ASIAN DEVELOPMENT BANK

REGIONAL SEMINAR

ON

CONTROL OF WATER SUPPLY DISTRIBUTION SYSTEMS

(Singapore, 8-11 February 1983)

A SUMMARY REPORT

Water Supply Division

FOREWORD

The Asian Development Bank held a Regional Seminar on the Control of Water Supply Distribution Systems in Singapore from 8 to 11 February 1983. The Seminar was organized for the benefit of major water supply utilities, particularly those in the urban areas of developing member countries (DMCs) of the Bank which generally have a high percentage of unaccounted-for water. The response from the DMCs was encouraging, and the deliberations of the Seminar were very useful.

The Seminar provided an opportunity for senior officials dealing with water supply in DMCs to share their views and experiences. The papers presented by the participants dealt with various important aspects of the subject. The Bank staff also benefited from the Seminar as it enhanced their understanding of the measures needed to improve the control of water supply distribution systems effectively. Programs for leakage detection and control are as important as programs for the augmentation of water supply.

This report has been prepared by the Bank's Water Supply Division, with the assistance of a staff consultant, and summarizes the proceedings of the Seminar. On behalf of the Bank, I wish to place on record our sincere gratitude to all the Seminar participants for their most valuable contributions. I also wish to thank the governments of DMCs for enabling the participants to attend the Seminar.

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REGIONAL SEMINAR ON CONTROL OF WATER SUPPLY DISTRIBUTION SYSTEMS

A SUMMARY REPORT

I. INTRODUCTION

1. The Asian Development Bank organized a Regional Seminar on Control of Water Supply Distribution Systems in Singapore from 8 to 11 February 1983. The Seminar was financed by a regional technical assistance grant approved by the Bank on 25 October 1982. Preparation and conduct of the Seminar were carried out by the Water Supply Division (Infrastructure Department) of the Bank. Seminar facilities were provided by the Public Utilities Board (PUB) of Singapore.

2. The Seminar was organized for the benefit of major water supply utilities, particularly in the urban areas of developing member countries (DMCs) of the Bank which generally have a high percentage of unaccounted-for water. Most water supply projects involve the enlargement of existing water supply systems together with measures to reduce unaccounted-for water from a range of 30-50 per cent of water supplied to about 20-35 per cent. Since the information on recent developments in water supply distribution system control is fragmented, a water supply utility embarking on a program to reduce unaccounted-for water often has little knowledge of the experience of others. The Seminar's main objective was therefore to share information and discuss new techniques and programs for making distribution system control in urban areas more efficient. The long-term objectives of the Seminar were: (i) to define a consistent approach to water supply distribution system control in future Bank-financed projects; (ii) to find out ways to determine achievable reduced unaccounted-for water targets; (iii) to establish an efficient system of controlling unaccounted-for water in urban areas; and (iv) to improve the operating efficiency and profitability of water supply utilities in the DMCs.

3. The Bank has been providing financial and technical assistance for water supply projects since 1968. By the end of 1983, 52 loans (totalling $1,074.20 million) and 32 technical assistance grants (totalling $6.79 million) had been provided to support water supply and sewerage projects in the Bank's DMCs. The Bank has also financed two regional activities, including this Seminar,[1] at a cost of $102,000. Singapore was selected as the venue for the Seminar in order to take advantage of the experience of PUB which had succeeded in reducing unaccounted-for water to about 10 per cent of water supplied.

4. Twenty-two officers from 12 DMCs[2] participated in the Seminar. In addition, seven resource persons (selected by the Bank), one observer from the International Bank for Reconstruction and Development (IBRD) and five observers from three DMCs (Papua New Guinea, Philippines and Singapore) attended. Most of the participants and observers were senior Government officials from water supply authorities or individuals from agencies responsible for water supply services. A list of participants is in Appendix 1 and the Seminar Program in Appendix 2.

5. Apart from the papers presented by the resource persons and participants, an overview prepared by Bank Staff on the basis of responses received to a questionnaire sent by the Bank to the participants from DMCs was also presented (see pages 5-14). In addition a technical visit to PUB's Woodleigh Complex, the site of Singapore's first water treatment plant, was arranged for the benefit of resource persons, participants and observers. They were shown around the Meter Repair and Testing Workshop and Service Operations Centre where demonstrations of leak detection, with conventional and modern equipment and computer analysis of billing, collection and consumption to assist detection of leakage or waste, were given. The handling of complaints and reports of leaks from the public was also witnessed at first hand.

1/ The other regional activity was the Working Group Meeting for Water Supply and Sewerage Development held in Manila in October 1977.

2/ Bangladesh, Hong Kong, India, Indonesia, Malaysia, Nepal, Pakistan, Papua New Guinea, Philippines, Singapore, Sri Lanka, and Thailand.

6. The papers presented by the resource persons dealt with various important aspects of the subject. Country papers (presented for all DMCs represented) highlighted individual countries' problems and prospects in the field of water distribution control and facilitated inter-country comparisons and exchange of experience. A list of papers presented is given in Appendix 3.

7. In the papers presented and the discussions held at the Seminar, various terms, such as 'unaccounted-for water', 'water losses', 'unaccountable water', 'ineffective water' and 'non-revenue water', were used to refer to the quantity of water which does not serve its intended use. It was agreed that, since no one phrase was completely accurate in any paper on this subject, definition of the term used should be provided by the author himself.

8. The Seminar focussed attention on the problems faced by several water supply utilities in the 12 DMCs which had participated in the Seminar. It was appreciated that most of the water utilities experienced problems arising from lack of water meters or defective water meters; inadequate supply capacity leading to intermittent water supply; old and defective service connections; public standpipes; and illegal connections. Though there was general awareness of the significance of reducing unaccounted-for water, it was noted that actual success in controlling water losses was constrained by a number of factors, including lack of detection equipment; complexity of old systems and the inadequacy of isolating valves and wash-outs; low pressure; lack of trained personnel; and inadequate system records.

9. It was generally recognized that most of the water supply authorities wished to have better control of their water supply distribution systems. As such, they were becoming increasingly conscious of the need to adopt various measures to overcome their system deficiencies, including standardization of designs and products; production of spare parts locally; metering public standpipes; technology transfer from developed to developing countries; and sharing of experience among developing countries. Though the stage reached by various authorities in implementing program for obtaining better control of their distribution systems differed, in general,

efforts were being made to identify the causes of unaccounted-for water; procure leakage detection equipment and train staff in its use; adopt improved billing and collection procedures; and enlist public cooperation and support through publicity campaigns and better public relations.

10. The discussions in the Seminar stressed the need for adopting effective measures to improve the control of water supply distribution systems. The measures identified included mapping of the facilities; soil survey; adopting a progressive leakage detection program technically and financially appropriate to the problems experienced; pressure control; audit of water use; preventive maintenance; standardization; coordination among various public utilities; and training of manpower. The significance of water pricing policies and tariffs, as well as public education and prompt response to complaints, was also highlighted in the Seminar. The Seminar's summary is given on pages 34-37. A selected bibliography is in Appendix 4.

II. AN OVERVIEW*

Introduction

11. A common feature of the operation of water supply utilities in the urban areas of developing countries is the high percentage of unaccounted-for water, which is often in the range of 30 to 50 per cent of the quantity of water produced and sometimes even higher. Since it is believed that water supply utilities would benefit from an exchange of ideas and experience among themselves and with international experts, the Bank has organized this regional seminar on the control of water supply distribution systems.

12. A questionnaire was sent to 25 water utilities to obtain relevant information for preparing an overview of the operational aspects of various water supply systems in the Bank's developing member countries (DMCs). By the end of January, 17 responses had been received. This paper presents the conclusions drawn from the data contained in the replies.[1]

13. The range of population of the service areas of the water supply authorities that completed the questionnaire is from 22,000 to 7 million; six with less than one million people and three above 5 million. The extent of the population served also ranges widely, from 20 to 100 per cent of the population in the service area, the average being about 73 per cent.

General Trends

14. Water supply systems in the major cities of DMCs were installed over a wide range of years, some as long ago as 125 years and some as recently as 40 years. Major expansion to these initial systems was either slow or not required and generally made after several decades. Recently, system expansion has tended to become more frequent, often once in a decade. In the older systems, although surface water was

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* Prepared by the ADB Staff and presented at the Seminar.

1/ As one response does not give specific details of any particular water supply system, the figures refer to 16 responses.

invariably the supply source, treatment works were not always provided and in several cases treatment plants were provided several years after the supply source had been installed. The main reasons for the need for frequent expansion of water supply systems are:

a) rapid growth of urban population;

b) increase in per capita demand; and

c) shorter design periods or phasing of proposed construction.

15. Metering of service connections was adopted from the beginning of service in four places. In two cases, metering was introduced nearly one hundred years after the initial supply had been provided. Generally, metering was adopted in the late 1940s, and in a large number of systems both metered and unmetered connections exist. A trend exists to install water meters on all connections, or at least on connections for institutional use, such as schools, government offices etc. and industries. In three of the 12 places where the service was started with unmetered connections, all service connections are now metered.

16. In the early days, tariffs were simple and remained in force for long periods. Revisions to tariffs have become frequent in the last two to three decades following the approach that the amount payable by a consumer should be related to the quantity and nature of consumption. This approach has been easier to follow whenever commercial accounting has been adopted by the water supply utility. The maximum number of years since any water tariff was last revised is seven. On an average, tariffs are now in force for about two and a half years.

Service Parameters

17. The responses show a wide range of such basic data for water supply utilities operation such as per capita consumption, pressures, etc. Local factors, such as population density, climate and terrain, obviously affect the data but, nevertheless, the responses reveal a large range of data as shown below:

Parameter	Range	Average
Per capita supply (lpcd)	60-423	195
Per capita pipeline length (meters)	0.35-6.35	1.35
Per cent of connections metered	0-100	70
Maximum and minimum pressure (meters)	15-130 max./0-30 min.	48 max.; 5 min.
Number of public standposts per 1,000 population served	0-3.21	1.72
Service staff engaged per 1,000 population served	0.153-2.35	0.66
Service connections per 1,000 population	34-207	120

18. The smallest size of pipeline is shown as 20/25 mm in three responses, 38 mm in one response, 50 mm in two responses, 75/80 mm in three responses, 100 mm in five responses, and 250 mm in one response. In one response, the smallest size of pipeline is noted as 12 mm, probably referring to the service connection pipe. The largest size of pipeline varies from 300 to 3,000 mm.

19. Preference in the modes of supply is not specifically noticeable for elevated storage tanks at constant initial pressure or through direct pumping into the system at variable pressure. The former mode is stated in eight responses, the latter in two responses with a mixture of both in five responses.

20. For the type of faucet in public standpipes also, no preference is noticeable. The responses indicate that special faucets such as "self-closing" and "waste-not" taps are not commonly used and are mentioned in only two responses.

21. Five water supply utilities replace meters at regular intervals which range from four to seven years. The remaining utilities replace meters only when they have become defective.

Unaccounted-for Water

22. There is general awareness of the significance of reducing unaccounted-for water. Actual success in controlling unaccounted-for water is stated to be constrained by one or more of the following factors:

a) lack of detection equipment (eight responses);

b) complexity of old systems and inadequacy of isolating valves, air valves and wash-outs (four responses);

c) lack of trained manpower (three responses);

d) inadequate system records (two responses);

e) low pressure (two responses);

f) lack of training (two responses); and

g) lack of funds (one response).

23. The general practice is to deal with visible leakages. Listening sticks and electrical/electronic devices that magnify the noise of leaking water have been used since the 1960s and 1970s at seven places. More advanced equipment, such as computerized devices which correlate leak noise picked up by two microphones to locate the site of leakage, are becoming better known and two responses indicate intention to acquire such equipment. Available equipment is indicated not to be used to its full potential. The reasons for this are stated to be lack of manpower, interference caused by traffic and traffic noise, and low system pressure.

24. The extent of unaccounted-for water and its components is a subject of guesswork in most cases, accurate data not being available for lack of proper flow recording instruments at the supply sources. However, it is recognized to be a high percentage of the water supplied in almost all responses. The common range is 25 to 40 per cent of the water supplied although the minimum and maximum figures are 9 and 50 per cent of water produced. The average is 34 per cent.

25. The breakdown of unaccounted-for water, often based on empirical judgement, shows wide variation. Leakage from pipelines, wastage by consumers, metering errors and illegal tapping are identified as major causes, and public standpipes, public use and other factors are noted or believed to be of minor consequence. The table below shows the range and average for these factors:

Factor	Per cent of Unaccounted-for Water: Range	Average
Leakage from pipelines	10 – 75	34.5
Wastage by consumers	0 – 55	20.7
Metering errors	3 – 35	13.6
Illegal tapping	2 – 40	12.3
Public standpipes	4 – 31	9.2
Public use	0 – 15	7.9
Others	0 – 8	1.8

Billing and Collection

26. The interval of billing varies from one to six months; 11 responses show monthly, three responses bimonthly, one quarterly, one four-monthly, and one half-yearly. In one case industrial service connections are billed monthly and domestic bimonthly. In another case, meters are read bimonthly but billing is monthly. Billing of unmetered connections is on the basis of a fixed amount for a given connection which is often collected along with other local/municipal dues and taxes. A nominal discount is given in one case for timely payment of water bills but in general, no rebate or discount is offered. A surcharge is usually collected for delay in payment at a rate which varies from five to 10 per cent of the billed amount. The surcharge is doubled in three cases after the delay exceeds a specified period ranging from one month to six months. Instead of a surcharge, a small penalty in two cases about US nine cents and US 24 cents, is imposed.

27. Disconnection procedure, though basically applicable for default in settlement of dues, varies in complexity and duration of default before actual disconnection procedures are initiated. Other reasons for initiating disconnection procedures are inability to read a consumer's meter for a period of three months, meter tampering, and wastage of water or violation of statutes such as the use of substandard materials in internal plumbing. The duration for which default in payment is tolerated usually ranges from one to four months. In one case, liability for disconnection results from an unpaid account exceeding specified limits – about US$65 for domestic and US$650 for industrial connections.

28. Liability for disconnection in most cases does not result in disconnection. The responses indicate that only 10-91 per cent (average 28 per cent) of the service connections liable for disconnection are actually disconnected.

29. Reconnection is, in all cases, possible after default is removed and arrears are cleared together with the surcharge imposed for delay. The reconnection is usually made on payment of a fee which varies from US 80 cents to US$400, the average being US$34. For reconnection of industrial consumers, a higher fee is charged in two cases — twice that for a domestic connection in one case and 5.6 times in the other.

30. The level of accounts receivable, as compared with average annual billings divided by 365, are shown in 13 responses, and range from 15 to 500 days, the average being 163 days.

Tariff

31. Eleven of fifteen responses listing metered tariffs state that progressively higher tariff rates are applied to higher levels of consumption. The remaining four responses state that fixed per unit rates are applied regardless of the level of consumption. Average domestic tariffs, per cu m, for consumption of 20 cu m of water ranged from as low as US$0.02 per cu m to as high as US$0.17 per cu m. In all cases commercial/industrial rates are higher, usually twice the domestic rate.

32. Eight responses state that in addition to metered connections, there are also unmetered connections. In all these cases for the unmetered connections, the tariff depends on, and increases with, the size of the pipe. Several of the responses indicate that in addition to the service connection charge, revenue for water operations is also raised by a tax on the property the service connection supplies. Several responses indicate that the water utility can insist on the use of a meter if it is felt that the consumption of an unmetered connection is excessive. Only one response, from an urban water supply utility supplying less than one million people, shows all connections to be unmetered.

33. With regard to charging policy for domestic supplies, a charge is made for all water consumed with the exception of two authorities. One of these exceptions does not charge for a small basic supply quantity; this is applicable to all customers regardless of quantity consumed or wealth of the consumer. The other exception charges water at progressively higher rates, but bills below a certain amount (equivalent to a basic supply) need not be paid. As compared to the progressive increase of tariffs for increasing consumption applied in blocks, one utility charges higher per unit rates for a higher level of consumption with the high rate made applicable to total consumption. This utility's view is that its approach strongly encourages conservation and charges the user with high consumption heavily since he is generally presumed to belong to a high income group. Only one response indicates that a lower tariff rate can be applied if a consumer claims to have a large family.

Operational Data

34. Periodic reporting of operational data to management varies considerably, from monthly to annually. Ten of the 16 responses indicate that a record of the age of the pipeline is maintained; 12 responses indicate that a record of the location of burst is kept (of which 10 indicate that a record of the location of leaks is also kept) but only four responses indicate that such records are utilized for preparing pipe replacement programs.

35. Supply source and bulk water meters are calibrated if, found or suspected to be defective, according to four responses; periodic calibration, ranging from monthly to annually, is mentioned in three responses.

36. Five responses indicate that a record of the activities of the leakage detection and repair teams is maintained but the degree of detail recorded varies greatly. Details included in the records include: itinerary of the team; number of leaks located and length of pipeline surveyed; location sketch of leakage; assessment of quantity of water lost; pavement type and the kind and size of pipeline; and a weekly monitoring of collected data.

Problems Experienced

37. The responses indicate a wide variety in the actual and perceived problems of operating a distribution system. Most responses indicate that the major problem encountered is the damage caused to water supply pipelines by construction activities of other utilities in the vicinity of pipelines. The responses show that the utilities have little or no control over such activities and often the damage is not reported and not immediately visible.

38. Inherent problems associated with the operation of the existing systems are mentioned in ten responses. Such problems include old pipelines; lack of isolating valves, air valves and pressure relief valves; non-segregation of high and low areas of service; interconnection of separate zones of supply which results in an excessive number of valve operations in a year; long service connection pipe; leaks concealed under concrete pavements or other structures; corrosive soil; and lack of proper maps of pipe network.

39. Two other major problems mentioned in seven responses and which appear to be more prevalent in the less developed countries, are the presence of unauthorized/illegal connections and the illegal installations by consumers on their service connection of small pumping units which suck water directly from the supply mains.

40. Two responses state that increasing road traffic, both in volume and weight, causes an increasing number of pipeline leaks.

41. Other problems reported by various responses are as follows:

a) inadequate capacity of source of supply to meet demand;

b) discoloration of water at consumer's faucets due to iron pipes;

c) intermittent supply causing corrosion of iron pipes which leads to rust particles blocking meters;

d) large percentage of distribution pipelines believed to be beyond repair;

e) leakage from old reservoirs and pipelines;

f) inaccurate water meters;

g) lack of equipment for leakage detection and repair;

h) lack of public education in the need to conserve water; and

i) lack of trained manpower.

42. In one response, lack of sense of responsibility among the field staff is lamented; in another, enforcement of legislation is recommended and in yet another, computerization of billing is blamed for creating confusion in accounts. These responses indicate that a wide variety of subjects has a bearing on the problems of water distribution.

Measures Being Adopted

43. Most water supply authorities are aware of the need to take steps to obtain better control of their water supply distribution systems. The measures being adopted, as stated in the responses, relate to actual and perceived problems. In seven responses, specific remedies are suggested in addition to measures which are routinely applied for overcoming system deficiencies. They include:

a) standardization of designs and products;

b) production of spare parts locally;

c) metering of public standpipes;

d) technology transfer from developed to developing countries; and

e) sharing of experience among developing countries.

44. The stage reached by the various authorities in implementing a program to obtain better control of their distribution system differs widely but in general:

a) efforts are being made to identify the factors causing unaccounted-for water;

b) interest is being shown in procuring leakage detection equipment and in having the staff trained in its use;

c) improved billing and collection procedures are being adopted; and

d) public cooperation is being sought through special campaigns, audio-visual media and better public relations.

Conclusion

45. The responses show that water supply authorities face considerable problems in controlling distribution systems; many of these problems have accumulated over long periods. Control of such systems is emerging from a situation of empirical practices and ad-hoc approaches to one of rational practices and systematic approaches. Further research and increasing cooperation among the professions concerned with the operation of water supply utilities, together with the establishment of programs for the training of personnel involved in distribution system control and for the education of consumers not to waste water, should ensure that the improvements now under way continue. However, with large parts of many distribution systems now reaching the end of their useful life, there is a pressing need to upgrade the knowledge and control of the systems to limit the extent of unaccounted-for water. Hence, the responses indicate that an increase in the present, often inadequate, investments in water supply distribution system control will, in almost all cases, pay good returns.

III. PROBLEM OF UNACCOUNTED-FOR WATER

The Problem and its Magnitude

46. It was recognized that in the majority of urban areas a large percentage of the water entering the distribution system either did not reach the consumers or did not generate revenue. Water being a valuable resource, it was felt that the importance of detection, identification and control of unaccounted-for water should be widely appreciated. Though the techniques of control of water distribution system have progressed significantly over the last two decades, water authorities all over the world have, all too often, been faced with the problem of accounting for the water produced. The balancing of the continuity equation between the two points, namely, the treatment plant and consumer's meter, has always posed a challenge to water authorities and it invariably ends with an unexplained component known as "unaccounted-for water", which needs to be controlled. The major components of unaccounted-for water are: customer metering losses; illegal water use; public water use; transmission and distribution leakage; and unavoidable losses.

47. The Seminar noted with concern the magnitude of the problem of unaccounted-for water in the developing countries. From the overview presented by Bank Staff (see Chapter II), questionnaire responses to 25 water utilities in the DMCs revealed that the common range of unaccounted-for water was from 25 to 40 per cent of water produced. Leakage ranged from nil to 55 per cent, metering errors from 3 to 35 per cent and illegal use of water was also assessed in a very wide range from 2 to 30 per cent.

48. It was widely recognized that any water distribution network was prone to leakage and a program for leakage prevention was as important as a program for the augmentation of water supply. In a water distribution system there are numerous components susceptible to underground leakages but the major contributors are: (i) consumer's connections, particularly when materials prone to corrosion such as galvanised steel or iron (G.I.), are used, and (ii) daily operated sluice valves

leaking through their glands. It was pointed out that, generally, leakages contributed by G.I. pipe consumer connections were of the order of 60 to 70 per cent of the total leakages. Though the quantity of leak through a single G.I. pipe connection is small, because of its small magnitude, it usually remains undetected for a long period. A large number of such leaky connections collectively form a major source of leakage. It was noted with interest that according to the experiments carried out by Liverpool Corporations of UK, loss of one drop of water a second amounts to 8 gallons per week.

49. The Seminar identified a number of reasons contributing to the weakening of G.I. pipes and fittings used for consumers' connections which included: (i) short lifespan of G.I. pipes and fittings which, on an average, is about 10 to 15 years depending upon the soil conditions but can be as short as five years in aggressive conditions; (ii) laying of the consumer connections without adequate bedding, which under traffic loads causes joint failures; (iii) galvanic corrosion when different metals such as gun-metal ferrules and G.I. pipelines are used; and (iv) bad workmanship. Short life of gland packings in the sluice valves was identified as a major factor contributing to leakages in daily operated sluice valves.

Historical Reasons

50. The Seminar recognized that there were certain historical factors which had also contributed to the high percentage of unaccounted-for water in the water supply systems obtaining in major cities of the DMCs. It was noted that the cores of many existing distribution systems were installed as long ago as 125 years and have now exceeded their useful life, especially with the increased pressures and volumes in the substantially expanded systems. Also system expansion has become a more or less continuous process to meet the demands of rapidly growing populations, the increase in per capita consumption and shorter design periods or phasing of construction. This has led to non-uniform standards of materials and construction, less than adequate system records and, in a large number of systems, the existence of both metered and unmetered connections. Moreover, in association with more frequent tariff revisions in the last two to three decades, the updating of customer records and the modernisa-

tion of billing and accounting procedures has often not kept pace with the rate of expansion of a system.

Intermittent Water Supply Systems

51. It was pointed out that intermittent water supply systems existed in many large urban areas in the region mainly due to inadequate supply capacity. Such systems have many operational problems including the expellation of air that interferes with meter readings, rapid corrosion in pipelines and meters and also public health hazards. It was recognised that detection of leakage in intermittent water supply systems was difficult and could only be done reliably by totally isolating areas when pressurized and then carrying out leakage detection. The greatest hazard in an intermittent water supply system was contamination by infiltration of stagnant water around leak points during non-supply hours. The problem becomes grave when leakpoints are near open drains or sewers.

Other Causes

52. A number of other causes contributing to water losses were identified:

a) wastage by consumers (this is not unaccounted-for if the wastage occurs downstream of the meter);

b) lack of water meters and defective water meters;

c) inadequate up-keep and control of wastage at public standpipes;

d) illegal connections;

e) lack of requisite detection equipment, trained manpower, proper maps of pipe network, and adequate system records;

f) non-segregation of high and low pressure areas of service;

g) damage caused to water supply pipelines by adjacent construction activities.

Remedial Measures

53. The Seminar emphasized the need to improve the control of water distribution systems and reduce the amount of unaccounted-for water. The measures recognized included soil survey; mapping of facilities; adopting a progressive leakage detection program tailored both technically and financially to suit the problems experienced; pressure control; audit of water use; preventive maintenance; standardization of designs and products; maintaining high standards of construction; coordination among various public utilities; training of personnel; proper pricing policies and tariff; and public education and cooperation.

IV. TECHNIQUES FOR LEAKAGE DETECTION

54. Leakage in water distribution networks arises from many causes and cannot be expected to be prevented completely. Leakage control, therefore, should be a combination of detection and repair of as many leaks as possible and improvement of the network by the adoption of better materials and higher construction standards. The Seminar highlighted the need for more effective leakage control to meet growing technical and financial constraints on the development of new water resources and to protect distribution systems against contamination through infiltration. Both the ongoing surveillance of systems and the use of most appropriate leak detection techniques were recognized to be significant.

Leakage Survey

55. It was felt that leakage surveys were an important part of water utility maintenance and could help in substantially reducing the underground leakage losses. Leakage from underground piping generally comes to the surface where it becomes visible but, under favorable conditions, it can escape underground and remain undetected. Underground leakage has always been a problem to detect and is a major source of water loss for many water utilities. Over recent years, however, methods and equipment have been developed for non-visible leak detection, and are now employed by many utilities in systematic leakage surveys. It was agreed that leakage surveys had to be an ongoing operation in a water utility as relapse to original conditions had been observed within about three years of cessation of leakage control programs. Leakage surveys also help in updating inventories of pipelines and valves and in detection of illegal connections.

Factors Affecting Leakages

56. The Seminar identified the following as major factors affecting leakages:

a) **Pressure:** Increases in pressure cause higher water loss from leaking pipes, joints and fittings and also increase the number of leaks. Pressure surges, caused by pump or valve operation, can cause pipe fractures, movement of inadequate thrust blocks, or separation of unrestrained pipe joints.

b) **Soil Movement:** Movement in the soil can cause pipes to fracture, joints to separate or result in local stress concentrations within pipes or fittings which can lead to eventual failure. Subsurface mining excavations or changes in soil moisture resulting from an over-pumping of groundwater can result in subsidence, often unevenly distributed, over wide areas (for example, in Bangkok).

c) **Corrosion:** Leakage caused by internal and external corrosion of galvanised steel or other metallic pipes is a serious problem. When the water flowing through the pipe is corrosive in character it causes corrosion of the interior pipe wall. This type of corrosion manifests itself in the development of corrosion tubercules on the interior walls of iron and steel pipes. These tubercules are often associated with pitting and usually overlie anodic areas where localized attack of the metal occurs. External corrosion is an equally serious problem and is caused by the characteristics of the soil or groundwater. In addition, galvanic corrosion occurs where different metals are in contact, for example, steel bolts in cast iron joint rings. As corrosion proceeds, the residual thickness of metal is reduced, weakening the pipe walls or bolts and hence diminishing the ability of the pipe or joint to withstand internal pressure. Ultimately, this process leads to failure with resultant leakage. Deterioration of concrete or asbestos-cement pipe can be caused by soil or water containing high levels of sulphates or excess acidity.

d) **Traffic Loading:** Vibrations and high loading caused by road traffic may also result in stress on buried pipes with insufficient cover, contributing to broken or cracked pipes and leaky joints.

e) **Methods of Operation:** Methods of operation adopted by a water utility can result in significant leakage. For example, blow-off valves carelessly left open and discontinued service lines left abandoned without closure at the main pipe often cause water losses.

Traditional Methods for Leak Detection

57. Various techniques for leak detection, including both traditional and new techniques, were discussed. The traditional methods are simple and generally consist of the use of a sensor to detect the noise generated by a leak. The leak noise travels through the ground and along the pipe and can be heard at the ground surface or at a point along the main, as for instance, at a curb box. The devices used can be classified as: (a) sensors with mechanical amplification which can be handled by non-specialists but do require skill and practice; (b) mechanical sensors with electronic amplification; and (c) electronic detectors which can be especially effective and which can also be used to find curb boxes and pipes where the exact location is not known. Such equipment is fairly inexpensive. A single operator or a two-man crew could cover three to five kilometers of pipeline a day.

58. The Seminar noted that the traditional methods were still being widely used in developed countries (in Paris, traditional methods account for most of the leaks detected, which annually amounted to 20,000 leaks in mains and 65,000 leaks in fittings). It was, however, generally agreed that traditional methods for leakage detection were most suited to developing countries as they were quite inexpensive and easy to adopt. In this context, special mention was made of sensors with mechanical amplification (belonging to the stethoscope family) and electro-mechanical sensors.

New Leak Detection Methods

59. The Seminar also discussed new leak detection methods which are now coming into use and are put to work when conventional methods are inoperative or where many problems have to be resolved rapidly and effectively within a small area. It was agreed that the acoustic correlation system, was an

effective new leak detection method. The acoustic correlator locates a leak point in a pipeline by taking a peak value of the cross-correlation function of the leak sounds picked up from a pair of sensors attached at two points on the pipeline, usually one upstream and one downstream of the leak. The original correlator developed in Britain was a monopoint correlator. The correlator which has subsequently been developed in France is considerably more potent. It can simultaneously work on 512 different time delays and choose the best correlation. The effectiveness of this technology has been further enhanced through the use of adapted frequency filters that shut out most parasite noises liable to perturb the search. The leak is thus located accurately and quickly.

60. There are a number of advantages that accrue from the use of the acoustic correlator. The correlator can be operated even when there is a high degree of external noise, thereby enabling leakage detection to be changed from night work, necessary with traditional methods, to day work. It identifies even weak noises that escape the notice of traditional methods and can detect leaks in deeply-laid mains. It yields excellent results for all pipe materials with the exception of PVC. It pinpoints leaks accurately and, as such, its use reduces digging and repair costs to the minimum. When operating conditions are favorable it can survey up to 6 kilometers of pipeline per day. It has, however, some limitations also. It yields poor results on plastic pipes. Its use requires sufficient pipe accesses; at least one curb box every 200 metres. Despite its limitations, it was agreed that the acoustic correlator provided the water authorities with a powerful tool that could help reduce water losses significantly.

61. Apart from the acoustic correlator, there are a number of other new leak detection methods which are quite effective. One of the new methods yielding good results involves the use of radio-active tracers and tracer gases. This technology has the draw-back of being slow and rather expensive, but it can find leaks that resist other methods, such as in plastic pipes and where the interval between access points to pipelines is too great. Other innovative methods recently experimented with at the UK Water Research Centre are remote sensing or the use of foam swabs. The remote sensing method has proved to be effective in rural areas but

appears to be impracticable in urban areas. Paris is now experimenting with a new computerised method for detection of pipe ruptures. This new method has not yet been put to work in a water supply system and, although it cannot be used to detect small leaks, it seems promising for rapid detecting of major leaks. Other techniques are being studied, including: (i) in-pipe investigation with a submersible microphone and camera; (ii) location of areas having a higher than average earth moisture level which may be due to leakage from water pipelines; (iii) infra-red photography; and (iv) radio location (radar) method which helps in locating and mapping underground pipes, masses of water and cavities, through a pulse radar system.

62. It was acknowledged that the equipment associated with these new sophisticated methods can be rather expensive and needs staff who are qualified and trained in its use. The methods can however be economical when used by trained staff, taking into account the reduction in the time for leak detection and repair and also in the cost of diggings. It was, however, felt that in most developing countries these sophisticated instruments should be used to supplement and not to replace completely the simpler traditional equipment. In fact, no one leak detection method suits every system; each water utility would have to select the technique best suited to that particular distribution system.

Leakage Detection in Intermittent Water Supply Systems

63. The Seminar strengthened the view that carrying out a leakage program for an intermittently operated water supply would require considerable initial preparation work. The steps suggested for an effective program included updating the distribution system drawings, making the appurtenances on the system operable, installing new valves in the system to facilitate zoning; pressurize each zone in turn at night and conduct a sounding test for leakage.

V. CONTROL MEASURES

64. It is well-known that a high percentage of expensive treated water is leaking to waste and is benefiting neither the consumer, who has eventually to pay for the capital investment, nor the water supply authority which does not receive revenue for leaked water. With new unpolluted water sources becoming scarce and more expensive to develop, controlling leakage and other water losses has become a prime concern of water authorities and the resources allocated for this purpose are now regarded as a lasting investment. It was widely agreed that, to be effective, a program for reduction of losses should cover at least the three main causes of water loss, namely, (i) inadequate and inaccurate flow measurement; (ii) unauthorized use; and (iii) leakage.

Inadequate and Inaccurate Flow Measurement

65. It was agreed that unless the flows were measured at all points of supply and consumption, there was no way of knowing precisely how much water was being lost in the system. An unmetered system is therefore at an immediate disadvantage when it comes to determining the inputs required to reduce losses. Flows entering treatment plants are usually adequately measured by flumes or weirs, but treated water entering the distribution system is often monitored much less accurately. A common practice is to simply multiply a nominal pump capacity by the number of hours of operation, which might be grossly inaccurate because of varying pump head, friction in pipes and wear in pumps and motors. Where meters are used they are often inaccurate because they are not installed in accordance with the manufacturers' specification and are often used for flows outside the range for which they were designed. Moreover, checking and recalibration is being done only rarely; it was agreed that this was a vital and inexpensive task that should be performed regularly.

66. It was pointed out that though private consumers' meters accounted for a large percentage of the income of water supply utilities, they were the most neglected part of the system.

As a result of poor maintenance a sizeable number of these meters register inaccurately or are unserviceable at any given time. All manufacturers recommend workshop checks after a stipulated period for standard residential meters but these are seldom carried out. Experience has shown that when consumers have an unserviceable meter and are charged on a flat rate basis, they make little effort to save water or to repair leaking domestic installations with the result that their water use often increases substantially.

67. As regards industrial consumers, it was pointed out that they often made considerable changes in their water consumption as a result of change or expansion in their manufacturing operations with the result that the water meter installed became unsuitable for the new range of consumption. The supply authority is not usually notified of the changes or is unable to react quickly. An oversized meter will often fail to register low flows and an undersized meter will break down under high flows and pressures. In both cases, there are errors in measurement which could be as high as 90 per cent.

Unauthorised Use

68. It was acknowledged that clandestine, unmetered connections in urban water supply networks were widespread in the DMCs and were as much a social problem as an administrative one. They are found mostly in slums and shanty towns normally populated by poor people who have moved from undeveloped rural areas to the cities in search of work and livelihood and who are not accustomed to paying for the use of water. They can also be found among the more prosperous domestic, commercial and industrial consumers in some cities where processing of new applications for connections takes several months and thus prevents occupation of the premises.

69. Temporary unmetered water supplies provided for building sites during construction of new housing estates were also common targets of illegal connections. When construction is completed, these supplies are capped off and replaced by proper metered systems but residents are often able to reopen the temporary lines and obtain unmetered supply. Unauthorised free water is also obtained widely in some cities from unmetered fire or street-cleaning hydrants.

Leakage

70. In most of the DMCs, leakage resulting from cracked or burst pipelines or from faulty valves or fittings is the major factor contributing to unaccounted-for water. Use of poor materials in pipe work and fittings, inadequate workmanship and supervision during installations, corrosion and geological instability contribute to high rates of pipe ruptures and valve failures.

Methods of Leakage Control

71. While it would be both impractical and uneconomic to ensure that a water distribution system never leaked, it is evident that there is an economic limit to the loss of water that should be tolerated through leakage. It was agreed that a problem facing water supply authorities was how to select the target level for reducing water losses and the most appropriate method for dealing with leakage in a system while ensuring that the savings achieved justified the capital cost. The Seminar recognized the following as different approaches to controlling leakage within a distribution system:

a) **Passive Control:** Under this method only those leaks which become self-evident are located and repaired.

b) **Regular Sounding:** This method involves teams of men using listening equipment systematically working their way through the distribution system to locate leaks which are not evident.

c) **District Metering:** Under this method bulk flow meters and integrators are installed within the distribution system to meter defined areas (districts) continuously and register the total quantity of water consumed. For fully metered systems, summation of individual consumer's meters can be undertaken instead. The total weekly or monthly consumption in each district is compared with the previous week's or month's consumption in that district and, on a per capita consumption basis, with other districts. Inexplicable discrepancies usually indicate leakage or other losses which are then investigated.

d) **Waste Metering:** Under this method the distribution system is sub-divided and isolated into areas typically containing 1000 to 2000 households (properties). These valves are closed at night and the supply to each isolated area arranged through a single flow meter capable of measuring the low rates of flow that occur at night. Measurements are made at regular intervals (say monthly) and when large increases compared to previous measurements are encountered, leakage is sually indicated and steps are taken to locate and repair the leaks. Additional night flow measurements in isolated sub-areas may be used to pinpoint leaks more precisely.

e) **Combined District and Waste Metering:** This method embodies both district and waste metering. When increases in demand are indicated on the district meters, the waste meters downstream of them are used in order to sub-divide the district into more manageable units and to guide inspectors to the areas of greatest leakage.

f) **Pressure Control:** The Seminar acknowledged the close relationship between pressure and leakage. Experiments have shown that a given reduction in pressure causes a proportionately greater reduction in leakage. Judicious pressure control will therefore assist in reducing leakage, but will not solve the problem and should be regarded as a temporary expedient until leakage detection and repair can be carried out.

Determining the Most Appropriate Method

72. Selection of the most appropriate method, it was felt, would depend on: (a) the level of leakage within the system; (b) the cost of leakage (or conversely the benefit to be derived from reduction in leakage); and (c) the cost and effectiveness of each method of control. Generally, the higher the financial and economic cost of leakage, the lower the target should be for reduction of losses and the greater the expenditure on leakage detection.

73. The Seminar learned that the Water Research Centre (WRC) of UK claims to have evolved a procedure which helps in selecting the most appropriate method of leakage control for virtually any water distribution system. WRC advises that the procedure can be used to: (i) determine a leakage control policy where none exists; (ii) review an existing policy; and (iii) determine the operational resources to implement the chosen method, the cost of implementation, and the likely savings, including the deferment of capital schemes which would otherwise be required to satisfy increases in water demand.

75. The savings which can result from the application of a systematic, analytical approach to leakage detection are much more impressive in developing countries, particularly in arid countries where the implementation of new water supply schemes would be relatively more expensive. In addition, the potential return on investment is greater because of lower labor costs in most of these countries relative to the price of energy and capital works.

Other Control Measures

76. It was generally agreed that the following measures also contributed significantly to the control of unaccounted-for water:

a) **Mapping** — For identification and control of unaccounted-for water it is essential to have complete and accurate mapping of a water distribution system. Ideally, maps should extend to cover the location of all customer connections. Recording of the precise position of all valves is vital.

b) **Repairing Leaks** — Some specialized techniques identified were: (i) *freezing*; if a pipeline cannot readily be isolated by valves, a length upstream of the leak may be frozen by application of liquified air to the pipe; (ii) *inside repair*; for medium to large pipelines, leaks may be repaired from inside the pipe with a specially developed rubber band and steel clamp; (iii) *pipe-in-pipe*; a short length of smaller pipe can be fabricated on site from rolled steel plate and inserted in a leaking pipe of bigger diameter, with the space between the two pipes then being filled with cement mortar; and (iv) *pipe rebirth*; in which complete lengths of pipeline are lined by insertion of a plastic pipe, such as, polyethelene or PVC.

c) **Planning** – For effective leakage control careful planning, intensive field survey and analytical investigations are called for. Since a program of leakage control is of a continuing nature, there is need for (i) manning the water undertaking with trained personnel and skilled technicians, supported with suitable instruments and equipment; (ii) achieving coordination between the operation and maintenance, construction, and planning wings; and (iii) embarking on proper planning and layout of distribution system extensions, taking account of operational and maintenance aspects.

d) **Standardization of Designs and Products** – It was generally accepted that a major problem in the developing countries was the low standard of internal plumbing. Discussions revealed that various DMCs were following different standards in this regard. While some of these countries have developed their own standards, most are attempting to follow international standards and often falling short of the requirements owing to lack of availability of suitable materials. It was also felt that in this particular field there was need for technology transfer from developed to developing countries as well as for sharing of mutual experience among the developing countries themselves. In this context, the Seminar noted that efforts were being made by the Asia-Pacific group within the International Water Supply Association to establish regional standards for the Asia-Pacific Region to meet the specific needs of the region.

e) **Training** – The Seminar agreed that engineers in charge of operation and maintenance, waste prevention, planning and design, and the supporting technical staff should be given proper training and orientation in the planning and conduct of preventive maintenance of water distribution systems as this aspect required specialized skill, technique and careful implementation of field work. Training programs should include theoretical and practical aspects of leakage detection.

f) **Public Information and Education** – Public information and education was also identified as one of the effective means for leakage control. It was suggested that initial information regarding control programs could be disseminated through radio, television, the press, and printed literature distributed with water bills. Special programs and lectures at community level for school children and adults could follow, with the object of informing them about the water supply system and its significance, impact of leakage on tariff levels and the value of conservation. It was noted with interest that in USA a program was launched in 1970 with the object of educating the general public about the significance of water conservation and leak detection. The program started with educating children through fairy tales and crossword puzzles, aimed at developing water consciousness, and later utilized such media as specially designed bill inserts, films, radio spots and slide presentations. These efforts were supplemented with talks on the subject before invited audiences. Such a public forum method was reported to be very helpful.

77. Other measures considered efficacious for control of water loss were identified as: metering of public standpipes; evolving appropriate pricing policies and tariffs; simplifying application procedures for new customer connections; promoting further research and increasing cooperation among the professionals and utilities concerned with water supply; greater use of physical methods to prevent wastage in customers' properties, including restrictors, spring-loaded taps and hoses, and dual flush WC cisterns.

VI. FINANCIAL ASPECTS OF WATER DISTRIBUTION CONTROL

Economic and Financial Criteria

78. The Seminar highlighted the significance of economic and financial aspects of control of water distribution. It was agreed that there was a need to establish economic and financial criteria for loss reduction programs so as to determine investment levels for optimal loss reduction.

79. It was agreed that while in the case of economic analysis the problem was looked at from the national perspective so as to include the welfare of the utility as well as the consumers, the financial viewpoint was concerned only with the financial viability of the enterprise. Some Seminar participants felt that while both sets of criteria were needed for proper analysis, the economic criteria were comparatively more important from the point of view of national resource application. Bank staff pointed out that it has been the Bank's practice that, having first agreed in principle with a DMC to finance a water supply project, it is then primarily concerned with the financial viability of that project.

Cost Benefit Analysis Approach

80. The Seminar acknowledged that it would be beneficial to adopt the cost benefit analysis approach, which meant that if in any loss reduction or rehabilitation program the present value of benefits exceeded the present value of cost, the program should be implemented. In the case of technical losses (leakage) the benefit could be measured in terms of value of water saved which, in fact, meant the avoided cost of production. This cost is the sum of deferred investments in future supply facilities and their operation and maintenance costs.

81. It was felt that, to maximize results, efforts should be made to optimize loss target levels, balance investment and rehabilitation efforts in terms of loss control in different parts of the distribution systems, and determine the amount of effort which should be put into improving technical losses and controlling unbilled consumption.

Unbilled Consumption

82. The Seminar discussed the problem of unbilled consumption and its impact on the financial aspect of water distribution control. It was agreed that detection of illegal connections and installation of meters would generally induce consumers to cut back on their consumption. The saving in water achieved in this manner is, in fact, a saving to the utility in terms of the reduced production cost. In addition, the utility improves its revenue.

Pricing Policy

83. It was widely accepted that pricing policy had an important role to play in encouraging conservation and loss control within the premises of the consumer. Whereas it is general practice to set water tariffs based on the financial cost of supply, it was suggested that the price level should also reflect to some extent the economic cost of supply. Another aspect is to keep in mind certain social considerations, such as poor consumers' basic needs. It was agreed that an incremental block tariff was much more effective than single rate tariff, as it provided the necessary incentive to the consumer to conserve water and also would enable the poor consumers who used little water to be charged a low price subsidized by high consumption customers.

84. It was noted that in most of the utilities in the DMCs, incremental block tariff systems were in operation. Average domestic tariff per cu m for consumption of 20 cu m of water ranges from as low as US$0.02 per cu m to as high as US$0.17 per cu m. However, in practically all cases, commercial/industrial rates are higher, up to twice the average domestic rate. Utilities with unmetered connections charge either through local property tax or with a tariff system that relates to, and increases with, the diameter of the property connection. Several utilities will insist that a meter be installed if they feel that the consumption through an unmetered connection is excessive.

Billing and Collection Procedures

85. The Seminar also discussed the role of billing and collection procedures in the context of water loss reduction and

revenue optimization. Different billing systems are being followed by the water supply authorities in the DMCs. The interval of billing varies from one month to six months. In general, no rebate or discount is offered for prompt payment but a surcharge is often levied for delay in payment at a rate which varies from 5 to 10 per cent of the billed amount. Disconnection procedure, though basically applicable to default in settlement of bills, varies in complexity and with duration of default. Disconnection is also practised by some DMCs following inability to read a consumer's meter for a period of three months, meter tampering, wastage of water and violation of statutes. Liability for disconnection in most cases does not result in disconnection. On an average, only 28 per cent of disconnection notices served are actually implemented. Reconnection is possible in all cases after default is removed and arrears are cleared.

86. It was agreed that there was room for streamlining the billing and collection procedures in most water utilities to improve collection efficiency. Some DMCs have computerized their billing system which provides information on different user groups and also facilitates monitoring of consumption patterns. To cut down billing time, a prototype computer system has been developed in which the meter reader carries a small computer to calculate and issue bills at the consumer premises as the meters are read.

VII. SUMMARY

1. Problem of Unaccounted-for Water

87. The Seminar recognized the seriousness of the problem of unaccounted-for water in the DMCs, where the common range was from 25-40 per cent of the water supplied and sometimes as high as 50 per cent. The major components of unaccounted-for water were identified as: (i) transmission and distribution leakage; (ii) customer metering losses; (iii) illegal water use; and (iv) unavoidable losses.

88. It was widely recognized that all water distribution networks were prone to leakage and programs for leakage detection were as important as programs for augmentation of water supply. The Seminar identified a number of causes for water leakage which included corrosion of consumers' connections of G.I. pipes; daily operated sluice valves leaking through their glands; the advanced age of some distribution systems; and poor workmanship coupled with non-uniform standards of materials and construction.

89. On the basis of the review of 18 papers submitted by the participants from 12 DMCs, the Seminar concluded that water authorities in these countries had a number of common problems which hampered improvement in the control of their distribution systems. These were identified as:

a) defective meters, insufficient meters or no meters at all;

b) intermittent supply or inadequate capacity of existing supply source;

c) defective service connections;

d) defective old water mains;

e) substandard materials in consumer properties;

f) inadequate or no leakage detection equipment or lack of staff to carry out detection effectively;

g) vandalism and standpipe leakage;

h) illegal connections;

i) inadequate number of valves on distribution system;

j) inadequate mapping;

k) poorly trained staff; and

l) poor workmanship for pipe laying and service connections.

2. Techniques for Leakages Detection

90. Recognizing that leakage was a major problem in a water distribution network, the Seminar highlighted the need for effective leakage detection and control programs particularly in view of growing constraints in water resources development.

91. The Seminar identified the following as major factors affecting leakages:

a) **Pressure** – Higher pressures cause higher water loss from leaking pipes and fittings and also increases the number of leaks.

b) **Soil Movement** – Can cause pipe and joint failure or result in local stress concentrations leading to eventual failure.

c) **Corrosion** – Caused by internal and external corrosion of pipelines.

d) **Traffic Loading** – Traffic vibration and loads can result in stress on buried pipes with insufficient cover, leading to cracked or broken pipes and leaky joints.

e) **Methods of Operation** – Careless practices such as not sealing off abandoned service lines, can result in significant leakage.

92. Acknowledging the important role of leakage survey in updating the inventory of pipelines and valves and detection of illegal connections, the Seminar emphasized that it should not be a one-time program and should be an ongoing operation for any water supply authority.

93. Various traditional and new techniques for leakage detection were discussed at the Seminar. The traditional methods, which are very simple and inexpensive, involve the use of a sensor to detect noise generated by a leak. The devices used were classified as: sensors with mechanical amplification; mechanical sensors with electronic amplification; and electronic detectors. Among the new techniques, the acoustic correlation system and the use of radio-active tracers and tracer gases for leak detection were considered quite effective.

94. It was, however, acknowledged that since the new techniques were rather sophisticated and expensive and needed technically trained staff for operation, they were unlikely to replace completely the traditional simple methods in developing countries. Instead, they should be used to supplement the traditional equipment.

3. Control Measures

95. Recognizing the fact that a high percentage of treated water was being wasted, the Seminar stressed the need for effective programs for controlling leakage and other unaccounted-for water. Such programs should tackle at least the following three main causes of loss: (i) inadequate and inaccurate flow measurement; (ii) unauthorized free use; and (iii) leakage.

96. The Seminar discussed the various methods of controlling leakage including: (a) Passive Control; (b) Regular Sounding; (c) District Metering; (d) Waste Metering; (e) Combined District and Waste Metering; and (f) Pressure Control. Selection of the most appropriate method of leakage control would depend on the level of leakage within the system, the cost of leakage, and the cost and effectiveness of each method of control. The Seminar learned of an analytical procedure evolved by WRC of UK for determining the most appropriate control method for any distribution system.

97. Other measures which the Seminar considered efficacious for the control of unaccounted-for water included: complete and accurate mapping of distribution systems; effective and lasting repair of leaks using specialized techniques when necessary; careful planning of leakage control programs and intensive field survey; standardization of designs and products; comprehensive training of personnel; and public information and education.

4. Financial Aspects of Water Distribution Control

98. The Seminar agreed on the need to establish economic and financial criteria for loss reduction programs. Economic criteria were comparatively more important with regard to national resource application, while financial criteria constitute the usual basis for individual project analysis.

99. The Seminar acknowledged that it would be beneficial to adopt the cost benefit analysis approach to decisions regarding implementation of a reduction of rehabilitation program.

100. With respect to unbilled consumption, efforts to detect illegal connections followed by installation of meters have two advantages, namely a general reduction in consumption by these consumers as well as a new source of revenue for the water authority.

101. Pricing policies played a significant role in encouraging conservation and loss control within the premises of the consumer. The Seminar subscribed to the view that price levels should reflect to some extent the economic cost of supply, as well as the financial cost of providing the water. Keeping poor consumers' basic needs in mind, the Seminar agreed that an incremental block tariff was more appropriate than a single rate tariff, as it provided incentives to consumers to conserve water.

102. Billing and collection procedures were also discussed; it was generally acknowledged that there was room for streamlining billing and collection procedures in most DMC water authorities in order to improve revenue collection efficiency.

Appendix 1
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REGIONAL SEMINAR ON CONTROL OF WATER SUPPLY DISTRIBUTION SYSTEMS

LIST OF PARTICIPANTS

Country Participants	Position
Bangladesh	
Shariful Islam	Chairman, Dacca Water Supply and Sewerage Authority
Mohammed Quadiruzzaman	Executive Engineer, Public Health Engineering
Hong Kong	
Chan Yan Kee	Government Water Engineer, Hong Kong Water Authority
India	
S.A. Swamy	Addl. Chief Engineer (Water), Delhi Water Supply and Sewerage Undertaking
V.M. Shidhaye	Chief Engineer, Municipal Corporation of Greater Bombay
Indonesia	
Amaruddin Djajasubita	Head, Technical & Management Guidance Section, Directorate of Sanitary Engineering, Ministry of Public Works
Eddy Kurniady	President Director, Bandung Water Supply Enterprise

Country Participants	Position
Korea	
Koo Bon Dae	Director, Engineering Division, Water Works Bureau, City of Daegu
Malaysia	
Lai Cheng Cheong	Senior Assistant Director, Jabatan Kerja Raya J1, Kuala Lumpur
Fu Yin Henn	Assistant Director, Public Works Department
Nepal	
Ratnakar Dutta	Manager, Water Supply & Sewerage Board, Kathmandu
Pakistan	
Mohammed Ashraf Abro	Managing Director, Water & Sanitation Agency Hyderabad Development Authority
Ashiq Ali Chaudhry	Director, Operation & Maintenance, Water & Sanitation Agency Faisalabad Development Authority
Papua New Guinea	
Dick Nihara	Assistant Engineer, National Capital District Interim Commission

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Country Participants	Position
Philippines	
Ricardo T. Quebral	Assistant General Manager, Metropolitan Waterworks & Sewerage System
Teofilo I. Asuncion	Project Manager, Network Rehabilitation Project, Metropolitan Waterworks & Sewerage System
Mario I. Quitoriano	Manager, Field Operations Dept., Local Water Utilities Administration
Singapore	
Foo Chee Sai	Superintending Engineer, Public Utilities Board
Solomon Islands	
J.D. Gwynne	Under Secretary, Ministry of Transport, Communications & Government Utilities
Sri Lanka	
N.D. Peiris	Chairman, National Water Supply & Drainage Board
Thailand	
Charoen Boonyachandranon	Director, Technical & Planning Dept., Metropolitan Water Works Authority
Precha Prapruttitam	Director, Provincial Water Works Authority

RESOURCE PERSONS

Judo Kaerts	First Engineer, Compagnie Intercommunale Bruxelloise des Eaux, Belgium
Jean Bustarret	Campagnie Generale des Eaux, France
Viswanathan Raman	Deputy Director, National Environmental Engineering Research Institute, India
Keiji Gotoh	Technical Adviser, Japan Waterworks Association
Mohan Munasinghe	Senior Energy Adviser, Ministry of Power & Energy, Sri Lanka
M.J. Rouse	Director of Engineering, Water Research Centre, England
Gordon L. Laverty	Manager (Interdepartmental Programs), East Bay Municipal Utility District, U.S.A.

OBSERVERS

Claudio Fernandez	Financial Analyst, Urban & Water Supply Division (East Asia & Pacific) World Bank
Kenneth H. Tomkins	Deputy City Engineer, National Capital District Interim Commission, Papua New Guinea
Oscar Ilustre	General Manager, Metropolitan Water Works & Sewerage System Philippines
Carlos Leano, Jr.	General Manager, Local Water Utilities Administration Philippines
Ong Ho Sim	Acting Chief Water Engineer, Public Utilities Board, Singapore
Owen Liu	Deputy Chief Water Engineer, Public Utilities Board, Singapore

BANK STAFF

Lewis Hayashi, Deputy Director, Infrastructure Department

David A. Howarth, Manager, Water Supply Division

John Richardson, Senior Project Engineer

Paritosh C. Tyagi, Project Engineer

Christina Gamboa, Technical Assistant

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REGIONAL SEMINAR ON CONTROL OF WATER SUPPLY DISTRIBUTION SYSTEMS
Venue: Public Utilities Board Building, Singapore

PROGRAM

TUESDAY, 8 FEBRUARY 1983

INAUGURAL SESSION

Time(h)	Name	Topic/Item
0900	David A. Howarth	Welcome
0915	–	Self Introduction
1000	Ong Ho Sim	General Remarks
1015	Paritosh C. Tyagi	Overview & Announcements
1030	Coffee	

SESSION 1: PLANNING METHODS

1045	M.J. Rouse	Dealing with Leakage
1115	–	Discussion
1135	Chan Yan Kee	Unaccounted-for Water in the Hong Kong Water Supply System
1145	N.D. Peiris	Greater Colombo Water Supply Distribution System
1155	K.H. Tomkins	Port Moresby Water Supply Conservation Program
1205	–	Discussion
1215	Lunch Break	

SESSION 2: OPERATIONAL MEASURES

1400	V. Raman	Manpower Training and Infrastructure Requirements for Leakage Control Program
1430	–	Discussion
1450	R.T. Quebral	Metro Manila's Experience in Reducing Non-Revenue Water

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Time(h)	Name	Topic/Item
1500	T.I. Asuncion	Program to Reduce Non-Revenue Water for Metro Manila
1510	M.I. Quitoriano	Leakage Detection Survey (in Water Districts of the Philippines)
1520	Koo Ban Dae	Overview of Daegu City's Program for control of Water Supply Distribution System
1530	–	Discussion
1545	C o f f e e	

SESSION 3: OPERATIONAL CONTROL

1600	J. Bustarret	Leakage Detection Methods and Applications
1635	–	Discussion
1655	K. Gotoh	Detection and Control of Leakage in Water Distribution System
1725-1800	–	Discussion

WEDNESDAY, 9 FEBRUARY 1983

SESSION 4: METERING, BILLING AND COLLECTION

0815	Shariful Islam	Control of Water Supply Distribution System at Khulna, Bangladesh
0845	–	Discussion
0900	J. Kaerts	Significance of Metering in Water Distribution System Control
0930	–	Discussion
0950	C. Boonyachandranon	Unaccounted-for Water: Metropolitan Water Works Authority, Bangkok

Time(h)	Name	Topic/Item
1000	Precha Prapruttitam	Proposal of Haadyai-Songkhla Distribution System Control, Thailand
1010	Lai Cheng Cheong	Quality Control of Water Supply Distribution Systems in Peninsular Malaysia
1020	–	Discussion
1030	C o f f e e	

SESSION 5: COUNTRY PAPERS

1045	Foo Chee Sai	Control of Water Wastage in Singapore
1130	Mohammad Ashraf Abro	Hyderabad Water Supply: Control of Water Distribution System
1140	Ashiq Ali Chaudhry	Faisalabad Water Supply: Control of Water Distribution System
1150	–	Discussion
1215	L u n c h B r e a k	

SESSION 6: PUBLIC EDUCATION

1400	R. Dutta	Control of Water Supply Distribution System in Greater Kathmandu
1420	S.A. Swamy	Delhi's Water Distribution System
1430	V.M. Shidhaye	Leak Detection and Waste Prevention Programme – Experiences of Municipal Corporation of Greater Bombay
1445	Eddy Kurniady	Control of Supply of Drinking Water to Bandung Population

Time(h)	Name	Topic/Item
1500	A. Djajasubita	Control of Small Town Water Distribution System in Indonesia
1530	–	Discussion
1545	Coffee	

SESSION 7: FINANCIAL CONTROL

Time(h)	Name	Topic/Item
1600	G.L. Laverty	Guideline for Identifying and Controlling Unaccounted-for Water
1645	–	Discussion
1715	M. Munasinghe	Financial Aspects of Water Distribution Control
1800	–	Discussion
1825-1830	–	Announcements

THURSDAY, 10 FEBRUARY 1983

Time(h)	Name	Topic/Item
0830		Technical Visit to Woodleigh Complex: Demonstration of Leak Noise Correlator and visit to Meter Workshop and System Operations Center
1215	Lunch Break	
1400		Technical Visit to PUB Building Film Show – The following films were screened: 1. Water Resource & Service 2. Drip 3. Water Follies

FRIDAY, 11 FEBRUARY 1983

SESSION 8: GENERAL DISCUSSION

Time(h)	Name	Topic/Item
0830	L.A. Hayashi	Address
0845	–	Remarks by Observers

Time(h)	Name	Topic/Item
0945	–	General Discussion
1030	Coffee	

CONCLUDING SESSION

1045	D.A. Howarth	Seminar Conclusions
1100	–	General Discussion
1200-1215	Paritosh C. Tyagi	Vote of Thanks

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REGIONAL SEMINAR ON CONTROL OF WATER SUPPLY DISTRIBUTION SYSTEMS

LIST OF PAPERS PRESENTED AT THE SEMINAR*

A. Resource Persons Presentations

1.	Dealing with Leakage	M.J. Rouse
2.	Manpower Training and Infrastructure Requirements for Leakage Control Program	V. Raman
3.	Leakage Detection Methods and Applications	J. Bustarret
4.	Detection and Control of Leakage	K. Gotoh
5.	Significance of Metering in Water Distribution System Control	Judo Kaerts
6.	Guideline for Identifying and Controlling Unaccounted-for Water	Gordon Laverty
7.	Financial Aspects of Water Distribution Control	M. Munasinghe

B. Country Papers

8.	Unaccounted-for Water in the Hong Kong Water Supply System	Chan Yan Kee
9.	Greater Colombo Water Supply Distribution System	N.D. Peiris
10.	Port Moresby Water Supply Conservation Program	K.H. Tomkins
11.	Metro Manila's Experience in Reducing Non-Revenue Water	R.T. Quebral

* Papers presented can be made available upon a written request to Mr. J.M. Gomez, Manager, Water Supply Division, ADB.

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13. Leakage Detection Survey (in Water Districts of the Philippines) — M.I. Quitoriano

14. Overview of Daegu City's Program for Control of Water Supply Distribution System — Koo Bon Dae

15. Control of Water Supply Distribution System at Khulua — Shariful Islam

16. Unaccounted-for Water: Metropolitan Water Works Authority, Bangkok — C. Boonyachandranon

17. Proposal of Haadyai-Songkhla Distribution System Control, Thailand — Precha Prapruttitam

18. Quality Control of Water Supply Distribution Systems in Peninsular Malaysia — Lai Cheng Cheong

19. Control of Water Wastage in Singapore — Foo Chee Sai

20. Hyderabad Water Supply: Control of Water Distribution System — Mohammed Ashraf Abro

21. Faisalabad Water Supply: Control of Water Distribution System — Ashiq Ali Chaudhry

22. Control of Water Supply Distribution System in Greater Kathmandu — R. Dutta

23. Delhi's Water Distribution System — S.A. Swamy

24. Leak Detection and Waste Prevention Program: Experiences of Municipal Corporation of Greater Bombay — V.M. Shidhaye

25. Control of Supply of Drinking Water to Bandung Population — Eddy Kurniady

26. Control of Small Town Water Distribution System in Indonesia — A. Djajasubita

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