one as small as 2½ gpd with great accuracy. However, he had known it to fail on two occasions but in both cases all other methods tried had also failed. However, he felt that present equipment would have been more successful with these particular leaks.

The only circumstance which he had known to interfere with the equipment had been proximity to jet engines. Nevertheless, these did not prevent the accurate location of a particular leak of 300 gpd, in a kerosene pipeline, near the runway of a busy international airport earlier this year.

Mr. J. R. M. Kearsey (Bristol Waterworks Company) said that the paper, and the contributions to the discussion, had been limited to the location of waste in trunk and distribution mains. Had the author any experience or was he aware of research being done into the precise location of leaks from service reservoirs?

Mr. R. M. Stenberg (Scandiaconsult) referred to leak detection experience in Sweden.

Earlier speakers had mentioned domestic metering. In Sweden, about 85 per cent of all domestic premises were metered. But this was only partly a help in waste control, owing to the errors in measurement. Fig. 10 showed a symbolic presentation of water

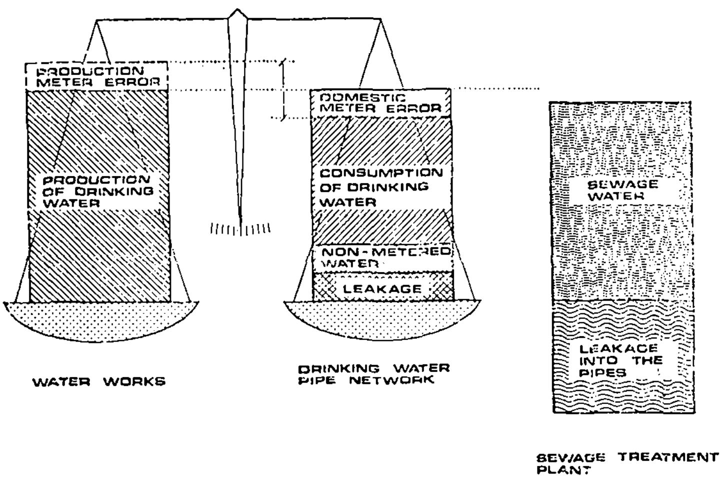

Fig. 10. Symbolic presentation of water and sewage water in a community pipe network

and sewage water in a pipe network. Metering errors might cause the scales not to balance, and this could give an impression of high leakage, although all that was necessary was control and adjustment of the meters.

Part of the consumption was not metered, e.g. the water used for flushing and cleaning of pipes, and this amount must be estimated. The remainder in the scale might be leakage. The amount of this would seldom be less than 8 to 12 per cent in well run networks.

In addition to the water actually used by consumers which had been transferred into sewage water, there was also leakage into the sewage pipes from rain and drainage. The treatment of this water cost per unit about the same as the production of potable water. The amount of infiltration might well be 40 per cent. For the last two years attempts had been made to work out methods for detecting leaks and wrong connexions into sewage pipes. This work was subsidized by the Government. Especially studied were methods of measuring and recording flows through manholes.

Turning to methods of detecting leaks, those used in Sweden were similar to those employed in the U.K. Waste metering was to a great extent carried out by consultants on a service basis. More use was made of electro-magnetic flow-meters rather than gate meters because they had been found to be more convenient in that part of the equipment could be housed in a van, thus providing cover for the operator.

Measuring the minimum night flow by means of water levels in storage reservoirs, as mentioned by Mr. Edkins (p. 117), was gaining popularity since another useful piece of equipment had been designed by Scandiaconsult. It was a precision level meter, the sensor of which was a rod about 1 m long, suspended in the water surface of the reservoir. It was connected by cable to an instrument, which could be located in a car close to the water tower (Fig. 11). This instrument could detect changes in water level of 0·2 mm, and it was normally possible to determine the out-flow from the reservoir in about 5 min and to make sufficient valve closures to monitor several districts during one night.

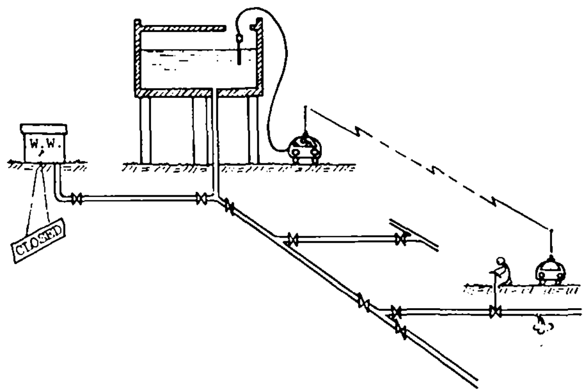

Fig. 11 District measurement of the MNF with the new precision level meter.

Of course, listening was used to a great extent and when repairing the leaks the gangs were issued with a card making it simple to calculate the volume of each leak (Fig. 12).

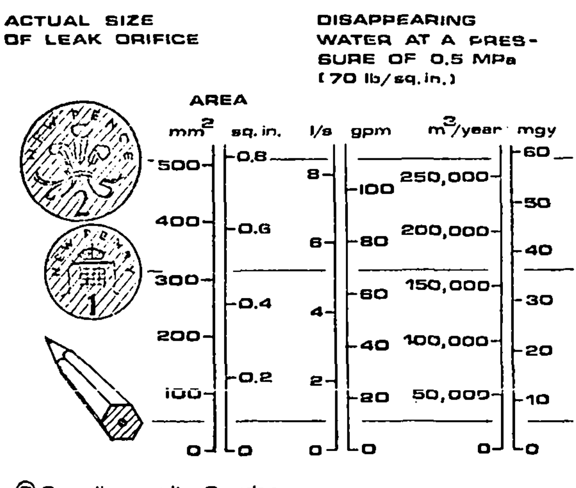

Fig. 12 Calculating chart for leakage rates.

A further method of leak detection which he himself had developed was called the "pressure-differential method". The existence of large leaks might be known from measurements, etc., but their precise location might be difficult to determine because of extraneous noises from industry or traffic or because of the depth of the main (in Northern Sweden mains might be laid to a depth of 3 m). It was well known that the position of a leak might be determined through pressure measurements and by establishing a graph of the gradient lines on both sides of the leak. However, the pressure loss must certainly be high to be measured by means of pressure gauges. By using a differential liquid manometer it was possible to measure friction gradients down to 2 in 1000 (Fig. 13).

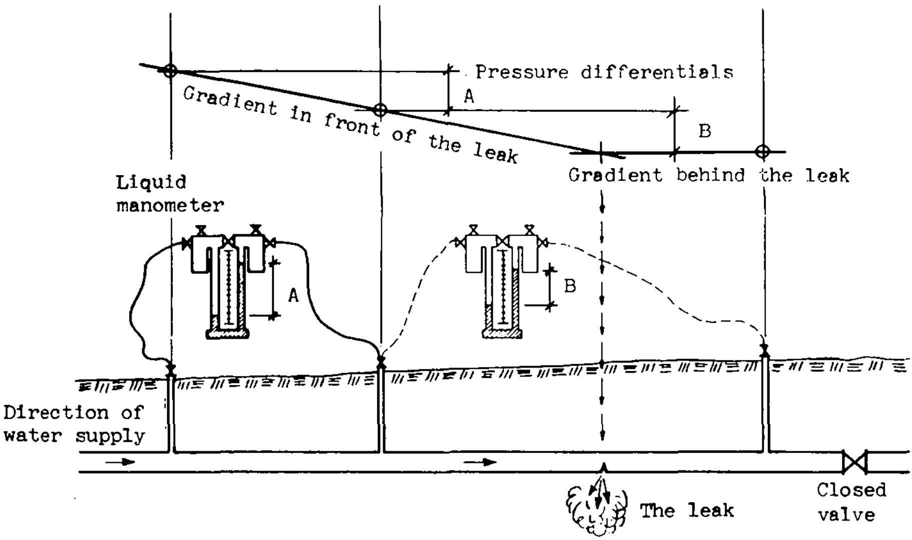

Fig. 13. Pinpointing a leak by the pressure differential method.

The manometer was designed to withstand mains pressure and, in addition to the normal venting and short-circuiting valves, facilities were built in to enable the hoses to be flushed. Small reservoirs were incorporated to prevent the manometer fluid from entering the mains via the hoses, in the case of careless operation of the valves.

The liquid used in the manometer would depend upon the expected pressure differential, which could be calculated from a knowledge of the leakage rate, main diameter, length, and roughness using a standard-loss equation. In case the measured pressure differential was low, the temperature in the hoses might influence the gravity of the water within thus giving misleading results. Immediately before reading off the manometer it was recommended to flush the hoses. During the flushing the manometer valves must be kept in a position to keep the manometer fluid unaffected.

Author's Reply to Discussion

Mr. R. A. Chisholm, replying to the discussion, wrote that Mr. Gill had identified certain aspects of the nature of leak noise and its generation and transmission, and how these affected acoustic methods of leak location. The points he had mentioned were those over which one had no control, and which generally would not be known to an operator using acoustic equipment. These, therefore, might be considered as "variable" conditions.

We must also consider the operator and his use of a particular piece of equipment. Here the conditions of use, and factors affecting the detection of leak sound, were to a large extent constant. These aspects included the contact of a pick-up with ground or fitting surface, the design of the pick-up, the characteristics of any amplifier device, and the signal indicating method.

It was the familiarity of an operator with a particular piece of equipment, its constancy of use and handling, and constancy of operator skill which led to the apparent success of one set of equipment over another. This was as true of highly sophisticated equipment as it was of the "$\frac{1}{2}$ in bar of Sheffield steel" that one inspector he knew had a preference for. The inspector claimed this was largely responsible for his ability to pinpoint leaks accurately.

Since one of the major difficulties in waste detection was that of pinpointing leaks, perhaps a more concerted effort might be applied, as part of waste control, in the area of preventing leaks. Areas for consideration included those of improving the specification of water tightness on new mains, together with close control over the quality and specification of mainlaying.

The use of nitrous oxide had been of particular value in terms of ensuring "tightness" of mains—but since its commercial application this had been more true in the gas and oil industries than in water supply. In relation to mainlaying standards, the benefits of care had been made particularly evident in the case of PVC pipes. In WRC investigations of bursts or leaks, a high proportion of the causes of leakage or failure was found to be mishandling, faulty installation, or inadequate attention to standards of laying and so on. Often these faults did not show up in initial hydraulic tests, but gave rise to failure of pipes some time after commissioning. There was less evidence available at WRC in the case of other materials, but examples had come to light in cast iron and asbestos cement. One wondered how many leaks or main failures which occurred and were not identified to WRC could have arisen through similar causes.

Mr. Avent drew attention to the particular problem of mains leakage as opposed to leakage on consumers' premises. As regards the policy of waste control here, he had made some reference in his preceding remarks. It might be of interest, however, to mention that quantitative comparisons of "mains" and "consumer" leakage carried out by both WRC and water undertakers in the past had shown that some 30 per cent of the total leakage in domestic areas occurred "beyond the stop tap". Whilst this was a fair proportion, it was of course generally comprised of many small leaks, whereas the remaining 70 per cent occurring in mains was generally comprised of larger leaks. Hence the cost effectiveness of waste control should be greater, if mains leaks were tackled first.

Mr. Hutton's reference to the "Hydrotronic" system again identified the problem that however sophisticated acoustic equipment might be, there must inevitably be the leak that either did not produce a sound or the sound was so attenuated that the equipment could not detect it. The need for a "leak sound" was of course a requirement of the correlation equipment described in the paper, but unlike most "acoustic amplifiers", a high extraneous noise to signal ratio did not give problems.

The simple answer to Mr. Kearsey's question was that he was not aware of "research" into location of leaks from service reservoirs. However, he knew that various specific, attempts had been made by some water undertakers, in some instances successfully, using "tracer" techniques. He believed that various salts, and chlorine, had been used in this way. There was of course the possibility of use of nitrous oxide in a similar manner. The advantages of this would be similar to those when it was used for mains leak location, viz. the presence of water for sampling was not essential, as the gas would come out of solution when water leaked out to atmosphere. These suggestions must of course relate to exposed surfaces, or ground areas close to buried surfaces of a service reservoir.

9. FUTURE MEASURES TO MINIMIZE THE WASTE OF WATER

By E. F. YOUNG, BSC, MICE (*Member*)*

CONTENTS

INTRODUCTION

BEFORE DISCUSSING MEASURES AIMED at minimizing waste of water which might be developed in the future, it is rewarding first to look at practices adopted by our predecessors. Ever since piped water supplies were made available, those responsible for supplying water have been concerned with leakage and waste both from undertakings' pipes and from within consumers' installations.

The breakthrough in reduction of waste was undoubtedly the replacement of wooden pipes by iron pipes; the basis of present-day byelaw practice to prevent waste was established when supplies changed over from intermittent to constant supply.

One has only to read the evidence given at a Board of Trade inquiry held in July 1872 in London to appreciate the undertakings' genuine concern with the extent and effect on their systems of waste of water within consumers' installations from the use of substandard and faulty water fittings. The regulations which resulted from this inquiry were devised to prevent unnecessary waste at each point of delivery and use of water; taps, ballvalves and WCs received particular attention.

Arguments were advanced in favour of a regulation providing for all water, other than that used for drinking, to be taken to a storage cistern; this argument continues to be advocated, even to-day. However, the case in favour of the storage cistern failed then because it could not be proven that the adoption of such a regulation would lead to less waste of water.

Loss of water from undertakings' distribution pipes C 1750 to 1820 was thought to be about one-third of the total supply. Wooden pipes had average lives of about 20 years and often failed where they passed over sewers which themselves were in poor condition. Screwed iron pipes, introduced before 1820, suffered from many joint failures at times of severe frosts. This led to the eventual development and widespread use of lead run jointed iron pipes and to a requirement that supply pipes would be laid 2½ ft below ground. Undertakings realized that their shareholders' interests were best served by preventing waste of water because this reduced expense involved in pumpage and it also postponed the need for further capital expenditure on additional source works and mains. These considerations hold true to-day and surely always will.

* Directorate General Water Engineering, Department of the Environment.

However, we are no nearer now than they were over 100 years ago in being able to establish where and in what quantities water ends up after entering the distribution system. Efforts to quantify leakage and to evaluate the results of waste prevention operations are still of doubtful accuracy. Further measures must be concerned with these matters.

DOE WORKING GROUP ON WASTE OF WATER

The Department of the Environment (DOE), through the Directorate General Water Engineering, set up a Working Group (WG) in January 1974. The WG includes representatives from the Institution of Water Engineers, the Chartered Institution of Public Finance and Accounts, the National Water Council (NWC), and the Scottish Development Department, as well as administrators, engineers and economists from the DOE.

The terms of reference of the WG include the identification and evaluation of the relative importance of common and most frequent points of leakage, investigation of the present waste of water and the examination, comparison, and evaluation of present methods of leak location, waste detection, and prevention. In addition, the WG was to consider and advise on an appropriate cost-benefit method to help water authorities decide the amount that should be expended on waste detection and prevention.

The directors of operations of Regional Water Authorities (RWAs) have co-operated by issuing a questionnaire devised by the WG to some 30 selected pre-1st April 1974 water undertakings. The questionnaire elicits information on waste control practice, organization, staffing, expenditure, statistics of incidents, and asks for views on such matters as the importance of various factors in waste and economic evaluation which may have been carried out by the undertaking.

The WG is in the process of receiving and analysing the data from the completed questionnaires, after which they propose to identify research needs and to publish an interim report early in 1975.

THE ROLE OF RWAs

The RWAs, with the assistance of the NWC, will no doubt take stock of the present position concerning waste control within their areas. As opportunity and time permits, each water authority may rationalize and develop waste control organization and practice. There is a need for co-ordination between administrative, technical, and financial representatives from the water authorities on all aspects concerning waste control. A number of controlled pilot studies could be undertaken which should give answers to many outstanding questions. With adequate pooled resources for research, and a willingness to accept that waste is a subject worthy of urgent and continuous consideration, the way is now open for progress.

That there is scope for this surely no-one will deny. Information received by the WG indicates that there is a wide divergence in practice at present, as one might expect. Water supply is capital intensive and it is necessary to get best value for money. Water authorities will wish to demonstrate that they are taking all reasonable measures to control waste. This means they will need critically to examine and compare the levels of waste control organizations, expenditures and results achieved, particularly in those management divisions where high capital investment might be required within the next decade.

ORGANIZATIONAL STRUCTURES FOR WASTE CONTROL

Waste control organizations follow no set pattern; they have evolved on a historical basis. Some management units include an independent organization which deals exclusively with waste, whereas in others waste control is decentralized being handled within each distribution area as part of the normal work.

The usual method of determining the levels of future annual expenditure on various aspects of waste control is simply to budget on current expenditure, allowing for inflation. Often, the work actually carried out depends on the availability of staff (once the needs of other types of work have been satisfied).

Staff recruitment for waste detection duties poses difficulties primarily due to the regular night work which is involved. Thus, future measures which might be developed depend very much on recognition of the need to increase job satisfaction. Attempts will continue to be made to reduce present manning levels through work study incentive schemes. Decentralization of activity within management units is said to enable greater advantages to be taken of local knowledge.

The eventual organization which may evolve might comprise three parts. Water authority headquarters might provide a co-ordinating and advisory service which also monitored and evaluated results achieved as well as arranging for bulk purchase of equipment and the training of middle-level staff. The second part might be based on the provision of mobile teams to back up at infrequent intervals the permanent staff within divisions by means of intensive effort directed in areas where there is no more than minimal routine surveillance. The third part would be the local staff providing the necessary continuous effort in routine waste control.

The main item of expenditure on waste control is labour, which may account for as much as 70 per cent of the total cost. The need for a carefully thought out policy for future recruitment and efficient use of labour is therefore obvious.

FUTURE OBJECTIVES

There is need to examine two aspects of waste control within each management division. The first is economic assessment of the optimum expenditure on waste control, the second the determination of waste indexes.

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.

The second aspect to be examined would be, for want of a better description, the determination of a waste index. What is envisaged is a standard or target maximum loss rate per service. The index would be determined arbitrarily having regard to age of services and of mains, type and age of property supplied with water, pressure, ground conditions (particularly where mains are laid over coal measures) and so on. The actual average index (i.e. total unaccounted for flow divided by the number of properties) would be determined after waste meter surveys. Such an index method of representing waste could be of far more use than figures of overall percentage waste.

THE AGE FACTOR

Many water engineers place the age of mains, pipes and fittings high on the list of contributory factors to waste of water. Many distribution mains are over 80 years old. A majority are probably of grey cast iron; the age of these pipes is not necessarily a primary cause of failure. Usually, the fault lies in a combination of adverse ground conditions; the pipes becoming progressively weaker with age. Where these mains are located under heavily trafficked roads, the incidence of fractures and leakage depends upon the pavement design, rather than the age of the pipeline.

Regarding consumers' communication and supply pipes, the situation is somewhat different. For every mile of undertaking mains there might be as many as 120 separate consumers' supply pipes. Whereas the mains could be expected to be of a high standard in strength, having been laid and jointed with care, the same cannot be said of supply pipes. Varying ground conditions, and differing standards of backfilling and workmanship often combine to produce a greater probability of fracture or leakage and one that increases in the course of time. We need to know more about these smaller pipes, particularly as regards the extent of leakage and incidence of fractures in old lead and the newer plastic tubing.

PRESSURE AND LEAKAGE

It is generally accepted that wherever possible normal working pressures in both mains and consumers' installations should be reduced to the minimum consistent with satisfactory service. Efforts in this direction will undoubtedly continue but there are problems. In some areas, mains pressures are as high as 10 bars.

However, some quite startling results may be seen after significant reductions in pressure; reduced consumption of water as well as reduced leakage losses could be the case. Perhaps a better case could be made for more widespread use of fittings and appliances being served from cold water storage cisterns.

Reducing normal working pressures would also lessen the number of bursts in old mains and services where pipes and fittings are of limited strength.

GROUND CONDITIONS

The ground in which pipes are laid and conditions in the area influence potential leakage in many ways. Thus, leakage may result from differential ground movement, corrosive soil, transfer of vibration and movement under traffic. We need to establish a corelation between these factors and leakage and to evaluate the relative importance of each. The result might lead to redesign of pipe joints, the development of new materials for coating of pipes and to a change in practice where pipelines are laid under or near heavily trafficked roads.

In some areas, conditions are such that many points of leakage do not show up on or at the ground surface, making it necessary to go out and locate them.

QUALITY OF MATERIALS AND WORKMANSHIP

Poor quality of fittings and bad workmanship in pipelaying and jointing are probably major factors contributing to waste of water. Mainlaying works are usually under the control of the water authority, who specify strength and design of pipelines and supervise pipelaying and testing. However, work in consumers' installations, particularly in small diameter pipelines laid in ground near houses, cannot be given the same degree of supervision or inspection. There is need to maintain standards of bending strength and ability to resist internal pressure in piping used in services and to provide for initial pressure testing of supply pipes in order to prove jointing efficiency. Research might be justified in this direction. Leakages above ground, whether in pipework or at fittings may readily manifest themselves, but the same cannot be said for buried pipework. The level of waste for years ahead may well be governed by the quality of materials and labour used in both mains and services over the past 50 years.

LOCATION OF LEAKS

Improvements in design and scope of leak location equipment will no doubt continue, but progress will be governed by the attitude of water authorities. It has been suggested that there could be scope for more compact and reliable equipment and for development of equipment to locate leakage from plastic pipes and fittings.

The availability of mobile waste detection units will enable many areas previously not subjected to waste water metering to receive attention. The relative advantages of fixed and mobile units deserves consideration; there is probably a need for both.

INSPECTION OF CONSUMERS' INSTALLATIONS

This work is particularly labour intensive. It is a matter for consideration as to whether inspections should be confined to those carried out on first connexion of a new installation, or whether subsequent regular inspections should be made.

However, the Report of the Technical Committee on Back-siphonage in Water Installations (to be published shortly) contains recommendations for frequency of routine inspection for dwellings and for industrial and other premises. For the latter, inspections not less frequently than once each year are recommended, but for the former inspections would generally be when contamination, leakage or other defect is being investigated. There is obvious advantage to be obtained from combining regular contamination and leakage prevention inspections.

LEAKAGE FROM SUPPLY PIPES, TAPS AND BALLVALVES

No-one knows what proportion of water lost underground occurs beyond consumers' communication pipes. Similarly, the quantities of water lost from bursts following frost damage or from leaking water fittings is not known. From the information available, one might say that whereas an underground leak is found each year on mains and associated valves and hydrants for each 4 mile length of main, leaks are found at the annual rate of one for every 70 communication and consumers' supply pipes. On average a defective tap is found each year for every 50 services and a defective ballvalve for every 70 services.

Can any valid conclusions be drawn from these figures? Would we be correct in seeking better designs for taps and ballvalves or should we investigate why these fittings become defective? Even when a free rewashering service is offered, it is possible that the majority of taps which are rewashered are done so not as a result of the consumer reporting but as a result of house to house inspection. Does this point to the need for the water authority to initiate prosecutions for careless waste, particularly in cases where a free rewashering service is available? Are the penalties adequate?

METERING DOMESTIC SERVICES

Unless all points of supply of water are metered, we will never really know how much of the water put into supply is unaccounted for. A benefit from metering of domestic services might be to encourage consumers to consciously use less water by attending to the maintenance of their installations. Careless waste from dripping taps and ballvalves needs to have a value put on it.

FLUSHING CISTERNS

Automatic flushing cisterns are considered by many engineers to be the cause of considerable waste of water. Various suggestions have been made to deal with this including a requirement for a maximum frequency of operation, the fitting of time-controlled actuator operated valves to limit the hours each day during which such cisterns may operate, and the use of photo-electric cell actuators. Clearly, this subject merits detailed consideration and a DOE Project Committee which is studying water economy in the home intends to review the present situation.

It has also been suggested that the wider use of flushing cisterns designed to give flushes of two different volumes should be promoted.

CONCLUDING REMARKS

Whilst no-one will doubt that it is essential to stop needless and obvious waste by repairing defects, it is surely more important to get at the root causes of defects so that action can be taken to reduce their incidence. There is a need to know more about the basic causes of leakage.

Should we adopt as a principle of practice a requirement for new mains in future to be virtually leak-proof, having indefinite life expectancies? Alternatively, are we satisfied that sufficient care is being given to the quality of workmanship in pipelaying and jointing? What are the economics of higher standards?

What should be the target frequency of inspection of existing installations? Should this be arrived at having regard to the age of installations?

How many lost mains and abandoned services are there, and how many old ferrule connexions leak?

An obvious criticism of this paper could be that it advocates nothing new because it has all been said before. My answer to this is that one hopes that in 25 years' time we will not have to go over the same ground yet again. Having identified the problems, we should exert ourselves to solving them.

DISCUSSION

Author's Introduction

Mr. E. F. Young, in introducing his paper, reminded delegates that his views might not coincide with those of the Department of the Environment.

Explaining why only a synopsis of his contribution had appeared in the advance copies of the papers comprising the Symposium, he said that his Director had thought he should await the issue of the other authors' papers, from which he might glean material on which to base his own contribution. As it turned out, he had had to write the paper without the benefit of seeing the other contributions; consequently, much of what he had said might have been covered already, but such points as were duplicated were probably those which merited restating. Perhaps his contribution would sum up the discussion and, hopefully, point to future action.

Mr. Young then read extracts from his paper, the full text of which is reproduced above. The synopsis which appeared in the advance copies of the papers is not reproduced.]

In conclusion, he said that the papers comprising the Symposium were eminently readable and informative. The papers, and the views expressed in the discussions, deserved careful reading—together they should influence "future measures", focussing attention on this most important, but little appreciated, subject of waste of water.

VERBAL DISCUSSION

Mr. C. Hurst (Thames Water Authority), in opening the discussion, referred to the list of factors to be discussed which the author had given in the synopsis included in the advance copies of the papers.

The author had said that we needed a means whereby benefits from waste control could be expressed in cash terms to be set against the cost. He himself queried this. Could not too much time be spent worrying about the economics and not enough time reducing the waste? Mr. Reid had stated that the cost of waste detection represented 1 per cent of the annual revenue and his waste was about 12 per cent. At this stage should not the economist look at the other 99 per cent of expenditure?

He agreed that we needed to know the extent of the leakage problem, and suggested that a code of practice was needed so that everybody could compare the same data.

Regarding the author's reference to training, this was the first time that the human element had come into the discussion. Was it not true that in all forms of management, the most important was the human element? We must train inspectors; we must motivate; we must stop spending more time on paperwork and devote the time to the motivation of employees!

Concerning the reduction of pressures in the distribution system, if the pressure was reduced by about 10 per cent, the reduction in waste paid for the installation of the pressure-reducing valve. Both Mr. Giles and Mr. Reid had pointed out that the night line was greatly reduced by the introduction of pressure-reducing valves.

The Metropolitan Division of the Thames Water Authority ensured that all hot and cold fittings were fed from a storage tank in the property; only one tap was supplied direct from the mains. Was it not essential that such regulations were common to all byelaws? Should not it also be essential to lay a 22 mm service into properties? It would be possible to install pressure-reducing valves on the mains feeding that area and reduce pressures to about 50 ft.

Concerning the question of domestic metering, if a household used 100 gal of water per day the annual charge (based on a figure of 35p/1000 gal) would be £12.77. If the introduction of metering showed a reduction of 30 per cent in demand, and assuming that the true cost of producing the water supplied was 15p/1000 gal, the annual saving would be £1.65. Was domestic metering really economic?

Finally, he said that he favoured a free rewashing service.

Mr. N. G. Semple (Scottish Development Department) said that there was a great diversity of policy on waste saving between different authorities, and it was tempting to think that there should be more uniformity. But there was a measure of choice justifiable in the effort which was put into waste control and this deserved consideration. For reason of the non-financial benefits to be derived from reduction of leakage, there was an argument in favour of spending more than would be justified on strictly economic grounds but the economic level on waste control must always be the point of reference and while extra expenditure might be justified, the amount of it should be known so that it could be judged as to its value.

However, it was hard to find any justification for expending less than the economic amount of effort, but this raised the point of how this amount could be determined for a particular authority and district at a particular time. Undertakings understandably found themselves at any time in a static situation where the measures adopted each year were often simply a slight adjustment to what was done previously. Consequently, it was not easy to know what was the right amount of effort to apply. More consideration should be given to the initiation of pilot schemes to measure the effect of a substantial increase (or decrease) in effort to be compared with the change in the amount of water lost and also its financial value locally and the results should be published.

More attention should be given to the whole subject of waste control. Perhaps it should be reviewed annually by authorities. It must lose its "Cinderella" image, and its real importance in the day-to-day operation of an undertaking must be highlighted. Firstly, however, an agreed set of definitions was necessary, for comparison purposes.

Mr. R. B. Tabor (Thames Water Authority) said that the author had asked if there was evidence to show whether any improvement was necessary in standards of materials being used for pipelaying practice. He himself had, in the past few years, been involved in a research project sponsored by the former Metropolitan Water Board in conjunction with the City University into the causes and remedies of failure in cast iron water mains.

An interim report was published at a symposium on failures in mains held at the University in 1973; a further report would be presented soon. Without wishing to pre-empt the findings it was possible to state that there was evidence to show that underground pipes (particularly when buried for long periods) were subjected to considerable external forces from the surrounding ground and therefore the slightest variation in conditions was liable to trigger off a failure which, in small diameter cast iron mains, generally was of the transverse type. Contrary to previous thinking changes in water temperature were not considered to be a major cause but differentials in air temperature and possible changes in traffic patterns might be trigger mechanisms. In any event, it was clear that mainlaying techniques needed to be reviewed in order to isolate pipes from ground forces. Research into this aspect was, at present, being carried out as part of the current project. The interesting aspect of this was that the same techniques would be required for laying of plastics pipes, particularly of the rigid type such as PVC, as would be needed with asbestos cement and cast iron mains. Whilst the use of ductile iron might appear to be a solution, further experience might be required to gain information as to its corrosion resistance.

Mr. R. M. Poole (Anglian Water Authority), referring to water main systems laid in aggressive soil, compared them to the corroding chassis of a car, which required comparatively small and infrequent repairs until uniformly increasing general corrosion led to its sudden and complete collapse.

He sought the author's opinion as to when such water mains should be replaced and wondered whether this might be considered an expenditure on water waste control. The standard answer to the question was that repairs should continue until it became more economical to relay the mains. However, this really missed the point of the question.

The query was based on the probability that there were mains systems in which long lengths, amounting to several miles, were corroding at a comparatively uniform rate. If, therefore, general action was not taken until the frequency of bursts indicated that an emergency situation had been reached, it could prove beyond the resources of the authority to deal with the work quickly enough to prevent a major breakdown of water supply in the affected areas.

Mr. H. J. Eikelschulte (Vetco Inspection Gmbh) said that the discussion so far had dealt with the location of leaks and not with their prevention. In oil and product pipelines various methods were in use in order to protect the lines, i.e. cathodic protection or inspection by application of internal corrosion detection instruments or leak detectors. Had it been envisaged to use similar methods in water mains?

The above-mentioned methods were mainly applied to protect the groundwater sources. In Germany the absence of leaks in oil or product lines had to be verified by pressure differential tests or leak detector runs at regular intervals. He asked for the author's view on these methods with regard to water protection.

Mr. H. J. Giles (National Water Council) said that waste control was essentially an activity whose existence largely depended upon economic considerations. Several ancilliary benefits occurred as a spin-off from waste control—accurate distribution plans, regular operation of valves providing security during emergency and maintenance operations, and an increased knowledge of the distribution system—all of which should occur in normal distribution management but often did not. Rarely was a value given to these benefits, possibly because they were difficult to quantify. Nevertheless, the benefits were real and an effort should be made to evaluate them.

Mr. D. Watson (Central Water Planning Unit) was sure that the author had not intended criticism when noting that little was known of what happened to water once it entered the distribution system. Yet the criticism was justified and warranted repetition.

At present there were only some 15 years of reliable annual totals of public supply consumption, about five years of Section 114 direct abstraction returns, and some incomplete sewage statistics on which to forecast future trends and to provide a comprehensive picture of the water industry for England and Wales. These records gave no breakdown of unmeasured use, nor were they classified to provide total use in major industries.

As part of the effort to prevent waste and misuse of resources it was essential to know more about industrial use and various unmeasured uses for commercial, public, and fire-fighting purposes and inside and outside the home. Much useful fragmented information was already available in distribution offices, but it needed to be collected together and analysed. Similarly, the classification of PWS metered records industry by industry was now overdue.

He stressed the importance of getting to grips with such problems quickly and urged that they be given priority.

Author's Reply to Discussion

Mr. E. F. Young, replying to the discussion, said that Mr. Hurst had reviewed the factors to be discussed as listed in the synopsis to the paper which had been included in the advance copy issued to delegates. We did need a method whereby benefits from waste control could be set against cost. There were cases where little effort appeared to be directed to reducing waste. How else could expenditure be justified in these cost-conscious days other than by showing that benefits accrued which exceeded those from spending the same money on new works? To the best of his knowledge all expenditure on water was presently under the microscope. The McNaughton Report (Ministry of Health 1949) cited by Mr. Giles in his paper indicated that expenditure up to 10 per cent of the undertakings' wages bill might be justified on waste control.

He agreed that there appeared to be a case for further expenditure on research into waste control. Improvements in standards of materials and practices would only take place when need was established; it was not self-generating.

Concerning limiting of pressures, Mr. Hurst had no doubts that such would be sensible. However, this practice was by no means universal nor were the practical difficulties easily overcome in many areas of the country. The question of fully pressurized versus fully stored installations was a matter for another forum. With the exception of Eire and southern Italy, all the other countries in the EEC had fully pressurized installations.

As regards a free rewashering service, Mr. Hurst favoured such a method. However, many pre-1st April 1974 water undertakers had either not provided such a service or had abandoned the practice, following financial evaluation of the service.

Concerning domestic water metering, Mr. Hurst should await eventual publication of further information on the subject. Mr. Hurst was convinced that domestic metering was not viable; he himself had no views because each case should be considered on its merits. All he would say was that the disadvantages mentioned by Mr. Hurst were not accepted as applying in most overseas countries.

He was grateful to Mr. Semple for his positive suggestions. He paid tribute to him for the great interest and enthusiasm he had brought to the work of the working group on waste of water.

Four main points had been raised. Determination of the economic level of waste of water; measurement of benefit following expenditure; periodic review; and status of staff involved.

In time of strict financial control, capital expenditure of all types needed to be carefully reviewed and if possible, reduced. We could not reduce annual expenditure, most being on wages. One might conclude that we should accelerate work on waste control and to catch up any backlog particularly where savings were likely to postpone further expenditure provisionally planned to be incurred within the next 5 years (i.e. a 5-year rule?). Annual expenditure would be increased and it would put waste control in competition with other capital expenditure schemes. As Mr. Semple had reminded him, we needed to be increasingly cost-effective; he concluded, quite rightly, that capital expenditure planned for new works would have to be compared for cost-effectiveness with expenditure on waste control and they should compete for finance.

As regards measurement of benefit, simply repairing leaks, even after finding them would not, in the short-term, tell what benefit was accruing. When each leak was located, it should be evaluated as follows:

(*a*) If the leak was one which manifested itself or would have done in the course of time—ignore it for purposes of ascertaining benefit;

(*b*) If it was one which could have run for years but for its discovery by waste control procedures—assess it by its capacity (rate loss of water);

(*c*) Aggregating annually, one could say we spent £x and found y mgd of leaks;

(*d*) The value of saving y mgd for years was assessed by the saving in recurrent expenditure on chemicals and on power plus the savings from deferring capital expenditure in future on providing y mgd new capacity.

As regards periodic or annual reviews, water authorities would surely wish to assess and publicize their achievements.

Finally, he felt sure that the results of waste control would become appreciated by management. This was linked with Mr. Semple's appeal for the reporting of the results of pilot schemes in typical areas to measure the effects of substantial change in effort.

Mr. Watson had emphasized the need for fundamental information and he could do nothing better than to endorse his remarks. From his own contacts with water authorities he noted that they fully realized the deficiencies and were attempting to come to grips with these problems.

He thanked Mr. Tabor for his contribution concerning the causes and remedies of failure in cast iron water mains. Hopefully, the results of the research when eventually published would give designers guidance as to changes in current practice. That differentials in air temperature might be an important criterion was a new concept as far as he was concerned and it would be interesting to learn whether our colleagues in Scotland could bear this out from their own experiences.

Mr. Poole asked whether expenditure on mains replacement might be considered an expenditure on water waste control and at what point a uniformly increasingly corroding main should be replaced. As regards expenditure, it was of no consequence to what vote one allocated expenditure so long as needful work was undertaken; what was important was that economics and convenience were both considered. Management would, or should, be aware of potential weak links which manifested themselves by frequency of failure. As to when replacement of a main actually occurred depended not only upon economics as such, but also on authorities' financial viability; compromise between competing demands for capital expenditure might involve the unpalateable acceptance of risk. It was a balance between various probabilities which needed review from time to time.

Mr. Giles had referred to the additional benefits to management of a water undertaking as a result of well-organized waste control. The point he made was important and merited inclusion in any cost benefit exercise but, as Mr. Giles had said, it was difficult to express the benefits in cash terms.

Mr. Eikelschulte had raised two points. In his experience, cathodic protection was practiced usually for trunk and feeder distribution mains which were either of continuously welded steel or mechanically jointed steel with bonding across joints. Prevention was better than curing leakage and this principle was cardinal in British water engineering. Concerning routine pressure differential testing on leak detection runs, the former posed practical problems particularly for the important trunk mains. As regards leak detection runs, the use of regular waste water meter runs was established practice in Britain.

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