

CHAPTER 13

BILLING AND COLLECTION

13.1 INTRODUCTION

Revenue management system is an important aspect of any Water supply System as it governs the financial aspect. Besides fixing a tariff structure, billing and collection of revenue play an important part.

13.2 TARIFF FIXATION

The water charges to be fixed by the utility take into account the ability of the system to meet the expenditure on the following heads. (i.e.)

- Operating Cost (excluding establishment cost).
- Establishment Cost.
- Depreciation.
- Debt Services & Doubtful Charges.
- Asset replacement fund.

Tariff structure should be fixed and revised periodically. Automatic increase of tariff periodically on index basis can also be adopted. Where the same authority also provides sewerage system, charges for this can also supply through Public stand post, may be charged and also be included as a percentage of the water charges.

13.3 CATEGORIES OF CONSUMERS

The various categories of consumers are:

- i) Domestic,
- ii) Commercial (Business entities, Hotels, Industries etc.),
- iii) Government Authorities,
- iv) Partly Commercial,
- v) Bulk Consumers.

Among the five categories, the domestic consumers are the privileged class of people in terms of supply of water and collection of taxes mainly because they use water for their healthy existence. The other categories of consumers largely use water while carrying out commercial/business activities. Therefore, the distribution of cost incurred on the maintenance of such system to each class of consumers should be logically and appropriately determined with

reference to the level of service rendered. Finally, a projected income on account of water charges should take into account the various factors stated in the paragraph above.

13.4 METHODS OF WATER CHARGES

The methods of levying water charges can be any one or more of the following:

- A. Metered System:
 - 1. Actual consumption of water.
 - 2. Minimum fixed charge.
- B. Non-Metered System:
 - Fixed charge per house per month.
 - Fixed charge per family per month.
 - Fixed charge per tap per month.
 - Percentage of rateable value of the property.

13.5 WATER BILLING PROCESS

The various stages in the Cycle of Water Billing Process are:

- Data gathering (Meter reading in case of metered billing).
- Generation of bill based on this data.
- Distribution of bill to consumer.
- Payment of the Bill by the Consumer.
- Sending the receipt details to billing section.
- Related accounting.

Irrespective of the basis of the billing-metered/unmetered the billing system needs three major database:

- Master Data - This is the data, which needs to be entered only once when the consumer/connection is added into the database. This data is relatively static in nature and does not change periodically. Various data items, which need to be stored, (depending on the type of water charges) are:

Consumer number, name of consumer, address, type of use, type of consumer, tap size, data of connection, details of feeder line, locality, house number, water connection number, number of taps, number of families, meter make, meter number, first reading, ownership of meter, deposit amount etc.

- Data for each billing cycle - This data will be entered for every consumer for every cycle and will be used for calculating the demand of that billing cycle. Various data items which need to be stored are-

Consumer number, data of meter reading/period for which billed, status of the connection and any changes in master data etc.

- Receipt Data - This data will be the data related to the payments made by the consumer against the bill issued. This data will be entered on daily basis irrespective of the billing frequency. Various data items which need to be stored are:

Consumer number, date of receipt, receipt number, details of the collection center, cash/cheque (If cheque - cheque no, bank branch) Part payment/adhoc payment/deposit, account head for posting etc.

13.5.1 DATA GATHERING

For better administrative control over the complete billing process the city/town is divided into various zones/sections geographically or as per the distribution networks (service reservoir wise). It is observed that the cities already have ward numbers or localities which can be used as they are but if the billing is as per the distribution network the billing system can provide very important feed back as far as water/revenue losses are concerned (unaccounted for water - UFW).

These zones are further divided into smaller area (Wards) for better control. The person responsible for gathering data from these areas is the meter reader/ward clerk. In case of metered system the number of consumers who can be handled by one-meter reader will depend upon the geographical spread of the area and other office jobs to be performed by the person. In many utilities the range vary from 800 to 1500 consumers per month. In case of unmetered system the number can be increased.

The prime responsibility of meter reader/meter clerk will be to gather all the data related to the water connections in the given area, to collect all the data related to new connections/disconnection or any change in the category.

13.5.2 GENERATION OF BILLS

The water rates/tariff structure may have one or more aspects from the following - consumption based, flat rate, minimum charges, fixed charges, average consumption based etc.

Depending on the data gathered the demand for a particular billing period is calculated. The outstanding amount is worked out on the basis of details of payments received. The charges for delayed payments or amounts not paid are calculated as per the rules. The bills are generated area-wise.

13.5.3 DISTRIBUTION OF BILLS TO CONSUMER

The distribution of bills can be done using any one of the following:

- i) By post or courier,
 - By persons specially appointed for this purpose
 - By concerned meter readers/ward clerks
- ii) In a special round for distribution of bills,
- iii) At the time of meter reading for the next round.

(This option saves effort/manpower but there is delay in one complete cycle in reading and distribution of bills).

13.5.4 PAYMENT OF BILLS BY CONSUMER

The payments can be accepted at any one or more of the following:

- Counters at various offices of the Board/Corporation/Utility.
- Various branches of bank/banks authorized for accepting payments.
- Door to door/on the spot recovery by concerned person/team.
- Electronic fund transfer through various banks offering such option/directly.
- By cheque through post or drop boxes.
- Through societies authorised by government, such as cooperative societies.
- On line payments.
- Automatic kiosk.

13.5.5 SENDING RECEIPT DETAILS TO BILLING SECTION

The collection counter/bank/person shall send the receipt details to the billing section periodically (preferably daily basis) and the same is entered into the system and the totals cross-checked.

13.5.6 RELATED ACCOUNTING

The billing section also carries out the accounting related to these receipts such as posting of receipts, generation of demand registers or ledgers on periodic basis. The complete accounting related to the billing can be more efficiently carried out by the computerized system.

13.5.7 FREQUENCY OF BILLING

The frequency of Billing governs the cash flow of the water billing system and thus more frequency means regular cash flow.

The frequency of billing depends mainly on the type of system used. For non-metered system the billing could be quarterly and for the metered system the billing could be bi-monthly. But in both cases all non-domestic, Industrial, Bulk Consumers must be billed monthly. The only other factor which can be considered in this respect is the availability of manpower for billing process and the cost of issuing bills in one complete billing cycle.

13.5.8 DELAYED PAYMENTS

Since water is being treated as a commodity consumed the advance billing is generally not carried out. It is therefore 'a must' to levy penalty/interest on the delayed payments of the bills.

13.6 COMPUTERISED WATER BILLING SYSTEM

Computers are now widely used in day to day activities. For a water billing system, which is complex, repetitive and has voluminous data, computerization is recommended. Computerisation overcomes many of the defects in the manual system, is fast and gives a control on the system. Computerisation helps in decision-making. The output formats can be

tailored to suit quick retrieval of information that is necessary for decision making. Consultants and experts are now available to help in setting up a computerized system.

13.6.1 ADVANTAGES OF COMPUTERISATION

The advantages of the computerisation of billing and collection are as follows:

- Listing of customer accounts with unserved bills.
- Quantity analysis on line.
- Query for list of debtors.
- Quick MIS for on the spot analysis of important parameters.
- Bills generated for the month.
- Amount collection up to the date.
- Number of connections.
- Total working and Nonworking meters.
- Disconnection.
- Water consumption.
- Demand Collection Balance (DBC) statement.
- Receivables monitoring and fixation of targets for billing.
- Performance indicators.
- Meter reader performance.
- Collection efficiency.
- Billing pattern.
- Water consumption.
- Billed units.
- Reports on debtors requiring continuous persuasion.

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CHAPTER 14

SYSTEM MANAGEMENT

14.1 INTRODUCTION

14.1.1 NEED FOR EFFECTIVE MANAGEMENT

Lack of effective management or poor management is the single largest factor which causes the greatest negative impact on water supply systems. This is clearly evident when there are no well defined objectives, no long term planning, no short term programming or budgeting. Hence there is a need for guidance to the managers in-charge of the O&M of urban drinking water supply systems in formulating and implementing activities aimed at improving the efficiency and effectiveness of O&M. The ultimate objective of the managers is to provide to the consumer the best quality service at the lowest cost.

14.1.2 WHAT THE CHAPTER CONTAINS

In this chapter the systems approach to management of O&M - conceptual framework, methodology, centres of decision and basic indicators for the development of management information systems, is briefly introduced. Decision support systems are explained and management of water supplies in emergency situations is described.

14.2 SYSTEMS APPROACH TO MANAGEMENT

14.2.1 SYSTEMS APPROACH

In a systems approach, each water supply organisation is considered as an overall agency within which is a range of organizational systems. Each organizational system is known by its area of specific action and represents specific functions. These systems can be commercial, operational, planning, administrative support (transport, supplies etc.), financial, human resources and management information. These main systems can be further classified according to the differences in decision making and information processes, inputs, outputs, interactions and interconnections. The processing of information linked to the management activities is the basis for determining targets, fixing priorities, schedules, responsibilities, distribution of resources and the entire decision-making process.

14.2.2 ADVANTAGES OF SYSTEMS APPROACH

This approach enables managers to describe and reorganize the service framework of a water supply agency and to allocate resources so that targets can be achieved. This approach will also be the basis for management control to measure results, take corrective action, formulate new parameters and distribute new resources. This approach allows managers to study

relationships between various wings of the agency and hence facilitates analysis of the functioning of the agency.

14.2.3 OPERATIONAL SYSTEM

The objective of an agency's operational system is:

- To establish standards for the delivery of water that is satisfactory in respect of quality, quantity, continuity, coverage and cost.
- To maintain the installations and equipment in a condition that will ensure that they can be operated satisfactorily, function efficiently and continuously, and last as long as possible at lowest cost, and
- To produce information on the water supply and their component units with specific reference to their functioning and their adequacy to meet the needs of users, thus enabling the agency to evaluate the performance of the installations and the effectiveness of the services.

14.2.4 COMPONENT ELEMENTS

The component elements of a water supply operational system are collection, treatment, storage and distribution of water including customer support. Main functions in O&M are:

- Installations and equipment will be operated in order to carry out production and distribution of drinking water.
- Monitoring by the agency the functions of operation of the facilities.
- Monitoring the agency's services regarding quality, continuity and coverage of water supply.
- Carrying out maintenance activities efficiently and economically.
- Monitoring the performance of the equipment and evaluating the effectiveness of maintenance.
- Maintenance information will be gathered for pointing out potential problems such as weakness of structures, reliability of equipment and identifying obsolete equipment and determining how long the facilities can function usefully.

Maintenance objectives and standards are set-forth so that maintenance activities yield maximum benefit at minimum cost.

14.3 MANAGEMENT INFORMATION SYSTEM (MIS)

The efficient and effective performance of an agency depends on a clear relationship between management activities such as planning, organisation, selection and training of staff coordination, direction and control of the functions of the agency. The interaction between the individuals at different management levels, together with use of information in the decision making process, is important to the agency's performance. Each of the management levels has different centres of decision and each of these is supported by an information system. Management Information System is defined as a formal system of making available to the management accurate, timely, sufficient, and relevant information to facilitate the decision

making process to enable the organisation to carry out the specific functions effectively and efficiently in tune with organisation's objectives. Organisations have many information systems serving at different levels and functions within the organisation. The data fed into the MIS initially is internal data and later data from other institutions such as from community and others can also be fed. Each agency has to decide as to which information is relevant and then evolve its own procedures for accurate collection, measurement, recording, storage and retrieval of data. The MIS can be developed either by manual data collection or by use of software.

14.3.1 ORGANISATIONAL STRUCTURE

In order to achieve the objectives of the operational system, efficient administration of the processes is necessary. Management uses the productive capacity of the agency's staff to achieve the objectives. Managers are responsible for influencing how the agency is organized to attain its objectives. The organizational structure should be such that it allows coordination between all units of O&M. Human, financial and material resources should be constantly available for carrying out the O&M activities. Management activities and centres of decision are organized according to the authority and coordination (functional).

14.3.2 MANAGEMENT LEVELS

The levels of management and assignment of functions will vary from agency to agency depending on the situation and the staff. Normally there are three levels viz. Senior, middle and operational management. These levels and their functions are as follows:

14.3.2.1 Senior Management

Senior management responsibilities include: decisions which will have long term effect and setting objectives for quantity and quality of water, setting priorities for expansion of coverage and setting targets to be achieved, administration of personnel matters and efficient use of funds, conservation of water (prevention of wastage of water), arranging for a situation analysis and taking up long term planning and forecast of the agency's ability to provide coverage at lowest cost, raising productivity levels, ensuring that best safety procedures are followed etc.

14.3.2.2 Middle management

Middle management is concerned with how efficiently and effectively resources are utilised and how well operational units are performing, prepare medium term plans including procurement and distribution of resources, expanding coverage of services, reducing water losses, reducing costs and increasing productivity, monitoring water quality etc.

14.3.2.3 Operational management

Operational management is to ensure that operational units work efficiently and last as long as possible, work for reducing and controlling leaks, undertake measurement of flows and pressures and monitoring the performance of the water supply system, ensure quality control of water in production and distribution, implement preventive maintenance programmes, improve efficiency, increase productivity and reduce costs and establish lines of communication with community and foster good public relations.

14.3.3 SIZE OF ORGANISATION AND SCALE OF OPERATIONS

The agency has to adapt to the environment in which it operates and hence will have organizational units to suit its size and complexity. In an agency that serves only one local area, all managerial functions can be carried out at the local level. Metropolitan and regional agencies will need to regroup senior and middle management centrally and delegate operational management to local or area levels. Depending on the number of localities for water supply, the agency may set up intermediate (circles), regional (divisions) or sub-regional (sub-divisions) for operational management of O&M with a concentration of technical resources such as equipment, qualified staff, workshops, transport etc. to supervise and support operations at local level.

14.3.4 CENTRES FOR DECISION MAKING

Normally an agency has decision centres at three levels, strategic at senior level, tactical at middle level and operational at lower level. Strategic decisions are those with long term influence. Tactical decisions are effective in the medium term and operational decisions apply to short term.

14.3.5 MANAGEMENT INDICATORS

The results of actions by managers at the strategic, tactical and operational level are measured by management/performance indicators. These indicators represent a situation, an event or a change brought about by an action aimed at achieving a target set by the agency. These indicators allows the management to set targets, monitor the O&M, evaluate the performance of the agency and take necessary decisions and corrective actions.

14.3.5.1 Limitations

The performance monitoring indicators mentioned here are only indicative and the concepts and procedures suggested herein need to be adjusted as appropriate to suit specific problems of each agency. The performance indicators mentioned herein may supplement but not replace any existing performance indicators. Performance monitoring indicators have to be prepared for individual schemes on the basis of an exhaustive assessment of the water supply service under review. Suggested performance indicators of O&M are given in the **Annexure 14.1**. Each agency has to choose the relevant indicators and then generate the data for MIS required to assess the appropriate indicators.

14.3.5.2 How to use the indicators

The performance indicators and the information generated thereon can be the basis for the decision making process involving determining targets, deciding priorities, drafting schedules of O&M, assigning responsibilities and in distribution of human, material and financial resources. In the planning process these indicators provide basis for preparing long term, medium term or short-term plans with appropriate finances allocated in the budgets. These performance indicators provide a measure of what has been achieved so that the results can be evaluated and disparities corrected. Based on the results the targets and indicators need to be changed so as to be nearer to reality. Some of the uses of these indicators are :

- i) Maintenance information can be used to assess changes in conditions of installations and equipment and identify potential problems such as weaknesses of structure, reliability of equipment or obsolete equipment and also determine how long the facilities can function usefully.
- ii) The maintenance activities can be reformulated to achieve maximum yield at minimum cost.
- iii) The data can be used for the preparation of budget. The best justification for the next year's budget is an accurate record of previous year's activities, costs, workload, growth and production. Similarly the records on use of spares and materials and performance of equipment can be used to document the importance of the programme and get adequate financial support.
- iv) The trend in the agency's workload can indicate where the workload has increased or where the performance has deteriorated requiring more staff.
- v) The need for new equipment can also be justified while preparing budget. Age is not necessarily the only factor for replacing the equipment. Record on production, use and cost of maintenance to keep the equipment operational may also substantiate the need for replacement.
- vi) The review shall bring out need for buying new equipment. Additional equipment (including safety equipment) may become necessary from a review of the performance either due to hiring of staff or the need for developing of equipment for specific purpose.
- vii) The review will provide an assessment of what spares, and consumables are required for the next year/future.
- viii) The review can also bring out the need for economy, for hiring external specialised agency or hiring additional staff for attending to routine or breakdown maintenance or repair work.
- ix) The indicators can be used to measure productivity, reduction in breakdowns or frequency of breakdowns linked to productivity levels so as to achieve reasonable level of maintenance with minimum cost.

Each agency has to choose appropriate methods of evaluating effectiveness in achieving the O&M objectives.

14.4 COMPUTERISED MIS

With the advancement of the Information Technology in this millennium, there is a need to adopt a methodology to align the information strategy with the business strategy of the organisation to derive maximum benefits of computerisation. A computerised system is a more sophisticated method of providing useful information in different formats to different levels within the organisation for discharging duties in a more efficient way. Computers are good at rapid and accurate calculation, manipulation, storage, and retrieval but less good at unexpected or qualitative work or where genuine judgement is required. It has been suggested that computers can be used to best advantage for processing information, which has the following characteristics.

- (a) Number of interacting variables.
- (b) Speed is an important factor.
- (c) Accuracy of the output.
- (d) Operations are repetitive.
- (e) Involves large amounts of data.

A computer package for design and management of information systems is composed of the three distinct entities viz.

14.4.1 INFORMATION SYSTEMS DIVISION

Information system department comprises of a group of information specialists, programmers and system analysts.

14.4.2 THE TECHNOLOGY

Appropriate technology involving the hardware and software is adopted.

14.4.3 THE ENVIRONMENT

Includes the external specialists, hardware and software vendors, consultants, competitors and Government.

14.5 VARIOUS MAIN/SUB SYSTEM FOR MIS IN WATER INDUSTRY

In order to make an effective MIS, it is necessary to identify the potential sources of data in each and every functional area and create reports needed by all users irrespective of their proficiency in data processing. The following are the main/sub systems of a water supply organisation from which the reports for MIS can be generated.

14.5.1 FINANCIAL MANAGEMENT INFORMATION SYSTEM

Financial Accounting

Payroll

Revenue Management

General Ledger

Accounting

Funds

14.5.2 PROJECT MANAGEMENT INFORMATION SYSTEM

Engineering Planning and Design

Construction

Contracts and Monitoring

14.5.3 HUMAN RESOURCE MANAGEMENT INFORMATION SYSTEM

Manpower planning and Recruitment

Personnel Development and Training

14.5.4 MATERIAL MANAGEMENT INFORMATION SYSTEM

Purchasing

Inventory Control

14.5.5 OPERATION AND MAINTENANCE MANAGEMENT INFORMATION SYSTEM

Operation

Maintenance

14.5.6 MARKETING MANAGEMENT INFORMATION SYSTEM

Customer Information

Demand Forecasting

Market planning

14.6 REPORTING SYSTEM

- Operational control level - Handling transactions, process data, preparing detailed reports of various activities, lists, documents, schedules, summary.
- Management control level - obtaining operations data, sorting, analysing and Prioritising, Modifying all information to the requirements for higher level, planning, scheduling, identifying out-of control situations, making decisions, reporting
- Strategic planner level - response to the queries, projections with regard to objectives, resources, and policies of organisation.

14.7 FORMATS OF REPORTING

Various reports to be generated and their exact formats will have to be decided by the authorities concerned so that the MIS together with norms that have been set up will clearly highlight the performance indicators. Some of the following type of information in water industry is suggested for strategic planners level.

14.7.1 FINANCIAL INFORMATION SYSTEM

Monthly capital budget progress details

Annual Billings, Collections, O&M expenditure, Surplus/Deficit

14.7.2 OPERATION AND MAINTENANCE INFORMATION SYSTEM

- Daily reservoir levels, rainfall details, quantity available at source, quantity treated and consumed.
- Weekly % samples with residual chlorine more than 0.2 ppm.
- Weekly pending complaints.
- Fortnightly report on details of new connections.
- Daily status report on mobile water supply.
- Monthly % of unaccounted for water.

14.7.3 HUMAN RESOURCE INFORMATION SYSTEM

- Monthly report on staffing and salary.

14.7.4 PROJECT PLANNING AND CONTRACTS INFORMATION SYSTEM

- Physical and financial status report on ongoing project works.
- Monthly report on contract works awarded.

14.7.5 MATERIAL INFORMATION SYSTEM

- Monthly inventory status report.
- Quarterly report on suppliers' performance.

14.7.6 MARKETING INFORMATION SYSTEM

- Monthly demand forecasting and market planning.

14.8 EMERGENCY / DISASTER PLANNING

14.8.1 DISASTER MITIGATION MANAGEMENT

Any event, natural or man-made, which disrupts a water supply system, can be termed as an emergency. The disasters that may affect a water supply system may vary but the effects are similar. Such disasters occur suddenly. There is no warning and there is no time to plan out how to meet the situation on the spot. It is therefore essential that an advance plan be prepared to meet such exigencies.

14.8.2 EMERGENCY EVENTS

Planning for all types of disasters is not possible. Past experience of emergencies in the system as well as of other systems is very useful in drawing up an emergency plan. We can identify emergencies that are likely to occur; units likely to be affected and steps taken in the past. Some of the events or emergencies that may arise are:

- Power failure.
- Storms and flooding.
- Epidemics.
- Fire.
- Earthquakes and landslides.
- Explosions.
- Breakdown of water supply system units like pumping burst mains etc.
- Strikes by workmen.
- Sabotage or vandalism.
- Water supply Bioterrorism.

14.8.3 STRUCTURE OF THE PLAN

In the preparation of an emergency plan, the following steps should be taken:

1. Consider the whole water supply system and break it up into subsystems from the source upto the consumer's end. Necessary maps, drawings etc. must be included as part of the plan.
2. List the units in each sub-system.
3. Find out what kind of emergency can occur either on the whole subsystem or on the individual units.
4. Plan to prevent such emergencies.
5. Simulate the effects of each emergency on the sub-system or units.
6. Prepare a plan for action for each emergency like meeting water demand through alternative sources, re-routing of supply, rotational supply, supply through tankers etc. The person in charge of each problem area must know the system and be equipped with the necessary plans, materials, personnel etc.
7. Prepare a plan for repairing, restoring the normal supply. The operators, supervisors, workmen must be trained and made aware of the different kinds of work to be taken. This would include knowledge of location of valves, electrical connections to different parts and units of the system. Absence of trained personnel to make critical decisions and carry out orders is often a critical issue.
8. List all agencies, authorities with whom coordinations is necessary, like the State administration, fire department, police etc. with telephone numbers, addresses and names of the persons to be contacted.
9. List all suppliers of equipment, materials, contractors who have to be contacted with names, telephones numbers and addresses.
10. Identify the headquarters for control and instructions. Proper communication facilities are very essential between the control room and various site units.
11. Make provision for medical care, lodging, food etc. for the staff who will be on round the clock duty. This is more necessary when the location of the disaster is far away like transmission mains, intakes etc.
12. Adequate transport arrangements are necessary. List of vehicles that can be required within the organisation as well as from other departments should be maintained with details of the officers to be contacted.

The considerations to be taken in planning for emergencies would include:

- (a) The minimum water required for survival for a person could be 3 to 5 litres per day, whereas the desirable would be about 15-30 l/p/d. For Health centres, it could be 40-60 l/patient per day for inpatients and 5 l/p/day for outpatients. Other demands for good sanitation and hygiene may be estimated. If the emergency is long drawn out, other demands will have to be considered. The figures will depend on local conditions.
- (b) Ground water through hand or motive pumps, ponds, lakes etc.

- (c) Disinfection through chlorine compounds is a widely used technique. Emergency stocks and sources of supply must be planned for.
- (d) Proper security like armed guards etc. may be necessary. If treated water supply is available at convenient distances, use of tankers and transport through tanks can be arranged easily and offers flexibility.

The action plan must include:

- Immediate measures to sustain life.
- Intermediate measures.
- Long term measures.

14.8.4 THREAT OF BIO-TERRORISM

In the recent past, bio-terrorism has assumed importance. Water supply facilities are identified as a potential target. Determination of contamination of water before it reaches the consumer is difficult, as laboratory tests are time consuming. However the following precautions can be taken:

1. Increased security measures and more diligent monitoring for pathogens and chemical toxins.
2. Residual chlorine in the storage or service reservoir is a defence against contamination. Chlorine may not be effective against chemical toxins but it can be effective against some biological toxins and pathogens. Cholera and the botulin toxin that causes botulism can be inactivated by chlorine. However, resistance of many biological agents like plague and brucellosis to chlorine is unknown.
3. Besides tanks, pipelines are also vulnerable, especially where water supply is intermittent. Contaminants can be injected in the pipelines. Monitoring a vast network of pipe is difficult and residual chlorine again is a safeguard.
4. Ensure that all tanks, manholes are covered and under security surveillance. The size of a water utility system may be the best defence. It will require a large quantity of contaminant to poison a reservoir or tank to cause death or debilitation to someone consuming a glass of water. Calculations can be made to determine the quantity of known toxins like potassium cyanide and others required for poisoning the tank or reservoir. Huge quantities of toxin will be required and it will show the logistics of obtaining and administering the volume of toxin required for contaminating the reservoir or tank. This will be a quick check when rumours are spread about poisoning of water at a reservoir or tank. Also using an animal as a guinea pig who can be fed with the alleged poisoned water can also be a check.
5. Detection of chemical and biological agents that are a threat to water supply is now receiving emphasis. Fast on-site tests utilising DNA analysis for pathogens such as anthrax have been developed. There is need to keep abreast of such developments.

ANNEXURE 14.1
PERFORMANCE INDICATORS

S. No.	Indicator	Method of calculation	Remarks
1.	Coverage of area with water supply	Area with water supply/Total area	Identify areas to be provided water supply in the future plans
2.	Index of population covered by service (%)	Length of streets with water pipelines/total length of streets	Is extension of main required?
3.	Percent covered by service	Population served/total population	How to serve the un-served population?
4.	Service level	Quantity of water produced per day/population served	
4.1	Index of population served by public taps (%)	Population served by public taps/total population	
4.2	Average population served by one public tap	Population served by public taps/number of public taps	
5.1	Index of water distributed or measured (%)	Quantity measured or distributed/quantity produced	
5.2	Index of water distributed through public taps (unmeasured %)	Quantity of water supplied through public taps/total quantity of water	
6.	Water not accounted for	Water bills/water produced	
7.	Staff productivity	Number of connection/ Number of Staff	
8.	Operational costs per staff	Total O&M cost/Staff number	
9.	Operational cost per connection	Total O&M cost/number of connections	
10.	Operational cost per KL of water produced	O&M Cost/quantity of water produced in KL	
11.	Production cost	Cost of production/quantity of water produced in KL	
12.	Distribution cost	Distribution cost/quantity of water produced in KL	
13.	Index of use of production or treatment capacity	Quantity of water produced/ installed capacity	
14.	Index of use of transmission line capacity	Quantity of water transmitted/ designed transmission capacity	
15.	Index of use of pumping station capacity	Quantity of water pumped per day/installed capacity	
16.	Index of use of reservoir capacity	Average quantity of water distributed/available storage capacity of reservoirs	

17.	Index of use of energy at treatment plant	Energy consumed per day/ quantity of water pumped per day i.e KW/KL pumped	Is there a need for an energy audit by an external agency?
18.	Index of use of energy at treatment plant	Energy consumer per day/ quantity of water treated per day i.e. KW/KL treated	
19.	Index of use of Coagulant at treatment plant	Coagulant consumed per day/ Quantity of water treated per day (mg/L)	
20	Index of treatment losses	Treated water produced/raw water received	
21.	Index of water quality at treatment plant	Percent samples with greater than permissible turbidity	
22.	Index of unwholesome samples in distribution system	Percent unwholesome samples	
23.	Index of disinfection at treatment plant	Percent samples with less than desired residual chlorine	
24.	Index of use of chlorine at treatment plant	Chlorine consumed per day/ quantity of water treated per day (mg/L)	
25.	Index of power failures at pumping stations	Hours of pumping lost/ 24 hours or designed pumping hours	
26.	Index of other failures at pumping stations	Hours of pumping lost due to reasons other than power failure/24 hours or designed pumping hours	
27.	Index of failure of pumping mains	Hours of pumping lost due to transmission line defects/ 24 hours or designed pumping hours	
28.	Mean time between failure of pumping equipment	Average of time interval between two successive failures of pumping equipment in a year	
29.	Mean time between failure of pumping mains	Average of time interval between two successive failures of pumping mains in a year	
30.	Index of failures		
30.1	Power	Power failures/total failures	
30.2	Pumping equipment	Equipment failures/Total failures	Is the equipment reliable or obsolete
30.3	Pumping main	Pumping main failure/Total failures	

31.	Level of maintenance at pumping stations	Number of prearranged preventive maintenance work orders actually carried out/ Number required to be carried out	
32.	Breakdown works	Number of breakdown works orders carried out by agency's staff	
33.1	Index of works done by outsiders	Number of breakdown works orders carried out by specialised agency	Is it economical compared to agency's own staff?
34.	Distribution system (Zone wise)		
34.1	Index of supply timings	Actual hours of water distributed in a day/required distribution hours	
34.2	Storage ratio	Quality of water distributed/ quantity of storage	
34.3	Residual chlorine	Percent samples with less than desired residual Chlorine	
34.4	Bacteriological quality	Percent unwholesome samples/total samples tested	
34.5	Storage reservoirs cleaning	Actual number of times cleaned/required number of times to be cleaned	
35.	Level of maintenance of pipe lines		
35.1	Number of Leaks reported per day	Number of leaks/km of distribution system	
35.2	Index of Leaks attended per day	Leaks attended per day/Leaks reported per day	
35.3	Number of cross connections reported per thousand connections	Number of cross connections reported/number of connections (in thousands)	
35.4	Number of points with negative pressures		
36.	Consumer connections		
36.1	Total number		
36.2	Domestic (%)		
36.3	Commercial (%)		
36.4	Industrial/bulk (%)		
36.5	Unauthorised connections		
37.	Water audit		
37.1	Index of water distributed	Water distributed/water received at the reservoir	
37.2	Index of Billing	Water billed/water distributed	

37.3	Index of domestic supply (%)	Total domestic supply/total distributed	
37.4	Index of commercial supply (%)	Total commercial supply/total distributed	
37.5	Index of Industrial supply (%)	Total Industrial supply/total distributed	
37.6	Functioning of consumer meters	Number of meters non functional/number of meters	Is there a need to change over to accurate and reliable meters?
37.7	Connections with large consumption	Number of connections	Identify those connections with large (?) consumption whose meters are out of order
38.	Financial Indices		
38.1	O&M cost as per capita/per connection	Total O&M Cost/population served or no. of connections	
38.2	Cost of production of water/KL	Total O&M cost/Quantity of water produced	
38.3	Energy costs as percent of O&M cost	Energy cost/O&M cost	Are the energy costs going up?
38.4	Spares cost or repairs and replacement costs as percent of O&M cost	Repairs & replacement cost/O&M cost	
38.5	Consumables cost as percent of O&M cost	Cost of consumables/O&M cost	
38.6	Staff costs as percent of O&M cost	Staff cost/O&M cost	
38.7	Operating ratio for the previous year	Operating revenue/ operating expenses	Identify the reasons for fewer ratios. Is there a need for revision of tariff?
38.8	Current year's operating ratio (as on date of review)	Operating revenue for the year/operating expenses	Identify reasons for shortfall
38.9	Ratio of revenue demanded	Bills served or revenue demanded/budgeted demand	Identify reasons for shortfall
38.10	Ratio of consumer connections Billed	No. of consumer connections for whom bills are served/ total number of connections	Identify if bills are not served for those connections with large (?) consumption
38.11	Ratio of revenue collected	Revenue collected/bills raised	If the connections with large (?) sums due who have not paid their bills

38.12	Status of disconnection notices	Number of notices served/ number of defaulters	Identify whether disconnection notices are served for connections with large sums due (?)
39.	Safety Record		
39.1	Number of accidents per Km or connection	Total number of accidents/ total length of pipe lines or no. of connections	
39.2	Percent fatal accidents	Number of fatal accidents/ total accidents	
40.	Consumer satisfaction		
40.1	Number of consumer meets organized at section level	Number	
40.2	Number of consumer complaints per thousand connections	Number of consumer complaints received per day/ Number of connections in thousands	
40.3	Consumer complaints attended (no water/inadequate pressure/poor quality)	Average Number of consumer complaints (weekly or monthly) /number of connections	
40.4	Ratio of consumer complaints attended	Number of complaints received/number of complaints attended on the same day	
40.5	Ratio of unattended complaints (spilled over to next day)	Number of complaints left unattended on the same day/ number of complaints received	

CHAPTER 15

WATER AUDIT AND LEAKAGE CONTROL

15.1 INTRODUCTION

WATER AUDIT

Water Audit of a water supply scheme can be defined as the assessment of the capacity of total water produced by the Water Supply Authority and the actual quantity of water distributed throughout the area of service of the Authority, thus leading to an estimation of the losses.

Otherwise known as non-revenue water, unaccounted-for water (UFW), is the expression used for the difference between the quantity of water produced and the quantity of water which is billed or accounted for (Table-15.1).

TABLE 15.1
UNACCOUNTED-FOR WATER

Water accounted for	Residential		Billed water	Revenue water	
	Commercial				
	Industrial				
	Institutional				
	Special Consumption + Operational Consumption				
Water not accounted for	Illegal Consumption		Losses	Non-Revenue water	
	Loss of water	Over flow			
		Leakage			
		Waste			
	Metering errors	Macro-metering errors			
		Micro-metering errors (House connection meters)			
Estimation errors					

15.2 OBJECTIVE OF WATER AUDIT

The objective of water audit is to assess the following.

- i) Water produced,
- ii) Water used,
- iii) Losses both physical and non-physical,
- iv) To identify and priorities areas which need immediate attention for control.

15.3 PLANNING AND PREPARATION

Planning and preparation shall include the data collection element and the preparation of sketch plans for the distribution centres and other locations for the installation of the flow meters. Also included within this shall be the confirmation of flow rates for the bulk meter locations which has been carried out by the use of portable ultrasonic flow meters.

15.3.1 VERIFICATION AND UPDATING OF MAPS

Mapping and inventory of pipes and fittings in the water supply system: If the updated maps are available and bulk meters are in position network survey can be taken up as a first step. Otherwise maps have to be prepared and bulk meters fixed.

The agency should set up routine procedures for preparing and updating maps and inventory of pipes, valves and consumer connections. The maps shall be exchanged with other public utilities and also contain information on other utility services like electricity, communications etc. Refer to 8.4.2.1 and 8.4.2.3 in Chapter on “Operations and Maintenance of Distribution System”.

15.3.2 INSTALLATION OF BULK METERS

The major activity during the overall water audit will be bulk meter installation at those points on the distribution network where water enters the system. It is expected that bulk meters will be required at the following locations:

- All major system supply points.
- All tubewells which supply the system directly.
- Major transfer mains which are expressly required for audit.

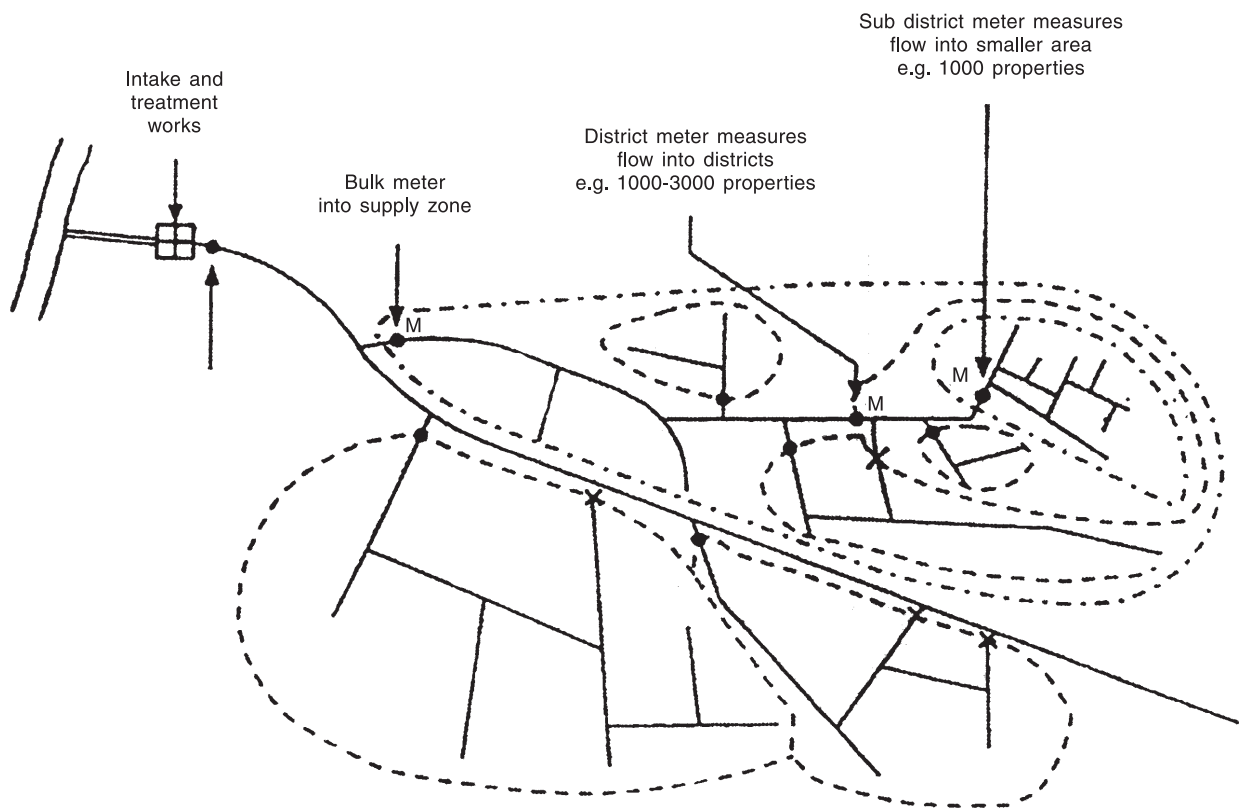
At distribution centres, the most appropriate meter position is on the outlet pipe from the service reservoir. Installation of a meter at this point will allow measurement of flows into the system not only if supplies are coming from the service reservoir but also if they are being pumped directly from the clear water reservoir (CWR). Refer Fig 15.1

The size of the meter can be determined by:

- Number of properties served.
- Per capita consumption (litres/person/day).
- Population density.
- Hours of supply.

Meter sizes must be sized according to current supply hours. Future changes to system operation may require the substitution of some bulk meters with those of a smaller size, due to reductions in flow over longer supply hours.

It is expected that bulk meters installed in locations where supply is rationed will tend to over-read. This is because when supplies are turned on, the air present in the pipes can cause the meter to spin. This problem may be overcome through the use of combined pressure and flow loggers. Flow through the meter will be recorded in the normal way. However, analysis of the pressure and flow plots together will enable the identification of those period of time when a flow is recorded at zero pressure. This time should correspond to the period when the meter is spinning, and the true flow through the meter over a period of time can therefore be calculated.



15.4 MONITORING OF THE PRODUCTION SYSTEM

The assessment of the leakage rates through the various features of the water supply system should be undertaken. These will include:

- Raw water transmission system.
- Reservoirs.
- Treatment Plant.
- Clear-water transmission system.
- Inter zonal transmission system.
- Tube wells.

15.4.1 TRANSMISSION SYSTEM

The methodology adopted to make an assessment of the level of losses in the transmission system is to install insertion probes/bulk meter at both ends of each section of main being monitored, thus monitoring both the inflow and outflow of the section. This monitoring should be done for a minimum period of 7 days. The difference of inflow and outflow will indicate the losses in the transmission main. The advantage of this method is that the trunk main need not be taken out of service.

Another way to measure leakage is to close two valves on the main. 25mm tapping are made on either side of the upstream valve and a small semi-positive displacement flow meter is connected between the two tappings. Flow through this meter will indicate the leakage in the main between the two closed valves. It must be ensured that the down stream valve is leak proof.

The approximate position of any leakage measured can be determined by the successive closing of sluice valves along the main in the manner of a step test.

15.4.2 RESERVOIRS

To reduce or avoid any leakage or consequent contamination in reservoirs, the reservoirs should be periodically tested for water tightness, drained, cleaned, washed down and visually inspected.

The losses in water storage structures can be monitored for a particular period noticing the change in the level gauges when the structure is out of use i.e. there is no inflow and outflow of water during this monitoring period.

The most reliable method for measurement of leakage from a service reservoir is to fill it to full level and isolate it from supply and to measure change in level over suitable time period. Suitable equipment to measure reservoir levels could be chosen like:

- Sight gauges

- Water level sensors (as per manufacturers instruction)

- Float gauges

- Submersible pressure & level transducers (as per manufacturers instruction).

15.4.3 TREATMENT PLANT

The losses in treatment plant can be monitored by measuring the inflow into the plant and outflow from the plant with the help of mechanical/electronic flow recorders. The difference of inflow and outflow for the monitoring period will indicate the water losses in the plant. In case the loss is more than the design limit, further investigation should be carried out for remedial measures.

15.4.4 TUBE WELLS

In conjunction with the programme of bulk meter installation is the operation to monitor the approximate yield from the tubewells This exercise can be carried out by the installation of semi-permanent meters to the tube wells on a bypass arrangement similar to that for the bulk meters. This can be effected utilising the smaller diameter bulk meters. Insertion probes or the

portable ultrasonic flow meters will be used for measurement of flows on the common feeder mains.

15.5 MONITORING OF DISTRIBUTION SYSTEM

Distribution system comprises of service reservoirs, distribution mains & distribution lines including appurtenances, consumer service lines, connections viz. metered, unmetered (flat rate), public stand posts, hydrants, illegal connections. The area of the city is divided into Waste Metering Areas (WMA)/ Sample area zones. Since at one time it is not possible to carry out water audit in all WMAs, it is done for a part of the city at one time followed by other parts of the city in future. This has to be a continuous process managed by a water audit wing or a Leak Detection cell.

Water audit of the distribution system consists of:

- i) Monitoring of flow of water from the distribution point into the distribution system (WMA).
- ii) Consumer sampling.
- iii) Estimating metered use by consumers.
- iv) Estimating losses in the appurtenances and distribution pipe line network including consumer service lines.

15.5.1 MONITORING FLOW INTO THE DISTRIBUTION SYSTEM

A bulk meter of the appropriate type and size is installed at the outlet pipe of the service reservoir or at the point where the feeding line to the area branches off from the trunk main. If water from the WMA flows out into another zone a valve or meter is to be installed at this outlet point.

15.5.2 CUSTOMER METER SAMPLING

Water audit is a continuous process. However, consumers' meter sampling can be done on yearly basis by

- Review of all existing bulk and major consumers for revenue. A co-relation between the production/power consumed in the factory vis-a-vis water consumption can be studied.
- Sampling of 10% of all bulk and major consumers.
- Sampling of 10% of small or domestic consumers.
- Series meter testing of large meters suitably according to standard, calibrated meter
- Testing of 1% large and 1% domestic meters.
- Estimating consumption at a representative 5% sample of Public Stand Posts (PSP) and unmetered connections by carrying out site measurements.

All non-functioning and broken meters in the sample areas will be replaced and all meters may be read over a week. This information will be brought together with information derived from the workshop and series testing in order to estimate the average water delivered and

correction factors for consumer meters These factors can then be extrapolated to the rest of the customer meter database

15.5.3 CUSTOMER METERED USE

The average consumption per working meter is calculated by dividing the total consumption of all working meters in the WMA by the number of working meters. This average consumption is then multiplied by the meter correction factor derived from the customer meter sampling exercise in which the serial metering test and bench test of meters is done. Average slow or fast percentage of test recording of meters is known as correction factor. This average metered consumption multiplied by the correction factor is known as water used by consumer. Unmetered connections & illegal connections will also be treated to have same consumption as metered property.

Estimating customer metered use can also be carried out using the customer data obtained from the customer billing records. Consumption analysis will be carried out by:

- Consumer type.
- Revenue zone/sample area/WMA.
- Direct supply zone/sample area/WMA.
- Overall for the city/Water Supply Scheme.

During the analysis the correction factors derived in the sampling exercise will be applied for metered consumption. Default values will be applied to connections with estimated bill. Public Stand Posts (PSP), unmetered and illegal use will also be treated as metered consumption. Analysis of the billing data will enable the production of:

- A report on overall water delivered.
- An estimate of water delivered to wards/sample areas/WMA.
- UFW i.e., Physical losses and non-physical losses.
- Errors in assessment of water production. (in case of tube wells).

15.5.4 LOSSES IN CUSTOMER SERVICE LINES AND APPURTENANCES

Losses can be calculated by deducting from the total quantity, the following :

- Metered consumption.
- Unmetered consumption (assuming metered use).
- Illegal connection consumption (assuming metered use).
- PSP use.
- Free supply, fire-hydrants, use in public toilets, parks etc.

15.6 ANALYSIS

The information of the results of monitoring the distribution system together with the results of the bulk metering exercise will be consolidated and brought together to produce the water balance report and the overall water audit report. These results may be interpreted in financial terms.

Further exercise will be done to classify the water consumed/wasted/lost in financial terms with relation to the current and future level of water charges. This exercise will be carried out as a result of the field tests and the review of existing records forming part of the overall water audit.

This water audit will provide sufficiently, accurate areawise losses to prioritise the area into 3 categories viz.

1. Areas that need immediate leak detection and repair.
2. Areas that need levels of losses (UFW) to be closely monitored.
3. Areas that appear to need no further work at the current time.

It is recommended that cursory investigation should be carried out in the areas that appear to have the least levels of losses (UFW), locating any major leaks, followed by the leak repairs would reduce the losses (UFW) levels further.

After water audit of few cities it has been established that the components of UFW may generally be as follows:

i) Leakage (physical losses)	75 to 80%
ii) Meter under-registration	10 to 15%
iii) Illegal/unmetered connections	3.5 to 6%
iv) Public use	1.5 to 3.5%

15.7 PROBLEMS FACED IN WATER AUDIT

- Proper network details in the shape of maps are not available. If at all some maps are available, these are not updated with proper indication of appurtenances.
- Normally much attention is not paid by the Water authorities to the water audit of the water supply schemes.
- Barring a few major cities, separate Water audit units are not available with the Authority. Wherever these units are available the water audit staff is not motivated enough to carry out the work.
- By and large, water authorities are not equipped with the necessary equipment.
- Proper budgetary provision is not available for carrying out continuous and effective water audit.
- Lack of co-ordination between the Water Audit unit and operational and maintenance staff.
- No emphasis is given on Information Education and Communication (IEC) activities for conservation of water.

Water audit provides fairly accurate figures of both physical and non-physical losses in the different waste metering areas of city. Accordingly the areas with higher percentage of losses can be identified for carrying out the leakage control exercise for reduction of water losses. As explained earlier, the reduction in losses will result in saving in the form of:

- i) Operational cost
- ii) Capital cost

Apart from this, the saving in losses will result in consumer satisfaction, improved water quality and additional revenue to the Water Authority and postponed of augmentation schemes.

15.8 OBJECTIVE OF LEAKAGE CONTROL

The overall objective of leakage control is to diagnose how water loss is caused and to formulate and implement action to reduce it to technically and economically acceptable minimum. Specifically the objectives are :

- To reduce losses to an acceptable minimum.
- To meet additional demands with water made available from reduced losses thereby saving in cost of additional production and distribution.
- To give consumer satisfaction.
- To augment revenue from the sale of water saved.

15.9 WATER LOSSES

The water losses can be termed into two categories.

1. Physical losses (Technical losses)
2. Non-physical losses (Non-technical losses/Commercial losses)

15.9.1 PHYSICAL LOSSES (TECHNICAL LOSSES)

This is mainly due to leakage of water in the net work and comprises of physical losses from pipes, joints & fittings, reservoirs & overflows of reservoirs & sumps.

15.9.2 NON-PHYSICAL LOSSES (NON-TECHNICAL LOSSES)

Theft of water through illegal, already disconnected connections, under-billing either deliberately or through defective meters, water wasted by consumer through open or leaky taps, errors in estimating flat rate consumption, public stand posts and hydrants.

15.10 LEAKAGE DETECTION AND MONITORING

The major activities in the leak detection work in the distribution system:

- Preliminary data collection and planning.
- Pipe location and survey.
- Assessment of pressure and flows.
- Locating the leaks.
- Assessment of leakage.

15.10.1 Preliminary data collection and planning

The water distribution drawings are to be studied and updated. The number of service connections is to be obtained and in the drawings of the roads the exact locations of service connections marked. The district and sub-district boundaries are suitably fixed taking into

consideration the number of service connections, length of mains, pressure points in the main. The exact locations of valves, hydrants with their sizes should be noted on the drawings.

The above activities will help in planning the conduct of sounding of the system for leaks or for fixing locations for conduct of pressure testing in intermittent water supply system before commencement of leak detection work or for measuring pressure and leak flow in the continuous water supply system.

15.10.2 Pipe Location Survey

Electronic pipe locators can be used during survey. These instruments work on the principle of Electro magnetic signal propagation. It consists of a battery operated transmitter and a cordless receiver unit to pick up the signals of pre-set frequency. There are various models to choose from. Valve locators are metal detectors that are available which can be used to locate buried valves.

Assessment of pressure and flows

Data loggers are used to record the pressure and flows. It is an instrument which stores the raw data electronically so as to be able to transfer it to the computer with a data cable link. Two types of portable data loggers are used either with a single channel or dual channel.

Single channel loggers are of the analogue type with built in pressure transducers. A simple push fit connection with the street main enables direct recording of pressure for future retrieval.

Dual channel loggers consist of an analogue type sensor for pressure and a digital type sensor for recording flow reading. A pulse head for picking up a flow reading and its conversion into an electronic pulse is required with this logger. The data of pressure and flows are stored into the data loggers during the test. Subsequent transfer of the data is made electronically into the computers magnetic storage for further processing.

In the absence of electronic equipment, the pressures can be ascertained by tapping and providing a pressure gauge. Flows can be assessed by using meters on a bypass line.

15.10.3 Locating the Leaks

To zero in on the possible location of leakages, the following methods or combination of methods could be adopted.

(a) Walking

Walking over the main looking for telltale signs of presence of water.

(b) Sounding

Sounding is the cheapest and an effective method of detecting leaks in a medium - sized water supply system.

Sounding could be categorised into two types: Direct & Indirect

(a) Direct sounding is made either on the main or fittings on the main such as sluice or air valves, fire hydrants stop taps or any other suitable fittings.

(b) Indirect sounding consists of sounding made on the ground surface directly above the mains for locating point of maximum sound intensity. This method is a good supplement for confirming location of leak noise identified through direct sounding

Water escaping from a pressurised pipe emits a sound similar to the sound that can be heard when a sea shell is held upto the ear.

The range of frequency of the sound depends upon many factors such as nature of leak, size of hole through which water is escaping, the pipe material, nature of ground in which pipe is laid etc.

The equipment used is:

(a) Non-Electronic Equipment

These are also known as listening sticks. They are simple pieces of equipment consisting of a hollow rod of any material with an ear piece

(b) Electronic

These are electronic listening stick consisting of a metal rod that is screwed on to a combined microphone and amplifier unit. The sound can be amplified by using a volume knob and could be heard through earphones.

There are also ground microphone consisting of a microphone unit and an amplifier unit, the microphone unit is attached to a handle that enables the unit to be placed on top of the ground, the signal received is amplified and passed on to the user through headphones. Some equipment have indicators.

(c) By the use of gas tracer

Sulphur hexafluoride gas tracer is injected into the main and will surface out along with water at point of leak. A detector is used to search for the substance that escapes. This is very suitable in rural areas where bore holes can be made easily at suspected points. The content of each bore hole is sampled in turn using a hand detector to ascertain the presence of gas.

(d) By using a Leak Noise Correlator

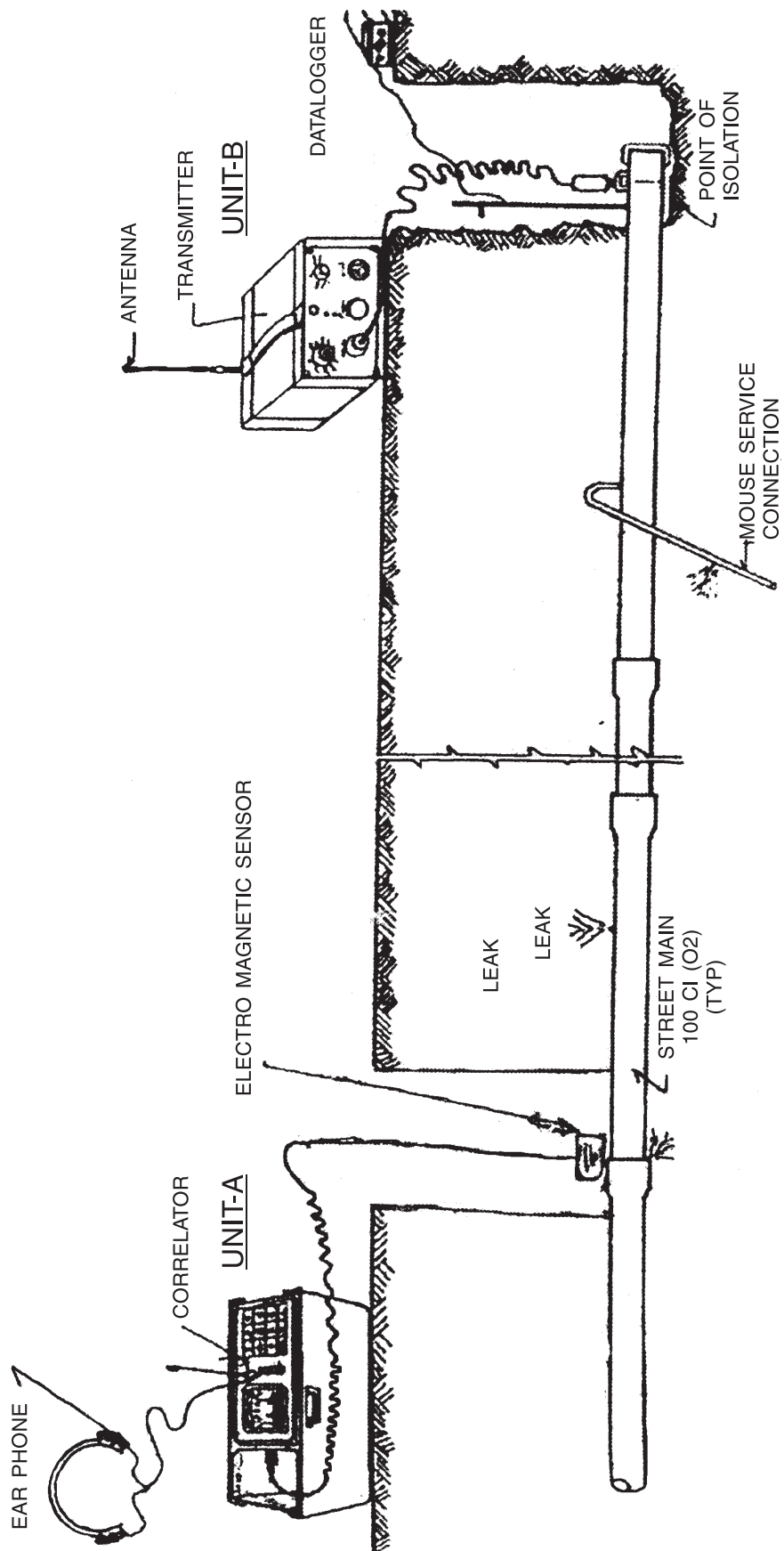
The leak noise correlator is an instrument consisting of a Radio transmitter unit and a correlator unit. (Fig. 15.2) Both the units are placed on the test mains at the two ends of the stretch under correlation by attaching their magnetic sensors to the mains. The correlator unit identifies the various frequencies of leak sounds and calculates automatically the distances of the leak points from the correlator unit

To minimize the possibility of human error, operator involvement in calculation is limited to merely operating the measurement "start key". This initiates the measurement procedure and automatically determines the leak position on the integral display, combined with the measurement curve and the operating conditions.

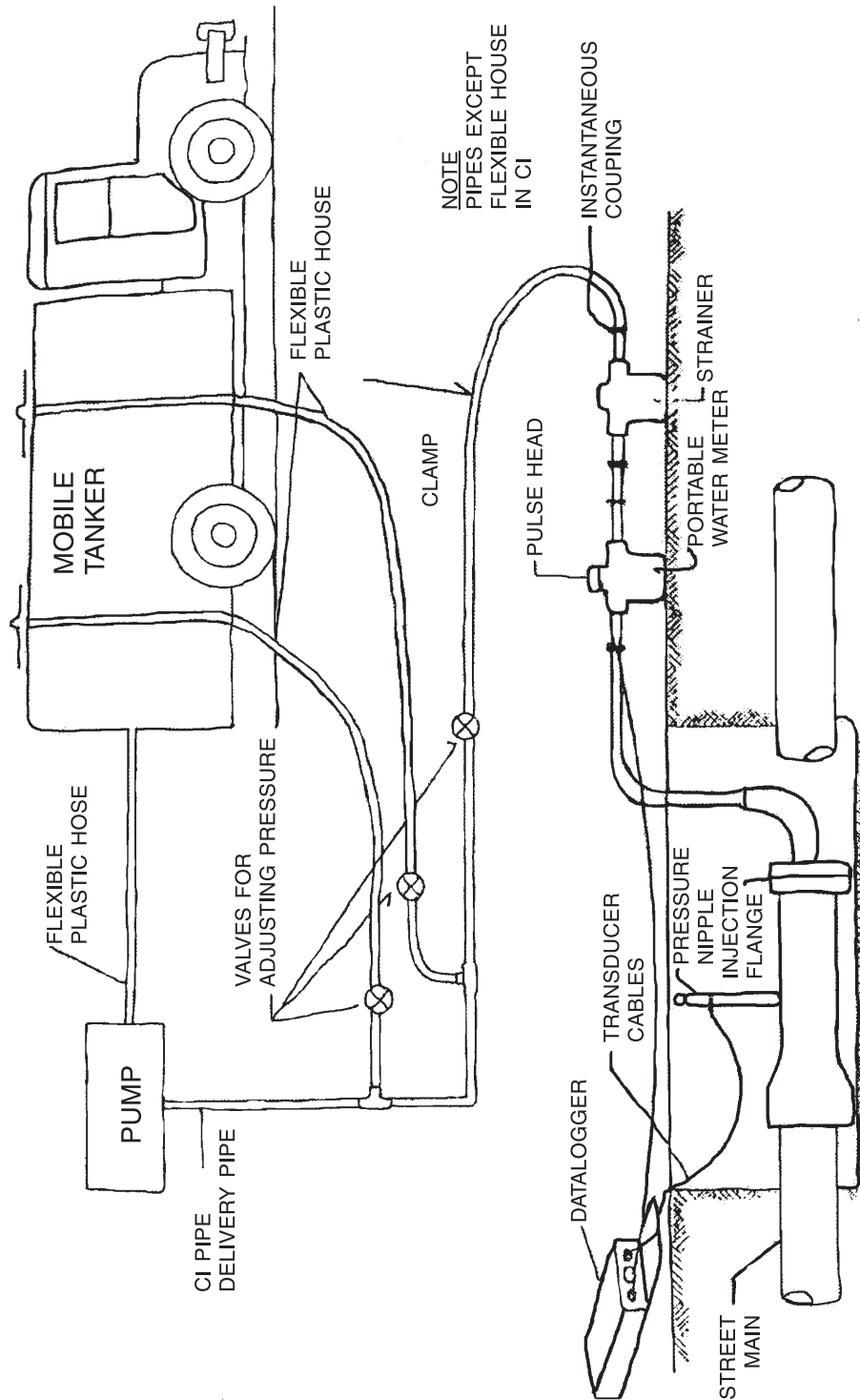
15.11 ASSESSMENT OF LEAKAGE

To conduct tests for assessment of leak the following equipment are needed:

- Road measurer.
- Pipe locator.
- Valve locator.
- Listening sticks or sounding rods.
- Electronic sounding rods.



- Leak noise correlator.
- A street water tanker attached to a pump with ease to fabricate pipe assembly with valves to control pressure (Fig 15.3).
- Turbine water meters with pulse head, pressure point and data loggers.
- Leak Locator.



The methods for assessment of leaks and location of leaks in cases of water supply system on intermittent basis and on continuous basis are described below separately.

15.11.1 INTERMITTENT SUPPLY

Supply for short hours under low pressure is common in developing countries.

Leak detection equipments and meters do not function effectively under low pressure. Hence the necessity to increase pressure over a particular duration of time to measure leak flow. To achieve this end, the stop taps at consumers end are closed and the boundary valves of test areas are also closed for isolation of the water mains to be tested. The assessment can be done as under:

In the selected area to be tested, obtain all details of the water supply system such as location and size of mains valves, consumer connections. If they are not readily available utilise road measurers to measure length; pipe locators to detect the alignment of pipes; valve locators to locate the valves. Study their working condition and restore them to operational level.

Decide the isolation points of test area, either by closing the existing valves or by cutting the main and capping it during test. The consumers connections may be isolated by closing the stop taps. If stop taps are not available they can be provided or connections can be temporarily plugged or capped.

Water is drawn from the tanker and injected into mains of test area by using a pump. A bypass pipeline returns the water partially to the tanker.

By manipulating the valves provided on the pump delivery and on the return lines, the desired pressure is maintained.

The water that is pumped in, is measured by a meter with pulse head and a data logger for recording the flow. A pressure transducer is also provided to log the pressure at the injection points. Since all exit points are closed, the amount of water recorded by the meter as flowing is obviously the amount of leakage in the system.

Down loading of loggers is done into a computer and graphs of flow and pressure with time are obtained. Consequent to tests and repairs to leaks the reduction in leak flow and the improvement in pressure can be obtained from typical computer graphs (Fig.15.4 and 15.5).

15.11.2 CONTINUOUS SUPPLY WITH ADEQUATE PRESSURE

(a) District Metering

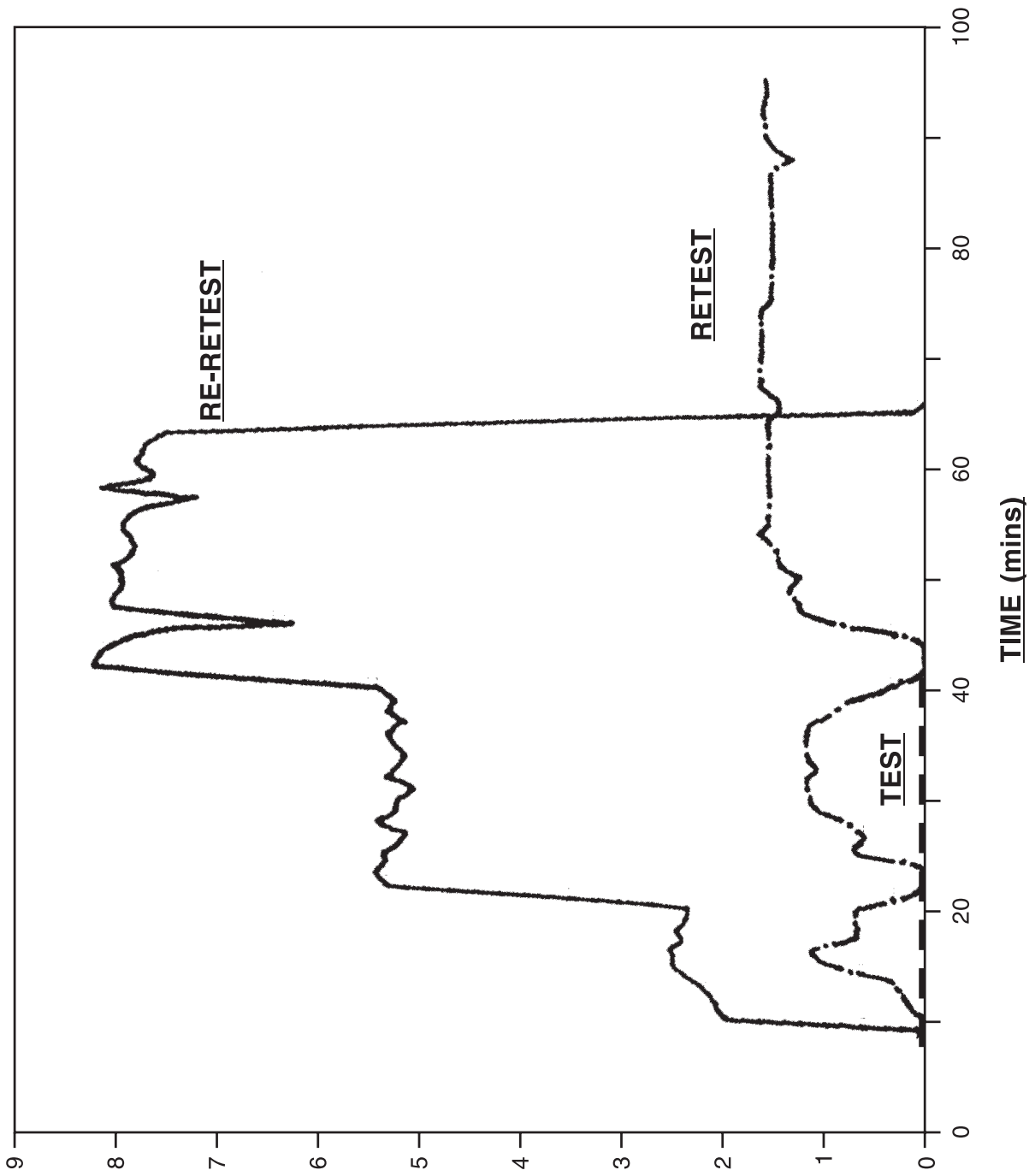
The term district metering is used to describe the method whereby flow meters are installed on all major supply lines and strategic points within the distribution system. The meters are then used to monitor the overall performance of the system establishing average daily flows into various districts.

District meter areas ideally consists of 2000 to 5000 properties.

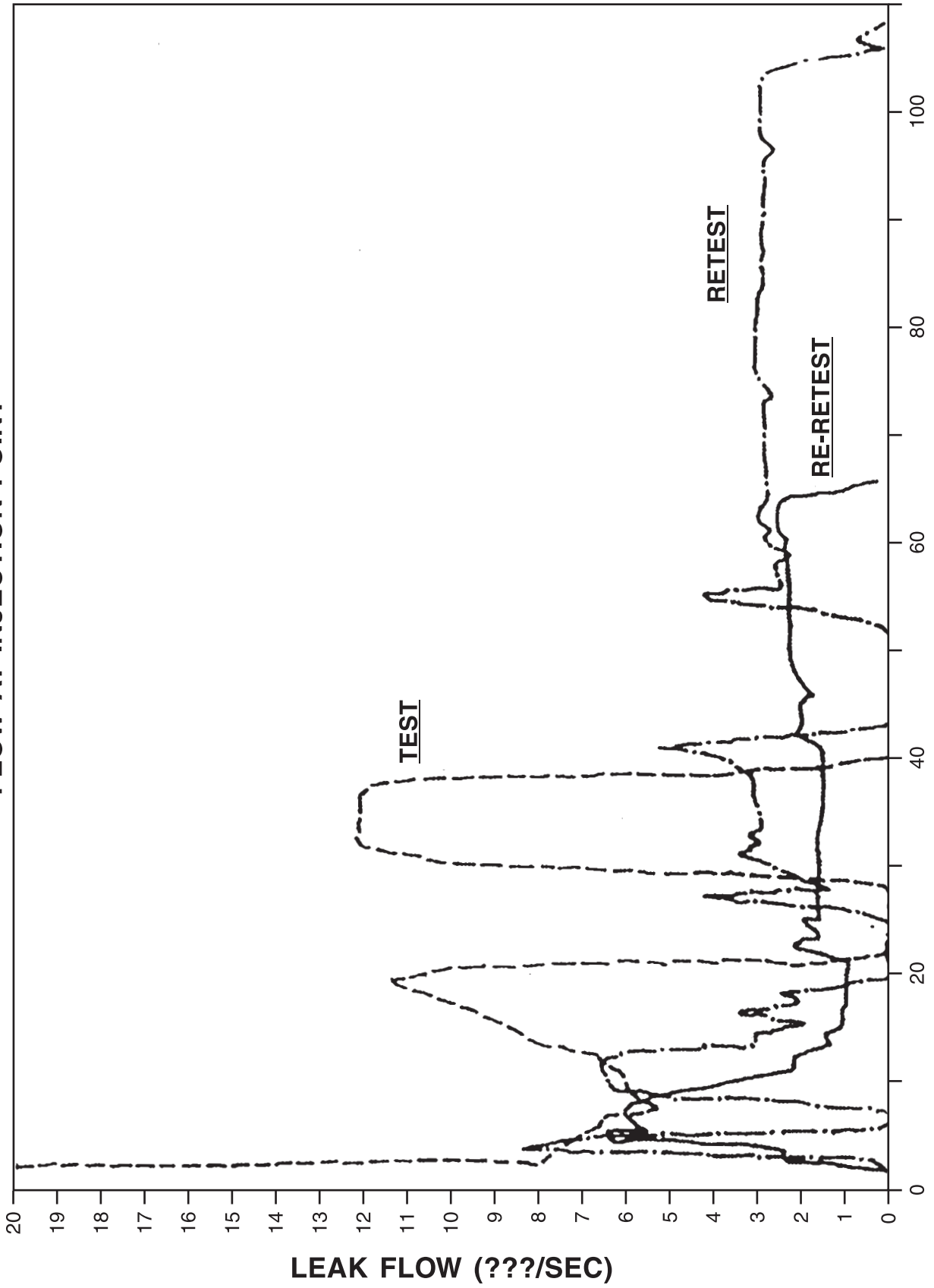
Size of the district meter should be such that it is capable of recording night flow without loss of accuracy and also must be capable of supplying peak flow without introducing serious head loss.

The District Meters should be read at weekly intervals at the same time of day as previous readings of the meter.

PRESSURE POINT 2



FLOW AT INJECTION POINT



Various types of flow meters such as venturi, pitot tube, insertion turbine meters, magnetic, ultrasonic flow meters etc. are available.

Once a district is established, repair of all known and ascertained leaks is undertaken. The measured flow into the district is then taken as the norms. Any significant variation in the measured flow indicates possible leakage and may be further investigated.

(b) Waste Metering

Within the distribution network, each metering district can be sub-divided into waste meter zones. The zone can be isolated by closing any interconnection with adjacent zones or 'boundary valves'. If the flow is then measured at times when there is virtually no normal usage, such as the early hours of 2.00 A.M. to 3.00 A.M. in the morning, then the recorded flow through the meter or 'Minimum Night Flow Method' gives an indication of the leakage level within the zone (Fig 15.6 & 15.7).

(c) Step Testing

The method of closing valves within the district so as to successively reduce the size of the district supplied by the meter is known as step testing. This is done by closing intermediate valves or 'step valves', whilst simultaneously monitoring the effect of these alterations at the waste meter. A sudden reduction in night flow corresponding with the closure of a step-valve will indicate leakage on a particular section of main.

This section can be investigated in detail using sounding techniques, the leak noise correlator and the ground microphone. The detected leak points are repaired. The exercise is repeated and reduction in leakage is noted.

Starting furthest from the waste meter, valves are successively closed so that less and less of the district is supplied via the meter. The sequence of closing valves is followed right up to the meter where upon the flow should drop to zero.

The success of both waste metering and step testing depends to a large extent upon the ability to isolate the waste meter district from rest of the system and this obviously depends upon valves shutting down tight.

Step testing is effective when the step size is approximately 100 properties. In smaller districts of up to 1000 properties the district should be divided into not less than 10 steps.

A detailed record of the inspection and leaks located and repaired should be maintained.

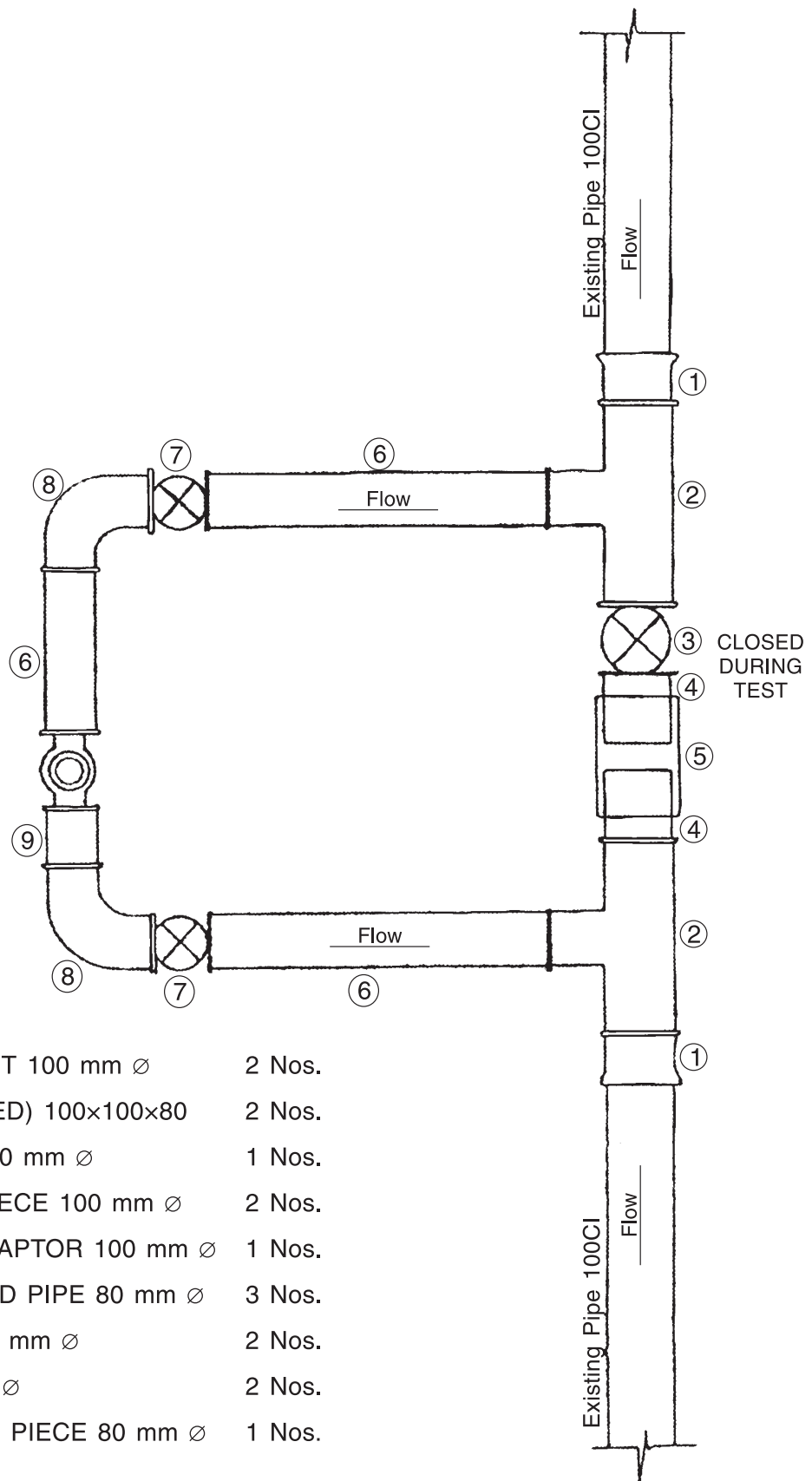
15.12 ACCEPTED NORMS FOR EXPRESSION OF LEAKAGE

Leakage within distribution mains be expressed in terms of night flow rate:

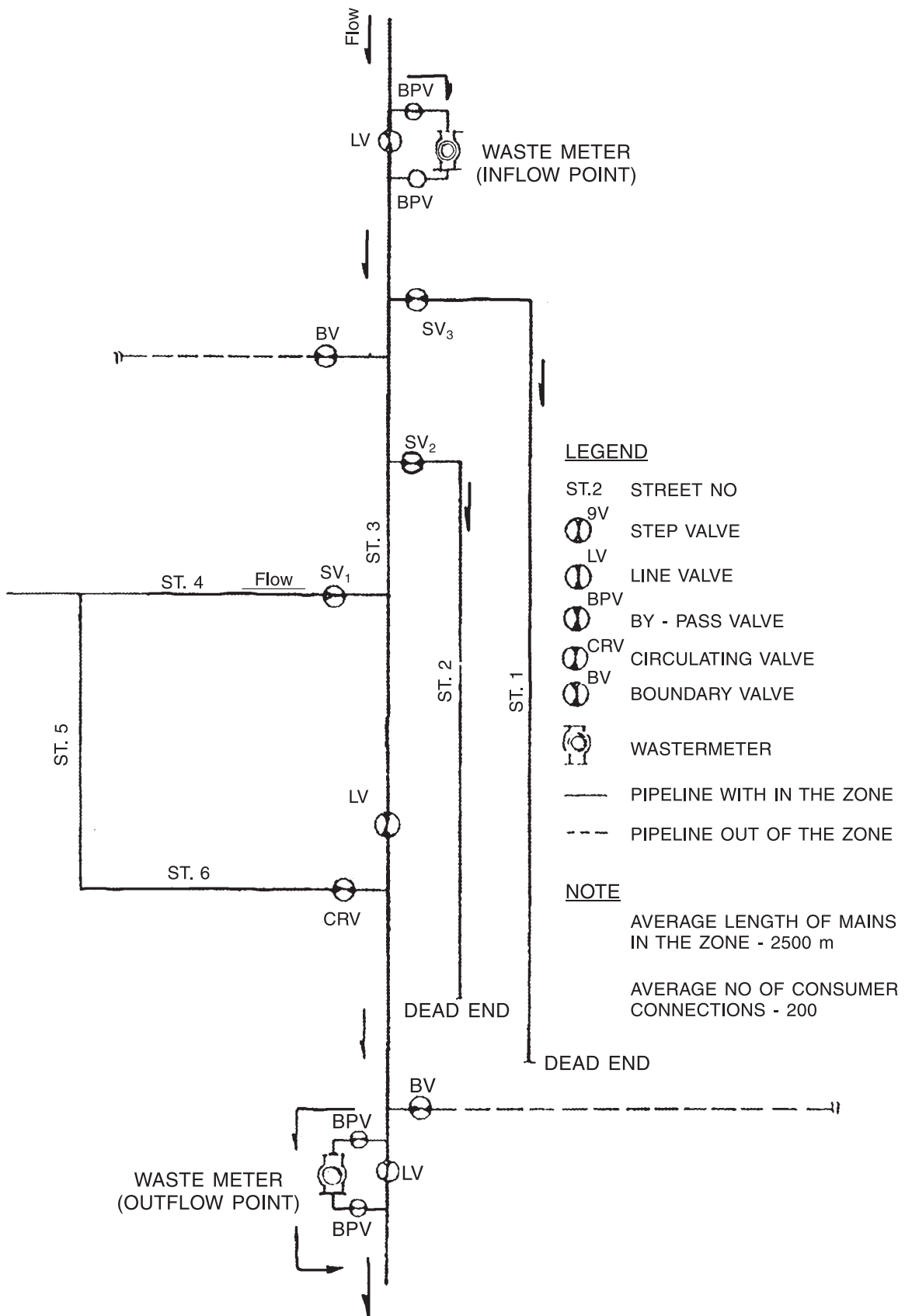
- i) Litres/household/hour for urban areas and for whole systems.
- ii) Litres/Kilo Meter of main/hour for rural areas.

Leakage from service reservoir may be usually expressed as a percentage of its capacity. Direct measurement of leakage from trunks mains are best expressed in litres/kilometer of main/hour.

WASTE METER



- | | |
|--|--------|
| ① FLANGED SOCKET 100 mm \varnothing | 2 Nos. |
| ② TEE (ALL FLANGED) 100x100x80 | 2 Nos. |
| ③ SLUICE VALVE 100 mm \varnothing | 1 Nos. |
| ④ FLANGED TAIL PIECE 100 mm \varnothing | 2 Nos. |
| ⑤ INCH METRIC ADAPTOR 100 mm \varnothing | 1 Nos. |
| ⑥ DOUBLE FLANGED PIPE 80 mm \varnothing | 3 Nos. |
| ⑦ SLUICE VALVE 80 mm \varnothing | 2 Nos. |
| ⑧ BEND 90° 80 mm \varnothing | 2 Nos. |
| ⑨ FLANGED SHORT PIECE 80 mm \varnothing | 1 Nos. |

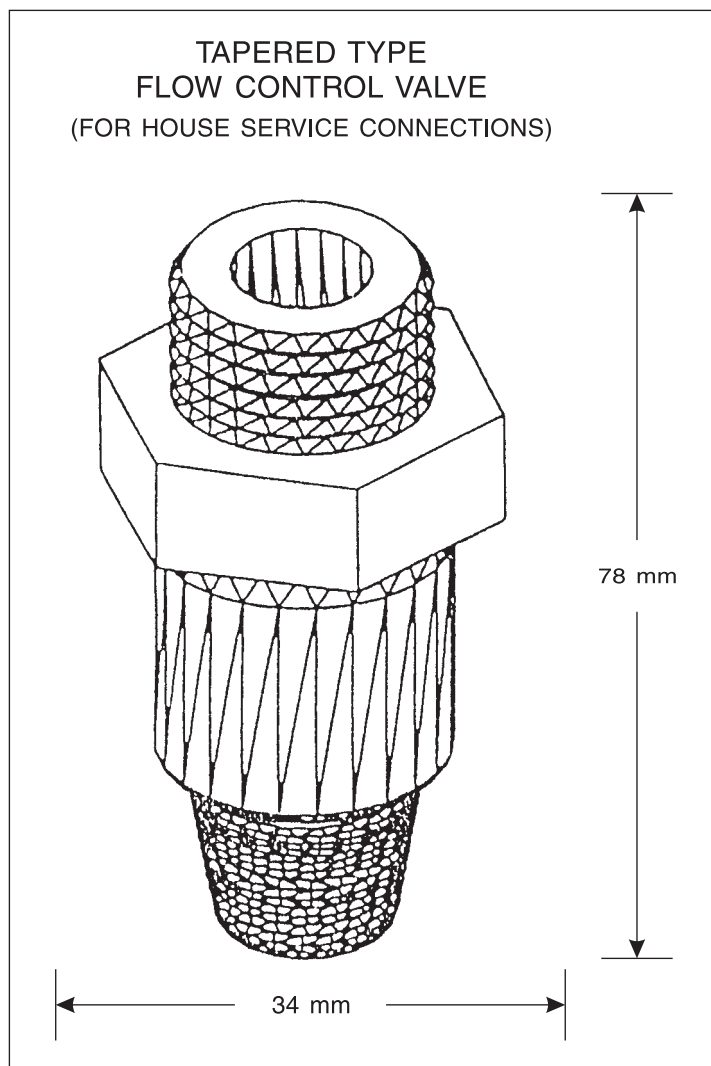


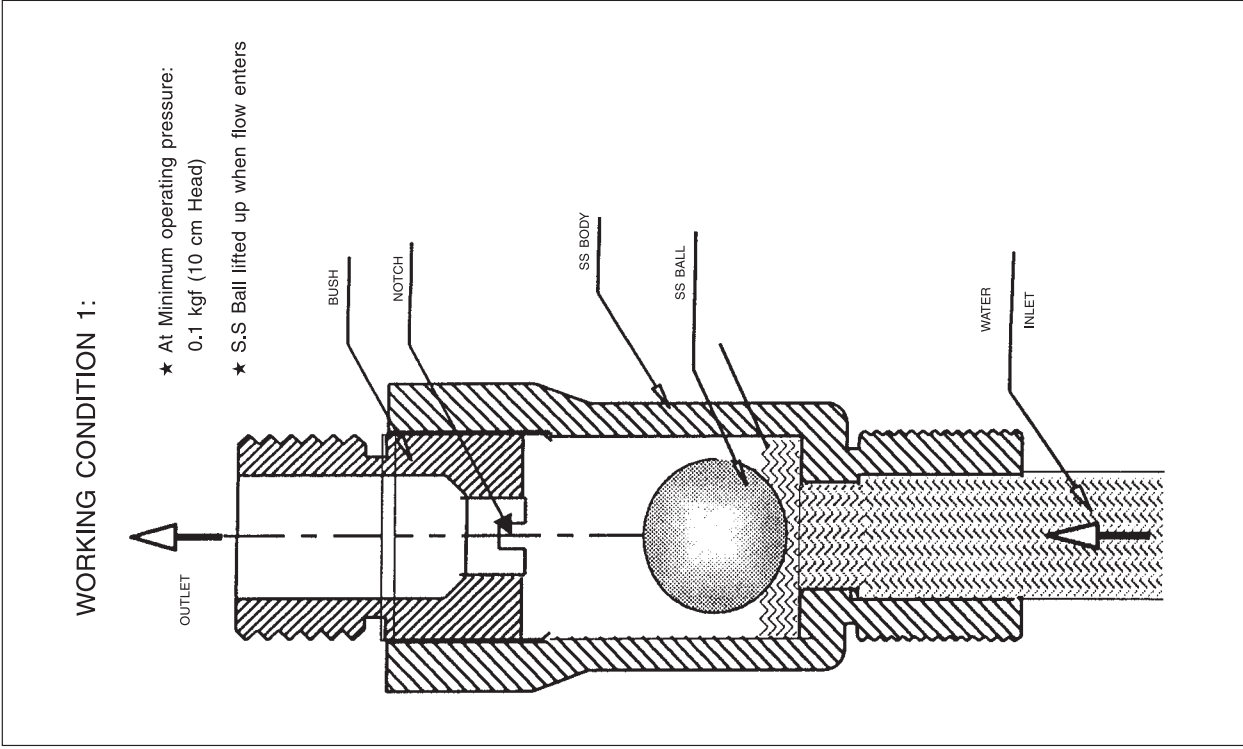
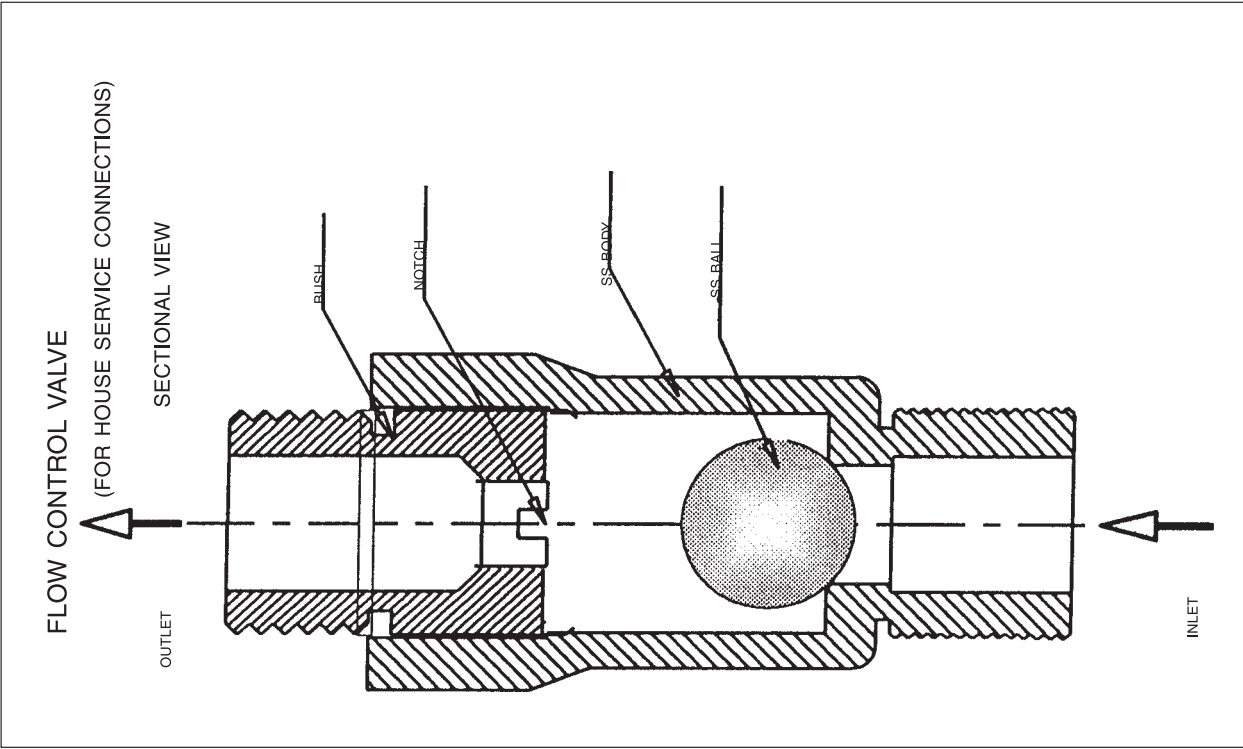
15.13 PREVENTION OF UFW IN CONSUMER CONNECTION

For domestic connection galvanized iron pipes are mainly used. After a period of time these pipes get choked due to corrosion/tuberculation. For house service connection, non-corrosive pipes can be used. The water supply drawing should have correct layout of the pipes, diameter, material, valves etc. This would facilitate proper maintenance. For arresting the illegal drawal of water from the distribution system by way of using small electrical driven motors in consumer connections, a mini Flow Control Valve in the form of a tapered ball drive system fixture, working on float principle, has been developed and found to be very successful in proper control & maintenance of service connection flows, even with supply hours ranging barely between 1-2 hours a day.

It allows only the designated flows 5lpm (or) 10lpm (or) 15lpm (or) 20lpm (or) upto 25lpm in the house service line beyond it's location irrespective of the incoming quantity of flows in the line and can be protected from external tampering with a sealed box.

This arrangement is simple economical & free from tampering. As the insertion of this device may not be agreeable to the residents, the process of installation of this device needs to be accomplished tactfully.

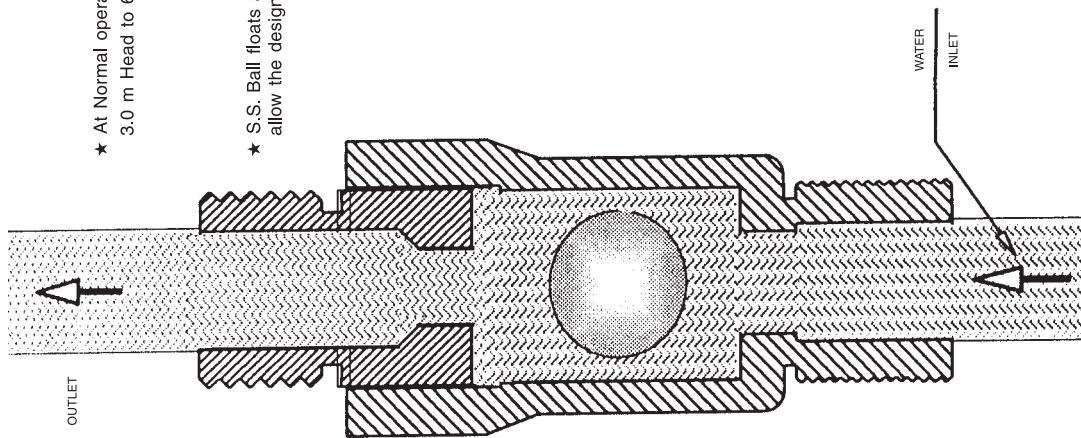




WORKING CONDITION 2:

★ At Normal operating pressure:
3.0 m Head to 6.0 Head

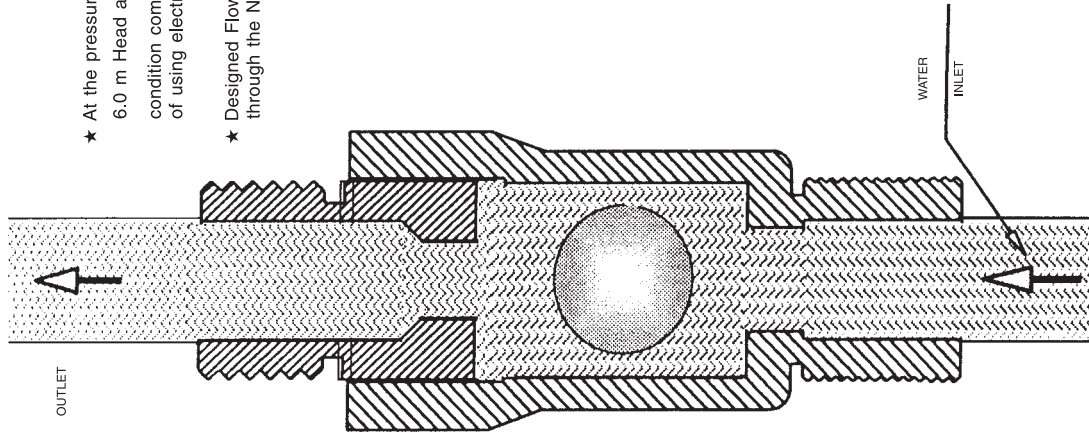
★ S.S. Ball floats at appropriate levels to
allow the designed quantity of flow



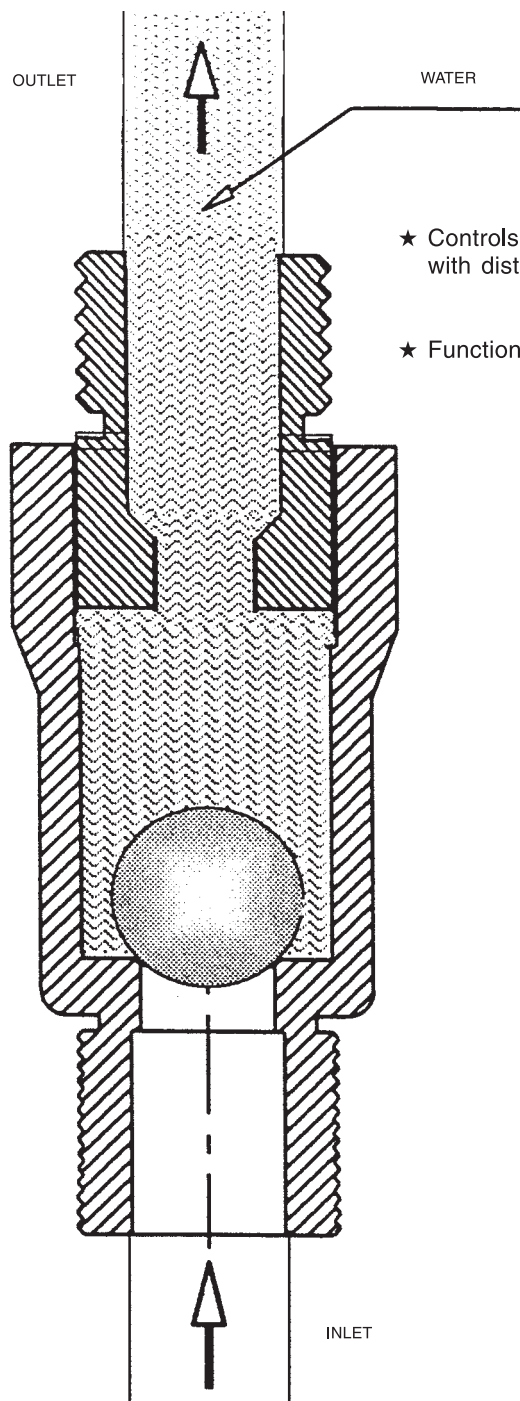
WORKING CONDITION 3:

★ At the pressure Level:
6.0 m Head and above
condition comparable to situation
of using electric suction motor

★ Designed Flow allowed only
through the Notch



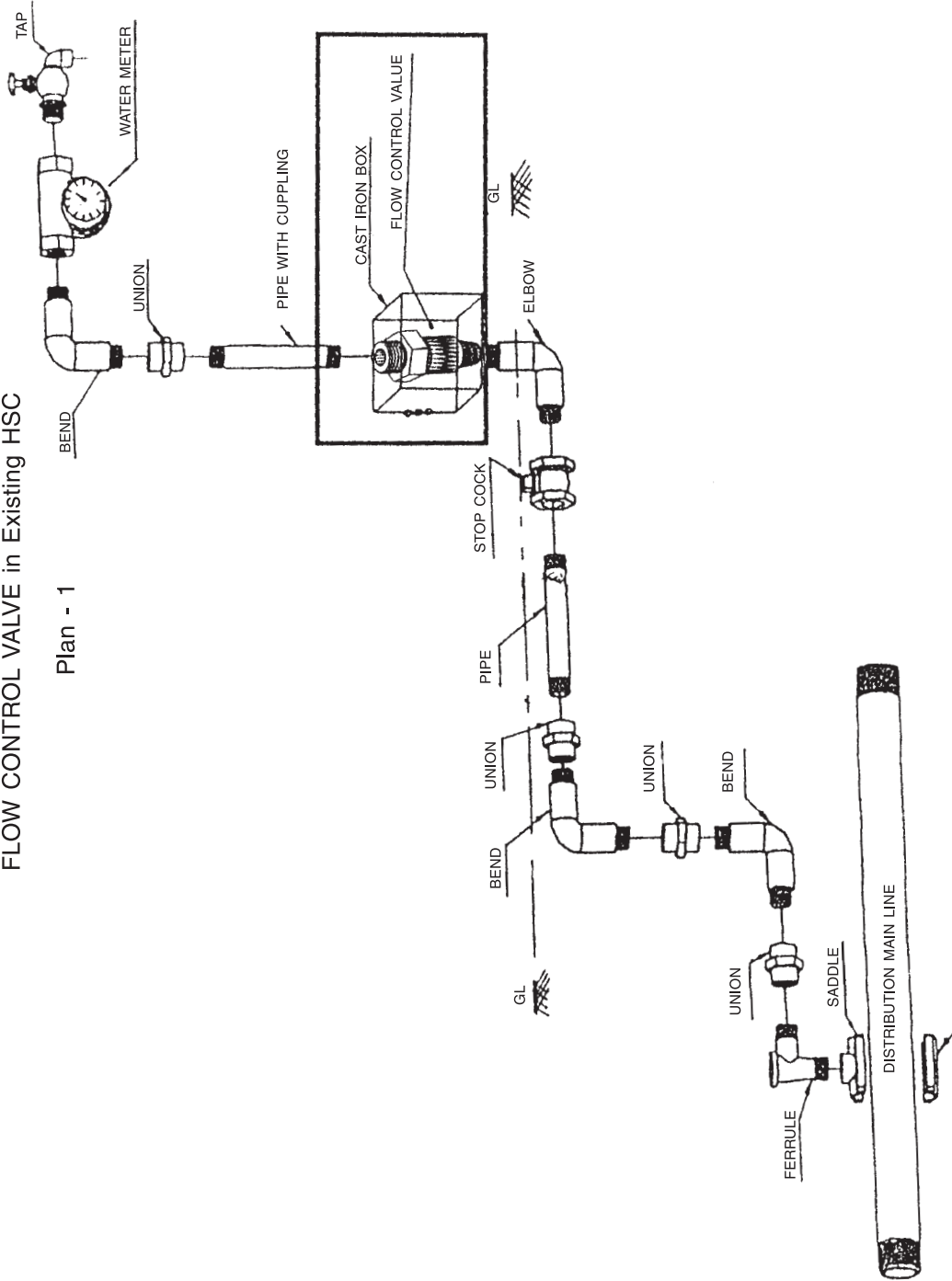
WORKING CONDITION 4:



- ★ Controls return flow from households with distribution closed
- ★ Functions as a non-return valve

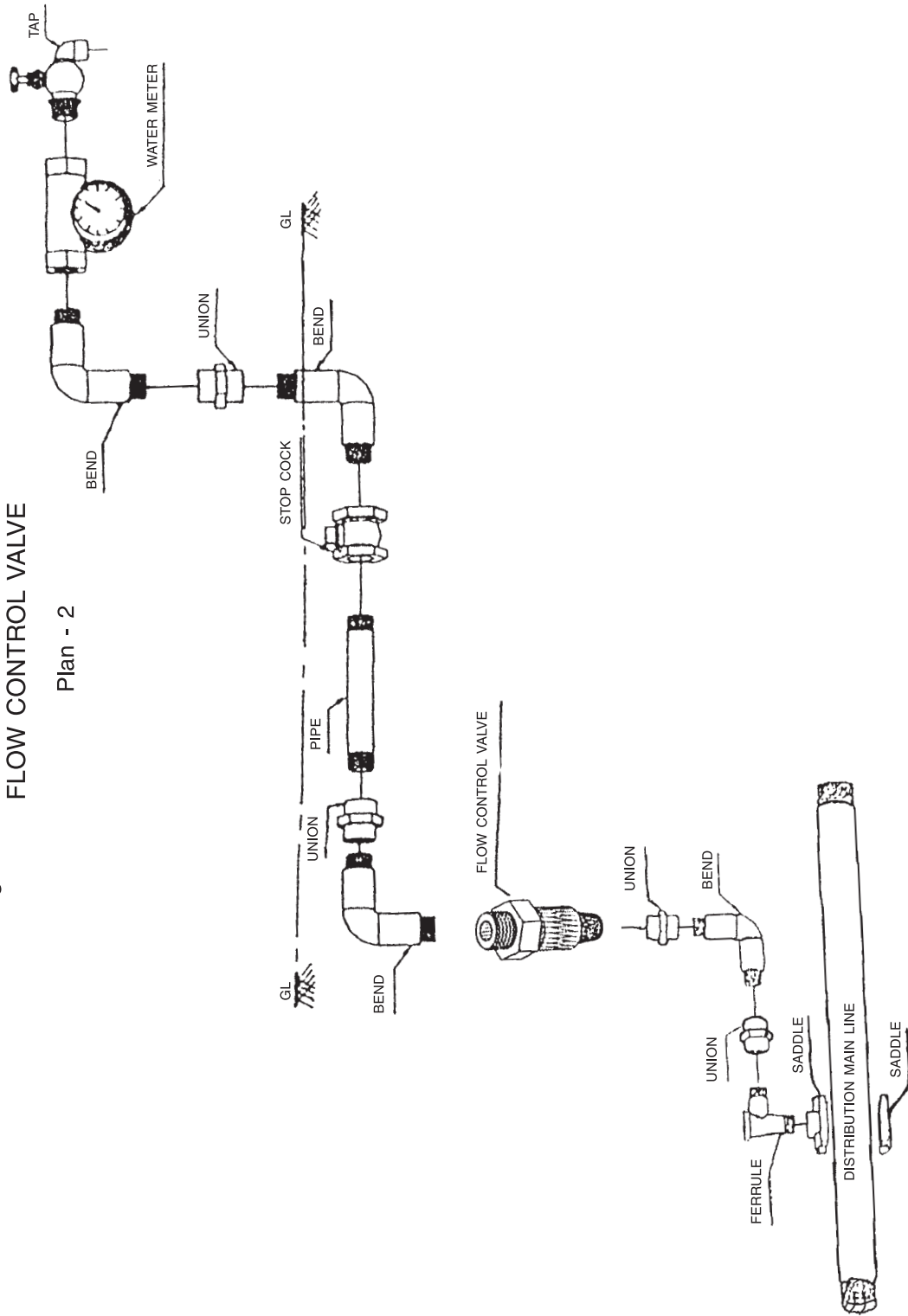
Fixing Details for MALE TYPE STAINLESS STEEL
FLOW CONTROL VALVE in Existing HSC

Plan - 1



Fixing Details for MALE TYPE STAINLESS STEEL
FLOW CONTROL VALVE

Plan - 2



15.14 TRAINING

Training to the engineers should be conducted on the following aspects establishing new leakage district:

Monitoring leakage levels

Location of leakage using equipment such as leak noise correlator amplifiers and listening sticks.

Leak detection methods possible under the different condition.

15.15 ASSESSMENT OF UFW AFTER COMPLETION

After completion of all the improvements a review of the number and nature of complaints received before, during and after the project should be undertaken and may be tabulated (Table 15.2).

An independent survey is to be carried out on the consumers after completion of the UFW works and the consumers are to be surveyed to give their opinion on various categories of water supply, the duration of supply, the pressure available and the quality of water.

The over all assessment of these figures will give the impact of the UFW exercise.

15.16 BENEFITS OF WATER AUDIT AND LEAK DETECTION

Water audits and leak detection programmes can achieve substantial benefits, including the following :

(a) Reduced Water Losses

Water audit and leak detection are the necessary first steps in a leak repair programme. Repairing the leak will save money for the utility, including reduced power costs to deliver water and reduced chemical costs to treat water.

(b) Financial Improvement

A water audit and leak detection programme can increase revenues from customers who have been undercharged, lower the total cost of whole sale supplies and reduce treatment and pumping costs.

(c) Increased Knowledge of the Distribution System

During a water audit, distribution personnel become familiar with the distribution system, including the location of main and valves. This familiarity helps the utility to respond to emergencies such as main breaks.

(d) More Efficient Use of Existing Supplies

Reducing water losses helps in stretching existing supplies to meet increased needs. This could help defer the construction of new water facilities, such as new source, reservoir or treatment plants.

(e) Safeguarding Public Health and Property

Improved maintenance of a water distribution system helps to reduce the likelihood of property damage and safeguards public health and safety.

(f) Improved Public Relation

The public appreciates maintenance of the water supply system. Field teams doing the water audit and leak detection or repair and maintenance work provide visual assurance that the system is being maintained.

(g) Reduced Legal Liability

By protecting public property and health and providing detailed information about the distribution system, water audit and leaks detection help to protect the utility from expensive law suits.

15.17 LEAKAGE REPAIR TECHNIQUES

There are a number of different techniques for repairing pipes that leak. These techniques depend on the severity of leak, type of break in the pipe, the condition of the pipe and the pipe material.

A repair clamp to cover the defect.

A cut out of the defective section of pipe work/fittings & replacement with a short length of pipe.

Relay/Renewal of the whole or section of the pipe.

For more details, refer to Chapter 10 regarding Repairs of Pipelines.

15.17.1 LEAK REPAIR PROCEDURAL OVER VIEW

The first consideration will be site safety.

Notify the customer before the commencing the work.

Always locate other utilities before commencement of work.

Always allow a small flow of water to be maintained through the pipe line thus sustaining a positive pressure and reducing the risk of contamination.

Always ensure that the operatives excavate suitable sump hole below the pipe work to ensure no contamination enters the pipe.

**TABLE 15.2
ANALYSIS OF COMPLAINTS RECEIVED IN THE DIVISION
BEFORE AND AFTER THE UFW WORKS**

	Nature of Complaint		
	Defective Water Supply	Water Leak	Water pollution
Division	2 months prior to work	2 months prior to work	2 months prior to work
Total No. of connections	Month prior to work	Month prior to work	Month prior to work
No. of connections tested	During work	During work	During work
Month/Year completed	Month after work	Month after work	Month after work
% of Division covered	2 months after work	2 months after work	2 months after work

CHAPTER 16

ENERGY AUDIT & CONSERVATION OF ENERGY

16.1 INTRODUCTION

Energy is very scarce commodity particularly in developing and underdeveloped countries. Cost of energy is spirally increasing day-by-day. Generally pumping installations consume huge amount of energy wherein proportion of energy cost can be as high as 40 to 70% of overall cost of operation and maintenance of water works. Need for conservation of energy, therefore can not be over emphasized. All possible steps need to be identified and adopted to conserve energy and reduce energy cost so that water tariff can be kept as low as possible and gap between high cost of production of water and price affordable by consumers can be reduced. Conservation of energy is also important and necessary in national interest as the nation is energy deficit due to which problems of low voltage, load shedding and premature failures of equipments are encountered.

Some adverse scenarios in energy aspects as follows are quite common in pumping installations:

- Energy consumption is higher than optimum value due to reduction in efficiency of pumps.
- Operating point of the pump is away from best efficiency point (b.e.p.).
- Energy is wasted due to increase in head loss in pumping system e.g. clogging of strainer, encrustation in column pipes, encrustation in pumping main.
- Selection of uneconomical diameter of sluice valve, butterfly valve, reflux valve, column pipe, drop pipe etc. in pumping installations.
- Energy wastage due to operation of electrical equipments at low voltage and/or low power factor.

Such inefficient operation and wastage of energy need to be avoided to cut down energy cost. It is therefore, necessary to identify all such shortcomings and causes which can be achieved by conducting methodical energy audit.

Strategy as follows, therefore need to be adopted in management of energy.

- i) Conduct thorough and in-depth energy audit covering analysis and evaluation of all equipment, operations and system components which have bearings on energy consumption, and identifying scope for reduction in energy cost.
- ii) Implement measures for conservation of energy.

Energy audit as implied is auditing of billed energy consumption and how the energy is consumed by various units, and sub-units in the installation and whether there is any wastage

due to poor efficiency, higher hydraulic or power losses etc. and identification of actions for remedy and correction.

In respect of energy conservation, various organisations are working in the field of energy conservation and have done useful work in evolving measures for energy conservation. The reported measures are discussed in this chapter. The measures if adopted can reduce energy cost upto 10% depending on the nature of installation and scope for measures for energy conservation.

16.2 ENERGY AUDIT

Scope of energy audit, suggested methodology is discussed below. Frequency of energy audit recommended is as follows:

Large Installations	Every year
Medium Installations	Every two years
Small Installations	Every three years

16.2.1 SCOPE OF ENERGY AUDIT

Energy audit includes following actions, steps and processes:

- i) Conducting in depth energy audit by systematic process of accounting and reconciliation between the following:
 - Actual energy consumption.
 - Calculated energy consumption taking into account rated efficiency and power losses in all energy utilising equipment and power transmission system i.e. conductor, cable, panels etc.
- ii) Conducting performance test of pumps and electrical equipment if the difference between actual energy consumption and calculated energy consumption is significant and taking follow up action on conclusions drawn from the tests.
- iii) Taking up discharge test at rated head if test at Sr. No. (ii) is not being taken.
- iv) Identifying the equipment, operational aspects and characteristic of power supply causing inefficient functioning, wastage of energy, increase in hydraulic or power losses etc. and evaluating increase in energy cost or wastage of energy.
- v) Identifying solutions and actions necessary to correct the shortcomings and lacunas in (iv) and evaluating cost of the solutions.
- vi) Carrying out economical analysis of costs involved in (iv) and (v) above and drawing conclusions whether rectification is economical or otherwise.
- vii) Checking whether operating point is near best efficiency point and whether any improvement is possible.
- viii) Verification of penalties if any, levied by power supply authorities e.g. penalty for poor power factor, penalty for exceeding contract demand.
- ix) Broad review of following points for future guidance or long term measure:

- C-value or f-value of transmission main.
- Diameter of transmission main provided.
- Specified duty point for pump and operating range.
- Suitability of pump for the duty conditions and situation in general and specifically from efficiency aspects.
- Suitability of ratings and sizes of motor, cable, transformer and other electrical appliances for the load.

16.2.2 METHODOLOGY FOR ENERGY AUDIT

Different methodologies are followed by different organisations for energy audit. Suggested methodologies for installations having similar and dissimilar pumps are as follows:

16.2.2.1 Study and Verification Of Energy Consumption

(a) All Pumps Similar (Identical):

- Examine few electric bills in immediate past and calculate total number of days, total kWh consumed and average daily kWh [e.g. in an installation with 3 numbers working and 2 numbers standby if bill period is 61 days, total consumption 5,49,000 kWh, then average daily consumption shall be 9000 kWh].
- Examine log books of pumping operation for the subject period, calculate total pump - hours of individual pump sets, total pump hours over the period and average daily pump hours [Thus in the above example, pump hours of individual pumpsets are : 1(839), 2(800), 3(700), 4(350) and 5(300) then as total hours are 2989 pump-hours, daily pump hours shall be $2989 \div 61 = 49$ pump hours. Average daily operations are: 2 numbers of pumps working for 11 hours and 3 numbers of pumps working for 9 hours].
- From (i) and (ii) above, calculate mean system kW drawn per pumpset [In the example, mean system power drawn per pumpset = $9000 / 49$ i.e. 183.67 kW].
- From (i), (ii) and (iii) above, calculate cumulative system kW for minimum and maximum number of pumps simultaneously operated. [In the example, cumulative system kW drawn for 2 numbers of pumps and 3 numbers of pumps operating shall be $183.67 \times 2 = 367.34$ kW and $183.67 \times 3 = 551.01$ kW respectively].
- Depending on efficiency of transformer at load factors corresponding to different cumulative kW, calculate output of transformer for loads of different combinations of pumps. [In the example, if transformer efficiencies are 0.97 and 0.975 for load factor corresponding to 367.34 kW and 551.01 kW respectively, then outputs of transformer for the loads shall be 367.34×0.97 i.e. 356.32 kW and 551.01×0.975 i.e. 537.23 kW respectively.
- The outputs of transformer, for all practical purpose can be considered as cumulative inputs to motors for the combinations of different number of pumps working simultaneously. Cable losses, being negligible, can be ignored.
- Cumulative input to motors divided by number of pumpsets operating in the combination shall give average input to motor (In the example, average input to

motor shall be $356.32 \div 2$ i.e. 178.16 kW each for 2 pumps working and $537.23 \div 3$ i.e. 179.09 kW each for 3 pumps working simultaneously.

- viii) Depending on efficiency of motor at the load factor, calculate average input to pump. [In the example, if motor efficiency is 0.86, average input to pump shall be 178.16×0.86 i.e. 153.22 kW and 179.07×0.86 i.e. 154.0 kW].
- ix) Simulate hydraulic conditions for combination of two numbers of pumps and three numbers of pumps operating simultaneously and take separate observations of suction head and delivery head by means of calibrated vacuum and pressure gauges and/or water level in sump/well by operating normal number of pumps i.e. 2 number and 3 numbers of pumps in this case and calculate total head on the pumps for each operating condition. The WL in the sump or well shall be maintained at normal mean water level calculated from observations recorded in log book during the chosen bill period.
- x) Next operate each pump at the total head for each operating condition by throttling delivery valve and generating required head. Calculate average input to the pump for each operating condition by taking appropriate pump efficiency as per characteristic curves.
- xi) If difference between average inputs to pumps as per (viii) and (x) for different working combinations are within 5% - 7%, the performance can be concluded as satisfactory and energy efficient.
- xii) If the difference is beyond limit, detailed investigation for reduction in efficiency of the pump is necessary.
- xiii) Full performance test for each pump shall be conducted as per procedure described in para 16.2.3.
- xiv) If for some reason, the performance test is not undertaken, discharge test of each single pump at rated head generated by throttling delivery valve need to be carried out.

If actual discharge is within 4% - 6% of rated discharge, the results are deemed as satisfactory.

If discharge varies beyond limit, it indicates that wearing rings are probably worn out. The clearance need to be physically checked by dismantling the pump and measuring diametral clearances in wearing rings and replacing the wearing ring.

(b) Dissimilar Pumps

Procedures for energy audit for dissimilar pumps can be similar to that specified for identical pumps except for adjustment for different discharge as follows:

- Maximum discharge pump may be considered as 1(one) pump-unit.
- Pump with lesser discharge can be considered as fraction pump-unit as ratio of its discharge to maximum discharge pump. [In the above example, if discharges of 3 pumps are 150, 150 and 100 litres per second respectively, then number of pump-units shall be respectively 1, 1 and 0.667. Accordingly the number of pumps and pump-hours in various steps shall be considered as discussed for the case of all similar pumps.]

16.2.2.2 Study of Opportunities for Saving in Energy

The study shall cover the aspects detailed in para 9.10.2.1 (iv), (v) & (vi).

16.2.2.3 Checking Operating Point and Best Efficiency Point

As far as possible duty point should be at or near the best efficiency point. If difference in efficiency at duty point and b.e.p. is above 5%, economical analysis for replacement of pump shall be carried out and corrective suitable action shall be taken.

16.2.2.4 Checking for Penalties Levied by Power Authority

Check power bills for past few months and see whether any penalty for low PF, contract demand etc. is levied. Corrective action for improving PF and revising contract demand shall be taken on priority.

16.2.2.5 Broad Review of Performance of System Components

Broad review of the points in para 16.2.1 shall be taken up, studied and discussed.

16.2.3 PERFORMANCE TEST OF PUMPS

16.2.3.1 Parameter to be Determined

- Head
- Discharge
- Power input to motor
- Speed of pump

16.2.3.2 Specific Points

- Only one pump-motor set shall be tested at a time.
- All gauges and test instruments shall be calibrated.
- Rated head shall be generated by throttling valve on pump delivery.
- Efficiency of motor shall be as per the manufacturer's curve or type test certificate.
- Water level in the sump/intake shall be maintained practically constant and should be measured frequently (once in every 3-5 minutes).
- Test should be conducted for sufficient duration (about 30-60 minutes) for better accuracy.

16.2.3.3 Test Gauges and Instruments

Following test gauges and instruments are required for performance test.

- *Determination of head*
 - * Pressure and vacuum gauges.
 - * Float gauge with calibrated scale to measure elevation difference between water levels and pressure gauge or elevation difference between two gauges.

- *Determination of discharge*
 - * Flow meter
 - * In absence of flowmeter, volumetric measurement preferably at both source and discharging point wherever feasible or otherwise at one of the two points which is reliable shall be carried out.
- *Power input*
 - * 2 numbers of single phase wattmeter
 - * Current Transformer (CT)
 - * Potential Transformers (PT)
 - * Test lids
 - * Frequency-meter
- *Speed*
 - * Contact tachometer
or
 - * Non-contact optical tachometer

16.2.3.4 Test Codes

- Test shall be generally conducted as per IS 9137 - Code for acceptance test for pumps - Class 'C'. Where high accuracy is desired, test shall be conducted as per IS 10981 - Code for acceptance test for pumps - Class 'B'.
- Correction for rated speed corrected to average frequency during the test shall be carried out as per affinity law specified in IS 9137, IS 10981 and IS 5120 (Technical requirements for rotodynamic special purpose pumps).

16.3 MEASURES FOR CONSERVATION OF ENERGY

Measures for conservation of energy in water pumping installation can be broadly classified as follows:

i) Routine Measures

The measures can be routinely adopted in day to day operation and maintenance.

ii) Periodical Measures

Due to wear and encrustation during prolonged operation, volumetric efficiency and hydraulic efficiency of pumps reduce. By adopting these measures, efficiency can be nearly restored. These measures can be taken up during overhaul of pump or planned special repairs.

iii) Selection Aspects

If during selection phase, the equipment i.e. pumps, piping, valves etc. are selected for optimum efficiency and diameter, considerable reduction in energy cost can be achieved.

iv) Measures for System Improvement

By improving system so as to reduce hydraulic losses or utilized available head hydraulic potentials, energy conservation can be achieved.

16.3.1 ROUTINE MEASURES

16.3.1.1 Improving Power Factor to 0.98

Generally as per rule of power supply authority, average power factor (PF) of 0.9 or so is to be maintained in electrical installations. If average PF is less than 0.9 or specified limit over the billing period, generally penalty at rate of 0.5% of bill per each 1% (may vary) shortfall in PF is charged. It is, therefore, obligatory to maintain PF to level of 0.9 or specified limit.

Improving PF above the limit is beneficial for conservation of energy. The power factor, can be improved to level of 0.97 or 0.98 without adverse effect on motors. Further discussion shows that considerable saving in power cost can be achieved if PF is improved.

If PF is corrected from 0.90 to 0.98, the annual saving in energy consumption is Rs. 1,64,000/- for 1000 kW load and saving in kVA recorded amounts to Rs. 1,31,000/-. Total saving thus, shall be Rs. 2,95,000/- per annum. Detailed calculations are as follows.

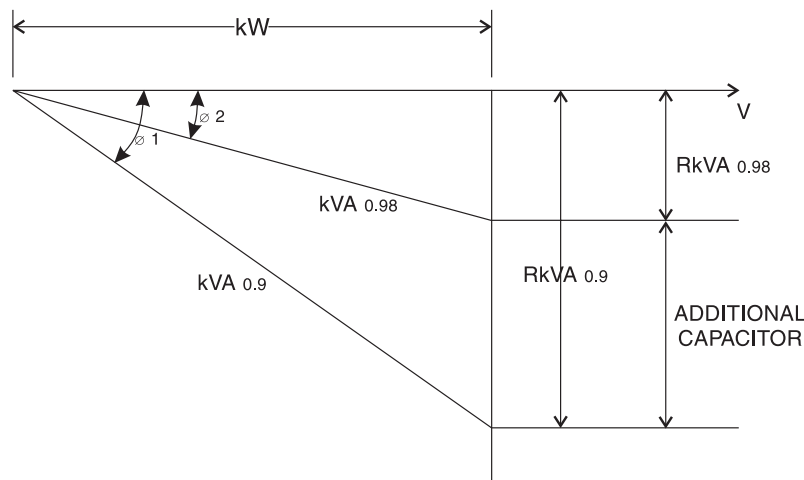


FIG. 16.1: CORRECTION OF POWER FACTOR

$$\text{Initial power factor (Cos } \phi_1) = 0.90$$

$$\text{Improved power factor (Cos } \phi_2) = 0.98$$

Considering 1000 kW load and 3.3 kV system, the load current and copper losses are:

$$\begin{aligned} I_{0.90} &= \frac{1000}{\sqrt{3} \times 3.3 \times 0.90} \\ &= 194.4 \text{ A} \end{aligned}$$

$$\begin{aligned} I_{0.98} &= \frac{1000}{\sqrt{3} \times 3.3 \times 0.98} \\ &= 178.5 \text{ A} \end{aligned}$$

$$RI_{0.90}^2 = 30 \text{ kW assuming 3\% copper losses}$$

As copper losses \propto (current)²,

$$\begin{aligned} RI_{0.98}^2 &= 30 \times \left[\frac{178.5}{194.4} \right]^2 \\ &= 25.3 \text{ kW} \end{aligned}$$

Thus reduction in copper losses due to improvement of PF is 30 - 25.3 i.e. 4.7 kW.

Therefore saving in power cost due to copper losses per annum

@ Rs. 4/- per kWh

$$\begin{aligned} &= (30.0 - 25.3) \times 24 \text{ hours} \times 365 \text{ days} \times \text{Rs. } 4.0 \\ &= \text{Rs. } 1,64,688/- \\ &\text{say Rs. } 1,64,000/- \end{aligned}$$

The kVA recorded at PF 0.9 and 0.98 are,

$$\begin{aligned} \text{kVA}_{0.90} &= 1000/0.90 = 1111 \text{ kVA} \\ \text{kVA}_{0.98} &= 1000/0.98 = 1020 \text{ kVA} \end{aligned}$$

Saving due to reduction in recorded kVA demand @ Rs. 120/- per kVA per month

$$\begin{aligned} &= (1111 - 1020) \times 12 \text{ months} \times \text{Rs. } 120.0 \\ &= \text{Rs. } 1,31,000/- \text{ per annum} \end{aligned}$$

Total saving in energy cost

$$= \text{Rs. } 2,95,000/- \text{ per annum}$$

It can be shown that additional capacitors required to improve PF from 0.9 to 0.98 is 283 kVAR. Approximate cost shall be about Rs. 1,41,500/-. Thus by spending the amount once, yearly benefit of Rs. 2,95,000/- can be achieved.

Maximum recommended limit for PF correction is 0.98, which allows for margin of 2% below unity. PF above unity is detrimental for induction motors.

For improving PF to 0.98, automatic power factor correction (APFC) with suitable contactors and capacitor banks shall be provided in panel. The APFC shall be provided on both sections of the panel so that even though the two transformers are on part load without parallel operation, PF correction shall achieved in both sections of the panel.

16.3.1.2 Operation of Working and Standby Transformers

As regards operation of working and standby transformers, either of two practices as below is followed:

- i) One transformer on full load and second transformer on no-load but, charged.
- ii) Both transformers on part load.

On detailed study, it can be concluded that operation of both transformers on part load is economical.

Saving in energy cost is Rs. 2.37 lakhs per annum for 1100 kVA demand as per calculations below.

- i. One transformer always on load and second transformer on no-load, but charged. The load and no-load losses as per tests are as follows:

$$\begin{aligned} \text{No load losses for 1600 kVA transformer} &= 1.80 \text{ kW} \\ \text{Load losses for 1100 kVA load} &= 13.50 \text{ kW} \end{aligned}$$

Therefore, total cost of energy losses for two transformers per annum

$$\begin{aligned} &= (1.80 \times 2 + 13.50) \times 24 \text{ hours} \times 365 \text{ days} \times \text{Rs. } 4.00 \\ &= \text{Rs. } 5.99 \text{ lakhs} \end{aligned}$$

ii) Both transformers on part load (50% load on each transformer)

$$\begin{aligned}\text{Load losses at 50\% load} &= \frac{1}{4} \text{ of full load losses} \\ &= \frac{1}{4} \times 13.5 \text{ kW} \\ &= 3.375 \text{ kW}\end{aligned}$$

Therefore total cost of energy losses per annum

$$\begin{aligned}&= (1.8 + 3.375) \times 2 \text{ nos.} \times 24 \text{ hours} \times 365 \text{ days} \times \text{Rs. } 4.00 \\ &= \text{Rs. } 3.62 \text{ lakhs}\end{aligned}$$

∴ Saving in energy losses if operation (ii) is followed

$$\begin{aligned}&= \text{Rs. } 5.99 - \text{Rs. } 3.62 \\ &= \text{Rs. } 2.37 \text{ lakhs per annum}\end{aligned}$$

However, it may be noted that fault level increases if the transformers are operated in parallel. In view of above and to ensure that objective of energy conservation is achieved, operation and control of two transformers shall be as under:

- i) Both transformers shall be kept on part load without paralleling.
- ii) In order to avoid parallel operation, interlock in two incoming breakers and bus-coupler shall be provided to ensure that only two numbers of breakers (out of three breakers) are closed. Thus incoming breakers shall be closed and bus coupler shall be kept open during normal operation.

16.3.1.3 Voltage Improvement by Voltage Stabiliser or at Transformer by OLTC

If motor is operated at low voltage, the current drawn increases, resulting in increased copper losses and consequent energy losses.

Operation of 500 kW motor at 90% of rated voltage results in increased energy cost of about Rs. 2,45,000/- per annum as shown below.

$$\begin{aligned}\text{Low voltage } V_1 &= 90\% \\ \text{Rated voltage } V_2 &= 100\% \\ \text{Since } I_1 V_1 &= I_2 V_2 \\ I_1 / I_2 &= V_2 / V_1 \\ &= 1.11\end{aligned}$$

Consider 1000 kW motor load having RI^2 losses of 30 kW at V_2 .

$$\begin{aligned}\text{Therefore } RI^2 \text{ losses at 90\% voltage } (V_1) &= 30 \times 1.11^2 \\ &= 37.0 \text{ kW}\end{aligned}$$

Increase in RI^2 losses due to low voltage

$$\begin{aligned}&= 37.0 - 30.0 \\ &= 7.0 \text{ kW}\end{aligned}$$

Annual extra energy cost due to increase in RI^2 losses at low voltage

$$\begin{aligned}&= 7.0 \times 24 \text{ hours} \times 365 \text{ days} \times \text{Rs. } 4.00 \\ &= \text{Rs. } 2,45,280/- \\ &\text{say Rs. } 2,45,000/-\end{aligned}$$

It is, therefore, beneficial to correct operating voltage to rated voltage of motors.

Voltage can be corrected by selecting appropriate tap on tap changing switch of transformer. More preferable measure is to provide on-load tap changer (OLTC) on transformer or automatic voltage stabiliser due to which voltage can be maintained at rated

level. Taking into account high capital cost of Rs. 4.0 - 5.0 lakhs, OLTC, use of OLTC may be restricted to transformer of capacity 1000 kVA and above. Voltage stabiliser may be provided below 1000 kVA. If off-load tap changer is provided, suitable tap shall be selected to have proper voltage at motor terminals.

16.3.1.4 Reducing Static Head (Suction Side)

A study shows that energy can be saved if operating head on any pump is reduced. This can be achieved by reducing static head on pumps at suction end or discharging end or both. One methodology to reduce static head on pumps installed on sump (not on well on river/canal/lake source) is by maintaining WL at or marginally below FSL, say, between FSL to (FSL - 0.5 m) by operational control as discussed below.

(a) Installation where inflow is directly by conduit from dam

In such installations, the WL in sump can be easily maintained at FSL or slightly below, say, FSL to (FSL - 0.5m) by regulating valve on inlet to sump.

(b) Other installations

By operational control

In case multi-pump installation, where inflow is from preceding pumping station, following action, if feasible will be beneficial for energy saving.

- i) The pumps shall be sequentially started when WL is above mean WL and last pump shall be started when WL is slightly below FSL. This would ensure that WL is at or near FSL and the pumps will operate on lower static head.
- ii) If WL falls below mean WL, one pump may be temporarily stopped and restarted when WL approaches FSL.

However, frequent starting and stopping should be avoided to prevent reduction in life of contactors and motors. Normally pumps should not be stopped unless 30 minutes running is completed.

Small pumps for maintaining WL at FSL in sump (where inflow is from preceding pumping station).

In case of multiple pump installation, if small pump of low discharge is provided in addition to main pumps, objective of maintaining WL within the range of 0.5 m of FSL can be achieved. The main pumps shall operate continuously. The small pump shall be started when WL reaches FSL and stopped when WL recedes to lower set level, say, FSL - 0.5 m. The start and stop operation of small pumps can be automatic with level control system. Fig.16.2 shows the conventional and proposed pumping installation in sump and level variation.

The selection of pumps and operation shall be as under:

- i) Rated combined discharge of duty pumps shall be 97-98% of the design discharge.
- ii) The small pump (1 working + 1 standby) shall be rated for 5 to 6% of design discharge and start and stop of the pump shall be automatic with level control arrangement.
- iii) Main pumps (working) shall be operated continuously.

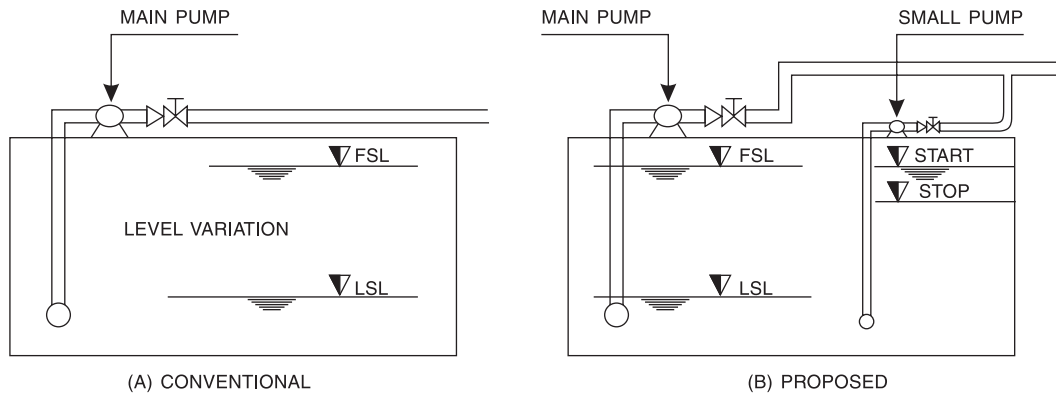


FIG. 16.2: CONVENTIONAL AND PROPOSED PUMPING INSTALLATION IN SUMP

- iv) The small pump shall start when water level reaches FSL and shall stop when water level drops to lower set level, (say $FSL - 0.5$ m.).
- v) Due to stopping of small pump as outflow reduces to 97 to 98% of inflow, the water level shall rise and when water level reaches FSL, operation (iv) will repeat.
- vi) Thus water level will be maintained between FSL and lower set level, say $(FSL - 0.5$ m) resulting in reduction in head and consequent reduction in energy consumption.

Normally water depth in sump is 3.0 - 4.0 m. Reduction in head on pump on an average shall be about 1.5 m and corresponding saving in energy cost can be achieved.

Small pumps can be submersible type and can be located in the existing pump house without need of extra space. Cost of these small pumps shall be very meagre and can be normally recovered within 6-12 months due to saving in energy cost.

16.3.1.5 Keeping Strainer or Foot Valve Clean and Silt Free

Floating matters, debris, vegetation, plastics, gunny bags etc. in raw water clog the strainer or foot valve creating high head loss due to which the pump operates at much higher head and consequently discharge of the pump reduces. Such operation results in :

- Operation at lower efficiency as operating point is changed. Thus, operation is energy wise inefficient.
- Discharge of the pump reduces. If the strainer/foot valve is considerably clogged, discharge can reduce to the extent of 50% or so.
- Due to very high head loss in strainer/foot valve which is on suction side of the pump, NPSHA may fall to low level causing drop in pressure to below vapour pressure. This may result in cavitation of pump and consequent damages due to pitting, vibration etc.

The strainers or foot valve should therefore, be cleaned regularly. Frequency of cleaning should be more during rainy season depending on load of floating matters.

While cleaning, care need to be taken to take out clogging matters and dispose away from stream. In no case, the clogging matters should be flushed back to source well/sump as the same shall return to strainer/foot valve with inflowing water and clog it again.

Number of cases are reported where silt deposition in well increased so much that the strainers were immersed in silt. Such operation causes very high head loss and if deposition level is very high the pump may get starved.

It is, therefore, necessary to carry out desilting work after every monsoon. In order to facilitate desilting work without taking total shutdown, it is desirable to provide compartments in the well/sump.

16.3.1.6 Preventing Throttling of Pump

At times, if motor gets overloaded, field officer resorts to throttling of pump to prevent overloading of motor. The effect of throttling is shown in Figure 16.3. Due to throttling, operating point is shifted from point 'A' to point 'B' which though prevented overloading of the motor, discharge is reduced resulting in operation for more number of pumping hours to fulfil demand and therefore, increase in energy consumption. The operation is also generally at low efficiency and consequently results in increased energy cost. Such throttled operation therefore should be avoided.

If the impeller is trimmed by following relationship given in authoritative books on pumps, purpose of preventing overloading of motor can be achieved with same power requirement corresponding to throttled operation. The relationships are as follows.

$$\frac{Q_1}{Q_2} = \frac{D_1}{D_2} \qquad \frac{H_1}{H_2} = \left[\frac{D_1}{D_2} \right]^2 \qquad \frac{P_1}{P_2} = \left[\frac{D_1}{D_2} \right]^3$$

where Q = discharge H = head P = power input D = impeller diameter

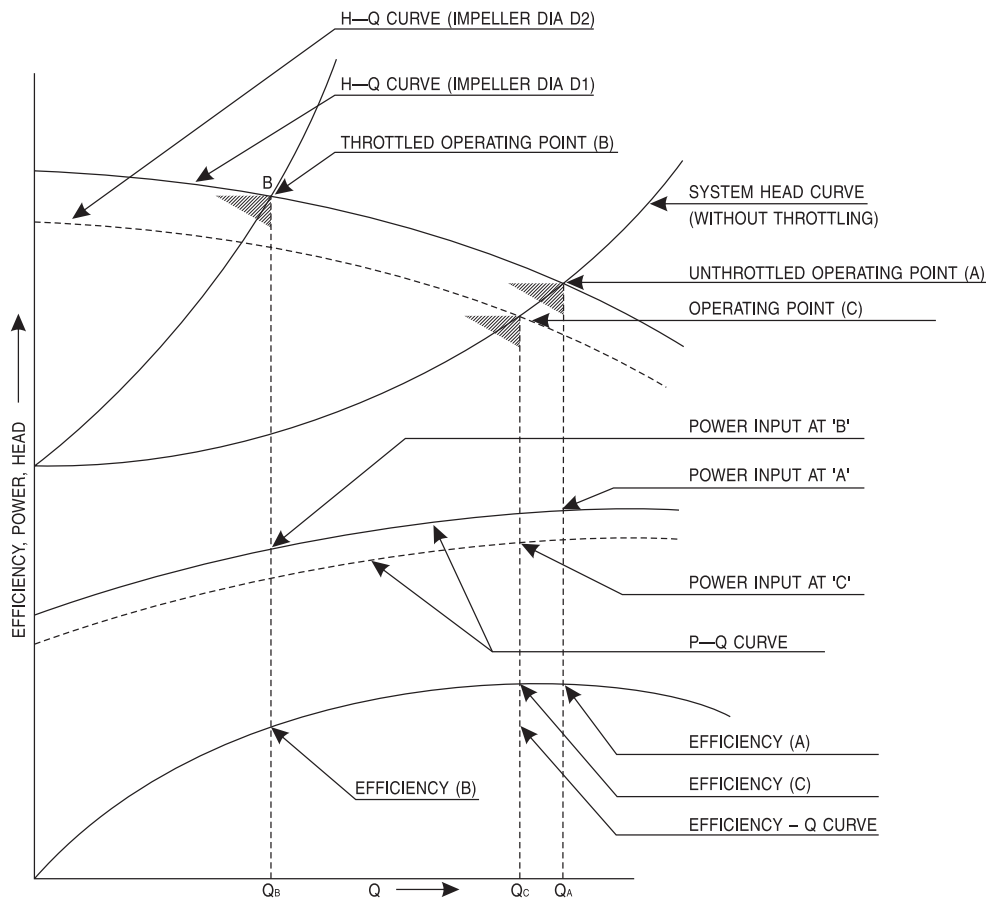


FIG. 16.3: EFFECT OF THROTTLING AND TRIMMING IMPELLER

The curves shown in broken lines are characteristic curves for trimmed impeller. The H-Q characteristic of trimmed impeller intersects the system head curve at point C. Thus point 'C' is operating point of trimmed impeller. The discharge QC is much more than QB at the same power. Thus operating hours of the pump can be reduced and energy can be saved. It is also seen that pump efficiency at point C is much higher than that at point B. Thus operation at point C is highly beneficial from point of energy consumption.

Precise diameter to which impeller need to be trimmed can be worked out by trial and error by using above relationships, drawing H-Q curve for each such assumed diameter and determining point of operation given by intersection of H-Q curve and system head curve and power drawn.

Maximum permissible reduction in diameter is 15-20% of maximum impeller diameter shown on manufacturer's characteristic curves.

16.3.1.7 Replacement of existing Mercury Vapour Lamps by Sodium Vapour Lamps

Sodium vapour lamps are considerably energy efficient as compared to mercury vapour lamps. Lumens per watt of SV lamp is nearly twice that of MV lamps. Hence mercury vapour lamps should be replaced by sodium vapour lamps of lower wattage as and when MV lamps become unserviceable to reduce energy bill.

16.3.2 PERIODICAL MEASURES

16.3.2.1 Restoring Wearing Ring Clearance

Due to wear of wearing rings shown in Fig.16.4, the clearance between wearing ring increases causing considerable reduction in discharge and efficiency. Reduction in discharge upto 15 - 20% are observed in some cases. If wearing rings are replaced, the discharge improves to almost original value.

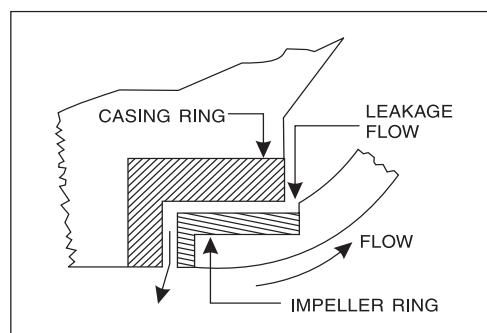


FIG. 16.4: A TYPICAL WEARING RING

Minimum clearances between impeller wearing ring and casing wearing ring for new pumps are generally as per table given in para 11.3.1.4.

Initial leakage through wearing rings is of the order of 1 to 2% of discharge of the pump. Due to operation, wearing rings wear out causing increase in clearance which increases leakage loss and results in consequent reduction in effective discharge of the pump. A study shows that even though discharge is reduced, power reduction is very marginal and as such the pump operates at lower efficiency. Reduction in discharge upto 15% to 20% is not

uncommon. Thus the pumps have to be operated for more number of hours causing increase in energy cost.

If wearing rings are replaced, the clearances can be brought to original value and discharge can be improved almost to rated value and wastage of energy which may be as high as 15% can be avoided.

It is advisable to replace wearing rings of pump to specified clearance once in 3 - 4 years or when discharge of the pumps reduces by 5% or more.

16.3.2.2 Reducing Disk Friction Losses

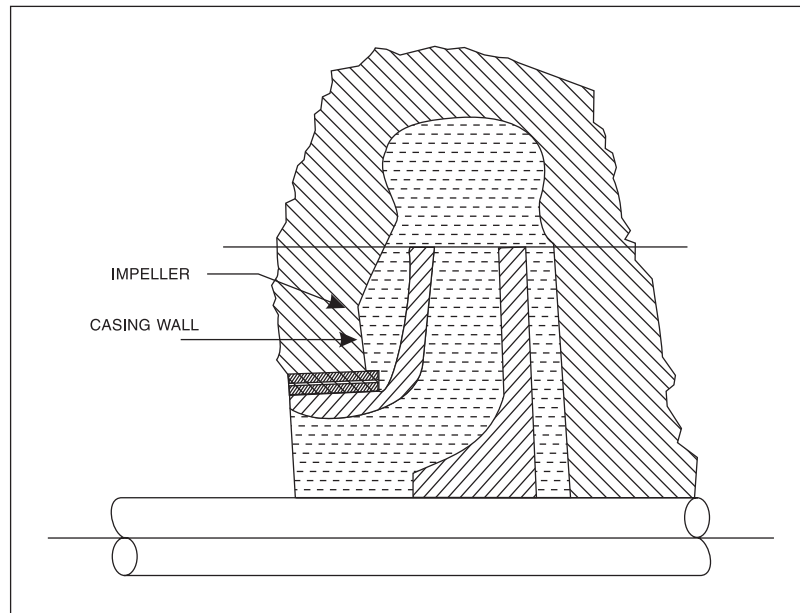


FIG. 16.5: IMPELLER AS A DISK

Disk friction losses in pump accounts for about 5% of power consumed by the pump. The phenomenon of disk friction loss is as follows :

The water particles in space between impeller shrouds and walls of casing/bowl acquire rotary motion due to rotation of impeller which functions as disk. The particles move outwards and new particles approach disk at centre. Thus re-circulation is established and energy is spent.

A study shows that if surfaces of the impeller and casing are rough, the disk friction losses increase. If casing is painted and impeller is polished, disk friction losses can be reduced by 20% to 40% of normal loss. Thus as disk friction loss is about 5% of power required by the pump, overall saving in power consumption will be 1% to 2%. For large pump the saving can be very high.

Disk friction loss in 500 kW pump is normally 25 kW (at 5%). The loss can be reduced by 5kW to 10 kW. Thus saving in power cost per annum for operation @24 hrs./day and tariff as Rs. 4/- per kWh would be about Rs. 1.75 lakhs to Rs. 3.50 lakhs.

In addition if inner surfaces of the casing and the impeller are coated with commercially available coatings, further reduction in total power consumption can be brought down by additional 1% to 2%.

16.3.2.3 Scrapping down Encrustation inside Column Pipes

Due to operation over prolonged period, encrustation or scaling inside the column pipe develops causing reduction in inside diameter and making surface rough. Both phenomenon cause increase in friction losses. If scrapping of encrustation is carried out whenever column pipes are dismantled energy losses can be avoided.

16.3.3 SELECTION ASPECTS

16.3.3.1 Optimum Pump Efficiency

Optimum efficiency of pump can be ensured by appropriate selection such that specific speed is optimum. Specific speed, N_s is given by,

$$N_s = \frac{3.65N\sqrt{Q}}{h^{0.75}}$$

- where N = rotative speed, rpm
Q = discharge, m³/s
h = head per stage, m

Thus by varying N and number of stages and therefore h, the optimum specific speed can be chosen and optimum efficiency can be ensured.

Fig. 16.6 shows variation of efficiency with variation in specific speed and discharge. It can be seen from the figure that N_s should be around 250 for optimum efficiency. It should not be less than 100 as efficiency is very low and in water supply installation, N_s should not be more than 295 as power required at shut off is more than that at b.e.p. requiring higher motor rating. Otherwise such pumps are to be started and stopped against open delivery valve which is not possible if parallel operation of pumps is involved.

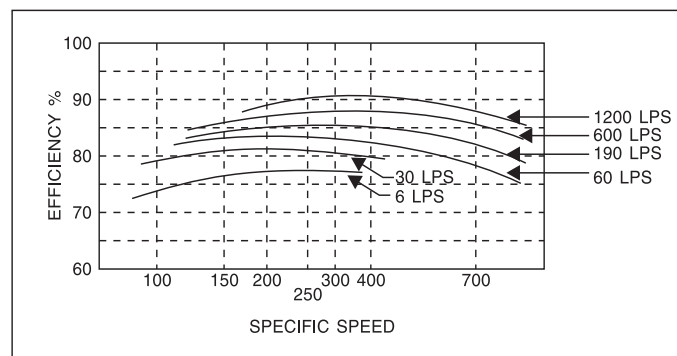


FIG. 16.6: PUMP EFFICIENCY VERSUS SPECIFIC SPEED & DISCHARGE

16.3.3.2 Optimisation of Sluice Valve/Butterfly Valve and Non-Return Valve on Pump Delivery

'K' values of sluice valve and non-return valve are 0.35 and 2.50 respectively which amount to combined 'K' value of 2.85. Due to very high 'K' value, head loss through these valves is significant and therefore, it is necessary to have optimum size of valves.

Typical comparison of design velocities, head loss and energy loss in sluice valve and NRV are as follows :

Q	=	600 lps		
Head loss	=	$K \frac{V^2}{2g}$		
			$V_1=2\text{m/s}$	$V_2=2.5 \text{ m/s}$
Head loss			0.58 m	0.72 m
HP consumed for the head loss			5.80 hp	7.20 hp
Energy cost per annum			Rs. 1.52 lakhs	Rs. 1.90 lakhs
@ Rs. 4/- per kWh for 24 hrs. working				

Thus energy cost for the typical case can be reduced from Rs. 1.90 lakhs per annum to Rs. 1.52 lakhs per annum i.e. saving of about Rs. 0.38 lakh per annum. Similar analysis is applicable if butterfly valve is provided instead of sluice valve. It is also necessary to optimise suction pipe diameter and valve on suction side.

On detailed study, following design velocities are found optimum for determining size of the valves and pipes.

Suction pipe/valve	1.5 to 1.7 m/s
Delivery pipe/valve	1.5 to 2.0 m/s

16.3.3.3 Column Pipe Diameter for V.T. Pump

Selection of economical diameter of column pipe is of utmost important, particularly for raw water V.T. pumps where length of column pipes is considerable and at times as high as 30 m. Head loss in column pipe upto 2-3 m is not uncommon if diameter is not selected suitably. Figure in IS 1710 for V.T. pumps shows head loss in column pipe per 10 m length for variation in Q and diameter of column pipe.

Following design velocities are recommended for optimum diameter of column pipe.

Q	Design Velocity
Upto 50 lps	1.5 m/s
51 - 100 lps	2.00 m/s
101 - 300 lps	2.25 - 2.5 m/s
Above 300 lps	2.75 m/s

16.3.3.4 Delivery Pipe for Submersible Pump

As delivery pipe for submersible pump is comparatively long and therefore, head loss in delivery pipe is considerable, it is of importance to select proper diameter. Optimum design velocity is around 1.1 - 1.5 m/s. However, pipe diameter should not be less than 50 mm.

16.3.3.5 Sodium Vapour Lamps for External Illumination

In new installation, SV lamps should preferably be used for external illumination as the SV lamp is energy-efficient as compared to MV lamp.

16.3.4 MEASURES FOR SYSTEM IMPROVEMENT

16.3.4.1 Replacement of Old and Inefficient Pumps

At times it is observed that the pump efficiency reduces by about 10% - 15% and can not be improved though wearing rings are replaced and overhaul carried out to the pumpset because of abnormal deterioration in pump. In such a case, it is necessary to replace the old and inefficient pump to save the tremendous wastage of energy.

Typical calculations are as follows:

DATA : Design pump efficiency	=	0.75
Deteriorated pump efficiency	=	0.65
whp of the pump	=	490 HP
bhp of the motor	=	670 HP

$$\begin{aligned} \text{Therefore increase in HP required due to reduction in pump efficiency} \\ &= (1 / 0.65 - 1 / 0.75) \times 490 \\ &= 100.5 \text{ HP} \end{aligned}$$

$$\begin{aligned} \text{Hence, excess energy cost per annum} \\ &= 100.5 \times 0.746 \times 24 \text{ hours} \times 365 \text{ days} \times \text{Rs. } 4.00 \\ &= \text{Rs. } 26.27 \text{ lakhs} \end{aligned}$$

$$\begin{aligned} \text{Cost of replacement of pump at Rs. } 2500/- \text{ per bhp} \\ &= 670 \times 2500 \\ &= \text{Rs. } 16.75 \text{ lakhs} \end{aligned}$$

Thus, the analysis shows that the cost of such replaced pump can be recovered within about 8 months due to saving in energy cost.

It can, therefore, be concluded that replacement of old and inefficient pump after completion of its useful life is economical and needs to be taken up in a phased manner as important measure for energy conservation.

Normal life for pumps can be taken as follows:

- Submersible pump 4 - 7 years
- Centrifugal pumps 15 - 20 years
- Vertical Turbine pumps About 15 years

16.3.4.2 Dispensing with Sump if Inlet is from Dam

Usual arrangements of intake works as shown in Figure 16.7 is to admit water to sump through inlet pipe and to pump water from sump into rising main. Depending on WL in impounded reservoir and in sump, the head equal to difference between two water levels is lost. In case of one head works, FSL is 342.0 m and LSL in sump is 322.0 m. Thus when dam is full, almost 20 m head is lost. It can, thus be concluded that on an average 10 m. head is lost.

If pumping arrangement is such that suction to the pump is taken directly from inlet pipes as shown in figure 7(b) and (c), the available full head from impounded reservoir can be utilised. A surge well (shaft) as shown in (b) is necessary to control water hammer pressure in inlet pipe.

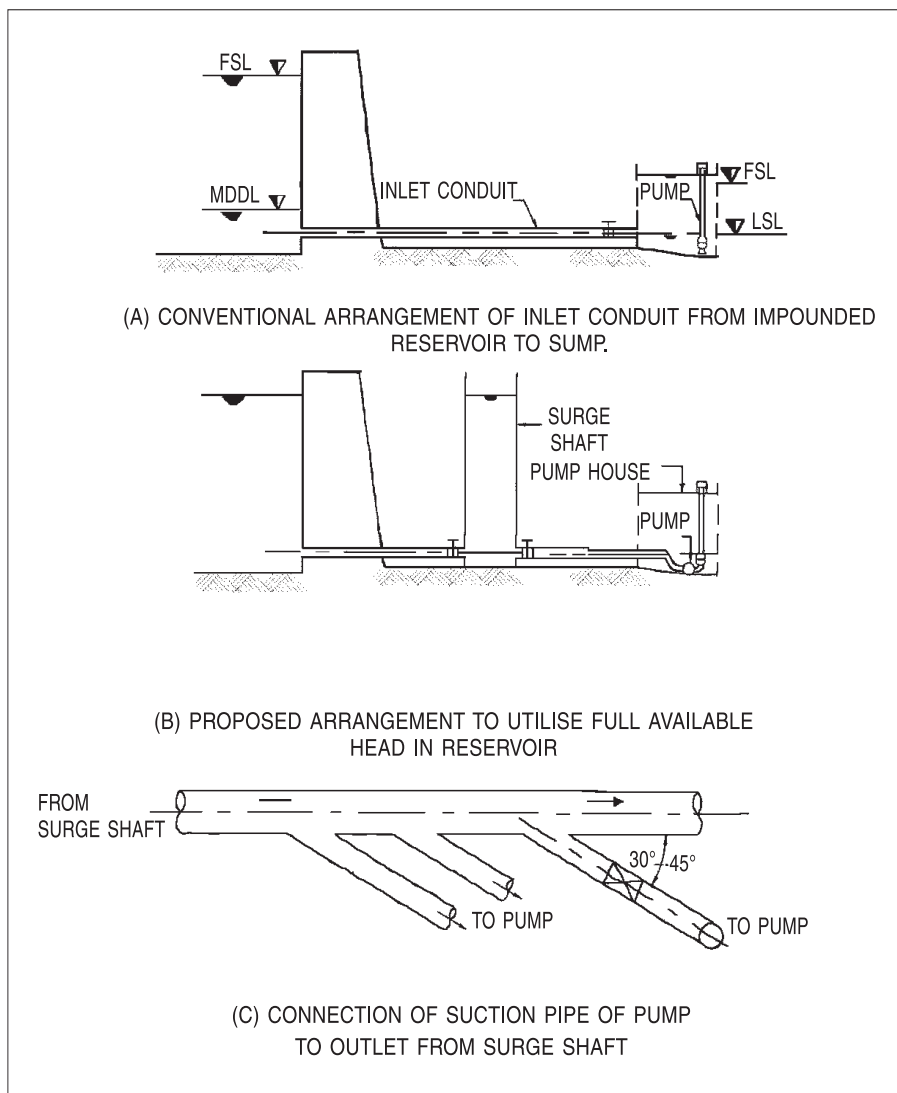


FIG. 16.7: INTAKE FROM IMPOUNDED RESERVOIR

Caution should however, be exercised while adopting the measure as explained above. The inlet conduit should be oversafe for water hammer pressure encountered if flow suddenly stops due to sudden stopping of pumps on power failure. In addition, well designed water hammer control device on inlet conduit is necessary. Thirdly multiple control gates or valves are necessary to isolate the inlet conduit in the event of any likely burst.

The arrangement is successfully tried in one scheme and is proposed for another scheme. Saving achieved in case of first water supply scheme is Rs. 36.0 lakhs per annum. In case of second scheme, the saving in head is about 14.0 m and predicted saving in energy cost is Rs. 71.0 lakhs per annum.

These days, as impounded reservoirs are preferred as assured sources, some such situation may be feasible and can be utilized to reduce head and save tremendous amount of energy.

16.3.4.3 Preventing Open Channel Flow in Rising Main

In case of rising main if HGL is cutting the pipeline at hump and thus causing open channel flow in downstream section as shown in Figure 16.8, feasibility of lowering the pipeline at hump and thus reducing head on the pump need to be examined and if feasible, should be implemented.

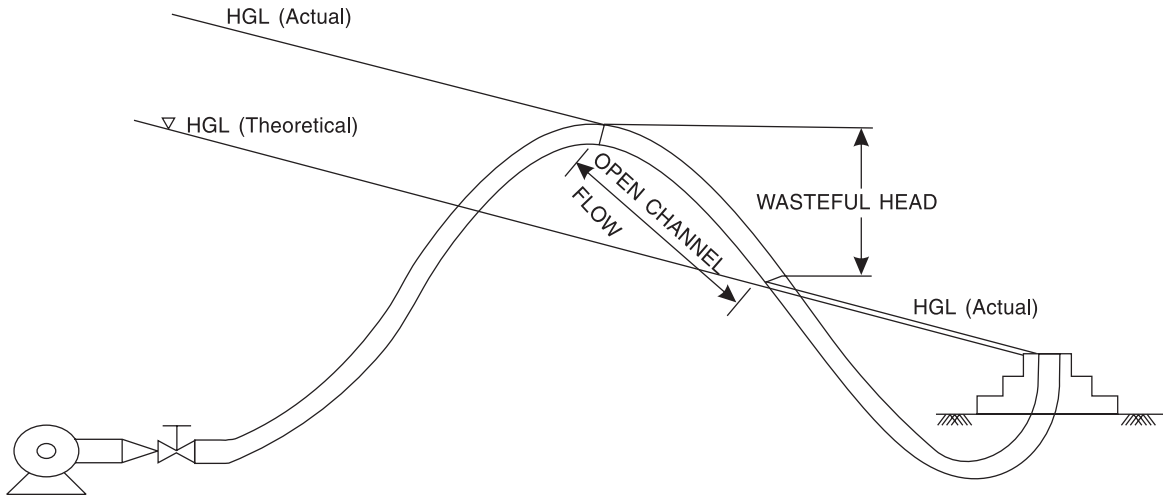


FIG. 16.8: HGL CUTTING AT HUMP OPEN CHANNEL FLOW

16.3.4.4 Providing Wash Water Pumps instead of tapping from Clear Water Rising Main or Filling Wash Water Tank from Reservoir

In some installations, wash water tank is fed from tapping on clear water rising main as shown in Figure 16.9, or, from reservoir at higher elevation. This practice is adopted to save capital cost of wash water pump without realising that such operation results in tremendous wastage of energy. As head on clear water pump is usually much higher than that required for wash water pump, considerable head and energy are wasted.

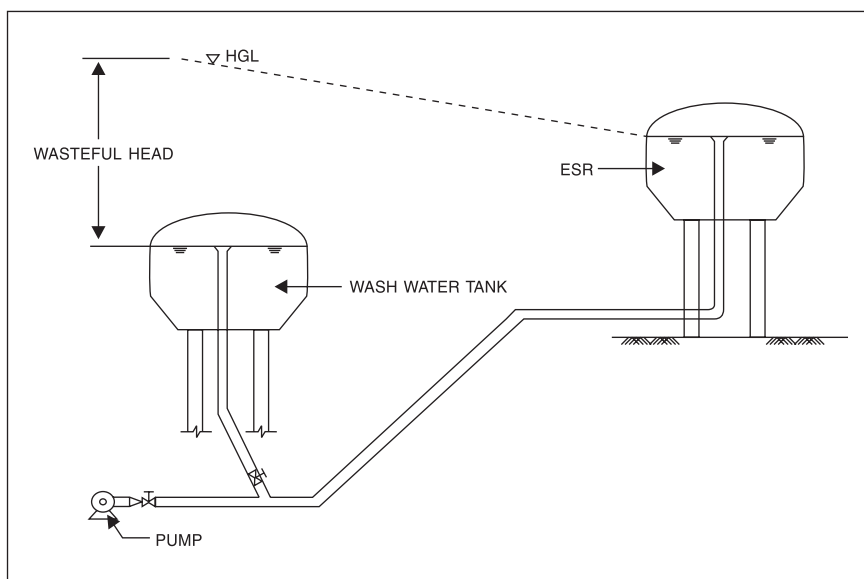


FIG. 16.9: FEEDING WASH WATER TANK FROM PURE WATER RISING MAIN

Details of impact on energy consumption in one case is illustrated below, which shows wastage of energy to the tune of Rs. 7.25 lakhs per annum.

DATA	<ul style="list-style-type: none"> • Plant Capacity • Wash Water quantity required 	<p>300 ML/day</p> <p>2.5 % i.e. 7.5 ML/day</p>
	<ul style="list-style-type: none"> • Head on main pump • Efficiency of main pump • Head for wash water pump 	<p>33 m</p> <p>0.75</p> <p>15 m</p>
	<p>Therefore, wasteful head</p> <p>Energy wasted per day</p>	<p>(33-15)</p> <p>18 m</p>

$$\frac{7.5 \times 10^6}{3600} \times \frac{18}{75} \times \frac{1}{0.75} = 666 \text{HP-hours}$$

Cost of wastage of energy per annum

@ Rs. 4 per kWh = Rs. 7.25 lakhs

The energy wasted can be saved by providing wash water pumps in clear water house for filling the wash water tank.

Capital cost of wash water pumps of 40 HP x (1W + 1S) would be about 6.40 lakhs. The capital can be recovered within very short period of 11-12 months by saving energy.
