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COMMUNITY WATER SUPPLY AND SANITATION

PIPES AND OPERATION AND MAINTENANCE IN SELECTED CITIES OF PAKISTAN

WORLD HEALTH ORGANIZATION, GENEVA, 1990

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PIPES AND OPERATION AND MAINTENANCE IN SELECTED CITIES OF PAKISTAN

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Geneva, December 1989

PRESENTATION

This report is intended to encourage national discussions on themes of great importance for the optimization of water supply and sanitation systems in Pakistan. Particular emphasis is given to the difficult problem being faced by several water agencies, regarding the use of concrete pipes in their network systems.

The author of this report visited the cities of Islamabad, Lahore, Faisalabad and Karachi from 11 April to 03 May 1989. Details on these visits including persons and institutions visited are described in a travel report prepared on 03 July 1989.

This report is divided into 6 sections and 2 annexes. The first section deals with background and objectives of this work. Section two presents an overview of the sector situation including information on coverage, criteria for design of works, types of pipes used for water and sanitation within the country and a preliminary analysis of problems concerning pipes and water losses. Section three deals with the present status of pipes and operational aspects of the water supply and sanitation systems of the four cities visited. Sections four and five include discussions, conclusions and recommendations. Section six proposes a plan of action for starting the process of implementation of the recommendations of this document. The annex 1 is a Table comparing the various types of pipes in use in Pakistan. The annex 2 is a list of basic equipment to be utilized for training of personnel in Network Survey and Losses Control.

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ANNEXES

LIST OF ABBREVIATIONS

AC	Asbestos Cement
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BSS	British Standards
CA	Cast Iron
CDA	Capital Development Authority
CFS	Cubic feet per second
CFT	Cubic feet
CM	Centimeter
cm2	Square centimeter
DI	Ductile Iron
dia	Diameter
ft	Feet
GI	Galvanized Iron
GPCD	Gallons per capita per day
gpm	Gallons per minute
IPHER	Institute of Public Health Engineering & Research
ISO	International Standard Organization Specification
i/d	Internal diameter
in	Inches
KDA	Karachi Development Authority
KWSB	Karachi Water & Sewerage Board
kg	Kilogram
kpa	Kilopascal
l/sec	Liters per second
lpcd	Liter per capita per day
MG	Million gallons
MS	Mild Steel
m3/s	Cubic meter per second
mgd	Million gallons per day
mm	Millimeter

O&M	Operation and Maintenance
OD	Outside diameter
PHED	Public Health Engineering Department
PRCC	Prestressed Reinforced Concrete
PSI	Pounds per inch
PVC	Polyvinyl Chloride
RCC	Reinforced Concrete Pipe
Rs	Rupees
UNDP	United Nations Development Programme
US$	American dollar
WASA	Water and Sanitation Agency
WHO	World Health Organization

EXECUTIVE SUMMARY

The water supply and sanitation agencies in Pakistan are experiencing great difficulties in properly attain their objectives of producing and distributing water under acceptable conditions of quantity, quality, regularity and reliability at a minimized cost. The water supply systems are not operating with efficiency and effectiveness because of several factors which are presented and discussed in this report. It is estimated that 30 to 50 per cent of the produced water in large cities of Pakistan is presently being lost or wasted. The water supply in these cities is frequently intermittent with serious implications to water quality and to the useful life of the works.

The poor performance of existing Prestressed Reinforced Concrete Pipes and the difficulties involved in the maintenance of this type of material is certainly contributing to soaring levels of water losses observed at the production and distribution systems. Nevertheless there are other important constraints associated to the current performance of the sector which should be tackled if sustainable improvements are to be sought. A better organization of the water agencies, undertaking of network surveys, implementation of leak detection programmes, improvement of maintenance services, improvement of mapping systems, implementation of macro and micrometering systems are some of the issues which should be tackled if an improved efficiency and effectiveness of the institutions are to be achieved.

This document analyses the situation of water agencies in selected major cities of Pakistan concerning the current practices with respect to design, purchase (manufacture), installation, inspection, testing, operation and maintenance of water supply and sewer pipes and the overall performance of these water agencies with emphasis on aspects of unaccounted-for water.

A few large cities of Pakistan were chosen to represent the country in the above mentioned study. They were: Islamabad, Lahore, Faisalabad and Karachi. Visits to the water authorities of these cities were organized so that basic information for the preparation of the present assessment could be obtained.

Thousands of kilometers of concrete pipes have been installed throughout Pakistan in the past years. Although these pipes have presented failures since they started being operated, the number and the importance of these failures have significantly increased, particularly in the case of PRCC pipes, utilized in water supply systems. One of the major problems being faced by the water authorities in Pakistan is the large amount of water being lost through leaks in PRCC pipes due to the difficulty of cutting off the pipelines for repairing leaks and the lack of resources in these institutions to perform this work promptly.

Failures of PRCC pipes in Pakistan are associated with several factors including the following: aggression by substances or agents presents in the environment; influence of the characteristics of the cement and aggregates; electrochemical corrosion; inadequate mortar coating; deficiencies in the process of fabrication including aspects of quality control; inadequate manipulation and installation of pipes; poor quality control of welding practiced in steel cylinders (in case of PRCC steel); poor quality rubber ring used in joints and deficiencies in the process of operation and maintenance, including lack of preventive measures.

There is a tendency nowadays, in Pakistan to replace concrete pipes to more reliable types of pipes as Mild Steel(MS), Ductile Iron(DI) and Polyvinyl Chloride (PVC). In two of the four visited cities (Faisalabad and Lahore), PRCC pipes are no longer being purchased.

In addition to the technical analysis regarding aspects of both concrete pipes and unaccounted-for water, and a respective list of recommendations for minimizing the present problems, this report is also addressed to the organizing of efforts and mobilization of resources, internally and externally, for improving institutional and technological aspects of operation and maintenance in the concerned water and sanitation agencies.

SECTION 1

INTRODUCTION

1. BACKGROUND

Pipelines represent a major component of water supply and sewerage systems. Their implementation require huge investments. The cost of constructing water supply and sewerage systems in Pakistan ranges between US$20 - US$50 per capita in rural areas and US$300 - US$700 per capita in cities and towns. A city of one million people may invest up to a total of one billion dollars in water supply and sewerage, most of which is spent on distribution systems(11).

The problems regarding pipes and maintenance of water and sewerage systems in Pakistan are not new. A report prepared by Mullick(28) in 1970 describes several constraints and problems affecting the water and sewerage systems in Islamabad. Given the present situation, these problems have not experienced substantial charges along the years. Most of the recommendations of the above report are still applicable.

Some estimates indicate that 30 to 50 per cent of the water produced in water supply systems in Pakistan is lost before arriving to the customers(1). These numbers however, result from rough evaluations as no water system in Pakistan is provided with reliable macro or micrometering systems capable of generating updated figures on water produced and on water delivered to consumers. The figures regarding water losses, and even the lack of figures in this regard, are effective indicators of the poor water agencies' performance.

No considerable efforts have been made in the past for improving the efficiency and effectiveness of the water agencies in Pakistan. Isolated actions are being presently undertaken by KWSI and WASA/LAHORE which are directed towards a better use of the existing systems. The results of these actions are not yet known. Although there are relevant projects under implementation, there is a major drawback in the current interactions within the country: the water agencies are working in isolation without an effective coordination capable of optimizing the scarce resources available for activities of this nature.

One of the major problems in Pakistan is the poor performance of pipes in use within the country. The water pipe manufactured locally generally has a life span of 15-40 years i.e. mild steel (MS) pipe used in Islamabad (not protected) failed in about 15 years and prestressed reinforced concrete pipe in Karachi is failing in 20-25 years. Smaller sized asbestos cement pipe is more durable once protected from impact forces, and provides a longer useful life(1).

A few large cities of Pakistan were adopted as a representative sample of the country concerning the present study. These cities are the following: Islamabad, Lahore, Faisalabad and Karachi.

2. OBJECTIVES

The major objectives of the present study are:(1)

- To review the current practices with respect to design, purchase (manufacture), installation, inspection, testing, operation and maintenance of water supply and sewer pipes used in selected major cities in Pakistan
- To study the condition and behavior of the existing water supply and sewerage lines
- To recommend programmes to reduce leakage/waste/breakage and where serious deficiencies exist, outline comprehensive future programmes for the design (manufacture), procurement, installation, etc. for both water and sewer pipes.

- To study the conditions and to provide information relevant to establishing a water supply and sanitation technicians school

SECTION 2

OVERVIEW

1. THE WATER SUPPLY AND SANITATION SECTOR

It is estimated that 30 per cent of reported illness and 40 per cent of deaths in Pakistan are attributable to water borne diseases. One of the consequences of this situation is loss of human efficiency and economic resources expressed in terms of numbers of working hours lost(29). The situation in the year 1986 is that 78 per cent of urban and 28 per cent of rural population have access to safe water supply, in the form of public standposts and yard and house connections. About 14 percent of the rural population is estimated to be served by public handpumps, installed by the concerned provincial water departments. The remaining urban as well as rural population relies upon private sources consisting mostly of open wells , handpumps and springs. However, in some areas surface water such as canals, rivers, rain water ponds, etc. are also being used for washing and bathing purposes.

Table 2.1 presents the estimates of population served through house connections and public standposts for urban areas of Pakistan in 1986(29). The table shows that presently about 77 per cent of the urban population have access to the piped water supply. Approximately 59 per cent of the urban population is being served through service connections while the remaining 18 per cent is relying upon public standposts. The remaining population depends upon private sources such as handpumps, open wells etc.(29).

TABLE 2.1

WATER SUPPLY COVERAGE FOR URBAN AREAS(1986)

PROVIN -CE	PROJEC- TED POPULA- TION (1000)	POPULATION SERVED (THOUSAND) Service Connect ion	Public Taps	Total	PERCENTAGE POPULATION SERVED Service Connect ion	Public Taps	Total
PUNJAB AND IS- LAMABAD	15 065	8 515	1 410	9 925	56.5	9.4	65.9
SIND	9 557	6 016	2 843	8 859	62.9	29.8	92.7
NWFP	1 904	982	514	1 496	51.6	27.0	78.6
BALU- CHISTAN	912	541	251	792	59.3	27.5	86.8
TOTAL FOR PA- KISTAN	27 438	16 054	5018	21 072	58.5	18.3	76.8

PHED criteria provides per capita domestic water demand, ranging from 10 to 60 gpcd (37.9 to 227 lpcd) depending upon the design population varying from 700 to above 100 000. The suggested demand includes water unaccounted-for which should not be greater than 25%(3).

PRCC pipes are manufactured in Pakistan in sizes from 300mm to 2000 mm. The largest manufacturer of these pipes is the Karachi Development Authority which has a total capacity of 30 000 tons per annum. These pipes are largely used in water mains as well as sewer lines(13).

Reinforced Cement Concrete (RCC) pipes are normally used for sewer lines. They are usually fabricated close to their point of use because of their weight and because of the simplicity and low cost of the required equipment. Joints in PRCC or RCC pipes are socket-spigot type fitted with rubber rings or collar type of 1/2 inch larger dia. than pipes, and filled with mortar.

Asbestos Cement pipes of diameters from 80mm to 600mm have been manufactured in the country. The total production capacity of AC pipes is greater than the present demand. The joints of AC pipes are collar-type with rubber rings. Asbestos Cement Pressure Pipes are manufactured in Pakistan since the setting up of the first factory at Karachi in 1967. The pipes are being manufactured in conformity with Pakistan Standard Institute Specification No. 428 which is equivalent to International Standard Organization Specification No. ISO-160(18). Rubber rings are manufactured in conformity with ISO/R 1398 of 1970 and Pakistan Standard 1538/1982(13).

PVC pipes used in water supply are manufactured in sizes from 80 mm to 350 mm. There are two major industries within the country manufacturing PVC pipes for water supply systems. In addition, there are more than 200 small factories producing mainly electrical pipes and pipes for housing industry. Some of these industries are suppliers of the water agencies in Pakistan(13).

Cast Iron Pipes are being manufactured in Pakistan for public water supply. They are capable of withstanding working pressures up to 400 ft. (12 kg/cm2). This type of pipe is being manufactured in conformity with Pakistan Standards Institute specifications which are equivalent to that of British Standard specifications No. 78 of 1948. They are not internally lined or protected in Pakistan. Thus, they are vulnerable to corrosion and tuberculation(18). Cast Iron Pipes are more commonly used within the country where smaller diameters are involved in water distribution and sewerage systems(19).

During the past few years, Ductile Iron pipes have been imported and used in a number of foreign aided projects(13). There are some ongoing projects which are considering this type of alternative as the most suitable for the construction of works which are of great importance within the respective water systems. The major drawback of this type of alternative is the absence of factories fabricating this type of pipe in Pakistan and the high cost of importation of this material.

Mild Steel Pipes are being fabricated in Pakistan for the range of diameters used by the water agencies within the country. Although poor quality pipes have been fabricated and installed in the past it seems that this problem has been overcome. Several agencies have selected MS pipe as the most suitable alternative for the construction of transmission lines because of its reliability under the present conditions of fabrication, reasonable price and because of the possibility of local fabrication.

The situation of the pipe network systems in Pakistan is critical due to the profusion of failures in PRCC and other pipes and due to the difficulties to repair them and to the inconveniences that this situation causes to both the consumers and the water agencies.

2. THE PRIORITY PROBLEMS

2.1. PIPES

The quality of PRCC pipes (particularly noncylinder pipes) is extremely sensitive to the manufacturing process control. As discussed in other part of this report there is a great number of factors to be controlled in a manufacturing process, each one affecting the quality of the finished product. Although the professionals involved in quality control show great concern and dedication to their work, the quality of PRCC and RCC pipes in Pakistan fall short in expectations as to the required quality.

The PRCC pipes have an initial cost substantially lower than the cost of alternatives as MS or Ductile Iron. However, the drawback of concrete pipes being fabricated in Pakistan is threefold: lack of reliability, difficult repairing (in almost all cases the supply has to be cut off for carrying out repairing tasks), and short useful life as compared to MS or Ductile Iron.

PRCC pipes have been extensively used as transmission mains and primary network in some large cities of Pakistan in the past years. Because of the poor quality control in the process of fabrication and installation of these pipes, the water agencies are currently facing serious problems regarding the need for frequent interruptions of supply for maintenance work.

There are cases in which the pipelines are allowed to leak for months until an appropriate moment is found for cutting off supply for repairing simultaneously several leaks and other eventual failures. Therefore, if concrete pipes are likely to be used in Pakistan in the future, it is advisable that strong efforts be made to improve their quality.

Despite the fact that the initial cost of PRCC pipe is smaller than the cost of other solutions they do not represent the best financial alternative under the present circumstances. Nevertheless, they could be a suitable alternative for use as pressure pipes, provided that an increase in their useful life and performance were achieved.

The selection of the type of pipe to be purchased should be based on a number of other relevant aspects as, for example, the following:

- aggressiveness of the soil

- availability of financial resources for importing pipes

- cost

- flexibility of the system concerning interruption of supply for maintenance purposes

- local production of pipes

- period of time for delivery of purchased pipes (imported or locally manufactured)

- possibility of controlling quality of delivered pipes

reliability

- type of traffic on the surface above the pipeline

- work involved in maintenance

2.2. WATER LOSSES

The water losses in large cities of Pakistan range from 30 to 50 percent of the produced water(1). Despite the lack of reliable information on this matter it is probable that the unaccounted-for water figures represent a great percentage of the produced water in these cities. These figures are a consequence of constraints being faced by the water agencies in Pakistan including lack of financial and technical support for the proper management, including the operation and maintenance of the water and sanitation services. An analysis of the above constraints is made in item 4.1

SECTION 3

FINDINGS

1. BRIEF ASSESSMENT ON THE SITUATION OF PIPES AND THE WATER SUPPLY SYSTEMS IN SELECTED CITIES

1.1. ISLAMABAD

The population of Islamabad, is 250 000(1986). The total water production is 40 mgd(1.919m3/s). From that, 32.8 mgd(1.437m3/s) is obtained from eight treatment plants located at Simly Dam and other surface water sources. The production per capita is therefore 160 gpcd(605 lpcd). The operation and maintenance of Islamabad water supply system is the responsibility of the Water and Sewerage Maintenance Directorate of Capital Development Authority(CDA).

The CDA intends to increase the water production in phases to about 100 mgd(4.38 m3/s) by the year 2000 to attend a projected population of 621 000. The incremental supplies will be obtained by improving the existing sources and developing new sources, especially Khanpur Dam.

1.1.1. SITUATION OF PIPES

The following types of pipe have been utilized in the water supply and wastewater systems of Islamabad:

- Prestressed reinforced cylinder concrete pipe (PRCC steel)

- Prestressed reinforced noncylinder concrete pipe (PRCC)

- Asbestos Cement (AC)

- Cast Iron (CA)
- Galvanized Iron (GI)
- PVC
- Mild Steel (MS)

In accordance with reference (7) the following are the basic procedures and standards concerning the use of pipes in Islamabad:

(I) (a)	Current codes of practice in designing	British code of practice is followed in design of water supply and sewerage systems in Islamabad
(b)	Materials	Materials for manufacturing the pipes are used as per BSS or ASTM as applicable in different cases
(c)	Manufacturing	The following specifications are used in manufacturing of pipes for water supply and sewerage projects:

1. AC pipes	PSS 428/1964
2. PVC pipes	BSS 3505/1968
3. GI pipes	BSS 1387/1967
4. Steel pipes	BSS 1387/1967
5. PRCC steel core pipes	AWWA specification C 301
6. RCC pipes for sewerage	ASTM C-14-75 BSS-558 1945

(d)	Installation inspections	The installation and inspection of pipes are carried out in accordance with Pak:PWD specifications, Public Health Eng. Department specifications,

		BSS & ASTM which ever is applicable according to contract agreements of the works
(e)	Testing of water and sewer pipes	Testing in factory is carried out as per manufacturing specification and after laying the test is carried out as per specification mentioned for (d) above
(II)(a)	Present practice for installation	The pipe installation is done in accordance with the specifications as mentioned in para I(d)
(b)	Inspections	Inspections are carried out during execution of works by various field officers and is seen that works are carried out as per relevant specifications and contract agreements. Deficiencies if any are pointed out at site to the supervising staff or through inspection notes and the same are got rectified.
(c)	Testing of water and sewerage pipes before and after installations	The same as described in para I(e)
(d)	Leakage detections	The water supply lines when tested under required test pressure give signs of leakage on the trench surface. Such points are dug out and leakage points are repaired according to the condition of leakage detected. In case of sewerage lines, the first manhole is filled with water up to a head of 4 ft(1.2 m) and the end of

pipe at next manhole is plugged temporarily. If there is any leakage in the sewer line the water head in the first manhole comes down and the water appears at the leaking joint or pipe on the ground surface. The leaking point is repaired keeping in view the nature and magnitude of leakage.

(e) Permissible leakage

In water supply lines 230 liters per 24 hours per kilometer per 25 mm diameter of pipe is permissible. ASTM allows 10 to 50 gallons per inch of diameter per mile for 24 hours. A one or two hours test is generally ample to permit inspection. Mostly ASTM standards are maintained.

(III) Any other problem related to water and sewer pipes

There are only two factories in Rawalpindi and Hassabdal, which manufacture PRCC & RCC pipes and can be depended upon as regards specifications etc. The testing arrangements in the factories are not very effective. The joints of PRCC pipes are not perfectly leak proof and fail due to rubber and rings which slip out for pressure higher than 45 PSI. If the joints of these pipes are improved and made more water tight by the manufacturers, these pipes are more economical than MS or ductile iron pipes.

The Gul Pipe Works factory has been one of the most important suppliers of concrete pipes for the water supply system of Islamabad in the past years. This firm has manufactured about 300km of 4" - 48"(100mm - 1200mm) diameter concrete pipes for use at the water supply, sewerage and drainage systems of Islamabad since 1967. The following are the types of pipes produced by this factory.

- Prestressed reinforced concrete cylinder pipe (water)

- Prestressed reinforced concrete noncylinder pipe (water)

- Reinforced concrete pipes (sewerage and drainage)

- Nonreinforced concrete pipes (sewerage)

This factory utilizes very simple equipment manufactured locally.

Simple Prestressed Reinforced concrete pipes(noncylinder) have been mainly used in Islamabad in Peripheral Mains and in some cases in distribution lines as well. They have been used in sizes from 9 inch(225 mm) to 24 inch(600 mm) diameter. They consist of a concrete cylinder called "Shell" with a male and female ends. They contain MS reinforcement and after proper curing are wrapped with high tensile wire under tension to 75 percent of its ultimate tensile strength. A layer of mortar coating is applied over the high tensile wire for protection against rusting. This pipe is also jointed with a rubber ring inserted between the male and female ends(20).

Steel core prestressed pipes (prestressed reinforced cylinder concrete pipes) have been used in the two parallel conduction mains of 36 inch dia(914 mm), from Simly Dam to Noorpur covering a distance of about 17 miles(28 km) and for 21 inch dia (530 mm) raising main from Rawal Sump to 5 MG Reservoir(19,000 m3) and from Central Sump to 7 MG Reservoir(26,000 m3). These pipes consist of Mild Steel(MS) Sheet Cylinder 16 SWG and 10 SWG with socket and spigot ends welded to it for jointing purposes. The welded cylinder is 16 ft(4.8 m) long. After proper testing it is lined with concrete of designed thickness from inside by centrifugal spinning method. After proper curing this lined cylinder is helically wrapped with high tensile wire at a designed spacing and tension equivalent to 75 percent of its ultimate tensile strength. A protective layer of mortar coating is then applied by guniting over the steel cylinder and high tensile wire. This layer protects the high tensile wire and the steel cylinder against rusting and is, therefore, an important component in the manufacture of pipe. A rubber gasket is used to join the pipes(20).

The twin pipelines of 914 mm dia. should carry a flow of 12 MGD (526 l/sec.) each (as established in project). They were installed 22 years ago but started to be operated in full capacity after 1983. Although leaks and bursts have been reported since the pipelines were put into operation, the problem have been aggravated after 1983 with the increment of their working capacity.

The main characteristics of the two transmission lines from Simly to Islamabad are the following:

- Diameter: 36" (914 mm)
- Extension: 92 000 ft (28 km) each
- Discharge capacity: 12 MGD (526 l/sec) each
- Design pressure: 257 PSI (1 771 kpa)
- Thickness of the mild steel shell: 1/16" (1.59 mm)
- Concrete of the core: 1:1:2
- Pre-tension: 6 gauge high tensile steel wire
- Thickness of cement mortar coating : 1" (25.4 mm)
- Joints: bell and spigot with a 7/8" rubber ring (there are also rigid welded joints)

The figures 3.1 and 3.2 show sectional details of pipe construction(3)

The following text has been quoted from a report prepared by A. Q. Nomani from CDA, concerning the performance of the two transmission mains from Simly to Islamabad(3):

"The First Line was commissioned in 1967 with a discharge of only up to 8 MGD (350 l/sec) against the designed discharge of 12 MGD (526 l/sec). There were little problems with the line in the initial stage. After commissioning of Simly Dam in the year 1982, the line is running to its full capacity. Thereafter there are frequent troubles with joints and the pipes which leak or burst under pressure. All such joints were being repaired as well as burst pipes replaced during annual shut downs arranged especially for this purpose. However, the frequency of pipe burst has recently increased."

"The first line was given a shut down recently on 21/01/1988 to facilitate replacement of two pipes and repairs at three other points. After repairs the line was restored at 3:00 a.m. on 22/1/1988. Water had reached 5MG Reservoir at 11:00 a.m. on 22/01/1988. The pressure in the pipeline gradually increased up to 172 PSI (1 185 kpa) at Gumrah Kus which is a maximum pressure zone. At 6:00 P.M the pipeline burst near Gumrah Kus at a place where the pressure was roughly 150 PSI (1 033 kpa). The pipe was immediately replaced with MS pipe and the line was again restored at 11:00 P.M. on 23/01/1988. Water reached 5MG reservoir at 3:00 a.m. on 24/01/1988 but the line burst for the second time at another place between Pind Begwal and Sihali Bridge at 4:00 A.M. on 24/01/1988 where the pressure was roughly 120 PSI (827 kpa). The maximum pressure at Gumrah Kus at that time was 170 PSI (1 171 kpa). The burst pipe was thereafter replaced with MS pipe and it was restored at 1:00 a.m. on 25/01/1988. The water was gradually released and it reached 5MG reservoir at5:00 P.M. on 25/01/1988. It took long time to reach 5MG reservoir because a defect in the welding of new pipe eliminated by giving a short shut down after the line was restored at 1:00 a.m."

"During the period from 21/01/1988 to 25/01/1988 there was a short supply of 25% of the total supply and therefore a number of complaints were registered which were attended by the Tanker Service. The shortage persisted up to 26/01/1988 because the reserves of the consumers had completely exhausted by 25/01/1988."

"Site inspections had been carried out on both occasions of pipe bursting incidents. It was observed that the protective mortar coating was damaged at the location of bursting and the high tensile steel wire had broken due to its rusting. With the release of tension due to breaking of high tensile wire, the pipe could not resist the water pressure. The condition of adjacent pipes where excavations had been done for replacement was also not found to be satisfactory. It appears that the protective mortar coating has come out at most places and such places would be the source of danger. The pipes may burst any time. The second line which was laid a couple of years after the first line presents similar condition."

The causes of the failures described above can be associated with the poor operational situation of these two lines. The work developed by the consulting firm "National Engineering Services Pakistan"(3) who studied their present state show that important elements of control are out of service. The table 3.1 summarizes the failures observed. There are strong evidences that one of the factors contributing to the problems reported is the uncontrollable increase and decrease in pressure because of hydraulic transients. In addition to the fact that the pipelines are not provided with effective devices for preventing transient pressures, it seems that most of the air valves and washouts of the two lines are not in operating conditions.

The working pressures observed at some lengths of these conduction mains are close to the hydrostatic testing pressure at the factory. These pressures reach 170 PSI(1 173 kpa) at critical points. The existing surge valves are not in operating conditions therefore exposing pipelines to pressures above their design capacity. Bursts have occurred with unreasonable frequency at these points(3).

At many locations the designed outlet pipe does not exist and the chambers are full of mud. Some house connections from the washouts have been reported(3). These valves are of great importance to prevent transient pressures in the operations of shutting down and restoring the pipelines. The impossibility of operating these valves produce significant increase in risks of breakdowns and other failures.

TABLE 3.1

INVENTORY OF FAILURES OBSERVED AT
THE CONDUCTION MAINS FROM SIMLY TO ISLAMABAD

	Washout	Air Valve
1. Leakage	11	6
2. Valves submerged in water or mud	4	2
3. Valve is plugged	6	18
4. Chamber cover is missing	9	20
5. Chamber cover is welded or sealed with mortar	7	8
6. Outlet pipe is missing	10	-
7. Valve missing	0	2
8. Chamber sealed with mortar or choked with mud	3	0
9. Pipe connection to houses	2	1

Total number of air valves inspected : 91

Total number of washout valves inspected: 59

Number of air valves which are not in working condition: 30 (33%)

Number of washouts which are not in working condition: 20 (34%)

The quantity of leaks and particularly leaking joints is increasing and CDA is lacking capacity to repair them promptly. The repairing of most of the leaks occurring in PRCC pipes cannot be carried out without shutting down the respective pipelines. As most of them are trunk mains or transmission mains the CDA faces serious difficulties for performing this type of work.

In accordance with the CDA there are two general causes of failures of PRCC pipes in Islamabad, which are: lack of effective quality control and poor quality material utilized in its fabrication.

The following are the types of failures occurring in PRCC pipes:

- leak through defective joints
- leak through pipe walls
- Burst by blowing of concrete cylinder with or without tearing of high tensile wires

The CDA advocates that the following are the main causes of leaks through joints:

- Lack of quality control in the fabrication and installation of pipes
- Incorrect alignment of pipes (deflection between pipes greater than allowed)
- Poor quality rubber
- The grooves are not regular and their dimensions not uniform and not compatible with the used rubber

Joint leaks have been repaired by the method cf calking which has not proved to be satisfactory(12).

There is a great number of different factors presented and discussed in other part of this report which may be contributing to the present situation of the existing pipelines. Most of them are of irreversible nature for they are linked to the design of the pipes, to the material utilized in their fabrication and to the techniques employed in their manipulation, transportation and protection. For instance, the process of corrosion of high tensile wires cannot be stopped nor minimized unless techniques of high cost be utilized. The cathodic protection which would be possible and of low cost if implemented during the construction of the line would be of high cost and of unpredictable results if implemented at this point. The identification and repairing of pipes presenting corrosion of wires or shell before a leak or a burst occurs is virtually impossible under acceptable financial conditions. Nevertheless, it is possible to envisage the following phases for upgrading of pipelines:

(a) to identify lengths of pipeline more susceptible of suffering break down and to carry out studies to determine cost-effectiveness and technical viability of rehabilitation.

(b) to select one of the following techniques for rehabilitation:

- Thermostatic pipe insertion process
- Insituform process
- Insertion of steel pipe
- Replacement of selected extends of deteriorated pipelines
- Others

Whatever is the selected process it should present structural properties to resist the water pressure independently of the structural support given by the PRCC pipe. This is one of the reasons why the rehabilitation of pressure concrete pipes is rot a very common practice. The references (30) and (31) are excellent manuals dealing with this issue.

All lengths of pipelines on bridges are being replaced with MS pipes.

This decision was originated by the deterioration of the cement mortar coating and corrosion of high tensile wires and the risks implied in a possible burst of pipes at these locations.

The incidence of leaks in PRCC pipes is known to be quite frequent. However, there is not routine treatment of information on this matter. Although interventions for repairing pipes are recorded, such information isnot used for generating managerial indicators.

Survey on the resistivity of the soil along selected lengths of the conduction mains was performed. However, the collected information is not sufficient to compose any reliable conclusion. Further studies are required to define whether the pipes are being submitted to galvanic or electrolytic corrosion and how this process is affecting them(3).

The experience of Islamabad lead to the conclusion that despite the low initial cost of PRCC pipes their use is not encouraging because of the following rationale(12):

- They are very heavy thus making handling and transportation difficult
- Difficulty of repairing or replacing burst or damaged pipes
- Need for steel specials
- Susceptibility to incidental damage
- Damage occurring during transportation and handling
- Greater number of joints
- Difficulty of making larger tapping into the pipe

For this reason, CDA/Islamabad decided not to use PRCC pipes for future construction of transmission mains. The replacing materials are MS pipes and Ductile Iron Pipes.

Steel pipes used in Islamabad until 15 years ago were not protected properly. Only a coat of bitumen was applied. The pipes were manufactured at the site of construction. Most of these pipes were corroded and rusted during the construction. Some of these, have already been replaced(12).

The new MS transmission lines being used in Islamabad, however, are in accordance with international standards. The welding work is being carried out properly with all joints being tested systematically by x-ray techniques. Protective coatings are being applied both externally (fiber glass and black bitumastic enamel synthetic) and internally (cement mortar lining). These pipes are being manufactured locally.

The Ductile Iron Pipes are being imported for the construction of a new pipeline. The quality of this type of pipe is generally excellent but they are very expensive in Pakistan. Efforts are being made by national and international groups for setting up a ductile iron factory in Pakistan.

Several other types of pipes have been used in Islamabad, without such dramatic failures as those above reported. Asbestos cement pipes of small size, have been used in several sectors of Islamabad without serious maintenance problems. This type of pipe, however, was found to be unsuitable to be utilized in discharge pipelines of pumping stations. There are, currently, three factories in Pakistan, manufacturing A.C. pipes. These are located in Karachi, Khushab and Hassanabdal(12).

Unplasticized (rigid) PVC pipes are used in Islamabad for small sizes. Bell and spigot type joints with rubber rings are available in Pakistan for this type of material(12).

Welded steel pipes are currently manufactured in Lahore and Karachi. The protective coating of recent MS pipes in Islamabad is in accordance with international specifications. They have, externally, protective coating of black bitumastic enamel synthetic between impregnated work fibre glass. Internally, the pipes are to be lined either with epoxy coat, spun bitumen or cement mortar(12).

New waterworks are being constructed in Islamabad. They are intended to improve the reliability of the present water works and to achieve continuity of supply. The sectors are presently supplied during two hours per day. The following are some of the major waterworks being constructed in Islamabad:

- 36" MS pipe, extension 9906m from 7MG reservoir to sector E-10 along Margala Avenue at Islamabad. Cost: Rs. 37.73 million (US$ 1.91 million)

- 500mm MS pipe, extension 3962m and 500mm ductile iron pipe, extension 7163m from Korang water works to 5 MGR reservoir in sector F6. Cost: Rs 12.37 million (US$ 0.625 million).

- Phase III of the bulk water supply to Islamabad

  (a) Construction of a filtration plant at Simly, capacity 18 MGD (9461/sec)

  (b) Construction of a 48" main, extension 28,041m, ductile iron from Simly to Islamabad. Cost: RS 1,285.43 million (US$ 64.92 million)

The pipes used in the sewerage and drainage systems of Islamabad are simple reinforced cement concrete pipes conforming to BSS 556 which is a non-pressure pipe. It consists of a concrete cylinder having MS reinforcement inside it. In Islamabad, it has been usually jointed by means of a collar sealed through mortar. It can be, alternatively, manufactured with a socket and spigot ends for use with rubber ring gaskets. The CDA started recently to use this type of pipe without MS reinforcement(20).

The quality control of sewer lines seems to be not properly carried out. Surfaces at joints are neither regular nor smooth. The inspection of pipes at the site of the construction is not effective resulting in the possible use of poor quality pipes. On the other hand, the use of nonreinforced pipes may be inconvenient as their resistance to tensile stress is negligeable. They are susceptible to crack under soil differential tensions, poor backfilling material, poor bedding, high external loads, etc.

The quality control of new concrete pipes (non reinforced) utilized at the sewerage system of Islamabad should improve. A number of pipes were found at the site of the construction presenting failures of concrete (cracks) at the spigot. The installation of these pipes would cause leaks of sewage or infiltration of underground water. The procedures for the installation of pipes including transportation, stocking of pipes in the yard, bedding, alignments, are not in accordance with international standards.

1.1.2. OTHER OPERATIONAL ASPECTS

There is not an effective operation control of the water supply system of Islamabad. The larger service reservoirs (the 7MG and the 5MG reservoirs) are not connected to an operational information system as it would be required. As the level meters of these two reservoirs were not in working conditions it is doubtful that the control valves are being operated at the proper moments. These reservoirs are locally controlled by operators.

Several valves of large diameter installed in pipelines of the network system are leaking through glands or through joints. The repairing of these valves have been a difficult task due to poor quality of available packing material used in the stuffing boxes, due to excessive roughness of spindles and due to existence of different types of valves and manufacturers which makes impossible the interchangeability of spare parts.

CDA does not count with a workshop for repairing of valves and other mechanical or electrical equipment. The maintenance service is carried out through the use of private workshops within the city. This procedure has the drawback of introducing delay in some priority services and of reducing drastically the capacity of the institution concerning the implementation of preventive maintenance programmes.

It seems that the number of existing leaks in Islamabad is considerable. The problem is more serious in the case of PRCC pipes for the repairing of most of these leaks require the shutting down of the respective pipelines. As it is not possible to shut down a major line each time a leak occurs, the CDA adopts the procedure of shutting down the pipeline recurrently for repairing several leaks simultaneously. Therefore there are many visible leaks running on the streets of Islamabad which are not repaired until the next shutting down of the concerned pipeline. CDA/Islamabad counts with one device for detection of not visible leak which has not been utilized for systematic survey.

Electromechanical maintenance in Islamabad is carried out with the support of local private workshops. The CDA carries out the dismantling of pumps, motors and other devices and send them to private workshops for due action. Thereafter, the CDA reinstalls the equipment accordingly.

CDA counts with a suitable mapping system which, however, has not been updated accordingly during the past years. Therefore relevant information concerning modifications of the pipe network may have been lost. The pipe network is represented in maps of scales 1:4000, and 1:1000.

The water produced in Islamabad is not metered. There are neither bulk meters for metering the water being delivered to the distribution system nor house meters for metering the water rendered to consumers. The water produced is estimated either by the design capacity of the works or by investigations based on instantaneous measurements of flow. None of them are reliable and are therefore providing rough estimates of flow rates.

The absence of flowmeters combined with lack of an effective maintenance service and poor quality material utilized in the pipe network system is certainly leading to the soaring levels of per capita production in Islamabad which is estimated to be 605 lpcd.

1.2. LAHORE

Lahore, with its 3.314 million inhabitants(1988), is the capital of the province of Punjab. It is the second largest city of the country with its supplies obtained from deep wells. The water supply system of Lahore is operated by the Water and Sanitation Agency (WASA). The population served by piped water supply is 2.75 million inhabitants (82 %). There are 176 tubewells in operation (March 1989) in the production system, which are responsible for all produced water in Lahore. No other sources of water are utilized. These tube wells have a depth of 200-600 ft (60-180 m). The extracted water is of good quality, requiring solely disinfection. Chlorinators are installed in all tube wells discharges. The production of water is 180 mgd (7886 l/sec). The per capita production is about 65 gpcd (246 lpcd). These figures are only estimates as a large percentage of the pumping lines of the deepbore tubewels are not provided with permanent flowmeters. A little percentage of housing connections are being metered.

The water supply system does not count with service reservoirs except for an old reservoir of 2.95 MG (11 000 M3) operating in the old walled city. The Wall City Reservoir was constructed 50 years ago by the British Government. It is divided into four compartments and its zone of influence embraces the old part of the city whose population is roughly 0.5 million inhabitants. Obviously, the reservoir falls short in capacity, considering the population under its zone of influence. This service reservoir is an exception in Lahore's water supply system as storing of water has not been considered in the conception of the system. There are just a few service reservoirs of small capacity in operating conditions within the city.

The tubewells pump directly to the distribution network. This is a regular practice and it is accepted that the houses are provided with domestic reservoirs to avoid problems concerning lack of regular supply. The water supply system, however, operates continuously without the need for shutting off selected sectors. WASA/Lahore seems to be one of the few water agencies in Pakistan in which the water supply to the network system is continuous.

The following are some basic data on Lahore's water supply and sewerage systems:

<u>Water Supply (March 1989)</u>

- Served population (with house connections)(million)	2.75
- Additional population to be served by 1995(million)	0.37
- per capita production(gal/inh/day)	80

<u>Sewerage (March 1989)</u>

- Served population(million)	2.15
- Service target by 1995(million)	2.75
- Additional target coverage through Punjab Government Department(million)	0.65

<u>Population (March 1989)</u>

- Total population(million)	3.314
- Population under WASA responsibility(million)	3.08
- Population under other agencies(million)	0.434

The procedures and techniques in use in Lahore for the operation and maintenance of the water and sewerage systems should improve. The complexity of the Lahore's systems requires the use of suitable technology and effective mechanisms and managerial procedures for an optimized use of the existing facilities. For instance, there are not effective instruments installed in the system for controlling flows and pressures in a permanent basis. A few flow meters are installed at the tube wells discharges pipelines for measuring the water produced at these installations. However these meters are not functioning properly nor are being utilized for supporting the operation control of the system.

The pressures are measured by metallic gauges in selected points of the distribution system (generally at the discharge of tubewells). These gauges are not usually permanently fixed at the points of measurement. They are installed each time they are to be read and then removed. The frequency of this operation is 15 days. This information is utilized for defining the times of operation of the several wells affecting a specific area. Therefore, the timetables orienting the operation of the wells are established in accordance with a previously prepared plan of operation. They are not based on real time operation, as usual.

WASA/Lahore is equipped with an effective maintenance service. There are different installations and units responsible respectively for carrying out maintenance service regarding pumps, motors, flowmeters and other electromechanical equipment. Practically all the required maintenance services are carried out in-house.

WASA is not facing problems concerning PRCC pipes as this type of pipe has not been utilized in Lahore since several years ago. A few pipelines of this material are still in operation. However, they do not represent a factor of concern either for the operation or for the maintenance of the system.

WASA/Lahore, however, utilizes reinforced concrete pipes for the sewerage system. There is a local private company which is the major supplier of the institution. The several phases of the manufacturing process are usually under inspection. A WASA's engineer in charge of quality control is permanently in close contact with the factory. Each manufactured pipe receives a code number which is registered on the pipe itself. If the inspection results in nonacceptance then the respective pipe code is registered in the WASA control notebook. At the reception of the pipes the latter are once more inspected and their code numbers checked against code numbers of previously rejected pipes. Thereby WASA is prevented from receiving pipes in the construction site which had previously been rejected in the factory premises. Despite this quality control, leaks in joints appear to be one of the drawbacks of this type of pipe. The factory, with support from WASA, is carrying out investigations aimed at identifying and correcting the problem. New designs for grooves are being tested.

The following is the information supplied by the WASA (LDA), Lahore, concerning codes and practices for water supply and sewer(9):

1. Current codes of practice in designing, materials, manufacturing, installation inspection, testing of water and sewer pipes

The material for RCC sewer pipes is inspected/tested in accordance with Government of Pakistan specifications of materials of construction contained in schedule of rates Volume-1 Part-1 (1964) and the manufacturing, testing and installation of pipes is carried out in accordance with BSS Class-L for 9" i/d sewer pipes and ASTM C-76 for RCC pipes ranging from 12" i/d to 66" i/d.

As regards water supply pipes manufacturing, the specifications for different pipes are observed by the manufacturers. The pipes being used for water supply lines are AC pipes, CI pipes and MS pipes. However hydraulic testing of the laid lines is done as per AWWA specifications.

2. Present practice for installations, inspections testing of water and sewer pipes before and after installation, leakage detection, and permissible leakage allowance etc.

The water supply pipelines are tested for hydraulic test in accordance with AWWA specifications whereas RCC pipe sewers are also tested hydraulically in accordance with ASTM C-76 specifications.

1.3. FAISALABAD

The population of Faisalabad is about 1,000,000. Ninety percent are served with water supply. There are two types of sources in Faisalabad. About 60 percent of the water produced is extracted from the Rakh-Branch Canal through four treatment plants. The other 40 percent are extracted from 60 deep wells placed along the Rakh-Branch Canal. The total water production is about 72 MGD (3.15 m3/sec). The average production per capita is about 327 lpcd. The number of house connections in Faisalabad is 85,947 (1989). The number of metered house connections is 8,000 (11 percent). The maximum pipe diameter in the water supply system is 20in (500 mm) and the smallest diameter is 3in (75 mm). The material utilized for house connections is galvanized iron.

In accordance with WASA/Faisalabad a very small percentage of pipes is

PRCC (about 3,000 m). The remaining PRCC pipes are being removed for it is cost-effective to replace them.

The use of asbestos cement in water supply systems has been questioned in Faisalabad due to its possible implication to health. WASA/Faisalabad has decided not to use asbestos cement pipes in their systems to avoid possible health risks. Instead, the institution is using PVC pipes for the distribution network (it is important to mention that in accordance with a number of credible investigations on this matter, no evidence exists that the use of AC pipes in water supply systems offers risks to health). There is no information on the total extension of pipelines and on its composition.

The current practices for manufacturing, installation, inspection and testing of pipes are based on the AWWA/ASTM codes. The installation process is mainly labor oriented instead of being mechanized due to the availability of abundant manpower(8).

The water production is estimated as the production system do not count with flowmeters. The pipe network is not entirely interconnected. Most sectors are completely isolated from each other, therefore resulting in a non-flexible system.

WASA/Faisalabad is only repairing visible leaks as they are reported to the institution by users or field staff. Equipment for underground leak detection is not available.

The installation of house connections is of responsibility of the consumer. The latter purchases the required material at the local market. The WASA assigns a worker who installs the house connection. This type of procedure is particularly inconvenient as the tendency in this case is that the user will not be committed with the quality of the material being purchased. He will seek for low cost material to the detriment of quality. The consequence will be the short useful life of the house connection and the possibility of leakage during this time.

The repairing of leaks is undertaken manually. There is not the support of heavy equipment for network maintenance. The justification for the profuse use of workers without the support of mechanical equipment is the low cost and ample availability of manpower in Faisalabad. There is no information on the efficiency and effectiveness of the network maintenance. Electromechanical maintenance is carried out through private workshops within the city.

The operation control of the production system is being carried out with great difficulties. The operational units (reservoirs, wells, etc.) cannot receive or transmit communication promptly as there is lack of equipment (telephones, radios). Sometimes the operators have to perform long distances on foot to get to a service reservoir which is eventually overflowing.

Although the pipe network is mapped there is not routine updating and therefore it is believed that the existing maps are not reliable.

The tariffs in Faisalabad for nonmetered house connections are as follows:

Diameter (in)	Rate per month (Rs)
1/4	12
3/8	35
1/2	70
3/4	175
1"	400

For metered house connections the tariff is 8 Rps. per 1000 Gallons(3.78 m3).

A project for the construction of 25 new deep wells is being financed by the Japanese Government. The capacity of this new system is 60 MGD (2.63 m3/sec). The wells were perforated at the bed of Chenab River at a distance of 18 km from Faisalabad. The project includes the construction of the transmission main which is a 36" (900 mm) DI 18 km of extension.

1.4. KARACHI

Karachi is the largest city of Pakistan, counting with a population of 6.7 million (1986). The water production and respective sources as well as type of treatment is presented in table 3.2, as follows(4):

TABLE 3.2

WATER PRODUCTION OF THE WATER SUPPLY SYSTEM OF kARACHI (1986)

Source	Supply (mgd)	Supply (m3/sec)	Source Type and Treatment
Indus River	252	11.04	Surface; Filtration and Disinfection
Hub Dam	107	4.69	Disinfection Only
Haliji Conduit	24	1.05	Nil
Dumlottee Well	6	0.26	Disinfection
Total	389	17.04	

In accordance with reference (4) a population of 4.4 million is served by house connections whereas 2.3 million is attended by public standposts. The table 3.3 shows the composition of produced water in Karachi (1986).

Table 3.3

Composition of Produced Water in Karachi(1986)

Use	Water delivered		Percentage
	MGD	m3/sec	
House connection	144	6.31	37
Standposts	47	2.06	12
Industrial	23	1.01	6
Commercial	19	0.83	5
Unaccounted for water	156	6.83	40

The water production and unaccounted-for water are rough estimates as both the macrometering and the micrometering systems do not provide reliable figures.

The concrete pipes used in Karachi for the water supply system are prestressed reinforced concrete noncylinder pipes. The concrete core is reinforced and longitudinally stressed with high grade steel. The prestressing is carried out on the concrete ccre, as in Karachi, steel cylinders are not used.

The first plant for the manufacturing of Prestressed Reinforced Cement Concrete Pipes was built by the Karachi Development Authority in 1968. The manufacturing process in the plant is patented in Australia under the name of "rokla process." In the process, a steel pipe is made by longitudinal welding of steel plate. The pipe so made is deposited with cement concrete on its inside and outside in spinning mold. Thus a cement concrete pipe with a steel core is made. The pipe is then wrapped with a pretension high tensile steel wire which is anchored at the end of pipe. The wire is covered with cement concrete which is finally cured. Pipes under this process have been manufactured up to 2250 mm. These have been used for transmission of water under pressure exceeding 24 kg/cm2. They are known as bulk water mains in Karachi Development Authority. Troubles were experienced with occasional bursts of these pipes when water supply to Metropolitan Karachi Area was temporarily stopped(18).

The PP Factory (Prestressed Pipe Factor) is a governmental institution linked to KDA. It was implemented in cooperation with the Australian government. Royalties are still being paid to Australia. Most of the pipes of the water supply and sewerage systems in Karachi have been supplied by KDA through its associated factory. The KWSB may alternately purchase pipes directly from other factories or from abroad with or without the support of KDA.

The following standards are generally in use of KWSB for water and sewerage works:

(a) Pressure pipes:

- Ductile Iron Pressure Pipes, specials and fittings - ISO-02531

- Low pressure for steel pipes - BS-534, 449, 3601, 3602, 3351

- MS pipes high pressure - AWWA C-200

- German standard - DIN-1625, 1772

- Japan standard - G-3457

(b) Sewerage pipes:

- Sewerage pipe standard - ASTM - C76

- Testing standards - ASTM-134, A-134, A-139, ASTM A-381, A-211

In accordance with reference (5), the following are the causes of vulnerability of the water supply transmission system in Karachi:

(1) Power failure/breakdowns

(2) Mechanical trouble in pumping units or control valves, etc.

(3) Breaches or serious erosion of berms, turbidity, growth of excessive weeds in canals and formation of algae, etc.

(4) Bursts or leakages or blockages in system

(5) Airlocks/water hammer, back surge

(6) Dislocation of water mains, siphons, conduits, caused by floods, heavy rains and sand lifting

In accordance with the same reference the causes of inadequacies in the distribution network are the following:

(1) Present water supply system was designed and laid decades back and is now mostly inadequate/undersize/worn out

(2) The existing network extended by different distribution agencies from time to time is incapable to ensure equitable distribution of available supply to all areas. The disparity is of the order of 3 to 5 gallons/day(11 to 19 l/day) - 25 to 30 gallons/day(95 to 113 l/day) - 50 to 60 gallons/day(190 to 227 l/day), varying from area to area

(3) The average supply for domestic use is restricted to 21 gallons/head/day(80 lpcd) and 28 gallons/head/day(106 lpcd) for non-domestic use against normally required 50 to 60 gallons/head/day(190 or 227 lpcd)

(4) Despite replacement of 21 km (costing Rs. 82 millions under IDA credit 1374-Pak), many sections of the trunk mains network of the city distribution system still remair vulnerable, causing frequent leakages/bursts and barring pressurization.

(5) The Board's efforts through attending to over 1300 leakages, provision of suitable interconnections and installation of intermediate boosting stations could only provide partial improvement but at a high recurring cost

(6) The cost of renovation/improvement required is high - roughly estimated to be of the order of Rs. one billion

The KWSB is undertaking special efforts for improvement of water supply. They are as follows (5):

(1) Improvement of quantity and services efficiency: establishment of 13 complaint centres area-wise equipped with telephones, vehicles and emergency squads

(2) Installation of boosters for low pressure zones

(3) Interconnections for equitable distribution

(4) Segregation of water supply system for industrial and residential zones

(5) Clearance of chocked mains - removal of roots and silts, etc. - replacement of worn-out, rusted and undersized water mains

(6) Check against unauthorized overdraw by upstream consumers through effective patrolling system

(7) Establishment of leak detection unit and repair of leakages

(8) Establishment of leak detection unit and repair of leakages (over 1,700 leaks repaired)

(9) Special measures to encounter and remove contamination of water - 250 samples/week being tested random as against 100/week earlier

Although the special measures taken by KWSB for improving the situation of the water supply are relevant and should produce good results, there are other aspects linked to the efficiency and effectiveness of the institution which should be embraced as commented in item 4.2.

2. SCHOOL FOR TRAINING TECHNICIANS FROM WATER AGENCIES

The water supply and sanitation sector in Pakistan lacks suitable facilities, equipment and organizational arrangements for training of technicians, particularly those dealing with operation and maintenance of water supply and sanitation systems. Thus, the water agencies in Pakistan would greatly benefit from the implementation of a school for training technicians, within the country. This school should be designed to be sustainable and capable of generating the required resources for its functioning. It should be able to improve continuously and cope with new needs of the water agencies in the country. The idea is to implement the school to serve the province of Punjab, in a first phase.

The WASA/Lahore implemented a training centre in 1978 to serve only the staff working in the institution. Its premises comprise a constructed area of about 1000m2 inside a land of approximately 8000m2. The following installations are available:

- 1 classroom with capacity for 30 students

- 1 room for demonstration of appurtenances and equipment for operation, maintenance and construction of ws/s systems

- 1 "testfield" for simulation of undeıground leaks

- 1 kitchen

- 1 cafeteria

Regular training courses have been carried out since the creation of the centre including the following, imparted from 1986 to 1989:

TABLE 3.4

TRAINING PROGRAMMI

WASA/LAHORE, 1986-1989

Course	No. of participants
Training course for junior. clerks	63
Training course for junior. & senior. clerks	87
Training course for pump operators	33
Civil Defense training	273
Job guide development programme	9
Training for newly recruited engineers	22

It has been agreed by all involved parties in Lahore (WASA, PHED, Institute of Public Health Engineering and Research) that the existing training centre at WASA's premises should be selected as the place for the implementation of this provincial school. Substantial improvements in the existing installations will be required. These improvements have to be envisaged in the light of the new training requirements expressed in terms of both the number of persons to be trained and expertise areas.

It would be advisable that representatives from three major institutions within the province of Punjab constitute the board of governors of the school. These institutions are PHED, WASA and the Institute of Public Health Engineering and Research.

SECTION 4

DISCUSSION AND CONCLUSIONS

The available information on the present state of pipes and on general aspects of O&M is not sufficient or appropriate to allow the preparation of a precise diagnostic on the situation of the visited water agencies in Pakistan, regarding these issues. The composition of materials used in the network systems is not well known. The records of failures has not been kept properly. Techniques and managerial procedures are not well defined and information in all fields is often not available. For instance, it has not been possible to workout managerial indicators which would be of great use for comparisons of performance of different institutions within the country and from abroad.

1. GENERAL ASPECTS CONCERNING PIPES

1.1. OVERVIEW

The following are the main types of pipes in use in Pakistan:

1.1.1. CONCRETE PIPES

Concrete pressure pipe found in water works is confined mainly to large size transmission mains. It cannot normally compete with AC, CI, or steel pipes in smaller sizes. It is felt that concrete pipe manufacturing industry in Pakistan needs standardization and better quality control. Concrete pipe is susceptible to attack from various aggressive chemicals, including hydrogen sulphide which may be generated in sewers. Concrete pipes with integral PVC linings, are being manufactured in Pakistan. The linings are keyed to the internal walls of the pipes before they are cured(19).

The AWWA(6) establishes that the construction of PRCC steel should begin with a full-length welded steel cylinder. After joint rings are attached to each end, the pipe is hydrostatically tested to ensure water tightness. A concrete core with a minimum thickness of 1/16th times the pipe diameter is placed either by the centrifugal process(lined cylinder pipe) or by vertical casting (embedded cylinder pipe). After the core is cured by steam or water, the pipe is helically wrapped with high strength hard-drawn wire using a stress of 75 percent of the minimum specified tensile strength. The wrapping stress ranges between 150,000 and 220,000 psi. The wire spacing is accurately controlled to produce a predetermined residual compression in the concrete core. The core is covered with a cement slurry closely followed by a dense coating of mortar or concrete that is rich in cement content. Steam or water is used to cure the coating. The standard joint for prestressed concrete cylinder pipe is sealed with a rubber gasket and steel joint rings, as shown in Fig.4.1 and 4.2. The spigot ring is a rolled shape containing a rectangular recess for holding a continuous solid ring gasket of circular cross section. The gasket is compressed by the flat portion of the steel bell ring when the spigot is pushed into the bell. Both joint rings are sized to close tolerances on a hydraulic press by expanding beyond the elastic limit. Core diameter and volume of the gasket are tightly controlled to ensure a reliable high pressure seal. After field assembly, the exterior joint recess is grouted to protect the steel joint rings. The internal joint may or may not be pointed with stiff mortar depending on the type of water the pipe will carry and the type of protective coating applied to the joint rings during manufacture.

The PRCC pipes cost about 50% less than MS pipes in Pakistan. However, the MS pipes, if well protected, may have a useful life three or four times longer than concrete pipes presently manufactured in Pakistan. MS pipes are strong, reliable, flexible, resistant to over-pressures caused by hydraulic transients and they have the advantage of not experiencing burst. Repairing work is much easier and faster than in the case of MS pipes. Despite this, they may be seriously affected by negative pressures originating from hydraulic transients. Negative pressures in MS pipes may have the effect of making them collapse under especially adverse circumstances.

The installation of either concrete pipes or MS pipes should be preceded by a careful study on hydraulic transients. Air valves, discharge valves, relief valves, air chambers and one-way tanks may be required and should be permanently kept in operating conditions.

Mullick(28) suggests that the following factors should be considered as main causes of failures in PRCC pipes in Pakistan.

a) Manufacturing process:

- Insufficient or irregular prestress in the concrete and steel cylinders.

- Irregular application of neat cement parts on the wound wires before and after coating. Overexposure of pipes under the sun before installation.

- Poor quality rubber rings used in joints and therefore loss of elasticity.

- Lack of regularity and smoothness of the surfaces in contact with the rubber ring. Lack of uniformity of the grooves, implying in non-compatibility with the rubber ring.

- Poor quality control of material used in the preparation of concrete and mortar. Possible incidence of chlorides and other aggressive materials.

- Insufficient or excessive thickness of mortar coating.

- Deficient quality control of the manufacturing process.

b) Installation of PRCC pipes

- Careless transportation and manipulation of pipes.

- Laying of pipes on a hard or unlading surface (such as rock, hard clay or slate).

- Laying of pipes under unfavorable conditions, eg: steeper slopes, bridges, etc.

- Improper fixing in place of the rubber ring (lack of soapy material).

- Improper or insufficient concrete anchor blocks.

- Improper alignment of pipes.

- Improper backfilling (stones, rocks)

- Lack of cathodic protection under condition of low resistance and high potential.

- Heavy traffic over the buried pipes.

c) Operation of PRCC pipes:

- Excessive pressure generated by hydraulic transients.

- Movement of earth-moving machinery and excavation over the pipes.

- Intermittent water supply generating alternately high pressure and negative pressure.

- Non-functioning or insufficient number and capacity of air valves and drain valves, aggravating the above-mentioned condition.

- Working pressures above those established by the adopted standard.

1.1.2. STEEL PIPES

Mild steel pipelines seem to be a suitabl alternative for water transmission pipelines in Islamabad. They are not heavy and present excellent machineability. In addition to the good performance of MS pipes they present the advantage of being manufactured locally. For instance, the new pipeline of 36" diameter deriving from the PRCC steel conduction main from Simly to Islamabad is being constructed in strict accordance with international standards. The welding work is being carried out properly and the joints are systematically inspected by x-ray devices. Protective coatings are being applied on both the internal and external surfaces of the pipeline.

It is important to protect steel pipes against corrosion. Without such protection the useful life of the pipe would be considerably reduced. Cement mortar, bituminous enamel, coal tar epoxy are generally used as lining materials. Cathodic protection should be applied if this is proved to be necessary. The function of cathodic protection is to preserve a well-designed and well-protected pipeline. It is not intended to serve as a substitute for good coating practices(19).

1.1.3. PLASTIC

Plastic pipes(chiefly PVC) are being used for public water supply in Pakistan for sizes up to 250 mm. They have been used for drains, sewers and water supply lines. Although joints made out of plastic solutions have been used in the past, the present joints use bell and spigot sealed by rubber rings.

The main advantages of this type of pipe are(19):

- low friction coefficients
- it is not subject to tuberculation and corrosion
- it is not subject to galvanic or electrolytic corrosion
- because of lightness, it is easily handled, transported and installed

The main disadvantages are:

- possibility of age brittleness
- susceptible to suffer the effect of installation stresses
- it is not available for sizes exceeding 250 mm in Pakistan
- cannot be used for pressures higher than 12 kg/cm2 in Pakistan
- cannot be used above ground because it is attacked when exposed to sun

1.1.4. VITRIFIED CLAY

Vitrified Clay is an inert material which is not affected by a normal soil-water-sewage environment. Jointly with plastic pipes, they are the most indicated pipes to be used where aggressive environments are to be faced. VC and plastic pipes are largely utilized abroad for sewer pipes in sizes up to about 600 mm. VC pipes are not extensively used in Pakistan.

1.1.5. DUCTILE IRON

The DI pipes have both the resilience of steel and the grey cast iron's resistance to corrosion. The graphite particles, which are spherical, are responsible for considerably improved ductility and toughness of the ductile iron pipes. This type of material has good machineability being easy to cut and drill(12). The vulnerability to tuberculation of this type of pipe has been overcome through lining with mortar from the inside. The joints are bell and spigot type, with rubber ring seal.

Ductile Cast Iron pipes and fittings are not manufactured in Pakistan at present. Their import is subject to high rate of import duties which make them more expensive than locally manufactured pipes. Despite their high cost, they are increasingly being imported for use in transmission mains of great importance and where higher degrees of reliability are required.

1.1.6. CAST IRON (Grey)

Extensive use of cast iron pipes have been made in the past in Pakistan. Most of these pipes have experienced a reduction in their carrying capacity along the years because of tuberculation and corrosion. The most frequent attitude of the water agencies in these cases is to replace the old pipelines. There are situations, however, in which the rehabilitation of these pipelines, through internal cleaning and lining, is cost-effective.

1.1.7. ASBESTOS CEMENT

Asbestos Cement pipe has been used both for water supply and sewerage systems in Pakistan. The main advantages of this type of pipe are(19):

- Lightness which facilitates handling and transportation
- Long sections minimizing number of joints
- Easily made
- Tight joints
- Smoothness, resulting in low head-loss
- They are not affected by galvanic and electrolytic corrosion
- Ease in cutting and making connections
- Their jointing is very simple
- No problem of incrustation or deposition, therefore, no problem of reduction in carrying capacity

The following are the main limitations of AC pipes:

- They are unsuitable for sizes greater than 600 mm and for pressures exceeding 24 kg/cm2
- They should not be used in above ground installations as they should not be exposed to shock and aggressions from the environment
- They are subject to sulphate action of soil
- Low tensile and flexural strength
- Low resistance to impact

AC pipes are most economical for small size pipelines. PVC pipes, however, are most economical for use in pipe network systems for diameters up to 100mm(18).

1.2. PROTECTION OF PIPES[1]

Most water supply systems are affected to some degree by internal corrosion often associated with encrustation, tuberculation, or the formation of a hard protective scale inside the pipe(11). The effects range from inconveniences such as "red" water and minor leaks, to serious operational problems, such as widespread leaks, loss of water pressure, blocked water lines, and contamination of water by heavy metals, such as lead. Uncontrolled internal corrosion eventually causes such extensive damage that costly rehabilitation or replacement of whole lines became necessary.

In accordance with Prevost(11) there are two traditional types of lining that can be used to protect metallic (iron or steel) pipes against internal corrosion: cement mortar lining and enamel-type lining.

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[1] This item is based on ref. (7)

Cement mortar lining is widely used for internal corrosion control and provides suitable protection. Nevertheless, it is expensive and uses highly specialized technology and equipment. This may represent a serious constraint for developing countries. Although cement mortar lining reduces the internal diameter of pipe this adverse effect is compensated by an increase in smoothness of the internal walls. In the case of large-diameter pipes the overall result is ar increase in the carrying capacity of the pipeline. This effect may be the opposite in the case of small-size pipes, where the carrying capacity of the pipeline may decrease.

Enamel-type linings include coal tar, bitumen, and epoxy linings(11). Coal tar is no longer used for protection of drinking water pipes. The reaction of phenols from the coal tar with chlorine from the water produces a strong taste to water. Nevertheless, the name has struck to more refined products that do not have the same adverse effect and are defined in the standards. Epoxy resin and polyurethane linings are the most effective of the enamel-type linings, but are difficult to apply and almost impossible to repair in the field(11). The resin to be used must be carefully selected to minimize bacterial growth. Pinholes are the most common defect in epoxy linings, which are usually 0.2 to 0.3 millimeters thick. Recent research indicates that this problem can be solved by increasing the minimal thickness of the lining to 0.55 millimeters, which requires a nominal thickness of one millimeter, to allow for manufacturing variations. These conditions apply to normal municipal water supply and water conveyance systems. Special linings providing good protection against corrosion and abrasion have been and are being developed for industrial applications, such as slurry pipelines. These are typically thick, often fiber reinforced, epoxy-type or polyurethane linings and could be considered in special circumstances. Although epoxy resin and polyurethane linings are the most effective of the enamel-type linings, they are difficult to apply and almost impossible to repair in the field. They can be used successfully to keep pipes clean and corrosion-free until installed than to protect then against corrosion over the long term. These types of coating are utilized as sealing coats for nonmetal pipe although pressurized water in the porous material under the lining may damage it when the pressure is removed(11).

All of these enamel linings are widely used, but are not very successful in preventing corrosion over the long term because any minor defect in the enamel, such as pinholes, causes blistering and peeling, leading to extensive corrosion. Also, heat from welding melts bitumen and similar linings and leads them to form a veil within welded steel pipes; the veil breaks up as water flows, and debris may spread throughout the system and into water meters and other appurtenances(11).

A soil survey should provide information on the likelihood, nature, and importance of possible corrosion due to changing soil conditions along the pipeline route and of the intensity of anticipated stray currents(11).

In the case of sewer pipes, severe damage from sulphide corrosion has been reported worldwide since the turn of the century, when many sewer systems were beginning to age(11). With the exception of pipes made of inert materials, all sewer pipe is subject to sulphide corrosion. In the sewer system, the interceptors and rising mains are those most likely to be affected. Sulphide corrosion, however, does not affect the secondary and tertiary collection networks, which are usually built of pipes made out of inert materials. The end result of such corrosion may be service disruptions, line blockages, and ultimate collapse of the sewer itself. The worst conditions are found in stagnating sewage as occurs in rising mains, pump station sumps, and where turbulence increases the release of hydrogen sulfide gas. Since high turbulence is likely to occur mainly at junctions, outlets of rising mains, and at manholes, all parts of a sewer line do not have to be made equally resistant to corrosion. The life of a sewerage system is therefore inevitably limited in most cases, since corrosion damage will occur and will have to be endured. However, systems as a whole should be designed to last at least fifty years.

The most expensive solutions for protecting sewerage systems against corrosion, such as PVC linings, are not always necessary. There may be other less expensive, satisfactory solutions. For example, concrete or cement mortar-lined metal pipe may be manufactured with an inner sacrificial layer of concrete, 25-50 millimeters thick.
Sulphate-resistant or high alumina cements and, where available,

calcareous aggregates may increase the life expectancy of such pipe by three to five times. Therefore, two different methods for increasing the life of concrete pipe are available: either providing material to be consumed by corrosion or using pipe material that is more resistant to corrosion. In any event, the quality of the concrete is of paramount importance. Similar solutions are available for the protection of steel and iron pipe, but these are not applicable to asbestos-cement pipe. The best way to extend the life of an asbestos-cement sewer pipe is to select a higher "class," i.e., thicker, pipe than needed for structural strength(11).

No ordinary bitumen, epoxy-resin, or plastic lining has yet proven effective in construction or repair since even minor defects permit decay to begin behind such linings. The only effective, long-proven lining is plastic sheeting that is mechanically locked to the concrete. This is, however, not compatible with centrifugal casting of concrete pipe. The lining sheets must be carefully welded at the pipe joints during pipe laying. The invert of the pipe, which is permanently wet, needs no protection(11).

Good ventilation is important, although it usually removes condensation (which is necessary for the corrosion process to occur) only in the immediate vicinity of the air inlets. Ventilation does not, therefore, solve the corrosion problem in all parts of a long sewer. Chemical additives, such as oxidants and chlorine, are effective but usually are too expensive, except, perhaps, when the injection of oxygen into rising mains is feasible(11).

Periodic flushing in sewers is necessary to remove solids(11).

Repair of a corroded sewer system is a major undertaking. It is always expensive and causes many inconveniences; therefore, rehabilitation is becoming an increasingly attractive alternative to replacement(11).

External coatings, unlike internal linings, are usually successful on all types of pipes, whether iron, steel, asbestos-cement, or concrete. Bonding of the coating to the pipe is, of course, critical and works particularly well with nonmetallic pipe(11).

A satisfactory bond requires adequate surface preparation (grit-blasting), the use of primers on metal pipe, and the strengthening of the coating with glass fiber, or asbestos felt, or plastic tape. AWWA, DIN, ASTM, and other coating standards specify satisfactory protection for most cases. However, tougher coatings and linings have been or are being developed for the most severe conditions such as offshore pipelines and industrial pipelines subject to abrasion or erosion, which are rare in water conveyance (or sewerage) projects(11).

The earlier coatings were of coal tar, which is no longer acceptable as an all-purpose protection and has been replaced by more refined products that often use the same name and are sometimes called bitumens. Later, metallic zinc spray coating sealed by coal tar-type varnish was developed for cast/ductile iron pipe. This kind of coating does a good job by self-healing of defects such as scratches that expose the bare metal, but cannot correct severe mechanical damage. It works well, for example, in soils with a ph between 4.5 and 9 and resistivity as low as 500 ohm per centimeter. In 1952, the polyethylene sleeve was developed for iron pipe; it can also be used with reinforced concrete pipe. These sleeves are fitted just before installation and can easily be repaired with tape if damaged. They are satisfactory in most soils for long periods of time even when exposed to anaerobic bacteria or to stray currents, which they virtually prevent unless gaps occur in the sleeves where corrosion can penetrate. In very corrosive soils, although perhaps not in the most severe conditions, sleeves can provide additional protection to iron pipe coated with the above mentioned zinc/coal tar layer(11).

Uncoated steel pipe can quite rapidly be damaged because of its thinness. It must be protected by a 3 to 4 millimeter thick well-bonded coal tar, bitumen, or epoxy-type coating, fiber reinforced felt or covered with vinyl tape. These coatings may be applied either in the field just prior to installation - in which case continuity of the coating is best achieved. (This process implies the use of welded joints.) Or in factory, which provides better conditions for application. In either case, the coating must be checked with a holiday detector (high voltage spark) at the last possible stage during installation, and any defects must be repaired(11).

Prevost(11) suggests the following procedures for prevention of corrosion and for cathodic protection:

- Soil surveys shall be undertaken at an early stage of design. These shall include a preliminary desk study of topographical and geological maps and a review of other available information in order to assess overall corrosion risks and identify hot spots and areas where detailed surveys and soil analyses will be needed. This desk study shall be checked and completed in the field by all appropriate means, including electric resistance surveys. Office and field surveys shall be used to determine the frequency, location, and depth of soil sampling and analyses and of further electric resistance measurements. When external corrosion problems have been discovered on existing lines, similar procedures shall be used to help determine where remedial action is needed and what the best solutions are.

- Soil surveys shall be carried out even if cathodic protection is anticipated. As accurate an assessment as possible shall be made of the likelihood, nature, and importance of possible corrosion due to changing soil conditions along the pipeline route and of the intensity of anticipated stray currents.

- Pipe coatings and other protective measures, possibly even pipe material, shall be selected on the basis of soil survey findings.

- High quality concrete of adequate composition shall be required for all types of reinforced concrete pipe Quality shall be assured through adequate manufacturing equipment and procedures, systematic or random inspection during the manufacturing process, and by a thorough inspection at installation. Permeability of the cement mortar coating protecting the prestressing wires shall not exceed 10^9 centimeters per second.

- All new reinforced concrete and prestressed concrete pipe shall be fitted with a connector terminal located during manufacture at a specified spot on the pipe and at installation on the crown, allowing for measurement of the electric potential of the steel reinforcement to ground, and for a possible connection to a cathodic protection system, without a risk of damaging mortar or concrete coating. Reinforcing bars, wires, and steel cylinders (if any) shall be electrically bound. The loops of prestressing wires shall be short-circuited by steel strips squeezed between them and the concrete core and shall be thoroughly embedded in a cement paste applied on the concrete core or cylinder just before they are wrapped on it.

- Cathodic protection shall be used only in pipe systems that cannot be adequately protected otherwise, such as all welded steel transmission pipelines, electrically continuous lines, and possibly in complex systems where interference may create problems among pipelines of different types and uses, particularly when some of them are cathodically protected. If installed, cathodic protection shall be designed by competent and experienced engineers, in accordance with the CEOCOR guidelines, the BSI CP 1020 Code of Practice, or other equivalent documents.

- Cathodic protection shall not be used with prestressed concrete pipe, unless the pipe is in greater danger of corrosion from factors other than hydrogen embrittlement.

- Cathodic protection shall be made operational as system construction progresses.

- Provision shall be made at the design or construction stage to supply the system operator with the trained staff, transportation, equipment, and needed supplies in a timely fashion. Operators shall monitor their systems for corrosion problems, make voltage surveys on a regular basis, and keep adequate records and maps of the results. Cathodic protection staff shall be adequately trained.

- Close collaboration among underground facilities operators (water, gas, electricity, and transportation) shall be instituted and maintained to secure protection of their systems against corrosion, especially when any one of these utilities is using cathodic protection. Such collaboration shall begin as early as possible, preferably at the design or construction stage.

1.3. REHABILITATION OF PIPES

The careless selection of pipes, the lack of quality control in its process of fabrication and installation, and inadequate maintenance, usually lead to premature rehabilitation or replacement. The cost of rehabilitation is very high, ranging from 15 to 40 percent of the replacement cost. Despite this, rehabilitation may be convenient as this alternative do not require opening of trenches in congested urban areas. In addition, the rehabilitation process will be less time consuming than replacement. Measures should be taken for preventing the deterioration of pipes to avoid the need for their rehabilitation or replacement. These preventive measures are normally cost-effective.

Several rehabilitation processes have been developed recently. They generally use sophisticated equipment, materials of difficult obtention in developing countries, extensive know-how, and expert labor. There are several specialized firms around the world dealing with specific technologies of rehabilitation.

The use of suitable technologies for rehabilitation can expand the useful life of a pipeline from 50 or 70 years, as it is usually adopted in developing countries, to 100 or 150 years as usual in industrialized countries. It is important to emphasize that even a very deteriorated pipeline is an important asset which, whenever possible, should be rehabilitated, renewed, or replaced, rather than abandoned.

The cost of rehabilitation is normally less than the cost of laying new pipes. However, such a cost may be sometimes substantially higher than replacement costs by conventional means. The higher costs of rehabilitation may be sometimes justified by the fact that it requires shorter periods of service disruption and causes less traffic congestion.

Sometimes, however, rehabilitation cannot be justified. Although the rehabilitation of large size pipelines is frequently cost-effective, it may not be so in the case of rehabilitation of small size pipelines as smaller pipe installation costs relatively more.

A thorough evaluation of the system must be carried out before effective rehabilitation takes place. This evaluation consists of a detailed inspection, with measurements of coefficients of friction through loss-of-head tests, maximum, minimum and average rates of flow, as well as investigations of customers' complaints, meters, and soil conditions. This study should result in a reasonably accurate assessment of the pipeline, the extent of damage, and clear indications of the remedial work required, along with a budget and work programme. In most systems, problems will not be spread evenly throughout, and some sections or components will need more work than others (such as manholes, junctions in sewers, junctions of pipes of different materials, blockages, sections conveying waters of different qualities in water systems, and sections located in aggressive soils). Thus local rehabilitation rather than system-wide work may be the answer(11).

References (30) and (31) are manuals dealing with rehabilitation of pipes. Reference (30) was prepared by the "District Urbain de Nancy" and deals with rehabilitation of water and sewer pipes. Reference (31) was prepared by the "Water Research Centre" and the "Water Authority Association" and although it is confined to sewerage rehabilitation, the manual provides guidelines and procedures to assist planners and designers in making the most appropriate decisions regarding this work.

The rehabilitation processes are designed to renovate water pipes from the interior only, even when the problems are a result of external corrosion or structural deficiencies. It may not be possible to rehabilitate a system that demonstrates extensive structural damage(11). This may be a major problem in the case of PRCC pipes rehabilitation as one of the problems resulting from the deterioration of this type of pipe is the loss of its structural reliability. A few methods would be, however, applicable in this case.

The following are some selected methods for rehabilitation of pipes. This list is not intended to be the state-of-art on this matter. Investigations directed towards the improvement of old methods and towards the development of new methods are progressing rapidly in the industrialized world.

a) Cement Mortar Lining

- Cement mortar lining is not a structural process. Thus, it cannot be expected to solve the problem of deteriorated pipes which have lost their structural properties, for instance, deteriorated PRCC pipes.

- The cement mortar lining has the property of sealing leaks particularly in the case of corroded steel pipelines.

- Hazen Williams C-value is greatly increased after the lining process. For diameters greater than 150 mm, C-values of 130 or even 145 have been reported(32)

b) Bitumen Lining

- This is not a long term technique. Bitumen coatings are expected to last less than 10 years.

- Bitumen lining produces a considerable increase in C-value for all diameters.

- The cost of rehabilitation with bitumen lining process is lower than most of the current processes.

c) Thermoplastic Pipe Insertion

- The use of high density polyethylene pipe for insertion in deteriorated pipelines is a sound alternative for rehabilitation.

- This process is one of the few available structural processes of rehabilitation.

- The process leads to considerable C-value increases for pipes of large diameters

d) Fibre Reinforced Cement Lining(FRC)

- This process of rehabilitation has the property of imparting structural strength to the lining.

- Health effects associated with the presence of glass fibre in the conveyed water are not well known(in the case of drinking water pipelines).

- Similarly to high density polyethylene, this process leads to considerable C-value increases for pipes of large diameters

e) Insituform Lining

- The structural property of the lining implemented through this process is limited by the diameter of the pipeline and the internal pressure. High internal pressures may require thick lining leading to reduction in carrying capacity of the pipeline.

- The process uses needled terylene felt, encapsulated in a polyurethane bag vacuum impregnated with polyester resin.

- The process is effective for sewer pipelines. Although it is also technically suitable for drinking water pipelines, there is lack of information on health aspects concerning their use for this purpose.

f) Epoxy Resin Coating

- This is not a structural lining process. Therefore it is not suitable for rehabilitation of concrete pipes.

- Because of the small reduction in internal diameter and because of the smoothness of the finished walls the C-value increases considerably.

- Some types of resin are not appropriate for application in drinking water pipelines due to unknown health effects.

- No clear indication on durability of the lining

1.4. REPAIRING OF PIPE FAILURES[2]

Cave(22), classifies pipe failures into three basic categories as follows:

- Hoop stress
- Ring failure
- Beam failure

Hoop stress failures are caused by excessive internal pressure and are characterized by blowouts at the weakest point in the pipe wall. Once internal pressure reaches a point that the pipe wall can no longer contain, a blowout occurs. Hoop stress of that for which the pipe was designed, or can be caused by normal pressure in pipes weakened by other factors such as corrosion and/or temperature induced stress.

Ring failures are caused by excessive external pressure and are characterized by longitudinal splits or crushed pipe walls. The pipe embedment provides the proper support against external loads. Failure may be due to improper embedment installation, lack of depth to guard against traffic loading or frost action, a change in site conditions under which the pipeline external load is increased, or by pipe walls weakened by other factors.

Beam failures are caused by differential loading along the pipe and

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[2]The repairing techniques described in this item are based on papers presented at the Distribution System Symposium organized by the American Water Works Association, references (22) to (25).

are characterized by circumferential pipe breaks. Differential loading can be caused by improper bedding causing the pipe to rest in high points in the embedment rather than being uniformly supported. Differential loading can also be caused by unstable soils, changes in soil types along the pipeline, point loads applied by adjacent objects, or by stress concentrations where pipes penetrate structural walls.

According to Cave(22) the following are the main causes of breaks:

(a)- Excessive Pipe Loading

Pipes can be overloaded for a number of reasons causing a hoop, ring, or beam failure. Excessive internal pressure can result from surge or water hammer, or from exceeding the pressure rating of the materials in place. Surge or water hammers can cause excessive positive or negative pressure and subsequent pipe failure. Surges can be caused by inadequate, or malfunctioning surge equipment, by power failures at pumping facilities, and by fast closing or slamming valves. Excessive pressure can be caused by malfunctioning regulating valves or use of excessive pressure to meet flow demands in marginal pipelines.

Excessive external pressure is controlled by the pipe material and the pipe embedment. The embedment is designed to cradle the pipe and to assist the pipe in resisting external soil pressures. Soil and traffic loading over the pipe provides forces which try to flatten the pipe. The embedment provides the cradling action, the side support, and the upper uniformity to support the pipe walls and to apply the loading uniformly. Poor soil conditions such as expansive clay or marshy/organic soils can break down this support through soil movement and embedment migration. If the embedment is not properly placed or compacted, non-uniform loading and possibly excessive loading can occur. Failure of the embedment to support the pipe can cause excessive loading and a main break. A change in site conditions can also cause excessive loading. Since soil loading on a pipe increases with depth, addition of excessive fill over a pipe can cause design parameters to be exceeded. Also since traffic loading increases as depth of cover is removed, a change in conditions which reduces a pipe's depth of cover can cause problems.

Any additional construction over or under a pipe can cause problems at later dates if the short term or long term loading on the pipe exceeds upper limits.

Differential loadings can also cause excessive forces which can cause a main break. Improper placement of pipe and embedment, as previously stated, can cause non-uniform or point loads. Supporting the pipe on its bells without providing proper cradling the length of the pipe, gaps in the embedment support, or large stones in the embedment will cause non-uniform support and differential loading. Point loads can also occur where insufficient clearance exists between the pipe and other utility crossings. Shear loads can be encountered at entrances to tunnel sections, manholes or other structures if flexibility is not allowed and if proper support is not provided.

(b)- Temperature Induced Stress

Cold weather can cause main breaks as the temperature of the water falls. Pipe shrinkage caused by the low temperatures can cause breaks as contraction forces build up. Circumferential breaks usually occur, when the tensile forces exceed the material rating Slip joints are not always enough to solve the problem. Friction between the pipe and the embedment causes pipe restraint which allows the contraction forces to build.

Soil forces can build in hot as well as in cold weather. Highly expansive clays can cause excessive external loadings as the soil dries during hot weather and expands in wet weather. As the soil movement occurs, compressive and differential forces can trigger main breaks.

(c)- Corrosion

Pipeline corrosion can be a major contributor to main breaks. A pipeline designed to with excessive pipe loading and temperature induced stress can be weakened enough by corrosion to yield and break. Two major sources of external corrosion are usually experienced. Galvanic corrosion is caused by interaction of "hot" or corrosive soil with a metallic pipeline. A galvanic cell will be set up along pipeline where varying potentials exist between the pipe and the soil. The current causes loss of pipe material and if sufficient weakening of the walls occur, a main break results. For grey cast iron, corrosion results in loss of the iron. The graphite portion that remains may carry the pressure and flow until it is disturbed by external or changing factors that cause the graphite to easily fail.

Another type of corrosion is due to stray DC electric currents. These currents can be induced from various sources. The induced current causes corrosion and loss of pipe material at the point where the current leaves the pipe.

For some utilities, internal corrosion can be a problem due to the chemistry of the water. If the water is slightly corrosive in nature, the inside of unlined metal pipe can be attacked. The resulting corrosion blooms can cause flow blockage as well as breaks.

Other miscellaneous types of corrosion exist such as microbiological corrosion where anaerobic bacteria under the right conditions cause removal of iron from the pipe walls through bacterial/chemical reactions.

Cave(22) indicates also that at some point in time, all pipelines will reach a point where replacement is justified, based on maintenance costs. Once main breaks begin to occur on a pipeline, a trend can usually be established to predict the number of breaks that can be expected over the following years. Using cost per repair and annualizing factors, a projected maintenance cost for the pipeline can be calculated. Replacement costs and associated annualizing factors can be used to calculate projected annualized replacement costs. For some future time, say 20 years, the repair and replacement costs should be compared. If the projected repair costs are more than the replacement costs, then replacement is justified. Formulas for determining replacement criteria are varied. Several factors should be included in the considerations such as the cost of having a pipeline out of service for repairs, customer service outages, location, difficulty to repair, potential contamination, and potential damages. Some of these factors will vary from city to city and require careful consideration to meet the needs of the utility. To establish a replacement programme, an established means for collecting main break data is needed. A records of the location and date of each break as well as an accurate system map is needed to establish a proper data base.

Fleming(23), describes the techniques currently being used by the Los Angeles Department of Water and Power for repairing of leaks, as follows:

Blow outs

Blow outs generally involve extensive damage to streets, undermines pavements causing flooding and widespread mud and debris accumulation. Immediate service shut down is usually required. Once precautions are made for the safety of the work area, excavating and pumping is performed to expose favorable cast iron and asbestos cement pipe without fractures or pitting to connect to. Extra precautions are taken to prevent any foreign materials or contaminated water from entering a main break which has exposed the interior of the main. The damaged section is then cut out utilizing a small hand held carborundum power saw and a new section of ductile iron pipe is cut to replace it. Asbestos cement pipe is cut with hydraulic pipe cutters or a hand cross cut saw. Due to variations in the O.D. between old grey cast iron pipe and ductile iron pipe, or transite pipe and ductile iron pipe, two cast transition couplings are used in the repair. These couplings connect any combination of types of pipe where both pipe O.D.'s fall within the same O.D. range making up a difference of approximately 1/4 inch in outside diameter. Some common applications are:

Coupling different classes of cast iron pipe of the same normal size.

Coupling different classes of asbestos cement pipe of the same normal size.

Coupling cast iron and asbestos cement pipe of the same normal size

Immediately prior to the installation of the new section of pipe, the interior of the pipe is sprayed with a 5%, or greater solution of chlorine. Couplings are disassembled, with a follower and resilient gasket placed on the old grey cast iron main or asbestos cement main and the remainder of the coupling placed on the new cast iron pipe to be installed. Upon lowering the new pipe into position, the couplings are pulled together and centered over the joints and tightened to approximately 70-80 foot pounds. After the new section is installed, the main is filled, flushed, pressurized and checked for leakage at the couplings. If the new section of pipe is of any significant length, it is supported with wood blocking to relieve any strain in the couplings. The entire newly installed section of ductile iron pipe, including the couplings are wrapped loosely in polyethylene wrap prior to backfilling.

If the excavation and/or undermined areas are extensive, slurry materials consisting of 3/4 sacks of cement per cubic yard of sand is transported by transit mix trucks and poured into the excavation and voids to within 6 inches of street surface. The surrounding street surface is cleaned of all mud and debris. The slurry backfilled excavation is left barricaded and exposed until the slurry has cured and temporary pavement can be installed.

Extensive pavement damage due to a break requires the Leak Supervisor to coordinate with city street maintenance personnel to determine the dimensions of the damage for replacement. This meeting takes place several weeks after the break to allow for pavement settlement to appear.

Longitudinal Splits

Longitudinal splits are similar to blow outs in respect to damage, which may be extensive street damage, pavement undermining, flooding and widespread mud and debris.

The split section is cut out using a carborundum power saw or hand saw if asbestos cement pipe is being cut and installing a new section of ductile iron pipe utilizing cast transition couplings in the repair. Immediately prior to installation of the new section of pipe, the interior is sprayed with a 5% or greater solution of chlorine. The cast transition couplings are disassembled with a follower and resilient gasket placed on the old cast iron main or asbestos cement main in the excavation and the remainder of the coupling placed on the new ductile iron pipe.

Upon lowering the new pipe into position, the couplings are pulled and centered over the joints and tightened to approximately 70 - 80 pounds. If the span of the new installed pipe is of significant length, temporary wood blocking is placed to prevent strain in the couplings. The main is then refilled, flushed, pressurized and checked for further leaks. The newly installed pipe is then loosely wrapped in its entire length, including the couplings with polyethylene wrap. The excavation is backfilled with slurry and followed by permanent paving one day later.

Circumferential Breaks

Circumferential breaks have the potential to cause extensive damage, but the majority of these breaks surface with minimal damage. Water surfacing from the street is usually a good indication of the origin of the break.

A series of holes are drilled over the top of the main near the surfacing water, utilizing a sounding bar, the exact location of the break can be determined. The main remains pressurized while the street pavement is cut with a pneumatic pavement breaker and a diaphragm pump runs continuously during the excavation of the break.

Once the break has been exposed, the main is thoroughly scraped and cleaned with a wire brush to remove dirt, mud and corrosion. The surrounding surface of the pipe is inspected for rough spots and sharp edges which are filed smooth.

A stainless steel, single band 360 degree repair clamp is selected with the O.D. range that covers the O.D. of the pipe being repaired and a width to allow at least 3 inches of clamp overlap on each side of the break. These clamps are used in the repair of asbestos cement, cast iron and ductile iron pipe. They are used in various types of repairs, such as holes, round cracks, breaks, cracked or otherwise damaged asbestos cement pipe couplings, joining the rough barrel or machined ends of asbestos cement pipe, coupling separated pipe with a gap of 1 inch or joining varying pipe sizes and kinds up to 1/4 inch difference in diameter. Circumferential cracks or breaks at directly inserted corporation valves are repaired using a vented 360 degree stainless steel repair clamp.

If the clamp is installed alongside the break with the intent of sliding it over the break, the pipe is lubricated so the clamp can slide freely. A reference point is marked on the pipe in order to centre the clamp over the break. The clamp is placed alongside the break with the center bolt of the clamp engaged in the lug and finger tight. The clamp is then slid over the break to the reference mark and rotated on the pipe in the direction indicated by arrow to seat the gasket flap smoothly on the pipe. The remaining bolts are installed to a torque of approximately 70 - 80 foot pounds. The clamp is then wiped clean, dried and inspected for leakage. The entire exposed section of pipe and the repair clamp is wrapped with polyethylene wrap. A slurry mixture of dry sand or the excavated soil, if not too wet or muddy, is mixed with a sack of cement and used as backfill, placed in lifts of 8 inches and compacted with pneumatic tampers to within 6 inches of the street surface. Paving contractors are dispatched within two hours to reapply a permanent asphalt surface.

Small Leaks

Most small leaks and breaks can be repaired within a 2 x 3 foot excavation. Pneumatic pavement breakers are used to cut concrete and asphalt street surfaces. The asphalt or concrete is kept separated from the soil. This is done in anticipation of using the soil for slurry backfill if not too wet or muddy. The leak is then excavated by hand while a diaphragm pump runs continuously in keeping the excavation free of water. The leak is exposed and thoroughly cleaned of dirt, mud and corrosion with a wire brush and scraper. The surrounding surface of the pipe is inspected for further rough spots, pitting, holes and fractures.

As a practice, smaller leaks are not shut down for repairs. This eliminates problems related to shutting down mains, the interruption of service, and possibly contaminating the main. With the main pressurized, it sometimes becomes very difficult to slide a repair clamp over a leak. With a very badly graphitized main the gate man will pinch down the pressure in order to install a clamp. In doing this he will isolate the leak by shutting surrounding gate valves, leaving one valve partially open throttling and relieving pressure at a fire hydrant, thus reducing the volume of water and pressure at the leak and allowing pumps to keep the excavation free of water during repairs.

In the event that the mains condition will allow wood to be driven into the leak without further damage, slender redwood or pine wedges are widdled and driven into the leak and sawed off flush with the surface of the main. To completely stop any leakage and to secure the wedges driven into the leak, a sharp metal centre punch is driven into the centre of the wooden wedges and extracted. Small wooden wedges are then driven into that extraction, tightening and securing the wooden wedges in the leak. This can be continued to achieve a drip dry situation. With the leak plugged with wooden wedges, a full circle clamp can now be placed and centered over the leak and tightened to 70-80 foot pounds. The clamp is then wiped dry and checked for leakage. The entire exposed section of pipe and clamp is wrapped loosely with polyethylene wrap for corrosion protection. The excavation is backfilled with slurry and immediately resurfaced.

Lead Bell Joint Leaks

Many of these leaks occur at heavy valves or fittings due to settlement. The joints are recaulked with a variety of small to large pneumatic or hand caulking irons, forcing the leak back into the bells lead lock. Extreme deflections at bell joints are also contributing causes of many joint leaks. These are usually repaired by melting out the lead joint and relieving some of the deflection, installing in-line couplings, clamps or fittings. Leaking rubber bell joints are repaired by installing a bell joint leak clamp or cutting out the bell, installing a short section of pipe with transition couplings. Leaking or broken asbestos cement collars are removed, installing a 360 degree stainless steel repair clamp.

Doty(25), recommends the following techniques for repairing and tapping of concrete cylinder pipe:

(a) Small Hole in the Pipe Cylinder

Frequently, a small hole in the pipe cylinder can be repaired without welding by using either a full circle stainless steep clamp or a bolt-on repair clamp. Using this procedure, the damaged area must be cleared of sharp or jagged edges and the rod or wire wrap, Portland cement mortar coating, and outer core (if applicable) must be removed at least 2 in. (5cm) beyond the outside edge of the resulting hole in the steel cylinder. This area is then filled and built up using layers of camelback rubber to a height of 1 in. (2.5 cm) above the surrounding Portland cement mortar coating. The appropriate repair clamp is then applied to the pipe to compress the camelback rubber against the steel cylinder sealing the hole. For the bolt-on clamp, place one half of the assembly over the damaged area and bolt on the other half using the all-thread rods and nuts and washers provided. Excess rod length should be trimmed off. The manufacturer's directions should be followed if using a full circle stainless steel clamp. The author's experience has shown that the use of the stainless steel clamps is best limited to 24 in. (600 mm) and smaller diameter pipes. Whichever repair clamp is used, it should be covered with a joint wrapper, or diaper, which is filled with a mortar mixture of 2-1/2 parts of sharp sand to 1 part of Portland cement and sufficient water to make a thick, yet pourable, liquid. It is possible to make minor repairs to the pipe lining while using this repair procedure.

(b) Repair of a Pretension Concrete Cylinder Pipe

The ideal repair of a concrete cylinder pipe will permit the repair of the pipe lining or inner core, as well as the cylinder and Portland cement mortar coating. If the damaged pipe is Pretension Concrete Cylinder Pipe, the repair can be made by welding a "dry" tapping assembly which is a flange with a flange nipple and reinforcing collar, directly to the steel cylinder. Note that although the assembly is referred to as being for dry taps, it can be and is applied to lines not fully free of water and in conditions that are certainly not dry. The repair procedure is to first remove any ragged edges from the penetration of the steel cylinder, thus creating a more-or-less round hole of the same diameter as the flange nipple. At this point, the interior of the pipe can be inspected and any damaged areas repaired with a quick setting Portland cement mortar. The Portland cement mortar coating is then removed to create an open area on the steel cylinder slightly larger than the reinforcing collar. The reinforcing circumferential rods wrapped about the cylinder should be cut and laid back for reuse. The flange nipple and flange are then weldedto the reinforcing collar which is welded to the steel cylinder. The reinforcing rods are put back place and tack-welded to the reinforcing collar or to the steel cylinder. More quick setting mortar is applied to the inside base of the flange nipple. A blind flange is then placed over the outlet. The completed repair will require replacement of the Portland cement mortar coating and placing Portland cement mortar over the blind flange for corrosion protection. Those familiar with the manufacture of Pretension Concrete Cylinder Pipe will recognize this repair procedure as being essentially the same procedure as is used to fabricate flanged outlets into pipe at the manufacturing plant.

(c) Prestressed Concrete Lined or Embedded Cylinder pipe

If a Prestressed Concrete Lined or Embedded Cylinder pipe has been damaged, the procedure described above must be modified. In this repair a threaded outlet assembly will be welded to the steel cylinder to provide access for repairing the pipe lining. It will still be necessary to remove the ragged edges from the punctured cylinder to create a round hole. Before any coating, prestressing wire, or outer core is removed, however, a bolt-on repair clamp must be placed around the pipe. Prior to bolting on the clamp, a "window" must be cut into one half of the clamp. This window should be 4.6 in. (10-15 cm) greater in its square dimension than the diameter of the outlet to be installed. After the clamp is in place, the coating, wires, or core have been removed, and the threaded outlet assembly is welded to the steel cylinder; the lining of the pipe is repaired with a quick setting Portland cement mortar and the area above the threaded outlet assembly is built up with quick setting Portland cement mortar to the level of the repair clamp. The window square, less a cutout the diameter of the outlet, is welded back to the repair clamp and to the neck of the outlet assembly. The entire assembly should then be protected with a minimum 1 in. (2.5 cm) 2-1/2:1 sharp sand to Portland cement mortar mixture poured into a joint wrapper placed around the damaged area. This procedure is analogous to the in-plant fabrication of threaded or flanged outlets on Prestressed Concrete Cylinder Pipe with the bolt-on repair clamp assuming the role of the steel wrapper which is placed over the steel cylinder.

Extensive Affected Areas

There are, of course, instances when the damage to the pipe and the steel cylinder is more extensive and a 6-8 in. (15-20 cm) outlet cannot cover the affected area. In these cases, the most effective method for on-site repair is the weld-on repair clamp. The weld-on repair clamp is made from 3/16 in. (4.76 mm) steel plate rolled to match the outside diameter of the pipe's steel cylinder. It is furnished in two halves with a threaded outlet fabricated into each half. The installation procedure is somewhat the same as for bolt-on or outlet repairs. Ragged edges or severely damaged pieces of the steel cylinder must first be removed along with two 5 in. (12 cm) bands of Portland cement mortar coating the length of the clamp apart. The rod or prestressing wire wrap must also be removed in these bands to allow free contact with the steel cylinder. The clamp is then placed around the pipe with the larger, usually 4 in. (10 cm), outlet pointed downward. A ratchet chain hoist, or come-along, is used to hold the clamp in place while welding is done attaching the clamp to the steel cylinder and welding the two halves together. The reinforcing rod on Pretension Concrete Cylinder Pipe should then be tack welded to the repair clamp. If the repair is being performed on a Prestressed Concrete Cylinder Pipe, the prestressing wire cannot be welded but is attached to the repair clamp using wire keepers that are welded to the clamp. One feature of this repair procedure is that it can be performed with the damaged line still under pressure. In this situation, the threaded outlets are fitted with valves to allow the water to escape while welding is underway. If the weld-on clamp is installed on a dry or near dry line, the repair is completed by pouring a Portland cement mortar slurry (2-1/2:1 sharp sand to Portland cement) into the upper threaded outlet and covering the entire assembly with a joint wrapper which is filled with the same mortar mixture. While a repair made on a pressurized line cannot include grouting the inside of the clamp, the assembly should be protected by Portland cement mortar poured into a surrounding joint wrapper.

Pressure Tapping Assemblies

Although pressure tapping assemblies for concrete cylinder pipe are usually used to add service connections or branch outlets to existing pipelines, they can also be used as repair assemblies. Frequently, the user will have pressure tapping assemblies on hand thus avoiding the need to await delivery of a repair assembly. Small punctures of the steel cylinder are best repaired by using a 2 in. (5 cm) threaded service connection assembly. This size assembly is most frequently stocked by users as it can be bushed down for smaller taps. The Portland cement mortar coating is removed from an area slightly larger than the base of the tapping assembly gland. The tapping assembly saddle is then bolted into position using the steel straps provided and the rod or wire is removed from the opening to expose the steel cylinder. A corporation stop is installed in the gland and the gland is bolted securely into the saddle so that the rubber gasket in the gland is compressed against the steel cylinder in order to form a watertight seal. Note that the corporation stop should be used even when the tapping assembly is being used as a repair assembly. The tapping machine is then attached to the corporation stop and the bit advanced through the steel cylinder and lining. After the drill is withdrawn, the corporation stop closed, and the tapping machine removed, the entire assembly is covered with a Portland cement mortar slurry (2-1/2:1 sharp sand to Portland cement) poured into a joint wrapper. Care should be taken to see that the mortar slurry also fills the space between the tapping assembly and the pipe, especially the space between the Portland cement mortar coating and the gland.

Larger areas of damage will require that a flanged outlet pressure tapping assembly be used for making the repair. The diameter of the flanged outlet should be at least 2 in.(5 cm) greater than that of the puncture of the steel cylinder and subject to the limitation of the outlet being no larger than the next standard pipe size smaller than the pipe being repaired. The flanged outlet pressure tapping assembly consists of three parts: the saddle, the gland, and the U-bolt straps or clamp style "halfback". Once again, the Portland cement mortar coating is removed from an area slightly larger than the base of the gland, the saddle portion of the assembly is bolted in place, centered on the opening in the coating. The space between the pipe and the saddle, including the "halfback" if applicable, must then be filled with quick-setting Portland cement mortar which should ideally be allowed to harden before any additional work is done. Next the wire or rod wrap is cut and removed, along with the outer core if a Prestressed Concrete Embedded Cylinder Pipe is being tapped or repaired, to expose the steel cylinder. The tapping assembly gland is then securely bolted in place and the compression of the gland's rubber gasket against the steel cylinder checked with a feeler gauge. A tapping valve is then bolted to the gland flange. Note that it is imperative that a support be placed beneath the valve at this point to prevent the weight of the valve and tapping machine assembly from pulling the gland gasket away from the steel cylinder, thus breaking the watertight seal. The tapping machine is then connected to the valve which has been closed to insure that the shell cutter and pilot bit assembly can be withdrawn a sufficient distance to clear the valve gates after the cut is complete. The valve is then opened and the entire assembly air tested to assure watertightness before the shall cutter assembly is advanced through the steel cylinder and pipe lining. Upon completion of the tap, the shell cutter assembly is withdrawn, the valve closed, and the tapping machine disconnected from the valve. the entire pressure tapping assembly must then be protected with a 2-1/2:1 sharp sand to Portland cement mortar slurry poured into a joint wrapper. Note that if the flanged outlet pressure tapping assembly is being used as repair assembly, the tapping valve may be omitted. In such instances, the tapping machine is connected directly to the gland flange and a blind flange is placed over the outlet after repairs to the pipe lining are made with a quick setting Portland cement mortar. The entire assembly must still be encased in Portland cement mortar for corrosion protection.

2. PRIORITY ACTIVITIES IN PAKISTAN

2.1. CONCEPTS

The design of actions for improving the performance of pipes in Pakistan should be structured with the perspective of the overall improvement of the water agencies within the country. A suitable strategy for starting this process would be the implementation of O&M programmes involving selected water agencies under the leadership of a national agency.

Programmes of O&M and optimization of water supply and sanitation systems are aimed at improving the efficiency of institutions to achieve the best possible utilization of the existing capacity of the systems. Such programmes, despite being focussed on management and operative aspects related to operation, maintenance and rehabilitation, also involve specific projects related to other areas. The projects and activities which are included in an O&M programme are directed towards the minimization of the major constraints for the efficiency and effectiveness of the water agencies. These projects and activities should be organized to be gradually implemented in accordance with priority requirements and also, in accordance with the limitations of the water agencies.

The O&M programmes should be considered as a stage of an institutional development process. At this stage efforts would be oriented to the priority areas of the water agencies, which would allow the implementation of a more comprehensive institutional development programme.

2.2. OBJECTIVES

The specific objectives of an O&M programme are:

- to promote and support the efforts for strengthening the managerial and operational capability of water supply and sanitation institutions in order to improve their efficiency and effectiveness

- to improve O&M services and related support areas

- to optimize the installed capacity of the services and to seek for the financial self sufficiency of the sector
- to extend the coverage, regularize the service rendered to the population and delay investments for new constructions
- to achieve control and reduction of unaccounted for water
- to identify basic requirements as needed by operational staff to perform improved operation and maintenance work, e.g. tools, equipment and transport.

2.3. PROGRAMMES AND PROJECTS

The improvement of O&M and the optimization of water supply and sanitation systems usually represent one of the most important steps in the institutional development process and its attainment includes the implementation of selected programmes and projects. The following headings of programmes and projects are likely to meet most of the requirements of a wide range of water agencies in Pakistan. However, it would be important to emphasize that despite the present attempt to identify the needs of water agencies in Pakistan, it should be recognized that they are not necessarily entirely applicable to all institutions. Specific programmes have to be formulated, organized and implemented for each institution within the country. Such programmes might include all or only some of the projects listed bellow or eventually others which are not listed:

- Network survey (Pitometric Survey)
- Control of Leakage
  - visible
  - not visible
- Macrometering (production and distribution systems)
- Network Mapping
- Control of Operation
- Revision of Design and Construction Criteria
- Preventive and Corrective Maintenance (electrical, mechanical, civil and instrumentation)
- Distribution Network Maintenance
- Maintenance of Flowmeters (including house meters)
- Improvement and Rehabilitation of House Connections, Transmission Lines and Network's Pipelines
- Improvement of Material and Equipment Quality

The following is a brief description of these projects:

Network Survey

A Network Survey Service is usually designed with the objective of obtaining, processing, analyzing, and disseminating operational data regarding flows, pressures, and water levels. It allows the undertaking of analysis of different configurations of the hydraulic systems under real or simulated perspectives.

The following tests and studies can be carried out by the use of this methodology:

- Measurement of flow and pressure with portable equipment(for analysis of flows and pressures during periods of time varying from 10 minutes to 7days)
- Determining of the carrying capacity of transmission mains and trunk mains

- Studies on actual average "per capita" consumptions and other consumption coefficients (monthly, daily and hourly consumption coefficients)

- Field accuracy tests of permanent flowmeters

- Calibration curves of differential pressure flowmeters (primary devices)

- Characteristic curves of centrifugal pumps and evaluation of pumping stations' performance

- Delimitation of pressure zones

- Evaluation of the residual capacity of pipe network systems

- Studies on the performance of transmission systems and pressure zones in support to the operational control of water supply systems

- Special tests

Macrometering

The implementation of a macrometering system is directed towards the obtention, analysis, and dissemination of systematic operational data regarding flows, pressures and water levels. A macrometering system is of great importance to orient the operation of the water supply system and for the generation of statistical information on production and distribution of water.

Leakage Control

The major objective of a leakage control service is to reduce the average time which elapses from the starting up of a leak to its elimination. The reduction of the "leak's duration" should be achieved through effective managerial and operational actions. The leakage control service should include different procedures and interactions for visible and non-visible leaks. The strategy to minimize the effects of visible leaks involve the implementation of suitable methodologies to: identify and characterize leaks; disseminate information internally and externally to the agency; repair leaks; accountancy on water losses; and community participation and cooperation. The detection and localizing of non-visible leaks should involve specific techniques, appropriate equipment and skilled personnel.

Network Mapping

The objective of this project is to implement a mapping system or to improve it if it already exists. This mapping system should be designed in such a manner that updated information on pipelines and respective appurtenances would be reliably represented on sets of maps with suitable scales. The design of this system should foresee procedures for recuperation and for continuous updating of information.

Operation Control

The chief objective of the operation control project is to systematize the obtention, processing and analysis of variables which characterize the hydraulic status of the water supply system. These variables include flows, pressures, and level meters as well as the status of control valves and pumping stations. The recurrent analysis of this information in a real time basis allows adjustments of these variables to achieve the best configuration of the hydraulic system in response to the demands of the system.

Revision of Design and Construction Criteria

The objective of this project is to adjust design and construction criteria in order to minimize construction costs and to facilitate operation, maintenance and control of performance of water supply systems. The design of water supply systems should foresee facilities for undertaking of leakage control programmes, metering, operation of the pipe network and maintenance of pipes and appurtenances.

Preventive and Corrective Maintenance(electrical, mechanical, civil, and instrumentation)

The objective of this project is to implement a managerial and operational system to achieve an effective service for preventive and corrective maintenance. This system should be able to establish dates, places, installation, equipment and the maintenance action to be undertaken. The system should also be able to generate information for evaluation of the quality and reliability of the process. The installations, equipment, material and vehicles should be improved in accordance with the designed system.

Distribution Network Maintenance

This project deals with the improvement of efficiency and effectiveness in the maintenance of the pipe network including housing connections. This project should deal with: preparation of daily working plans; composition and size of teams; required tools, material, equipment and vehicles; coordination of activities; quality control of the maintenance services and training of personnel for both an improvement in skills in specific work and for best relationship with consumers.

Maintenance of Flowmeters

Establishment of a policy for maintenance of flowmeters including definition of recurrent time for preventive maintenance; design and construction(or improvement) of workshop facilities; programming and coordination of activities (internal and external); register of existing meters; configuration of maintenance teams.

Improvement and Rehabilitation of House Connections, Transmission Lines, and Network's Pipelines

The objectives of this project are:

- To improve the conditions of the house connections through the following preventive measures: improvement of specifications; establishment of a sound method for sizing house connections; improved standards for installation, inspection, reception and quality control.

- Implementation of policies, programmes and methods for rehabilitation and replacement of house connections, transmission lines and network pipelines.

Improvement of Material and Equipment Quality

This project is directed towards the implementation of technical and administrative procedures aimed at improvements regarding acquisition, inspection during the fabrication, testing, acceptation, transportation and storage of material and equipment.

Other projects seem to be of great importance and priority for the water agencies in Pakistan, and should be included in an optimization programme, as well. These projects are: Customer's Register, Metering, Billing and Collection.

The adequate formulation of programmes for the improvement of O&M and optimization of water supply and sanitation systems should possibly include the undertaking of parallel projects and actions to support and facilitate their implementation, as follows:

- Organizational Arrangements, particularly with regard to the units dealing with O&M and related fields

- Development of Human Resources, including the improvement of managerial performance; training courses; elaboration of post profiles and personnel profiles and rearrangement of cadres; strengthening of Human Resources Development unit

- Development of an Information System, destined to collect, process and disseminate information on operation, maintenance and related areas

- Improvement of the Transport Service, including the adequacy of the transport facilities, in terms of quality and quantity and the improvement of the vehicles' maintenance service

- Improvement of Material and Equipment Supply, in order to guarantee a timely delivery of spare parts and maintenance material

The quality of water is also linked to operation, maintenance and optimization of water and sanitation systems. A better quality of water implies better conditions of piped systems. Conversely, improved O&M services imply less risk of contamination of drinking water. Despite this, drinking water quality monitoring and related activities will not be addressed in this document as they are out of the scope of this work.

3. SCHOOL FOR TRAINING TECHNICIANS

The idea of implementing a school for training skilled technicians from water agencies was discussed with representatives from both WASA/Lahore and PHED. It was agreed that the use of the existing training centre at WASA would be of great importance for achieving this endeavour. The idea is to modernize, to equip and to expand the present training centre and utilize it as a school for training engineers, technicians and laborers from ws/s agencies within the province of Punjab.

There is a huge demand for a school of this nature in Pakistan. As an initial effort, the school should be designed to serve the province of Punjab. In another stage, decisions would be taken regarding the implementation of similar schools for each province, or alternately, the expansion of this school at Punjab, for coverage of all water agencies within the country

SECTION 5

RECOMMENDATIONS

1. RECOMMENDATIONS CONCERNING NATIONAL POLICIES AND STRATEGIES

The definition of national policies and the development of suitable guidance on the use of pipes in water supply and sewerage systems would be of great relevance for the water agencies in Pakistan. These water agencies are adopting independent solutions for their problems concerning water and sewer pipes. The definition of national policies would allow the undertaking of common efforts for improving the quality and adequacy of pipes within the country.

There is a deep lack of balance between resources utilized for constructing new waterworks and the resources utilized for using the existing facilities properly. Much has to be done in this field, and the coordination of efforts involving sector and local agencies within the country would be of great importance in the implementation of lines of action to be taken towards the optimization of ws/s systems.

A national commission should be constituted, whose priority objective would be to tackle the above mentioned issues and to design appropriate plans of action to overcome the identified problems. This commission should be coordinated by a national agency and should be composed of representatives from selected water agencies within the country. WHO would indicate a representative if this should be requested.

It would be advisable to organize discussions and consultations involving local and international enterprises in order to seek for support to the idea of producing other types of pipes in addition to those being manufactured in Pakistan. Mild Steel Pipes and Ductile Iron Pipes, for instance, should be produced and utilized in Pakistan for there are situations in which the presently produced pipes are not applicable. The local production of MS pipes and DI pipes would prevent importations which represent a major drawback for water agencies.

Some water agencies have developed specifications for the manufacture, reception and installation of ws/s pipes. Others, utilize international standards which are not always complete or appropriate to the conditions of the country. Thus, the development of national standards for water and sewerage pipes would be of great interest and importance for the water and sanitation sector, and would therefore eliminate the shortcomings of unsuitable specifications and noneffective general references to international standards, in the process of the purchasing of pipes.

The UNDP is presently exerting efforts directed towards the improvement of O&M in Pakistan which are in line with those being exerted by WHO. It would be convenient to the Government of Pakistan and to both organizations if the recommendations of this report were implemented jointly by WHO and UNDP in cooperation with the respective water agencies. This procedure would avoid duplication of efforts.

A national workshop should be organized to discuss the above mentioned recommendations and to start a concrete process of cooperation and coordination between water agencies.

2. RECOMMENDATIONS CONCERNING PRESTRESSED REINFORCED CONCRETE PIPES

Despite the fact that a number of water agencies in Pakistan have decided to stop using PRCC pipes in the construction of water supply systems, the following recommendations however, may be important to the water agencies, who, for different reasons have to continue using this type of material. These recommendations are based on inspections in a number of factories visited in Islamabad, Lahore and Karachi. They are also based on current procedures used in Pakistan for fabrication, acceptance, installation, operation and maintenance of pipes.

2.1. RECOMMENDATIONS CONCERNING FABRICATION OF PRESTRESSED REINFORCED CONCRETE PIPES

All materials used should be in strict accordance with the respective international standards. Inspections and testing of materials should become a routine in the process of pipe-manufacturing.

The wrapping stress in the high-tensile wire should be best controlled through the use of appropriate instrumentation. The wire stress is being poorly controlled and the consequences of this are, the reduction of the mechanical resistance of the piece and an increase in the vulnerability of the pipe regarding internal pressures.

The smoothness and density of finished surfaces of pipes should be improved. This is particularly important at the internal surface of the bell at the circumferential zone in contact with the rubber ring. A best smoothness of the internal surface of the bell will prevent cutting of the rubber ring during installation.

The design of the joints should be improved in such a way that when the pipe is laid it will be self-centering, therefore preventing the rubber ring from supporting the weight of the pipe.

The rubber ring should provide the correct volume required to fill the groove and the annular space between the bell and spigot. The dimensions of the grooves should be in strict accordance with the dimensions of the rubber ring to prevent that the latter be over-stretched or under-stretched. The rubber ring should be in contact with the three surfaces of the grooves and with the internal surface of the bell.

The quality control of the rubber ring is not being carried out properly by the water agencies. This is an extremely important factor which should be tackled if the quality of new waterworks is to be improved. Tests recommended by international standards should be regularly performed, specially those concerning simulation of pipe ageing. The loss of elasticity of rubber rings may be one of the causes of problems regarding leaks through joints.

In the case of fabrication of prestressed reinforced cylinder concrete pipes, special care should be taken when designing and manufacturing the cylinder. Each steel cylinder, with joint rings welded to its ends, should be submitted to a hydrostatic test.

A cement slurry (1 bag of cement to 6 gals. of water) should be applied to the core just ahead of the mortar coating. This provides additional protection to the wires. The mortar coating should have a thickness of not less than 5/8 ins. over the wire to prevert infiltration of humidity. On the other hand, thickness of the mortar coating should not be excessive to prevent cracks in the coating.

The quality control of the manufacturing process should be of continuous concern to the water agencies. The water agencies should be able to inspect all phases of fabrication. Material, fabricated parts and pipes which are found to be unsuitable should be rejected and removed from the site of the work.

2.2. RECOMMENDATIONS CONCERNING INSTALLATION AND MANIPULATION OF PRCC PIPES

Every precaution should be taken to prevent the pipes from impact or point loading resulting from contact with rocks or other obstacles on the ground. Pipe ends are particularly vulnerable to damage caused by shock.

Pipes should be handled carefully by using appropriate equipment so as to prevent damage to either the inside or outside surface of the pipe.

The trench bottom on which the pipe is to be laid should be free of rocks or other objects and prepared true to line and grade.

Sheeting and bracing should be designed in accordance with the type of soil and characteristics of the trench. The primary function of trench sheeting and bracing is to prevent a cave-in of the trench walls or areas adjacent to the trench, thus, meeting safety requirements.

At the installation of the pipe, both the bell and the spigot and the rubber ring of the adjoining pipe should be thoroughly clean and free of any dirt or mud. Then a vegetable-type lubricant (petroleum-based lubricants are not recommended for natural rubber rings) should be applied to the spigot groove, the rubber ring and the initial stretch of the bell. The rubber ring should then be positioned in the spigot groove and care should be taken to ensure that the rubber ring is distributed uniformly around the circumference of the groove. The joint is then engaged. This engagement should be made with a straight-in pull in order to avoid a rolled rubber ring. This is of particular interest for the water agencies in Pakistan since in opposition to the common practices adopted in the country, the rubber ring must not roll out of the groove at the engagement of pipes.

Pipes should be properly aligned to prevent over-stretching or under-strecthing of the rubber ring. For this reason excessive deflections should be avoided.

Special measures should be taken whenever the environment is aggressive in such an extent as to result in short useful life of the pipe. In these cases, the use of richer mixes, thicker mortar cover, dielectric top coatings monitoring and cathodic protection should be considered. However in most of these cases the best alternative is to select another type of pipe more resistant to these aggressions.

2.3. RECOMMENDATIONS CONCERNING OPERATION OF PRCC PIPES

Pipes should be prevented from either excessive or negative pressures generated by hydraulic transients. Although in all visited systems the pipelines are provided with devices for minimizing the effects of transients, they are not adequate nor are in working conditions. Special efforts should be made by the water agencies to improve this situation.

Some of the major transmission lines are equipped with metallic gauges for controlling variation of pressures. Despite this it would be advisable for the water agencies to replace these visual gauges to pressure recorders if an effective control of pressures is to be achieved. Over-pressures and under-pressures caused by transient effects have a duration of a few seconds. These variations in pressure, which occasionally are the important ones, would be registered in a chart if pressure recorders were to be conveniently installed.

The useful life and the reliability of the transmission lines depend on the effectiveness of their operation and maintenance. Control valves should be carefully operated to avoid excessive transient pressures. If the control valve is a gate valve then the last 5 to 10 turns towards the closing position should be specially carefully executed. It is absolutely important that the air valves be well dimensioned and kept in acceptable conditions of operation. Before the operation of shutting down of a pipeline, the air valves and washout valves should be thoroughly checked. A working plan should then be prepared destined towards repairing of the defective valves, at the same time that other major maintenance services are being carried out in connection with this operation. After repairs, the restoration of the pipe should be carried out carefully with washouts being closed successively after the arrival of the water at each point of discharge.

2.4. RECOMMENDATIONS CONCERNING MAINTENANCE OF PRCC PIPES

The MS pipes replacing defective PRCC pipes should be conveniently protected with suitable coating, as described in another part of this report. MS pipes are vulnerable to the external environment, as well as to the water it conveys. Without internal protection for instance, tuberculation will occur which will drastically reduce the carrying capacity of the pipeline.

The practice of replacing defective PRCC noncylinder pipes by MS pipes with smaller diameters, will cause reduction in the carrying capacity of the pipeline. It is more suitable to prepare the MS pipe which will replace the concrete pipe, in such a manner that reductions at its extremities will allow the use of the same internal diameter as in the PRCC pipe.

The technique of cutting away extremities of PRCC pipes in order to allow the insertion of MS pipes should be avoided. Instead, adaptors should be prepared at the extremity of the MS pipes to allow the use of original extremities of the PRCC pipes.

The practice of cutting new PRCC (noncylinder) pipes and their use in conjunction with a sleeve to replace a damaged pipe should be avoided. This procedure weakens the two pieces of pipe. Instead of sectioning PRCC pipes for maintenance purposes they should be fabricated with the appropriate dimensions to meet the requirement for this specific use.

The MS pipes replacing defective PRCC pipes, should be conveniently protected with suitable coating, as described in another part of this report. MS pipes are vulnerable to the external environment as well as to the water it conveys. Without internal protection tuberculation will occur which will drastically reduce the carrying capacity of the pipeline. Internal corrosion may also occur if adequate internal coating is not provided. Without external protection MS pipes may suffer chemical aggression and galvanic and electrolytic corrosion imposed by an eventually aggressive environment.

There is a great number of different factors presented and discussed in other parts of this report, which may contribute to the adverse conditions of PRCC pipes in Pakistan. Most of them are of irreversible nature for they are linked to: the design of the pipes, to the material utilized in their fabrication and to the techniques employed in their manipulation, transportation and protection. For instance, the process of corrosion of the high tensile wires cannot be stopped or minimized unless techniques of high cost are utilized. The cathodic protection, which would be possible if implemented during the construction of the line would be of high cost and of unpredictable results if implemented at this point. The identification of alternatives for upgrading of pipes presenting corrosion of wires or shell, should include cost-effective techniques of rehabilitation. It is possible to envisage the following alternatives for solving the problem:

(a) to identify lengths of pipeline more susceptible of failing and replace them with MS pipe or other reliable material.

(b) to study the viability of using one of the following techniques for rehabilitation of these pipelines:

- Thermostatic pipe insertion process

- Insituform process

- Insertion of steel pipe

- Others

(c) whatever the selected process, it has to present structural properties to resist the water pressure independently of the structural support given by the PRCC pipe.

3. RECOMMENDATIONS CONCERNING OTHER TYPES OF PIPES

Although MS pipelines in Pakistan are being properly constructed and tested before being put into operation, additional protective measures are required. MS pipes have low resistance against electrolytic and galvanic corrosion and are sometimes susceptible to suffer corrosion even if they are effectively protected with standardized coatings. Therefore, studies should be conducted in order to define the need for additional protection. The resistivity of the soil along the line should be determined and pipe-ground potential measurements should be made. If low resistance and high potentials are detected then a cathodic protection system should be designed, implemented and operated accordingly.

Severe damage to concrete pipes utilized in the wastewater systems of Pakistan has been reported throughout the past years. One of the possible alternatives for minimizing this problem in the forthcoming years is to include in the specifications for purchasing of this type of pipe requirements regarding the need for an inner sacrificial layer of concrete. Another possibility is to improve the resistance of the concrete used in this type of pipe by using resistant or high alumina cements and calcareous aggregates. Other alternatives, for instance, PVC lining, may not be available in Pakistan.

Vitrified-clay pipe is an inert type of pipe traditionally used in non-pressure wastewater systems for diameters up to 600 mm. Private firms should be encouraged to manufacture this type of pipe due to their competence in terms of cost, reliability and resistance to sulfide corrosion.

4. GENERAL RECOMMENDATIONS REGARDING OPTIMIZATION OF THE WATER SUPPLY AND SEWERAGE SYSTEMS

The water supply and sanitation agencies in Pakistan should improve their efficiency and effectiveness to make it possible to extend water supply and sanitation services to those who live in less privileged urban/poor or rural areas. By reducing water losses and by increasing revenue in urban areas it should be possible to extend coverage to fringe and poor areas; to reduce operational costs; to postpone investments for the expansion of production works and to shift financial resources to coverage of fringe/poor and rural areas. In order to accomplish these improvements in Pakistan, programmes aimed at the optimization of the water and sanitation services should be implemented. These programmes should include projects on the following issues to be formulated in accordance with specific requirements of each water agency:

(1) Operation of Water Supply Systems

- Network Survey (Pitometric Survey)
- Leakage Control
- Macrometering
- Network Mapping
- Control of Operation
- Revision of Design and Construction Criteria
- Micrometering

(2) Maintenance of Water Supply Systems

- Preventive and Corrective Maintenance
- Distribution Network Maintenance
- Maintenance of Flowmeters (including house connection meters)
- Improvement and Rehabilitation of House Connections and Pipelines
- Improvement of Material and Equipment Quality

(3) Improvement of Operation and Maintenance of Sewerage Systems

- Operation Control of Collection and Disposal Facilities
- Operation Control of Pumping Stations
- Record Keeping
- Emergency Service and Repairs
- Preventive Maintenance

(4) Support Projects (Organizational Arrangements, Training, Development of Information Systems, Transportation, Supplies)

The objectives, basic concepts and a brief description of these projects are presented in another part of this document.

The situation of the pipe network systems in some cities in Pakistan is critical due to the profusion of failures in PRCC pipes and due to the difficulties of repairing these and to the inconvenience that this situation causes to both the consumers and the water agencies. It would be advisable to carry out feasibility studies approaching the rehabilitation of these pipelines rather than constructing new works to replace them.

WASA/Lahore seems to be one of the few water agencies in Pakistan whose water supply system ensures continuity of supply to all sectors of the distribution system. This example should be followed by other water agencies in Pakistan. It is likely that extremely important and relevant improvements would be achieved in these water agencies if effective measures would be undertaken as proposed in this document.

5. SPECIFIC RECOMMENDATIONS CONCERNING THE VISITED WATER AUTHORITIES

5.1. ISLAMABAD

In accordance with estimations made by CDA the water production per capita in Islamabad is about 600 lpcd. This figure is extremely high in comparison with those presented in other cities of Pakistan. Even with this high production per capita the water supply in Islamabad is intermittent, each sector being supplied a few hours per day. Thus, it is urgent, and of great importance, that the CDA undertake actions for reducing the unacceptable levels of unaccounted-for water in Islamabad.

The CDA/Islamabad should count with suitable workshops capable of performing basic maintenance services. The main benefit of such a facility is the greatest flexibility of this service. Although private workshops should continue performing maintenance services in association with CDA it would be important that this institution count on workshops for emergency service and with mobile equipment for preventive maintenance. A study should be carried out to define the maintenance services to be performed by private workshops and those to be performed by CDA.

CDA should establish a programme directed towards proper maintenance and rehabilitation of blocking valves. In addition to the water losses through glands and joints most of these valves are not in operating conditions, thus representing a serious constraint for efficient operational procedures. As this is an specialized work it should be preferably carried out directly by CDA.

The present difficulties concerning maintenance of blocking valves are, to a great extent, caused by the excessive number of different types and trademarks of existing valves and by the poor quality of these valves. More precise specifications for purchasing of blocking valves should be prepared, and systematic acceptance tests should be carried out.

The quality control of new concrete pipes (non reinforced) utilized at the sewerage system of Islamabad should improve. Surfaces at joints are neither regular nor smooth. A number of pipes were found at the site of the construction presenting failures of concrete (cracks) at the spigot. The installation of these pipes would cause leaks of sewage or infiltration of underground water. The procedures for the installation of pipes including transportation, stocking of pipes in the yard, bedding, alignments, should be in accordance with the adopted international standards.

A best understanding of the process of deterioration of concrete pipes should be accomplished. Although there is basic information concerning failures in different types of pipes, this information is not processed. Information concerning failures is registered in formats which are used for purposes of maintenance planning and execution. However, this information is not used for working out managerial indicators which would be of great importance for the establishment of a managerial information system in CDA.

Managerial indicators as well as the units responsible for the generation of these indicators, should be identified. The collection, processing and dissemination of the managerial indicators, should be carried out with an established frequency, by a specific unit.

It would be advisable that a single agency takes full responsibility for planning, design, construction, operation and maintenance of the water supply and sanitation systems in Islamabad. This agency should evolve to self-sufficiency regarding financial planning and management and possibility to recruit their own staff and make their own rules and bylaws.

5.2. LAHORE

There are not effective instruments installed in the system for controlling flows and pressures on a permanent basis. A few flow meters are installed at the tube wells discharges pipelines for measuring the water produced at these installations. However, these meters are not functioning properly nor are being utilized for supporting the operation control of the system. A macrometering system should be designed and implemented as this would be a valuable instrument for operation and maintenance, and would provide important information for design and construction of new works.

Pressure recorders should be installed in selected points of the distribution system in replacement of the present process of measuring pressures each 15 days through metallic gauges. The information obtained from these pressure recorders together with other variable from the water supply system, should be utilized on a permanent basis for the adoption of operational decisions.

The operation of wells in accordance with a preestablished timetable should be avoided. The decisions regarding working hours of pumps should be taken based on operational parameters (pressures, flows, general information on the status of the water supply system, etc.), in real time.

The problem regarding lack of effective sealing of joints of reinforced concrete pipes for the wastewater system is leading to some investigations involving changes in the design of the grooves of the spigot. Although these investigations may be of some importance, a shortcut to an effective solution for the problem would be the fabrication of the pipes in more strict accordance with the adopted standards.

Despite the fact that the WASA/Lahore is provided with a reasonable infrastructure for training of personnel, little has been achieved in this field in the past three years. It is strongly recommended that the WASA/Lahore takes the lead, jointly with PHED, in the process of creating a School for training technicians and engineers from water agencies within the province of Punjab.

The field installations for simulating underground leaks at the training centre should be improved. They do not reflect the number of situations which occur in a pipe network system. In addition to this, the pressures in these installations are not sufficient to simulate leaks under normal conditions of operation.

5.3. FAISALABAD

The decision of WASA/Faisalabad to stop using Asbestos Cement, due to possible implications to health, should be reviewed. Although Asbestos Cement pipes are not the best alternative in terms of useful life and reliability they are competitive in price and are fabricated locally. On the other hand, in accordance with a number of credible investigations on this matter, no evidence exists that the use of AC pipes in water supply systems offers risks to health.

5.4. KARACHI

Although the special measures being implemented by KWSB for improving the situation of the water supply are relevant and should produce good results, there are other aspects linked to the efficiency and effectiveness of the institution which should be embraced in a programme for optimizing the existing facilities, as discussed in another part of this report.

A number of experiments are being undertaken in order to define best policies, procedures and techniques to be adopted in crucial issues as leak detection, micrometering and macrometering Despite the fact that these investigations may be of some benefit for the KWSB it seems that they could have been avoided as the problems in Karachi and the respective solutions for these problems could discard the support of these ongoing experiments. Rather than experiments the KWSB should implement effective programmes directed towards the optimization of the existing ws/s system.

6. DATA AND OBSERVATIONS FROM THE MISSION RELEVANT TO ESTABLISHING A WS/S TECHNICIANS SCHOOL

The school for training personnel from water agencies should be implemented at the provincial level. The first school would be implemented in Lahore to serve the Province of Punjab. Other schools would be later on implemented in other provinces in the light of lessons learned from this first project.

It has been agreed by all involved parties that the existing training centre at WASA's premises should be selected as the place for the implementation of this provincial school. Substantial improvements in the existing installations will be required. The idea is to modernize, equip and expand the present training centre and use it as a school for training engineers, technicians and laborers from ws/s agencies within the province of Punjab. These improvements have to be envisaged in the light of the new training requirements expressed in terms of both the number of persons to be trained and programmatic area.

It would be advisable that representatives from three major institutions within the province of Punjab constitute the board of governors of the school. These institutions are PHED, WASA and the Institute of Public Health Engineering and Research.

The following action directed towards the implementation of the school is the preparation of a detailed project. The accomplishment of this would be possible through the organization of a mission including the following professionals:

- expert in O&M
- expert in training
- electromechanical (local)
- architect (local)

Required time for this mission: three weeks

Although the training requirements in terms of number of technicians and type of training courses have been roughly estimated the training programme to be carried out at the School and the number of employees to be trained should be best defined. This work should be performed tentatively by national officials prior to the arrival of the proposed mission.

SECTION 6

PLAN OF ACTION

1. IMMEDIATE ACTIONS

1.1. To organize a "National Workshop on Pipes and Optimization of Water Supply and Wastewater Systems" whose major objectives are the following:

- To review the current practices with respect to the design, manufacturing, purchase, installation, inspection, testing, operation and maintenance of water supply and sewer pipes in Pakistan.

- To evaluate the effect of pipe conditions with regard to the effectiveness and efficiency of the water agencies.

- To define criteria for selecting pipes for sewer and water supply.

- To identify causes of high rates of unaccounted for water and wastage of water in cities in Pakistan.

- To outline major lines of action for the improvement of water and sewer pipes and for the optimization of water supply and sanitation systems in Pakistan.

This Workshop would be of great importance not only for discussing failures and measures for improving the performance of pipes but also for discussing sector policies and strategies directed towards the optimization of the water supply and sanitation systems within Pakistan. A suitable date should be defined in consultation with the national institutions involved. The terms of reference, agenda and background documents would be prepared by WHO. Presentations on the present performance of selected water authorities should be also performed. Either the PHED/Lahore or the KWSB/Karachi would be suitable candidate for hosting the Workshop. A formal letter of invitation to this effect should be forwarded to PHED/Lahore or KWSB/Karachi to ensure their engagement in this endeavour. The total duration of the workshop should be five days and it should be addressed to managers from selected water agencies in Pakistan.

1.2. To organize a mission aimed at the preparation of a project proposal for upgrading the existing training centre administered by WASA/Lahore. The draft of the project proposal should be available at the end of the mission. The document to be prepared as the output of the mission should be composed of two parts, as follows:

- The project proposal itself, in which objectives, strategies, activities to be carried out and costs are presented in a summarized manner.

- An annex to this project proposal, in which detailed information on the above mentioned themes is provided including the preliminary design of the new installations, definition of equipment to be purchased, etc.

This mission should take place soon as there is a willingness in Pakistan for this endeavour, as well as a strong need for the development of a training programme for personnel from water agencies. The terms of reference of this mission are as follows:

(a) Title:

Feasibility Study - Establishment of a School to Train Skilled Technicians from water supply and sanitation agencies.

(b) Objectives:

- Determine the expected output expressed in terms of number of students to meet the specialized needs for the Province of Punjab.

- To propose the required organizational arrangements for the functioning of the School.

- Estimate size, complexity and cost of the school(to be located on the existing installations of the Training Centre of WASA/Lahore).

- Recommend proposed curriculum and course duration to meet the needs for Operation, Maintenance, Construction, Planning and Design of water supply and sanitation systems.

- Design workshops for training in plumbing, electricity(industrial and testing), instrumentation, maintenance, etc., including selection of required equipment and installations.

- Design the upgrading of the existing test field for simulation of underground leaks

(c) Duration of the Mission:

Three weeks

(d) Participants:

- Expert in Training

- Expert in Operation and Maintenance

- Electromechanical Engineer (local)

- Architect (local)

(e) Place:

The working sessions will be carried out in the present premises of the Training Centre of WASA/Lahore.

1.3. To carry out a training course on "Leak Detection and Network Survey".

This training course would be addressed to engineers from Water Agencies. It should be imparted as part of an overall strategy for implementing a programme aimed at the optimization of the water supply and wastewater systems in Pakistan. It is a practical course in which the participants will learn how to optimize their systems by using suitable and non-sophisticated techniques. The execution of this activity will require the purchasing of equipment as presented in annex 2. UNDP would be possibly interested in supporting this activity. The course has a total duration of 80 hours.

2. MEDIUM AND LONG TERM ACTIONS

Formulation of programmes for the improvement of Operation and Maintenance and Optimization of Water Supply and Sewerage Systems. This action would be carried out under request from the water agencies in the light of policies and recommendations from the National Workshop on Pipes and Optimization of Water Supply and Wastewater Systems".

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ANNEX 1

TYPES OF PIPES IN USE IN PAKISTAN

PRESTRESSED REINFORCED CONCRETE CYLINDER PIPE

- Good initial carrying capacity
- Slight reduction in carrying capacity with time because of destruction of smoothness of the walls
- The expected durability is about 75 years
- This time bay be drastically reduced in case of aggressive environment
- The durability of PRCC pipes is also highly dependent on quality control in the process of fabrication
- It is heavy and of difficult transportation
- Careless transportation may damage its extremities
- Breaks in PRCC steel pipes are often quite destructive
- Although the process of deterioration is slow and gradual the bread downs are destructive and dangerous particularly in the case of high pressures

PRESTRESSED REINFORCED CONCRETE NONCYLINDER PIPE

- Good initial carrying capacity
- Slight reduction in carrying capacity with time because of destruction of smoothness of the pipe walls
- Expected durability: 75 years
- This time may be drastically reduced in case of aggressive water and

aggressive environment

- The durability of PRCC pipes is also highly dependent on quality control in the process of fabrication

- Heavy and of difficult transportation

- careless transportation may damage its extremities

- Breaks in PRCC pipes are often destructive

- Although the process of deterioration is slow and gradual the breakdowns are destructive and hazardous particularly in the case of high pressures

REINFORCED CONCRETE PIPE

- Can be used for moderate water pressures

- Can support high external loads

- Good initial carrying capacity

- Slight reduction in carrying capacity along time because of destruction of smoothness of the pipe walls

- Expected duration: 75 years

- This time may be drastically reduced in case of aggressive water and aggressive external environment

- Heavy and of difficult transportation

- Generally fabricated nearby the construction site

- It fails gradually as pipelines are not submitted to high pressures

PLASTIC PIPES

- May be damaged by concentrated loads caused e.g. by stones in the soil
- Plastic practically do not present loss of carrying capacity with service
- Extended exposure to sunlight (ultraviolet radiation) should be avoided, since it may lead to embrittlement of the material

ASBESTOS CEMENT PIPE

- Support moderately high water pressures
- Support appreciable external loads provided they are properly bedded
- Good initial carrying capacity
- Slight reduction in carrying capacity
- Asbestos Cement pipe has proved to have a long duration. However its duration may be seriously affected by adverse environment
- Its weight is about one-quarter that of cast iron pipe of the same diameter
- Highly affected by careless transportation and handling
- Asbestos Cement pipe fail suddenly. However, this is of minor concern regarding safety as AC pipe is used in small sizes
- Care is necessary in cutting and drilling due to implication to health of inhaling of fine dust

STEEL PIPE

- Resist high internal pressures

- Low resistance to external loads particularly in case of negative pressures and large sizes. These can lead to collapsed pipes

- The above can be minimized by proper design, construction, operation and maintenance of the pipeline

- High elasticity and weldability

- Good mouldability and machineability

- Steel pipe without internal lining present a rapid loss of capacity because of tuberculation and corrosion

- Cement and bituminous-enamel linings present a slight loss of carrying capacity

- The expected durability of coated pipes is about 25 - 50 years

- Highly susceptible to corrosion especially at joints

- It is lighter than cast iron and concrete pipe

- The transportation requires protection measures to avoid deformation of extremities, particularly in the case of larger sizes

- Normal laying length: 6 - 9 m

- Steel pipe fails slowly

- Corrosion is followed by small size perforations which get enlarged with time, instead of sudden blow ups

- Repairs are simple and may be performed without taking the pipeline out of service

DUCTILE IRON PIPE (LINED WITH CEMENT MORTAR)

- Good mechanical and bending strength

- Good initial carrying capacity

- Slight reduction in carrying capacity with time because of destruction of smoothness of the pipe walls.

- Expected durability: 100 years

- This time may be seriously affected by rubber rings quality

- Susceptibility to corrosion is greater than that of grey cast iron

- Must be protected when bedded in aggressive soils

- It is lighter than cast iron pipe and concrete pipe

- Highly resistant to impact

- It is not usually damaged during transportation

- Failures in Ductile Iron pipe are hardly ever destructive or hazardous

CAST IRON PIPE

- Support moderately high water pressures

- Support appreciable external loads provided they are properly bedded

- Cast iron without internal lining present a rapid loss of carrying capacity because of tuberculation and corrosion

- Cement and bituminous-enamel linings present a slight loss of capacity over the years

- Durability when coated: 100 years
- This time may be seriously affected by type and quality of joints
- Quite resistant to corrosion
- Transportation is difficult because of weight
- May be affected by shock or careless handling
- Normal laying length: 3.6 m
- Breaks in cast iron pipes are often quite destructive

ANNEX 2

BASIC EQUIPMENT FOR TRAINING IN UNACCOUNTED-FOR WATER

BASIC EQUIPMENT FOR TRAINING IN UNACCOUNTED FOR WATER

A DESCRIPTION, QUANTITY AND COSTS

1. SIMPLEX PITOT ROD

1.1 Description

The Simplex Pitot Rod is a portable primary flow meter which consists of a pair of tubes in a casing. One tube transmits the reference pressure received at the side orifices, and the other tube transmits the impact pressure received at impact orifice, which faces the flow. The difference between these pressures is proportional to the velocity. The threads of a connecting nut of the simplex rod fits a 1" corporation cock which presents the following characteristics: male thread 1 1/2" O.D, twelve threads per inch and a 1" clear opening.

1.2 Quantity: 3 as follows:

- 1 for pipes of diameter 1000 mm or less
- 1 for pipes of diameter 1200 mm or less
- 1 for pipes of diameter 1500 mm or less

1.3 Cost*: approx.: US$ 5000.00

2. PIPE CALIPER

2.1 Description

This instrument is used for measuring the internal diameter of pipes. It consists of a brass rod which passes through an eccentric stuffing box. The lower end is hook shaped, and to the other end is attached an index collar and handle. The threads of the connection nut of the pipe caliper fits a 1" corporation cock.

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*: Total cost for the three Simplex Pitot Rods

2.2 Quantity: 1 for pipes of diameter 1000 mm or less
1 for pipes of diameter 1500 mm or less

2.3 Cost (approx.): US$ 1500.

3. CORPORATION COCK

3.1 Description

The corporation cocks are for male threads 1 1/2" O.D. - twelve threads per inch and 1" clear opening. Where other makes of corporation cocks are employed, an adapter should be provided having male threads to fit the items 1 and 2 and female threads to fit the corporation cock.

3.2 Quantity: 20

3.3 Cost (approx): US$ 1000

4. U-TUBE

4.1 Description

The U-tube is used for metering the differential pressure generated by the Simplex Pitot Rod. The top assembly is provided with fittings which connect to each side and in turn to each other through blocking valves. The top assembly is easily removable for pouring liquid into manometer or for the insertion of the cleaning brush.

The U-tube will be connected directly to the Pitot Rod through two lengths of hose. The U-tube will be supplied in its case with two pairs of hoses and with the cleaning brush.

4.2 Quantity: 3

4.3 Cost (approx.): US$ 3200

5. DRILLING AND TAPPING MACHINE FOR STEEL AND CAST IRON

5.1 Description

The machine will be used to drill, tap and insert corporation cocks (1") in mains under pressure, particularly steel and cast iron pipes. To be supplied with all accessories and tools including case, drills, saddle gaskets, chains, wrenches, etc.

5.2 Quantity: 1

5.3 Cost (approx.): US$ 4000

6. DRILLING AND TAPPING MACHINE FOR ASBESTOS - CEMENT AND PLASTIC

6.1 Description

The machine will be used to drill, tap and insert corporation cocks (1") in mains under pressure through the use of a service clamp and a corporation cock. The machine should be supplied with all accessories and tools including carrying case, wrenches, cutting grease, etc.

6.2 Quantity: 1

6.3 Cost (approx.): US$ 3000

7. SIMPLEX PITOT TUBE RECORDER

7.1 Description

This instrument will record the velocity of water flow on a circular chart, proportionally to the differential pressure between Impact and Reference orifices of a Simplex Pitot Tube. The velocity chart will be graduated in meters per second or feet per second, from 0 to 10 ft/sec (0-3m/s) with a graduation of 0.5 ft/sec (0.5 m/s). Accuracy: not less than 1% of indicated velocity.

7.2 Quantity: 2

7.3 Cost (approx.): US$10 000

8. DEADWEIGHT TESTER

8.1 Description

Deadweight tester for calibration of test gauges. Minimum pressure: 5 psi, maximum pressure: 500 ps. The weights will be supplied to allow minimum graduation of 5 psi. Accuracy: 0.1% of indicated pressure.

8.2 Quantity: 1

8.3 Cost (approx.) US$ 1200

9. TEST GUAGE

9.1 Description

High accuracy test gauge provided with Bourdon tube pressure element. Dial provided with integral band of mirror polished aluminium under the tip of the pointer to improve legibility. The instrument will be used for measuring pressure in water mains in distribution network systems. Accuracy: 1/4% of full scale. Dial size: 6" to 8". Connection: 1/4" male NPT.

9.2 Quantity: 4, as follows:

1 x with range 0 - 60 psi, minor graduation 0.2 psi
1 x with range 0 - 100 psi, minor graduation: 0.5 psi
1 x with range 0 - 150 psi, minor graduation: 0.5 psi
1 x with range 0 - 200 psi, minor graduation: 1 psi

9.3 Cost (approx.) US$ 1000.

10. PORTABLE PRESSURE RECORDER

10.1 Description

The instrument will be used for measuring pressure in water mains, in distribution network systems. The following are the main characteristics of the instrument:

- Range: 0 - 150 psi, graduation 1 psi
- 1 pen recorder
- Chart: circular, 12"
- Pressure connections: 1/4" NPT
- Chart Drive: mechanical; chart drive speed: 24 hours
- Overange protection
- To be supplied with 100 charts

10.2 Quantity: 2

10.3 Cost (approx.): US$ 3000

11. PIPE LOCATER

11.1 Description

Transistorized pipe locator provided with visual and audible indication of the volume of signal being monitored. Possibility of locating pipes up to 4m depth and of determining the depth of pipes. The instrument consists of two principal component parts: a transmitter assembly and a receiver assembly. The transmitter assembly generates an electromagnetic field which surrounds the buried metal object or propagates along it in the case of a pipe. The receiver detects and traces the transmitter-induced electromagnetic field. To be supplied with earphone, long life batteries (200 hours of operation) and all required accessories.

11.2 Quantity: 1

11.3 Cost: US$ 1500

12. VALVE BOX LOCATER

12.1 Description

Designed to locate valve box and other metallic devices buried underground under paving. Effective to a depth not less than 1.5m. Provided with both a visual reading and audible signal. Long life battery (200 hours of operation). Earphone, carrying case and all required accessories.

12.2 Quantity: 1

12.3 Cost: US$ 1200

13. GEOPHONE

13.1 Description

Mechanical leak detector instrument for location of leaks in water lines. To be supplied with a wooden carrying case.

13.2 Quantity: 2

13.3 Cost: US$ 900

14 SONOSCOPE/WATER PHONE

14.1 Description

This mechanical instrument is an amplifier of the sound of escaping water through hydrants, valves, meters, etc.

14.2 Quantity: 3

14.3 Cost: US$ 100

15. AQUA-SCOPE OR SIMILAR

15.1 Description

Sonic leak detection instrument for detecting and pinpointing leaks from the surface. Supplied with carrying storage case, electronic receiver module, headset, ground microphone and handle, test rod microphone, detachable test rod tip, analog meter module, battery charger (200 vac) plunger bar and resonant plate and earphones, operation manual.

15.2 Quantity: 1

15.3 Cost: US$ 5000

16. AQUAPHON OR SON-I-KIT OR SIMILAR

16.1 Description

Leak detection instrument provided with filters for more accurate leak location. To be supplied with test rod, ground microphone with handle, earphones, carrying case, test rod extension, special ground microphone with handle for unpaved areas, plunger bar and resonant plate, operation.

16.2 Quantity: 2

16.3 Cost: US$ 8 000

17. LEAK NOISE COLLRELATOR

17.1 Description

For location of leaks through cross-correlation principle. Accuracy in the location of leaks, not less than 0.5m. To be supplied with radio transmitters, accelerometer sensors, power supply/battery charger and earphones. To be utilized for locating leaks in all types of pressure mains (asbestos cement, plastic, cast iron, etc.)

17.2 Quantity: 1

17.3 Cost: US$ 20 000

18. ADDITIONAL TOOLS AND MATERIALS

18.1 Description

Other small items as tools, manometeric liquids and others will be purchased at the local market when training activities concerning unaccounted for water would be carried out.

18.2 Cost: US$5 000

TOTAL COST: US$ 76 200

LIST OF MANUFACTURERS AND SUPPLIERS

1. The F.B. Leopold Company, Inc.
   227 South Division Street, Zelienople,
   Pennyslvania 16063-1313, U.S.A.
   Phone: (412) 452-6300
   Telex: 866 474

2. Metrotech Corporation
   670 National Avenue
   Mountain View, California 94043, U.S.A.
   Phone: (415) 965 9208
   Telex: 171 408

3. Chandler Engineering Company
   7707 East 38th Street, Tulsa, Oklahoma 74145, U.S.A.
   Phone: (918) 627 1740
   Telex: 796118
   Cable: CHANDLER-TULSA, USA

4. Budenberg Gauge Co. Ltd.
   Broadhearth, Nr. Manchester,
   England

5. Fisher Research Lab.
   Export Department
   P.O. Box 1896, New Haven, CT 06508, U.S.A.
   Phone: (203) 288 1638
   Telex: 963487
   Fax: 203 287-8099

6. Heath Consultants Inc.
   P.O. Box CS-200
   100 Tosca Drive
   Stoughton, MA. 02072 - 1591, U.S.A.
   Phone: (617) 344-1400
   Telex: 924486

7. Joseph G. Pollard Co., Inc.
   New Hyde Parc
   Long Island, NY 11040, U.S.A.
   Phone: (516) 746 0842

8. Hermann Sewerin
   Pfälzer Strasse 2
   Postfach 2851
   D - 4830 Gütersloh 1
   Phone: 05241/1805
   Telex: 933 817

9. SEBA Messtechnik GmBH & COKG.
   Sonnengasse 13
   9020 Klagenfurt
   Austria
   Phone: 04222/41670-0
   Telex: 422 082

10. Mueller Co.
500 West Eldorado Street
P.O. Box 671
Decatur, Illinois 62525, U.S.A.
Phone: (217) 423 4471

11. Foxboro International Ltd.
Redhill, Surrey RH1 2HL
United Kingdom
Telex: 892 852
A/B: 892 852 FOXINT G

12. Babcock-Bristol Limited
Process Industries Division
Oldington Vale Trading Estate
Stourport Road
Kidderminster, Worcestershire
United Kingdom
Phone: Kidderminster, (0562) 743001
Telex: 339 586

13. Brown Boveri Kent Plc.
Biscot Road
Luton
Bedforshire, LU3 1AL
United Kingdom
Phone: Luton (0582) 31255
Telex: 825 066 BBKENT G
Cables: Kents Luton

14. ASCHCROFT INSTRUMENTS

15. Palmer Environmental Services Ltd.
6 Knightwood Court
Gapton Hall Industrial Estate
Great Yarmouth, Norfolk NR31 ONG
United Kingdom
Phone: (0493) 600 563
Telex: 975 313

16. Kent Meters Limited
Pondwicks Road
Luton
Bedfordshire LU1 3LJ
United Kingdom
Telex: 825 367

17. HUOT
BP 36
55301 Saint Mihiel Cedex
France

18. FONTAINERIE ET ROBINETTERIE DU CENTRE
Sainte Lizaigne
36260 Reuilly
France
Telex: 751 471 F

19. BAYARD
166, Avenue du 4 Août
69625 Villeurbane Cedex
Telex: 340 253 F

20. PONT A MOUSSON S.A
91, Avenue de la Libération
54000 Nancy
France
Telex: 961 183 F

21. PAMCO Industries
Centre d'affaires Paris Nord
Batiment Ampère V
93153 Le Blanc Mesnil
France
Telex: 213 627 F

22. USIBA
B.P. 121 F
93162 Noisy le Grand, Cedex
France
Telex: 231 023 F

23. AQUAMAT SA
Z.I.
7, rue de l'Atome
B.P. 90
67800 Bischeim
France
Telex 890 327 F

24. Jules RICHARD et PECKLY
166, quai de Bezons
94102 Argenteuil
France
Telex: 698 719 F

25. BOUDON
29, rue du Progrès
93100 Montreuil
France
Telex: 210 769 F

26. JUMO REGULATION SA
ZI de Borny
7, rue des Drapiers
B.P. 5031
57071 Metz Cedex
France

27. RADIODETECTION
Neufmarché
76220 Gournay en Bray
France

C - EQUIPMENT AND SUPPLIERS

Equipment	Suppliers
1	1
2	1
3	10
4	1
5.	10
6	10
7	1
8	4 - 11 - 12 - 13 - 14
9	4 - 11 - 12 - 13 - 14 - 16
10	11 - 12 - 13 - 16
11	2 - 5 - 6 - 7 - 8 - 9
12	2 - 5 - 6 - 7 - 8 - 9
13	6 - 7
14	6 - 7
15	2 - 5 - 6 - 7
16	2 - 5 - 6 - 7 - 8 - 9
17	2 - 5 - 8 - 9

ANNEX 3

PHOTOGRAPHS

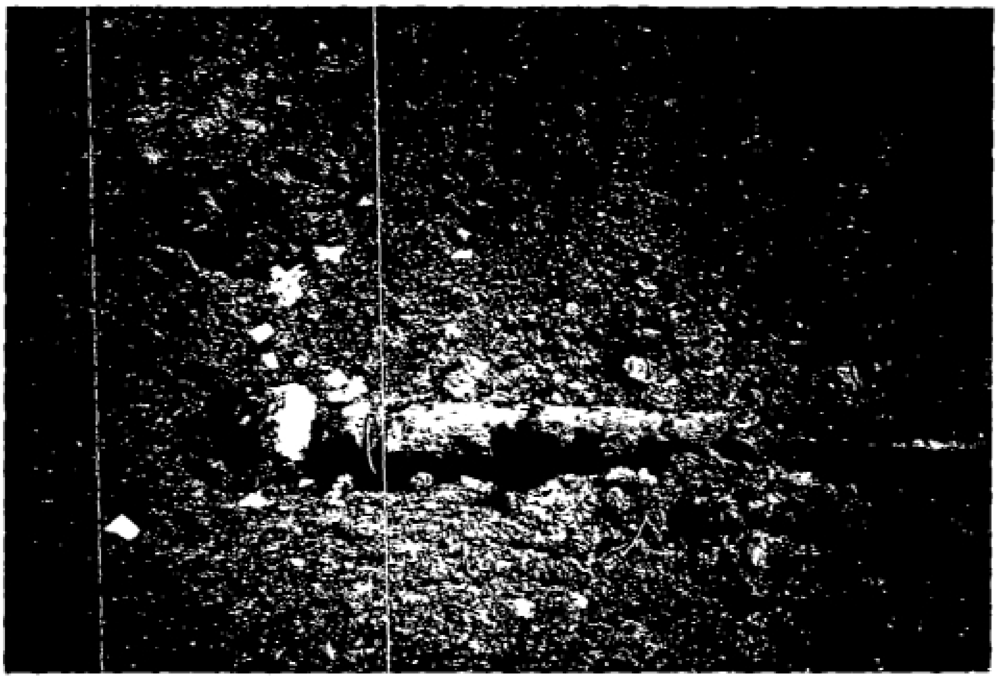
ISLAMABAD

PHOTOGRAPH 1

REPLACEMENT OF PRESTRESSED REINFORCED NON-CYLINDER PIPE (PRCC) 30" WITH MILD STEEL PIPE (MS)

PHOTOGRAPH 2

DETAIL OF THE JOINT PRCC/ MS IN WHICH THE EXTREMITY OF THE MS IS INSERTED INTO THE PRCC



ISLAMABAD

PHOTOGRAPH 3

JOINT REPAIR OF A DISTRIBUTION PIPELINE (PRCC NON-CYLINDER PIPE)

PHOTOGRAPH 4

JOINT REPAIR OF A TRANSMISSION MAIN 36" PRCC STEEL. FIRST ATTEMPT WAS NOT SUCCESSFUL AS THE JOINT WAS STILL LEAKING

ISLAMABAD

PHOTOGRAPH 5

JOINT REPAIR OF A TRANSMISSION MAIN 36" PRCC STEEL

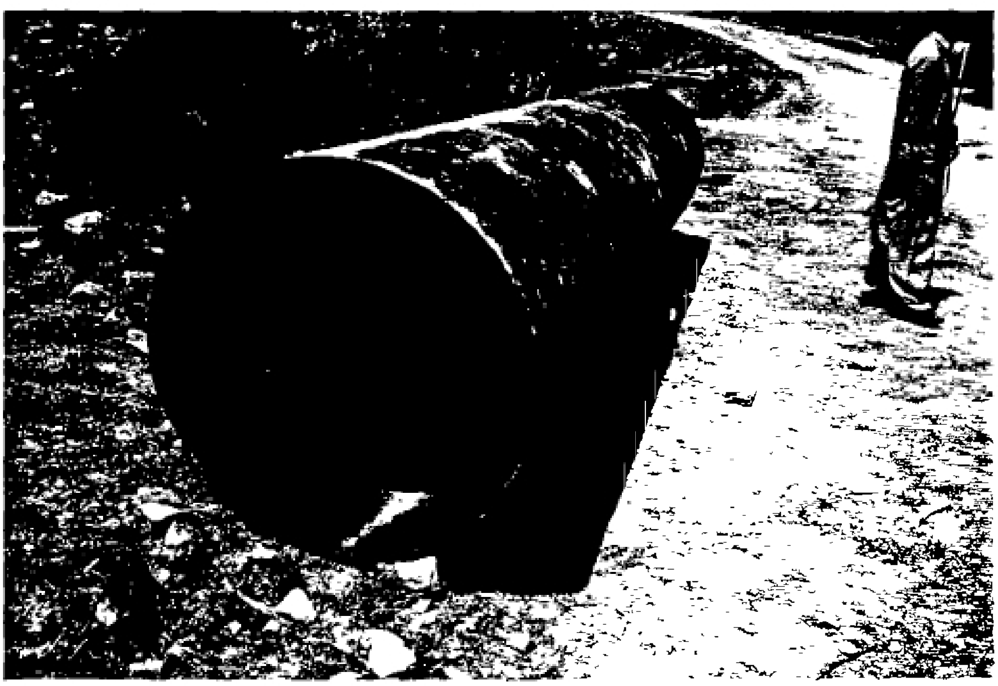
PHOTOGRAPH 6

CLAMP USED IN ISLAMABAD FOR REPAIRING OF PRCC STEEL PIPES

ISLAMABAD

PHOTOGRAPH 7

MS PIPE USED FOR REPLACEMENT OF PRCC STEEL 36"



ISLAMABAD

PHOTOGRAPH 8

FABRICATION OF PRCC PIPE THROUGH MOULDS PLACED ON SPINNING WHEELS

PHOTOGRAPH 9

CURING OF PIPES. NOTE THAT PIPES ARE NOT ENTIRELY SUBMERGED

ISLAMABAD

PHOTOGRAPH 10

PRESTRESSING OF A PRCC NON-CYLINDER PIPE

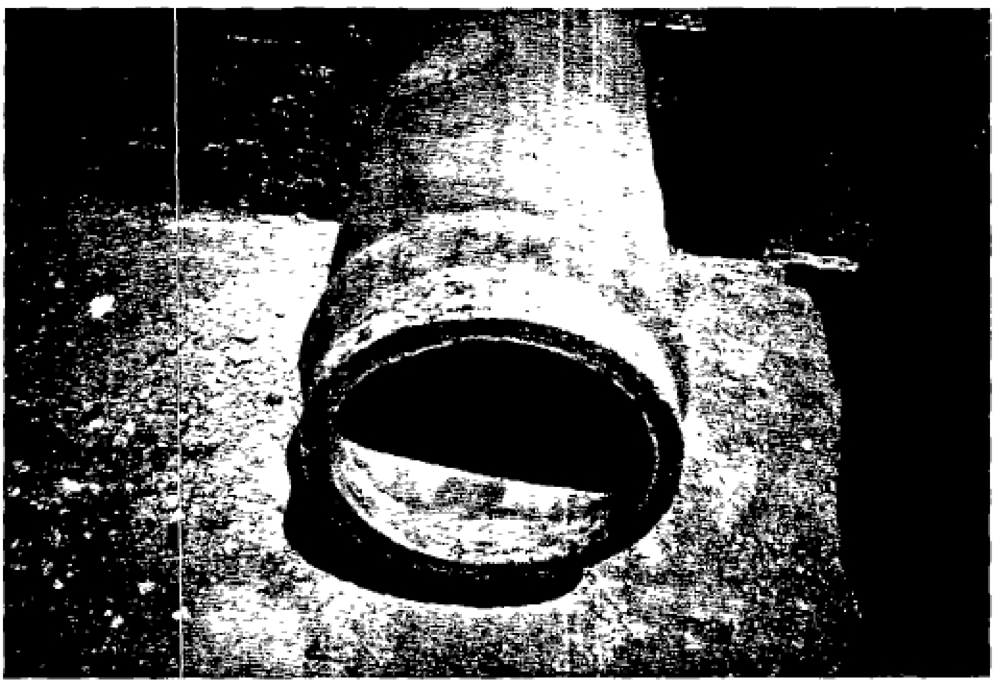
PHOTOGRAPH 11

FINISHED BELL OF A PRCC NON-CYLINDER PIPE

ISLAMABAD

PHOTOGRAPH 12

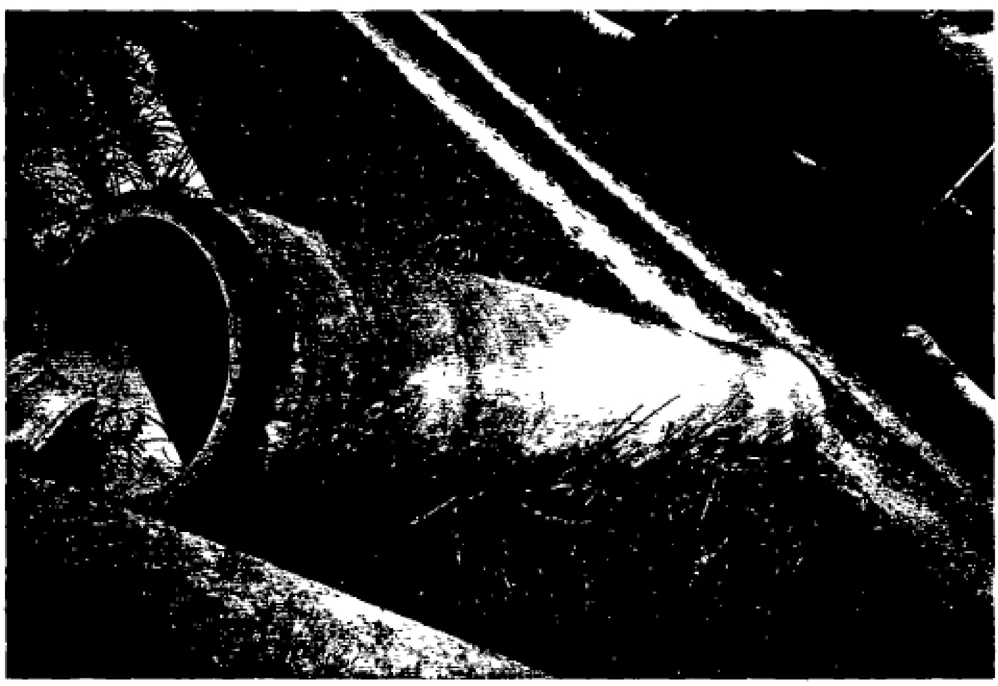
FINISHED SPIGOT OF A PRCC NON-CYLINDER PIPE



ISLAMABAD

PHOTOGRAPH 13

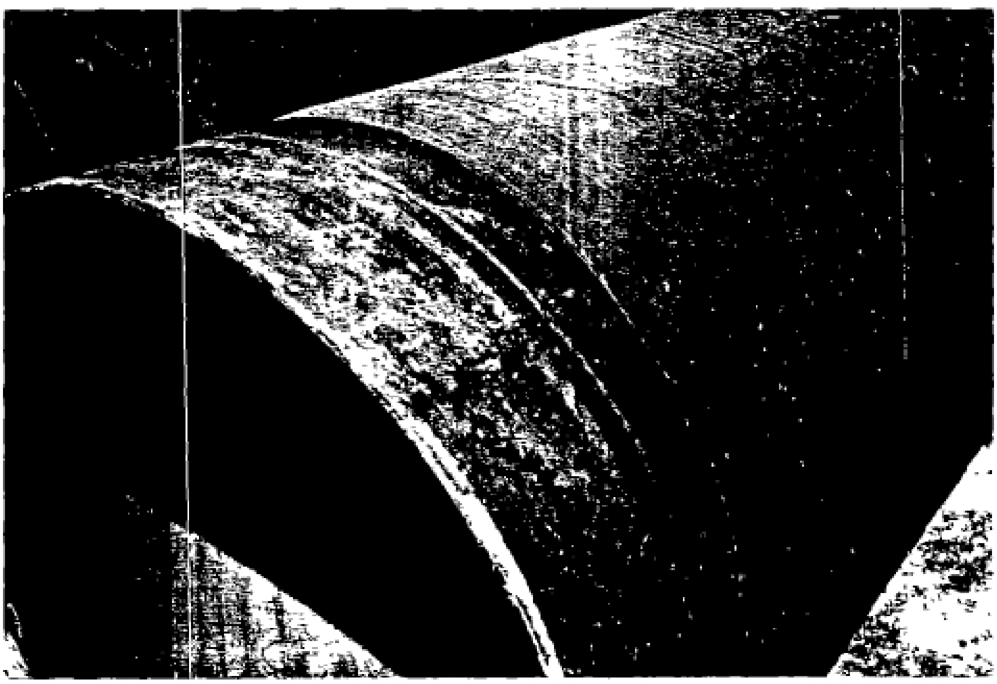
DOUBLE GROOVES OF THE SPIGOT OF A PRCC STEEL PIPE



ISLAMABAD

PHOTOGRAPH 14

MILD STEEL PIPE (36") BEING USED FOR THE CONSTRUCTION OF THE TRUNK MAIN FROM 7 MG RESERVOIR TO SECTOR E-10: EXTERNAL PROTECTIVE COATING OF FIBER GLASS AND BLACK BITUMASTIC SYNTHETIC ENAMEL



ISLAMABAD

PHOTOGRAPH 15

SEWER PIPES (NON-REINFORCED)

ISLAMABAD

PHOTOGRAPH 16

DISCHARGE VALVE WITH A LEAKING BLIND FLANGE. PRCC STEEL PIPELINE FROM SIMLY TO ISLAMABAD

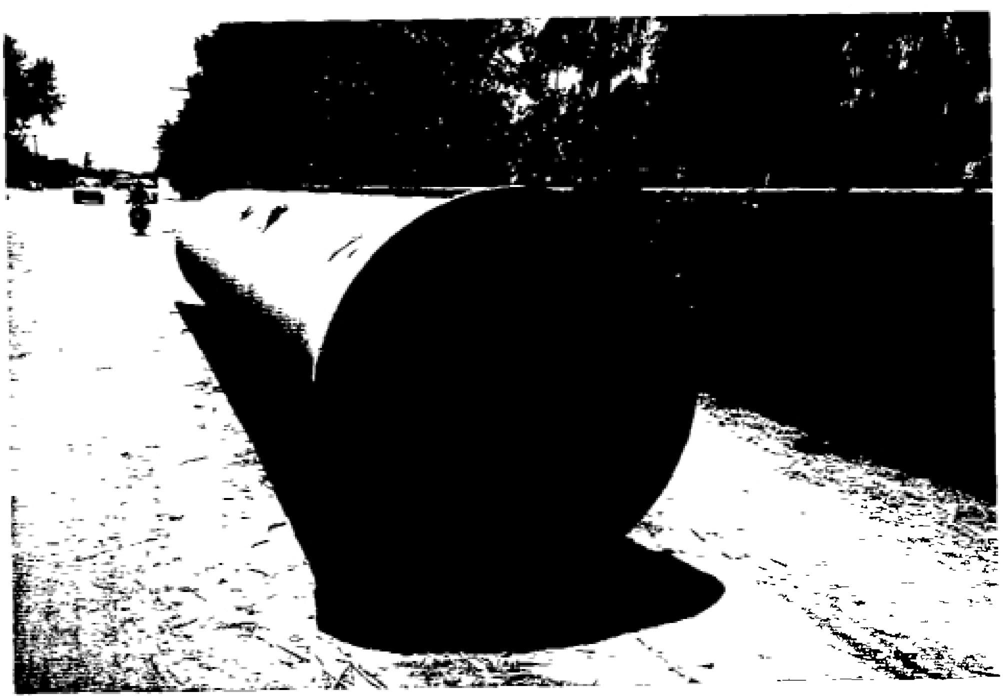
PHOTOGRAPH 17

OVERFLOW AT THE G-6-111 SUMP

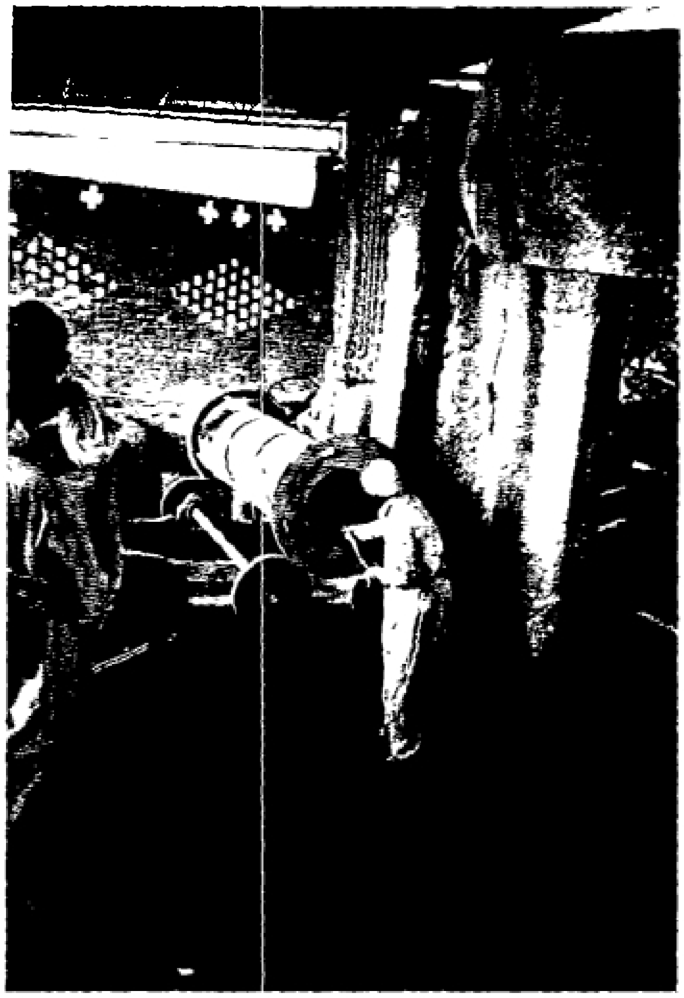
FAISALABAD

PHOTOGRAPH 18

DUCTILE IRON PIPE BEING USED FOR THE CONSTRUCTION
OF A 36" PIPELINE, 18KM OF EXTENSION



LAHORE



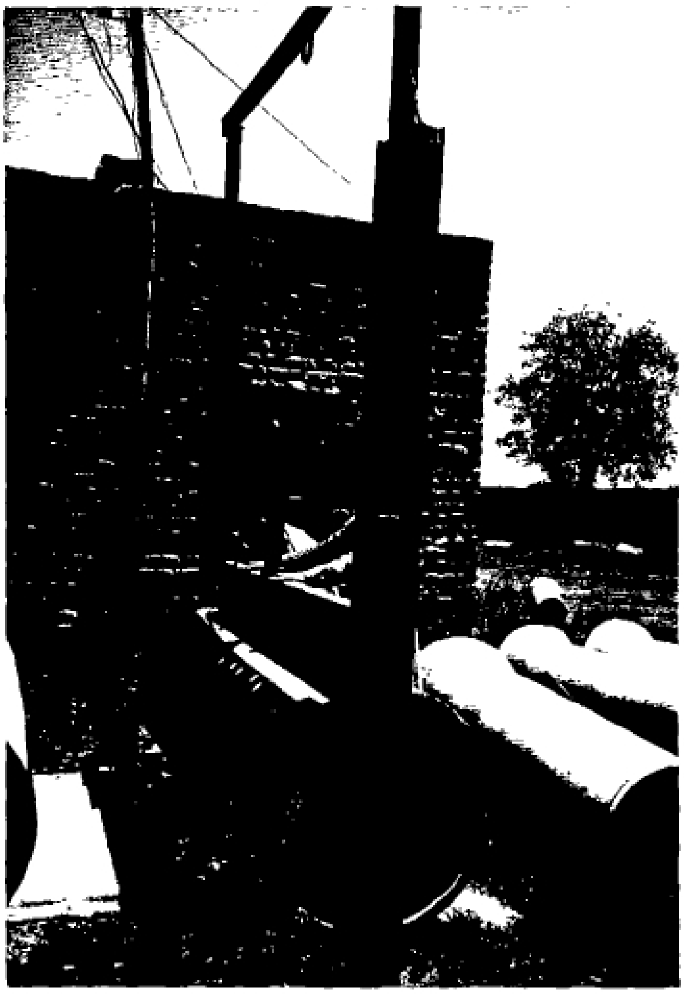
PHOTOGRAPH 19

FABRICATION OF RCC PIPE THROUGH MOULDS PLACED ON SPINNING WHEELS

PHOTOGRAPH 20

RCC MOULDS. CURING OF PIPES

LAHORE

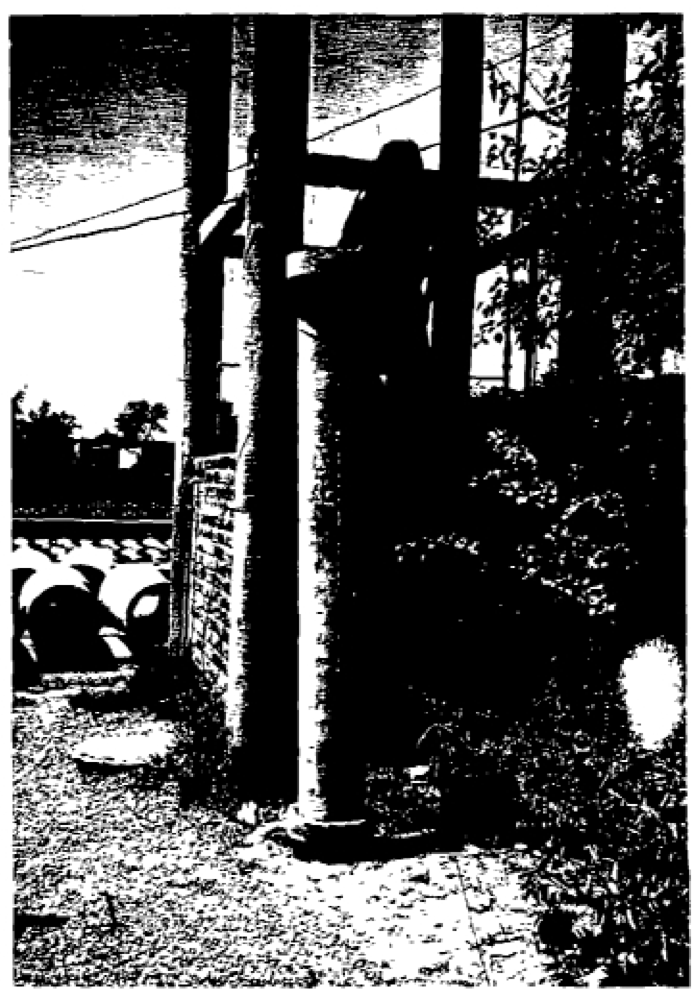


PHOTOGRAPH 21

CRUSHING STRENGTH TEST
OF RCC PIPES

PHOTOGRAPH 22

SPECIAL HYDROSTATIC TEST
TO CHECK THE EFFECTIVENESS
OF A NEW DESIGN OF JOINT
IN AN RCC PIPE



LAHORE

PHOTOGRAPH 23

TRAINING CENTRE IN WASA'S PREMISES. FIELD TEST FOR SIMULATION OF LEAKS

PHOTOGRAPH 24

TRAINING CENTRE IN WASA'S PREMISES: METAL ROD FOR LEAK DETECTION

LAHORE

PHOTOGRAPH 25

DEMONSTRATION OF A MANHOLE AT WASA'S TRAINING CENTRE

PHOTOGRAPH 26

FLOWMETER INSTALLED FOR SHORT PERIODS AT THE OUTLETS OF TUBEWELLS FOR MEASURING OF WATER PRODUCED

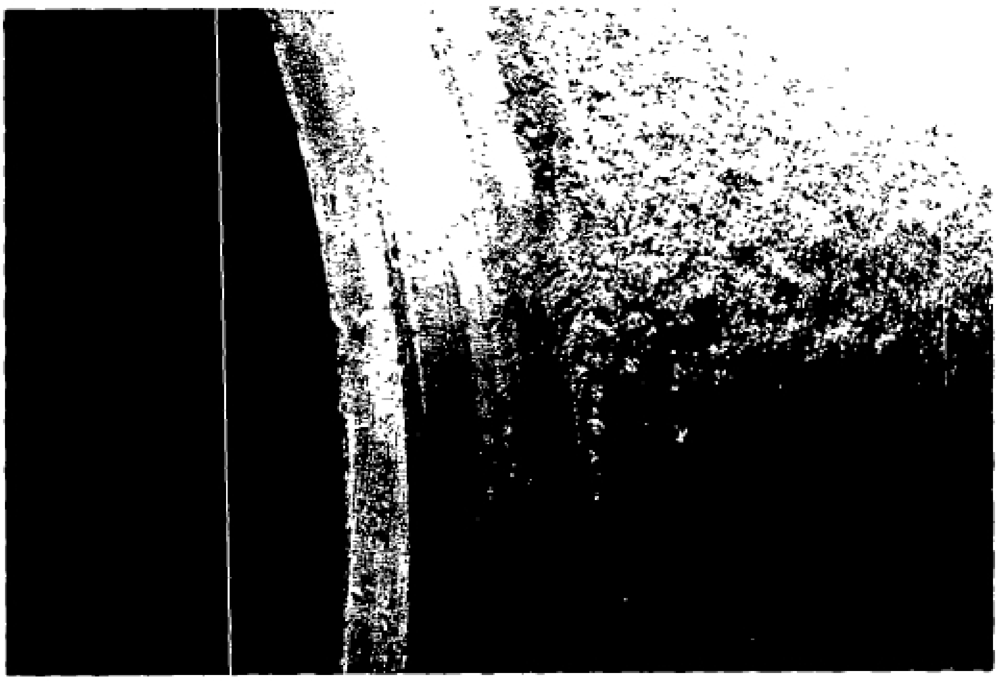
KARACHI (KDA)

PHOTOGRAPH 27

SPRAYING MACHINE FOR SPRAYING OF CEMENT AND MORTAR COATING OVER SURFACE OF PIPE

PHOTOGRAPH 28

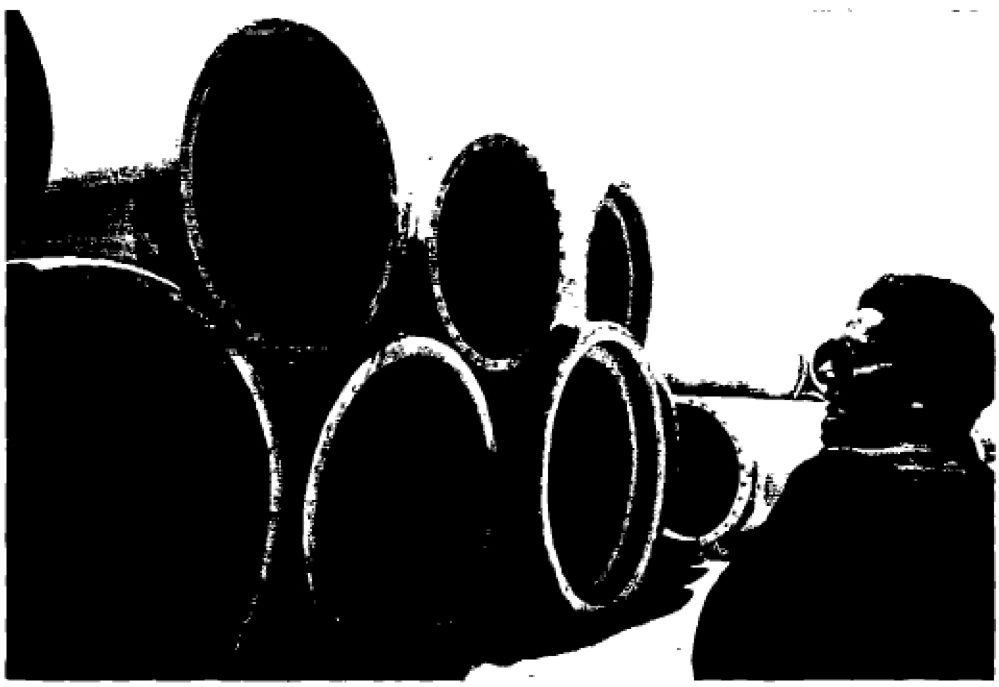
SPIGOT OF A PRCC NON-CYLINDER PIPE



KARACHI (KDA)

PHOTOGRAPH 29

PRCC NON-CYLINDER PIPES FABRICATED AT KDA' FACTORY

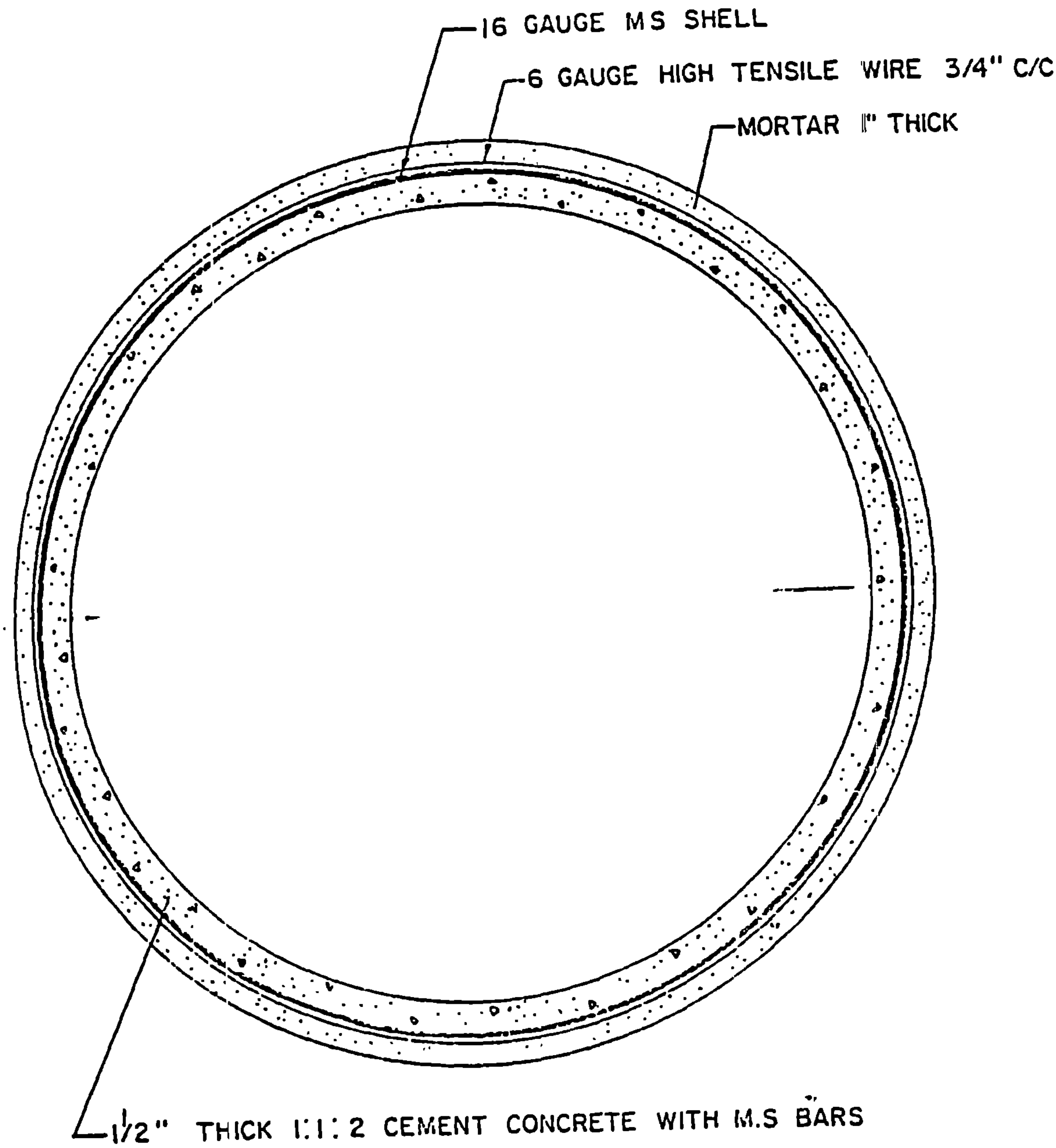


ANNEX 4

FIGURES

FIGURE 3.1

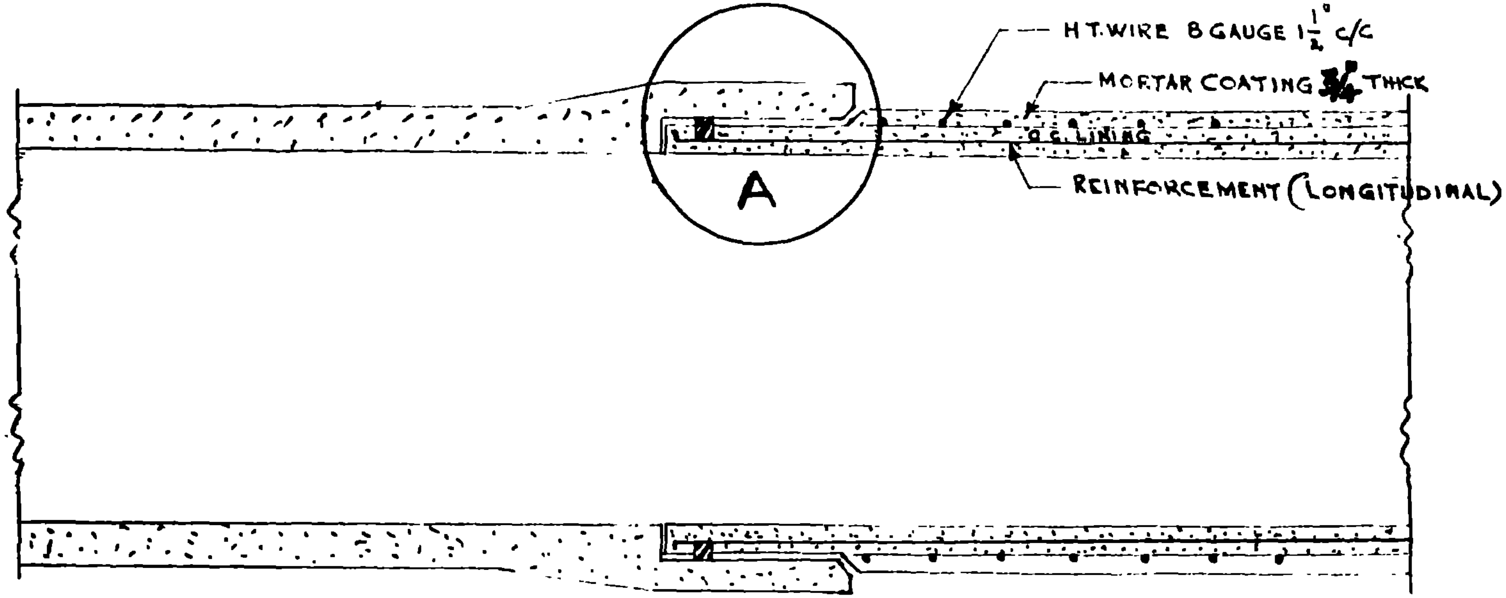
SECTIONAL DETAILS
OF PIPE CONSTRUCTION (36")



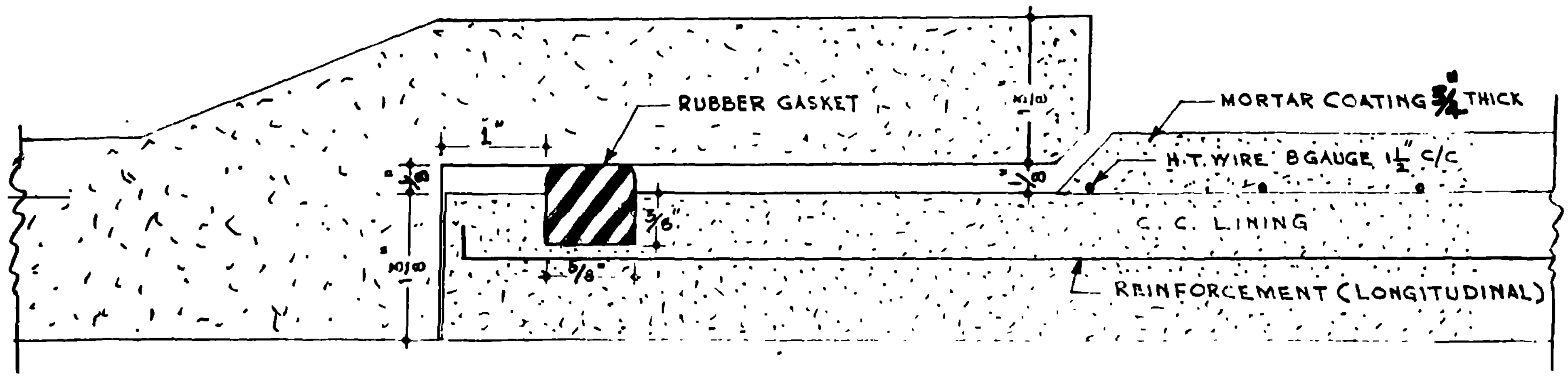
Source: Capital Sevelopment Aauthority. Rehabilitation of water treatment plant at Simly and conduction mains from Simly to Islamabad. 1989 (ref. 3)

FIGURE 3.2

DETAILS OF PRCC JOINTS USED IN ISLAMABAD



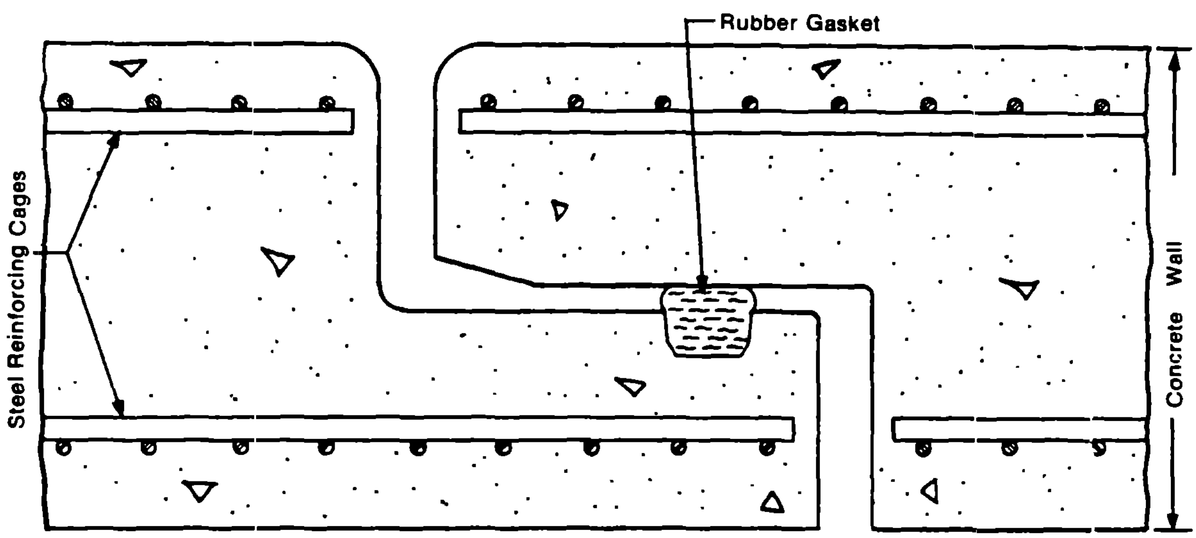
TYPICAL FLEXIBLE JOINT OF PRCC PIPE



ENLARGED DETAIL AT 'A'

FIGURE 4.1

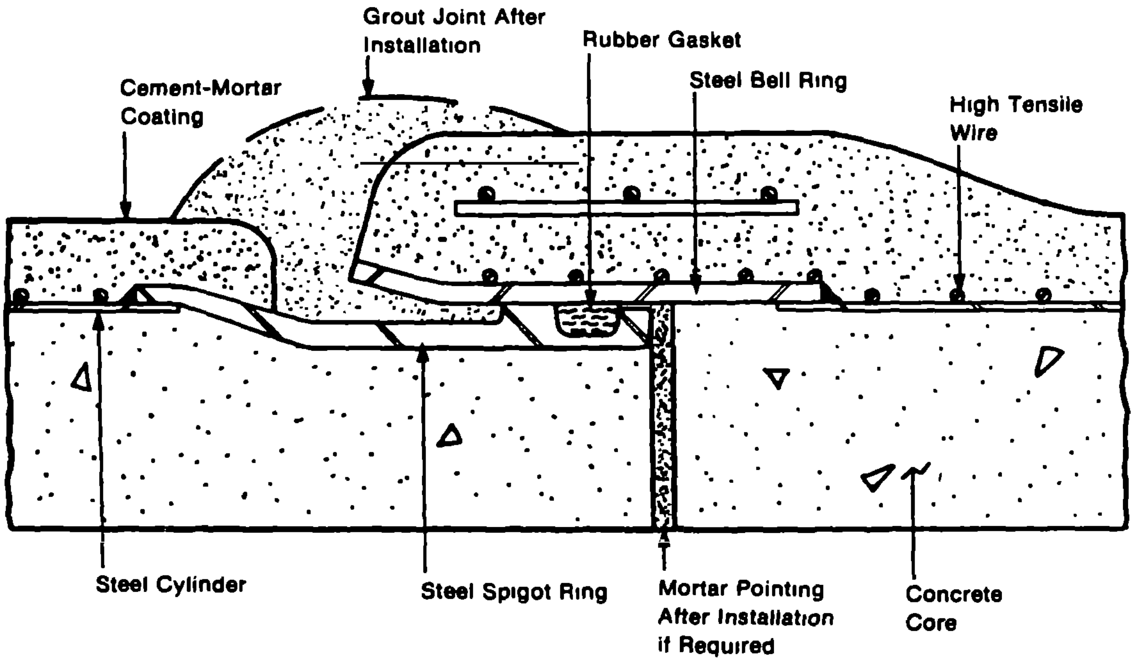
REINFORCED CONCRETE PIPE
WITH CONCRETE BELL AND SPIGOT JOINT



Quoted from ref.(6)

FIGURE 4.2

RESTRESSED CONCRETE CYLINDER -
LINED CYLINDER PIPE CROSS SECTION



Quoted from ref.(6)

For further information, write to:

The Manager
Community Water Supply and
Sanitation, EHE/CWS
World Health Organization
1211 Geneva 27, Switzerland