

Continued from front flap

Besides, the CPHEEO implements AUWSP for small towns (scrutinizing/approving the schemes received from State Departments from techno-economic angle), solid waste management in 10 airfield towns, sponsors research studies, organises training courses for the in-service engineers working in the water supply and sanitation sector. It has developed computer software for design of water supply distribution networks, sewerage networks, economical size of pumping main & distributed them to all the States & ULBs for extensive use. To its credit, it has prepared and published the following Manuals, which are technical guidebooks for the help of field engineers:

1. Manual on Water Supply & Treatment, Third Edition, Revised-updated, May 1999.
2. Manual on Sewerage & Sewerage Treatment, Second Edition, 1993.
3. Manual on Municipal Solid Waste Management, 2000.

### Greater Shillong Water Supply Project – 7.5 MGD Water Treatment Plant

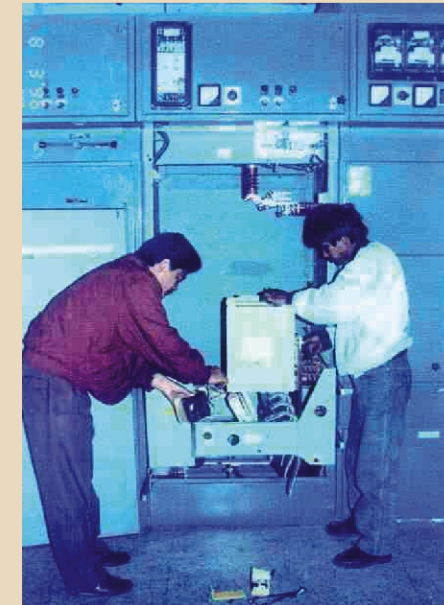
↓ CLARIFLOCCULATOR: Water from the flash mixer flows through 600 mm size central shaft of the clarifier and enters the flocculating zone 1.5 m dia, 5 m effective depth through four openings in the shaft. In the flocculator, water is stirred by three sets of paddles. Then the water passes to the clarifier of size 37 m dia and 4 m deep. The settled water from the clarifier passes to the battery of 6 nos. of rapid gravity filters.



↑ RAW WATER CHANNEL: Raw water through the inlet channel is received in inlet chamber. The rate of flow of raw water is measured by flow meter. Alum solution from the constant dosing tank flows directly through a taper needle valve at preset dosage, which adjusts itself automatically to any change in the flow rate of water. The raw water then enters the flash mixer where the coagulant is added and rapidly mixed.



↑ Control consoles for 6 nos. rapid sand filters. The 7.5 MGD water treatment plant at Mawphlang is one of its kinds in the North East to be installed with pneumatic operation.



← Maintenance of the HT motor control centre in progress. The electric motors installed are directly fed with a voltage of 6.6 Kv.

→ Battery of 6 nos. BHR 35-30° 4 stage self water lubricated pumps installed in the intake pumping station. Each pump has a transmission line of 38 m.



MANUAL ON

OPERATION AND MAINTENANCE OF

WATER SUPPLY SYSTEMS



MANUAL ON

OPERATION AND MAINTENANCE OF  
**WATER**  
SUPPLY SYSTEMS

CENTRAL PUBLIC HEALTH AND ENVIRONMENTAL ENGINEERING ORGANISATION

MINISTRY OF URBAN DEVELOPMENT  
NEW DELHI

In collaboration with



World Health Organization

JANUARY 2005

### Ministry of Urban Development

The Ministry of Urban Development is the nodal Ministry in charge of various aspects of Urban Development including Urban Water Supply and Sanitation in the country. The Ministry formulates of policies, strategies pertaining to aspects of urban development including water supply, sanitation and municipal solid waste management and implements Centrally sponsored Accelerated Urban Water Supply Programme (AUWSP), Solid Waste Management & Drainage in 10 Airfield Towns, Public Health Engineering Training Programme etc. The Ministry also facilitates funding from external & bilateral agencies for urban water supply and sanitation sector.

### Central Public Health & Environmental Engineering Organisation (CPHEEO)

The CPHEEO was constituted under the erstwhile Ministry of Health & Family Welfare, Directorate General of Health Services (DGHS) in 1953 as per the recommendations of the Environmental Hygiene Committee to deal with water supply and sanitation in the country. In 1973-74, the CPHEEO was affiliated to the Ministry of Urban Development (erstwhile Ministry of Works & Housing). It is functioning as the technical wing of the Ministry. Though water supply and sanitation is a State subject, the policies, strategies and guidelines are being provided by CPHEEO to the States & U.Ts. Governments including Municipal Corporations/Committees. The CPHEEO plays a vital role in processing the schemes posed for World Bank/Bilateral & Multilateral agencies and institutional financing such as LIC. It acts as an Advisory body at Central level to advise the concerned State agencies and Urban Local Bodies (ULBs) in implementation, operation & maintenance of urban water supply, sanitation and solid waste management projects and helps to adopt latest technologies in these sub sectors.

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MANUAL ON

**OPERATION AND  
MAINTENANCE OF  
WATER SUPPLY  
SYSTEMS**

**CENTRAL PUBLIC HEALTH AND  
ENVIRONMENTAL ENGINEERING ORGANISATION**

MINISTRY OF URBAN DEVELOPMENT  
NEW DELHI



**WORLD HEALTH ORGANISATION**

JANUARY 2005

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मंत्री  
Minister  
संसदीय कार्य एवं शहरी विकास  
Parliamentary Affairs &  
Urban Development  
भारत सरकार  
Government of India  
निर्माण भवन, नई दिल्ली-110011  
Nirman Bhavan, New Delhi-110011

## MESSAGE

The UPA Government attaches top-most priority to provide drinking water to all sections in urban and rural areas of the country and augmenting availability of drinking water sources. There is an imminent need to reduce water losses in the distribution system by way of reduction of unaccounted for water, non-revenue water and adoption of technologies for leakage detection and control. There is also need to put an end to the acute drinking water shortage in cities, especially in southern states, where desalination plants are proposed to be installed all along the Coromandel Coast starting with Chennai.

I am glad to know that an Expert Committee constituted by the Ministry of Urban Development has brought out a comprehensive Manual on Operation & Maintenance of Water Supply Systems. It has been a long felt need for the sector to the people. I congratulate all those who have been instrumental in bringing out this Manual, including the World Health Organization (WHO) for providing financial support.

I recommend that all Public Health Engineering Departments and Water Boards in urban areas make full use of this Manual.

(GHULAM NABI AZAD)

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## FOREWORD

Safe and adequate drinking water is vital for sustaining the quality of life in urban areas. Provision of this facility to the burgeoning urban population is a challenging task for State Governments and Union Territories. Ministry of Urban Development has been assisting this sector through policy formulation, central financial assistance, human resource development, obtaining external assistance and preparation of manuals and guidelines.

One of the problem areas of the sector has been the absence of proper operation and maintenance of the water supply systems, resulting in wastages, leakages, high-energy consumption, etc. There has been a long-standing need for bringing out a comprehensive manual on the subject. Ministry of Urban Development, therefore, constituted an Expert Committee under the chairmanship of Adviser, Central Public Health & Environmental Engineering Organization (CPHEEO). The World Health Organization (WHO) provided financial assistance for the purpose.

The Manual was finalized by the Expert Committee after considerable deliberations and contributions by the Members, as well as feed back obtained from State Public Health Engineering Departments and Water Utilities during the National Workshop Organized at Thiruvananthapuram, Kerala from 19th to 21st June, 2003. The Manual covers all the aspects of operation and maintenance, including treatment of water from various sources, drinking water quality surveillance, water audit and leakage control, human resource development and public private partnerships.

I trust that the Manual would provide valuable guidance not only to the managers of water supply systems, but also to other key personnel, including grass-root level operators and technicians.

I am pleased to acknowledge the contribution made by the Members of the Expert Committee, invaluable comments/suggestions given by field level organizations and sector professionals and financial assistance provided by World Health Organization in the preparation of the Manual.

(ANIL BAIJAL)

# PREFACE

The Ministry of Urban Development and Poverty Alleviation had constituted an expert committee in February 2001 for the preparation of Manual on Operation and Maintenance of urban water supply systems to fulfill the long time demand of the field engineers working in the urban water supply and sanitation sector. The composition of the Committee was:

1. Shri V. B. Ramaprasad  
Adviser (PHEE) CPHEEO  
Ministry of Urban Development  
Government of India, New Delhi  
Chairman
2. Dr. D. M. Mohan  
Rtd. Chief Engineer  
Hyderabad Metropolitan  
Water Supply and Sewerage Board  
Non-Official Member
3. Shri N. R. Paunikar  
Rtd. Superintending Engineer  
Maharashtra Jeevan Pradhikaran  
Non-Official Member
4. Shri P. N. Gokhale  
Superintending Engineer  
Maharashtra Jeevan Pradhikaran  
Official Member
5. Shri D Cruz J.  
Rtd. Engineer in Chief  
Delhi Jal Board  
Non-Official Member
6. Shri M. M. Datta/  
Shri A. K. Sen Gupta  
National Professional Officer  
(Sanitary Engineer)  
WHO India Office  
Non-Official Member
7. Shri B. R. Nagendra  
Chief Engineer  
Bangalore Water Supply and  
Sewerage Board  
Official Member

- 
- |     |  |                                     |
|-----|--|-------------------------------------|
| 8.  | Shri T. R. Rane<br>Hydraulic Engineer<br>Greater Mumbai Municipal Corporation  | Official Member                     |
| 9.  | Shri Subal Chandara Bhowmik<br>Superintending Engineer<br>PHED, Government of Tripura                                  | Official Member                     |
| 10. | Shri R. Ramanujam<br>Managing Director<br>Kerala Water Authority   | Official Member                     |
| 11. | Shri R. N. Surya Narayana Singh<br>Engineering Director<br>Chennai Metropolitan<br>Water Supply and Sewerage Board     | Official Member                     |
| 12. | Shri M. N. Sharama<br>Rtd. Chief Engineer<br>PHED Govt. of Haryana   | Non-Official Member                 |
| 13. | Shri V. Subramaniam<br>Rtd. Superintending Engineer<br>TWAD Board  | Non-Official Member                 |
| 14. | Shri S. K. Kalra<br>Additional Chief Engineer (Rtd.)<br>PHED Govt. of Rajashtan  | Official Member                     |
| 15. | Shri D. S. Gundevia<br>General Manager and<br>Shri K. K. Shukla<br>Chief Water Analyst<br>Jal Sansthan, Kanpur         | Official Members                    |
| 16. | Shri M. Sankaranarayanan<br>Official Member-cum<br>Assistant Adviser (PHE)<br>CPHEEO,<br>Ministry of Urban Development | Official Member<br>cum Co-ordinator |
| 17. | Shri R. Sethuraman<br>Official Member cum<br>Joint Adviser (PHEE)<br>CPHEEO,<br>Ministry of Urban Development          | Member Secretary                    |
-

The Committee held nine meetings from June, 2001 to October, 2003 to deliberate & discuss various aspects related to O&M of Water Supply Systems and has drawn freely from all available literature in finalizing the manual. The Committee constituted three sub groups, which convened nine meetings in Mumbai, Chennai, Bangalore, Thiruvananthapuram and Delhi and deliberated/discussed the various aspects and also consulted some documents to incorporate in the draft chapters. The Committee also constituted an Editorial Sub-Committee with the following members for editing the Chapters.

1. Shri J. D'Cruz, Engineer-in-Chief (Rtd.), Delhi Jal Board
2. Shri M. N. Sharma, Chief Engineer (Rtd.) PHED, Govt. of Haryana
3. Shri V. Subramaniam, Superintending Engineer, TWAD Board
4. Dr. D. M. Mohan, Chief Engineer (Rtd.), Hyderabad Metropolitan Water Supply and Sewerage Board
5. Officials from CPHEEO

The Editorial Sub-Committee convened four meetings at Hyderabad and New Delhi and finalized the draft chapters of the Manual.

The Draft Manual was discussed thoroughly in the three day Workshop held at Thiruvananthapuram in June, 2003. The Workshop was attended by the officers of various water authorities, responsible for operation and maintenance of water supply systems. Later, the Expert Committee reviewed the suggestions made in the said Workshop and modified the Draft Manual accordingly.

The Committee places on record its thanks and deep appreciation to:

- The WHO for the financial support for the preparation of the manual as well as organizing the three day Workshop at Thiruvananthapuram.
- The Ministry of Urban Development for the necessary support and help in the preparation of the Manual.
- The Kerala Water Authority for its support and cooperation extended for organising the three day Workshop at Thiruvananthapuram.
- The PHE Departments, Water Boards, Urban Local Bodies, and individuals for their valuable suggestions on the draft manual.
- Shri R. Sethuraman, Joint Adviser (PHEE) and Shri M. Sankaranarayanan, Assistant Adviser (PHE), who in spite of their normal duties took care of all the logistics for holding the meetings which enabled the Committee to complete its work.

The contribution made by Shri B.B. Uppal, Deputy Adviser (PHE), Shri M. Dhinadhayan, Shri N. N. Hotchandani, Shri V. K. Chaurasia, Assistant Advisers (PHE) and Shri Sukanta Kar, Scientific Officer for enriching the contents of the Manual is very much appreciated.

Shri S. K. Gulati, Shri Ambuj Sharma, Shri R. Rajagopal, Shri Neeraj Kumar Kush, Shri S. Timothy, Ms Durga Rani Batra and Ms Ravi Rekha Bajaj have rendered commendable



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service to the Committee in the form of Secretarial assistance and Shri Chandra Singh & Ravinder Kumar for general assistance, which deserve appreciation.

The Committee also places on record its appreciation of the services rendered by the PHE Section of the Ministry without whose cooperation, the arduous task assigned to the Committee could not have been accomplished as per the time schedule.

**V. B. Ramaprasad**  
Chairman of the Committee &  
Adviser (PHEE), CPHEEO  
Ministry of Urban Development  
New Delhi

Date: 23rd October, 2003

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# CHAPTER 1

## INTRODUCTION

### 1.1 SECTOR ORGANIZATION

Water supply and sanitation is treated as a State subject as per the federal Constitution of India and, therefore, the States are vested with the constitutional right on the planning, implementation and cost recovery of water supply and sanitation projects. At the local level, the responsibility is entrusted by legislation to the local bodies like Municipal Corporation, Municipality, Municipal Council, Notified Area Committee/Authority for towns or on a State/Regional basis to specialized agencies. The economic and social programme of the country is formulated through five-year plans.

The Public Health Engineering Department (PHED) is the principal agency at the State level for planning and implementation of water supply and sanitation programmes. In a number of States, statutory Water Supply & Sanitation Boards (WSSBs) have taken over the functions of the PHEDs. The basic objectives for creation of WSSBs have been to bring in the concept of commercialization in the water supply and sanitation sector management and more accountability. Such Boards have been set up in Assam, Bihar, Gujarat, Karnataka, Kerala, Maharashtra, Orissa, Punjab, Uttar Pradesh and Tamil Nadu. The metropolitan cities of Bangalore, Hyderabad and Chennai have separate statutory Boards. The water supply and sanitation services in the cities of Mumbai, Kolkata, Delhi, Ahmedabad, Pune and few other towns are under the Municipal Corporations.

The Ministry of Urban Development & Poverty Alleviation, Government of India formulates policy guidelines in respect of Urban Water Supply & Sanitation Sector and provides technical assistance to the States & Urban Local Bodies (ULBs) wherever needed. The expenditure on water supply and sanitation is met out of block loans and grants disbursed as Plan assistance to the States, and out of loans from financial institutions like Life Insurance Corporation (LIC) and Housing and Urban Development Corporation (HUDCO). The Central Government acts as an intermediary in mobilizing external assistance in the water supply and sanitation sector and routes the assistance via the State plans. It also provides direct grant assistance to some extent for water supply and sanitation programmes in urban areas.

A modest beginning has been made to provide central assistance for provision of safe drinking water supply facilities in towns having population less than 20,000 (as per 1991 census) in the country. Accordingly, a Centrally Sponsored Accelerated Urban Water Supply Programme (AUWSP) has been launched in the country during 1993-94. Under this programme, 50% of the cost is provided by Government of India as grant, 45% by the respective Provincial Government as grant and the balance 5% is mobilized through beneficiary contribution.

The role of the Statutory Bodies (SBs) is by and large confined in some States to mostly construction activities only, while in States like Kerala, Karnataka & Maharashtra the State level body looks after operation, maintenance and cost recovery also. After commissioning of schemes, the SBs usually hand over the projects to the ULBs for Operation & Maintenance, or perform this function also on their behalf. Thus, the pattern varies across different States.

The responsibility of operation, maintenance and revenue collection is generally vested with the elected urban local body. However, in some cases, the specialized agencies such as the State Public Health Engineering Departments, Water Boards etc. are in charge of these functions and formulate the water tariff and implement the same with the approval of the Governments. For instance, in Rajasthan right from planning up to O&M of Water Supply & Sewerage Schemes is being carried out by the State PHED. The local bodies generally receive some grant assistance for capital works on water supply and sanitation from the State Government.

The State Water Supply & Sewerage Boards do not have much autonomy in setting tariffs and generating revenues for O&M. Since the State Governments have the power to issue directives to the Boards, it is apparent that tariff revisions still require prior consent of the respective State Government and in essence rests with the State Governments.

## **1.2 OPERATION & MAINTENANCE SCENARIO**

It has been observed that lack of attention to the important aspect of Operation & Maintenance (O&M) of water supply schemes in several towns often leads to deterioration of the useful life of the systems necessitating premature replacement of many system components. As such, even after creating such assets by investing millions of rupees, they are unable to provide the services effectively to the community for which they have been constructed, as they remain defunct or under utilized most of the time.

Some of the key issues contributing to the poor Operation & Maintenance have been identified as follows:

- i) Lack of finance, inadequate data on Operation & Maintenance
- ii) Inappropriate system design; and inadequate workmanship
- iii) Multiplicity of agencies, overlapping responsibilities
- iv) Inadequate training of personnel
- v) Lesser attraction of maintenance jobs in career planning
- vi) Lack of performance evaluation and regular monitoring
- vii) Inadequate emphasis on preventive maintenance
- viii) Lack of operation manuals
- ix) Lack of appreciation of the importance of facilities by the community
- x) Lack of real time field information etc.

Therefore, there is a need for clear-cut sector policies and legal framework and a clear demarcation of responsibilities and mandates within the water supply sub-sector.

From the Indian experience, it has been observed that in the case of pumping schemes, by and large, about 20 to 40% of the total annual Operation & Maintenance cost goes towards

the personnel (Operation & Maintenance Staff), 30 to 50% of the cost is incurred on power charges and the balance is utilized for consumables, repairs and replacement of parts and machinery and miscellaneous charges. In most of the cities in India, the tariffs are so low that they do not even cover the annual Operation & Maintenance cost.

Measures such as control of Unaccounted for Water (UFW) and metering of the water connections, as detailed below may help reduce the wastage of water and increase the revenue to the local body to the maximum extent.

### **1.2.1 UNACCOUNTED FOR WATER (UFW)**

Several pilot studies conducted in the country have shown water losses in the distribution systems to be of the order of 20 to 50% of the total flow in the systems. It has been noticed that maximum leakage (more than 80%) occurs in the distribution system and house service connections. In addition, losses do occur at the source, transmission system, treatment plant and service reservoirs, which may add up to another 10 to 20% of the total output. In India, where water supply is, by and large, intermittent (supply hours ranging from 3 to 10 hours), the external pollution may get sucked into the system through points of leak, during non-supply hours when the system is not under pressure, causing health hazards. Therefore, a systematic approach towards wastage, leakage and preventive maintenance should form an integral part of Operation & Maintenance on a regular basis to save considerable quantity of water, prevent possible contamination, improve pressures in the distribution system and increase revenues to make the systems self-sufficient. If such measures are taken up by the water supply agencies in the country, there may not be any immediate need to take up augmentation schemes. Another important aspect is non-availability of indigenous good quality and precise electronic leak detection equipment for usage in the leak detection exercise.

### **1.2.2 METERING OF WATER SUPPLY SYSTEMS**

There are no two opinions that metering of water supply is desirable to minimize wastage and to maintain economic pricing of water. Though most of the major towns have been provided with domestic and bulk water meters, over the years it has been observed that 20 to 50% of the installed meters remain defunct due to their poor quality. Sometimes tampering of the meters by the owners has also been noticed. Moreover, the infrastructure and repair facilities for water meters are not adequate in most of the Urban Local Bodies and Water Supply Boards, which delay their repairs and early reinstallation. In the absence of working meters, billing for water consumed is often estimated, either on average basis or on flat rate, as the case may be. Though a few companies have been manufacturing water meters for domestic use, it is necessary to get domestic and bulk water meters of the desired quality and precision manufactured within the country through technology transfer from developed countries for Indian market. As per the prevailing practice, the consumers own the domestic meters. As such, they have direct access to the meters. However, it is perhaps worthwhile to explore the possibility of owning such meters by the respective water supply agencies and local bodies themselves to ensure that the consumers do not have direct access to the meters so as to avoid possible tampering of the meters.

### **1.3 NEED FOR MODIFICATION IN POLICY FRAMEWORK FOR EFFECTIVE OPERATION AND MAINTENANCE**

In the light of the 74th Amendment to the Constitution, the role and responsibilities of Urban Local Bodies have increased significantly to provide the basic facilities of water supply and sanitation to the community on a sustainable basis. The said amendment has enabled the Urban Local Bodies to become financially and technically sound to provide these basic civic amenities to the community. Though certain degree of cross-subsidy is inevitable in respect of the economically weaker sections of the society, it is very necessary to run the water supply systems on commercial principles due to the fact that water is an economic good and as such it should no longer be considered as a free commodity. Therefore, imposition of realistic tariffs for various beneficiaries and its effective realization is the key to the success of water supply sector performance including that of operation and maintenance. Of late, it has also been observed that even the poor are willing to contribute some percentage of the user charges for such facilities, provided reliable service is ensured by the water supply authorities and Urban Local Bodies.

Apart from providing minimum required quantity of drinking water to the people, the operation and maintenance authorities should always bear in mind that its quality is maintained at all times to safeguard the health of the community. City level consumer forums may be set up to keep a vigil on the water sources to prevent possible contamination and make periodical reporting to the operation and maintenance agencies for appropriate action well in advance. At the same time, awareness programmes on water conservation, wastage prevention, water quality, personal hygiene etc. may have to be designed and implemented with the help of NGOs, Residential Welfare Associations and neighborhood committees.

Consumer satisfaction should be the topmost priority of the operation and maintenance agencies. Complaint/suggestion cells may be set up by the operation and maintenance agencies to enable the consumers to lodge complaints on aspects such as leakage and wastage of water, low pressure at consumer's end, contamination/poor quality of water, pilferage of system components, malfunctioning of water meters, problems related to meter reading, payment of bills, etc. and suggestions, if any, for better performance of the system. At the same time, all such complaints received by the operation and maintenance agencies should be attended to within a reasonable time frame, so as to win the confidence of the consumers.

#### **1.3.1 PUBLIC PRIVATE PARTICIPATION**

Though privatization of water supply and sanitation sector could not make significant progress as of now, there is substantial potential available in the country for privatization and hence there is an urgent need for the same. Perhaps, it could be introduced in phases, either on Build, Operate and Own (BOO) or Build, Operate, Own and Transfer (BOOT) basis. Primarily, it is possible in two ways i.e. privatization of the existing water supply systems and secondly, privatization of systems in newly developed townships, housing colonies, business and commercial complexes, etc. There are some inherent problems due to which privatization could not be introduced in the existing water supply systems. For

instance, many local bodies and water supply departments, which are responsible at the local level for the operation and maintenance of such systems, are unable to recover even the operation and maintenance cost from the beneficiaries. By and large, the tariff rates being charged from the consumers are very low and there is a general reluctance for enhancing the same. Under the circumstances, without aiming at full cost recovery, privatization cannot be a successful proposition.

#### **1.4 NECESSITY FOR AN O&M MANUAL**

The Manual on Operation and Maintenance is a long felt need of the sector. At present, there is no Technical Manual on this subject to benefit the field personnel and to help the O&M authorities to prepare their own specific manuals suitable to their organizations. The Chief Engineer's Conferences held in previous occasions including that held at Chandigarh, in November 1998 had also emphasized the need and requested the Ministry of Urban Development & Poverty Alleviation to take initiative to prepare the said Manual. Realizing the need, the Ministry has decided to prepare the said Manual and make it available to the field agencies.

#### **1.5 OBJECTIVES OF OPERATION AND MAINTENANCE**

The objective of an efficient operation and maintenance of a Water Supply System is to provide safe and clean drinking water in adequate quantity and desired quality, at adequate pressure at convenient location and time and as economically as possible on a sustainable basis.

In engineering parlance, operation refers to timely and daily operation of the components of a Water Supply system such as headworks, treatment plant, machinery and equipment, conveying mains, service reservoirs and distribution system etc. effectively by various technical personnel, which is a routine function. The term maintenance is defined as the art of keeping the structures, plants, machinery and equipment and other facilities in an optimum working order. Maintenance includes preventive maintenance or corrective maintenance, mechanical adjustments, repairs, corrective action and planned maintenance. However, replacements, correction of defects etc. are considered as actions excluded from preventive maintenance.

The O&M Manual is required to encompass various issues pertaining to an effective O&M such as technical, managerial, administrative, HRD, financial & social aspects etc.

##### **1.5.1 OBJECTIVE OF THE MANUAL**

The Manual on Operation and Maintenance is intended to serve as a guide to strengthening the technical, operational and managerial capabilities required of the concerned personal to operate and maintain water supply services as per acceptable norms of quantity quality, sustainability, reliability and cost.

##### **1.5.2 WHO WILL USE THE MANUAL**

This manual is intended primarily for the managers and technicians in-charge of the operation and maintenance of the urban drinking water supply systems.

### **1.5.3 HOW TO USE THE MANUAL AND LIMITATIONS OF THE MANUAL**

The procedures mentioned in the manual are intended to be guidelines for ensuring effective O&M of the water supply systems. This manual is not exhaustive but will serve as a reference volume for the agencies incharge of the water supply systems to develop their O&M programmes to suit their specific problems depending on the size of the system, type of agency and location of the water supply system. This manual should be used as a supplement and not to replace existing manuals which describe procedures and techniques for O&M. Any agency desirous of formulating O&M programmes should do so only on the basis of an exhaustive assessment of their existing water supply systems.

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## CHAPTER 2

# STRATEGY

### 2.1 INTRODUCTION

The large investments made to construct utilities intended to provide facilities for water supply are becoming unproductive in the sense that the objective for which they have been installed is not achieved mainly on account of poor Maintenance. Often the investments become unproductive, and a larger amount of money is required to replace and rebuild the system components. Interruptions in service occur owing to the breakdown of equipment as a result of poor maintenance. The utility control organisations are not able to ensure that the maintenance staff follow valid practices to achieve proper maintenance. The management of water supply systems in the water authorities is receiving relatively lower priority. Lack of funds coupled with lack of enthusiasm among the operation and maintenance staff to keep schemes in working condition; lack of training, lack of motivation among the staff may be reasons for the present status of the water supply systems.

### 2.2 DEFINITION OF OPERATION AND MAINTENANCE

In an engineering sense, operation refers to hourly and daily operations of the components of a system such as plant, machinery and equipment (valves etc.) which is done by an operator or his assistant. This is a routine work. The term maintenance is defined as the art of keeping the plant, equipment, structures and other related facilities in optimum working order. Maintenance includes preventive maintenance or corrective maintenance, mechanical adjustments, repairs and corrective action and planned maintenance. Often repairs, replacements and corrections of defects (of material or workmanship) are considered as actions excluded from preventive maintenance. In some organisations the normal actions taken by operation staff are considered as maintenance activities whereas a separate unit or cell does repairs and replacements. Often both corrective and preventive maintenance are included in the job functions of operators and limits to which operators are expected to do normal maintenance are set forth for various equipment. Budgetary provisions of operation and maintenance organisations also incorporate heads of expenditure under maintenance for cost of spare parts and cost of labour or contract amount for repairs and replacements.

### 2.3 STRATEGY FOR GOOD OPERATION AND MAINTENANCE

#### 2.3.1 INTRODUCTION

The minimum requirements for good operation and maintenance are:

- (a) Preparation of a plan for operation and maintenance.
- (b) Providing required personnel to operate and maintain.
- (c) Providing Capacity building programmes for the O&M personnel
- (d) Availability of spares and tools for ensuring maintenance.
- (e) Preparation of GIS based maps of the system
- (f) Preparation of a water audit and leakage control plan
- (g) Maintaining MIS records on the system including history of equipment, costs, life etc.
- (h) Action Plan for energy audit for saving on energy
- (i) Establishing a sound financial management system.

### **2.3.2 PREPARATION OF A PLAN**

A program or a plan has to be prepared for operation and maintenance of every major unit to be specifically written for that particular unit. The overall operation and maintenance plan of an organisation is made up of collecting operation and maintenance programmes of various individual units. This plan has to contain procedures for routine tasks, checks and inspections at intervals viz. daily, weekly, quarterly, semi-annually or annually.

The individual plans must be prepared for all units and all pieces of equipment. Each unit must have a plan to fix responsibility, timing of action, ways and means of achieving the completion of action and contain what objectives are meant to be achieved by this action. Generally actions recommended by the manufacturer or by the engineer who has installed the equipment or who has supervised the installation can be included. Often the contractor's recommended operation and maintenance procedures at the time of design or construction will be a good starting point for writing a sound programme. This plan has to be followed by the operation and maintenance staff and also will be the basis for supervision and inspection and also can be used for evaluation of the status of operation and maintenance.

If the labour costs for operation and maintenance are high compared to replacement cost, the latter course of action will be preferable. The managers shall realize that most of the operation and maintenance can be carried out without more staff. The existing operation and maintenance staff with little training can do the operation and maintenance work without any extra expense. Similarly, record keeping and analysing does not require any additional cost. However costs have to be provided in the budgets for spares, tools and plants, training to operation and maintenance staff and any specialized services for important equipment.

Briefly the plan shall contain what actions are required, when these actions are to be taken, who has to take these actions, how these actions are to be achieved and why these actions are required. The nature of maintenance can be described in a separate maintenance manual and related by numbers in the plan for reference, so that the maintenance staff know as to how to carry out the numbered actions. Checklists can be prepared for use by the supervision or inspecting officers to ensure that the actions indicated in the operation and maintenance plan are carried out promptly and properly. Check lists for various units of O&M of water supply and treatment are listed in the respective chapters.



### **2.3.3 MANAGEMENT REORIENTATION**

The management shall become service oriented and be prepared to run the organisations on a commercial basis. The management must be able to motivate the staff to perform better. It is essential that the organisation responsible for O&M is well qualified, experienced, efficient and still economical. Management is obliged to maintain the facilities in a reasonably good manner and hence they shall decide to produce a maintenance programme. Relevant persons with aptitudes must be chosen to work with available facilities. The persons should be trained to carry out the actions.

They should be supervised to ensure that all people do their duties. Spares and tools should be made available when needed. A good record system covering all equipment facilities and units should be established. The funds necessary to carry out the programme should be provided.

While in most of the cities, a large work force has been already created over a number of years and is being used for O&M of the systems, the suitability of skills and experience has not necessarily been tested. At the same time a radical change in the set up is also not possible in a short period. The strategy is therefore to define the optimum organisation required for O&M and work towards achievement of that, whenever there is opportunity available, to re-organise.

### **2.3.4 CATEGORIES**

The O&M function is performed by

- (a) operating staff and
- (b) supervisory staff.

While the former actually run the system, the latter monitor the operations and provide managerial support. It is difficult to propose a rigid organisational structure model for use at all places. It is likely to vary from place to place due to factors like site-specific requirements, availability of suitable manpower and age-old practices.

### **2.3.5 JOB DESCRIPTION**

When the plan or programme containing procedures to be adopted or actions to be taken is prepared for each piece of equipment, the person to carry out this action is to be identified. This person's job description should contain reference to the maintenance plan/programme. The job description of operating personnel shall clearly define the limits up to which these personnel can carry out normal maintenance. The job description of the Supervisor/Manager shall include the requirement that they shall ensure that the operating personnel conform to these limits and thus ensure the safety of the equipment.

### **2.3.6 TRAINING**

The personnel who are already available or chosen to carry out the actions contained in the programme may have to be trained through special courses or by "on the job training" to ensure that these personnel are thoroughly trained to carry out the actions listed in the plan of maintenance. This training is essential to prevent experimentation by operating personnel to meddle with equipment since often these operating personnel may not be capable to take

up the required maintenance. On the job training is preferred to class room training. The supervisors can be trained initially and they can later train their operators.

### **2.3.7 PRIVATIZATION**

Privatization of some or all functions of Operation and Maintenance can be considered to achieve (i) efficiency (ii) economy (iii) professionalism and (iv) financial viability of the system. In order to achieve the above stated objectives, the private entrepreneur needs to possess (i) adequately trained, qualified manpower for operation and supervision of the services (ii) infrastructure like equipment, material, testing and repairing facilities (iii) experience in operating similar systems (iv) financial soundness (v) capacity to meet the emergency situations.

### **2.3.8 COMPONENTS SUITABLE FOR PRIVATIZATION**

Based on the above requirements and the limited experience of a few organisations, the possibility of involvement of private agencies in O&M of entire or part of water treatment plants, pumping stations, distribution system and other components is analysed and indicated below.

### **2.3.9 STRATEGY FOR PRIVATIZATION**

There is a need to have alternative institutional mechanism for O&M of water supply utilities. In this regard, introduction of private agencies in O&M may be desirable to achieve efficiency and economy. It may make the existing O&M staff surplus. In most of the places operating staff has been appointed on a large scale in the permanent establishment and their removal or discontinuation of sanctioned posts will be a major hurdle in the effort of privatization. However when new systems are set up, it is possible to introduce some element of privatization. Suitable private agencies may develop in course of time, if they feel that they will work for a reasonably long period and if their fee is remunerative. Petty or minor repair and maintenance jobs can be let out on an annual contract basis. However the agency responsible for O&M should have a close control on the performance of private agencies and its own organisation. This calls for a set up somewhat similar to the one suggested below:

- i) Supervisory organisation of engineers, accountants, managers belonging to the O&M agency.
- ii) Day to day operation and maintenance of units like treatment plant, pumping stations and large transmissions with private agencies.
- iii) Day to day operation and maintenance of transmission mains and distribution system with private agency.
- iv) Repairs with private agencies: such as meter repairs, upkeep of chlorinators, chemical dosers, and instrumentation repair, maintenance and calibration.
- v) Supply of chemicals and spares to be arranged by O&M agency.
- vi) Payment of energy charges, raw water charges, telephone bills etc. to be made by O&M agency directly.
- vii) The organisation itself can decide to hand over to private agencies such duties which cannot be discharged by it economically/efficiently.

### **2.3.10 ROLE OF VOLUNTARY / NON GOVERNMENTAL ORGANISATIONS (NGOS)**

The role of Voluntary/NGOs can be important especially in the creation of public awareness on matters like water conservation, proper use of water by people and the need to pay price of water at affordable level. Water users' committees can be formed by active involvement of NGOs to periodically review the local problems, advise the agencies on improvements needed and future course of planning, upkeep of utilities within their jurisdiction, encourage the people to remit water charges regularly and encourage hygienic habits.

#### **2.3.10.1 Information Education Communication (IEC)**

The utility organisation can prepare Information-Education-Communication material and use the services of Voluntary organisation/NGOs in disseminating the information among the consumers and create awareness among the public

### **2.3.11 AVAILABILITY OF TOOLS & PLANTS AND SPARES**

The availability of spare parts for repairs and replacements is to be ensured by ordering and delivery of spare parts by organising an inventory system. Efficient management of stores is required to ensure that the required spare parts are available at all times. The list of spare parts to be procured can be drafted on the basis of manufacturers recommendations in the absence of which a list of spare parts can be prepared from the records of spare parts actually used in the previous years.

A good starting part is to start with the maintenance program and list item wise likely spares to be ordered for repairs and replacements. Spare parts which are difficult to be procured i.e. delivery times are longer shall be identified and the list of spares shall contain as to when these are to be ordered. Managers will have to review the list and take advance actions to ensure that spare parts are on hand when they are needed. Alternatively the required spares for five year periods are procured at the time the equipment is initially installed. The next important task is to ensure the availability of tools necessary to properly repair and correct both the routine problems and for facilitating repairs and replacements. Hence a list of tools and plants has to be prepared, again starting from the plan of maintenance for each unit and the final list of tools and plants is prepared to cover repairs of all the pieces of equipment. It will be also necessary to arrange for routine maintenance of tools and plants, for ensuring that they are in a fit state to be used when repairs and replacements are taken up.

A well organised stores unit shall be available, and accessible at all times to the operation and maintenance staff from which all required spare parts, tools etc., to enable the operation and maintenance staff to carry out the servicing, repairs or replacement, contained in the maintenance plan.

### **2.3.12 MAINTENANCE OF RECORDS**

The necessity for good maintenance records is often overlooked. The maintenance plan programme contains as to what should be done and when. But to decide as to how long an equipment is to be allowed to be kept in service requires information as to when it was installed, what is its normal life etc. Budgets for operation and maintenance can be prepared only on the basis of records of previous years maintenance. The managers shall realise that most of the maintenance can be carried out without more staff. The existing operation and

maintenance staff with little training can do the operation and maintenance work without any extra expense. Similarly, record keeping and analysing does not require any additional cost. However costs have to be provided in the budgets for spares, tools and plants, training to operation and maintenance staff and any specialised services for important equipment.

Good record system shall include the following minimum information to ensure the required maintenance.

1. Name of equipment and location of equipment
2. Number available or installed
3. Serial number
4. Type and class
5. Date of procurement/installation
6. Cost of procurement and installation
7. Name of manufacturer with address and telephone No.
8. Name of distributor/dealer if purchased through them with address and telephone number.
9. Name of servicing firm with address and telephone number.
10. Service manuals
11. Descriptive technical pamphlets
12. Major overhauls: Details of date, nature of cost
13. When next overhaul is due.
14. Date, type and cost of repairs and replacement
15. Cost of spares and cost of labour for repairs.

### **2.3.13 FINANCIAL MANAGEMENT**

It is essential to establish a sound financial management system to make the water supply system financially viable. This can be achieved by controlling expenditure and increasing the income. Control of O&M expenditure can be achieved by preparing an annual budget of income and expenditure of O&M, based on realistic estimates. The estimation of outlays on O&M varies from city to city and it is mainly a function of establishment and power charges for pumping schemes and often lesser or no power charges for gravity supplies. The break up of O&M cost varies from place to place. From the basis of available data the average breakup of O&M cost is likely to be as follows: Power Charges about 30 to 50%, Salaries as high as 36%, Chemicals such as Alum and Chlorine about 3 to 4%, Repairs and replacements about 10 to 15%, debt servicing about 20%, depreciation about 2%.

It will be possible to increase the revenue by reviewing water rates in case income is less and revise these in time to cover the losses. The organisation shall realise that full cost recovery of O&M cost by user charges is a must. The tariff structure is to be evolved to recover the O&M cost and have a surplus for debt servicing and depreciation. Though everyone shall contribute to the cost, it is still necessary that a survey on the paying capacity of consumers may be required to ensure that tariffs are affordable. It is always prudent to levy the minimum

payable charges by the economically weaker section and suggest higher rates to others who can afford. A review of free supplies through public stand-posts may be required. Perhaps the possibility of organised selling of water through public taps can also be studied. It will be necessary to establish a system of raising bills and recoveries to maintain the cash flow and also aim at a larger ratio of collection to billing. Cost recovery can also be achieved by reducing losses by applying better pipe laying and plumbing techniques, undertaking timely preventive maintenance, detecting and reducing losses and controlling illegal connections.

## **2.4 SUGGESTED STRATEGY**

This manual sets forth guidelines for maintenance programmes for most installations. This manual can be adopted as basis for the preparation of operation and maintenance programme.

### **2.4.1 ORGANISATION**

The organisation shall have sufficient autonomy with some checks and counter checks. Further the organisation shall be given the freedom to redeploy if not reduce the surplus personnel. Before attempting to reform the organisation, the managers shall be provided training. The managerial staff have to be trained in the management aspects so as to enable them to render customer oriented service. The need to manage the organisation to ensure financial viability shall be also taught to them. The need to have a performance evaluation to identify accountability for lapses and rewards for improved performance is to be highlighted. Training to managers shall also include financial, accounting, computer applications for efficient use of management information systems, apart from improved technologies.

### **2.4.2 OPERATION AND MAINTENANCE PLAN**

A comprehensive operation and maintenance plan shall be prepared to cover all the facilities. This plan shall contain what actions are to be taken, when these activities are to be taken, how these actions are to be taken and why these actions are required. Good house keeping is required to ensure that all equipment, buildings, surrounding areas and facilities are kept clean and orderly and shall look that it is being frequently cleaned and attended to. A central operation and maintenance cell shall be created which will have responsibility for supervision, monitoring and analysing all operation maintenance activities contained in the operation and maintenance plan. Supervisors shall be assigned duties to check the operation and maintenance by adopting check lists prepared by the management with reference to the plan. Officers shall be identified for monitoring whether the operation maintenance plans are followed or whether supervision of the plan is being done. The supervisor's check lists, checked by monitoring officers shall be analysed by the top management to locate persistent deficiencies and initiate corrective action. The first line supervisors shall be rewarded for timely identifying deficiencies in O&M.

### **2.4.3 TRAINING**

A job description shall be prepared for each operator, which shall contain detailed instructions as to how he will carry out the actions required of him in the operation and maintenance plan. The training shall evolve a personnel management policy, which will provide for a job training followed by performance evaluations and promotions. The supervisors shall be

trained to train the operators. Every operator who is assigned a job in the operation and maintenance plan/programme shall be given appropriate (on the job) training on how to perform the actions assigned to him. Inducements can be offered by way of incentives to those who have improved their performance by training.

#### **2.4.4 EVALUATION**

The success of operation and maintenance programme is shown by a decline of frequency of prearranged shutdowns, and emergency repairs. Improved O&M may result in increased availability of water to be sold, hence yielding more revenue and may also obviate the need to revise the tariffs. Further, the cost of repairs may also decline and equipment life may increase by the proper implementation of a maintenance program. However, funds required for upkeep and maintenance of the system components should be provided for, without which any strategy is bound to fail.

#### **2.4.5 RECORDS AND REPORTS**

A record and report system shall be enforced to list all basic data of each piece of equipment and the history of the equipment. A separate wing may be created to update information on the maps, and coordinate with local Municipal authorities, Urban Development authorities, Housing Boards, Industries, Infrastructure Corporations, Electricity Boards and Telecom Departments. A reporting system shall be provided for the operator to inform the supervisor/manager the problems of each equipment requiring the attention of repair and replacement crew or other specialised service personnel.

### **2.5 LIMITATIONS OF O&M STRATEGY**

#### **2.5.1 TYPE AND SCALE OF ORGANISATION**

Financial sustainability may not be feasible for the utility/organisation which is found to be overstaffed. Actions may have to be initiated to redeploy or reduce the excess staff.

#### **2.5.2 RECORDS**

Though an awareness can be created among the managers of water supply system about the importance of good maintenance, it will not be easy to initiate action in writing down the maintenance procedures. The foremost reason for such situation is the lack of reliable records, in the absence of which one may be forced to take decisions purely on guess work instead of taking decisions on the basis of reliable records.

#### **2.5.3 INADEQUACY OF FUNDS**

Inadequate investments in O&M is a common feature in several organisations which may say that there are no funds for maintenance of facilities or training of staff. Often, they may say that budgets meant for such items as procurement of spare parts or for painting to prevent corrosion or for training have been diverted to other works, on the premise that these works are not important. However lack of funds may not be a valid reason for routine maintenance, house keeping or minor adjustments etc., which can be attended to by the operation and maintenance staff even in the absence of funds. Maintenance of infrastructure is required to enhance the revenues which also requires budgetary provisions.

#### **2.5.4 METERING POLICY**

In most of the utilities the supply is intermittent and often this is cited as a reason for non working of meters. Correct selection of meters and good practice of fixing meters may obviate this. Meters are owned by consumers in several utilities and hence are not repaired promptly. Often there may be no bulk-flow meters available to provide data for evolving a policy regarding metering. Attention to metering may be initially required in high/bulk consumption areas. Several organisations may be having a metering policy regarding ownership and provision of bulk meters. A review of the metering policy may be required to ensure financial sustainability of the organisation.

#### **2.5.5 REMOTE LOCATION**

The facilities may be located at inaccessible places and it may take more time for qualified personnel to reach such places for attending to repairs or replacements.

#### **2.5.6 AGE OF EQUIPMENT**

In several installations the equipment might have outlived its life or out of previous neglect or misuse might have deteriorated up to a stage at which replacement of the equipment is absolutely necessary.

#### **2.5.7 TRAINED PERSONNEL**

The water works utilities are so diversified that simple training methods cannot be prescribed for general application. Sometimes it is difficult to find, in the utilities, well motivated personnel and the available staff may not be amenable for training. The availability of trained personnel who possess the knowledge to undertake the maintenance of complicated equipment may also become a limitation. Often those engineers who are accustomed to dealing with the equipment might have been transferred, making it difficult to maintain the continuity.

#### **2.5.8 STRENGTH OF ORGANISATION**

Some of the limitations, in trying any new strategy are organisations which are not ready to change its management attitude to run the water utility on financially viable lines, lack of motivation on the part of the staff etc.

### **2.6 IMPROVING O&M**

#### **2.6.1 ASSESSING THE STATUS OF O&M**

The status of O&M of any existing system can be assessed through a deficiency analysis after which the improvements can be planned. A possible line of action is indicated below:

#### **2.6.2 INSTITUTIONAL STUDY**

An institutional study is done wherein the parameters for operating and maintaining the facilities are fixed and the job requirements of various O&M personnel are identified along with their qualifications and or experience. The study should also explore possibility of providing on the job training to make up for the lack of qualifications and experience to discharge the job requirements. A realistic assessment of staff required is made and surplus

personnel if any are identified. In case of deficit of staff, the possibility shall be examined for entrusting some of the O&M activities to outside agencies on contract basis.

### **2.6.3 TRAINING REQUIREMENTS**

As a result of the institutional study it would be possible to list out the training requirements of individual personnel. Prepare a programme of training with time bound targets. Identify the facility to train and prepare training material. Implement the training programme. Assess the performance of O&M staff after training. Change or update the training programme to suit the situation as per the assessment.

### **2.6.4 MANAGEMENT INFORMATION SYSTEM (MIS)**

Quite often there is an acute dearth of information on material inventories, tools, spares, staffing pattern, costs etc. Hence setting up a Management Information System is one of the most important tasks in the institutional development which could lead to sustainable O&M. The authority must decide what information is important, who is to keep the record, periodicity of reporting system and formats of reporting. MIS is used to analyse and evaluate the performance of system. The MIS could also be used in assigning responsibilities and in distribution of human, material and financial resources to ensure sustainable O&M.

### **2.6.5 WATER AUDIT**

There are considerable losses in the water produced and distributed which leads to reduction in the income of the utility. Some of these losses are physical leakage of water and some are revenue losses. Hence a water audit will be required to be done to get fairly accurate figures of the following - Water production, Water assessed, Losses both Physical and revenue. Water audit could lead to prioritizing actions required to reduce the physical and revenue losses.

### **2.6.6 ENERGY AUDIT**

Power charges are likely to be as high as 30 to 50% of the total O&M cost. Hence an efficient use of power and reducing wastage of power will go a long way in efficient functioning of the utility. This could be achieved by a systematic energy audit which can identify the possible means to save energy and reduce power consumption.

### **2.6.7 PLANNING FOR EMERGENCIES**

It is possible that normal water supply may be disrupted due to any event, natural or man-made. Such disruptions occur suddenly leaving no time for planning to meet such contingencies. It is therefore essential that an advance plan be prepared to meet such exigencies. Past experience of emergencies in the system as well as of other systems is very useful in drawing up an emergency plan. Some of the events or emergencies that may arise are: power failure, storms and flooding, fire, earthquakes, explosions, breakdown of water supply system units like pumps and pumping mains, strikes by workmen, sabotage or vandalism and water supply bio-terrorism.

### **2.6.8 SAFETY IN O&M OPERATIONS**

Operations in O&M of a Water Supply System also may result in accidents. Hence there is a need for safety practices to be followed by the O&M personnel. Adoption of safe practices



and use of safety equipment may largely minimize accidents. Many accidents occur due to the human factor. Though the ultimate responsibility may be that of management, the operator cannot also be relieved of his responsibility. Hence a Safety Programme is to be written down for every organisation and it must be ensured that every one in the organisation scrupulously follows the safety practices.

### **2.6.9 PLUMBING PRACTICES**

In most Water Supply System, the leakages are occurring in consumer connections. This is mainly attributed to poor plumbing practices. The water supply regulations shall provide for a correct practice of giving connections and fixing meters, which shall be strictly enforced.

### **2.6.10 IMPROVEMENTS IN WATER QUALITY CONTROL**

At several places though the water treatment plants are equipped with good water testing laboratories, the required water quality control by testing is not followed or achieved. This has to be ensured.

### **2.6.11 COST RECOVERY**

For any water utility to be financially self sustained the tariffs should be reasonably fixed and water charges levied and collected and accounted as accurately as possible. The cost of production of water shall be worked out inclusive of debt servicing and expenditure incurred for O&M shall be reviewed. Reasonable tariffs shall be provided to ensure for full cost recovery.

### **2.6.12 ROLE OF PUBLIC PRIVATE PARTNERSHIP**

Improving the efficiency of O&M depends to a great extent on the proper functioning of instrumentation in alum coagulation, chlorination. However it is not always possible to find and employ personnel with specialized skills for the maintenance of flow meters, other instrumentation in water treatment plants and pumping installations, chlorination plants and alum dosers. Instead of trying to recruit additional staff for repairs and maintenance of these specialized equipment, it is always a better alternative to obtain on contract, the specialized services for maintenance of the above mentioned equipment. Such a practice may ensure proper functioning of the equipment with least cost.

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## CHAPTER 3

# SOURCES OF WATER SUPPLY

### 3.1 OBJECTIVE

The objectives of operation and maintenance of sources of water supply schemes are:

1. The water sources should be able to supply water which is safe to drink after treatment.
2. The water sources should be perennial and should ensure sustainable yield.
3. The quality of water should not be allowed to deteriorate.
4. There should be least or no disruption in water supply systems due to depletion of water sources.
5. There should be least possible expenditure on the repair and maintenance of the water sources.
6. Proper record of the water sources should be maintained so that their time to time performance could be known.
7. A methodical long-range programme of source inspection and monitoring should be introduced to identify problems so that a regular programme of preventive maintenance can guarantee reliability and continuity.
8. Survey maps shall be obtained or prepared for all possible sources of water like rivers, reservoirs, lakes, canals, wells, and springs etc. The maps already available should be updated from time to time.

### 3.2 SOURCES

#### 3.2.1 NATURAL SOURCES

Rain, snow, hail and sleet are precipitated upon the surface of the earth as meteorological water and may be considered as the original source of all the water supplied. Water, as source of drinking water, occurs as surface water and ground water. Three aspects should be considered in appraising water resources e.g., the quantity, the quality, and the reliability of available water.

#### 3.2.2 SURFACE WATER

Surface water accumulates mainly as a result of direct runoff from precipitation (rain or snow). Precipitation that does not enter the ground through infiltration or is not returned to the atmosphere by evaporation, flows over the ground surface and is classified as direct runoff. Direct runoff is water that drains from saturated or impermeable surfaces, into stream

channels, and then into natural or artificial storage sites (or into the ocean in coastal areas).

The amount of available surface water depends largely upon rainfall. When rainfall is limited, the supply of surface water will vary considerably between wet and dry years.

Surface water supplies may be further divided into river, lake, and reservoir supplies. Dams are constructed to create artificial storage. Canals or open channels can be constructed to convey surface water to the project sites. The water is also conveyed through pipes by gravity or pumping.

In general, the surface sources are characterized by soft water, turbidity, suspended solids, some colour and microbial contamination.

### **3.2.3 GROUND WATER**

Part of the precipitation that falls infiltrates the soil. This water replenishes the soil moisture, or is used by growing plants and returned to the atmosphere by transpiration. Water that drains downward (percolates) below the root zone finally reaches a level at which all the openings or voids in the earth's materials are filled with water. This zone is called the zone of saturation. The water in the zone of saturation is called the ground water.

Ground waters are, generally, characterized by higher concentrations of dissolved solids, lower levels of colour, higher hardness (as compared with surface water), dissolved gasses and freedom from microbial contamination.

A well that penetrates the water table can be used to extract water from the ground basin. The extraction of ground water is mainly by:

1. Dug well with or without steining walls
2. Dug cum bore wells
3. Cavity Bore
4. Radial collector wells
5. Infiltration galleries
6. Tubewells & bore wells.

Ground water that flows naturally from the ground is called a Spring.

## **3.3 SURFACE WATER MANAGEMENT AND MAJOR SOURCES OF POLLUTION**

### **3.3.1 USE OF SURFACE RESERVOIRS**

Methods of managing lakes and reservoirs used for domestic supplies vary widely depending on local conditions. In addition to serving domestic water needs, a reservoir may be used for flood control purposes, for hydroelectric power generation, for regulating releases, for recreational purposes or for providing water for agricultural, municipal and industrial uses. The amount and type of public use allowed on reservoirs also varies according to individual situations.

The methods of treating water depend upon raw water quality and range from disinfection only to complete treatment.

### **3.3.2 FACTORS AFFECTING WATER QUALITY**

Some of the factors affecting water quality within the Reservoirs and Lakes are:

1. Waste water, agricultural runoff, grazing of livestock, drainage from mining areas, runoff from urban areas, domestic and industrial discharges may all lead to deterioration in physical, chemical, or biological/bacteriological water quality within a reservoir.
2. Farming practices
3. Fish die off.
4. Natural factors:
  - Climate: temperature, intensity and direction of wind movements as well as the type, pattern, intensity and duration of precipitation,
  - Watershed and drainage areas: geology, topography, type and extent of vegetation, and use by native animals;
  - Wild fires;
  - Reservoir Areas: geology, land form including depth, area and bottom topography and plant growth at the time the reservoir is filled.

### **3.3.3 CAUSES OF WATER QUALITY PROBLEMS**

#### **3.3.3.1 Nutrients**

1 Moderate or large quantities of nutrients such as phosphates, nitrates and organic nitrogen compounds may act as a fertilizer in a reservoir to stimulate the growth of algae which may cause algal bloom.

The problems related to algal blooms are:

- i) Taste, odour and colour,
- ii) Increased pH
- iii) Shortened filter runs of treatment plants,
- iv) Dissolved Oxygen variation,
- v) Organic loading.

#### **3.3.3.2 Thermal Stratification**

Thermal stratification develops in lakes and reservoirs when the surface water begins to warm. The warm surface waters expand and become lighter than the lower waters. The water temperature difference causes variation in water densities, which create resistance to mixing. This ultimately results in Anaerobic Conditions in lower zones.

#### **3.3.3.3 Anaerobic Conditions**

Anaerobic conditions make water unpalatable due to colour and odour which are difficult to treat. Another major problem in anaerobic water occurs when iron and/or manganese exist in bottom sediments in the reduced state and pass into solution. Due to the presence of either iron or manganese in appreciable quantities within the domestic supply the water looks reddish, brown or just plain dirty and may stain clothes during washing and stain porcelain fixtures.

## **3.4 GROUND WATER MANAGEMENT AND MAJOR SOURCES OF POLLUTION**

### **3.4.1 USE OF GROUND WATER**

Important requirements of managing ground water are:

1. Regulation of Ground Water,
2. Prevention of pollution of ground water,
3. Conservation of ground water,
4. Effective preventive maintenance,
5. Artificial recharge of ground water.

### **3.4.2 MAJOR SOURCES OF POLLUTION**

- i) Landfills,
- ii) Mining activities,
- iii) Abandoned sites,
- iv) Abandoned wells,
- v) Agricultural practices,
- vi) Underground storage tanks and pipeline,
- vii) Increased salinity and salt water encroachment,
- viii) Septic tank and soakage pit system,
- ix) Petroleum exploration,
- x) Radioactive wastes.

## **3.5 SANITARY SURVEY OF WATER SOURCES**

The sanitary survey should include the location of all potential and existing health hazards and the determination of their present and future importance.

The information furnished by a sanitary survey is essential to evaluating the bacteriological and chemical water quality data. It is desirable to

- i) Identify potential hazards, and
- ii) Determine factors which affect water quality.

Following are some of the probable essential factors, which should be investigated in a sanitary survey.

### **3.5.1 SURFACE WATER**

- i) Proximity to watershed and character of sources of contamination including industrial wastes, oil field brines, acid waters from mines, sanitary landfills, and agricultural drain waters.
- ii) Population and wastewater collection, treatment and disposal on the watershed.
- iii) Closeness of sources of fecal pollution to intake of water supply.

- iv) Wind direction and velocity data; drift of pollution; algal growth potential in case of lake or reservoir supplies.
- v) Character and quality of raw water.
- vi) Protective measures in connection with the use of watershed to control fishing, boating, swimming, wading, ice cutting, and permitting animals on shoreline areas.
- vii) Efficiency and constancy of policing activities on the watershed and around the lake.

### **3.5.2 GROUND WATER**

- i) Nature, distance and direction of local sources of pollution.
- ii) Possibility of surface-drainage water entering the supply and of wells becoming flooded.
- iii) Drawdown when pumps are in operation, recovery rate when pumps are off.
- iv) Methods used for protecting the supply against contamination from wastewater collection and treatment facilities and industrial waste disposal sites.
- v) Presence of an unsafe supply nearby and the possibility of cross connections causing a danger to the public health.
- vi) Disinfection: equipment, supervision, test kits, or other types of laboratory control.

## **3.6 SURFACE WATER SOURCES**

Surface water sources may be divided into rivers, lakes and reservoirs as explained in para 3.2.2. Dams are constructed to create artificial storage. Some of the salient features of Dams are given below.

### **3.6.1 DAMS (GENERAL)**

#### **3.6.1.1 Location**

Dams are constructed to create artificial lakes or reservoirs. A dam conserves the surplus water brought down by a river during the periods when the supply exceeds the current demand, for utilization later on during the periods when demand outstrips the natural flow of the river. Storage is obtained by constructing barriers across a depression receiving runoff from a considerable catchment. The dam is located where the river is narrow but should open out upstream to provide a large basin for a reservoir.

#### **3.6.1.2 Types of Dams**

Dams may be classified into two main categories

**(i) Rigid dams**

These include dams of concrete, masonry, steel or timber.

**(ii) Non Rigid dams**

These include a) Rockfill dams b) Earthen dams c) Composite sections having a combination of rockfill and any type of earth fill construction.

### **3.6.1.3 Dams-Operational Functions**

#### **1. General**

The releases through the Outlet-works shall be made according to the predetermined regulations to suit the availability and demand.

#### **2. Spillway**

The water in excess of demand can be stored up to a predetermined level. Surplus water shall be automatically released through the pre-designed spillway.

#### **3. Outlet works**

During normal operation, the supplies shall be released through the outlet pipe. The downstream valve shall be used for regulation purposes and the upstream valve for emergency operation.

#### **4. Gauging facilities**

Gauges should be installed at suitable locations in approach channel, stilling basin and escape channel etc. and read at predetermined times.

#### **5. Initial filling of reservoir**

After completion of all works the impounding shall be carried out in stages. During initial filling a gradual rise in reservoir level is desired to avoid chances of a possible mishap due to leakage.

#### **6. Water level measurements**

Water level in the reservoir shall be recorded once a day during non-monsoon period and thrice a day during monsoon period or as decided by the Authorities keeping in view the local conditions.

#### **7. Storage Utilisation**

The initial live storage goes on reducing due to silting with passage of time. This point should be kept in mind while utilising the stored water.

#### **8. Outlet operation**

While the outlet starts operating, careful watch shall be kept to see if there is any formation of vortices or swirl around the intake structure. Precautions shall be taken to regulate the flow through outlet by operating control valves.

#### **9. General Precautions**

- Before the beginning of the monsoon season every year, it shall be ensured that all electrical and mechanical equipments are in perfect working order.
- Spillway and outlet structures shall be free of any unauthorised installation or devices.
- General vigilance shall be maintained on inflow conditions.
- Flood warnings shall be issued to all concerned.
- Strict watch shall be kept on the magnitude of inflow and outflow discharge.

#### **10. Flood Control**

Changing characteristics of the inflow, reservoir sedimentation and variations in water

use shall demand reassessment of flood retaining capacity and requirements. River downstream of dam must be periodically inspected for alterations in water use or obstruction and/or possible danger of damage from flooding to life and property.

#### **11. Emergency precautions and operations**

Emergency action plans shall deal with the following aspects

- Hydrological observations and flood warning schemes;
- Drawdown and flood control operation of reservoir;
- Emergency emptying of the reservoir;
- Evacuation of the flood threatened areas;
- Rescue operations and other emergency provisions;
- Equipment, material and support available for emergency relief;
- Emergency stand by of the public utilities;
- Emergency warning;
- Emergency communication and transportation;
- Emergency access to remote sites.

#### **3.6.1.4 Inspection of Dams**

For proper Operation and Maintenance of a dam and adopting remedial measures, regular inspection of the dam, appurtenant structures, reservoir area, and downstream channel in the vicinity of the dam should be conducted in a systematic manner.

Adequacy and quality of maintenance and operating procedures and operation of control facilities should be properly examined and all possible remedial measures should be taken to set right the deficiencies so detected.

Particular attention should be given to detecting evidences of leakage, erosion, seepage, excessive wetness or slushiness in the area downstream of dam, presence of sand boils, change in water table conditions downstream, slope instability, undue settlement, displacement, tilting, cracking, deterioration and improper functioning of the drains and relief wells, evidence of excessive pore pressure conditions, encroachment on the free board allowance.

Following guidelines outline some of the factors to be duly considered to ensure implementation of the operation and maintenance procedures.

##### **(a) Embankment Structures**

###### *1. Settlement*

The embankments and downstream toe areas should be examined for any evidence of localized or overall settlement, depressions or sinkholes.

###### *2. Slope Stability*

Embankment slopes should be examined for irregularities in alignment and variances from smooth uniform slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, and surface cracks which indicate movement.



3. *Seepage*

The downstream face of abutments, embankment slopes and toes, embankment-structure contacts, and the downstream valley areas should be examined for evidence of existing or past seepage. The presence of animal burrows and tree growth on slopes which may cause detrimental seepage should be examined.

4. *Drainage Systems*

The slope protection should be examined to determine whether the systems could freely pass discharge and that the discharge water is not carrying embankment material.

5. *Slope Protection*

The adequacy of slope protection against wave, currents and surface runoff that may occur at the site should be evaluated. The condition of vegetation cover should be evaluated.

**(b) *Spillway Structures***

Examination should be made of the structures and important features of all service and auxiliary spillways, which serve as principal or emergency spillways.

1. Control gates and operating machinery.
2. Unlined saddle spillways.
3. Approach and Outlet channels.
4. Stilling basin (Energy dissipators).

**(c) *Outlet Works***

The outlet works examination should include all structures and features designed to release reservoir water below the spillway crest through or around the Dam.

1. *Intake Structure:*

Entrances to intake structure should be examined for conditions such as silt or debris accumulation, which may reduce the discharge capabilities of the outlet works.

2. Operation and emergency control gates.
3. Conduits, sluices, water passages etc.
4. Stilling Basin (Energy dissipators).
5. Approach and outlet channels.
6. Drawdown facilities.

Facilities provided for drawdown of the reservoir to avert impending failure of the dam or to facilitate repair in the event of stability or foundation problems should be examined.

**(d) *Concrete Structure in General***

The examination of concrete structures shall include the following:

1. Concrete surfaces.
2. Structural cracking.
3. Movement - horizontal and vertical alignment.

4. Junctions.
5. Drains-Foundation, Joint, Face.
6. Water Passages.
7. Seepage or leakages.
8. Monolith joints-construction joints.
9. Foundations.
10. Abutments.

**(e) Reservoir**

The following features of the reservoir should be examined to determine to what extent the water impounded by the dam would constitute a danger to the safety of the dam or a hazard to human life or property.

1. *Shore Line*

The landforms around the reservoir should be examined for indications of major landslide areas which may reduce reservoir capacity or create waves that might overtop the dam.

2. *Sedimentation*

The reservoir and drainage area should be examined for excessive sedimentation or recent developments in the drainage basin, which could cause a sudden increase in sediment load thereby reducing the reservoir capacity.

3. *Backwater flooding*

The reservoir area should be examined for features subject to potential backwater flooding resulting in loss of human life and property.

4. *Watershed Runoff Potential*

The drainage basin should be examined for extensive alterations to the surface of the drainage basin such as changed agricultural practices, timber clearing, railroad or highway construction or real estate developments that might extensively affect the runoff characteristics. Upstream projects that might have impact on the safety of the dam should be identified.

**(f) Downstream Channel**

The channel immediately downstream of the dam should be examined for conditions, which might impose any constraints on the operation of the dam.

**(g) Special Observations**

1. Every attempt should be made to anticipate and have engineer-observers present on site at items of large spillway and outlet discharge.
2. Warning, safety and performance instrumentations:
  - piezometers, flow recorders, accelerometers, seismoscopes, joint meters, and gauge points, strain meters, stress meters, inclinometers, direct and inverted plumbines, surface reference monument, stage recorders, extensimeters,

- serviceability,
  - access to readout stations,
  - need for recalibration,
  - faulty readings and reasons,
  - alarm systems.
3. *During and after floods:*
- drift marked high water-lines,
  - evidence of taxed spillway capacity,
  - undesirable or dangerous spillway flow patterns,
4. *During and after large outlet releases:*
- Undesirable or dangerous spillway flow patterns, dynamic pressures, vibrations cavitation sonics.
5. *After earthquakes:*
- cracks, displacement offsets in structural features,
  - cracks, slumps, slides, displacements, settlements in embankments, cut-slopes, and fill slopes,
  - broken stalactites in galleries, tunnels, chambers,
  - toppled mechanical equipment,
  - sand boils.
6. *Surface evaporation*

Direct evaporation from water surface is influenced by temperature, barometric pressure, mean wind velocity, vapour pressure of saturated vapour and vapour pressure of saturated air.

Measurement of evaporation from water surfaces are commonly made by exposing pans of water to the air and recording the evaporation losses.

The evaporation from lakes, dams, impounding reservoirs, various structures in which water surface is exposed to the atmosphere, may result in considerable loss of water. Evaporation is a direct function of the surface area. An attempt should be made to minimize the surface area.

Evaporation is a continuous process. It cannot be eliminated though it can be controlled by use of certain chemicals developed specially for this purpose. Such chemicals are generally available in paste form and can be brought into the liquid form by mixing water. This can then be spread over the surface of water so as to form a thin film. This film is normally retained on the surface for more than 24 hours and needs to be replenished by spreading the chemical again. The film is transparent and sun rays can pass through it and the aquatic life is thus protected. The film is likely to be disturbed by wind which affects its covering efficiency. The cost of this process is quite high. Calculations should be made on the cost of this treatment versus the extra cost in arranging additional water. In certain circumstances, when alternative sources are not available, this process will be very useful.

### **3.6.1.5 Earthen Dams**

Following features should be examined for proper operation and maintenance.

#### **(a) Stress and Strain: Evidence and clues**

1. Settlement,
2. Consolidation,
3. Subsidence,
4. Compressibility,
5. Cracks, displacement, offsets, joint opening changes in concrete facing on rock fills,
6. Loss of freeboard from settlement,
7. Zones of extension and compression visible along dam crest or elsewhere,
8. Crushing of rock points of contact,
9. Differential settlement of embankment cross sectional zones visible along dam crest.

#### **(b) Stability : Evidence and clues**

1. Cracks, displacements etc., on embankment crest and slopes.
2. Sags and misalignments in parapet wall etc.,
3. Irregularities in alignment and variances from smooth, uniform face planes,
4. Bulges in ground surfaces beyond toes of slopes.

#### **(c) Inadequate seepage control: Evidence and clues**

1. Wet spots,
2. New vegetal growth,
3. Seepage and leakage,
4. Boils,
5. Saturation patterns on slopes, hillsides and in streambed,
6. Depressions and sinkholes,
7. Evidence of high escape gradients.

#### **(d) Erosion Control**

1. Loss, displacement, and deterioration of upstream face riprap, underlayment and downstream face slope protection,
2. Leaching.

#### **(e) Foundation**

1. Piping of weathering products,
2. Efficiency of foundation seepage control systems,
3. History of shear zones, faults, openings,
4. Zones of varying permeability,

5. Effect on permeability, uplift, foundation stability,
6. Subsurface erosion and piping etc.

### **3.6.1.6 O&M of Concrete Dams**

(these observations are applicable also to impounding reservoirs, intake structures, spillway control structures, lock walls).

Examine for evidence and clues for

**(a) *Stress and Strain: Evidence and Clues:***

1. Cracks, crushing, displacements, offsets in concrete monoliths, buttresses, face slabs, arch barrels visible on exterior surfaces and in galleries, valve and operating chambers, and conduit interior surfaces,
2. Typical stress and temperature crack patterns in buttresses, pilasters, diaphragms and arch barrels,

**(b) *Stability:***

1. Uplift pressures, pressure spurts from foundation drain holes, construction joints, and cracks,
2. Differential displacements of adjacent monoliths, buttresses and supported arch barrels or face slabs,
3. Disparities in regions near the interface between arches and thrust blocks,
4. Movement along construction joints,
5. Uplift on horizontal surfaces.

**(c) *Hillslides and river channels along the downstream toe of the dam:***

1. Leakage,
2. Seepage,
3. Stability,
4. Boils.

**(d) *Stability and seepage control at discontinuities and junctures:***

1. Embankment wrap around sections,
2. Water stops in monoliths and face slabs,
3. Reservoir impounding backfill at spillway control sections and retaining walls.

**(f) *Foundations:***

1. Piping of weathering products,
2. Foundation seepage control systems,
3. History of shear zones, faults, cavernous openings,
4. Zones of varying permeability,
5. Effect on permeability, uplift, foundation stability,
6. Subsurface erosion and piping.

### **3.6.1.7 Miscellaneous Items**

Observe following features:

*(a) Service reliability of outlet, spillway sump pump mechanical-electrical equipment*

- i) Broken or disconnected lift chains and cables,
- ii) Test operation including auxiliary power sources,
- iii) Reliability and service connections of primary sources,
- iv) Verification of operators understanding and ability to operate,
- v) Ease and assurance of access to control stations,
- vi) Functioning of lubrication systems.

*(b) Gate chamber, Galleries, Tunnels and Conduits*

Ventilation and heat control of damp, corrosive environment of mechanical-electrical equipment.

*(c) Accessibility and Visibility*

- i) Vegetable overgrowth,
- ii) Galleries-access ladders, lighting,
- iii) Access roads and bridges,
- iv) Communication and remote control lines, cables and telemetering systems.

*(d) Control of vegetation and burrowing animals*

- i) Harmful vegetation in embankments-oversize, dead root channels,
- ii) Harmful vegetation in structural concrete joints,
- iii) Obstructing vegetal growth in hydraulic flow channels,
- iv) Ground squirrels, rats and beavers.

### **3.6.1.8 Records of operation of Reservoir**

In order to ensure continued safe operation of dam and appurtenant works, including mechanical and electrical equipment installed therein, a record of operation and inspection of various works/equipment shall be maintained on suitable history sheets for future reference and guidance. Details of maintenance of all works undertaken and modifications, if any, carried out shall be carefully recorded so that proper assessment can be made subsequently in respect of adequacy/efficacy of repairs and modifications carried out. History sheets shall be prepared subsequently for civil, mechanical and electrical works. The record thus maintained shall be carefully scrutinized from time to time and remedial measures, as considered necessary, be taken.

The records shall include all items mentioned in item 3.6.1.4. (Operation and Maintenance).

## **3.7 INTAKES**

### **3.7.1 GENERAL**

An Intake is a device or structure placed in a surface water source to permit withdrawal of water from this source and its discharge into an intake conduit through which it will flow

into the water works system. Types of intake structures consist of intake towers, submerged intakes, intake pipes or conduits, movable intakes, and shore intakes. Intake structures over the inlet ends of intake conduits are necessary to protect against wave action, floods, stoppage, navigation, ice, pollution, and other interference with the proper functioning of the intake.

Intake towers are used for large waterworks drawing water from lakes, reservoirs and rivers in which there is either or both a wide fluctuation in water level or the desire to draw water at a depth that will give water of the best quality to avoid clogging or for other reasons.

### **3.7.2 PROBLEMS IN OPERATION**

Some of the problems that may arise during the operation of Intakes are given below. Necessary steps should be taken to set right the same.

- i) Fluctuations in water level,
- ii) Water withdrawal at various depths,
- iii) Hydraulic surges, ice, floods, floating debris, boats and barges,
- iv) Withdrawal of water of the best available quality to avoid pollution, and to provide structural stability,
- v) Operation of racks and screens to prevent entry of objects that might damage pumps and treatment facilities,
- vi) Minimising damage to aquatic life,
- vii) Preservation of space for
  - a) Equipment cleaning,
  - b) Removal and repair of machinery,
  - c) Storing, movement and feeding of chemicals.

### **3.7.3 OPERATION AND MAINTENANCE**

- i) Operating criteria, equipment manufacturer's operating instructions and standard operating procedures should be bound into a manual and used for reference by operators. If written references are not available for a particular facility, they should be prepared with the assistance of knowledgeable operators, engineers and manufacturers.
- ii) Screens should be regularly inspected, maintained and cleaned.
- iii) Mechanical or hydraulic jet cleaning devices should be used to clean the screens.
- iv) Intake structures and related facilities should be inspected, operated and tested periodically at regular intervals.
- v) Proper service and lubrication of intake facilities is important.
- vi) Operation of Gates and Valves.

Some of the causes of faulty operation are as under:

- Settlement or shifting of supporting structures which could cause binding of gates and valves,
- Worn, corroded, loose or broken parts,

- Lack of use,
- Lack of lubrication,
- Vibration,
- Improper operating procedures,
- Design errors or deficiencies,
- Failure of power source or circuit failure, and
- Vandalism.

#### **3.7.4 RECORD KEEPING**

The records to be maintained shall include the following aspects:

- i) A history of operations and maintenance performed on Intake facilities.
- ii) When and under what conditions, failure or malfunctions occur.

#### **3.7.5 SAFETY**

When working around Intake Structures proper safety procedure involving use of electrical and mechanical equipment and water safety should be observed. Proper safety procedures should be documented and included in the manual containing the operating procedure. For more details please refer to the Chapter 19 on 'Safety Practices'.

### **3.8 GROUND WATER**

#### **3.8.1 PREVENTIVE MAINTENANCE**

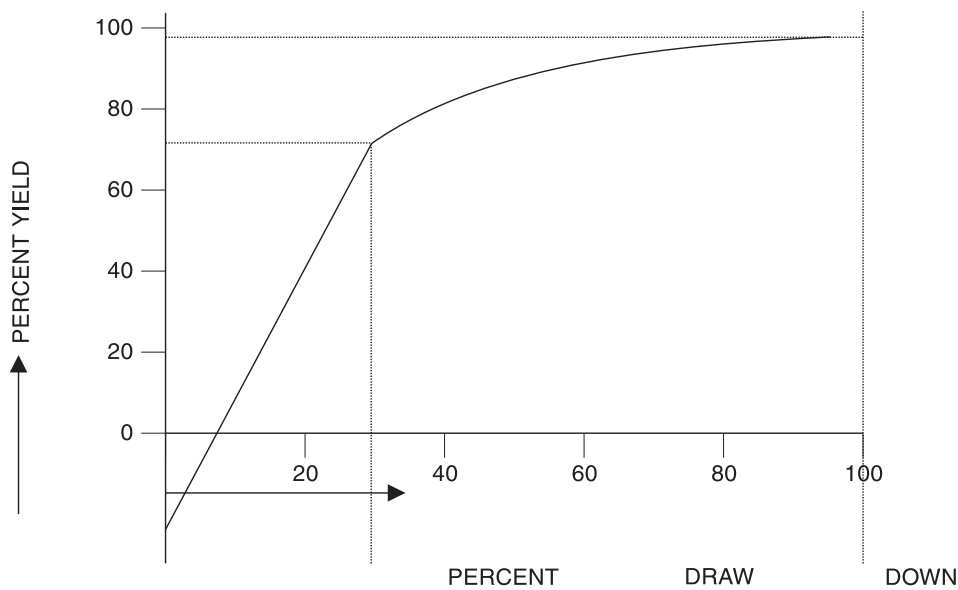
According to available data the specific capacity of wells should be measured at regular intervals either monthly or bi-monthly and it should be compared with the original specific capacity. As soon as 10 to 15% decrease in specific capacity is observed steps should be taken to determine the cause and accordingly corrective measures should be taken. Rehabilitation procedures should be initiated before the specific capacity has declined by 25%. A check list given below can be used to evaluate the performance of a well:

- i) Static water level in the production well,
- ii) Pumping rate after a specific period of continuous pumping,
- iii) Specific capacity after a specified period of continuous pumping,
- iv) Sand content in a water sample after a specified period of continuous pumping,
- v) Total depth of the well,
- vi) Efficiency of the well,
- vii) Normal pumping rate and hours per day of operation,
- viii) General trend in water levels in wells in the area,
- ix) Draw down created in the production well because of pumping of nearby wells.

A significant change in any of the first seven conditions listed above indicates that a well or pumping rate is in need of attention.



Preventive maintenance programme begins with well construction records showing geological condition, water quality and pumping performance. The data of optimum and efficient limit of operation should be available which is created at the time of testing and commissioning of the well. This data is normally in the form of a discharge draw-down curve (called yield draw down curve). According to this curve there is a straight line up to certain stage of draw down beyond, which the draw down increases disproportionately to yield. The end point of straight line is the point of optimum efficiency for the operation of well as shown in the attached figure.



This is generally found to be 70% of yield at draw down which can be created

### 3.8.1.1 Static Water Level (S.W.L.)

Pumping water level and Draw Down can be measured with the help of an electrical depth gauge of an Air line gauge.

In case of measurement by an electrical depth gauge an electrode is suspended in the tube well by a metallic cloth tape. The conductor terminal clip is fixed with the metallic casing of the tube well. The electric circuit is completed when the electrode touches the water surface which is indicated by the galvanometer. The corresponding depth is read on the tape.

Air line gauge method is most commonly used for measurement of S.W.L., Pumping Water Level and draw down. Air pipe can be lowered in tube well through a slot or a hole provided in the flange in case of flanged assembly and in the annular space in case of socketed assembly. In this method air is pumped into the line until the maximum possible pressure is reached. Normally the air line is full of water up to the level of water in the well (static or pumping water level). When air is forced into the line, it creates pressure which forces water out of the lower end until it is completely expelled and the line is full of air. If more air is pumped in, air, instead of water, is expelled and it is not possible to increase the pressure further. The head of water, C or E (as shown in the figure), above the end of the line maintains this pressure,

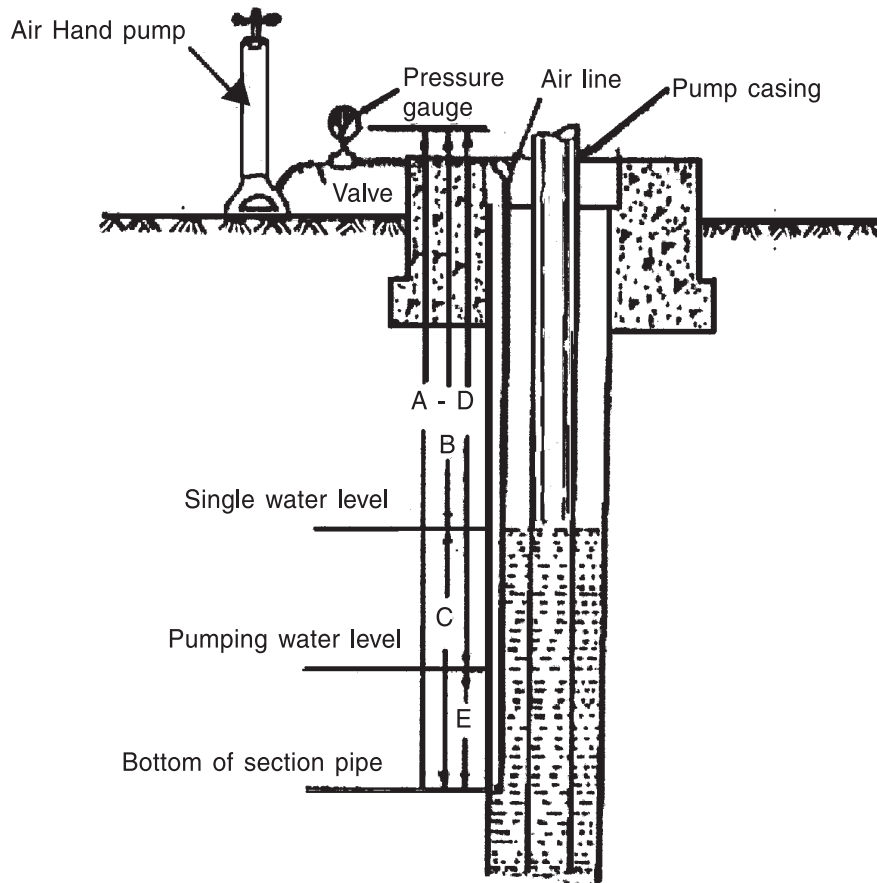


FIG. 3.0: AIR LINE INSTALLED IN A TUBEWELL FOR MEASURING WATER LEVEL

and the gauge shows the pressure or head above the end of the line. If the gauge is graduated in meters of water, it registers directly the amount of submergence of the end of the line. This reading subtracted from the length A of the line, gives the water level B or D (static or pumping water level).

### 3.8.1.2 Tubewell sounding

For identification of lithological details electrical logging can be used for uncased bores while Gamma logging can be used for both, cased and uncased bores. Bore hole camera can be used for identification of the condition of bore hole, casing and strainer pipes. These devices are commonly available in the market.

### 3.8.2 CONSERVATION OF GROUND WATER

Following are the steps for conservation of ground water:

- i) Improvement of home plumbing systems.
- ii) Reuse of recycled water.
- iii) By creating public awareness by Information, Education and Communication (IEC) activities.
- iv) By introducing sustainable water tariff.
- v) By rain water harvesting.

Ground Water Sources are costly structures which require careful design, construction, operation and timely maintenance. A trouble free service can be ensured by adopting the aforesaid practices. However, it has been experienced that a large number of Ground Water Sources constructed at high costs, operate at very low efficiencies or fail completely. The indication of source failures is either excessive sand pumping or steady decline in well yield. It may often be possible in few cases to rehabilitate the source by carrying out suitable remedial measures, but in most of the cases even the costly operations may not be effective to restore the source. In such cases the source is abandoned and a new source will have to be constructed.

### **3.8.3 CAUSES OF FAILURE OF WELLS**

Wells failure may be due to inadequate design, faulty construction and operation, lack of timely maintenance and repair and failures due to mechanical and chemical agents and adverse aquifer condition. The main causes for source failure are categorised as under:

- i) Incorrect design: for instance use of incorrect size of screen and gravel pack, wrong pin pointing of well site resulting in interference.
- ii) Poor construction e.g. the bore may not be vertical, the joints may be leaky, wrong placement of well screen, non-uniform slots of screen, improper construction of cement slurry seal to prevent inflow from Saline aquifer.
- iii) Corrosion of screens due to chemical action of water resulting in rupture of screens.
- iv) Faulty operation e.g. over pumping, poor maintenance.
- v) Adverse aquifer conditions resulting in lowering of water table and deterioration of water quality.
- vi) Mechanical failure e.g. falling of foreign objects including pumping assembly and its components.
- vii) Incrustations due to chemical action of water.
- viii) Inadequate development of wells.

Causes of failure of well mentioned above from (i) to (viii) are applicable according to type of source. The table at Annexure-3.1 indicates all causes of failure according to type of source.

### **3.8.4 REHABILITATION OF TUBEWELLS & BORE WELLS**

The correction of the situations mentioned above at (i) to (iii) above is a very difficult and costly affair. Therefore, a decision whether to rehabilitate an old well or construct a new should be based on the cost benefit analysis. Following remedial measures can be taken for correcting situation mentioned at (iv) to (viii).

#### **3.8.4.1 Faulty Operation**

Tube well should run in such a way that the pumping water level should always remain above the level of well screen. Over pumping will expose the well screen, which may result in incrustation and corrosion. Over pumping results in excessive draw down which may cause differential hydrostatic pressures, leading to rupture of well screen. Negligence in timely repair

and maintenance may result in poor performance of the tube well. Therefore, before any permanent damage is done to tube well it should be ensured that the tube well is operated at its designed capacity and timely repair and maintenance are done.

#### **3.8.4.2 Adverse Aquifer Conditions**

In adverse aquifer conditions where water table has depleted but the quality has not deteriorated, wells can generally be pumped with considerable reduced discharge.

#### **3.8.4.3 Mechanical Failure**

The falling of pumping set assembly and its components into the bore hole can be minimised by providing steel wire holdings throughout around the assembly length including pumping set or by providing and clamping a steel strip around the pumping assembly.

However, in spite of proper care sometimes foreign objects and pumping set assembly components may fall in the well. In corrosive water the column pipe joints and pump parts may get progressively weakened due to corrosion, get disconnected and fall into the well. These foreign & falling objects may damage the well screen resulting into failure of the well. However where well screen is not damaged, then by proper fishing the fallen objects can be taken out of the well making it functional again. Following are the steps taken for fishing out the fallen objects in the bore holes:

##### ***(a) Impression Block***

An impression block is used to obtain an impression of the top of the object before attempting any fishing operation. Impression blocks are of many forms and design. Figure 3.1 illustrates an impression block made from a block of soft wood turned on a lathe. The diameter of the block is 2 cm less than that of drilled hole. The upper portion is shaped in the form of a pin and driven to fit tightly into the box collar of a drill pipe. To ensure further safety, the wooden block is tied with wire or pinned securely to the collar. Alternatively, the block could be fixed to a bailer. A number of nails are driven to the lower end of the block with about 1 cm of it projecting out. A sheet metal cylinder of about 5 to 7 cm is temporarily nailed around the block to hold molten wax, which is poured into it. Warm paraffin wax, soap or other plastic material poured into the cylinder is left to cool and solidify. The metal cylinder is then removed. The nail heads hold the plastic material to the block. To locate the position of a lost object, the impression block is carefully lowered into the hole until the object is reached. After a proper stamp is ensured, the tool is raised to the ground surface, where the impression made in the plastic material is examined for identifying the position of the lost object and designing or selecting the right fishing tool.

##### ***(b) Fishing Tools to Recover Fallen Objects***

'The term 'fish', as used in tube well technology, describes a well drilling tool, pump component or other foreign body accidentally fallen or struck in bored wells & wells. The type of fishing tools required for a specific job will depend on the object to be lifted and the position in which it is lying in the well. It may often be necessary to design a fishing tool to suit a particular job. However, series of fishing tools suitable for different jobs are available in the market, which could be adapted or modified to suit a particular requirement.

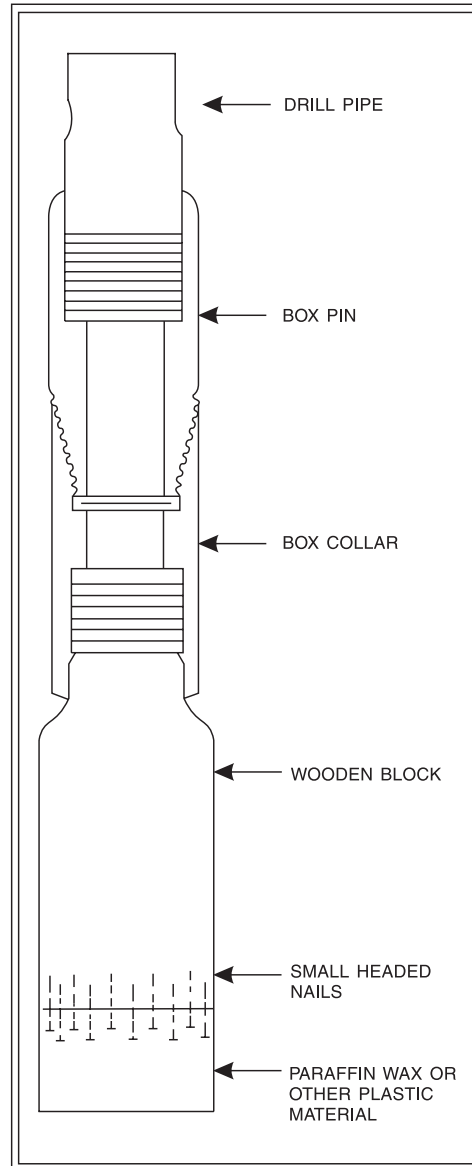


FIG. 3.1: IMPRESSION BLOCK

### 3.8.5 INCRUSTATION

#### 3.8.5.1 Diagnosing Incrustation Problem

Chemical incrustation is indicated by a gradual reduction in yield of the well. However, it can also happen with a gradual lowering of the water table due to over-pumping or inadequate ground water recharge. This fact can be verified by studying the behaviour of the ground water level over the service period of the tube well. Incrustation in the form of slime produced by iron bacteria decreases well yield due to clogging of the well screen and casing. Incrustation also clogs the fractures & fissures of rocky zone of well which is prevalent in bore wells. This trouble can be identified from the performance curves of the well. In this case the reduction in well yield is somewhat more rapid. Water quality analyses are used to identify the type of incrustation.

### 3.8.5.2 Types of Incrustation

The various types of incrustation in order of the frequency of occurrence are:

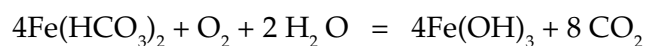
- Precipitation of carbonates, sulphates and silicates of calcium and magnesium.
- Precipitation of hydroxides, oxides and other compounds of iron and manganese.
- Slime produced by iron bacteria and other slime producing organisms.
- Deposition of soil materials (Mechanical Incrustation).

#### (a) Calcium and Magnesium

Calcium carbonate is one of the most extensively found minerals. Its solubility depends upon the quantity of free carbon dioxide in the water which in turn depends upon the pH, the temperature and the pressure. On pumping, a low pressure zone is created around the well and some of the dissolved carbon dioxide is released from solution. Some calcium bicarbonate is then reconverted into calcium carbonate which is deposited as a cement like material on the screen and in the sand and gravel around it. This incrustation builds up a shell around the screen which may be several centimeters thick. Partial incrustation may extend back as much as a metre into the water-bearing formation. In addition to the sand grains around the well which are cemented together, other substances like aluminium silicates, iron compounds and organic material may also be entrapped in the carbonate scales. Many a time the calcium carbonate may only be a small fraction of the deposit but is usually the basic binder. This type of deposit accounts for about 90 per cent of the cases of incrustation.

#### (b) Iron and Manganese Salts

Bicarbonates of iron and manganese are more soluble in water than their hydroxides. In incrusting regions the ground water is generally charged to its full capacity with these salts. It is believed that an increase of its velocity in the vicinity of the well is enough to upset the balance and precipitate out the insoluble iron and manganese hydroxides. These are jelly like and fluffy. Oxidation can then occur due to the dissolved oxygen in the water and these are transformed into hydrated oxides. Hydrated ferrous oxide is a black sludge while ferric oxide is reddish brown like common rust. Ferrous bicarbonates are moderately soluble in water, the solubility increasing if the water is acidic. Ferric salts are, however, insoluble in alkaline or weakly acidic water. Thus a reduction of acidity can also cause precipitation of the iron salts. Ferrous bicarbonates also get oxidised when they come in contact with oxygen to form insoluble ferric hydroxide.



Oxidation is more marked in water table tubewells, which are run intermittently, because air can get into the zone of daily depletion of water table and oxidise the salts there. In such cases sand particles of the aquifer can get progressively coated with iron oxide, thus reducing the void spaces and encroaching upon the storage capacity of the formation.

Clogging by manganese occurs much less frequently. Soluble manganese bicarbonates react with oxygen to form insoluble manganese hydroxide which precipitates as a sooty or dark brown deposit.

In general, waters containing more than 400 ppm bicarbonates, 100 ppm sulphates, or 400 ppm silicates can be considered incrusting. Water containing 2 ppm iron or 1 ppm manganese can be considered incrusting. Water can also pick up iron from the well casing itself.

*(c) Bacteria*

Iron bacteria such as crenothrix grow attached to the screen or voids of the aquifer, and feed on carbon compounds like bicarbonates and carbon dioxide in addition to the iron in solution. Release of carbon dioxide, deficiency of oxygen, and darkness favour their growth. During their life cycle they change the dissolved iron into the insoluble ferric state. This is deposited in the void of the aquifer surrounding the screen or in a jelly like sheath which surrounds the bacteria. This slime can clog the screen slots and the pores of the aquifer. They may grow in water pipes as well and clog the same. Similar bacteria can also cause oxidation manganese compounds to insoluble form.

Sometimes sulphate reducing bacteria are also found in ground water which reduce the sulphates in the water to hydrogen sulphide. Hydrogen sulphide so formed attacks the iron pipes to form insoluble iron sulphide, which deposits as a scale.

*(d) Silt and Clay Deposits (Mechanical Incrustation)*

Silt and clay material can sometimes move on to the screen and clog the same. This may also clog the fractures & fissures of rocky zone of a well which is prevalent in bore wells. Such clogging may be because of improper development or inadequate design and construction.

### **3.8.6 REHABILITATION OF INCRUSTATED TUBE WELLS AND BORE WELLS**

It is very necessary that the type of incrustation is determined before deciding upon the treatment to be given. This can be done by analysing the water pumped by a well and examining samples of aquifer from around the well screen. Samples of incrustation taken from other wells in the same formation give very good information.

The most important factor in treatment by chemicals is an effective contact between the chemical and the deposit on the well screen as well as in the aquifer adjacent to it. The chemical solution tends to penetrate only those parts of the aquifer where it gets the least resistance, i.e. which are comparatively free from clogging. Hence it is very necessary to agitate the solution vigorously and to surge it so as to force it into areas which offer resistance. A treatment may have to be repeated a couple of times and the second or subsequent treatment will open up the more heavily clogged up areas.

Incrusted wells can be cleaned by acids, chlorine, dispersing agents, etc. Hydrochloric and sulphuric acid are effective in removing carbonates and partially effective in removing iron and manganese oxides. Glassy phosphates are able to disperse iron and manganese oxides, silts and clays. Chlorine is effective in removing bacterial growth and slime.

Different methods of rehabilitating incrustated wells are given below:

#### **3.8.6.1 Hydrochloric Acid Treatment**

*(a) Inhibitor*

Carbonate-type incrustation (mineral scale) is removed by hydrochloric acid treatment. Concentrated hydrochloric acid of commercial grade (28% strength) is usually used in well treatment. It should contain a suitable inhibitor which helps in the quick dissolution of calcium and magnesium carbonates. It also slows down the acid attack on mild-steel well casings. Hence, the possibility of any damage to the pipe during treatment is minimised. If inhibited

acid cannot be obtained, a home-made inhibitor can be used. A solution of about 0.7 kgs of gelatine in warm water, added to 100 litres of acid is usually adequate.

**(b) Treatment procedure**

1. The arrangement of equipment required for hydrochloric acid treatment is shown in Fig. 3.2. It consists of a 2 to 2.5 cm diameter plastic pipe which is long enough to reach the bottom of the well. The pipe, supported by suitable clamps, is lowered into the well. The upper end of the pipe is provided with a funnel inlet and overflow arrangement with a T-joint. The overflow takes care of any sudden blow out.
2. A solution of hydrochloric acid is prepared as indicated above. The acid solution required for one treatment should be 1.5 to 2 times the volume of water in the screened portion of the well. Sufficient acid is poured into the well to fill the bottom 1.5m depth of the screen. The acid-feeding pipe is then raised to about 1.5m and more acid poured. Even though acid is heavier than water and will displace it, the two will mix readily when stirred and the acid becomes easily diluted.

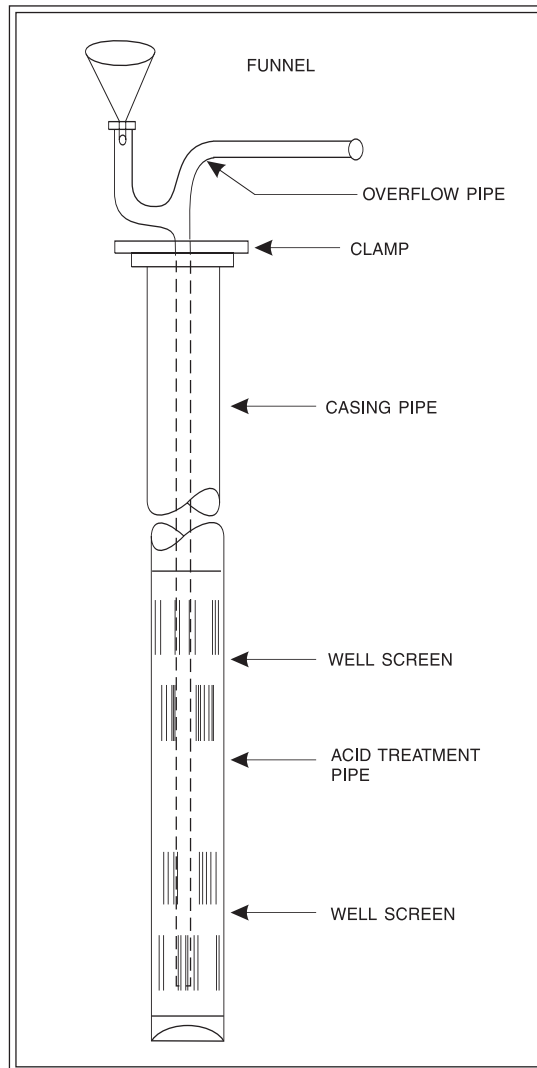


FIG. 3.2: SET UP FOR ACID TREATMENT OF TUBE WELLS



3. The effectiveness of acid treatment depends upon the contact between the chemical and the deposits on the well screen as well as in the adjacent aquifer. Chemical penetration will follow the path of least resistance. Hence, it is difficult to treat a clogged aquifer. It is, therefore, essential to agitate the acid solution vigorously and to surge it with a view to forcing the solution into the aquifer formations offering resistance. As soon as the acid solution is poured, it should be agitated in the well for one to two hours, with the help of a surge plunger. The solution should then be bailed out. Bailing is continued until almost clear water is obtained.
4. In the second stage of treatment, the process is repeated using the same quantity of acid. Surging is continued for a longer period before bailing out the water. Generally, two treatments should be sufficient to achieve the desired results. During acid treatment, neighbouring wells within a 60m radius should not be operated.

**(c) Adaptability**

Hydrochloric acid treatment is best suited when incrustation is due to calcium and magnesium carbonates. The treatment may not be successful in removing iron and manganese crusts. It attacks the steel well casing to some extent. However, damage can be minimised by using suitable inhibitors. Hydrochloric acid treatment is not suitable for agricultural strainers which consist of brass wire-mesh wrapped over a perforated galvanized iron pipe. In such a screen, treatment will result in rapid electrolytic corrosion of the screen.

**(d) Safety measures**

Hydrochloric acid is harmful to skin and can result in serious injury to eyes, if handled carelessly. Similarly, formation of gases, when the acid is poured into the well, can cause suffocation which could be fatal. Therefore, necessary care should be taken while treating the well. Good ventilation should be provided in the area around the pump house. All persons handling the acid should use rubber gloves and protective masks. A box of baking soda is kept handy, to neutralise the effect of acid if it falls on the body.

**3.8.6.2 Sulphamic Acid Treatment**

1. Hydrochloric acid and sulphamic acid are used when calcium carbonate is the principal incrusting material. Although it is more expensive than hydrochloric acid but it has number. of advantages i.e. it is less aggressive, it is relatively safe to handle and it does not attack M.S. well casings like hydrochloric acid. Hence, sulphamic acid is commonly used for treatment in case of wells having mild steel screens or casings with deposits of calcium and magnesium salts. Sulphamic acid ( $\text{NH}_2\text{SO}_3\text{H}$ ), is commercially available in granular and pelletised forms. It is available under different trade names having a corrosion inhibitor and a wetting agent. A colour indicator is also introduced in the pellet which would change the colour of the solution from violet to orange yellow, once the incrustation is completely dissolved. Sulphamic acid is soluble in water and the weak solution does not give any hazardours fumes nor irritates the skin.
2. Sulphamic acid in granular form is poured into the well through a plastic or iron pipe. The material so poured is agitated to dissolve it in water. Sometimes it is poured into the well in a 20 per cent solution with water. In this case, first the solution is prepared

by dissolving one bag of acid (powder or pellets) at a time in a 200 litre capacity drum. Arrangement is made for pouring the solution to the bottom end of the tube well. This is done by a 25 mm or suitable diameter PVC siphon tube, keeping one end of it in a funnel at the top of another 25 mm pipe already lowered into the bottom of the tube well through the space between the pump and well casing. The end of the siphon is to be kept in the tank containing the sulphamic acid solution. The solution is then poured into the tube well through the pipe. The rate of feeding of the solution is controlled by a valve provided at the end of the delivery pipe so that the solution enters the tube well gradually in order to avoid faster chemical reaction at the initial stage. The feeding rate is regulated in such a way that the entire solution is added over a period of 2 to 3 hours. The solution is allowed to remain in the tube well for about 24 hours.

3. When the acid is available in pelletised form, the pellets could be dropped directly into the well in small quantities. Additional granular material is added to the well, as the reaction proceeds so as to keep the required strength of the solution. With surging, the reaction can be completed in 16 to 24 hours. After this period of 16-24 hours, about 4 to 6 hours of adding the chemical, the well is developed by compressed air or pump. This will loosen the incrustated chemical on the tube well screen and the surrounding aquifer. The tube well water is then pumped out. Pumping is continued intermittently for about 10 hours, till clean water is obtained.
4. The quantity of the sulphamic acid required depends on the quantity of water in the well. The usually recommended quantity of sulphamic acid (by weight) to be added in a tube well is about 7 to 10 per cent of the weight of water in the well. Thus, in a 20 cm diameter tubewell with a water column of 100m, the volume of water being 3.14 m<sup>3</sup>, the total quantity of sulphamic acid required for a treatment is about 250kg. It is often desirable to add a corrosion inhibitor and a wetting agent (low detergent soap) to improve the performance of the acid. The quantities of both these additives are about 10 per cent each of the weight of sulphamic acid. The corrosion inhibitor prevents corrosive action of the acid on the metal of the well pipe. The wetting agent improves the dispersing and cleaning action of the acid. Fluronic F-68 or Pluronic L-62 are commonly used as wetting agents. When the two additives are used with the acid, it is necessary to mix them in a bucket containing clean water, so as to form a heavy but pourable slurry, and add this slurry to the well through a tube.
5. The solubility of sulphamic acid decreases with decrease in temperature as shown in Table No.1

**TABLE 1: SOLUBILITY OF SULPHAMIC ACID IN WATER**

Temperature °C	5	10	15	25
Dry acid solubility in 100 litres of water, kg	17	18	20	23
Acid concentration of saturated solution, %	14	15	17	19

## 6. Safety precautions

Sulphamic acid in granular and pelletised forms, though less aggressive than hydrochloric acid, should be handled with caution. However, when used as a concentrated solution, it should be very carefully handled. Water-proof gloves and goggles should be worn by those handling it. Hydrogen sulphide and carbon dioxide gases are produced in considerable volumes during the reaction. The former is produced when iron sulphate is present. Both these gases are heavier than air. Hence, no person should be allowed to stand in a depression or a pit near the well during treatment.

## 7. Necessary conditions for acid treatment

The following are the major requirements for acid treatment of water wells:

- i) The metal of the well screen must be such that it is not damaged by the acid.
- ii) The well screen must be constructed of a single metal in order to avoid electrolytic corrosion, as in the case of a bi-metallic alloy.
- iii) A fair knowledge of the kind of incrusting material is essential to determine the proper procedure in well treatment. Samples of incrustations taken from other wells in the same formation are useful indicators of the causes of incrustation. Water quality analysis is also useful to obtain information on the kind of incrusting material.
- iv) Adequate ventilation of well treatment site is necessary.
- v) Wells located in the neighbourhood (within 30m) of the well must be shut down during the process of treatment.

In all acid treatments, the acid should be handled with care. Good ventilation should be provided when operating in a confined area, like a pump house. Adequate provision should be made for disposing the waste water which is pumped out during its treatment. The waste water must be kept away from domestic wells, ponds or other water bodies used for human or cattle consumption. The waste, when diluted, will not adversely affect plants. Pumping the waste during acid treatment is a process of brisk surging, followed by slow pumping until the water becomes clear and free of odour and foam.

### 3.8.6.3 Aquifer Conditions which may not Respond to Acid Treatment

Acid treatment of water wells, though suitable under most conditions, may not result in any appreciable improvement under the following aquifer conditions:

- i) Shallow limited aquifers, subjected to recurring periods of over-draft.
- ii) Deeply buried narrow aquifers approaching over-development.
- iii) Aquifers of low permeability where operating heads are large.

Controlled pumping tests to determine well efficiencies and the hydraulic characteristics of aquifers are essential in determining the effectiveness of acid treatment or other development methods to increase the yield of water wells.

#### **3.8.6.4 Glassy Phosphate Treatment**

Glassy phosphate or polyphosphates are used for well treatment when iron oxide, manganese oxide, silt and clay are the materials causing incrustation. Sodium hexameta phosphate ( $\text{NaPO}_3$ )<sub>6</sub> is one of the most commonly used polyphosphates. They do not dissolve the incrusting material and fuming or boiling does not take place. Phosphates have cleaning and dispersing properties which, when coupled with vigorous agitation, break the incrusting material. Thus, the incrustation gets dispersed and is easily pumped out. Calcium hypochlorite is also added to it in small quantities. It helps in chlorinating the well and killing the iron bacteria or similar organisms which may be present in well water.

##### *(a) Treatment procedure:*

Glassy phosphate solution is prepared in a tank or drum. The amount of glassy phosphate to be added depends on the quantity of water in the well. Generally, 15 to 30kg of glassy phosphate is used for every 1000 litres of water in the well. It should be dissolved in water by suspending it in a tank in a cloth net or gunny bag, and should not be simply dumped. A mixture of about 1.2 kg of calcium hypochlorite per 1000 liters of water is desirable. It helps kill iron bacteria and other organisms. The solution so prepared is poured into the well. This is followed by vigorous surging, which will help the chemical loosen and disperse the deposits inside the pipe as well as outside. The dispersed material passes out through the screen openings. Surging can be done using a surge plunger, compressed air, or by horizontal jetting. If the pump installed in the well is not removed, the same can be used for surging. Surging by pumping is not very effective but can be used for convenience. Surging with a pump is done by starting and stopping it as often as possible. Operation is continued for a period of about four hours. The pump is then left idle for about two hours. The process is repeated twice or thrice. When the chemical has been in the well for about 24 hours, surging is again repeated several times. The waste is then pumped out and the well flushed thoroughly. Even while the well is being flushed out, surging is done a few times at intervals, and pumping continued until fairly clean water is obtained. The entire procedure may be repeated two or three times, using a fresh charge of polyphosphates and calcium hypochlorite. The chemical is quite safe to use and does not require any special safety precautions.

##### *(b) Removal of Hydrogen Sulphide (H<sub>2</sub>S) Bio Fouling:*

Sulphate reducing bacteria in ground water reduce the sulphates in the water to hydrogen sulphide, which produces foul smell known as bio fouling. This bio fouling can be removed by the method mentioned above. This can also be removed by super chlorination of water. Aeration method as mentioned at para 7.2 of Manual of Water Supply and Treatment (1999 Edition) can also be used for removal of the H<sub>2</sub>S bio fouling.

#### **3.8.6.5 Chlorine Treatment**

In case of wells incrustated with bacterial growth and slime deposits, chlorine treatment has been found most effective. Though acid may kill the bacteria, it is unable to remove the slime. Chlorine kills the bacteria as well as oxidises the organic slime, thus loosening it.

Calcium hypochlorite  $\text{Ca}(\text{OCI})_2$  is often used for chlorine treatment. It is available in powder form, containing about 70 per cent free chlorine. The quantity required is generally 20 to 25kg

for deep wells. Sodium hypochlorite Na OCl can also be used. Sometimes chlorine gas in water solution is also used but special equipment is required for its application.

### **Treatment procedure**

The desired amount of the chemical is put in the well directly, or in a water solution, to give the proper concentration of chlorine. When chlorine solution is used, it can be introduced into the well slowly through a plastic pipe of small diameter, over a period of about 12 hours in case of large wells. About 14 to 18 kgs of chlorine will be required for this purpose. Small wells require less chlorine and the period of application can be decreased accordingly.

Chlorine is corrosive in the presence of water. It should, therefore, be handled carefully so that it does not harm the pump, well casing and screen. It is not necessary to remove the pump, but it should be ensured that the plastic pipe carrying concentrated chlorine solution is not discharging the liquid directly on any part of the pump, well casing or screen. As soon as the chlorine solution is introduced, a sufficient quantity of water (50 to 100 times the volume of water standing in the well) is added to the well from an outside source, with a view to forcing the chlorine solution into the water-bearing formation. The well is then surged, using any of the standard techniques of surging. In case the pump has not been removed, the same can be used for surging, though not very effectively. Successful chlorine treatment of a well may require three or four successive operations.

#### **3.8.6.6 Combined Hydrochloric Acid and Chlorine Treatment**

Hydrochloric acid treatment followed by chlorine treatment is highly effective. The acid readily dissolves the carbonates while the chlorine helps to remove the slime deposited by iron bacteria. The two treatments are alternated, the acid treatment being performed first. The cycle may be repeated two or more times.

#### **3.8.6.7 Dry Ice Treatment**

The use of dry ice to open up incrustated screens is still in the experimental stage. Dry ice is carbon dioxide gas which is solidified by application of a large pressure. When it is put into a well, it is quickly converted into gas is not allowed to escape and is forced through the screen. In this process the material choking the screen is loosened. There may also be some reconversion of salts into soluble bicarbonates due to the action of dry ice. Dry ice can also be used after acid treatment for agitating and creating back pressures for surging. It may cause severe burns if it comes in contact with the body. Hence heavy gloves or tongs should be used while handling it.

#### **3.8.6.8 Hydro Fracturing**

This process is, generally, not used in this country for development purposes. Hydro fracturing is a process used to open-up clogged fractures and fissures in the rock surrounding the bore well by injecting water at a very high pressure. Hydro fracturing method can be used for rejuvenation of a low yielding or nearly dry bore well at a cost of 10 to 70% of the cost of bore well.

##### **(a) Conditions necessary for hydro fracturing**

1. Low yield/dry bore wells shall be considered for hydro fracturing.

2. Lithology of each bore well should be known.
3. Well-logging to be conducted to confirm the lithology and fracture zones of the bore well.
4. Quality of the water to be known.
5. Bore well should be of sufficient depth.
6. Bore well should be in good condition (like uniform diameter and verticality).

**(b) Basic components of hydro fracturing unit**

The basic components of the hydro fracturing unit include packer assembly, hydraulic pump for packing, supercharge pump for injecting water under high pressure, water tank, generator and submersible pumps of different horse powers. The packer assembly is supported by hydraulic hose and steel rope.

**(c) Operation**

Hydro fracturing can be carried out by

- Single Packer
- Double Packer

In the single packer technique, the packer will be placed above the fracture/work zone in the bore well and the bottom of the bore well acts as the closed end. In the double packer system, the packers are placed at the predetermined depths within the bore well.

The verticality of the bore well is checked up to the depth of packer setting and the packer is lowered and fixed by applying hydraulic pressure up to 300-350 bars and followed by injection of water into the bore well under great pressure, depending upon the depth, dimension and area of fracture. The pressure ranges from few tens to 170 bars. Once the maximum pressure builds up, the fractures, fissures, joints will break and interconnects among them and the pressure drops down suddenly indicating the development of fresh fractures or interconnection of existing fractures. Thus, this process can be repeated for lower fracture zones also. Subsequently, well logging and pump test will be conducted to assess the degree of hydro fracturing and improvement in yield.

Figure 3.3 indicates a set up of hydro fracturing unit.

**3.8.6.9 Explosives**

These are sometimes employed to develop and enlarge incrustated crevices and fissures of bore wells. Charges are used according to the hardness of the rock and the depth at which the charge is to be detonated.

**3.8.7 INADEQUATE DEVELOPMENT**

**3.8.7.1 General**

Sometimes due to carelessness at the time of construction proper development of the tubewell is not done which results in constant inflow of the sand particles causing choking of the filtering media and strainers. Such tubewells need redevelopment. The redevelopment of tubewell will have following effects :

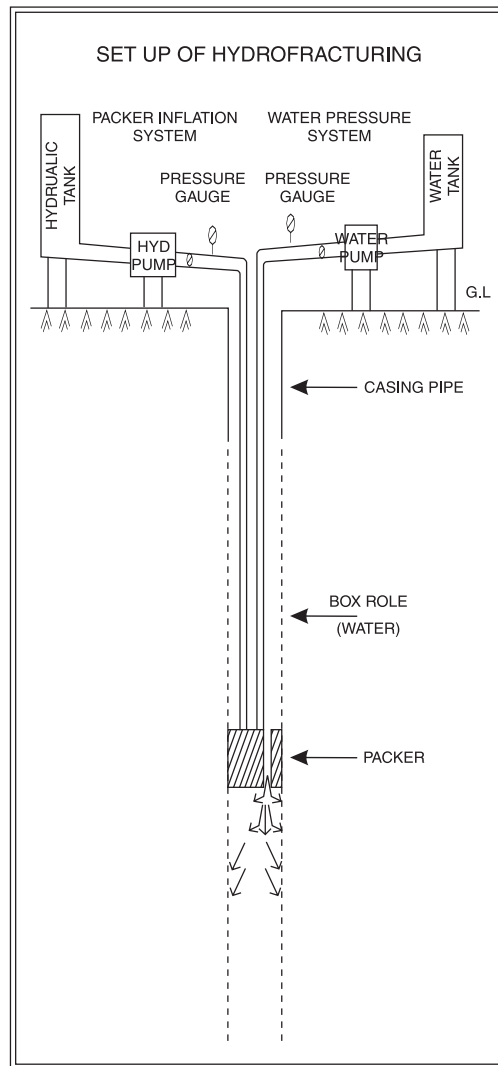


FIG. 3.3: SETUP OF HYDRO FRACTURING

1. Redevelopment of well involves removal of finer material from around the well screen, thereby enlarging the passages in the water-bearing formation to facilitate entry of water.
2. Redevelopment removes clogging of the water-bearing formation.
3. It increases the porosity and permeability of the water-bearing formation in the vicinity of the well.
4. It stabilize the formations around the well screen so that the well will yield sand-free water.
5. Redevelopment increases the effective radius of the well and, consequently, its yield.

### 3.8.7.2 Methods of Redevelopment

Following are the methods of well redevelopment :

- i) Over-pumping with pump.
- ii) Surging with surge block and bailing.

- iii) Surging and pumping with air compressor.
- iv) Back-washing.
- v) High-velocity jetting.
- vi) Dynamiting and acid treatment.

For rehabilitation purpose any suitable method of redevelopment can be used as mentioned above. The largely used method is surging and pumping with compressed air. In this method surging with compressed air is a combination of surging and pumping. In the process a large volume of air is released suddenly into the well casing pipe, which produces a strong surge. Pumping is done with an ordinary air lift pump. To achieve successful redevelopment of the well the submergence ratio (along with two airlines in water divided by its total length) is important. For obtaining the best results the ideal submergence ratio should be about 60%. The efficiency of development reduces rapidly if the desired submergence ratio is not maintained.

The equipment required for surging and pumping operation consist of an air compressor and a tank of required size, drop pipe and an airline with a suitable arrangements for raising and lowering each independently, flexible high pressure air hose for the supply of compressed air to the air pipe, pressure gauge, relief valve, a quick opening wall in the outlet of the tank, tee joint and pipe jointing material.

Normally, air compressors of 500 cum. per hour at 7kg/cm<sup>2</sup> to 800 cum. per hour at 17kgs/cm<sup>2</sup> are used for development/redevelopment work of the tubewell. Whenever under capacity air compressor is used for the development of the well, in such condition proper development is not possible and such wells become sick after a short period of use. These tubewells can only be rehabilitated by adopting the procedure of development of well which is known as redevelopment of the well.

### 3.8.7.3 Submergence Requirement of the Airline and Selection of Air Compressor

#### Submergence Requirements of the Airline

For achieving successful development/redevelopment of a well, submergence requirement of the airline is given below in table 3.2.

**TABLE 3.2**

Lift m	Maximum submergence %	Optimum submergence %	Minimum submergence %
6	70	66	55
10	70	66	55
15	70	66	50
20	70	64	50
25	70	63	50
30	70	60	45
40	65	60	45
50	65	60	45
60	60	50	40
70	55	50	40



#### **3.8.7.4 Selection of Air-Compressor**

The two most important factors in the selection of an air compressor for well development/redevelopment are the requirement of pressure and capacity. The required air pressure is determined, based on the length of air pipe below the static water level. Before air can be discharged from the lower end of the air pipe, the compressed air must push all the water out of the pipe. To do this, the air pressure must be greater than the water pressure before starting to pump water. The required pressure of compressor will be slightly more than submergence of the airline in the water.

A useful rule of thumb to estimate the compressor capacity is to provide about 0.28 m<sup>3</sup>/l of free air for each litre per minute of water at the anticipated pumping rate.

#### **3.8.7.5 Redevelopment Procedure**

For redevelopment of the tube well following steps are to be followed:

- Lower the drop pipe and air line in the well up to the desired submergence. The bottom of the drop pipe should be kept about 60cm above the bottom of the screen and the air line is kept about 30cm higher than the bottom end of the drop pipe.
- Turn on the air from the compressor and the well pumped by the conventional air lift principle until the discharge water is free from sand.
- Air entry into the well is then cut off by closing the valve between the tank and the compressor and in the meantime, the air line is lowered so that it is about 30cm below the bottom of the drop pipe. The airline is thus at the same position as in the back-washing method.
- The air valve is quickly opened to allow the compressed air from the tank into the well. This tends to surge water outwards through the well screen openings.
- The air pipe is raised again and the cycle repeated until the water discharged from the well is relatively free of sand. The above operation of back-washing and pumping completes one operation of surging.
- The entire assembly is then raised to a height of about one metre and the operations repeated until the well section along the entire length of the screen has been developed.
- Finally, the air pipe is lowered again to the bottom of the well and the equipment operated as a pump to flush out any sand that might have accumulated inside the screen.

Normally, with this method of redevelopment all the wells drilled in alluvial formation with inadequate development can be successfully redeveloped. This method has also been tried for sick wells drilled in rocky formations and encouraging results have been noticed. The use of disbursing agents like Polyphosphates have also been found useful in rehabilitating the wells with redevelopment method drilled in alluvial formation with inadequate development.

### **3.9 PREVENTION OF INCRUSTATION AND CORROSION**

At the time of construction of wells and even afterwards some steps can be taken for the prevention of incrustation and corrosion. These steps are given below:

### 3.9.1 PREVENTION OF INCRUSTATION

In case of wells where the water is charged with undesirable chemicals, incrustation cannot be prevented entirely, but it can be delayed, and kept in check by keeping the draw-down as small as possible. In this way a considerable release of carbon dioxide does not take place and precipitation of carbonates in well screens is kept in check. In order to reduce the head loss to a minimum, the well should be developed properly so that aquifer losses are reduced to the minimum. A screen having a large open area and fully penetrating the aquifer should be installed. This results in lower entrance velocities as well due to which precipitation of iron salts and carbonates is retarded. The pumping rate should be reduced and the pumping period increased. The required quantity of water may be obtained from several wells rather than pumping a few large wells at excessive flow rates. Lastly, the screen should be cleaned periodically, say once a year, even if the discharge has not fallen off. This last point is very important because if partial choking takes place, it is very difficult to eradicate the same completely.

### 3.9.2 PREVENTION OF CORROSION

#### 3.9.2.1 Application of Corrosion Resistant Paints and Coatings

Corrosion can be controlled to a large extent by applying anti corrosive paints on the steel pipes at the time of construction of the tube well. Non corrosive casing pipe and strainers (such as PVC pipes and strainers) can also be used at the time of construction of tube well to avoid corrosion. Some commonly used paints/coatings to control corrosion are of aluminium, asphalt, red lead and coal tar. Now a days, a number of epoxy paints for this purpose are also available in the market.

#### **Cathodic protection of mild steel tube wells in corrosive ground water:**

The following are two methods for applying cathodic protection against corrosion of mild steel pipes :

- (a) Sacrificial anode
- (b) Impressed current

**(a) Sacrificial anode:** For wells sacrificial anode cathodic protection is used which is detailed below:

In case of the sacrificial anode system of cathodic protection, a metal of higher negative potential than that of the material of the pipe to be protected is used as the anode. The metal pipe acts as the Cathode and the intervening water as electrolyte (Fig. 3.4), thus establishing the flow of electrons from the anode to this cathode. During electrolysis, the anode gets dissolved slowly and the metal ions in the solution are deposited at the Cathode. Thus, the main pipe (well pipe) is protected from corrosion by sacrificing the metal of the anode. Sacrificial anodes are easy to install and no power costs are involved. They are effective in prolonging the service life of mild steel tube wells in corrosive water. However, the anodes have to be replaced periodically at the end of their useful life.

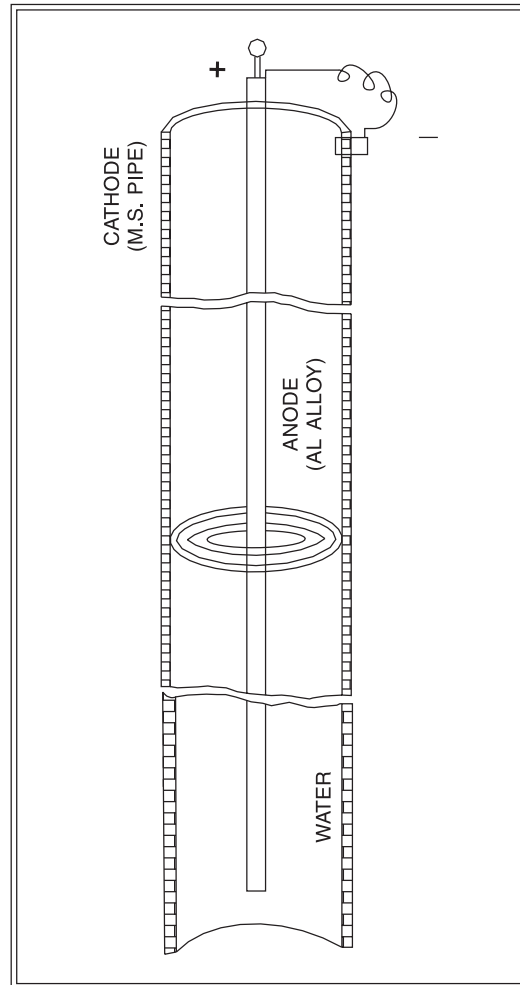


FIG. 3.4: CATHODIC PROTECTING ARRANGEMENT OF TUBE WELL

The anodes may be made of magnesium, zinc, aluminium, tin or their alloys. They are commercially available\* in diameters ranging from 1.5 to 8 cm and lengths of 1 to 3 m. Research findings have established the adaptability of Aluminium-zinc-tin alloy in the cathodic protection of tube wells (a commonly used alloy has Al 90%, Zn 7% and Sn 3%). Alloys cast in steel core pipes of 1 cm diameter are also available. The anode rods are threaded at their ends for jointing with each other through sockets or couplings.

(b) **Impressed Current:** In the Impressed current method electric current is passed from current source through anodes buried in the soil some distance from a mild steel pipeline. This method is extensively used in protecting mild steel pipelines in water supply projects but its applicability in wells has not yet been established.

### 3.10 ARTIFICIAL RECHARGE OF GROUND WATER

Artificial recharge of ground water can be achieved by the following:

- i) *Stream flow harvesting comprising of*
  - Anicuts
  - Gully plugging

- Loose stone check dams (LSCD)
- Dams
- ii) *Surface flow harvesting*
  - Tank
  - Ponds
- iii) *Direct recharge*
  - Recharge of wells
  - Through injected wells
  - Through roof top rain water harvesting structures

### **WELL PROBLEMS AND THEIR SUGGESTED SOLUTIONS**

These are given in Annexure 3.1 and 3.2.

## ANNEXURE: 3.1

**CAUSES OF FAILURE OF WELLS***Causes of failure marked as \*\**

S.No.	Types of Sources	Causes of failure							
		Incorrect design	Poor construction	Corrosion	Faulty operation	Adverse aquifer conditions	Mechanical failure	Incrustation	Inadequate development including silting
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
1.	Dug well with or without steining	**			**	**			**
2.	Dug cum bore wells								
	(i) With PVC casing	**	**		**	**	**		**
	(ii) With MS casing	**	**	**	**	**	**		**
3.	Cavity bores								
	(i) With PVC casing	**	**		**	**	**		**
	(ii) With MS casing	**	**	**	**	**	**		**
4.	Infiltration galleries								
	(i) Lined with brick masonry	**	**		**	**			**
	(ii) Lined with non-metallic perforated pipes	**	**		**	**		**	**
	(iii) Lined with non-ferrous metallic perforated pipes	**	**		**	**		**	**
	(iv) Lined with M.S. perforated pipes	**	**	**	**	**		**	**
5.	Radial collector wells								
	(i) Radial with non-metallic perforated pipes	**	**		**	**		**	**
	(ii) Radial with Non-Ferrous metallic perforated pipes	**	**		**	**		**	**
	(iii) Radial with M.S. perforated pipes	**	**	**	**	**		**	**
6.	Tubewells (borewells)								
	(i) With PVC casing & screen pipes	**	**		**	**	**	**	**
	(ii) With M.S. casing & screen pipes	**	**	**	**	**	**	**	**
7.	Borewells	**	**		**	**	**	**	**

## ANNEXURE: 3.2

**WELL PROBLEMS AND THEIR SUGGESTED SOLUTIONS**

S.No.	Type of well	Problem	Probable cause	Solution suggested
1.	Dug well	1. Silting 2. Decrease in yield	1. Over pumping 2. Adverse aquifer conditions	1. Disilting can be done manually with buckets. 2. Disilting can be done by using submersible mud pumps 3. Discharge should be reduced so that there is no inflow of silt with water. Rehabilitation procedure as per 3.8.4.1 should be followed.
2.	Dug cum bore well	1. Silting 2. Decrease in yield 3. Mechanical failure	1. Over pumping 2. Adverse aquifer conditions 3. Falling of foreign objects in the bore	Apart from solution suggested for S.No.1, the rehabilitation procedure for mechanical failure mentioned at 3.8.4.3 should be followed. Development should be done with the help of air compressor using surging and pumping technique.
3.	Cavity bore	1. Bore silting 2. Decrease in yield 3. Mechanical failure	1. Over pumping 2. Adverse aquifer conditions 3. Falling of foreign objects in the bore 4. Collapse of cavity	For mechanical failure rehabilitation procedure mentioned at 3.8.4.3 should be followed. The cavity reconstruction & desilting of bore should be done with the help of air compressor using surging and pumping technique.
4.	(i) Radial collector wells (ii) Infiltration galleries	1. Silting in well caisson/Sump well 2. Decrease in yield	1. Over pumping 2. Adverse aquifer conditions 3. Incrustation of radials 4. Blocking of screens with sand 5. Damage of M.S. screens due to corrosion.	Apart from the solution suggested for S.No.1 rehabilitation procedures mentioned at 3.8.5 may be followed. For flushing of sand from the blocked screens, backwashing with the help of air compressor should be done. Screens should not be allowed to become aerated and should not be kept unused for long periods.
5.	Tube well	1. Silting of tube 2. Decrease in yield 3. Mechanical failure	1. Over pumping 2. Adverse aquifer conditions 3. Incrustation of screens & aquifers 4. Falling of foreign objects in the bore 5. Damage of M.S. screens due to corrosion.	Rehabilitation procedures suggested 3.8.4.1, 3.8.4.2, 3.8.4.3, 3.8.5, 3.8.7 may be followed.
6.	Borewell	1. Silting of bore-well 2. Decrease in yield 3. Drying up of borewell 4. Mechanical failure	1. Over pumping 2. Adverse aquifer conditions 3. Incrustation and silting of fractures & fissures. 4. Falling of foreign objects in the bore	Rehabilitation procedures suggested 3.8.4.1, 3.8.4.2, 3.8.4.3, 3.8.5 may be followed

## CHAPTER 4

# TRANSMISSION OF WATER

### 4.1 GENERAL

#### 4.1.1 OBJECTIVE OF TRANSMISSION SYSTEM

The overall objective of a transmission system is to deliver raw water from the source to the treatment plants and transmit treated water from treatment plants to the storage reservoirs for onward supply into distribution networks. Transmission of raw water can be either by canals or by pipes whereas transmission of treated water is by pipes only. Transmission through pipes can be either by gravity flow or by pumping.

The objective of O&M of transmission system is to achieve optimum utilization of the installed capacity of the transmission system with minimum transmission losses and at minimum cost. To attain this objective the agency has to evolve operation procedures to ensure that the system can operate satisfactorily, function efficiently and continuously, and last as long as possible at lowest cost.

Routine and emergency operating procedures should be in writing and clear to all operators with the authority to act in emergencies. Further specific operational procedures are required for inspecting, monitoring, testing, repairing and disinfecting the system as well as for locating the buried pipes and valves. System records and maps should be updated and have sufficient details of the system facilities.

#### 4.1.2 NORMAL CONDITIONS

##### 4.1.2.1 Routine Operations

Normally the operations involve transmission of required water within the available head or within the pumping head. Operation of valves at reservoirs from which transmission channels/ mains start and operation of pumps (in case of pumping mains) from which the transmission mains start are the routine operations. Operation of chlorinators where installed are also included in the routine operations.

##### 4.1.2.2 Record of Flow, water levels and pressures

###### *(a) Gravity Channels and pipes*

A record is kept at the transmitting and receiving reservoirs about the valve operations, water levels and flows. Flow meters are installed at start and end points of transmission channels/pipes for monitoring the flows. Water levels in the reservoirs from which the channels/pipes transmit water and water levels in the receiving reservoirs are measured either by visible gauges or by automatic instruments.

### *(b) Pumping transmission mains*

Water levels in the sumps from which the water is being pumped are measured. Critical points are selected in the transmission system for monitoring of pressures by installation of pressure recorders and gauges. In the pumping systems, whenever water pressures in the pumping station drops below the designed system pressure, the operators are alerted to search for possible leaks in the pumping system. Similarly at the receiving end, if the required water levels are not building up at the storage reservoir, it indicates that the required quantity is either not pumped or there may be leakages enroute. At times whenever the maximum levels in the receiving reservoirs are reached the pumps will have to be stopped or the outlet valves of the reservoir have to be opened.

### *(c) Continuity*

Operators are required to check that the transmission of water takes place continuously and as per the requirement. Normally, the flow meter readings, water levels in reservoir and pressures in transmission mains are recorded and transmitted to the control room. The operators have to ensure the accuracy of the measuring instruments for flows, pressures and levels so as to perform the operations properly. Analysis of the records will enable the agency to evaluate how well the transmission system is working.

## **4.2 TRANSMISSION THROUGH CANALS OR OPEN CHANNELS**

### **4.2.1 INTRODUCTION**

Open channels and Canals are exposed watercourses for transmission of water from one specific point to another. Whereas 'Open Channel' is a general name for such a watercourse, a 'Canal' normally forms a part of canal network taken off from a river, a dam or a reservoir. Following discussion relates to a canal. The criteria for design, operation, and maintenance for open channels are identical to those of a canal.

The canals are meant primarily for irrigation purposes. The canal water is, however, liberally made available for drinking water supply schemes. While designing new canal projects the requirement for drinking purposes is pre-determined and necessary provision made in the design of the canal projects.

Under special circumstances, however, a specific canal may be constructed exclusively for a drinking water supply project. There are, however, a large number of small water channels taken off from the main canal system and are meant exclusively for the drinking water supply schemes.

### **4.2.2 MAPS**

Survey maps may be procured or prepared for the entire existing and proposed canal net work, which could be the probable source of raw water for drinking water supply projects. These maps shall show the contours, spot levels and important land features for the whole area where the water supply schemes are to be implemented or augmented.

Alignment of all main canals, branches, distributaries and smaller major and minor channels shall be marked on the maps. The old maps shall be updated from time to time particularly when an important project is to be undertaken.



Following information shall be obtained for all important points along the alignment from where the connections are likely to be taken.

- i) Natural surface level,
- ii) Full supply levels,
- iii) Bed levels,
- iv) Free board,
- v) Water surface slope,
- vi) Bed width, side slopes, velocity,
- vii) Subsoil water levels,
- viii) Hydraulic data of outlets, regulators, bridges, drainage crossings, off take channels.

### **4.2.3 WATER DISTRIBUTION PRACTICES**

The canals may run continuously or on rotational basis, depending on the availability of water and demand. Depending on the closure period of a canal, adequate storage of raw water has to be created at the site of the waterworks to endure uninterrupted water supply. Such storage is in the form of open square or rectangular tanks whose side slopes and bed are properly lined. Surfaces of such storage tanks are identical to those of the canals with a difference that the canal surfaces are exposed to flowing water whereas, the water in the storage tanks is comparative static.

### **4.2.4 OPERATION**

The key objective of proper operation and maintenance of the canal system is to ensure uninterrupted, assured, authorized water supply from head to tail of a canal distribution system, ensure efficient conveyance of water, saving seepage losses en-route, at economical maintenance cost. Hence well planned and executed programme of operation, maintenance and repair of canal system, timely and methodically, is very important.

The availability of canal water is far below the requirements except during the active monsoon months. In order to overcome this problem arising due to less availability of canal water as compared with the overall requirement the entire canal network is divided into different groups which are run strictly according to the sanctioned/notified rotational programme. Each feeding channel has a full supply turn followed by a closure turn. No supply can be allowed to go out of turn.

### **4.2.5 RECORD KEEPING**

An accurate and systematic record of the performance of a canal should be maintained by periodic observations of roughness coefficient, evaporation and seepage losses, life and behavior of the lining adopted, surge wave heights and performance of any special design features like pressure release systems, provision of humps or regulators etc.

### **4.2.6 MAINTENANCE OF UNLINED CANALS**

#### **4.2.6.1 Some of the most desirable requirements are**

- A clean bed.
- Straight clean slopes.

- Uniform berm widths.
- Uniform regular top width.

#### **4.2.6.2 Bed and Berms**

The beds and berms should be correctly aligned. These should be scraped, where necessary and especially in tail reaches. The canal should be straightened. The kinks and irregularities should be removed and curves should be eased off where scouring or silting takes place. Clearing operation should be started from downstream to upstream.

#### **4.2.6.3 Bed**

All grass should be scraped and weeds removed from the silted bed wherever they are found to exist since their presence induces silt deposits.

All accumulation or deposits or mounds of silt should be removed.

Beds should be levelled and their gradient regularized.

The canals that carry silt-free water from the reservoirs generally get infested with aquatic weed growth which reduces their capacity and impairs proper functioning. Such canals should be kept clear of aquatic weeds.

#### **4.2.6.4 Berms**

Berms should be kept straight by trimming projections after aligning them correctly.

#### **4.2.6.5 Silt Clearance**

Silt ejectors/desilting basins, wherever provided should be operated regularly to prevent accumulation of silt. Longitudinal sections of the silted bed of canals should be taken during closure immediately after monsoons and the gradient at which silt should be removed should be ascertained.

#### **4.2.6.6 Bridges and Siphons**

When a canal is running brushwood that collects at bridges, siphons and falls should be removed away from the banks, dried and burnt. When trees fall into a canal they should be removed at once. Silt and rubbish should be cleared from under the bridges.

#### **4.2.6.7 Scouring**

In case of excessive scouring at any point adequate measures should be taken to stop these.

#### **4.2.6.8 Flow and Gauges**

To have effective control in regulation, it is desirable to observe discharge at conspicuous places. Gauges should be installed at the head and tail of all the channels and at important points in between. Their readings should be observed and recorded daily.

#### **4.2.6.9 Banks**

- i) The banks should be brought up and maintained to full section. All holes should be traced out and fully opened up. The fallen or loose lumps of earth should be removed. Filling and repairing should be properly done. Both edges of the bank especially the

inner ones should be neatly aligned parallel to the canal. Both inner and outer slopes and toes of the banks should be free from irregularities. The top of both the banks should be kept smooth and free from holes.

- ii) Side slopes are usually kept 1:1 in cutting and 1.5:1 in filling. If the soil is comparatively sandy gentler slopes say 1.5:1 in cutting and 2:1 may be provided.
- iii) Following precautions may be taken to ensure stability of the Embankments and to maintain their slopes.
  - Adequate compaction to avoid settling on saturation,
  - Prevention of cracks due to settling of fills,
  - Prevention of seepage,
  - Protection from burrowing animals.

#### **4.2.6.10 Roads and Ramps**

Roads and ramps should be kept smooth and shall have a regular longitudinal grade. At outlets and bridge crossings the road should be specially attended. A dowel should be made to the desired size.

#### **4.2.6.11 Cross Drainage Works**

A canal has to intercept various drainage systems along its route. Most of the crossings are of the following types.

- (a) *Crossing the canal over the drainage*
  - Aqueducts
  - Syphon Aqueducts
- (b) *Crossing the Drainage over the Canal*
  - Supper Passage
  - Syphon

The water passages through these drainage works are usually restricted. These are liable to get damaged due to the obstructions created by floating objects like logs, trees, trunks, dead animals, soft material like twigs and leaves. Adequate measures have to be taken to avoid damage to these water passages.

### **4.2.7 MAINTENANCE OF LINED CANALS**

#### **4.2.7.1 Desirable Requirement**

It should maintain its imperviousness. It should continue to have the same discharge capacity for which it was designed. The reduction in discharge may be due to:

- i) accumulation of silt
- ii) cracking of lining
- iii) failure of drainage
- iv) growth of weeds, algae etc.
- v) seepage and evaporation.

No silt should be normally permitted to take place in a lined canal. Sometimes the canal may have to be run at less than the designed full supply demands on account of fluctuating water demands. Such condition may cause deposition of silt over the bed owing to low velocities of flow. Consequently discharge carrying capacity is adversely affected. The silt deposition in lined canals can be minimized by judicious operation of gates or cross regulators, silt ejectors/desilting basins, wherever provided.

#### **4.2.7.2 Inspection of Lining**

During the canal closure period the lining, its auxiliaries and special design features should be carefully inspected. Following points should be noted:

- i) Whether any cavities or pockets have been formed behind the lining.
- ii) Development of any cracks or displacement or damage to the lining.
- iii) Whether the filter material in the joints of the lining is sound, intact and leak proof and any weed growth in the joints has taken place.
- iv) Whether any pressure release arrangements and humps or regulators function effectively.
- v) Whether pipes and openings provided in the crest of the falls are choked.
- vi) Silt deposits and weed growth.
- vii) Full supply water level, gauges, bench marks etc.

#### **4.2.7.3 Lining - Defects and their Repairs**

##### **i) Defects**

Defects ranging from small settlement cracks to excessive heaving displacement and sinking of the lining may be due to following reasons:

- Cuts in soft fine ground soils especially when lining was laid on the soil without any special preparation of the subgrade.
- High water table situated considerably above the canal bed, especially in fine grained soils, where weep holes or other simple drainage devices are not very effective.
- Freshly laid embankments.
- High continuous spoil banks, left too near the canal excavation without sufficiently wide berms and adequate arrangement for draining the rain water away from the canal and similar situations permitting surface drainage to enter behind the lining.
- Cavities behind the lining caused due to sucking out action on subgrade material by oscillating waves or fluctuating supplies of water of the canal through cracks, open joints and holes in lining.

##### **ii) Remedies**

- Pockets or any activities detected behind the lining should be carefully packed with sand or other suitable material. During such operations, however, care should be taken to ensure that the lining does not get damaged or displaced.

- Damaged or displaced portions of lining should be removed and replaced by fresh lining of a quality comparable to the original lining. The subgrade should be thoroughly compacted and prepared before laying the fresh lining. The cracks (other than hair cracks ) should be filled so as to ensure water-tightness of the lining . A more effective sealing of the cracks may be obtained by cutting a V-groove along the face of the cracks before filling with sealing compound. Dumping powdered clay upstream of the cracks may seal minor cracks on the lining.
- The damaged or displaced portions of the joint filter should be carefully removed. The joint should be cleaned of dirt weed etc., before filling in fresh filter material.
- The choked pressure release pipes should be cleaned by intermittent application of air and water by rodding. Defective flap valves or other parts should be repaired or replaced. The humps or regulators should be well maintained and repaired.
- All drainage and pressure release pipes and openings should be cleaned of any dirt, debris etc. and water accumulating upstream of the fall, if any, should be drained.
- In pervious linings, such as boulder lining, any portion in which excessive settlement has taken place, should be repaired by dismantling, making up the subgrade and relaying the lining.
- The lining should be protected from ingress of rain water behind the lining.

#### **4.2.7.4 Reaches with High Subsoil Water Level**

The subsoil water level should be observed carefully and regularly during and after rainy season besides routine observations from time to time. In case of rise, the adequacy of pressure release systems or other remedial measures like humps, regulators etc. provided for the safety of the lining should be reviewed and further measures adopted.

#### **4.2.7.5 Seepage through Embankments**

Seepage through embankments, if any, should be observed at reasonable intervals of time. Observations of seepage flow should be made and abnormal increase in the seepage rate and soil particles should be reviewed with caution, its possible causes investigated and remedial measures taken.

#### **4.2.7.6 Silt Clearance**

If any silt deposition is detected during inspection, steps should be taken to investigate causes thereof and to take remedial measures for the same. Only in exceptional circumstances it may be necessary to excavate the silt and remove it. If any silting tendency is noticed in the form of reduction of discharge carrying capacity, cross-sections of the lined canal should be taken at frequent intervals to determine the extent of silting and to see if the silt deposited during monsoons can be flushed out during non-monsoon periods when the water is silt free. Where silt clearance is unavoidable, it should be done carefully by manual labour to prevent damage to the lining.

#### **4.2.7.7 Weed Removal**

Aquatic weed growth, if observed below the supply level should be removed. Land weed growing over the free board should also be controlled.

#### **4.2.7.8 Canal Banks and Ramps**

The canal banks should be inspected for the seepage conditions at the outer slope and for some distance beyond the toe, especially in high fill reaches. The roads and ramps should be properly maintained.

### **4.3 TRANSMISSION THROUGH PIPES**

#### **4.3.1 PROBLEMS IN TRANSMISSION MAINS**

##### **4.3.1.1 Leakage**

Water is often wasted through leaking pipes, joints, valves and fittings of the transmission system either due to bad quality of materials used, poor workmanship, and corrosion, age of the installations or through vandalism. This leads to reduced supply and loss of pressure. Review of flow meter data will indicate possible leakages. The leakages can be either visible or invisible. In the case of invisible leaks sections of pipeline can be isolated and search carried out for location of leaks.

##### **4.3.1.2 Leakage through appurtenances**

Most common leaks are through the glands of sluice valves. Leaks also occur through expansion joints where the bolts have become loose and gland packing is not in position. Leaks through air valves occur due to improperly seated ball either due to the damage of the gasket or due to abrasion of the ball, through the gland of the isolating sluice valve or through the small orifice.

##### **4.3.1.3 Air Entrainment**

Air in a rising main in free form will collect at the top of pipeline and then run up to higher points. Here it will either escape through air valves or will form an air pocket. With more accumulation of air the size of air pocket will rise. The cross sectional area of the pipe will diminish and the velocity of water will increase. The formation of air pocket will result in an increase of head loss. Other problems associated with air entrainment are: surging, corrosion, reduced pump efficiency and malfunctioning of valves or vibrations. In rare cases bursting of pipes also is likely to occur due to air entrainment.

##### **4.3.1.4 Water Hammer**

The pressure rise due to water hammer may have sufficient magnitude to rupture the transmission pipe or damage the valves fixed on the pipeline. Water hammer in water supply systems occurs due to rapid closure of valves and sudden shut off or unexpected failure of power supply to the pumps.

##### **4.3.1.5 Age of the system**

With age there is considerable reduction in carrying capacity of the pipelines particularly unlined CI, MS and GI pipes resulting in corroded pipes and leaks and hence in reduced quantity and pressures.

#### **4.3.1.6 Lack of Records**

Maps showing the actual alignment of transmission mains are not readily available. The location of pipes and the valves on the ground becomes difficult in the absence of system maps. Some minimum information about the location of pipes and valves and size of pipes and valves and the direction of opening of valves etc. is required, to operate and maintain the system efficiently.

### **4.3.2 OPERATION SCHEDULE**

#### **4.3.2.1 Mapping and inventory of pipes and fittings in the water supply system**

Availability of updated transmission system maps with location of valves, flow meters and pressure gauges is the first requirement for preparation of operation schedule. The agency should set up routine procedures for preparing and updating the maps and inventory of pipes, valves and tapplings if any on the transmission mains. The maps shall be exchanged with other public utilities and also contain information about the location of other utility services like electricity, communications etc. with reference to the alignment of transmission.

Valve location maps, apart from indicating location of valves, also show the direction to open the valve, number of turns to open, make of valve and date of fixing of valve. At times plan and profile drawings are also available which show the depth of pipe, pipe location vertically and horizontally and distance from reference point. Hydraulic gradient lines are also to be marked to indicate the pressures in the transmission system. They can be used for identifying high pressure or problem areas with low pressures.

The activities involved in mapping are :

- Establishment of consultative process with management of other utility services like electricity, communications etc.
- Definition of maps such as layout, scale, representation of pipes, valves, trappings/connections etc.
- Establishment of procedures for storage and retrieval and updating of maps and inventory information including intersections.
- Setting up procedures for collecting map information in the field including verification in the field for compliance of the as built drawings with design.

**Field Survey :** Existing maps are used or conventional survey is carried out for preparation and up-dation of maps. As an alternative to traditional survey and map preparation, total station method is gaining popularity. Total station instruments can be used for survey and mapping of pipelines where data is not readily available.

#### **4.3.2.2 Normal operations of the water supply distribution system**

The efficiency and effectiveness of a water supply transmission system depends on the operating personnel's knowledge of the variables that affect the continuity, reliability, and quantity of water transmitted. The operational staff should be able to carry out changes in the hydraulic status of the system as required depending on those variables promptly and effectively. Routine operations shall be specified which are activities for adjusting the valves and operation of pumps to match the prevailing conditions (flows, pressures, levels and operation of pumps).

Valve and pump operations will have to be controlled as per a schedule. The schedule shall contain operations for operating the transmission system. It should contain procedures to obtain, process, and analyse the variables related to water flows, pressures and levels as well as the consequences of manipulating control devices, such as operation of valves and/or pumps so that the hydraulic status of the system can match the required capacity of the system for transmission of water. When operators change their shifts information on valve closure and opening must be exchanged.

#### **4.3.2.3 Operations in abnormal conditions**

Operations other than routine viz. during breakdowns and emergencies have to be specified to be carried out in specific circumstances when normal conditions change i.e., when flows, pressures and levels and operation of pumps change.

#### **4.3.2.4 Evaluation of Hydraulic Conditions**

A continuous evaluation of the hydraulic conditions of the water supply system can be done by the O&M personnel after obtaining the data on water volumes in the reservoirs, flow meter readings from and into the reservoirs connected to a transmission system and compared with the expected performance. This evaluation shall lead to identification of operational problems and/or system faults. Depending on the type of problems actions have to be initiated to ensure that the system functions as per the requirement.

#### **4.3.2.5 System Pressures**

Maintenance of a continuous positive pressures in the mains at the time of transmission of water is required. Locations along the transmission mains which show low pressures have to be promptly investigated if necessary by measuring pressures with pressure gauges. Low pressures may be due to:

- i) purposefully or accidentally a line valve is left closed or partly closed or blockage may occur due to any material causing loss of pressure,
- ii) high velocities in small pipelines,
- iii) low water levels in service reservoir (SR) feeding into the transmission main,
- iv) failure of pumps either due to power failure or mechanical failure feeding the transmission system.

#### **4.3.2.6 Simulation of Transmission Network**

Operations have to be planned for specific circumstances such as failure at source, failure of pumps, leakages or bursts. Criteria have to be determined on the basis of analysis of the effects of particular operations on the hydraulic configuration of the water supply transmission system. These effects can be seen in simulated operating conditions. Mathematical simulation models can be developed from basic data on the network such as length, size, flow, characteristics of pumps, valves, reservoir levels etc. This approach can be very useful for analysing the effects of variables on large and complex water supply transmission systems.



#### **4.3.2.7 Sampling for Quality of Water**

The agency operating the water supply system is charged with the primary responsibility of ensuring that the water supplied to the consumer is of an appropriate quality. To achieve this objective it is necessary that the physical, chemical and bacteriological tests are carried out for the water samples collected at frequent intervals. The minimum number of samples to be collected from a water supply system should be as prescribed in the Chapter 15 of the Manual on Water Supply & Treatment. Samples should be taken at different points of the transmission system on each occasion to enable overall assessment. In the event of epidemic or danger of pollution more frequent sampling may be required especially for bacteriological quality.

#### **4.3.2.8 System Surveillance**

*Surveillance of Transmission system is done*

- To detect and correct sanitary hazards.
- To detect and correct any deterioration of the transmission system facilities.
- To detect encroachment of transmission system facilities by other utilities such as sewer and storm water lines, power cables, telecom cables etc. and
- To detect and correct damages to the system facilities by vandalism.

These checks are done routinely. In addition checks are done under special circumstances for assessing damage of the transmission system after flooding along the alignment following a heavy storm. All these checks are also done for above ground water facilities such as valves and valve chambers or exposed pipelines. Any activity or situation that might endanger the water facility or water quality shall be investigated and corrective action is to be taken. Surveillance shall also include looking for unauthorised construction activity on or near the utility's pipelines which may pose a physical threat to the mains. Any digging or excavation or blasting near the mains shall be closely supervised by the utility staff. Surveillance of Valve chambers and valves of the transmission system shall be done as noted in para 4.3.3.

### **4.3.3 MAINTENANCE SCHEDULE**

A maintenance schedule is required to be prepared to improve the level of maintenance of water Transmission system through improved co-ordination and planning of administrative and field work and through the use of adequate techniques, equipment and materials for field maintenance. The schedule has to be flexible so that it can achieve team action with the available vehicles and tools. Co-ordination of activities is required for spares and fittings, quality control of materials used and services rendered. Training of maintenance staff shall, apart from the technical skills, include training to achieve better public relations with consumers.

#### **4.3.3.1 Activities in Maintenance Schedule**

Following activities are to be included in the schedule:

- i) Develop and conduct a surveillance programme for leaks in pipelines, pipe joints and valves,
- ii) Develop and conduct a water quality surveillance programme,

- iii) Develop and conduct a programme for locating and repairing leaks including rectifying cross connections if any, arrange for flushing, cleaning and disinfecting the mains,
- iv) Establish procedures for setting up maintenance schedules and obtain and process the information provided by the public and the maintenance teams about the pipeline leaks,
- v) Establish repair procedures for standard services and with provision for continuous training of the team members,
- vi) Procure appropriate machinery, equipment and tools for repair of leaks and replacement of pipes and valves,
- vii) Allocate suitable transport, tools and equipment to each maintenance team,
- viii) Establish time, labour and material requirement and output expected, time required and other standards for each maintenance task, and
- ix) Arrange for monitoring the productivity of each team.

#### **4.3.3.2 Preventive Maintenance Schedule**

A preventive maintenance schedule has to be prepared for:

- i) Maintenance of the pipelines with particulars of the tasks to be undertaken, works not completed, works completed,
- ii) Servicing of valves, expansion joints etc.
- iii) Maintenance of valve chambers,
- iv) Maintenance of record of tools, materials, labour, and
- iv) Costs required to carry out each task.

##### ***(a) Servicing of Valves***

Seating of Valves which are subject to operations several times is likely to become leaky or pass the flow downstream even after closing tight. Periodical servicing will be required for valves, expansion joints, flow meters and pressure gauges. Corrosion of valves is the main problem in some areas and can cause failure of bonnet and gland bolts. Leaks from spindle rods occur and bonnet separates from the body. Stainless steel bolts can be used for replacement and the valve can be wrapped in polyethylene wrap to prevent corrosion.

##### ***(b) Manufacturers' Catalogues***

The manufacturer's catalogues may be referred and comprehensive servicing procedures should be prepared for the periodical servicing. These procedures shall contain manufacturer's name, address telephone number etc. and also the technical information furnished by the manufacturers of the equipment used in the transmission system such as sluice valves, BF valves, air valves, pressure gauges, flow meters, etc. The test certificates, inspection reports and warranty certificates of these equipment shall also be kept along with the manual.

##### ***(c) List of Spares***

A list of spares required for the transmission system shall be prepared and the spares shall be procured and kept for use. The list of probable spares to be kept in stock may include the following:

Spare check nuts and spindle rods and assorted bolts; nuts and washers for the flanged joints, gaskets for flanged joints for all sizes of sluice valves installed in the transmission system, spare manhole covers and consumables like the gland rope, grease, cotton waste, jointing material like rubber gaskets, spun yarn, pig lead and lead wool.

*(d) List of Tools*

The necessary tools equipment to properly repair and correct both the routine problems and for facilitating repairs and replacements in a Transmission system have to be identified and provided to the maintenance staff. Some of the tools for the maintenance work in a Transmission system : Key rods for operation of all sluice valves, hooks for lifting manhole covers, pipe wrench of appropriate sizes (200, 300 or 450 mm) DE spanner set, ring spanner set, screw drivers, pliers, hammers, chisels, caulking tools for lead and spun yarn, ladles and pans for melting and pouring lead joints, excavation tools such as crow bars, spades, iron baskets, buckets and de-watering pumps. In case of large diameter transmission system excavators, cranes, diesel welding sets, welding electrodes, gas cutting accessories and gas cylinders will also be required .

*(e) Maintenance of Chambers for appurtenances*

Valve chambers shall be checked to ensure that they are not damaged, nor filled up with earth or buried in pavement. Cover of valve chambers are stolen or broken up by vandalism or accidentally leading to damage to the valve itself or will lead to accidental fall into the open valve chamber; such situations have to be corrected on priority. Road improvement works require constant attention of water utility staff since the valves may be lost or at times the valve chambers in the roads have to be reconstructed to match the renewed road surface. Valve Chambers on cross country pipelines are likely to be tampered to collect water and are likely to be affected by floods and agricultural and industrial activities. Leakages at such places will affect the water quality by cross connections and hence these leaks require to be attended on priority.

#### **4.3.4 MAINTENANCE OF PIPELINES**

##### **4.3.4.1 Main Breaks**

Pipeline bursts/main breaks can occur at any time and the utility shall have a plan for attending to such events. This plan must be written down, disseminated to all concerned and the agency must always be in readiness to implement the plan immediately after the pipe break is reported. After a pipe break is located, determine which valve is to be closed to isolate the section where the break has occurred. Some important consumers may be on the transmission system and having an industrial process dependent on water supply which cannot be shut down as fast as the water supply lines are cut off and should be notified about the break. These consumers have to be informed about the probable interruption in water supply and also the estimated time of resumption of water supply.

After the closure of the valve the dewatering/mud pumps are used to drain the pipe break points. The sides of trenches have to be properly protected before the workers enter the pit. The damaged pipe is removed, and the accumulated silt is removed from inside the pipe and the damaged pipe is replaced and the line is disinfected before bringing into use. A report shall be prepared following every pipe break about the cause of such break, the resources

required for rectification and the time and cost required for repairing etc. so that the agency can follow up with measures for avoiding such breaks and also modify their plan to address such breaks in future.

#### **4.3.4.2 Deterioration of Pipes**

Pipes deteriorate on the inside because of water corrosion and erosion and on the outside because of corrosion from aggressive soil and water/moisture. Depending upon the material of the pipes these are subject to some deterioration, loss of water carrying capacity, leaks, corrosion and pitting, tuberculation, deposition of sediment and slime growth. Preventive maintenance of transmission system assures the twin objectives of preserving the bacteriological quality of water carried in the transmission mains and providing conditions for adequate flow through the pipelines. Incidentally this will prolong the effective life of the pipeline and restore its carrying capacity. Some of the main functions in the management of preventive aspects in the maintenance of pipelines are assessment, detection and prevention of wastage of water from pipelines through leaks, maintaining the capacity of pipelines, cleaning of pipelines and relining. The topic of assessment of leaks is dealt in detail in the Chapter 15 on Water Audit and Leakage Control in this manual

#### **4.3.4.3 Flushing of pipelines**

Flushing is done to clean the transmission lines by removing impurities or sediment that may be present in the pipe; this is particularly essential in the case of transmission lines carrying raw water. Routine flushing of raw water pipelines is often necessary. It is advisable that a programme for flushing is prepared and followed so that water mains are flushed before the water quality deteriorates and consumers start complaining. Since flushing is not the only solution to the water quality problems of a transmission system, proper operation of treatment process and cleaning of service reservoirs supplying water to the transmission system shall also be planned along with the flushing of distribution system. Flushing is usually done in low water demand, when the weather is favourable. Prior planning and good publicity with public will allow the flushing to proceed quickly and without confusion.

#### **4.3.4.4 Flushing and cleaning of pipelines**

Mechanical cleaning devices such as swabs and pigs are some times used if flushing does not improve the water quality. Scrapers or brushes are used in pipelines with hardened scales or extensive tuberculation. Sometimes scrapers and brushes are used before taking up lining works. The topics of cleaning of pipelines including cleaning and swabbing are dealt in Chapter 10 of Manual on Water Supply & Treatment.

#### **4.3.4.5 Cement Mortar Lining**

The present trend is to use cement mortar lined DI pipes or MS pipes so that they will not lose their carrying capacity with use and age. Still many new pipelines are proposed with unlined metal pipes and there are several existing pipelines with bare metal surface such as CI or MS. With passage of time these pipelines deteriorate and require rehabilitation. Cement mortar lining is done which stifles corrosion through its ability to develop high alkalinity. In-situ cement mortar lining of existing metal water mains has been beneficial where:

- i) Pipe carrying capacity has reduced due to tuberculation,
- ii) Water quality is affected due to release of corrosion products from the pipes to the water, and
- iii) Leaks occur through joints and pipe walls.

#### **4.3.5 LEAKAGE CONTROL**

Leakage of water in the transmission system occurs by way of leakage from pipes, joints & fittings, reservoirs & overflows of reservoirs & sumps. The objective of leakage control programme is to reduce to a minimum the time that elapses between the occurrence of a leak and its repair. The volume of water lost through each leak should be reduced by taking whatever action is technically and economically feasible to ensure that the leak is repaired as quickly as possible. To achieve this, the agency shall prescribe procedures for identifying, reporting, repairing and accounting for all visible leaks. It will be beneficial for the agency if the procedures involve the conscious and active participation of the population served by the agency apart from its own staff.

##### **4.3.5.1 Procedures for reporting Visible Leaks**

Utility has to establish procedures whereby the population residing along the transmission mains can notify the visible leaks to the agency. The agency staff can also report visible leaks found by them while carrying out other works on the water supply system. Utility has to establish procedures for prompt repair of leaks and for attending efficiently and accurately to the leaks. Critical areas where leaks often occur have to be identified and appropriate corrective measures have to be implemented.

##### **4.3.5.2 Procedures for detecting invisible Leaks**

In the case of transmission mains the leaks become visible due to the high pressures. However if it is necessary to identify the invisible leaks procedures have to be established for detecting and locating non visible leaks. Selection and procurement of equipment for detection and location of leaks must take into account the cost effectiveness and the financial capability of the agency. Description of equipment for leak detection and location and the methodology are described is given in the Chapter 15 of this manual. Management has to process the data and evaluate the work on detection and location of leaks and for dissemination of the results and initiate actions to control the overall problem of water loss.

#### **4.3.6 CHLORINE RESIDUAL TESTING**

A minimum free chlorine residual of about 0.2 mg/l at the receiving reservoir of a transmission system is often maintained to ensure that contamination is destroyed by the chlorine. Hence absence of residual chlorine could indicate potential presence of heavy contamination in the transmission system. If routine checks of the incoming water at the end of the transmission system are revealing, required chlorine residuals and any sudden absence of residual chlorine should alert the operating staff to take up prompt investigations. Immediate steps to be taken are:

- i) Re-testing of residual chlorine,
- ii) Checking chlorination equipment at the start of the transmission system,

- iii) Searching for source of contamination along the transmission system which has caused the increased chlorine demand,
- iv) Immediate rectification of source of contamination.

#### **4.3.6.1 Cross Connections**

Contaminated water through cross connections of water supply lines with sewers and drains is a problem prevailing widely. Regular survey along the alignment of transmission system has to be undertaken to identify potential areas likely to be affected by cross connections and back-flow. All field personnel should be constantly alert for situations where cross connections are likely to exist. Densely populated areas and slums without sanitation facilities located along the transmission lines are some of the locations prone for cross connections. After identifying the cross connections, remedial measures are taken up which include: providing horizontal and vertical separation between the water main and the sewer/drain, (refer to para 10.11.1 of Chapter 10 of this manual on Water Supply & Treatment).

#### **4.3.7 TELEMETRY AND SCADA SYSTEMS**

##### **Manual Monitoring**

Normally the Managers of O&M of water utilities monitor levels in service reservoirs fed by the transmission system and also monitor the flow meter readings of upstream and downstream reservoirs connected by a transmission system. The pressures of the pipeline at salient points are also monitored. Data on operation of pumps such as hours of pumping and failure of pumps and on water quality by measuring residual chlorine is also monitored. The manager usually uses the telephone line or wireless unit to gather the data, analyses the same and uses his discretion gained with experience and takes decisions to ensure that the system is operating with required efficiency. Manual collection of data and analysis may not be helpful in large undertakings if water utilities have to aim at enhanced customer service by improving water quality and service level with reduced costs. These days acquisition of such data by Telemetry and SCADA is being adopted. This Topic is discussed in Chapter 12 on Distribution system of this manual.

#### **4.3.8 RECORDS AND REPORTS**

##### **4.3.8.1 Record System**

A record system has to be developed which should be realistic and applicable to the operating problems involved in the Transmission system. Management must be clear as to why the data/information are collected, as to who will review the data and who will respond to the results of review. The most efficient way to keep records is to plan what data is essential and then prepare the formats followed by guidelines, fill the data, frequency and to send the record to for review and report. Sample records to be maintained are given below for guidance.

- i) Updated transmission system map with alignment plan and longitudinal section of the pipeline showing the invert levels and hydraulic grade lines of the pipelines and location of appurtenances, flow meters and pressure gauges,
- ii) Record of flow meter readings at upstream and downstream ends of the transmission system,

- iii) Record of water levels of the reservoirs at both upstream and downstream ends of the transmission system,
- iv) Pressure readings of the transmission system pipelines,
- v) Review of record of pressures and flows,
- vi) Identify the persistent low pressures in the transmission system,
- vii) Record on age of pipes/quality of pipes,
- viii) Identify pipelines to be replaced,
- ix) Presence of corrosive water in the system,
- x) Identify the source of leaks,
- xi) Identify the persistent leak points,
- xii) Status of bulk meters – functional,
- xiii) Identify the residual chlorine levels at the receiving and transmitting ends of the transmission system,
- xiv) Identify the bacteriological quality of the water sampled from the reservoirs linked to the transmission system,
- xv) Identify reasons for residual chlorine being absent/where bacteriological samples are unwholesome,
- xvi) Record on when the pipeline leaks were repaired or pipes changed and the cost of materials and labour cost thereof,
- xvii) Record on when the gland ropes of the valves distribution system were changed and the cost of materials and labour cost thereof,
- xviii) Record on when the spares of the valves were changed and the cost of materials and labour cost thereof,
- xix) Record on when the expansion joints were serviced and the cost of materials and labour spent for repairing the same,
- xx) Record on when the manholes on the valve chambers were changed and the cost of materials and labour cost thereof,
- xxi) Record on man-hours spent on routine operations in the transmission system in the previous year and the cost thereof,
- xxii) Record on total cost of repairs and replacements in previous year along with break up of material cost and labour cost with amount spent on outside agencies for repairs and replacements,
- xxiii) Record on when the exposed piping was last painted and the cost of materials and labour cost thereof.

#### **4.3.8.2 Reports**

With the accumulation of all essential data a report can be prepared evaluating the O&M of the facility. The report can identify the deficiencies in the system and its appurtenances and then plan future repairs to the transmission system, valves and other equipment or for replacement of defective valves or other equipment.

### 4.3.9 CHECKS TO BE CARRIED OUT IN TRANSMISSION SYSTEM

#### 4.3.9.1 Programme for carrying out checks in the transmission system

A programme has to be prepared for each zone of the transmission system which shall contain procedures for routine tasks, checks and inspections at intervals viz. Daily, weekly, quarterly semi-annually or annually. This plan shall fix responsibility, timing for action, ways and means of completing the action as to when and who should take the action and the need to take these actions. Simple checklists for use by the managerial staff can be prepared to ensure that the O&M staff have completed the tasks assigned to them.

#### 4.3.9.2 Check Lists

S. No.	Checks required/undertaken	Status	Suggested frequency of reporting
1.	Check whether the operation of valves is smooth without any abrupt stoppage during closure		
2.	Check whether closure of a valve results in complete stoppage of flow or if any flow passes the valve (passing valve)		
3.	Check for status of scouring and then proper closure of washout valves		
4.	Check for leaks through pipes		
5.	Check for leakage through valves at gland, bolts or any other place		
6.	Check for leaks at the appurtenances including expansion joints		
7.	Check for any signs of corrosion of pipelines		
8.	Check for the status of manhole covers over the chamber covers; are they corroded		
9.	Inspect for any possibilities of pollution of the transmission system		
10.	Check status of out-fall drain for scour valves and chances of contamination at scours		
11.	Assess the need for painting of the exposed piping work		
12.	Check for availability of spares for Valves, expansion joints and pipes and jointing materials		
13.	Carry out review of pressures		
14.	Carry out review of flows		
15.	Check age of pipes/C value of pipes		
16.	Check for corrosive water		
17.	Study inflows and outflows into the reservoirs linked to the transmission system		
18.	Identify source of leakage		
19.	Metering		
	Status of bulk metering		
	Review facilities for repair of meters		
20.	Availability of updated system map		



# CHAPTER 5

## WATER TREATMENT PLANT

### 5.1 INTRODUCTION

Water to be supplied for public use must be potable i.e., satisfactory for drinking purposes from the standpoint of its chemical, physical and biological characteristics. Drinking water should, preferably, be obtained from a source free from pollution. The raw water normally available from surface water sources is, however, not directly suitable for drinking purposes. The objective of water treatment is to produce safe and potable drinking water.

Some of the common treatment processes used in the past include Plain sedimentation, Slow Sand filtration, Rapid Sand filtration with Coagulation-flocculation units as essential pretreatment units. Pressure filters and Diatomaceous filters have been used though very rarely. Roughing filters are used, under certain circumstances, as pretreatment units for the conventional filters.

The treatment processes may need pretreatment like pre-chlorination and aeration prior to conventional treatment. The pretreatment processes comprising of Coagulation and Flocculation have been discussed under the main title of Rapid Sand filters in para 5.4 of this chapter. Detailed discussion on all such aspects as well as recommended unit operations, is given in the Manual on Water Supply and Treatment (1999 Edition) Ministry of Urban Development.

Figure 5.1 shows typical flow patterns of a Conventional Treatment Plant.

### 5.2 FILTRATION PLANTS

#### 5.2.1 SLOW SAND FILTER-PLANT

It may include Plain Sedimentation basins followed by the conventional Filter-Plant.

#### 5.2.2 RAPID SAND FILTER PLANT

It can be briefly divided into two main components:

1. The Pretreatment Works

These include the (1) Coagulation- Flocculation Units with adequate chemical dosing and rapid mixing facilities, and (2) Sedimentation Units to handle the effluent from the Coagulation-flocculation units.

2. Filter units.

#### 5.2.3 OTHER CATEGORIES

There are a number of other categories of filtration plants but not of common use. Of these Pressure filters are used for small treatment plants or industries. Roughing filters may be used

to reduce load on the treatment plants. Small streams of water in the catchment areas may carry large particles and floating matter. Introduction of the roughing filters will ensure entrapping of such undesirable material prior to the storage structures of the treatment units.

## **5.3 SLOW SAND FILTRATION**

### **5.3.1 PROCESS**

Slow Sand filtration was the first type of porous media filtration used in water treatment. This process is known for its simplicity and efficiency.

During the initial operational period of slow sand filters, the separation of organic matter and other solids generates a layer of biological matter on the surface of the filter media.

### **5.3.2 FILTER CONTROLS**

The pipe work, valves and devices used to regulate the operation of a filter should be properly planned. Adequate means must be available to:

- Deliver raw water into the supernatant reservoir,
- Remove scum and floating matter,
- Drain off supernatant water prior to filter cleaning,
- Lower water level in the bed,
- Control the rate of filtration and adjust it as bed resistance increases,
- Ensure that negative pressures cannot occur within the bed (the weir is the device usually used for this purpose),
- Convey filtered water to the filter water tank,
- Run filtered water to waste or to the inlet side of other filters during the ripening process,
- Fill sand bed from below with filtered water (from other filters) after cleaning.

### **5.3.3 OPERATION**

The operation of the filter is determined by the filtration rate, which is controlled at the effluent outlet. Inflow, which may be by gravity from a constant level reservoir, or by a pump, is adjusted so that the head of water in the supernatant reservoir remains constant at all times. Excessive raw water delivery will cause overflow through the scum outlets, while a reduction in the rate of inflow will cause the level in the supernatant water reservoir to drop; either condition should alert the operator to a defect in the mechanism controlling the supply of raw water.

The filtration rate is controlled by a single regulating valve on the effluent delivery. At the beginning of the filter run this will be partially closed, the additional resistance thereby provided being equal to that which will later build up within the filter bed. Day by day as the run continues this valve must be checked and opened fractionally to compensate for the choking of the filter and to maintain a constant filtration rate. In the early part of the filter run the daily build up of resistance will be almost imperceptible, calling for very little valve adjustment, but towards the end of the filter run the resistance will increase more rapidly,

necessitating a more positive opening of the valve and signalling the impending need for filter cleaning.

To enable the operator to regulate the valve precisely it is necessary to have some form of measuring device on the effluent outlet.

#### **5.3.4 CONTROL OF ALGAL GROWTH**

Excessive algal growth may cause trouble in the operation of open filters. Pretreatment by microstrainers is one method of removing the algae contained in the raw water. For more details please refer to para 5.8 of this chapter.

#### **5.3.5 DISSOLVED OXYGEN**

If the dissolved oxygen content of the raw water drops below the potential oxygen demand, anaerobic conditions may develop within the bed. To some extent a reasonable growth of algae in the supernatant reservoir oxygenates the supernatant water. Where the composition of raw water or climate does not favour the growth of algae, or where chemical dosing or some other device has been used to remove or exclude them, it may be necessary to use other expedients to increase the dissolved oxygen content, such as aeration of the incoming raw water.

Ventilators are provided as an integral part of the filter bed. It should be ensured that these function properly.

#### **5.3.6 WATER QUALITY**

Samples of raw and treated water will be taken at regular intervals for analysis. In a large waterworks with its own laboratory, sampling will almost certainly be carried out daily, since the effluent analysis constitutes the only certain check that the filter is operating satisfactorily and the raw water analysis provides what is possibly the only indication of a change in quality that might adversely affect the efficiency of treatment. In case of small plants with no laboratory facilities, an attempt should be made to conduct sampling on regular basis. Field testing equipment may be used to measure water quality. For more details please refer to Chapter 9 of this manual.

#### **5.3.7 FILTER CLEANING**

While the filter is in operation, a stage comes when the bed resistance increases so much that the regulating valve has to be fully opened and it is the right time to plan the cleaning of the filter bed since any further resistance is bound to reduce the filtration rate. Resistance accelerates rapidly as the time for cleaning approaches. Indicators may be installed showing the inlet and outlet heads, from which the head loss can be regularly checked; this gives a clear picture of the progress of choking and the imminence of the end of the run. Without any measurement of the head loss the only true indicator of build up of resistance is the degree of opening of the regulating valve, though the experienced operator may be able to recognize preliminary visual warnings in the condition of the filter bed surface. A slight deterioration in the effluent quality may be a reason for the need for cleaning.

To clean a filter bed, the raw water inlet valve is first closed, allowing the filter to discharge to the clear water well as long as possible (usually overnight). As the head in the supernatant reservoir drops, the rate of filtration rapidly decreases, and although the water above the bed

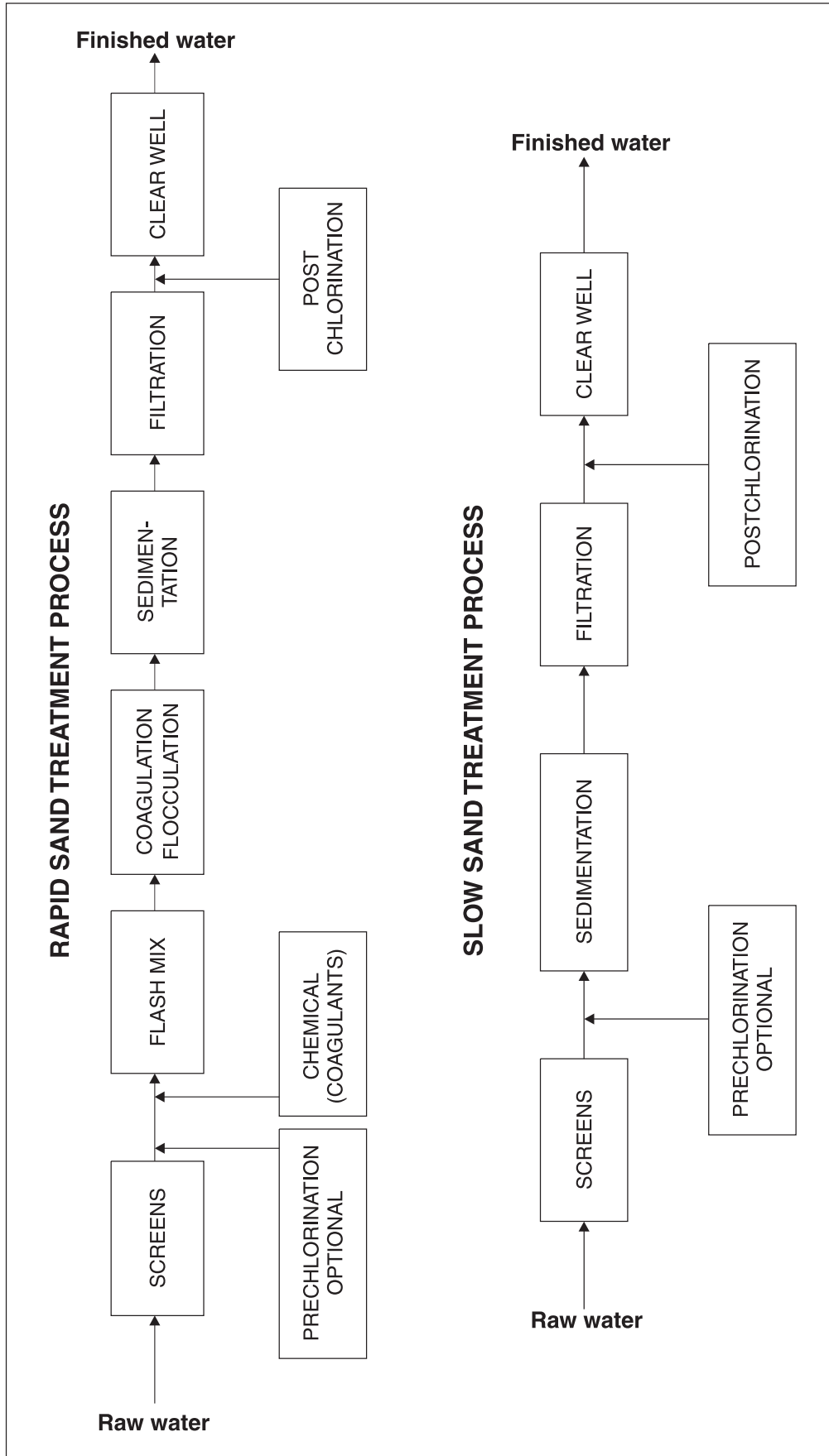


FIG. 5.1: CONVENTIONAL FILTRATION PROCESSES

would continue to fall until level with the weir outlet, it would take a very long time to do so. Consequently, after a few hours, the effluent delivery to the clear water well is closed, and the supernatant water outlet is run to waste through the drain valve provided.

When the supernatant water has been drained off (leaving the water level at the surface of the bed) it is necessary to lower the water within the bed still further, until it is some 100 mm or more below the surface. This is done by opening the waste valve on the effluent outlet pipe. As soon as the Schmutzdecke is dry enough to handle, cleaning should start. If the filter bed is left too long at this stage it is likely to attract scavenging birds that will not only pollute the filter surface but also disturb the sand to a greater depth than will be removed by scraping.

The cleaning of the bed may be carried out by hand or with mechanical equipment. Working as rapidly as possible, they should strip off the Schmutzdecke and the surface sand adhering to it, stack it into ridges or heaps, and then remove the waste material by barrow, hand cart, basket, conveyor belt or other device.

After removal of the scrapings the bed should be smoothed to level surface. The quicker the filter bed is cleaned the less will be the disturbance of the bacteria and shorter the period of re-ripening. Provided they have not been completely dried out, the microorganisms immediately below the surface will quickly recover from having been drained and will adjust themselves to their position relative to the new bed level. In this event a day or two will be sufficient for re-ripening.

Before the filter box is refilled, the exposed walls of the supernatant water reservoir should be well swabbed down to discourage the growth of adhering slimes and algae, and the height of the supernatant water drain and of the outlet weir must be adjusted to suit the new bed level. The water level in the bed is then raised by charging from below with treated water from the clear water well or from one of the other filters. As soon as the level has risen sufficiently above the bed surface to provide a cushion, the raw water inlet is gradually turned on. The effluent is run to waste until analysis shows that it satisfies the normal quality standards. The regulating valves on the effluent line will be substantially closed to compensate for the reduced resistance of the cleaned bed, and the filter will then be ready to start a new run.

During the cleaning operations precautions must be taken to minimize the chances of pollution of the filter bed surface by the labourers themselves. Such measures as the provision of boots that can be disinfected in a tray of bleaching solution should be taken. Hygienic personal behaviour must be rigidly imposed, and no labourers with symptoms that might be attributable to water borne or parasitic diseases should be permitted to come into direct or indirect contact with the filter medium.

### **5.3.8 RESANDING**

After several years' operation and, say, twenty or thirty scrapings the depth of filtering material will have dropped to its minimum designed level (usually 0.5 to 0.8 m above the supporting gravel, according to the grain size of the medium). In the original construction, a marker, such as a concrete block or a step in the filter box wall, is sometimes set in the structure to serve as an indication that this level has been reached and that resanding has become due.

During the long period of the filter use/run some of the raw water impurities and some products of biochemical degradation will have been carried into the sand-bed to a depth of some 0.3 to 0.5 m according to the grain size of the sand. To prevent cumulative fouling and increased resistance this depth of sand should be removed before resanding takes place, but it is neither necessary nor desirable that it should be discarded. Instead it is moved to one side, the new sand is added, and the old sand replaced on the top of the new, thus retaining much of the active material to enable the resanded filter to become operational with the minimum re-ripening.

This process (of replacing old sand on the top of the new) known as “throwing over” is carried out in strips. Excavation is carried out on each strip in turn, making sure that it is not dug so deeply as to disturb the supporting gravel layers below. The removed material from the first strip is stacked to one side in a long ridge, the excavated trench is filled with new sand, and the adjacent strip is excavated, throwing the removed material from the second trench to cover the new sand in the first. The operation is illustrated in Fig. 5.2. When the whole of the bed has been resanded, the material in the ridge from the first trench is used to cover the new sand in the last strip.

In areas where sand is expensive or difficult to obtain, the surface scrapings may be washed, stored and used for resanding at some future date. These scrapings must be washed as soon as they are taken from the filter, otherwise, being full of organic matter, the material will continue to consume oxygen, quickly become anaerobic, and putrefy, yielding taste and odour producing substances that are virtually impossible to remove during any washing process.

Sand Washing Machines should be provided for the bigger plants. Wherever provided, these should be operated regularly to prevent accumulation of sand and also to keep the machine in working condition.

### **5.3.9 RECORD KEEPING**

The following are the basic records that must be maintained:

1. The date of each cleaning (commencement)
2. The date and hour of return to full service (end of re-ripening period)
3. Raw and filtered water levels (measured each day at the same hour) and daily loss of head.
4. The filtration rate, the hourly variations, if any.
5. The quality of raw water in physical terms (turbidity, colour) and bacteriological terms (total bacterial count, E.Coli.) determined by samples taken each day at the same hour.
6. The same quality factors of the filtered water.
7. Any incidents occurring e.g. plankton development, rising Schmutzdecke, and unusual weather conditions.

### **5.3.10 AUGMENTATION OF THE CAPACITY OF AN EXISTING PLANT**

Some of the existing slow sand filtration plants need augmentation. There is a tendency to abandon the old plants and substitute the same with Rapid sand Filtration plants. It is

suggested that wherever possible the old Slow sand Filtration plants may be retained on account of the following reasons:

- i) Slow sand filter is less likely to go wrong under inexperienced operation.
- ii) It does not require skilled attendance.
- iii) Head consumed is less.
- iv) It provides greater reliability of the removal of bacteria.
- v) Operating costs may be less.

It is, however, adapted to waters low in colour, turbidity and bacterial count. Under such circumstances, provision of a roughing filter as a pretreatment unit gives good results.

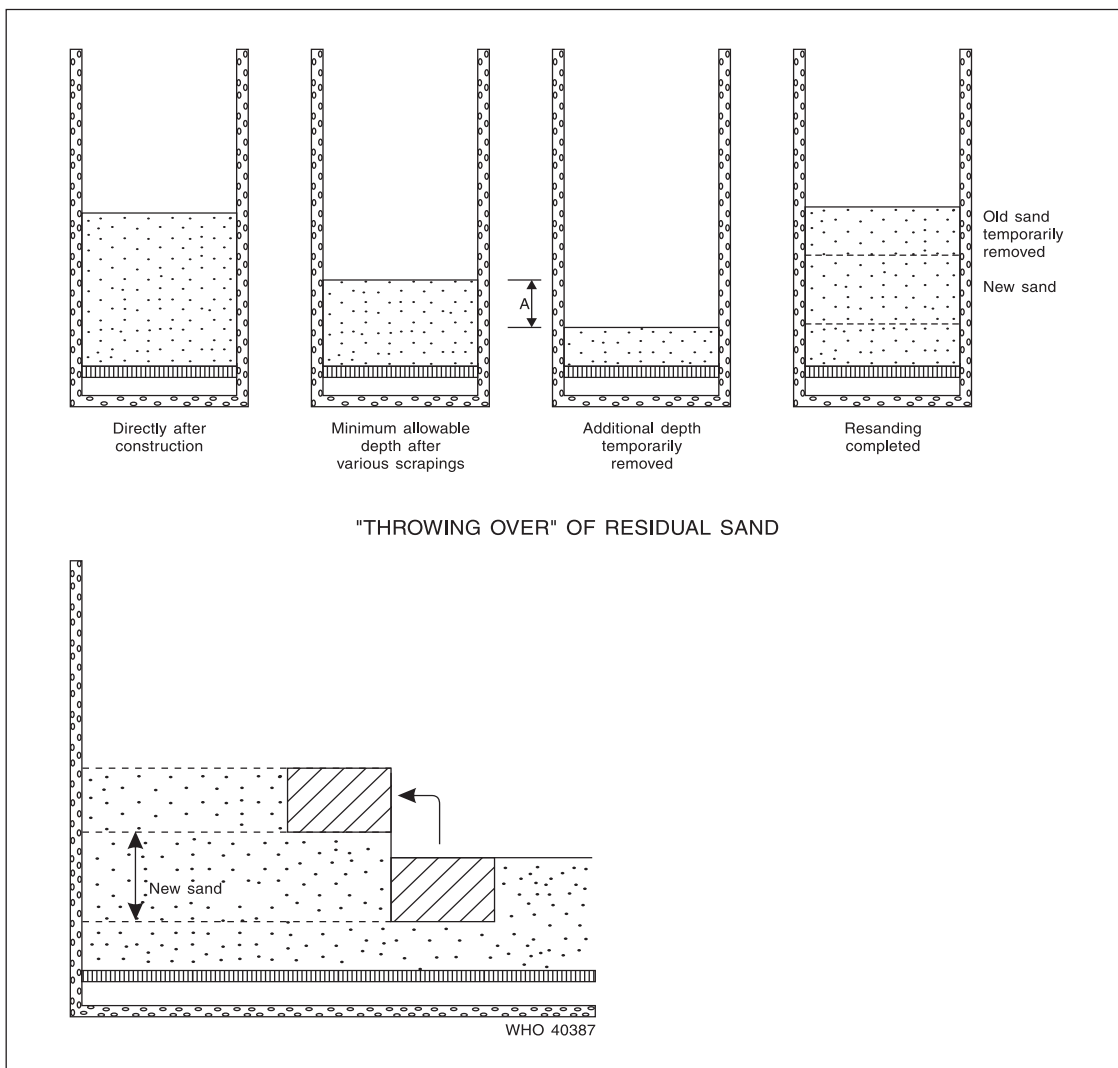


FIG. 5.2: RESANDING OF A SLOW SAND FILTER

## 5.4 RAPID SAND FILTRATION PLANTS

The pretreatment units which form essential parts of a Rapid sand filtration unit include (a) Coagulation and flocculation with rapid mixing facilities and (b) Sedimentation units.

## 5.4.1 COAGULATION AND FLOCCULATION

### 5.4.1.1 Purpose

The purpose of coagulation and flocculation is to remove particulate impurities, especially non-settleable solids (particularly colloids) and colour from the water being treated. Non-settleable particles in water are removed by the use of coagulating chemicals.

### 5.4.1.2 Chemical Coagulants Commonly used in Treatment Process

TABLE 5.1: CHEMICAL COAGULANTS

Name	Formula	Coagulant Primary/Aid
Ferric Alum	$\text{Fe}_2(\text{SO}_4)_3 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$	Primary
Poly Aluminium Chloride	$\{\text{Al}_2(\text{OH})_{2.7} \text{Cl}_{3.3}\}_{15}$	Primary
Ferric Chloride	$\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$	Primary
Calcium Hydroxide	$\text{Ca}(\text{OH})_2$	Primary/Aid
Calcium Oxide	CaO	Primary/Aid

The most commonly used coagulant is ferric alum. However, Poly Aluminium Chloride (PAC) is also used as a coagulant. The advantages of PAC are i) it gets properly dispersed, ii) it does not have any insoluble residue, iii) it does not affect the settling tanks, iv) it is more effective than alum v) it requires less space (may be about 50%). The disadvantage of PAC is that it is less effective in removal of colour.

### 5.4.1.3 Selection of Coagulants

Coagulation is a physical and chemical reaction occurring between the alkalinity of the water and the coagulant added to the water, which results in the formation of insoluble flocs.

The most important consideration is the selection of the proper type and amount of coagulant chemical to be added to the water to be treated.

Overdosing as well as underdosing of coagulants may lead to reduced solids removal efficiency. This condition may be corrected by carefully performing Jar tests and verifying process performance after making any change in the process of the coagulation process.

### 5.4.1.4 Jar Test

The jar test has been and is still the most widely used method employed to evaluate the coagulation process and to aid the plant operator in optimizing the coagulation, flocculation and clarification processes.

From the turbidity values of the settled water, settling velocity distribution curves can be drawn. These curves have been found to correlate well with the plant operating data and yield useful information in evaluating pretreatment, such as optimizing of velocity gradient and agitation and flocculation, pH, coagulation dosage and coagulant solution strength. Such curves cannot be generalized and are relevant to the plant for which the data have been collected through the Jar tests.

Typical Jar test Data sheet is given in Table 5.2.



In addition, the turbidity, colour and alkalinity of the raw and treated water should be measured for evaluation of the treatment.

**TABLE 5.2: JAR TEST DATA SHEET**

Date & Time	Flocculation period with RPM	Settling period	Jar no.	pH	Turbidity	Colour	Alkalinity CaCO <sub>3</sub>	Time for first floc. Formation	Remarks
			Control						
			1						
			2						
			3						
			4						
			5						
			6						

#### 5.4.1.5 Mixing

The main requirement of the mix is that all the coagulant be rapidly mixed with all the water instantly so as to achieve complete homogenization of a coagulant chemical in the stream to be treated. The reason is that the chemical reaction is extremely rapid, practically instantaneous, especially in waters with high alkalinity. Since this is not physically possible although desirable, it is important to approximate as nearly as possible to instant and complete dispersion.

To accomplish the mixing of the chemicals with the water to be treated, several methods can be used.

- Hydraulic mixing
- Mechanical mixing
- Diffusers and grid system
- Pumped blenders.

Mixing of the chemical coagulant can be satisfactorily accomplished in a special coagulant tank with mixing devices. Mixing may also occur in the influent channel or a pipeline to the flocculation basin if the flow velocity is high enough to produce the necessary turbulence. The shape of the basin is part of the flash mix design.

#### 5.4.1.6 Flocculation Basin – Operation

The objective of a flocculation basin is to produce a settled water of low turbidity which in turn will allow reasonably long filter runs. Following points should be considered during the operation of the flocculation basins.

### *Short Circuiting*

An important factor that determines the functioning of a flocculator is the short circuiting. In such a basin, against a predetermined 30 minutes agitation, a large portion may get only 10 minutes while another sizeable amount may get 60 minutes. Under such circumstances very inferior settled water is produced.

Short circuiting in flocculation basins is characterized by currents which move rapidly through and continue into the settling tanks. The floc removal problem is compounded then with flocculation which is incomplete and currents introduced into the settling process which further inhibit removal. Properly operated entrance, curtain baffles and exit weirs and launders can significantly improve settling.

The flocculators may be circular, square or rectangular. The best flocculation is usually achieved in a compartmentalized basin. The compartments (most often three) are separated by baffles to prevent short circuiting of the water being treated. The turbulence can be reduced gradually by reducing the speed of the mixers in each succeeding tank or by reducing the surface area of the paddles. This is called tapered-energy mixing. The reason for reducing the speed of the stirrers is to prevent breaking apart the larger floc particles, which have already formed. If the floc is broken up nothing is accomplished and the filter gets overloaded.

### *Dosing of the coagulant at a spot of maximum turbulence*

Rapid mix of coagulant at a spot of maximum turbulence, followed by tapered flocculation in three compartmentalized units allows a maximum of mixing, (reduced short circuiting) followed by a period of agglomeration intended to build larger fast settling floc particles. The velocity gradient is gradually reduced from the first to the third unit. The concepts of velocity gradient and tapered flocculation have been discussed in the Manual of Water supply and Treatment (1999 edition).

#### **5.4.1.7 Interaction with Sedimentation and Filtration**

The processes of coagulation and flocculation are required to precondition or prepare non-settleable particles present in the raw water for removal by sedimentation and filtration. Small particles (particularly colloids), without proper coagulation and flocculation are too light to settle out and will not be large enough to be trapped during filtration process.

Since the purpose of coagulation – flocculation is to produce particle removal, the effectiveness of the sedimentation and filtration processes, as well as overall performance, depends upon successful coagulation - flocculation.

#### **5.4.1.8 Coagulation - Flocculation Process Actions**

Typical jobs performed by an operator in the normal operation of the coagulation flocculation process include the following:

- Monitor process performance.
- Evaluate water quality conditions (raw and treated water).
- Check and adjust process controls and equipment, and
- Visually inspect facilities.

Fig. 5.3 shows the overall plan view of the coagulation-flocculation process of a typical plant.

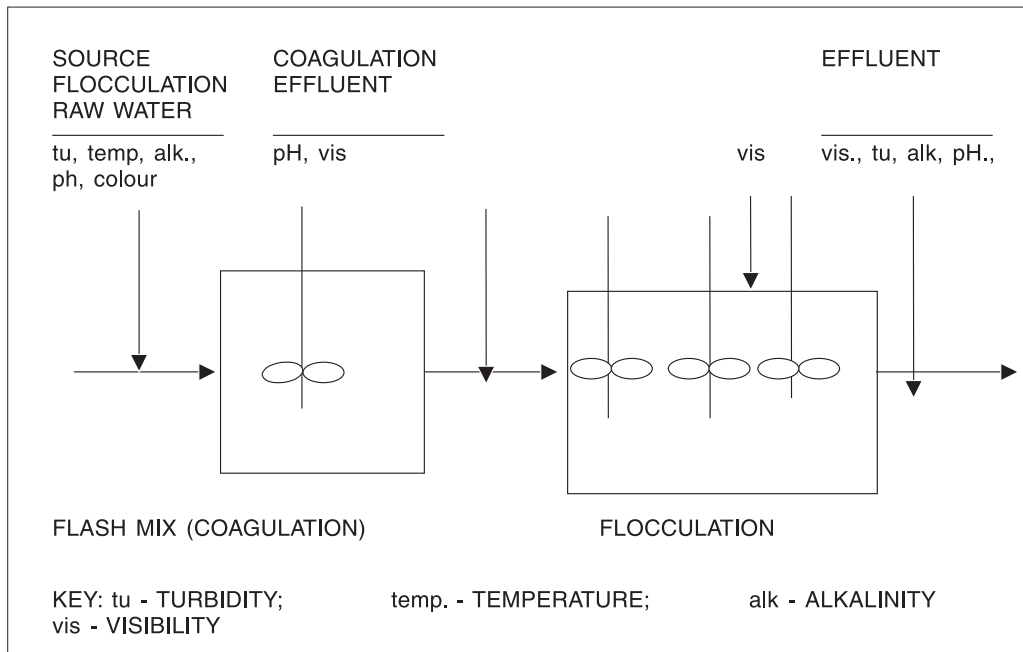


FIG. 5.3: COAGULATION-FLOCCULATION PROCESS MONITORING GUIDELINES

#### 5.4.1.9 Examination of the Floc

Examine the water samples at several points enroute the flow line of the water. Look at the clarity of the water between the flocs and study the shape and size of the floc.

- Observe the floc as it enters the flocculation basins. The floc should be small and well dispersed throughout the flow.
- Tiny alum floc may be an indication that the chemical dose is too low. A 'popcorn flake' is a desirable floc. If the water has a milky appearance or a bluish tint, the alum dose is probably too high.
- As the floc moves through the flocculation basins the size of the floc should be increasing. If the size of the floc increases and then later starts to break up, the mixing intensity of the downstream flocculator may be too high. Try reducing the speed of these flocculators or increasing the coagulant dosage.
- Examine the settlement of the floc in the sedimentation basin. If a lot of floc is observed flowing over the laundering weirs the floc is too light for the detention time. By increasing the chemical dose or adding a coagulant aid such as a polymer, a heavier, larger floc may be produced. The appearance of the fine floc particles washing over the effluent weir could be an indication of too much alum and the dose should be reduced. For precise evaluation you should make only one change at a time and evaluate the results.

Table 5.3 is a summary of coagulation-flocculation process problems; how to identify the causes of these problems and also how to go to correct the problems.

#### 5.4.1.10 Record keeping

Records of the following items should be maintained:

- Source water quality (pH, turbidity, temperature, alkalinity, chlorine demand and colour).
- Process water quality (pH, turbidity, and alkalinity).
- Process production inventories (chemicals used, chemical feed rates, amount of water processed, and amount of chemicals in storage).
- Process equipment performance (types of equipment in operation, maintenance procedures performed, equipment calibration and adjustments).
- A plot of key process variables should be maintained. A plot of source water turbidity vs. coagulant dosage should be maintained. If other process variables such as alkalinity or pH vary significantly, these should also be plotted.

**TABLE 5.3: COAGULATION-FLOCCULATION PROCESS TROUBLESHOOTING**

<b>Source Water Quality Changes</b>	<b>Operator Actions</b>	<b>Possible Process Changes</b>
Turbidity Temperature	<ol style="list-style-type: none"> <li>1. Perform necessary analyses to determine extent of change.</li> <li>2. Evaluate overall process performance.</li> <li>3. Perform jar tests.</li> <li>4. Make appropriate process changes (see right-hand column- Possible Process Changes).</li> <li>5. Increase frequency of process monitoring.</li> </ol>	<ol style="list-style-type: none"> <li>1. Adjust coagulant dosage.</li> <li>2. Adjust flash mixer/flocculator mixing intensity.</li> <li>3. Add coagulant aid or filter aid.</li> <li>4. Adjust alkalinity or pH.</li> <li>5. Change Coagulant(s)</li> </ol>
<b>Coagulation Process Effluent Quality Changes</b>	<b>Operator Actions</b>	<b>Possible Process Changes</b>
Turbidity Alkalinity pH	<ol style="list-style-type: none"> <li>1. Evaluate source water quality.</li> <li>2. Perform jar tests.</li> <li>3. Verify process performance:               <ol style="list-style-type: none"> <li>(a) Coagulant feed rate(s),</li> <li>(b) Flash mixer operation.</li> </ol> </li> <li>4. Make appropriate process changes.</li> </ol>	<ol style="list-style-type: none"> <li>1. Adjust coagulant dosage.</li> <li>2. Adjust flash mixer intensity (if possible).</li> <li>3. Adjust alkalinity or pH.</li> <li>4. Change Coagulant(s).</li> </ol>
<b>Flocculation Basin Floc Quality Changes</b>	<b>Operator Actions</b>	<b>Possible Process Changes</b>
Floc formation	<ol style="list-style-type: none"> <li>1. Observe floc condition in basin:               <ol style="list-style-type: none"> <li>(a) Dispersion,</li> <li>(b) Size, and</li> <li>(c) Floc strength (breakup).</li> </ol> </li> <li>2. Evaluate overall process performance.</li> <li>3. Perform jar tests               <ol style="list-style-type: none"> <li>(a) Evaluate floc size, settling rate and strength.</li> <li>(b) Evaluate quality of supernatant; clarity (turbidity), pH, and color.</li> </ol> </li> <li>4. Make appropriate process changes.</li> </ol>	<ol style="list-style-type: none"> <li>1. Adjust coagulant dosage.</li> <li>2. Adjust flash mixer/ flocculator mixing intensity.</li> <li>3. Add coagulant aid.</li> <li>4. Adjust alkalinity or pH.</li> <li>5. Change Coagulant(s).</li> </ol>

Note: All major problems should be reported to the authorities and response duly followed up.

#### **5.4.1.11 Safety Considerations**

In the coagulation-flocculation processes, the operator will be exposed to a number of hazards such as:

- Electrical equipment,
- Rotating mechanical equipment,
- Water treatment chemicals,
- Laboratory reagents (chemicals),
- Slippery surfaces caused by certain chemicals
- Flooding.

Confined spaces and underground structures such as valve or pump vaults (toxic and explosives gases, insufficient oxygen).

Strict and constant attention must be given to safety procedures. The operator must be familiar with general first aid practices such as mouth-to-mouth resuscitation, treatment of common physical injuries, and first aid for chemical exposure (chlorine).

For more details, a reference may be made to "Safety Practices" in Chapter 19.

#### **5.4.1.12 Startup and Shutdown Procedures**

##### *(a) Conditions requiring Implementation of Startup and Shutdown Procedures*

This is not a routine operating procedure in most of the plants. These procedures generally happen when the plant is shut down for maintenance. In some rare instances, shut down may be required due to a major equipment failure.

##### *(b) Startup Procedures*

1. Check the condition of all mechanical equipment for proper lubrication and operational status.
2. Make sure all chemical feeders are ready. There should be plenty of chemicals available in the tanks and ready to be fed to the raw water.
3. Collect a sample of raw water and immediately run a jar test using fresh chemicals from the supply of chemicals to the feeders.
4. Determine the settings for the chemical feeders and set the feed rates on the equipment.
5. Open the inlet gate or valve to start the raw water flowing.
6. Immediately start the selected chemical feed systems.  
Open valves to start feeding coagulant chemicals and dilution make-up water.  
Start chemical feeders.  
Adjust chemical feeders as necessary.
7. Turn on the flash mixer at the appropriate time. You may have to wait until the tank or channel is full before turning on the flash mixer. Follow the manufacturers instructions.
8. Start the sample pumps as soon as there is water at each sampling location. Allow sufficient flushing time before collecting any samples.

9. Start the flocculators as soon as the first basin is full of water.
10. Inspect mixing chamber and flocculation basin. Observe formation of floc and make necessary changes.
11. Remove any debris floating on the water surface.
12. Perform water quality analysis and make process adjustments as necessary.
13. Calibrate chemical feeders.

Note: Do not allow any untreated water to flow through the plant.

**(c) Shut down Procedures**

1. Close raw water gate to flash-mix chamber or channel.
2. Shut down the chemical feed systems.  
Turn off chemical feeders.  
Shut off appropriate valves.  
Flush or clean chemical feed lines if necessary.
3. Shut down flash mixer and flocculators as water leaves each process.
4. Shut down sample pumps before water leaves sampling location.
5. Waste any water that has not been properly treated.
6. Lock out and tag appropriate electrical switches.
7. Dewater basins if necessary. Waste any water that has not been properly treated.

Note: Do not dewater below-ground basins without checking groundwater levels.

Close basin isolation gates or install stop-logs.

Open basin drain valves

Be careful that the basin may float or collapse depending on ground water, soil or other conditions.

Good records of actions taken during start/shutdown operations will assist the operator in conducting future shutdowns.

**5.4.1.13 Laboratory Tests**

Process control water quality indicators of importance in the operation of flocculation process include turbidity, alkalinity, chlorine demand, colour, pH, temperature, odour and appearance.

**5.4.2 SEDIMENTATION**

**5.4.2.1 Sedimentation Basins**

The Basin can be divided into four zones.

Inlet zone

Settling zone

Sludge zone

Outlet zone

For more details a reference may be made to the Manual on "Water Supply and Treatment" published by Ministry of Urban Development. (1999 edition).

### **5.4.2.2 Basin Types**

The basins may be of the following types:

Rectangular basins.

Circular and square basins.

High Rate Settlers (Tube Settlers).

Solid Contact Units (Up-flow solid-contact clarification and up-flow sludge blanket clarification).

### **5.4.2.3 Sludge Handling**

#### *(a) Sludge characteristics*

Water treatment sludges are typically alum sludges, with solid concentrations varying from 0.25 to 10% when removed from a basin. In gravity flow sludge removal systems, the solid concentration should be limited to about 3%. If the sludges are to be pumped, solids concentrations as high as 10% can be readily transported.

In horizontal flow sedimentation basins preceded by coagulation and flocculation, over 50% of the floc will settle out in the first third of the basin length. Operationally, this must be considered when establishing the frequency of the operation of sludge removal equipment.

#### *(b) Sludge Removal Systems*

Sludge which accumulates on the bottom of the sedimentation basins must be removed periodically for the following reasons:

- i) To prevent interference with the settling process (such as resuspension of solids due to scouring).
- ii) To prevent the sludge from becoming septic or providing an environment for the growth of microorganisms that create taste and odour problems.
- iii) To prevent excessive reduction in the cross sectional area of the basin (reduction of detention time).

In large-scale plants, sludge is normally removed on an intermittent basis with the aid of mechanical sludge removal equipment. However, in smaller plants with low solid loading, manual sludge removal may be more cost effective.

In manually cleaned basins, the sludge is allowed to accumulate until it reduces settled water quality. High levels of sludge reduce the detention time and floc carries over to the filters. The basin is then dewatered (drained), most of the sludge is removed by stationary or portable pumps, and the remaining sludge is removed with squeegees and hoses. Basin floors are usually sloped towards a drain to help sludge removal. The frequency of shutdown for cleaning will vary from several months to a year or more, depending on source water quality (amount of suspended matter in the water).

In larger plants, a variety of mechanical devices can be used to remove sludge including

Mechanical rakes.

Drag-chain and flights.

Travelling bridge.

Circular or square basins are usually equipped with rotating sludge rakes. Basin floors are sloped towards the centre and the sludge rakes progressively push the sludge toward a centre outlet. In rectangular basins, the simplest sludge removal mechanism is the chain and flight system.

#### **5.4.2.4 Interaction with other Treatment Processes**

The purpose of sedimentation process is to remove suspended particles so as to reduce load on Filters. If adequate detention time and basin surface area are provided in the sedimentation basins, solids removal efficiencies greater than 95% can be achieved. However, high sedimentation basin removal efficiencies may not always be the most cost effective way to remove suspended solids.

In low turbidity source waters (less than about 10 NTU) effective coagulation, flocculation and filtration may produce satisfactory filtered water without the need for sedimentation. In this case, coagulation-flocculation process is operated to produce a highly filterable pinpoint, which does not readily settle due to its small size; instead the pinpoint is removed by the filters.

There is, however, a practical limitation in applying this concept to higher turbidity conditions. If the filters become overloaded with suspended solids, they will quickly clog and need frequent back washing. This can limit plant production and cause degradation in filtered water quality.

Thus the sedimentation process should be operated from the standpoint of overall plant efficiency. If the source water turbidity is only 3 mg/l, and the jar tests indicate that 0.5 mg/l of coagulant is the most effective dosage, then you cannot expect the sedimentation process to remove a significant fraction of the suspended solids. On the other hand, source water turbidities in excess of 50 mg/l will probably require a high coagulant dosage for efficient solids removal. In this case, the majority of the suspended particles and alum floc should be removed in the sedimentation basin.

#### **5.4.2.5 Operating Procedures**

From a water quality standpoint, filter effluent turbidity is a good indication of overall process performance. However one must monitor the performance of each of the individual water treatment processes, including sedimentation, in order to anticipate quality or performance changes. Normal operating conditions are considered to be conditions within the operating ranges of your plant, while abnormal conditions are unusual or difficult to handle conditions. In normal operation of the sedimentation process one must monitor.

- Turbidity of the water entering and leaving the sedimentation basin and temperature of the entering water. Turbidity of the entering water indicates the floc or solids loading on the sedimentation process. Turbidity of the water leaving the basin reveals the effectiveness or efficiency of the sedimentation process. Low levels of turbidity are desirable to minimize the floc loading on the filter.
- Temperature of the water entering the sedimentation basin is important. As the water becomes colder, the particles will settle more slowly. To compensate for this change, you should perform jar tests and adjust the coagulant dosage to produce a heavier and thus a settling floc. Another possibility is to enforce longer detention times when water demand decreases.



- Visual checks of the sedimentation process should include observation of floc settling characteristics, distribution of floc at the basin inlet and clarity of settled water spilling over the launder weirs. An uneven distribution of floc, or poorly settling floc may indicate that a raw water quality change has occurred or that the operational problems may develop.

#### **5.4.2.6 Process Actions**

In rectangular and circular sedimentation basins, it is generally possible to make a judgment about the performance of the sedimentation process by observing how far the flocs are visible beyond the basin inlet. When sedimentation is working well, the floc will only be visible for short distance. When the sedimentation is poor, the floc will be visible for a long distance beyond the inlet.

In up-flow or solid-contact clarifiers, the depth of the sludge blanket and the density of the blanket are useful monitoring tools. If the sludge blanket is of normal density (measured as milligrams of solids per litre of water) but is very close to the surface, more sludge should be wasted. If the blanket is of unusually light density, the coagulation-flocculation process (chemical dosage) must be adjusted to improve performance.

With any of the sedimentation processes, it is useful to observe the quality of the effluent as it passes over the launder weir. Flocs coming over at the ends of the basin are indicative of density currents, short circuiting, sludge blankets that are too deep or high flows. The clarity of the effluent is also a reliable indicator of coagulation-flocculation efficiency.

Process equipment should be checked regularly to assure adequate performance. Proper operation of sludge removal equipment should be verified each time the equipment is operated, since sludge removal discharge piping systems are subject to clogging. Free flowing sludge can be readily observed if sight glasses are incorporated in the sludge discharge piping . Otherwise, the outlet of the sludge line should be observed during sludge pumping. Frequent clogging of sludge pipe requires increasing frequency of sludge removal equipment and this can be diagnosed by performing sludge solids volume analysis in the laboratory.

A summary of routine sedimentation process actions is given in Table 5.4

Table 5.5 gives a summary of sedimentation process problems and remedial measures.

#### **5.4.2.7 Record Keeping**

Maintain daily operations log of process performance and water quality characteristics and keep the following records:

1. Influent and effluent turbidity and influent temperature.
2. Process production inventory (amount of water processed and volume of sludge produced).
3. Process equipment performance (type of equipment in operation, maintenance procedures performed and equipment calibration).

**TABLE 5.4: SUMMARY OF ROUTINE SEDIMENTATION PROCESS ACTIONS**

<b>1. Monitor Process Performance and Evaluate Water Quality Conditions</b>	<b>Location</b>	<b>Frequency</b>	<b>Possible Operator Actions</b>
Turbidity	Influent/ Effluent	At least once every 8-hour shift	<ol style="list-style-type: none"> <li>Increase sampling frequency when process water quality is variable.</li> <li>Perform jar tests.</li> <li>Make necessary process changes:                             <ol style="list-style-type: none"> <li>Change coagulant dosage.</li> <li>Adjust flash mixer/flocculator mixing intensity.</li> <li>Change frequency of sludge removal.</li> <li>Change coagulant</li> </ol> </li> </ol>
Temperature	Influent	Occasionally	
<b>2. Make Visual Observations</b>			<b>Possible Operator Actions</b>
Floc settling characteristics	First half of basin Inlet	At least once per 8-hour shift	<ol style="list-style-type: none"> <li>Perform jar tests.</li> <li>Make necessary process changes:                             <ol style="list-style-type: none"> <li>Change coagulant dosage.</li> <li>Adjust flash mixer/flocculator mixing intensity.</li> <li>Change frequency of sludge removal.</li> <li>Change coagulant</li> </ol> </li> </ol>
Floc distribution		At least once per 8-hour shift	
Turbidity (clarity) of settled water	Launders of settled water conduit	At least once per 8-hour shift Note-Depends on size of plant	
<b>3. Check Sludge Removal Equipment</b>			<b>Possible Operator Actions</b>
Noise, Vibration, Leakage, Overheating	Various	Once per 8-hour shift	<ol style="list-style-type: none"> <li>Correct minor problems.</li> <li>Notify others of major problems.</li> </ol>
<b>4. Operate Sludge Removal Equipment</b>			<b>Possible Operator Actions</b>
Perform normal operations sequence	Sed. Basin	Depends on process conditions (may vary from once per day to several days or more)	<ol style="list-style-type: none"> <li>Change frequency of operation:                             <ol style="list-style-type: none"> <li>If sludge is too watery, decrease frequency of operation and/or pumping rate.</li> <li>If sludge is too dense, bulks, or clogs discharge lines, increase frequency of operation and/or pumping rate.</li> <li>If sludge is septic, increase frequency of operation and/or pumping rate.</li> </ol> </li> </ol>
Observe conditions of sludge being removed			
<b>5. Inspect Facilities</b>			<b>Possible Operator Actions</b>
Check sedimentation basins	Various	Once every 8-hour shift	<ol style="list-style-type: none"> <li>Report abnormal conditions.</li> <li>Make flow changes or adjust launder weirs.</li> <li>Remove debris from basin water surface.</li> </ol>
Observe basin water over launder weirs.	Various	Once per 8-hour shift	
Observe basin water surface	Various	Once per 8-hour shift	
Check for algae buildup on basin walls and launders	Various	Occasionally	

Note: All major problems should be reported to the competent authorities and response duly followed.

**TABLE 5.5: SEDIMENTATION PROCESS TROUBLESHOOTING**

<b>1. Source Water Quality Changes</b>	<b>Operator Actions</b>	<b>Possible Process Changes</b>
Turbidity Temperature Alkalinity pH Color	<ol style="list-style-type: none"> <li>1. Perform necessary analysis to determine extent of change.</li> <li>2. Evaluate overall process performance.</li> <li>3. Perform jar tests.</li> <li>4. Make appropriate process changes (next column).</li> <li>5. Increase frequency of process monitoring.</li> </ol>	<ol style="list-style-type: none"> <li>1. Adjust coagulant dosage.</li> <li>2. Adjust flash mixer/flocculator mixing intensity.</li> <li>3. Change frequency of sludge removal (increase or decrease).</li> <li>4. Increase alkalinity by adding lime, caustic soda or soda ash.</li> <li>5. Change coagulant.</li> </ol>
<b>2. Flocculation Process Effluent Quality Changes</b>	<b>Operator Actions</b>	<b>Possible Process Changes</b>
Turbidity Alkalinity pH	<ol style="list-style-type: none"> <li>1. Evaluate overall process performance.</li> <li>2. Perform jar tests.</li> <li>3. Verify performance of coagulation flocculation process.</li> <li>4. Make appropriate process changes (next column).</li> </ol>	<ol style="list-style-type: none"> <li>1. Adjust coagulant dosage.</li> <li>2. Adjust flash mixer/flocculator mixing intensity.</li> <li>3. Adjust improperly working chemical feeder.</li> <li>4. Change coagulant.</li> </ol>
<b>3. Sedimentation Basin Changes</b>		
Floc Settling Rising or Floating Sludge	<ol style="list-style-type: none"> <li>1. Observe floc settling characteristics:               <ol style="list-style-type: none"> <li>a. Dispersion</li> <li>b. Size</li> <li>c. Settling rate</li> </ol> </li> <li>2. Evaluate overall process performance.</li> <li>3. Perform jar tests.               <ol style="list-style-type: none"> <li>a. Assess floc size and settling rate.</li> <li>b. Assess quality of settled water (clarity and color).</li> </ol> </li> <li>4. Make appropriate process changes (next column).</li> </ol>	<ol style="list-style-type: none"> <li>1. Adjust coagulant dosage.</li> <li>2. Adjust flash mixer/flocculator mixing intensity.</li> <li>3. Change frequency of sludge removal (increase or decrease).</li> <li>4. Remove sludge from basin.</li> <li>5. Repair broken sludge rakes.</li> <li>6. Change coagulant.</li> </ol>
<b>4. Sedimentation Process Effluent Quality Changes</b>		
Turbidity Color	<ol style="list-style-type: none"> <li>1. Evaluate overall process performance.</li> <li>2. Perform jar test.</li> <li>3. Verify process performance: Coagulation-flocculation process</li> <li>4. Make appropriate process changes (next column).</li> </ol>	<ol style="list-style-type: none"> <li>1. Change coagulant.</li> <li>2. Adjust coagulant dosage.</li> <li>3. Adjust flash mixer/flocculator mixing intensity.</li> <li>4. Change frequency of sludge removal (increase or decrease).</li> </ol>
<b>5. Upflow Clarifier Process Effluent Quality Changes</b>		
Turbidity Turbidity Caused by Sludge Blanket Coming to Top Due to Rainfall on Watershed	<ol style="list-style-type: none"> <li>1. Sec 4. above.</li> <li>2. Open main drain valve of clarifier.</li> </ol>	<ol style="list-style-type: none"> <li>1. See 4. above (sedimentation process).</li> <li>2. Drop entire water level of clarifier to bring the sludge blanket down.</li> </ol>

Note: All major problems should be reported to the competent authorities and response duly followed up.

#### **5.4.2.8 Start Up and Shut Down Procedures**

In the event of requirement for shut down or start up of processes on account of maintenance or a major equipment failure, proper procedures must be followed as per recommendations of the manufacturer of the plant and equipment. The procedures, in general, are given below:

##### **(a) Start up Procedure**

1. Check operational status and mode of operation of equipment and physical facilities.  
Check that basin valves are closed.  
Check that basin isolation gates are closed.  
Check that launder weir plates are set at equal elevations.  
Check to ensure that all trash, debris and tools have been removed from basin.
2. Test sludge removal equipment.  
Check that mechanical equipment is properly lubricated and ready for operation.  
Observe operation of sludge removal equipment.
3. Fill sedimentation basin with water.  
Observe proper depth of water in basin.  
Remove floating debris from basin water surface.
4. Start sample pumps.
5. Perform water quality analyses.
6. Operate sludge removal equipment. Be sure that all valves are in the proper position.

##### **(b) Shut Down Procedures**

1. Stop flow to sedimentation basin. Install basin isolation gates.
2. Turn off sample pump.
3. Turn off sludge removal equipment.  
Shut off mechanical equipment and disconnect where appropriate.  
Check that valves are in proper position.
4. Lock out electrical switches and equipment.
5. Dewater basin if necessary.  
Be sure that the water table is not high enough to float the empty basin.  
Open basin drain valves.
6. Grease and lubricate all gears, sprockets and mechanical moving parts which have been submerged immediately following dewatering to avoid seize up.

#### **5.4.2.9 Equipment**

##### **(a) Types of support equipment – Operation and Maintenance**

The operator will need to be thoroughly familiar with the operation and maintenance instructions for each specific equipment.

Flow meters and gauges.

Valves.

Control Systems.

Water Quality monitors such as turbidimeters.

Sludge removal equipment.

Sludge pumps.

Sump pumps.

**(b) *Equipment Operation***

Check the following:

1. Proper lubrication and operational status of each unit.
2. Excessive noise and vibration, overheating and leakage.
3. Pumps suction and discharge pressure.

**5.4.2.10 Safety Considerations**

**(a) *Electrical Equipment***

Avoid electric shock.

Avoid grounding yourself in water or on pipes.

Ground all electric tools.

Use a lock out and tag system for electric equipment or electrically driven mechanical equipment.

**(b) *Mechanical Equipment***

1. Keep protective guards on rotating equipment
2. Do not wear loose clothing around rotating equipment.
3. Keep hands out of valves, pumps and other equipment.
4. Clean up all lubricant and sludge spills.

**(c) *Open Surface water – filled structures***

1. Use safety devices such as hand rails and ladders
2. Close all openings.
3. Know the location of all life preservers.

***Valve and Pump Vaults, Sumps***

1. Be sure all underground or confined structures are free of hazardous atmosphere (toxic or explosive gases, lack of oxygen).
2. Work only in well ventilated structures.
3. Take proper steps against flooding.

For more details please refer to Chapter 19 - Safety Practices.

#### **5.4.2.11 Corrosion Control**

All metallic parts which are liable to corrosion must be protected. Please refer to Chapter 9 of Manual on “Water Supply and Treatment” (1999 edition) for detailed discussion on Corrosion Control.

#### **5.4.2.12 Preventive Maintenance**

Such programmes are designed to assure the continued satisfactory operation of treatment plant by reducing the frequency of breakdown failures. Typical functions include.

1. Keeping electric motors free of dirt and moisture.
2. Assuring good ventilation.
3. Checking pumps and motors for leaks, unusual noise and vibrations, overheating or signs of wear.
4. Maintaining proper lubrication and oil levels.
5. Inspecting alignment of shafts and couplings.
6. Checking bearings for overheating and proper lubrication.
7. Checking for proper valve operation.
8. Checking for free flow of sludge in sludge removal collection and discharge systems.
9. Good House Keeping.

### **5.4.3 FILTRATION (RAPID SAND FILTERS)**

#### **5.4.3.1 Interaction with Other Treatment Processes**

The purpose of filtration is the removal of particulate impurities and floc from the water being treated. In this regard, the filtration process is the final step in the solids removal process which usually includes the pretreatment processes of coagulation, flocculation and sedimentation.

The degree of treatment applied prior to filtration depends on the quality of water.

Typical treatment processes are shown in Figs. 5.4, 5.5, 5.6.

#### **5.4.3.2 Operation**

**Filter Operation:** A filter is usually operated until just before clogging or breakthrough occurs or a specified time period has passed (generally 24 hours).

**Backwashing:** After a filter clogs or breakthrough occurs or a specified time has passed, the filtration process is stopped and the filter is taken out of service for cleaning or backwashing.

**Surface Wash:** In order to produce optimum cleaning of the filter media during backwashing and to prevent mud balls, surface wash (supplemental scouring) is usually required. Surface wash systems provide additional scrubbing action to remove attached floc and other suspended solids from the filter media.

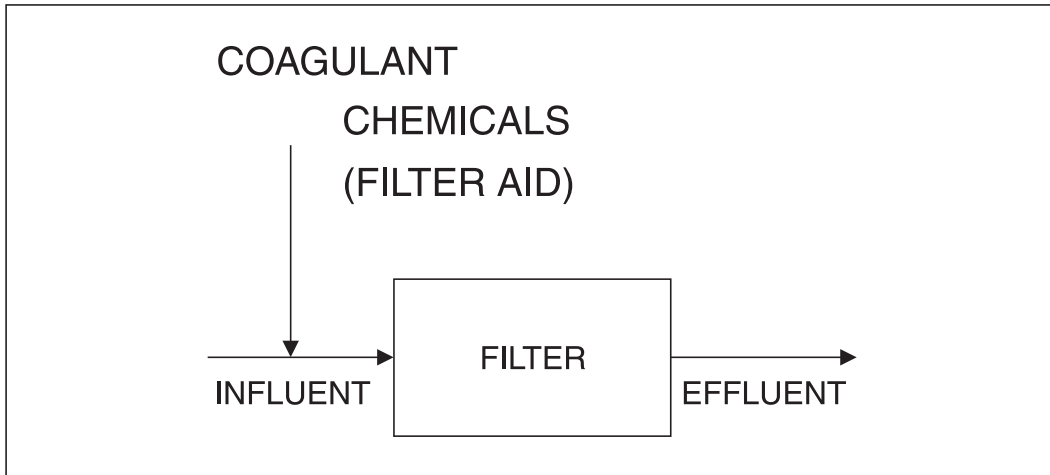


FIG. 5.4 IN LINE FILTRATION

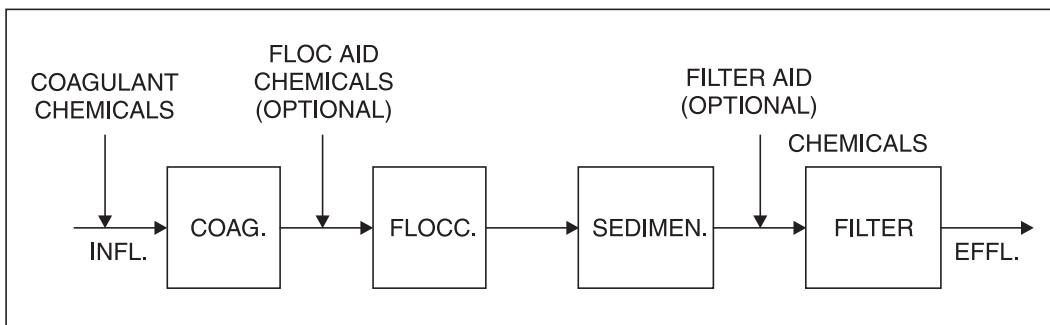


FIG. 5.5 CONVENTIONAL FILTRATION

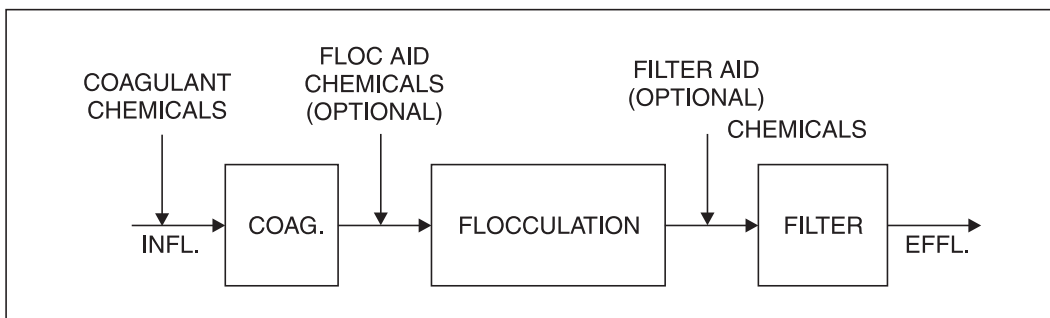


FIG. 5.6 DIRECT FILTRATION

### 5.4.3.3 Operational Procedures

#### (a) *The indicators of Normal Operating Conditions*

The filter influent and effluent turbidities should be closely watched with a turbidimeter. Filter Influent turbidity levels (settled turbidity) can be checked on a periodic basis at the filter or from the laboratory sample tap. However, the filter effluent turbidity is best monitored and recorded on a continuous basis by an on-line turbidimeter.

#### (b) *Process Actions*

Follow the steps as indicated below:

Monitor process performance.

Evaluate turbidity and make appropriate process changes.

Check and adjust process equipment (change chemical feed rates).

Backwash filters.

Evaluate filter media condition (media loss, mud balls, cracking).

Visually inspect facilities.

#### (c) *Important process activities and Precautions.*

1. Monitoring process performance is an ongoing activity. You should look for and attempt to anticipate any treatment process changes or other problems that might affect filtered water quality, such as a chemical feed system failure.
2. Measurement of head loss built up (Fig.5.7) in the filter media will give you a good indication of how well the solids removal process is performing. The total designed head loss from the filter influent to the effluent in a gravity filter is usually about 3 meters. At the beginning of the filtration cycle the actual measured head loss due to clean media and other hydraulic losses is about 0.9m. This would permit an additional head loss of about 2.1m due to solid accumulation in the filter.
3. The rate of head loss build up is an important indication of process performance. Sudden increase in head loss might be an indication of surface sealing of the filter media (lack of depth penetration). Early detection of this condition may permit you to make appropriate process changes such as adjustment of chemical filter aid feed rate or adjustment of filtration rate.
4. Monitoring of filter turbidity on a continuous basis with an on-line turbidimeter is highly recommended. This will provide you with continuous feed back on the performance of the filtration process. In most instances it is desirable to cut off (terminate) filter at a predetermined effluent turbidity level. Preset the filter cutoff control at a point where you experience and tests show that breakthrough will soon occur. (Fig. 5.8).
5. In the normal operation of the filter process, it is best to calculate when the filter cycle will be completed on the basis of the following guidelines:
  - Head loss.
  - Effluent turbidity level.
  - Elapsed run time.



A predetermined value is established for each guideline as a cut off point for filter operation. When any of these levels is reached, the filter is removed from service and backwashed.

6. At least once a year one must examine the filter media and evaluate its overall condition. Measure the filter media thickness for an indication of media loss during the backwashing process. Measure mud ball accumulation in the filter media to evaluate the effectiveness of the overall backwashing operation.
7. Routinely observe the backwash process to qualitatively assess process performance. Watch for media boils (uneven flow distribution) during backwashing, media carry over into the wash water trough, and clarity of the waste wash-water near the end of the backwash cycle.
8. Upon completion of the backwash cycle, observe the condition of the media surface and check for filter sidewall or media surface cracks. You should routinely inspect physical facilities and equipment as part of good housekeeping and maintenance practice. Correct or report the abnormal equipment conditions to the appropriate maintenance personnel.
9. Never bump up a filter to avoid backwashing. Bumping is the act of opening the backwash valve during the course of a filter run to dislodge the trapped solids and increase the length of filter run. This is not a good practice.

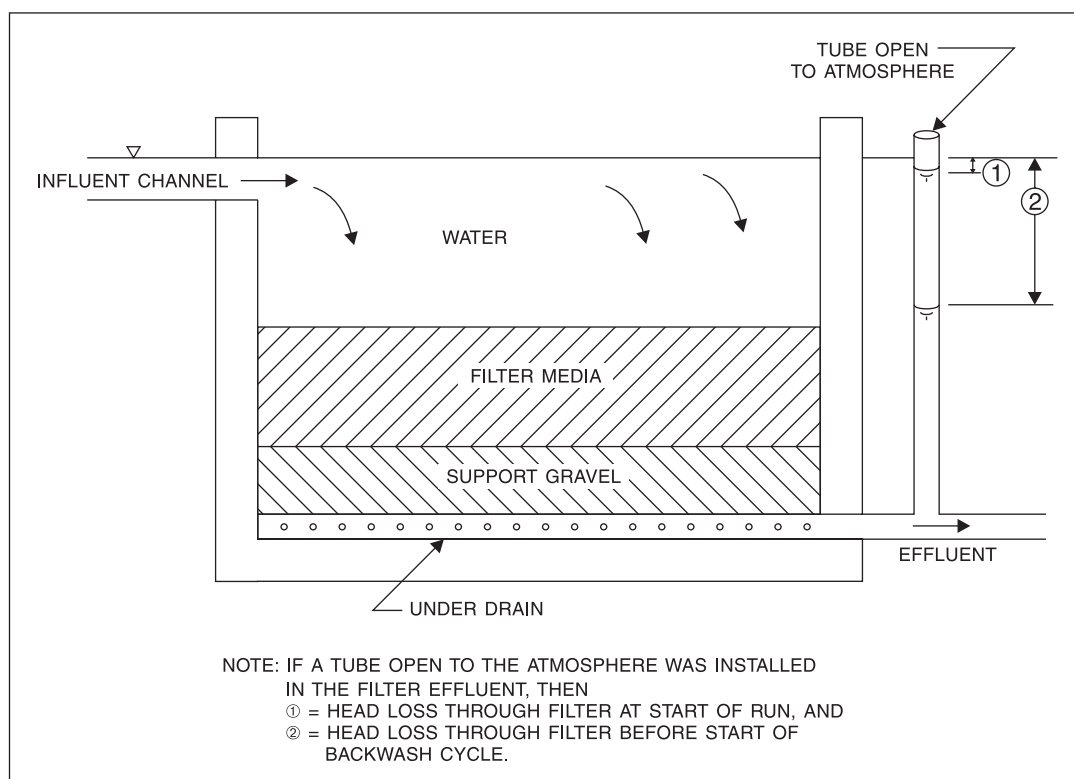


FIG. 5.7: MEASUREMENT OF HEAD LOSS

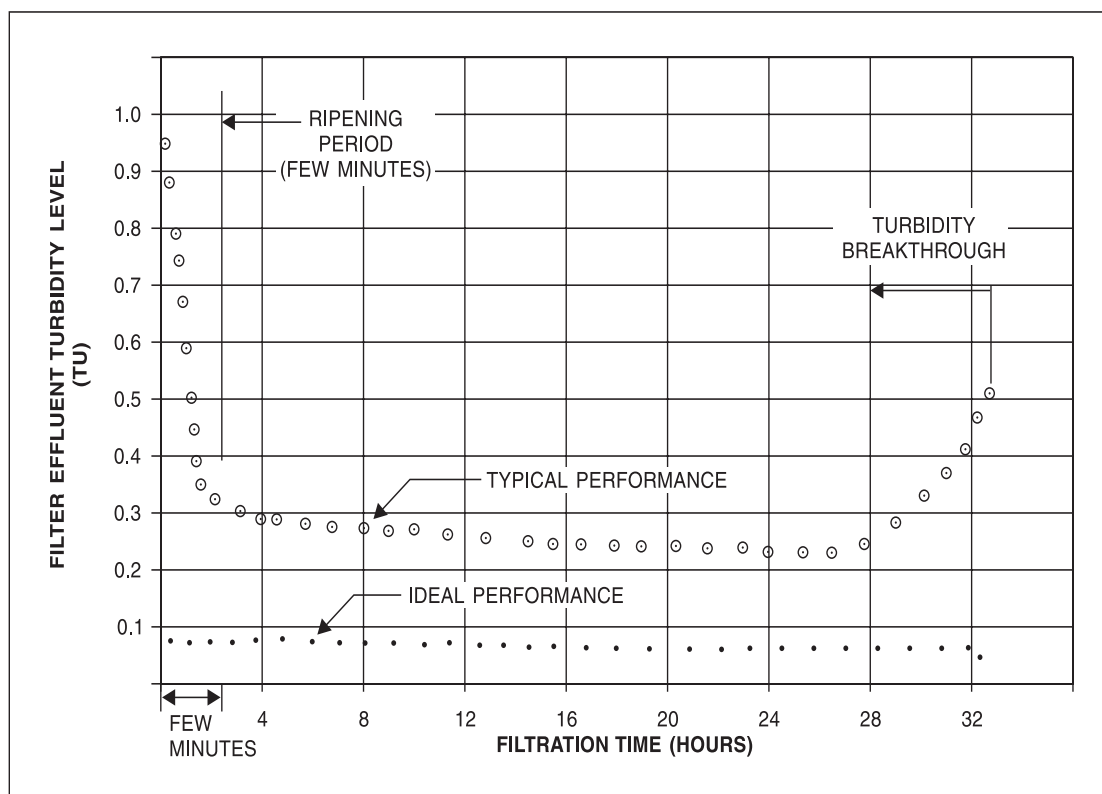


FIG. 5.8: TYPICAL FILTER EFFLUENT TURBIDITY DATA

- Shortened filter runs can occur because of air bound filters. Air binding will occur more frequently when large head losses are allowed to develop in the filter. Precautions should be taken to minimize air binding to avoid damage to the filter media.

A summary of routine filtration process action is given in Table 5.6.

Table 5.7 gives Filtration process trouble shooting problems.

#### 5.4.3.4 RECORD KEEPING

Maintain a daily operations log of process performance data and water quality characteristics. Accurate recording of the following items should be maintained.

- Process water quality (turbidity and colour).
- Process operation (filters in service, filtration rates, loss of head, length of filter runs, frequency of backwash, backwash rates, and UFRV-unit filter run volume).
- Process water production (water processed, amount of backwash water used, and chemicals used).
- Percentage of water production used to backwash filters.
- Process equipment performance (types of equipment in operation, equipment adjustments, maintenance procedures performed, and equipment calibration).

A typical daily operating record for a water treatment plant is shown in Table 5.8.

**TABLE 5.6: SUMMARY OF ROUTINE FILTRATION PROCESS ACTION**

<b>Monitor Process Performance and evaluate Water Quality Conditions</b>	<b>Location</b>	<b>Frequency</b>	<b>Possible Operator Actions</b>
Turbidity  Colour  Head loss	Influent/ Effluent  Influent/ Effluent	At least once per 8-hour shift.  At least once per 8-hour shift.  At least two times per 8-hour shift.	1. Increase sampling frequency when process water quality is variable. 2. Perform Jar Tests. 3. Make necessary process changes: Adjust coagulant dosage. Adjust flash mixer/flocculator mixing intensity. Change filtration rate. Back wash filter. Change chlorine dosage. Change Coagulant.
<b>Operate Filters and Backwash</b>			
Put filter into service. Change filtration rate. Remove filter from service. Backwash filter. Change backwash rate.	Filter module	Depends on process conditions	See Operating Procedures (para 5.4.3.3)
<b>Check Filter Media Condition</b>			
Media depth evaluation. Media cleanliness. Cracks or shrinkage.	Filter module	At least monthly.	1. Replace lost filter media. 2. Change backwash procedure. 3. Change chemical coagulants.
<b>Make visual Observations of Backwash Operation</b>			
Check for media boils and media expansion. Check for media carryover into washwater trough. Observe clarity of wastewater.	Filter module	At least once per day or whenever backwashing occurs.	Change backwash rate. Change backwash cycle time. Adjust surface wash rate or cycle time. Inspect filter media and support gravel for disturbance.
<b>Check Filtration Process and Backwash Equipment Condition</b>			
Noise, Vibration, Leakage, Overheating	Various	Once per 8-hour shift.	Correct minor problems.
<b>Inspect Facilities</b>			
Check physical facilities and algae on sidewalls and troughs.	Various	Once a day.	1. Remove debris from filter media surfaces 2. Adjust chlorine dosage to control algae.

Note: All major problem should be reported to the competent authorities and response duly followed up.

**TABLE 5.7: FILTRATION PROCESS TROUBLE SHOOTING**

<b>Source Water Quality Changes</b>	<b>Operator Actions</b>	<b>Possible Process Changes</b>
Turbidity Temperature Alkalinity pH Colour Chlorine Demand	<ol style="list-style-type: none"> <li>1. Perform necessary analysis to determine extent of change.</li> <li>2. Assess overall process performance</li> <li>3. Perform Jar tests.</li> <li>4. Make appropriate process changes.</li> <li>5. Increase frequency of process monitoring.</li> <li>6. Verify response to process changes (be sure to allow sufficient time for change to take effect)</li> <li>7. Add lime or caustic soda if alkalinity is low.</li> </ol>	<ol style="list-style-type: none"> <li>1. Adjust coagulant dosage.</li> <li>2. Adjust flash mixer /floculator mixing intensity.</li> <li>3. Change frequency of sludge removal (increase or decrease).</li> <li>4. Adjust backwash cycle (rate, duration).</li> <li>5. Change filtration rate (add or delete filters).</li> <li>6. Start filter aid feed.</li> <li>7. Change coagulant.</li> </ol>
<b>Sedimentation Process Effluent Quality Changes</b>		
Turbidity or floc carryover	<ol style="list-style-type: none"> <li>1. Assess overall process performance.</li> <li>2. Perform Jar tests.</li> <li>3. Make appropriate process changes.</li> </ol>	Same as source water quality changes.
<b>Filtration Process Changes/Problems</b>		
Headloss increase Short filter runs media surface sealing Mudballs Filter media cracks, shrinkage Filter not clean Media boils Media loss Excessive head loss	<ol style="list-style-type: none"> <li>1. Assess overall process performance.</li> <li>2. Perform Jar tests.</li> <li>3. Make appropriate process changes.</li> </ol>	<ol style="list-style-type: none"> <li>1. Adjust coagulant dosage.</li> <li>2. Adjust flash mixer/floculator mixing Media intensity.</li> <li>3. Change frequency of sludge removal.</li> <li>4. Adjust backwash cycle (rate, duration).</li> <li>5. Manually remove mudballs.</li> <li>6. Decrease filtration rate (add more filters)</li> <li>7. Decrease or terminate filter aid.</li> <li>8. Replenish lost media.</li> <li>9. Clear under drain openings of media, corrosion or chemical deposits; check head loss.</li> <li>10. Change coagulant</li> </ol>
<b>Filter Effluent Quality Changes</b>		
Turbidity breakthrough Colour pH Chlorine	<ol style="list-style-type: none"> <li>1. Assess overall process performance.</li> <li>2. Perform Jar tests.</li> <li>3. Verify process performance: <ol style="list-style-type: none"> <li>a) Coagulation and Flocculation</li> <li>b) Sedimentation process</li> <li>c) Filtration process.</li> </ol> </li> <li>4. Make appropriate process changes.</li> </ol>	<ol style="list-style-type: none"> <li>1. Adjust coagulant dosage.</li> <li>2. Adjust flash mixer/floculator mixing intensity.</li> <li>3. Change frequency of sludge removal.</li> <li>4. Start filter aid feed.</li> <li>5. Decrease filtration rate (add more filters).</li> <li>6. Change chlorine dosage.</li> <li>7. Change coagulant.</li> </ol>

Note: All major problems should be reported to the competent authorities and response duly followed up.

**TABLE 5.8: FILTER DAILY OPERATING RECORD**

FILTERS DAILY OPERATING RECORD

No.	Time		Hours operated			Head loss		Wash		Physical condition of filters
	Start	Stop	Today	Previous	Total	Start	Stop	Min.	M.Gals	
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										
11.										
No. of filters washed						Average filter rate				
Average run-hours						Max. hourly rate				
Total wash water						Total water filtered				
Percent of water filtered						No. filters operating				
Av. Time of wash-min						Filters out per wash-min.				
						Shift				
						Operator				

**5.4.3.5 Startup and Shutdown Procedures**

*(a) Routine Procedure*

Most plants keep all filters on line except for backwash and in service except for maintenance. Filters are routinely taken off line for backwashing when the media becomes clogged with particulates, turbidity breakthrough occurs or demands for water are reduced.

*(b) Implementation of Startup and Shutdown Procedures*

**1. Filter checkout procedures**

- Check operational status of filter.
- Be sure that the filter media and wash water troughs are clean of all debris such as leaves, twigs, and tools.
- Check and be sure that all access covers and walkway gratings are in place.
- Make sure that the process monitoring equipment such as head loss and turbidity systems are operational.
- Check the source of backwash to ensure that it is ready to go.

**2. Backwash Procedure**

- i) Filters should be washed before placing them into service.

The surface wash system should be activated just before the backwash cycle starts to aid in removing and breaking up solids on the filter media and to prevent the development of mud balls. The surface wash system should be stopped before completion of the backwash cycle to permit proper settling of the filter media.

A filter wash should begin slowly for about one minute to permit purging (removing) of an entrapped air from the filter media, and also to provide uniform expansion of the filter bed. After this period the full backwash rate can be applied. Sufficient time should be allowed for cleaning of the filter media. Usually when the backwash water coming up through the filter becomes clear, the media is washed. This generally takes from 3 to 8 minutes. If flooding of wash water troughs or carryover of filter media is a problem, the backwash rate must be reduced.

- ii) Procedure for backwashing a filter is as follows: (Fig. 5.9).

Log length of filter run since last backwash.

Close filter influent valve (V-1).

Open drain valve (V-4).

Close filter effluent valve (V-5).

Start surface wash system (Open V-2).

Slowly start backwash system (Open V3).

Observe filter during washing process.

When wash water from filter becomes clear (filter media is clean), close surface wash system Valve (V-2).

Slowly turn off backwash system (close V-3).

Close drain valve (V-4).

Log length of wash and the quantity of water used to clean filter.

**(c) Filter Startup Procedures**

Start filter

Slowly open influent valve.

When proper elevation of water is reached on top of filter, filter effluent valve should be gradually opened. This effluent control valve should be adjusted itself to maintain a constant level of water over the filter media.

Waste some of the initial filtered water if such a provision exists.

Perform turbidity analysis of filtered water and make process adjustments as necessary.

**(d) Filter Shutdown Procedures**

Remove filter from service by closing influent valve and closing effluent valve

Backwash filter.

If filter is to be out of service for a prolonged period, drain water from filter to avoid algal growth.

Note status of filter in operations log.

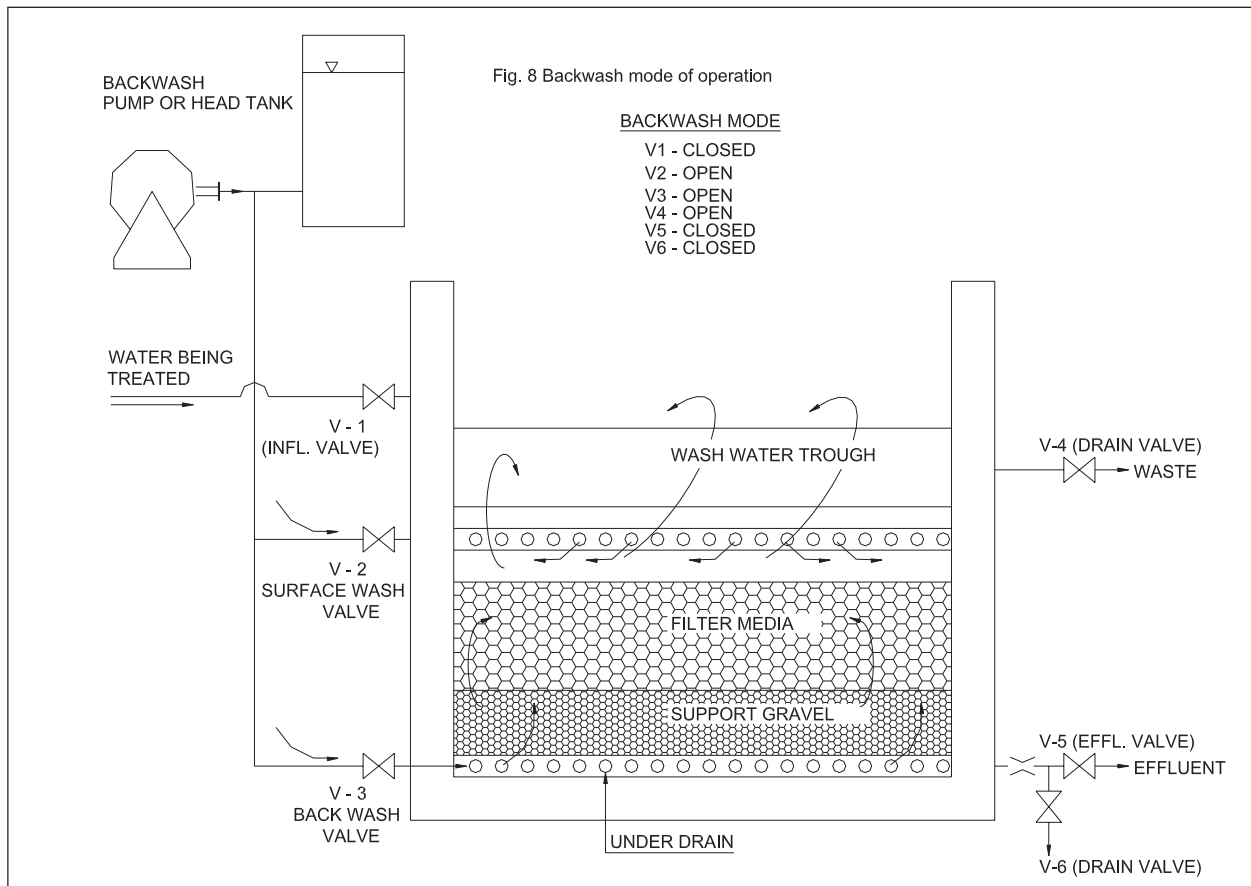


FIG. 5.9: BACKWASH OPERATION

#### **5.4.3.6 Support Equipment**

The operator must be familiar with the operation and maintenance instructions for each specific equipment item or control system.

##### **(a) Types of Equipment**

1. Filter Control Valves.
2. Backwash and surface wash pumps.
3. Flow meter and level/pressure gauges.
4. Water quality monitors such as turbidimeters .
5. Process monitors (headloss and water level).
6. Mechanical and electrical filter control systems.

##### **(b) Equipment Operation**

Before starting a piece of mechanical equipment, such as a backwash pump, be sure that the unit has been serviced on schedule and its operational status is known.

After startup, always check for excessive noise and vibrations, overheating, and leakage (water, lubricants). When in doubt about the performance of a piece of equipment, refer to manufacturer's instructions.

Periodic calibration and maintenance of the equipment is necessary.

#### **5.4.3.7 Preventive Maintenance Procedures**

Preventive maintenance programmes are to assure the continued satisfactory operation of treatment plant facilities by reducing the frequency of breakdown failures.

Routine maintenance functions include:

- Keeping electric motors free of dirt, moisture and pests (rodents and birds).
- Assuming good ventilation (air circulation) in equipment work areas.
- Checking pumps and motors for leaks, unusual noise and vibrations or overheating.
- Maintaining proper lubrication and oil levels.
- Inspecting for alignment of shafts and couplings.
- Checking bearings for overheating and proper lubrication.
- Checking the proper valve operation (leakage or jamming).
- Checking automatic control systems for proper operation.
- Checking air/vacuum relief systems for proper functioning, dirt and moisture.
- Verifying correct operation of filters and backwashing cycles by observation.
- Inspecting filter media condition (look for algae and mudballs and examine gravel and media for proper gradation).
- Inspecting filter underdrain system (be sure that the underdrain openings are not becoming clogged due to media, corrosion or chemical deposits).



#### **5.4.3.8 Safety Considerations**

##### **(a) Electrical Equipment**

1. Avoid electric shock (use preventive gloves).
2. Avoid grounding yourself in water or on pipes.
3. Ground all electric tools.
4. Lock out and tag electrical switches and panels when servicing equipment.

##### **(b) Mechanical Equipment**

1. Use protective guards on rotating equipment.
2. Don't wear loose clothing around rotating equipment.
3. Keep hands out of energized valves, pumps and other pieces of equipment.
4. Clean up all lubricant and chemical spills (slippery surfaces cause bad falls).

##### **(c) Open – Surface Filters**

1. Use safety devices such as handrails and ladders.
2. Close all openings and replace safety gratings when finished working.
3. Know the location of all life preservers and other safety devices.

##### **(d) Valve and Pump Vaults, Sumps, Filter galleries**

1. Be sure that all underground or confined structures are free of hazardous atmospheres (toxic or explosive gases, lack of oxygen) by checking with gas detectors.
2. Only work in well ventilated structures (use air circulation fans).

For more details please refer to Chapter 19 - 'Safety Practices'

#### **5.4.4 AUGMENTATION OF RAPID SAND FILTRATION PLANTS**

Augmentation of an existing Rapid Sand Filtration Plant can be carried out by converting the conventional filtration process to Variable Declining Rate Filtration with dual media filter units. The filter unit will, however, require additional depth. Special precautions are required to strictly adopt the specifications of the two filter media as regards effective size and specific gravity. During operation a special watch has to be kept to avoid intermixing of the two media.

### **5.5 PRESSURE FILTERS**

#### **5.5.1 INTRODUCTION**

Pressure Filters are Rapid Sand Filters placed in a closed water-tank. The water passes through the sand and emerges from the filter under a pressure greater than atmosphere.

Pressure filters are used primarily in small plants and in industries where the raw water is received, and the filtered water is discharged, under pressure.

The use of pressure filters for public water supplies is unusual because of cost, inefficiency of filtration and the relative poor quality of results obtained.

## 5.5.2 OPERATION

The filter is operated similar to a gravity- type filter except that the coagulated water is applied directly to the filter without mixing, flocculation, or conditioning. Automatic filters are available in which the valves are manipulated automatically to backwash at a predetermined time or head loss. It is to be noted that the head loss through the filter is approximately the same as through a gravity filter. The term “pressure filter” does not imply that water is pumped through the filter under a high pressure loss.

The coagulant, normally, is applied under pressure in the influent line to the filter, the influent water dissolving the alum as it enters the filter.

Following drawbacks have been noticed in the working of the Pressure filters. Efforts should be made during their maintenance to avoid the same.

- There is no scope for proper formation of the flocs, the entrapment of the un-settleable and colloidal particles and independent settlement of the settleable solids.
- The filter media becomes mixed up due to the water pressure. Cracks develop within the filter sand media and serious piping develops within the entire media.
- Due to intermixing of the media the under-drainage system gets damaged.
- The behaviour of the filter operation cannot be examined properly.

## 5.6 ROUGHING FILTERS

These filters are used to remove solid matters which would, otherwise, impair the operation of the conventional filters.

These may be of Horizontal flow or Vertical flow. When used as pretreatment units in slow sand filter, the plant can handle raw water of higher turbidity, colour and bacterial count.

When installed in a catchment area it reduces the load on the conventional plant by arresting coarser impurities and floating matter.

## 5.7 CHECK LIST

**Water Treatment Plant Information, Operation, Maintenance, Records etc.**

### 5.7.1 PLANT INFORMATION

#### 5.7.1.1 Source

Surface i. River ii. Reservoir iii. Dam iv. Lake v. Canal.

Ground i. Well ii. Tubewell iii. Infiltration well/gallery

#### 5.7.1.2 Intake

i. Location. ii. Pollution Source iii. Gates and Valves iv. Structural details.

#### 5.7.1.3 Treatment Processes

1. Screens.
2. Storage tanks/Pre-settling tanks.
3. Pre-disinfection/Pre-chlorination.

4. Aeration.
5. Coagulation and Flocculation.
  - (a) Mixing tank or Mixing channel,
  - (b) Chemicals: lime, alum, or others  
Conventional or tapered flocculation.  
Independent tank or in the form of a clarifier.
6. Sedimentation.  
Tanks (circular or rectangular)  
If circular, as independent tanks or as clariflocculators  
with or without Scrapers.  
Other important features.
7. Filters  
Slow, Rapid or Others.  
Filter box  
Filter media  
Desludging.  
Backwashing with water only or both with and air.
8. Clear Water Tanks.
  - i) Capacity
  - ii) Number
  - iii) Size

## **5.7.2 OPERATION, MAINTENANCE, RECORDS ETC.**

### **5.7.2.1 Flow**

Measurements: i. Raw ii. Settled iii. Filtered iv. Chlorinated.

#### **Flow Meters**

- i) Calibration and accuracy of equipment.
- ii) Charts and pen recorder.
- iii) Servicing of equipment.
- iv) Cleaning of sump, water channel etc.

### **5.7.2.2 Chemical Feeding**

- i) Dosing at a point of maximum turbulence
- ii) Jar test apparatus - ascertaining coagulant dosing.
- iii) cleaning V-notches, weirs and floor.
- iv) Mixer painting.
- v) Painting alum tank.
- vi) Spares for rapid mix

### 5.7.2.3 Flocculator

- i) Observing floc formation.
- ii) Checking speeds of paddles.
- iii) Checking short circuiting.
- iv) Sludge collection, if any, and to take remedial measures to stop it.
- v) Lubrication of mechanical devices.
- vi) Dosing lines
- vii) Valves and pipes.

### 5.7.2.4 Settling Basins

- i) Examination of floc:  
observing floc formation efficiency .  
floc distribution  
clarity of settled water.
- ii) Checking short circuiting.
- iii) Scrapers and squeezers.
- iv) Outlet weir adjustment, biological growth.
- v) Sludge lines and telescopic sludge devices if any.  
density of sludge.  
accumulation of sludge  
bleeding of sludge  
sludge disposal
- vi) Measuring turbidity at the end.
- vii) Watching efficiency of various components.
- viii) Overhauling all equipment.
- ix) Painting.
- x) Rail tracks.
- xi) Reduction gear box.

### 5.7.2.5 Filters

- i) Checking turbidity at start and end
- ii) Adequate depth of water
- iii) Rate of filtration
- iv) Head loss at different important stages
- v) Negative head
- vi) Filter run
- vii) Filter media surface cracks.  
mud balls  
slime growth

intermixing of media  
uplifting of under drain nozzles.  
filter media carry over.

viii) Backwashing

time and quantity of water used in backwashing.  
uniform washing of filter media.  
thickness of filter media before and after washing.

ix) Water quantity

received; wasted; consumed for backwashing; produced

x) Operation of Valves.

xi) Performance of blowers.

xii) Status of functioning of Instruments

xiii) Corrosion of Underwater equipment.

### 5.7.2.6 Records

#### (a) *Coagulation and Flocculation*

1. Source water quality (pH, turbidity, temperature, alkalinity, chlorine demand and colour).
2. Process water quality (pH, turbidity, and alkalinity).
3. Process production inventories (chemicals used, chemical feed rates, amount of water processed, and amount of chemicals in storage).
4. Process equipment performance (types of equipment in operation, maintenance procedures performed, equipment calibration and adjustments).

#### (b) *Sedimentation*

1. Influent and effluent turbidity and influent temperature.
2. Process production inventory (amount of water processed and volume of sludge produced.)
3. Process equipment performance (type of equipment in operation, maintenance procedures performed and equipment calibration).

#### (c) *Filtration*

1. Process water quality (turbidity and colour).
2. Process operation (filters in service, filtration rates, loss of head, length of filter runs, frequency of backwash, backwash rates, and UFRV).
3. Process water production (water processed, amount of backwash water used, and chemicals used).
4. Percentage of water production used to backwash filters.
5. Process equipment performance (types of equipment in operation, equipment adjustments, maintenance procedures performed, and equipment calibration).

## **5.8 ALGAL CONTROL**

Note : Only a brief description of removal of algae is being given in order to help the operator to understand and take effective steps in operating and maintaining such plant processes. For more details a reference may be made to the Manual of Water Supply and Treatment (Chapter 9).

### **5.8.1 INTRODUCTION**

Algae are unicellular or multicellular chlorophyll bearing plants without any true root, stem or leaves. They may be microscopic unicellular colonial or dense mat forming filamentous forms commonly inhabiting surface waters. Their growth is influenced by a number of factors, such as mineral nutrients, availability of sunlight, temperature and type of reservoir. During certain climatic conditions there is an algal bloom which creates acute problems for treatment and production of potable water.

The algae encountered in water purification plants are Diatoms, Green Algae, Blue Green Algae and Algal Flagellates. Algae may be seen floating (plankton) in the form of blooms.

### **5.8.2 PROBLEMS CAUSED BY ALGAE**

1. Many species of algae produce objectionable taste and odour due to characteristic oil secretions (Table 5.9). These also impart colour ranging from yellow-green to green, blue-green, red or brown.
2. Profuse growth of algae interferes with chemical treatment of raw water by changing water pH and its hardness.
3. Some algae act as inhibitors in process of coagulation carried out for water purification.
4. Some algae clog filters and reduce filter run.
5. Some algae produce toxins and their growth in drinking water reservoirs is harmful for humans and livestock.
6. Some algae provide shelter to a large number of bacteria, some of which may be pathogenic.
7. Some algae corrode metal tanks, forming pits in their walls.
8. Algae may also cause complete disintegration of concrete in contact with them.
9. Prolific growth of algae increases organic content of water, which is an important factor for the development of other organisms.

### **5.8.3 REMEDIAL MEASURES**

#### **5.8.3.1 Preventive Measures**

Preventive measures can be taken to a limited extent by making environmental conditions unfavourable as explained in Chapter 9 on Manual for "Water Supply and Treatment" (1999 edition).

#### **5.8.3.2 Control Measures**

Adequate records of number, kind and location of algae becomes handy for algal growth control. Details are given in the Manual for "Water Supply and Treatment" (Chapter 9).

*Algicide* dose used should be harmless to humans, have no effect on water quality, should be inexpensive and easy to apply. The most commonly used *algaecides* are copper sulphate and chlorine.

#### **5.8.4 COPPER SULPHATE TREATMENT**

##### **5.8.4.1 Toxicity and Dosage**

Copper Sulphate is toxic to many algae at comparatively low concentration, which is normally non-lethal to fishes and is relatively inexpensive.

Dosage of copper sulphate lethal for algae is expressed in terms of concentration of  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  in mg./l. The quantity of copper sulphate required has to be calculated on the basis of the type of algae present, period of its multiplication and volume of reservoir. Temperature, alkalinity and carbon dioxide content of water also influence dosage. Low temperature, high alkalinity and low carbon dioxide decrease effectiveness of copper sulphate.

Table 5.9 shows the approximate amount of copper sulphate required as lethal dose for various algae. It may be noted from the table that the mean recommended dose is 0.3mg./l; thus this dose may be used even in absence of laboratory control.

##### **5.8.4.2 Points to be taken into Account while Formulating Copper Sulphate Dosage**

The dose of copper sulphate, to be added to unknown water depth, has to be calculated by considering 4.5 metres depth of water as algae congregate in the upper zone only.

For alkaline water (alkalinity above 50mg./l as calcium carbonate) the dose should be based on surface area rather than volume of water as *algaecide* will be precipitated as copper bicarbonate before it can diffuse to lower depths. This difficulty can be overcome by scattering fine granular copper sulphate over the water surface. Water of intermediate alkalinity may be treated on volume basis.

Copper Sulphate is not effective at pH 8.5, hence before copper sulphate treatment pH should be adjusted to maximise result.

Laboratory tests should be performed ensuring that copper content is within permissible limit in water supplied (i.e. 0.05 mg/l).

Depletion of dissolved oxygen due to decomposition of dead algae and clogging of gills of fish by dead algae clusters can be avoided by starting application of copper sulphate at the dams or reservoirs, which gives ample time to fishes to get away from treatment sites.

##### **5.8.4.3 Method of Application**

Several methods of applying copper sulphate are available:

1. *General practice:* a bag containing required amount of copper sulphate crystals is hung at the point of entry of raw water into treatment plant.
2. *Burlap bag Method:* Required quantity of crushed copper sulphate crystals is placed in a cloth bag, which is dragged under the water surface by using a boat.
3. *Box Method:* Perforated wooden box containing copper sulphate crystals is supported in such a way that the depth of submergence can be varied as required at the point of entry of raw water into the treatment plant. The box should be filled to a point above

water level. Copper sulphate crystals are dissolved by water flowing through the box. Dose of copper sulphate can be controlled by raising or lowering the box.

4. *Spray Method:* 0.5-1% copper sulphate solution may be sprayed over the surface of water by conventional spraying equipment.
5. *Blower Method:* Large quantities of copper sulphate may be distributed over large reservoirs or lakes by using blower fitted motor boats. Finely granulated copper sulphate is fed into air entering the blower from a hopper fitted with a control valve.

### **5.8.5 CHLORINE TREATMENT**

#### **5.8.5.1 General**

Chlorine treatment is relatively cheap, readily available and provides prolonged disinfecting action. Though chlorine is generally used for disinfecting potable water it can also be used as an algacide. Prechlorination has specific toxic effect and causes death and disintegration of some of the algae. It also assists in removal of algae by coagulation and sedimentation. It prevents growth of algae on basin walls and destroys slime organisms on filter sand thus prolonging filter run and facilitating filter washing.

*Dosage :* Lethal dose of chlorine for common types of algae is given in Table no. 5.9. Effective chlorine dose should be such that sufficient chlorine is there to react with organic matter, ammonia, iron, manganese and other reducing substances in water and at the same time leave sufficient chlorine to act as algacide. Dose required for this purpose may be over 5mg/l. With chlorine treatment essential oils present in algae are liberated which may lead to development of odour and color and taste. Occasionally these oils as well as organic matter of dead algae may combine with chlorine to form intensified odour and taste. In such cases break point - chlorination is required. Post chlorination dose can be adjusted to obtain minimum 0.2mg/l residual chlorine in potable water at consumer end.

#### **5.8.5.2 Method of Application**

Chlorine is preferably applied as a strong solution of chlorine from chlorinator. A slurry of bleaching powder can also be used. For algal growth control, generally, chlorine is administered at the entry of raw water before coagulant feeder.

#### **5.8.5.3 Chlorine Treatment vs. Copper Sulphate Treatment**

Chlorination is preferred over copper sulphate treatment in certain conditions, which are as follows:

1. Copper Sulphate cannot be used when the application is too close to pipeline, as copper will plate out on metal thus becoming inactive.
2. Copper sulphate cannot be used to prevent algal growth in coagulant basin, as it will be immediately thrown out of solution.
3. If adequate time (for proper precipitation of the added copper sulphate) is not available between copper sulphate treatment and supply of water, copper sulphate treatment should be avoided and chlorine treatment should be preferred.



4. Death and decay of algae imparts taste and odour to water. It also results in increase of organic matter, which supports proliferation of saprophytes (organisms growing on dead organic matter) resulting in lowering of oxygen content of water. Breakpoint pre-chlorination helps in removal of taste and odour, also assists in coagulation and controls growth of saprophytes.
5. Certain algae are resistant to copper sulphate treatment.

### **5.8.6 MICROSTRAINER**

Algae can be removed from water by using microstrainer. The infested water can be passed through stainless steel drums with cloths of mesh size ranging from 15-45  $\mu\text{m}$ . Microstraining is a useful process for the removal of filaments and colonial algae, but it does not remove smaller species or reproductive forms which can multiply later on, creating problems. Microstraining cannot constitute a complete treatment for effective disposal of algae, but it can be used as a part of treatment line. Moreover, this procedure requires frequent cleaning of strainer.

## **5.9 REMOVAL OF IRON AND MANGANESE**

Note: Only a brief description of removal of iron and manganese is being given in order to help the operator to understand and take effective steps in operating and maintaining such plant processes. For more details a reference may be made to "Chapter of Manual of Water Supply and Treatment" (1999 edition).

### **5.9.1 INTRODUCTION**

Minerals like iron and manganese generally make their way into ground water from shale, sand stone and other rocks. These minerals dissolve in water containing carbon dioxide in absence of oxygen; the insoluble oxides of these elements being reduced and transformed into their soluble bicarbonates. These soluble bicarbonates when exposed to air by pumping lead to the formation of brown coloured oxides of iron and manganese which creates unaesthetic condition giving characteristic metallic taste and colour from brownish to blackish. It also stains plumbing fixtures and laundered material.

### **5.9.2 IRON**

#### **5.9.2.1 Occurrence**

Iron exists as reduced ferrous and chelated forms dissolved in ground water or in deeper layers of some water reservoirs lacking oxygen. In surface water, iron is generally found in its precipitated ferric form. Reduced iron in water promotes the growth of autotrophic bacteria in distribution mains creating serious nuisance. The problem is further aggravated when water also contains sulphates, as reduction of iron and sulphate compounds leads to the formation of disagreeable odour and black deposits of iron sulphide.

#### **5.9.2.2 Removal of Iron**

Chemical analysis of water for iron content as well as its various forms is a good start to provide clue to the removal method to be adopted. But it is always advisable to perform laboratory analysis and pilot plant studies before any particular method is adopted.

**TABLE 5.9: APPROXIMATE AMOUNT OF COPPER SULPHATE & CHLORINE REQUIRED AS A LETHAL DOSE FOR VARIOUS ALGAE\* (Suggested- to be adjusted according to alkalinity and temperature)**

Organism	Odour, Taste & Colour	Cause of Other Trouble	Copper Sulphate Dosage (Mg/L)	Chlorine Dosage (Mg/L)
<i>Diatomaceae:</i>				
Achnantes	–	–	–	0.25
Asterionella	Aromatic, Geranium, Fishy	–	0.12-0.20	0.5-1.6
Cyclotella	Faintly aromatic	Yes	–	1.0
Diatoma	Faintly aromatic	Yes	–	–
Fragilaria	Geranium, musty	Yes	0.25	–
Melosira	Geranium, musty	Yes	0.20	2.0
Meridion	Spicy	–	–	–
Navicula	–	Yes	0.07	–
Nitzschia	–	–	0.50	–
Stephanodiscus	Geranium, Fishy	–	0.33	–
Synedra	Earty	Yes	0.36-0.50	1.0
Tabellaria	Aromatic, Geranium, Fishy	–	0.12-0.50	0.5-1.0
<i>Chlorophyceae:</i>				
Chara	Garlic	Yes	0.1-0.5	–
Cladophora	Septic	Yes	0.5	–
Closterium	Grassy	–	0.17	–
Coelastrum	–	Yes	0.05-0.33	1.0
Conferva	–	Yes	0.25	–
Desmidium	–	–	2.0	–
Dictyosphaerium	Grassy, Nasturtium, Fishy	–	–	0.5-1.0
Draparnaldia	–	–	0.33	–
Eudorina	Faintly fishy	–	2.0-10.0	–
Entrtomorpha	–	–	0.5	–
Gloeocystis	Septic	–	–	–
Hydrodictyon	Septic	Yes	0.1	–
Microspora	–	–	0.4	–
Nitella flexilis	Bitter taste	Yes	0.1-0.18	–
Palmella	–	–	2.0	–
Pandorina	Faintly fishy	–	2.0-10.0	–
Protococcus	–	–	–	1.0
Scenedesmus	Grassy	–	1.0	–
Spirogyra	Grassy	Yes	0.12	0.7-1.5
Staurastrum	Grassy	–	1.5	–
Tetrastrum	–	–	–	1.0
Ulothrix	Grassy	–	0.2	–
Volvox	Fishy	–	0.25	0.3-1.0
Zygnema	–	–	0.5	–
<i>Cynophyceae:</i>				
Anabaena	Mouldy, Grassy, vile	–	0.2-0.48	0.5-1.0
Aphanizomenon	Mouldy, Grassy, sweet taste	–	0.12-0.5	0.5-1.0
Clathrocystis	Sweet grassy, vile	–	0.12-0.25	0.5-1.0
Coelosphaerium	Sweet grassy	–	0.2-0.33	0.5-1.0
Cylindrospermum	Grassy	–	0.12	–
Gloeocapsa	Red colour	–	0.25	–
Microcystis	Sweet taste	–	0.2	–
Oscillatoria	Musty, spicy	Yes	0.2-0.5	51
Rivularia	Mouldy, grassy	–	–	–

The most common method for iron removal from water is oxidation followed by sedimentation and filtration. In certain types of water treatment like pH correction and chemical oxidation can be carried out in addition to above mentioned processes.

**(a) Oxidation by Aeration**

The first stage of iron removal involves the oxidation of bivalent iron with oxygen present in air. Aeration also removes carbon dioxide and taste and odour producing substances. The rate of aeration depends on pH, alkalinity and organic content of water. Iron is oxidised at wide pH range. Increased aeration time is necessary for water containing carbon dioxide and hydrogen sulphide. Oxidation of iron on the other hand is retarded by the presence of humic acid.

**(b) Oxidation by Chlorination**

Oxidation of iron can be inhibited possibly due to binding of ferrous iron with organic substances, ammonia and other reducing agents. Chlorination can bring about oxidation of organic matter and other reducing agents in such conditions, which facilitates ferrous iron oxidation. Chlorination will oxidize iron without lime treatment for pH adjustment.

**(c) Oxidation by Potassium permanganate**

Potassium permanganate is more effective oxidising agent than chlorine. The reaction is independent of pH above 7.0 and is rapid, except in presence of hydrogen sulphide and organic matter where reaction time increases to 5-20 minutes prior to filtration.

**(d) Catalytic Method**

The process involves only oxidation and filtration and does not involve base exchange. In this method water is percolated through suitable contact material which oxidizes the iron. The contact material is made up of siliceous base exchange material, successively treated by solution of manganese chloride and potassium permanganate. It is used as filter as such or a layer of this material may be sandwiched between sand bed of pressure filter. Iron is oxidized when water percolates through this bed and also filters out. At intervals, filters should be backwashed to remove the deposits. The bed can be regenerated by potassium permanganate solution treatment.

**(e) Zeolite Plants**

Many times ground water or bottom strata of deep reservoirs contain iron in reduced state (i.e. its soluble form). In such condition Zeolite beds are used which takes up iron by process of ion exchange.

**5.9.2.3 O&M problems and remedial measures of typical IRP (Iron Removal Plants)**

Two types of such plants are described below:

**Compact type plant**

The process comprises of

- i) Spray Aeration through a grid of pipes to flush out  $\text{CO}_2$ ,  $\text{H}_2\text{S}$  and to improve pH level.

- ii) Trickling of aerated water through a contact catalytic media viz., limestone of 20 mm size or a combination of MnO<sub>2</sub> (Manganese dioxide) and lime; or hard coke, MnO<sub>2</sub> and limestone.
- iii) Sedimentation.
- iv) Filtration through Rapid Gravity Filter.
- v) Disinfection.

The structure consists of ordinary masonry or concrete. The aerator with contact media may be placed at the top of the sedimentation tank. Sedimentation tank may be rectangular with a length to breadth ratio of 3:1. The detention time may be around 3-5 hours. The surface loading may be around 25 m<sup>3</sup>/d/m<sup>2</sup>. Filter media shall consist of sand with effective size 0.5-0.7 mm and a depth of 750-1000 mm over a 450-600 mm deep gravel 3 to 50 mm size.

### **Operation and Maintenance**

1. The nozzles/orifices attached to the aeration pipe grid shall have their angles so adjusted as to ensure maximum aeration and to prevent loss of water. These nozzles/orifices shall require regular manual cleaning to remove incrustated iron. The residual iron deposits from inside the pipe grid shall be flushed out by opening end plugs or flanges. These operations should be repeated at least once in 2 months.
2. The limestone and other contact media require manual cleaning and washing at least once in 45-60 days.
3. The contact media bed should not remain exposed to sun for a long time to prevent hardening of bed by iron incrustation.
4. The sedimentation tank inlet baffle wall opening shall be cleaned of iron slime at least once in 45-60 days.
5. Sedimentation tank bed should be regularly scoured for removal of sludge.
6. Floc forming aid (coagulant aid) may be used for better coalescing and agglomeration.
7. The rapid gravity filter should have a water depth of about 1.2-1.5 m.
8. Since iron deposits create incrustation of filtering media, at least 100-150 mm of top sand layer of sand shall be scrapped and replenished with fresh sand at least once on 60 days. The whole bed may require replacement once in 2 years or so.
9. The characteristics of iron flocs are different from those of surface (river) water flocs. Due to the aeration process and contact of water with air, there may be incrustation of filter bed by residual oxidized deposits. To avoid this, common salt may be mixed with standing water and after 1-2 hours, the filter may be backwashed for better results and longevity of sand bed.

### **Package Type IRP (Iron removal plant)**

The process incorporates the following steps:

- i) Dosing of sodium aluminate solution to the raw water pumping line, to raise pH up to the optimum level and to ensure subsequent coagulation, as it is an alkaline salt.
- ii) Injection of compressed air for oxidation of dissolved iron.

- iii) Thorough mixing of raw water, sodium aluminate and compressed air for proper dispersion in a mixing chamber of M.S. welded cylindrical shell equipped with one M.S perforated plate fitted inside through which the mixture flows upward.
- iv) Passing the mixture through an oxidation chamber of M.S. shell, in which a catalytical media of MnO<sub>2</sub> (Manganese dioxide) is sandwiched between two M.S. perforated circular plates. (through which the mixture flows).
- v) Passing the above mixture in to a M.S. welded cylindrical shell type of filter in which dual media comprising of Anthracite Coal or high graded bituminous coal, 3-6 mm size, is placed at the top and finer sand of 0.5-1.00 mm size with 98% silica content is placed at the bottom, over a gravel supported bed. At the bottom is the under drainage system. Backwashing is done by air agitation followed by backwash with water.
- vi) Disinfection.

### **Operation and Maintenance**

1. Sodium aluminate should be so mixed as to raise the pH up to 8.5-9.5.
2. The quantity of compressed air should be so regulated as to achieve the optimum oxygen level.
3. The MnO<sub>2</sub> (Manganese dioxide) may need replacement every 6-9 months.
4. The inside of both the mixing chamber and oxidizing chamber should be coated with epoxy resin to avoid corrosion and incursion.
5. The filtration rate should be controlled within a range of 100-125 lpm/m<sup>2</sup>.
6. The inlet pipe at the top should be fitted with a cylindrical strainer to obviate the possibility of loss of anthracite coal during washing.
7. After backwashing, rinsing of filtering media for at least 5 minutes has to be done to resettle the filtering media before normal functioning.
8. Where the iron content is very high the whole media like MnO<sub>2</sub> (Manganese dioxide), anthracite coal, sand, gravel, strainers etc. require replacement and replenishment at least once a year for effective functioning and performance. The interior epoxy painting should also be done simultaneously.

## **5.10 MANGANESE**

### **5.10.1 OCCURRENCE**

In water manganese is usually present in soluble ionized form- manganese ion and manganese hydroxide. It can form complexes with bicarbonates, sulphates, silicates as well as with certain organic matter. It is often associated with iron and ammonium.

### **5.10.2 REMOVAL OF MANGANESE**

Manganese can be removed following the same procedure as for iron removal i.e. by oxidation, followed by sedimentation and filtration. Removal of manganese is a little difficult and complicated as compared to the iron removal. Oxidation of manganese is carried out by using following methods.

***(a) By Aeration***

Oxidation by aeration needs high pH of at least 8.5-10 with lime treatment to enhance the oxidation of manganese on coke or sand beds coated with manganese oxide; however, high removal is not assured.

***(b) By Catalytic Action***

Oxidation by catalytic action of pyrolusite ore is used in absence of air to change complex manganese compound to manganese hydroxide which is further oxidized to insoluble manganese hydroxide by aeration in second contact bed followed by filtration.

***(c) By Chlorination***

Manganese is oxidized by free residual chlorine at pH 8.4-10. The dose of chlorine should be selected to provide about 1.25 ppm free chlorine for each ppm manganese to be oxidized. Oxidation is aided by the use of 0.2 ppm copper sulphate, the copper acting as catalytic agent.

***(d) By Potassium Permanganate***

Potassium permanganate provides better oxidation than chlorine and the reaction is independent of the pH in range above 7.0; so manganese may be oxidized without lime treatment. The dose is about twice the content of manganese.

***(e) By Manganese Zeolite***

Manganese zeolite is an active contact material, which removes 1.63 kg. of manganese per cubic meter of zeolite per cycle by oxidation. Regeneration of zeolite bed can be accompanied by backwashing with solution of 3.26 kg. of potassium permanganate per cubic meter of zeolite. Incomplete regeneration will result in passage of manganese through contact beds.

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## CHAPTER 6

# DISINFECTION

### 6.1 INTRODUCTION

The disinfection of potable water is almost universally accomplished by the use of gaseous chlorine or chlorine compounds, because of the limitations of other procedures, for example ozone, ultraviolet light, chlorine dioxide etc.

Chlorine is easy to apply, measure and control. It persists reasonably well and it is relatively inexpensive.

#### 6.1.1 OBJECTIVE OF CHLORINATION

The primary objectives of the chlorination process are disinfection, taste and odour control in the system, preventing the growth of algae and other micro organisms that might interfere with coagulation and flocculation, keeping filter media free of slime growths and mud balls and preventing possible built up of anaerobic bacteria in the filter media, destroying hydrogen sulphide and controlling sulphurous taste and odour in the finished water, removing iron and manganese, bleaching of organic colour.

It can also be used for flushing pipeline before it is brought into operation after carrying out repairs etc. However in such case chlorinator is adjusted to apply chlorine or hypochlorite solution at the rate of 50 p.p.m. Heavily chlorinated water should be allowed to stand in the pipeline for at least 30 min. and preferably for 12 hours before being replaced with potable water.

For more details please refer to Manual on "Water Supply & Treatment", (1999 Edition).

#### 6.1.2 PRINCIPLES OF CHLORINATION

- Chlorine reacts with water to form hypochlorous acid (HOCl) and Hydrochloric acid (HCl). This hydrolysis reaction is reversible. The hypochlorous acid dissociates into hydrogen ions ( $H^+$ ) and hypochlorite ions ( $OCl^-$ ), free available chlorine is hypochlorous acid and hypochlorite ions.
- This free available chlorine can react with compounds such as ammonia, proteins, amino acids and phenol which may be present in the water, forming chloramines and chloro-derivatives which constitute the combined chlorine.
- Chlorination in presence of humic acid and fulvic acid forms Trihalomethane (THM) which is a health hazard.
- The combined available chlorine has less disinfecting properties as compared to free available chlorine.
- For more details please refer to Manual on "Water Supply and Treatment", (1999 Edition).

### 6.1.3 CHLORINATION PRACTICES

For details please refer to Manual on "Water Supply and Treatment", (1999 Edition).

### 6.1.4 METHODS OF APPLICATION OF CHLORINE

Disinfection is carried out by applying chlorine or chlorine compounds. The methods of application are as follows:

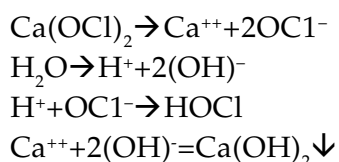
1. Preparing weak solution by bleaching powder, HTH etc.
2. Preparing weak solution by electrolysing brine solution.
3. By adding chlorine either in the form of gas or solution prepared from dissolving chlorine gas in small feed of water.

## 6.2 DISINFECTION BY BLEACHING POWDER

### 6.2.1 GENERAL

Bleaching powder or calcium hypochlorite is a chlorinated lime, which contains about 25 to 34% of available chlorine by weight. Chlorine being a gas is unstable and as such it is mixed with lime to retain its strength for a longer period, as far as possible. The bleaching powder is hygroscopic in nature. It loses its chlorine strength rapidly due to storage and hence should not be stored for more than three months. The method of chlorination by bleaching powder is known as hypo-chlorination.

The general reaction of ionisation of bleaching powder when mixed with water is as follows:



The calcium hydroxide settles as precipitate.

The combined action of hypochlorous acid and hypochlorite ion brings about the disinfection of water.

### 6.2.2 PREPARATION OF SOLUTION

- i) The concentrated solution of bleaching powder is prepared in one or two tanks of capacity suitable for 24 hours requirement.
- ii) The tank inside should be of glazed tiles or stoneware and should be covered.
- iii) The powder is first put on a perforated slab placed longitudinally inside the tank at a higher level, with respect to bed level of tank.
- iv) Water is sprinkled on the powder through a perforated pipe above this perforated slab. The solution of bleaching powder & water now enters the tank.
- v) The solution is rotated for thorough mixing of powder with water by a hand driven/motor-reduction gear operated slow speed stirrer.
- vi) The precipitates of calcium hydroxide settles at the bottom of the tank. The super-natant water, which contains  $\text{OCl}^-$ ,  $\text{Cl}^-$  is now ready for use as disinfectant. (See fig. 6.1)



### 6.2.3 DOSING OF SOLUTION

- i) The solution is discharged to a small measuring tank at a lower level through PVC pipe or any other material resistant to chlorine. The level of water in this tank is maintained constant through a float valve. A micrometer orifice valve discharges the solution at any pre-set rate, by adjustment on the scale fitted on it. The solution is dosed to the clear water channel by gravity at the time of entry to clear water reservoir. The waste precipitates at the bottom of tanks are taken out occasionally by scour valve. The system is shown in figure 6.1.

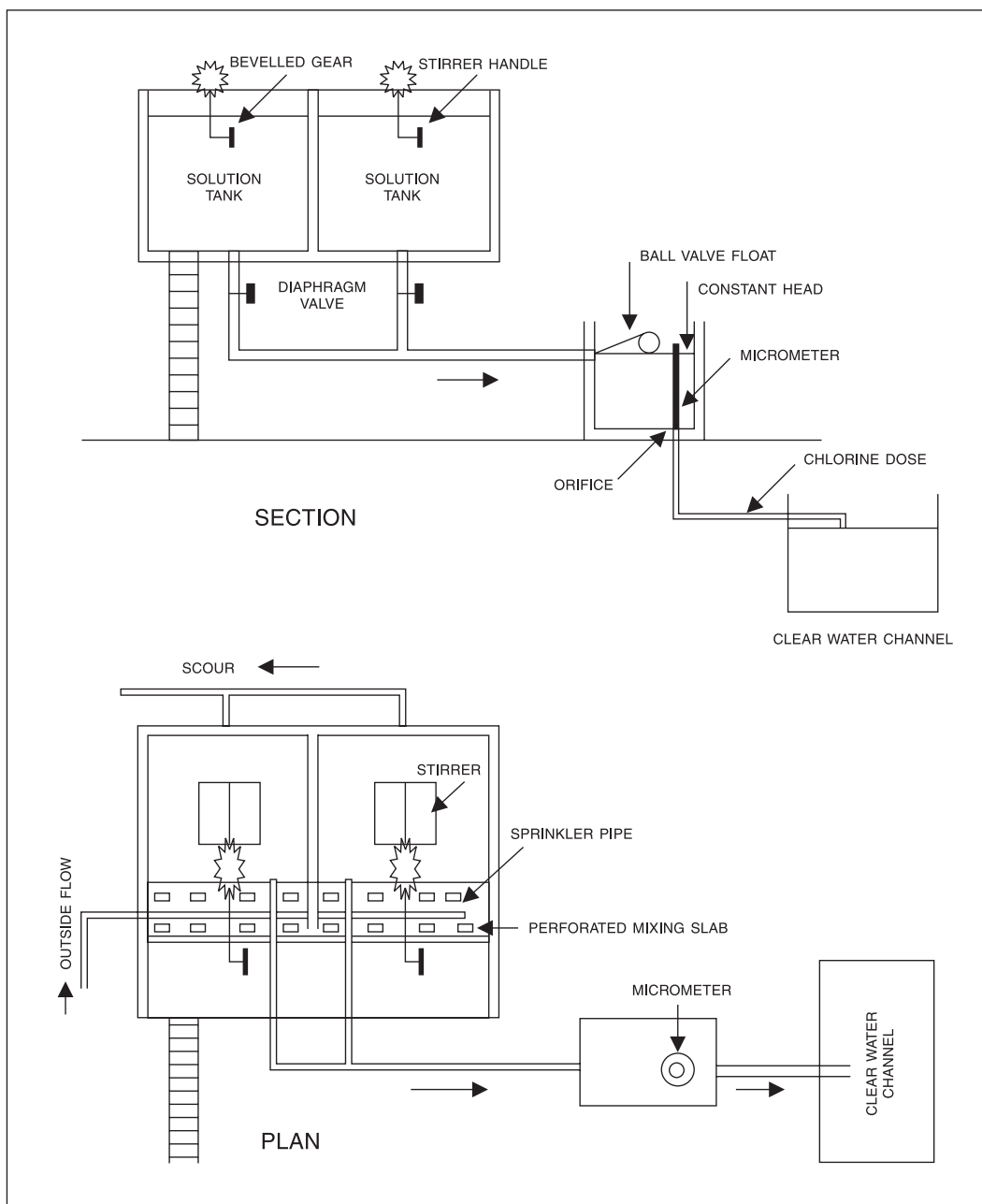


FIG. 6.1 TYPICAL BLEACHING SOLUTION DOSING

- ii) The dose has to be monitored properly, depending on the desired residual chlorine required in clear water reservoir.

#### **6.2.4 PRECAUTIONS**

- i) The operating personnel should use hand gloves, aprons and other protective apparel, while handling and mixing.
- ii) The valves, stirrer, tanks, plumbing arrangements require renovation at every 6 months or so.

### **6.3 ELECTROCHLORINATOR**

#### **6.3.1 PRINCIPLE OF OPERATION OF ELECTROCHLORINATOR**

Chlorine is instantly produced by electrolysing brine solution. Common salt is mixed with water to prepare brine solution. This solution is passed through an Electrolyser of electrodes comprising of anodes & cathodes, which are energised by D.C. current to produce NaOCl.

Overall reaction is as follows:



This solution of sodium hypochlorite is used as disinfectant.

#### **6.3.2 DESCRIPTION OF ELECTROCHLORINATOR**

The electrochlorinator set basically comprises of two compartments one comprising of Brine solution tank, electrolyser, cooler, etc. and the other comprising of compact panel board (rectifier). The schematic diagram as well as various parts of electrochlorinator are given in figure-6.2 for a typical electrochlorinator.

Normal life of electrochlorinator is 12 years provided reconditioning of the electrodes at regular interval of four years is carried out. These chlorinators are available at various capacities ranging from 50 gm/hr. to 18 kg/h of active chlorine production. (Refer fig. 6.2) The electrolyser consists of a number of electrodes as required. For 500 gm./hr. capacity plant, there are 6 nos. of electrodes comprising of anodes and cathodes. The rectifier is having facilities for auto tripping if there is variation in certain set conditions.

#### **6.3.3 PROCESS DETAILS OF ELECTROCHLORINATOR**

1. Make a concentrated brine solution @ 310 gm. of industrial grade salt with 97% purity or more salt in 1 litre of water in a brine solution tank. After pouring salt, the mixture is stirred either manually or through motor driven reduction gear arrangement. In order to reduce the capacity of brine solution tank, a concentrated solution is prepared.
2. Allow brine solution to flow inside the electrolyser at a controlled rate as required for a chlorinator which depends upon active chlorine production. But the quantity of water in brine solution tank is to be replenished, for which fresh water at the same rate is simultaneously sent after controlling the flow, through one of the flow meters (flow meter no. 2) placed in front of brine solution tank.
3. Dilute the concentrated solution with fresh water to attain a strength of 30 gm of salt per litre. Accordingly, fresh water is added to electrolyser, after controlling flow through flow meter No.1 (for 500 gm/h capacity plant, this rate is about 65 l/h) It

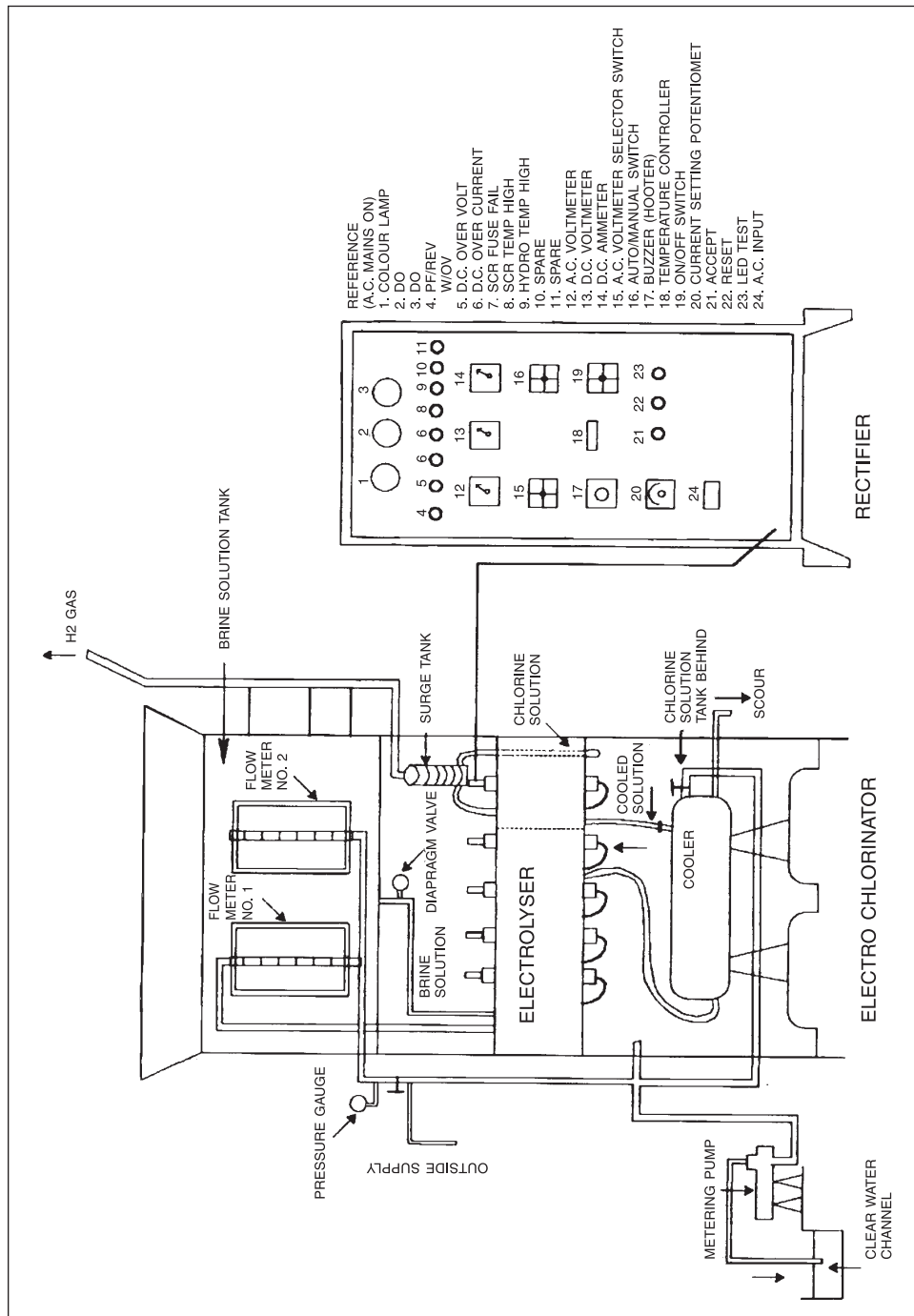


FIG. 6.2 ONSITE PRODUCTION OF HYPO-SOLUTION FROM COMMON SALT

may be mentioned here that for effective functioning of flow meters to control flow, one valve is installed in the common line and pressure through flow meters is controlled at specified pressure rating.

4. After filling the electrolyser with the required solution of salt and water, D.C. power supply through rectifier is put on.
5. The electrolysis process evolves heat. The maximum permissible temperature is of the order of ambient temperature + 12 degree centigrade.

6. In order to control the temperature, the aqueous solution is, required to be cooled through a cooler placed below the electrolyser chamber. The solution is introduced at one end of the cooler and fresh cold water is circulated through coil pipe placed inside the cooler. The cold water used for cooling is continuously discharged to a sump connected with clear water reservoir. The electrolysed solution after cooling is continuously introduced to the 2nd chamber of the electrolyser.
7. After complete electrolysis process, the solution of sodium hypo chlorite (NaOCl), Sodium chloride (NaCl), Water (H<sub>2</sub>O), hydrogen gas (H<sub>2</sub>) is now passed on to a surge tank which is placed on the rear side of electrolyser i.e. just below the brine solution tank. The hydrogen gas is allowed to escape through a pipe fitted at the top of the surge tank. The solution is now collected through an outlet pipe placed below the surge tank into a solution tank located below.
8. The concentration of active chlorine in the form of sodium hypochlorite solution is, therefore, 7.00 gm per litre.
9. The solution is now taken from the chlorine solution tank and dosed to the clear water reservoir through metering pump installed by the side of the electrochlorinator at the rate at which it is required.

#### **6.3.4 OPERATION OF ELECTROCHLORINATOR**

- i) For starting the operation, open the brine solution diaphragm valve for a flow to electrolyser. Flow meter No.1, for fresh water is now opened, so that dilution starts inside the electrolyser. The pressure of incoming fresh water should be 1 to 1.1 kg/cm<sup>2</sup>. As soon as the outflow from surge tank starts, electrical operation through rectifier is to be started.
- ii) Before starting rectifier, A.C MCB is to be put in 'ON' position. A.C. mains supply in 3 phases is to be checked through indicator lamps. A.C. voltage reading is checked so that requisite voltage of 355 V to 455 V comes to rectifier. By rotating potentiometer clockwise, the D.C. volt and D.C. ampere are set to 23-25 V & 95-100 Amps, respectively. Now electrolysis process is started.
- iii) Before closing the operation, brine solution diaphragm valve is to be closed and fresh water is to be allowed inside the electrolyser for cleaning of electrodes for 15-20 mins. Simultaneously, potentiometer is to be operated in anticlockwise direction slowly to set to "zero" position. Now AC main MCB is put to "OFF" position.
- iv) If there is any sudden power trip, potentiometer is to be set to 'Zero' position to avoid any sudden shock to the whole system, if power comes back again, immediately. In that case, brine solution diaphragm valve is also to be closed & only fresh water is allowed through flow meter No.1 for 10-15 minutes.
- v) If the temperature of hypo solution is increased (i.e. more than ambient temperature + 12°C), it is sensed through sensor & there will be auto tripping. Potentiometer is then brought zero position. Then brine solution is closed & fresh water is circulated through flow meter No.1 for 20 to 25 minutes, before re-starting. The cooler is checked conveniently to see its effectiveness.

- vi) Before closing down of the electrochlorination the flow meter No.1 will be operated for 15 to 20 minutes for cleaning the electrodes.

If the brine solution concentration is reduced, then the D.C volt will rise from 23 to 25 V & there will be corresponding fall of ampere reading from 95 to 100 A. At that time, the concentration is to be restored by adding salt & water.

- vii) Normally 4.5 kg. of common salt (NaCl) is required to produce 1 Kg. of chlorine with 4.5 kWh power.

### **6.3.5 MAINTENANCE OF ELECTROCHLORINATOR**

1. If there is deposition of chemicals on the body of the electrodes, then D.C. voltmeter will indicate high voltage & concentration of hypochlorite solution will reduce, which can be detected on checking chlorine content. In such a situation electrodes are to be cleared.
2. If there is any fault, at first, all fuses, contact points & their joints are to be checked.
3. D.C. voltage must be kept within the range of 23 volt to 25 volt. The rectifier shall be cleaned and checked occasionally so that all electrical connections remain intact.
4. Plumbing arrangements shall also be cleaned from time to time, if choked with salt deposition.
5. Due to accumulation of positive and negative ions on the anodes and cathodes of the electrolyser, the efficiency of electrolyser process gets reduced and as such the electrodes require cleaning every 25 to 30 days with water jet i.e. without touching them by hands.
6. The staff will require special training for routine maintenance and annual maintenance contract to the specialised agency could be considered for trouble free maintenance of the system.

## **6.4 CONVENTIONAL CHLORINATION**

The conventional chlorination facility i.e. adding chlorine for disinfection of water treatment consists of three essential parts:

1. Chlorine supply system
2. Metering system
3. Diffuser system

In addition to above, there are ancillary equipment, safety equipment, metering & control instrumentation and chlorine residual analysers.

### **6.4.1 CHLORINE SUPPLY SYSTEM**

#### *a) Chlorine Gas Supply System*

In gas supply system if the header run passes through an area where ambient temperature may fall below the temperature of the gas leaving the supply containers,

it is necessary to install a pressure reducing valve in the gas supply system. This valve prevents reliquefaction of the gas downstream of it. It is also a good practice to install liquid chemical trap upstream of the valve. The trap will serve to prevent liquid chemical from entering and flashing across the valve seat resulting in poor pressure regulation (Fig.6.3).

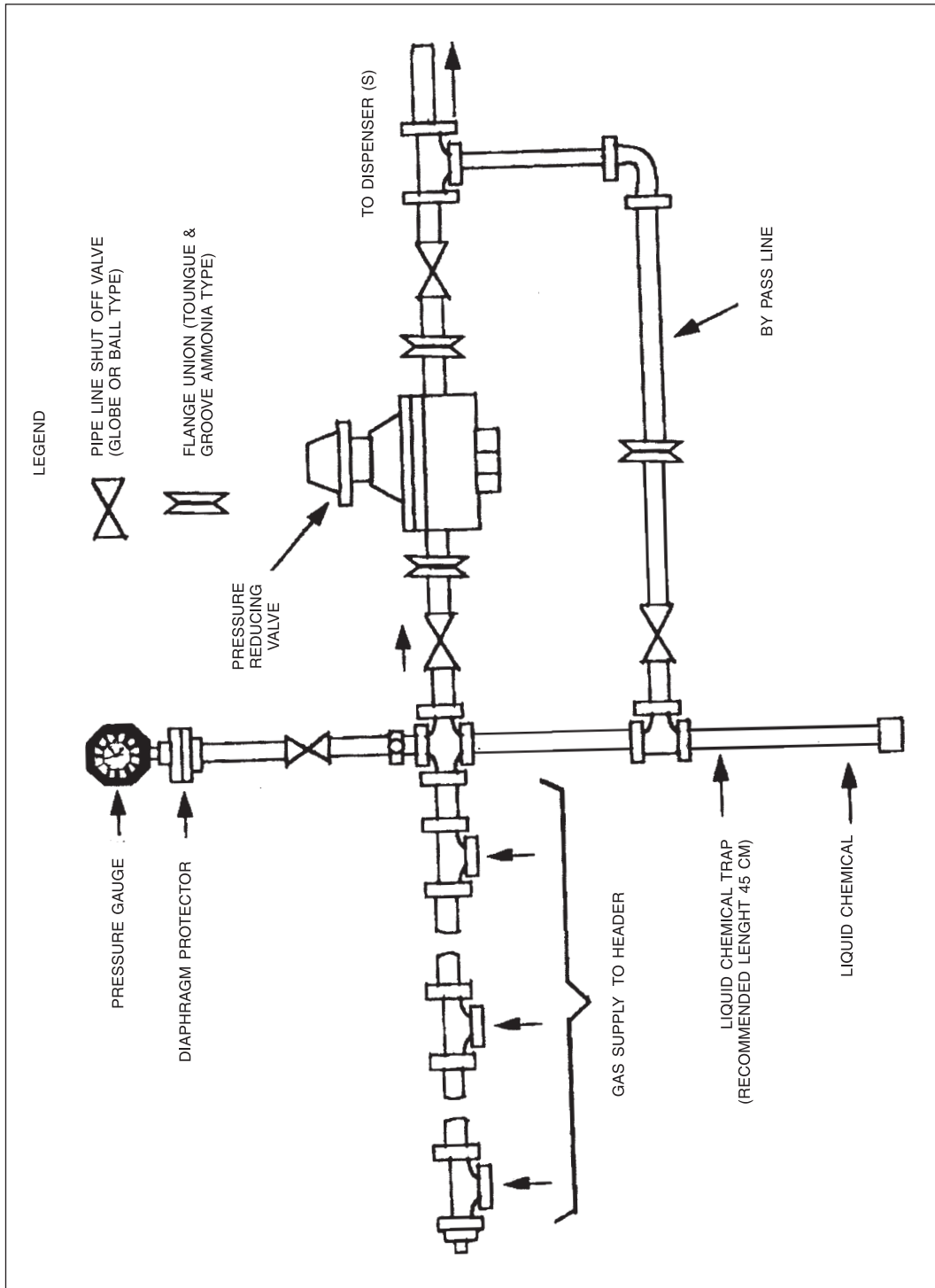


FIG. 6.3 GAS SUPPLY SYSTEM

**b) *Evaporator Supply System or Liquid Chlorine Supply System***

By means of an evaporator, liquid chlorine is converted into gaseous form. The details of Evaporator have been given in Manual on "Water Supply & Treatment" (1999 Edition).

Chlorinator operates the evaporator as per its requirement of chlorine. If requirement of chlorine gets reduced, pressure in the evaporator increases causing liquid chlorine level in it to reduce, thereby reducing its area, which in turn reduces heat transfer. On the contrary, if requirement of chlorine increases, the pressure in the evaporator decreases. As a result of it more liquid is pushed into the evaporator where it is evaporated at higher rate.(Refer Fig.6.4).

**c) *Chlorine Gas Filter***

Small chlorinators usually have same sort of built-in chlorine filter. However, any installation using ton containers (tonners) should have a chlorine gas filter as close as possible to the last cylinder, and always upstream of any external reducing valve. Commonly used material for this purpose is glass wool.

**d) *External Chlorine Pressure Reducing Valve***

Any installation using the variable vacuum system for automatic control requires such a valve to reduce the chlorine supply pressure to 2 to 2.75 kg/cm<sup>2</sup> ahead of the chlorinator to ensure the maximum possible accuracy of the control system. Secondly, this valve also reduces the pressure in the chlorine supply header to prevent re-liquefaction of the gas in the header between the last cylinder connected and the chlorinator (Fig.6.4).

## **6.4.2 METERING SYSTEM: CHLORINATOR**

A chlorinator is a device for feeding chlorine to a water supply. It also serves as gas metering device. Chlorinators are classified into two categories.

- Pressure type
- Vacuum type

### **6.4.2.1 Pressure Type Chlorinator**

It consists of a stop valve, gas filter, pressure reducing valve, regulating valve, an orifice tube with manometer and moisture seal.

The pressure type may be further classified into two groups on the basis of gas or solution feed.

**a) *Dry Feed Type***

These are not used in water treatment presently due to safety reasons.

**b) *Aqueous Solution Feed Type***

It has been established that the only satisfactory method of applying chlorine gas to water is to dissolve the measured feed of gas in a minor flow of water which is then added to the main bulk of the water. For this purpose three distinct types of solutionisers are available. In these systems minimum 1500 litres of water is required per kg of chlorine for making chlorine solution. If the pressure is increased the quantity

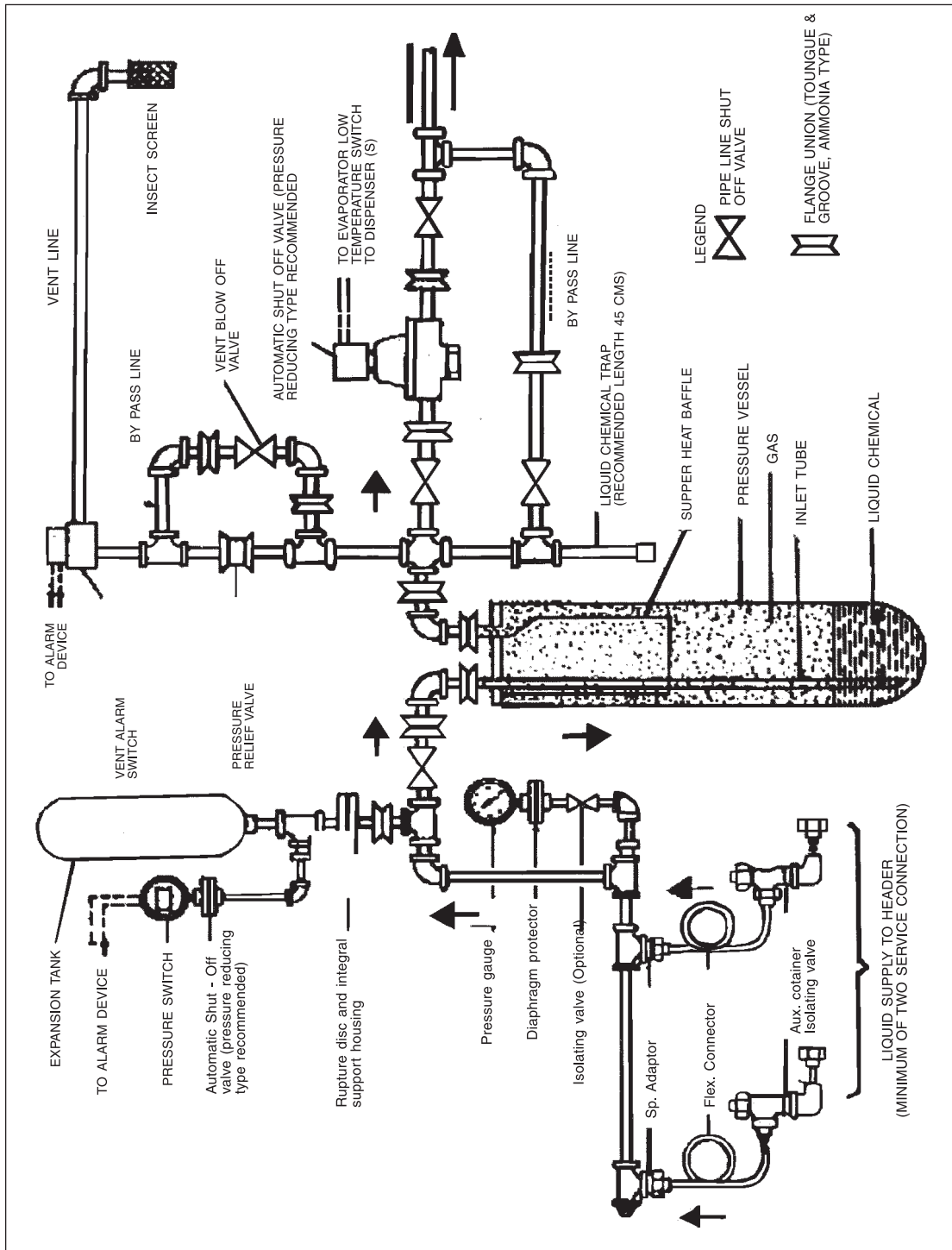


FIG. 6.4 LIQUID WITHDRAWAL SYSTEM

required for making the solution is decreased. The temperature of the water used for preparing the solution must be more than 10°C. If the temperature of the water is less it must be heated by safe methods before using for solution.

- Gravity feed or Absorption tower feed type.
- Application of the chlorine into a main under pressure i.e. Injector solutioniser.



### 1. Gravity Feed

This can be used where the hydraulic gradient at the point of injection is below the level of the base of the tower. The tower is an ordinary tubular vessel filled with pebbles for percolation of water. A perforated tray is kept at the top of the tower to have an even distribution of water. A perforated PVC or ebonite tube is situated centrally in the tower for efficient and uniform distribution of gas. The water while trickling absorbs the gas and the resulting chlorinated water is delivered through an outlet at the base of the tower. Further it is conveyed to the point of application by a rubber hose. For more details please refer Manual on "Water Supply & Treatment" (1999 Edition).

### 2. Injector Solutioniser

It serves the dual purpose of the conversion of chlorine gas into a chlorine solution and of injecting it into water mains under a hydraulic pressure. The metered gas is introduced to a water-sealed cavity surrounding the injector. The water emerging with high velocity from the jet of injector absorbs chlorine gas due to partial pressure developed around the throat. The resulting solution is passed through a recovery zone to regain the pressure and subsequently injected into water mains (Fig 6.5).

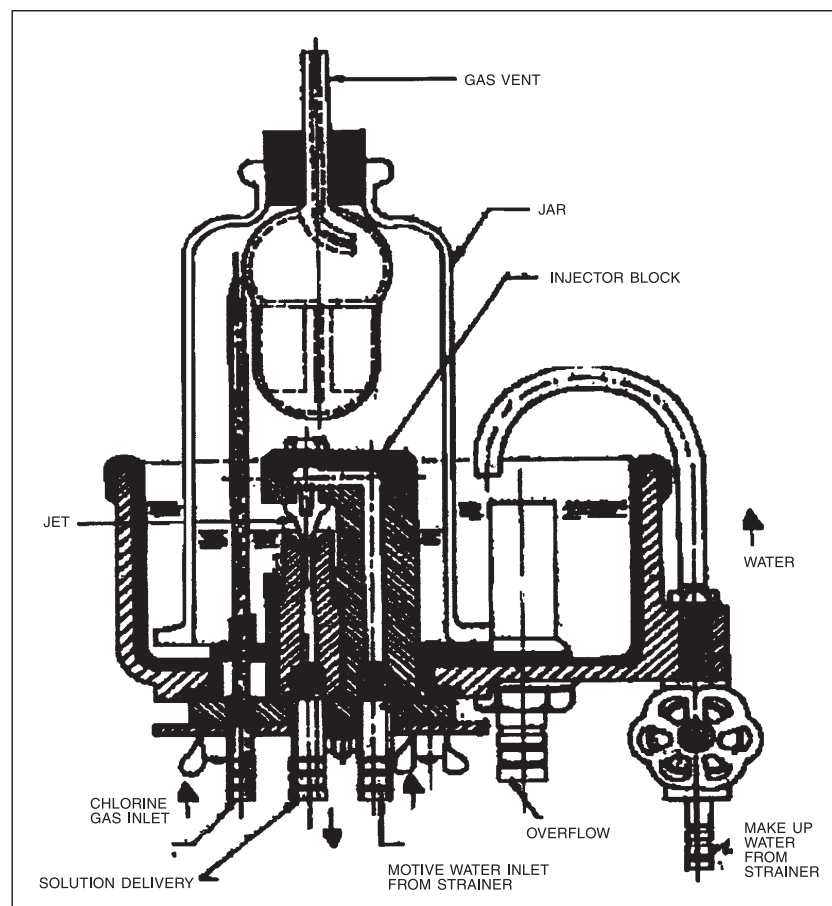


FIG. 6.5 CHLORINE GAS APPARATUS INJECTOR (PRESSURE TYPE) SOLUTIONIZER

It will be seen from the figure that make up water connection maintains the seal of the water across the injector. Hence chlorine does not leak through the jar unless pressure in the jar is increased. For letting the gas outside a gas vent is provided through HCl seal. This arrangement also serves the purpose of vacuum breaking in the system.

#### **6.4.2.2 Operation of Pressure Chlorinator with Aqueous Solution – Gravity Feed Type**

##### **(a) Start up of the chlorinator**

1. Turn on and adjust the water supply to the solutionizer.
2. With all cylinder connecting valves and regulating valves closed, open one cylinder valve; check the joint for leakage.
3. Slowly open the cylinder connecting valve and stop valve (when fitted). Check for leaks.
4. Open the cylinder connecting valves on any other cylinders that are to be brought into use if connected in parallel. After checking the joints for leakage, open the cylinder valves.
5. Slowly open the regulating valve until the meter indicates the required rate of discharge.

##### **(b) Shutting down**

1. Close the cylinder valve and wait until the meter reading returns to zero.
2. Close stop valve when meter shows zero.
3. Shut off the water supply to the tower.

#### **6.4.2.3 Operation of Pressure Chlorinator with Aqueous Solution-Injector Solutionizer Type**

##### **(a) Start up of the Chlorinator**

Carefully check all connections and make certain that all unions, hose clips are in order.

- Close the stop valve in the operating water supply and open the regulating cock when one is fitted in series with it. A regulating cock is incorporated except when a booster pump or pressure reducing valve is used.
- If the water pressure is to be 'boosted', start the pump.
- Open the water stop valve to the full extent immediately. It is important to open this valve quickly in order to apply full pressure as soon as possible.
- The make up water valve on the side of the tray should next be set so that there is a small surplus of water passing over the overflow tube.
- Close the chlorine regulating valve and stop valve if fitted and also the cylinder connecting valve. Open cylinder valve slowly and check the union joint on the cylinder for leakage.
- In the case of leakage attend to the same and set right the union joint.
- Slowly open the cylinder connecting valve attached to this cylinder and test for leakage at all joints between the cylinder connecting valves and the control panel.

- Open the chlorine stop valve (when fitted) and test for leaks up to the chlorine regulating valve.
- Open the cylinder connecting valves on the remaining cylinders. Test the unions on the cylinders for leakage.
- Open the chlorine regulating valve very slowly until the required rate of flow is indicated by the meter.
- The following conditions should then be noticed in the injector unit.
  - (a) The acid in the pressure released bulb should have risen about 6 mm to 12 mm up inside the inner tube.
  - (b) The quantity of water passing over the overflow should have increased slightly and there should be further increase if the flow of chlorine is set at a higher rate.
- It may then be possible to reduce the quantity of water by the injector, by reducing the pressure, either by throttling the regulating cock; by lowering the discharge pressure from the water supply pressure reducing valve or, by adjusting the pressure at which the by-pass type pressure relief valve comes into operation, according to the water supply arrangement incorporated. Such an adjustment is indicated when the suction created by the injector is such that it becomes impossible to maintain the seal in the tray. The adjustment should be made with the maximum flow of chlorine and when the pressure against which the injector is operating is also at maximum i.e. when the operating conditions are most exacting. The minimum suitable operating pressure is that which will deal with the chlorine without the acid in the lower part of the pressure release being forced into the upper part. When this condition arises, the acid seal is broken and chlorine is allowed to escape via the vent pipe.
- Following the adjustment of operating water supply, temporarily shut off the chlorine and, if necessary, reset the make up water valve until there is again a small surplus passing over the overflow. This volume is not critical from an operating point of view but it is desirable to avoid undue wastage of water.

**(b) Shutting down**

1. Close the chlorine stop valve (or other cylinder connecting valve when there is no stop valve) and wait until the meter reading returns to zero.
2. Shut off the water supply to the solutionizer by means of the stop valve, and stop the booster pump when one is used for the supply.

N.B. For a prolonged stoppage close the cylinder valves and then the cylinder connecting valves before closing the stop valve.

**6.4.2.4 Vacuum Type Chlorinator**

In this type of chlorinator, chlorine is handled below the atmospheric pressure. The vacuum system has several advantages:

- It is the easiest method of dissolving chlorine in water.
- Chlorine is easily handled when in solution.

- This is the most accurate way of metering chlorine gas since a constant density is maintained under vacuum and it is not affected by ambient temperature changes.
- Operation under vacuum is safer than operating under pressure.
- A metering system can be easily designed to stop automatically if the vacuum should fail.

It consists of a gas filter, pressure regulating valve, variable area flowmeter (Rotameter), vacuum regulating valve, pressure vacuum relief valve, drain valve and injector assembly. (Fig 6.6)

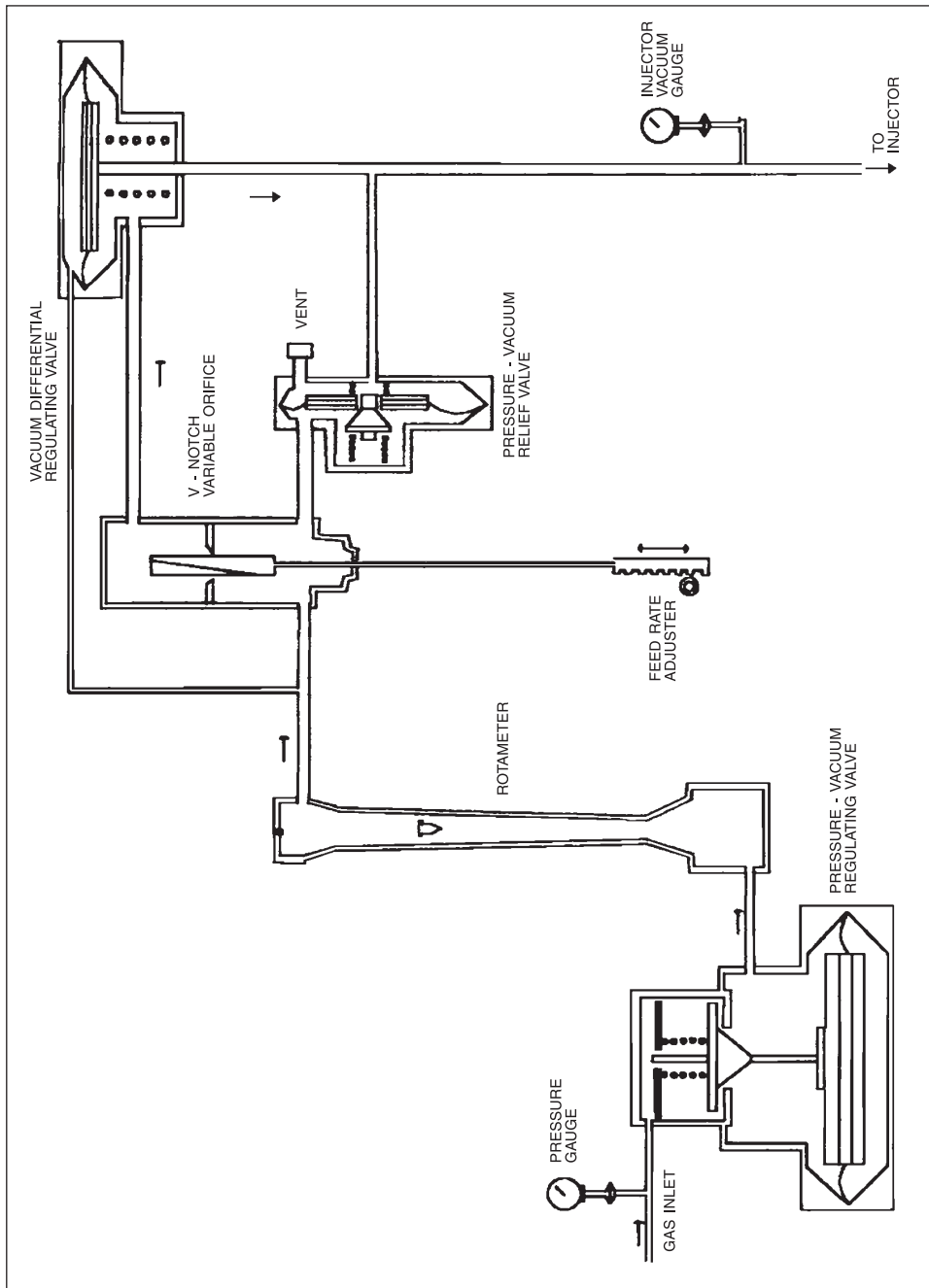


FIG. 6.6 TYPICAL CHLORINATOR

If the system is designed for chlorine gas withdrawal, the following procedure for starting up the system is adopted.

#### **6.4.2.5 Start up of Gas Chlorine System**

1. First start the booster pumps and make certain that the hydraulic conditions are satisfactory. For that purpose see the delivery water pressure & injector vacuum gauge reading. If the conditions are satisfactory, the vacuum gauge should show reading above 590 mm of Hg. If the chlorinator is not equipped with vacuum gauge, remove the tubing at the injector vacuum inlet and place a hand over the opening. If the injector is performing properly, the suction will be felt instantly on the portion of the hand over the opening. But it is advisable to have a vacuum gauge for proper operation of the plant with safety.
2. Check that all the chlorine valves on the supply line to chlorinators are closed.
3. When the injector system is functioning properly, open the valve of chlorine cylinder partially to allow the gas. Chlorine container should be connected to the system and kept ready before starting the plant.
4. Verify that all of the tubing, manifold and auxiliary valve connections are correct and that all union joints are properly gasketed. Check the leakage with ammonia stick and if there is any leakage, close the cylinder valve immediately and attend to the leaking joint to make it leak proof.
5. Check all the joints between cylinder valve to end.
6. Open the chlorine valve slightly to injector and check all the tubing and components of chlorinators for leakage. Attend if necessary by closing inlet valve. If there is no leak, then the chlorinator is ready for further testing.
7. Open fully the chlorinator gas inlet valve and check the chlorinator for range, automatic control and so on.
8. If at any stage leakage of chlorine is found, close the cylinder valve. Allow the gas in the system to be consumed through injector and then attend for leaking joints.
9. If the leakage is due to missing gaskets etc., close the cylinder valve. Leave the site immediately for safe area. With the help of breathing apparatus carry out the gas evacuation procedure through the chlorinators.
10. After all leaks have been corrected the next step will be to see that the chlorinator will reach its maximum capacity as specified. This is the most important operative criteria of the chlorinator installation.
11. If the chlorinator is not giving specified dose check for injector vacuum and chlorine pressure in the system and attend to the defects. The fault is normally in the hydraulics of the injector system. The next likely place is within chlorinator itself. A malfunction in either place is reflected by a low vacuum reading on the injector vacuum gauge.
  - i) The first step in this case is to check the vacuum leak within the chlorinators. If the leak is major, it can be discovered by shutting off the injector water suddenly and using ammonia on all the joints. This sudden removal of vacuum will create

slight pressure and chlorine will be expelled into atmosphere. Very small leak will not show up in this procedure.

- ii) Then check for 'O' ring seal in metering tube, vacuum relief valve, for defective spring or seat etc. and attend to it.
- 12. Vacuum will be affected due to long vacuum line between injector and chlorinator. If this is filled with air, the large amount of air reduces injector vacuum. Moreover if this line is leaking it will also reduce the vacuum.

Like a long vacuum line, a long chlorine solution line will also affect the injector vacuum. The air in this line, therefore needs to be removed.

- 13. Defective injector may also affect vacuum.

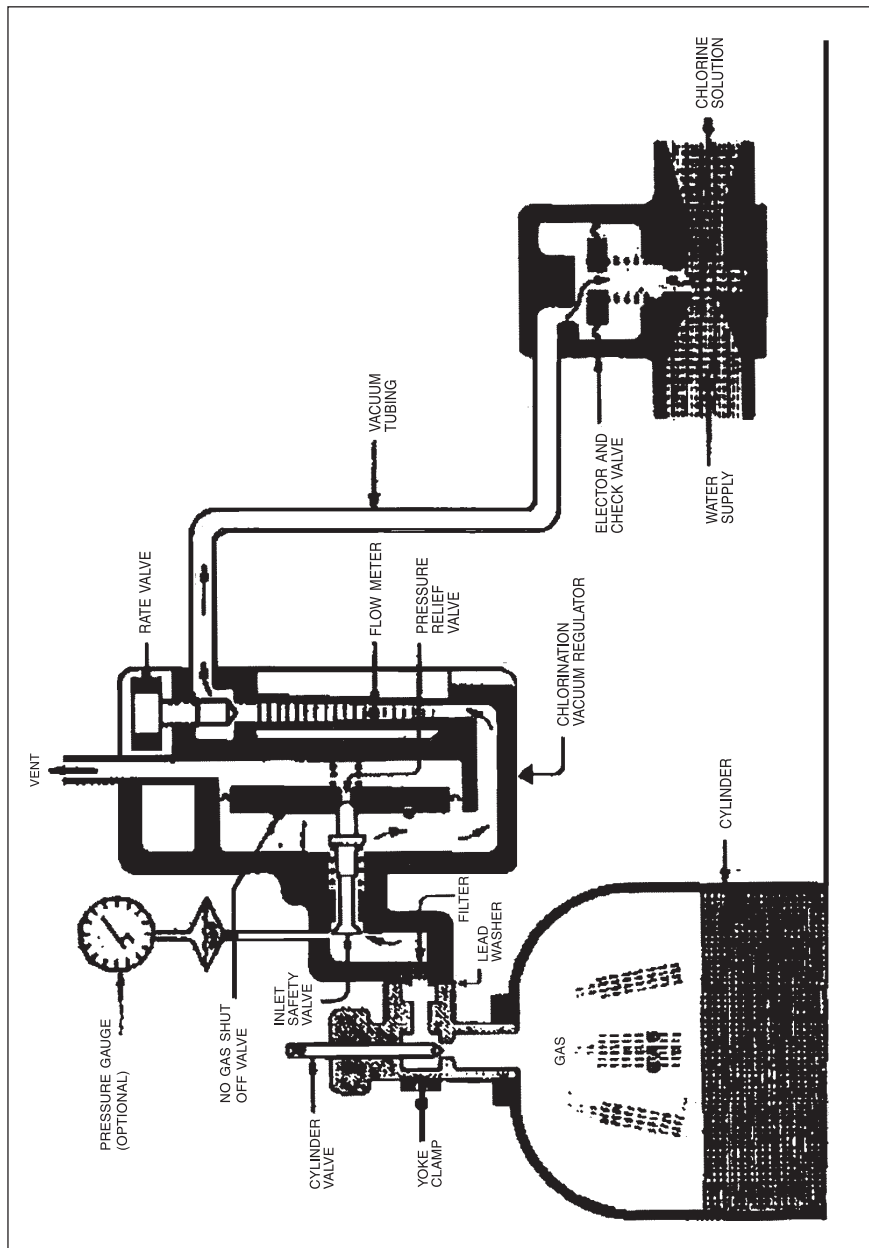


FIG. 6.7: CYLINDER MOUNTED CHLORINATOR

#### **6.4.2.6 Start up of Liquid Chlorine System**

If the system is designed for liquid withdrawal, the following procedure should be adopted for starting it up.

The procedure for start up on a liquid system is similar to gas system except for the role of evaporator. The evaporator is an extension of chlorine container system. Whatever happens in the container reflects into the evaporator pressure changes. The danger existing in liquid system is the possibility of trapping liquid chlorine in a pipe line. If this occurs and there is a significant rise in the ambient temperature, the liquid chlorine will expand & rupture the pipe line. For this reason, the liquid line between the evaporator & chlorine supply system should always remain open while the evaporator is operating. From safety point of view, rupture disc system with expansion chamber is provided on this line.

The first step preparatory for starting up a liquid system is to verify that the system is dry, because the moisture after coming in contact with liquid chlorine & metal of container forms ferric chloride which will pass through the chlorine control mechanism with stoppage of chlorine. Whenever this occurs the entire chlorine system must be flushed with water & thoroughly dried. In addition to this, chlorination equipments must be dismantled and cleaned.

When the operator is convinced that the chlorine supply system is clean & dry, the next step is to start up the evaporators. This is done by filling the water bath and adjusting the control devices. When the water bath reaches 65°C temperature, the chlorine pressure reducing valve & shut off valve will open and the system is ready for operation. When water temperature reaches 82°C, start the injector water system and follow the procedure mentioned in gas system.

#### **6.4.2.7 Procedure for stopping the plant**

Stopping the chlorination system is also important in order to avoid chlorine leakages as well as for the system safety. The procedure is as follows:

1. Shut off the chlorine supply system.
2. When the chlorine pressure gauge reaches zero remove the cylinder connection & allow the air to evacuate all the residual chlorine gas in the system while the injector is still in operating condition.
3. After the chlorine has been purged to the satisfaction of the operator, the injector system may be shut down.
4. Connect the openings with plastic plugs.
5. For liquid system the chlorine in the evaporator shall be completely consumed.
6. Then close the heater supply to the evaporator.

#### **6.4.2.8 Maintenance of Chlorination Equipment**

Chlorine being hazardous chemical, its operating machinery should be maintained properly. In view of this, it is advisable to carry out preventive maintenance of all these equipment keeping in mind the followings for effective maintenance management programme.

1. Deploy trained personnel
2. Prepare daily schedule i.e.
  - Check chlorine leakage by ammonia torch.

- Check exhaust fans working.
  - Check rotameter functioning.
  - Carry out physical verification of stock and position of tonners.
  - Check position of safety equipment.
  - Check vacuum of chlorinator.
3. Quantify the work.
  4. Use of work permit system. A written work permit system is essentially a document which identifies the plant to be worked on and details precautions to be taken before a work can start. It predetermines the safe procedure and is a clear record of the hazards that have been anticipated defining the appropriate precautions to be taken to avoid them. It is also a statutory requirement.
  5. Keep equipment record i.e. history cards.
  6. Analyse and plan every job.
  7. Forecast yearly & monthly maintenance programme.
  8. Prepare check lists for different types of preventive maintenance.
  9. Set up a manpower control.
  10. Set up a preventive maintenance programme.
  11. Use budgetary control – yearly & monthly budget.
  12. Provide material control.
  13. Always use recommended spares.
  14. Plan plant shut downs.
  15. Establish major overhaul procedures.
  16. Develop standard practices.
  17. Improve efficiency of the equipments.
  18. Train the supervisors.
  19. Train the maintenance staff.
  20. Analyse performance and cost.
- (b) Since the properties of Chlorine differ in liquid form, gaseous form, and solution form suitable material has to be selected for various components of chlorine equipment. (refer to appendix 6.1 for materials).
  - (c) Predominantly observed impurities in chlorine are Ferric chloride, Hexachlorethane and Hexachlorbenzene. Normally the chlorine available for disinfection purpose is 99.8% pure (IS 646).
  - (d) Ferric chloride is formed due to reaction of chlorine with water vapour & metal. This is deposited in the equipment during corrosion from liquid form to gaseous form. While carrying out maintenance of this equipment, warm water is used to clean the equipment. The cleaned equipment is dried thoroughly before putting into the system.
  - (e) Hexachlorethane & Hexachlorbenzene being volatile impurities, are deposited from the chlorine gas in the equipment wherever pressure changes occur in the system, for example



with pressure reducing valve. These impurities are removed while carrying out maintenance by means of trichloroethane or Isopropyl alcohol, Carbon Tetra Chloride (CTC) should never be used as it is carcinogenic.

- (f) Sometimes amongst other impurities, nitrogen trichloride may be present. This impurity is present when the brine solution from which chlorine is manufactured by electrolysis method, contains ammonia or its compound. Because of vapour pressure difference in nitrogen trichloride and chlorine in the evaporator, chlorine is evaporated first leaving more concentration of nitrogen trichloride in evaporator. If under such condition, the evaporator temperature exceeds 94°C, the evaporator may explode. It is, therefore, always recommended not to exceed evaporator temperature of 90°C.
- (g) Before carrying out any maintenance of the equipment, it should be confirmed that all the chlorine present in equipment is purged out completely. Any chlorine present in the piping will prove hazardous if welding work is carried out on it. Similarly while putting the chlorination system into use all the water vapours should be removed by means of moisture free dry air. The piping carrying chlorine of a length more than 3 mtrs. running from cylinder to the equipment should be provided with a pressure reducing valve just down stream of the cylinder. These two aspects reduce the maintenance problems to a minimum. Whenever cylinders are removed from the system, the disconnected piping should be plugged with Teflon or similar kind of material in order to avoid entry of humid air into it.

**TABLE 6.1: SUGGESTED MAINTENANCE OF CHLORINE EQUIPMENT  
PRESSURE CHLORINATOR – AQUEOUS SOLUTION FEED TYPE**

S.No.	Name of item	Period	Action needed
1.	Chlorine leakage	Daily	Inspect & take necessary action
2.	Pebbles in tower	15 days	Clean with water
3.	Calcium chloride	1 month or earlier if shape is changed	Replace
4.	Orifice	1 month	Clean with trichloroethene
5.	Stop valve & regulating valve	3 months	Clean with trichloroethene
6.	Diaphragm	3 months	Clean with trichloroethene
7.	Manometer	3 months	Clean with water
8.	Manometer	3 months	Calibrate
9.	Gasket	3 months	Replace
10.	Sleeves	3 months	Replace
11.	Filter	3 months	Clean or replace
12.	Pressure gauge	3 months	Inspect & calibrate if necessary
13.	Injector	3 months	Clean with water
14.	Tube	6 months	Replace
15.	Nut bolt	12 months	Replace
16.	Sulphuric acid	12 months	Replace
17.	Rubber hose	12 months	Replace

**TABLE 6.2: SUGGESTED MAINTENANCE OF CHLORINE EQUIPMENT AND FITTINGS — VACUUM TYPE CHLORINATOR**

S.No.	Name of item	Period	Action needed
1.	Chlorine leakage through fittings etc.	Daily	Inspect and take necessary action
2.	Chlorine leak detector & Exhaust fans	Daily	Inspect and take necessary action
3.	Safety equipment & Breathing apparatus	Weekly	Inspect and take necessary action
4.	Chlorine neutralisation system	Weekly	Inspect and take necessary action
5.	Water pump	3 months	Inspect and take necessary action
6.	Chlorine gas filter	6 months	Replace filter element
7.	Sedimentation trap	6 months	clean
8.	Rotameter tube & metering orifice	6 months	clean
9.	Wind cock	6 months	replace
10.	Gas header valve packing	1 year	Replace
11.	Stem & seat of valves	1 year	clean
12.	Injector throat	1 year	clean with mild HCl & then with water
13.	Lifting tackle/crane	1 year	Inspect and take necessary action
14.	Copper tubing between header & cylinder	1 year or screeching sound is heard on bending	Replace
15.	Header system	After every 250 Tons passing of chlorine	Clean with water & dry it
16.	Springs in the valves	2 years	Replace
17.	Pressure gauges & pressure switches	5 years	Replace
18.	Diaphragm in spring loaded valve	5 years	Replace
19.	Joints	Whenever opened	Replace gasket with new one. Wire brush the thread & use teflon tape for lubricant
20.	Evaporator vessel	250 tons of chlorine passage	Clean

**TABLE 6.3: COMPARISON OF CHLORINATORS**

S.No.	Description	Pressure Type Chlorinator			Vacuum Type Chlorinator	
		Dry feed	Aqueous solution Feed		With Differential vacuum regulator	Sonic flow type
			Gravity feed	Injector Solutioniser		
1.	Rate of feed (max)	230kg/d	230kg/d	230kg/d	4800 kg/d	240 kg/d
2.	Water requirement per Kg of chlorine (min.)	Nil	1500 lit.	Less than 1500 lit. but more than 300 lit.	300 lit.	300 lit.
3.	Accuracy	Low.	Low	Low	High	High
4.	Flow meter	Manometer	Manometer	Manometer	Rotameter	Rotameter
5.	Pressure at point of application	0.7 kg/cm <sup>2</sup> (max)	0.7 kg/cm <sup>2</sup> (max)	More than 0.7 kg/cm <sup>2</sup>	More than 0.7 kg/cm <sup>2</sup>	More than 0.7 kg/cm <sup>2</sup>
6.	Energy requirement	Low	Low	Moderate	Moderate	High
7.	Maintenance	Extensive	Extensive	Extensive	Moderate	Less
8.	Status	Not in production	Not in production	Not in production	In production	In production
9.	Remarks	Not suitable below 10°C water. It is used when quality of water for making solution is not good. It is less safe	Suitable below 10°C provided water for making the solution is beyond 10°C It is used when quality of water for making solution is good. It is less safe	Suitable below 10°C provided water for making the solution is beyond 10°C It is used when quality of water for making solution is good. It is less safe	Suitable below 10°C provided water for making the solution is beyond 10°C It is used when quality of water for making solution is good. It is more safe	Suitable below 10°C provided water for making the solution is beyond 10° C. It is used when quality of water for making solution is good. It is more safe

**TABLE 6.4: IMPORTANT FACTS ABOUT CHLORINE FROM SAFETY POINT OF VIEW**

	<b>Facts</b>	<b>Reasons</b>	<b>Remedy</b>
1.	Chlorine is supplied in liquid form under pressure & it requires heat for converting it into gas.	It occupies less space	Proper ventilation and proper handling.
2.	It is not poisonous but irritant.	It forms corrosive acid with body moisture and hence inhalation can cause respiratory injury ranging from irritation to death depending upon its concentration & duration of inhalation.	Use breathing apparatus.
3.	Dry gas is not corrosive but wet gas is highly corrosive.	It forms acid with water.	Do not use water on leaking container.
4.	It is neither flammable nor explosive but supports combustion of carbon steel at 251°C.	Containers are made up of carbon steel.	Do not carry out welding work on chlorine containers or piping unless purged out.
5.	Gas combines with ammonia & forms white smoke.	White smoke detects chlorine leak.	Use for detecting chlorine leakage through the system.
6.	Liquid chlorine has large coefficient of expansion.	If the container is filled with filling ratio of 1:19, complete container will be occupied by liquid chlorine at 84°C and hydrostatic rupture may take place.	Do not place the container near the fire or source of heat.
7.	Vapour pressure increases with temperature rise.	Container may rupture due to rise in pressure.	Do not place the container near the fire or source of heat.
8.	Gas is 2.5 times heavier than air.	Leaked chlorine settles at the ground level.	Install exhaust fans at ground level & inform the public to take higher level during chlorine leakages.
9.	It is slightly soluble in water but it gets absorbed in caustic soda, soda ash and hydrated lime.	During reaction with caustic soda. Soda ash & hydrated lime heat is evolved.	Use soda ash, caustic soda or hydrated lime for neutralisation of chlorine. Do not use water for neutralisation purpose. Do not push container into solution.
10.	Liquid leaks 15 times more than the gas.	It is because of viscosity difference as well as different laws of gas and liquid.	Turn the leaking container such as to allow leakage in gaseous form.
11.	Chlorine forms hydrate with water at temperature below 9.4°C.	Solid layer is formed.	In the case of liquid leak if chilled water is sprayed on the top a solid layer formation will reduce the rate of evaporation of chlorine.
12.	It is dangerous with ammonia gas, hydrogen, turpentine and hydrocarbon as reactions with these are explosive; powdered metal may cause fire in chlorine.	Fire may start in storage of chlorine.	Avoid storage of these materials in the chlorine storage. Do not lubricate the valves.

## 6.5 SAFETY ASPECTS OF CHLORINE

### 6.5.1 GENERAL

Chlorine is potentially dangerous. It is, therefore, important that person engaged in a chlorine plant or in any activity involving handling of chlorine should understand the hazards of chlorine and should know preventive measures needed. These are given below:

### 6.5.2 CYLINDERS

Cylinders are fabricated as per IS: 7681.

In a vertical position with the valve at the top, chlorine in gaseous form can be drawn from the cylinder. If, however, liquid chlorine is to be drawn, the cylinder can be inverted to bring the valve towards the bottom with the use of an inverting rack which holds the cylinder at  $60^\circ$ . The withdrawal rates of  $\text{Cl}_2$  at  $20^\circ\text{C}$  are 2 kg/hr and 10 kg/hr for gas and liquid chlorine respectively for 100 kg. The withdrawal rate depends upon ambient temperature and it reduces with reduction in temperature. (Fig. 6.8)

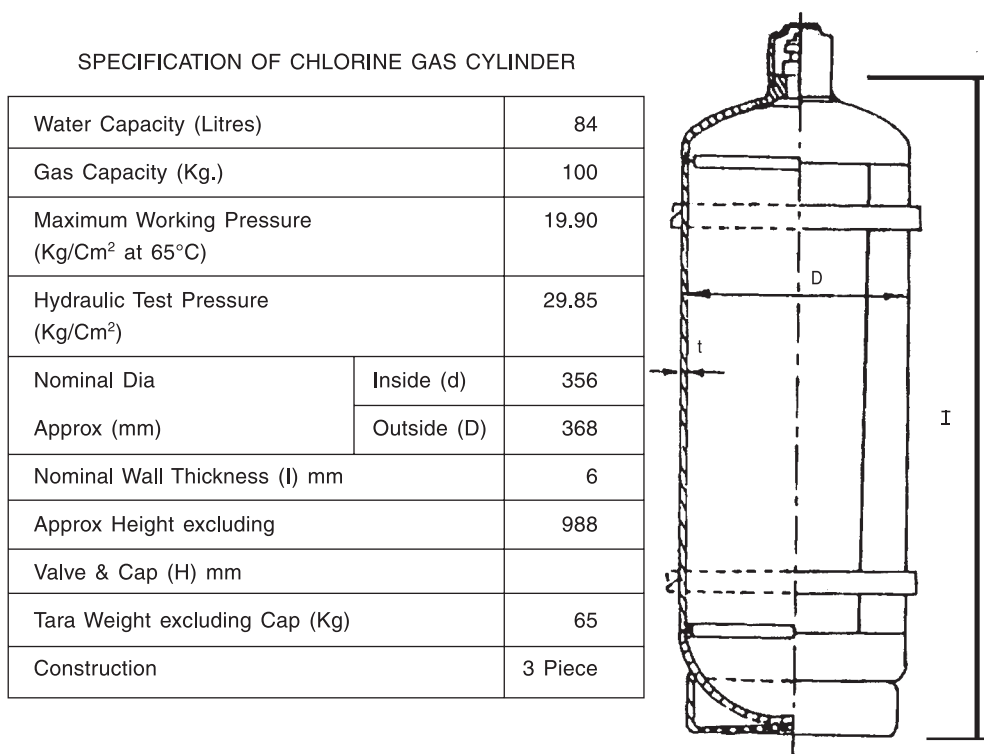


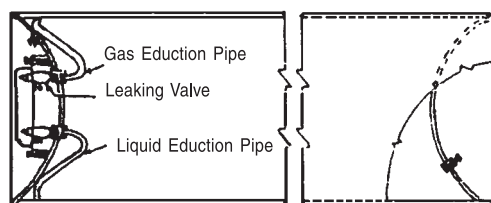
FIG. 6.8: DETAILS OF CHLORINE CYLINDER

### 6.5.3 TONNERS

Bigger containers are commonly known as "Tonners" Indian tonners are generally fabricated conforming to the British standards (B.S:1500).

These are kept horizontally so as to bring the two valves in vertical plane. Each has a capacity of approx. 900 kg. It has built-in safety by way of providing concave dished ends.

Both the valves are covered by a protective hood connected to the container by means of lugs. The inside ends of the valves are connected to the eduction pipes. (Fig. 6.9).



#### GENERAL SPECIFICATION

Water Capacity (approx.) Kg.	-	780
Chlorine Capacity (approx.) Kg.	-	930
Design Pressure, Kg/Cm <sup>2</sup>	-	19.9
Inside Diameter (approx.) mm	-	760
Shell Thickness, mm	-	10
Dished Ends Thickness, mm	-	9.6 (Min.)
Overall Length (approx.) mm	-	2085
Tare Weight (approx.) Kg.	-	520

FIG. 6.9: DETAILS OF CHLORINE TONNER

Tonnors manufactured in India after 1981 do not have fusible plug as per the Gas Cylinder Rules 1981. However, in imported design where these are provided, they melt between the temperatures of 70°C and 74°C thereby reducing the pressure inside the container in case of fire or high temperature.

The withdrawal rates of Cl<sub>2</sub> at 20°C are 7 kg/hr and 180 kg/hr for gas and liquid respectively. It depends upon ambient temperature.

#### 6.5.4 CONTAINER VALVES

Both chlorine cylinder as well as tonners must be fitted with standard valves conforming to IS: 3224 (Fig. 6.10).

#### 6.5.5 STORAGE & HANDLING OF CHLORINE CYLINDERS:

Chlorine is stored in special grade steel containers. As per IS:4379-1967, the colour of Chlorine container should be 'golden yellow'.

##### (a) Storage Area

1. Obtain storage licence from controller of explosives under Gas Cylinder Rules 1981 if the quantity of Cl<sub>2</sub> containers to be stored is more than 5 Nos.
2. Storage area should be cool, dry, well ventilated, and clean of trash and protected from external heat sources. Please refer to Manual on "Water Supply and Treatment", (1999 Edition), for further details.
3. Ventilation must be sufficient to prevent accumulation of vapour pockets. The exhaust should be located either near the floor or duct be provided extending to the floor. All fan switches should be outside the storage area.
4. Do not store container directly under the sun.

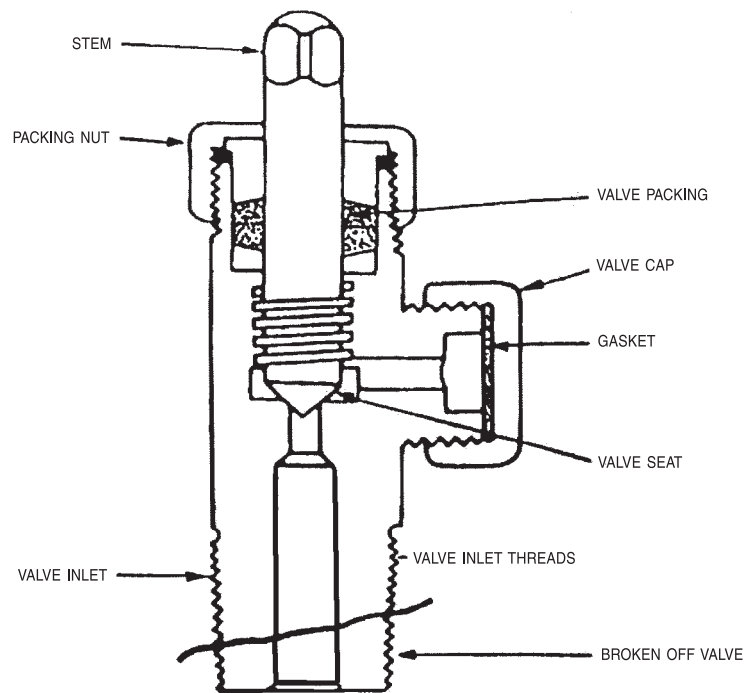


FIG. 6.10: STANDARD CHLORINE CONTAINER VALVE

5. Weather cock should be installed near the storage to determine wind direction.
6. The storage building should be of non-combustible construction with at least two exits opening outside.
7. Neutralization system should be provided.
8. Continuous monitoring of chlorine leak detection equipment with alarm should be installed in the storage area.
9. The area should be free and remote from elevators, gangways or ventilating system to avoid dangerous concentration of Chlorine during leak.
10. Two portable foam type fire extinguishers should be provided in the premises.
11. Corrosive substances shall not be stored nearby which react violently with each other.
12. Unauthorized person should not be allowed to enter into the storage area.
13. The floor level of storage shed should be preferably 30 cms (at least one foot) higher from the ground level to avoid water logging.
14. Ensure that all containers are properly fitted with safety caps or hooks.

**(b) Cylinder & Drum Containers**

1. Store chlorine cylinders upright and secure them so that they do not fall.
2. Drum containers should be stored on their sides on rails, a few inches above the floor. They should not be stacked one upon the other. They should be stored such that the valves are in vertical plane.

3. Keep enough space between containers so as to have accessibility in case of emergency.
4. Store the containers in a covered shed only. Keep them away from any source of heat as excessive heat may increase the pressure in container which will result into burst.
5. Do not store explosives, acids, turpentine, ether, anhydrous ammonia, finely divided metals or other flammable material in the vicinity of Chlorine.
6. Do not store containers in wet and muddy areas.
7. Store filled and empty containers separately.
8. Protective covers for valves are secured even when the containers are empty, except during use in the system.
9. Never use containers as a roller to move other equipment.
10. Never tamper with fusible plugs of tonners.
11. Check leakages every day by means of ammonia torch. However, it should not be touched to brass components like valves of container for safety.
12. Never carry out any welding work on the chlorine system as combustion of steel takes place at 251°C in presence of chlorine.
13. The boxes containing emergency kit, safety applications and self contained breathing apparatus should be kept in working order in an easily approachable area.

**(c) Use of Cylinders & Drum Containers in Process System**

1. Use containers in the order of their receipt, as valve packing can get hardened during prolonged storage and cause gas leaks.
2. Do not use oil or lubricant on any valve of the containers.
3. Badly fitting connections should not be forced and correct tool should always be used for opening and closing valves. They should never be hammered.
4. The area should be well ventilated with frequent air changes.
5. Transport the cylinders to the process area by using crane, hoist or railings etc.
6. The drum containers should be kept in a horizontal position in such a way that the valves are in a vertical plane. The upper valve gives out gas and the lower one gives out liquid chlorine.
7. The cylinder should be kept in upright position in order to release gas from the valve. For liquid chlorine withdrawal, it should be inverted with the help of an inverted rack.
8. Connect the containers to the system by using approved accessories.
9. Use copper flexible tube, with lead washer containing 2 to 4% antimony or bonded asbestos or teflon washer. Use yoke clamp for connecting chlorine container.
10. Never use rubber tubes, PVC tubes etc. for making connections.
11. Use the right spanner for operating the valve. Always keep the spanner on the valve spindle. Never use ill fitting spanner.



12. After making the flexible connection, check for the leakage by means of ammonia torch but it should not come in contact with a valve.
13. Keep minimum distance between the container valve and header valve so that during change-over of the container, minimum amount of gas leaks.
14. The material of construction of the adopter should be same as that of valve outlet threads.
15. The valve should not be used as a regulator for controlling the chlorine. During regulation due to high velocity of Chlorine, the valve gets damaged which in turn can cause difficulty in closing.
16. The tools and other equipment used for operating the container should be clean and free of grease, dust or grit.
17. Wear breathing apparatus while making the change-over of the container from the process header.
18. Do not heat the container to withdraw more gas at faster rate.
19. Use pressure gauge and flow measuring device to control the flow and to know the quantity of gas left in the container.
20. Use an inverted U type barometric leg or vacuum breaking arrangement for connecting the container to the process piping.
21. Withdrawal of the gas should be stopped when the gas pressure inside the container is between 0.1 to 0.5 kg/cm<sup>2</sup> approximately.
22. If withdrawal of the gas from the container connected to the process system has to be suspended for long intervals, it should be disconnected from the system, and the valve cap and hood replaced.
23. Gas containers should be handled by trained persons only.

**(d) Disconnecting Containers from Process System**

1. Use breathing apparatus before disconnecting the container.
2. First close the container valve fully. After removal of chlorine the process valve should be closed.
3. Remove the flexible connection, plug the flexible connection in order to avoid entry of humid air. Replace the valve cap or hood on the container.
4. Put the tag on the empty container & bring it to storage area marked for empties.
5. Check for the leakage.

**(e) Loading and Unloading of Containers**

1. The handling of containers should be done under the supervision of trained and competent person.
2. It should be done carefully with a crane, hoist or slanted ramp. Do not use magnet or sharp object for lifting the containers.
3. Small cylinders should not be lifted by means of valve caps as these are not designed to carry the weight.

4. The containers should not be allowed to strike against each other or against any hard object.
5. Vehicles should be braked and isolated against any movement.
6. After loading, the containers should be secured properly with the help of wooden wedges, rope or sling wire so that they do not roll away.
7. The containers should never be dropped directly to the ground or on the tyre from the vehicle.
8. There should be no sharp projection in the vehicle.
9. Containers must have valve caps and plugs fitted properly.
10. Check containers for leakage before loading/unloading.

**(f) *Transportation of Container***

1. The name of the chemical along with diamond pictorial sign denoting the dangerous goods should be marked on the vehicle.
2. The name of the transporter, his address and telephone number should be clearly written on the vehicle.
3. The vehicle should not be used to transport any material other than what is written on it.
4. Only trained drivers and cleaners should transport hazardous chemical
5. The driver should not transport any leaking cylinder.
6. The cylinder should not project outside the vehicle.
7. The transporter must ensure that every vehicle driver must carry "Trem Card" (Transport Emergency Card) and 'Instructions in writing booklet' and follow them.
8. Every driver must carry safety appliances with him, viz; Emergency kit, breathing apparatus etc.
9. The vehicles must be driven carefully, specially in crowded localities and on bumpy roads. Do not apply sudden brakes.
10. Check for the leakage from time to time.
11. In the case of uncontrollable leakage the vehicle should be taken to an open area where there is less population.

**(g) *Emergency Kit***

It consists of various tools and appliances like gaskets, yokes, studs, tie rods hoods, clamps, spanners, mild steel channels, screws, pins, wooden pegs etc. of standard sizes. Separate kits are used for cylinders and tonners. All the gadgets are designed for using in controlling or stopping the leakages from valves, fusible plug and side walls of cylinders and containers used for handling chlorine.

1. Leakage may occur through the valve. There are basically four types of valve leaks.
  - i) Valve packing
  - ii) Valve seat

- iii) Defective inlet thread
- iv) Broken valve thread

For controlling the leak please refer Fig. 6.12 & Fig. 6.14 for tonner & cylinder respectively.

2. Leakage may occur through container wall. For controlling such leakages, clamps are used for cylinders and chain and yoke arrangement is used for tonner. Sometimes wooden peg is used by driving into the leaking hole as a temporary arrangement. For controlling leak please refer Fig. 6.12 & Fig. 6.14 for tonner & cylinder respectively.
3. Leakage may occur through fusible plug.
  - i) If the leakage is through the threads of fusible plug, yoke, hood and cap nut arrangement is used to control the leak.
  - ii) If fusible metal itself in the plug is leaking, yoke and stud arrangement is used to control the leak.

#### **(h) Health Hazards**

Wet chlorine being corrosive, it forms corrosive acid with body moisture. Inhalation can cause respiratory injury ranging from irritation to death depending upon its concentration and duration of inhalation.

##### **1. Acute Exposure**

The first symptom of exposure to chlorine is irritation to the mucous membranes of eyes, nose and throat. This increases to smarting and burning pain. Irritation spreads to chest. A reflex cough develops which may be intense and often associated with pain behind the breast-bone. The cough may lead to vomiting. Cellular damage may occur with excretion of fluid in the alveoli. This may prove fatal if adequate treatment is not given immediately. Vomit frequently contains blood due to lesions of the mucous membrane caused by the gas. Other common symptoms include headache, retrosternal burning, nausea, painful breathing, sweating, eyes, nose, throat irritation, coughing, vomiting, increase in respiration and pulse rate. Massive inhalation of chlorine produces pulmonary oedema, fall of blood pressure and in a few minutes, cardiac arrest.

##### **2. Chronic Exposures**

Persons rapidly lose their ability to detect the odour of chlorine in small concentrations. On account of this, the concentrations beyond threshold limit value may exceed without notice. Prolonged exposure to concentrations of 5 ppm results in disease of bronchitis and predisposition to tuberculosis and concentration of 0.8-1.0 PPM can cause moderate but permanent reduction in pulmonary function. Person exposed for long period of time to low concentrations of chlorine may suffer from acne, tooth enamel damage may also occur.

#### **(i) First Aid - Trained Personnel and Equipment**

In the plant trained first aider having the knowledge in the use of aid equipment and rendering artificial respiration should be available. First aid box with necessary contents

should be available. Properly designed showers and eye fountains should be provided in convenient locations and they should be properly maintained. If oxygen is available the same should be administered by authorized person. Such training is imparted by civil defence.

**1. General**

Remove the affected person immediately to an uncontaminated area. Remove contaminated clothing and wash contaminated parts of the body with soap and plenty of water. Lay down the affected person in cardiac position and keep him warm. Call a physician for medical assistance at the earliest.

*Caution:* Never attempt to neutralize chlorine with other chemicals.

**2. Skin Contact**

Remove the contaminated clothes, wash the affected skin with large quantity of water.

*Caution:* No ointment should be applied unless prescribed by the physician.

**3. Eye Contact**

If eyes get affected with liquid chlorine or high concentration of chlorine gas, they must be flushed immediately with running water for atleast 15 minutes keeping the eyelids open by hand.

*Caution:* No ointment should be used unless prescribed by an eye specialist.

**4. Inhalation**

If the victim is conscious, take him to a quiet place and lay him down on his back, with head and back elevated (cardiac position). Loosen his clothes and keep him warm using blankets. Give him tea, coffee, milk, peppermint etc. for making good effect on breathing system.

If the victim is unconscious, but breathing, lay him down in the position mentioned above and give oxygen at low pressure until the arrival of doctor. If breathing has stopped, quickly stretch him out on the ground or a blanket if available, loosen his collar and belt and start artificial respiration without delay. Neilson arm lift back pressure method is useful. Automatic artificial respiration is preferable if available. Continue the respiration until the arrival of the doctor. Amboo bag can also be used for this purpose.

**(j) Fire & Explosion Hazards:**

Chlorine may react to cause fires or explosions upon contact with turpentine, ether, ammonia gas, hydrocarbons, hydrogen, powdered metals, sawdust and phosphorus.

Due to fire in the vicinity, the temperature of the containers rises excessively which results in explosion. In order to avoid explosion of the containers, remove all the movable containers from the fire zone immediately by wearing full protective clothing with respiratory protection. In the case of immovable containers, use water for cooling provided there is no leak.

(k) *Emergency Measures*

In case of leakage or spillage:

1. Take a shallow breath and keep eyes opened to a minimum.
2. Evacuate the area.
3. Investigate the leak with proper gas mask and other appropriate Personal protection.
4. The investigator must be watched by a rescuer to rescue him in emergency.
5. If liquid leak occurs, turn the containers so as to leak only gas.
6. In case of major leakage, all persons including neighbours should be warned.
7. As the escaping gas is carried in the direction of the wind all persons should be moved in a direction opposite to that of the wind. Nose should be covered with wet handkerchief.
8. Under no circumstances should water or other liquid be directed towards leaking containers, because water makes the leak worse due to corrosive effect.
9. The spillage should be controlled for evaporation by spraying chilled water having temperature below 9.4°C. With this water crystalline hydrates are formed which will temporarily avoid evaporation. Then try to neutralize the spillage by caustic soda or soda ash or hydrated lime solution carefully. If fluoroprotein foam is available, use for preventing the evaporation of liquid chlorine.
10. Use emergency kit for controlling the leak (Figs. 6.11, 6.12, 6.13 and 6.14).
11. On controlling the leakage, use the container in the system or neutralize the contents in alkali solution such as caustic soda, soda ash or hydrated lime.

*Caution:* Keep the supply of caustic soda or soda ash or hydrated lime available. Do not push the leaking container in the alkali tank. Connect the container to the tank by barometric leg.

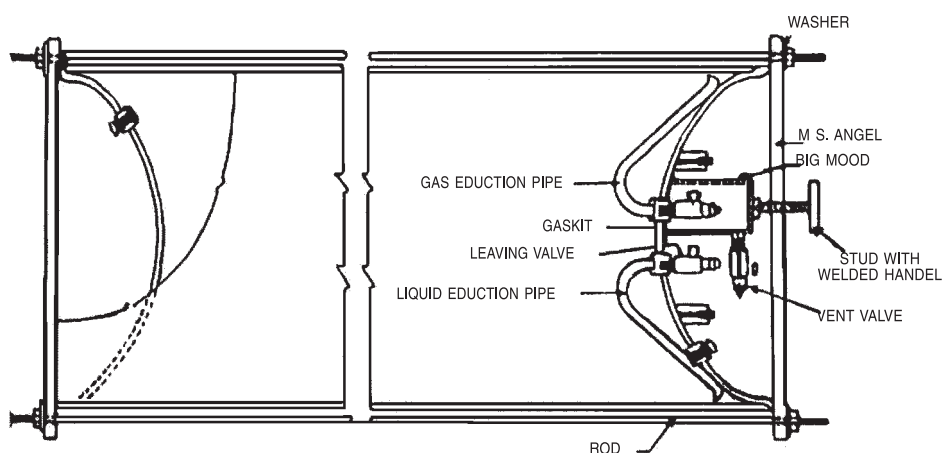


FIG. 6.11: APPLICATION OF EMERGENCY KIT

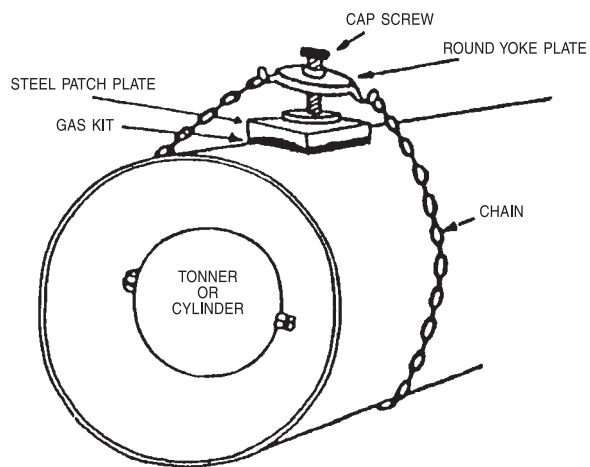


FIG. 6.12: USE OF CHAIN AND ROUND YOKE PLATE FOR TONNER CYLINDER WALL LEAK

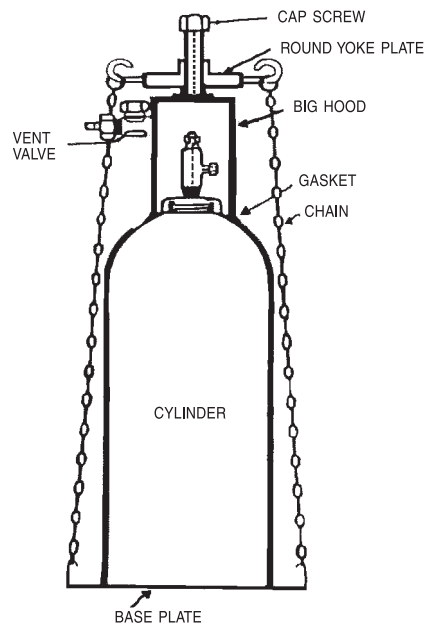


FIG. 6.13: CYLINDER VALVE HOOD ASSEMBLY DEVICE

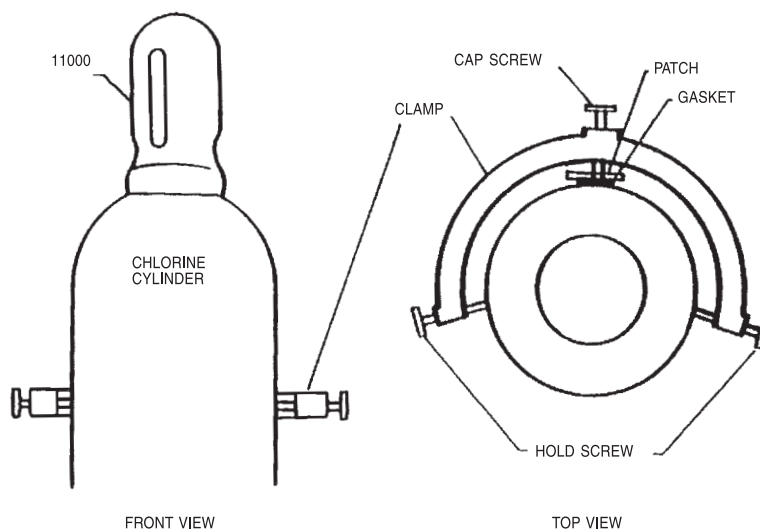


FIG. 6.14: CONTAINER WALL LEAK

12. If container commences leak during transport, it should be carried on to its destination or manufacturer or to remote place where it will be less harmful. Keeping the vehicle moving will prevent accumulation of high concentrations.
13. Only specially trained and equipped workers should deal with emergency arising due to major leakage.
14. If major leak takes place, alert the public nearby by sounding the siren.
15. Any minor leakage must be attended immediately or it will become worse.
16. If the leakage is in the process system, stop the valve on the container at once.

(I) *Personal Protective Equipment*

1. **Breathing Apparatus**

Various types of respirators and their suitability are as follows:

i) *Self-contained breathing apparatus*

This apparatus is equipped with a cylinder containing compressed oxygen or air which can be strapped on to the body of the user or with a canister which produces oxygen chemically when the reaction is triggered. This type of equipment is suitable for high concentration of chlorine in an oxygen deficient atmosphere. (Fig. 6.15).

ii) *Air-line respirator: Air-line length 90 mtrs. (max.)*

It is suitable for high concentrations of chlorine provided conditions permit safe escape if air supply fails. This device is suitable in any atmosphere, regardless of the degree of contamination or oxygen deficiency, provided that clean, breathable air can be reached. (Fig. 6.16).



FIG. 6.15 SELF-CONTAINED BREATHING APPARATUS



FIG. 6.16 AIR LINE RESPIRATOR

iii) *Industrial Canister Type Mask : Duration: 30 min. for 1% Cl<sub>2</sub>*

It is suitable for moderate concentration of chlorine provided sufficient oxygen is present. The mask should be used for a relatively short exposure period only. If the actual chlorine concentration exceeds 1% by volume or oxygen is less than 16% by volume, it is not useful. The wearer in such cases must leave the place on detection of chlorine or experiencing dizziness or breathing difficulty. (Fig. 6.17)

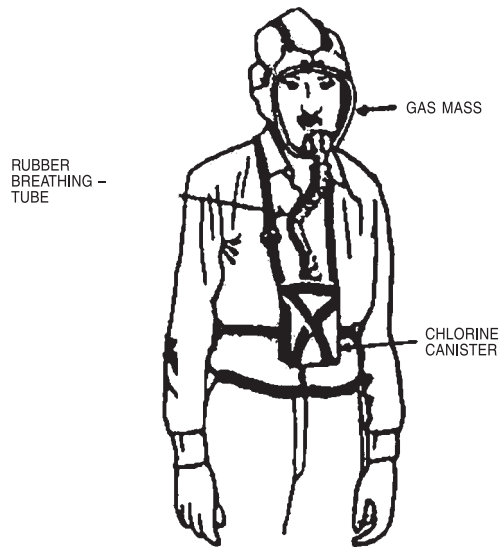


FIG. 6.17 USE OF CHLORINE CANISTER GAS MASK

## 2. Protective Clothing

Rubber, or PVC clothing is useful in massive exposure which otherwise creates mild skin burns due to formation of acid on the body.

## 3. Maintenance of Protective Equipment

1. Clean with alkali after every use.
2. Keep in polythene bag at easily accessible place.
3. Check them periodically about their suitability. Many times the seal ring of face mask gets hardened.

### (m) Employees Selection

Preplacement medical examination should be carried out of the persons to confirm that they are free from Asthma, Bronchitis and other chronic lung conditions.

Follow up medical examination should be carried out once in a year.

### (n) Employees Training

It is essential to impart training to the employees who have to face emergency.

This training should include following:

- i) Instructions in the action to be taken in an emergency.
- ii) Use of emergency kit.
- iii) Handling of containers.
- iv) First aid.
- v) Use of protective equipment.
- vi) Knowledge of Chlorine hazards.
- vii) Fire fighting.



- viii) Use of safety showers and eye fountains. (Fig. 6.18).
- ix) Crash shut down procedure for valves and switches.
- x) Communication system.
- xi) Study of plant layout with diagram.
- xii) Mock drills.

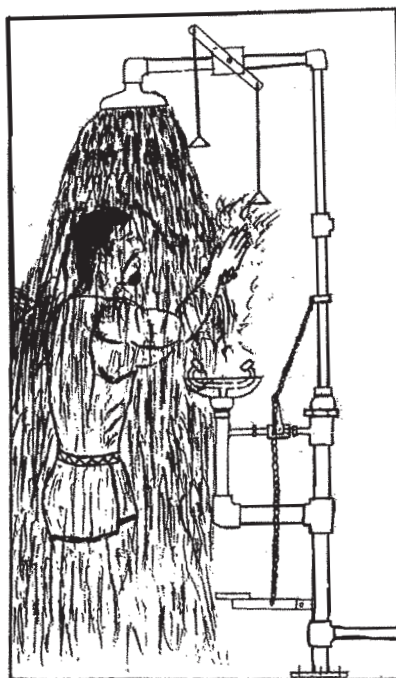


FIG. 6.18: EMERGENCY SHOWER AND EYE WASH FOUNTAIN

(o) *Neutralisation of Chlorine*

A suitable provision should be available for emergency disposal of chlorine from the leaking container. Chlorine may be absorbed in solution of caustic soda, soda ash and hydrated lime. Caustic soda is recommended as it absorbs chlorine more readily. If hydrated lime is used, the slurry must be continuously agitated and recirculated for chlorine absorption. The neutralization can be carried out by:

- Neutralisation tank holding caustic soda or hydrated lime or sodium carbonate in solution form.
- Scrubber.

i) *Neutralisation tank*

For the neutralization tank, following proportion of alkali and water is recommended in order to neutralize 900 kg. of  $\text{Cl}_2$ .

Chlorine kg.	Caustic soda & water		Soda ash & water		Hydrated lime & water	
	Weight (kg.)	Volume (lit.)	Weight (kg.)	Volume (lit.)	Weight (kg.)	Volume (lit.)
900	1160	3680	2720	9050	1160	11350

This system can be used only after controlling the leaking container by emergency kit and connecting it to the tank by inverted U tube of 11 m height. It is desirable to provide excess quantity of alkali solution over indicated quantities in the table in order to facilitate ready absorption. A suitable tank to hold the solution should be provided in a convenient location.

*ii) Scrubber*

This system consists of a blower, an alkali (NaOH) tank, an absorption tower packed with rasching rings, alkali circulation pump, piping valves, light weight FRP and PVC duct. In the event of leak which is uncontrollable with emergency kit this system would allow the person to breath easily rather than panic. In this system, the leak is confined by a hood covering the leaking container, sucking the Chlorine by blower and delivering it to absorption tower (Fig.6.19). Chlorine leak absorption capacity of the system is kept 100 kg/h & 200 kg./h for 100 kg. cylinder and 900 kg. tonner respectively.

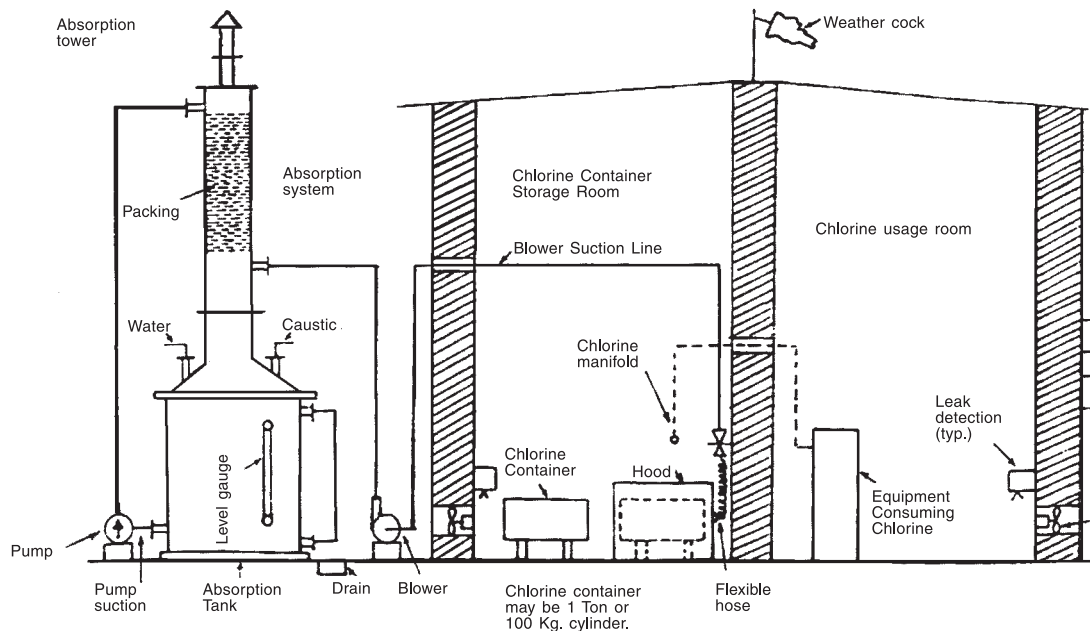


FIG. 6.19 TYPICAL CHLORINE LEAK ABSORPTION SYSTEM

*(p) Emergency Response Planning*

When a large quantity of chlorine or similar toxic or flammable gases are stored it is essential to have an emergency response planning as leakage of such gases may lead to a major accident such as emission, fire or explosion resulting from uncontrolled developments in the course of an industrial activity, leading to serious danger to man, immediate or delayed, inside or outside the establishment and/or to the environment, and involving one or more dangerous substances. It has, therefore, become obligatory on the part of occupier to take all measures necessary to prevent accidents and to limit their consequences for man and the environment. The hazard control can be achieved by drawing an effective 'onsite emergency plan' for individual organization and if necessary 'offsite emergency plan' by the local authority for that area.

## Onsite Emergency Plan

As chlorine is a hazardous chemical, handling and storage of it demand adequate precautions to avoid possible hazards. Leakage of chlorine may develop into a major emergency. Therefore the emergency procedure to cover this eventuality is essential. It is drawn in the form of on-site emergency plan.

The elements of onsite emergency plan are as follows:

1. *Identification of hazard chart*

In this case the site risk is evaluated by the expert and the extent of the probable damage is calculated on the basis of stored chlorine quantity, nearby population, wind direction, type of equipment failure etc. For this purpose hazard analysis is conducted in which case all the hazardous properties of chlorine are considered. If evacuation is required, the range of it is calculated.

2. *Appointing key persons*

In order to control the incident like chlorine leakage, it is essential to appoint various persons with their well defined responsibilities. Taking into account the various activities likely to be involved, the following key persons are appointed (i) Site Controller, (ii) Incident controller, (iii) Shift Executive Incharge, (iv) Communication Officer, (v) Safety Officer, (vi) Fire and Security Officer, (vii) Utilities and Services Incharge, (viii) Traffic Controller, (ix) First Aider

3. *Assembly Points*

These points are set up where persons from the plant would assemble in case of chlorine leakage. At these points the in-charge for counting the heads will be available.

4. *Emergency Control Center*

The control centre is the focal point in case of an emergency from where the operations to handle the emergency from are directed and coordinated. It contains site plan, telephone lines, public address system, safety equipment, first aid boxes, loud speaker, torches, list of essential telephone numbers, viz. fire brigade, police, hospital, civil defence, collector, factory inspector, organizational authorities, chlorine suppliers, mutual aid group, social workers, list of key persons and their addresses, copy of chemical fact sheet, location plan of fire hydrant, details of dispersion model of chlorine gas, population distribution pattern, location of alarm system.

5. *Procedure to meet Emergency*

The actions to be taken by the staff and authority are given below;

Emergency Alarm: An audible emergency alarm system is installed through out the plant. On hearing the alarm the incident controller will activate the public address system to communicate with the staff about the emergency and give specific instructions for evacuations etc. Any one can report the occurrence of chlorine leakage to section in-charge or incident controller through telephone or intercom or in person.

6. *Communication*

Communication officer shall establish the communication suitable to that incident.

## 7. *Services*

For quickness and efficient operation of emergency plan the plant is divided into convenient number of zones and clearly marked on the plan. These are emergency services viz. fire fighting, first aid, rescue, alternative source of power supply, communication with local bodies etc. The incident controller will hand over the charge to the site controller of all these coordinating activities, when the site controller appears on the site. The site controller will coordinate all the activities of the key persons. On hearing the emergency alarm system all the key persons will take their charge. In case of their absence other alternatives are nominated.

The person nominated for personnel and administration purposes will be responsible for informing all statutory authorities, keeping account of all persons in the plant including contract labour, casual workers and visitors. He will be responsible for giving information to press or any outside agencies. He is also responsible for organizing canteen facilities and keeping informed the families of affected persons.

The person nominated as security officer should guide police, fire fighting and control the vehicle entries.

The site controller or any other nominated person will announce resumption of normalcy after everything is brought under control.

The on site emergency plan needs to be evaluated by mock drill. Any weaknesses noticed during such drills should be noted and the plan is modified to eliminate the weaknesses.

## **6.6 STATUTORY REGULATIONS**

Applicable Acts and Rules are:

1. The Gas Cylinder Rules 1981.
2. The Factories Act 1948.
3. The Manufacture, Storage and Import of Hazardous – Chemicals Rules, 1989.
4. Public Liability Insurance Act & Rules, 1991.
5. The National Environment Tribunal Act 1995.
6. Chemical Accident Rules 1996.
7. National Environment Appellate Authority Act & Rules 1997.

APPENDIX: 6.1

**MATERIALS OF CHLORINE EQUIPMENT & ANCILLARIES**

S. No.	Equipment	Material
1.	Piping Rigid	Seamless carbon steel ASTM A 106 grade 'B' schedule 80 or equivalent BIS- 1030-1974
	For gas below atmospheric pressure	Rigid uPVC (for under shed), polyethylene tube, HDPE (outside shed).
2.	Piping (Flexible)	Annealed copper with cadmium plating.
3.	Globe valves	Body : Forged carbon steel Trim : monel or hastelloy 'C' Stuffing box : PTFE or graphite packing.
4.	Ball valves	Body & end piece: Forged carbon steel, ASTM A 105 or equivalent IS Seat : PTFE Ball : Monel
5.	Springs	Tantalum alloy, hastelloy
6.	Gasket	Lead containing 2 to 4% antimony or bonded asbestos.
7.	Chlorinator	Vacuum Regulator body : Carbon Steel Regulator diaphragm : FLUON, FEP, Cabinet: FRP 'O' ring & gaskets : Fluorocarbon lead oxide (litharge cured) viton
8.	Pressure gauge	Diaphragm: silver, tantalum, hastelloy, monel alloy Liquid: fluorocarbon, (silicon oil) fluorolube 'MO'10
9.	Differential Regulator	Body: u PVC, ABS, ebonite, PVDF
10.	Pressure relief valve	Body: uPVC, ABS, ebonite, PVDF Stem: Ag, hastelloy, monel
11.	Injector	Block: ebonite or PVC, ABS
12.	Evaporator	Vessel: boiler quality steel
13.	Rupture disc	Silver: monel, tantalum, hastelloy 'C'
14.	Rotameter	Glass: borosilicate Float: PTFE, tantalum, hastelloy, glass
15.	Filter media	Glass wool
16.	Diffuser & solution line	Rigid uPVC, saran or rubber lined steel, HDPE, natural rubber hose.
17.	Pressure reducing Valve	Body: Ductile cast iron Diaphragm: FPM (Viton), ECTFE/FEP Plugs: silver or tantalum, hastelloy Seats: PTFE
18.	Check valve springs	Tantalloy/hastelloy
19.	Non permanent joints	Mixture of linseed oil and white lead or mixture of linseed oil and graphite or teflon tape
20.	Permanent joints	Glycerine & litharge
21.	Screws	Monel & stainless steel

## APPENDIX: 6.2

### LIST OF SAFETY SYSTEMS AT CHLORINATION PLANT

1. Breathing apparatus.
2. Emergency kit.
3. Leak detectors.
4. Neutralisation tank.
5. Scrubber system.
6. Siren system.
7. Display of boards in local language for public cautioning, first aid and list of different authorities with phone numbers.
8. Communication system.
9. Tagging system for equipments.
10. First aid including tablets and cough mixtures.
11. Exhaust fans.
12. Testing of pressure vessels, chlorine lines etc. every year as per factory act.
13. Training & mock drill.
14. Safety showers.
15. Eye fountain.
16. Personal protective equipments.
17. Protecting hoods for ton-containers.
18. Fire extinguishers.
19. Wind cock.

APPENDIX: 6.3

**TROUBLE SHOOTING CHART FOR VACUUM TYPE CHLORINATOR**

Trouble	Cause	Remedy
1. Required gas flow not achieved at start-up.	<ul style="list-style-type: none"> <li>a. Insufficient ejector vacuum caused by insufficient water supply by pressure or excessive back pressure.</li> <li>b. Leakage at vacuum line connection at outlet from flowmeter, rate control valve, differential from flowmeter, differential pressure regulator, and/or inlet to ejector.</li> <li>c. Vacuum line(s) if flexible, crimped.</li> </ul>	<ul style="list-style-type: none"> <li>a. Refer to Trouble at S.no.6.</li> <li>b. Inspect each connection and remake if necessary.</li> <li>c. Replace vacuum tubing and arrange line(s) to eliminate crimping.</li> </ul>
2. Required gas flow rate is not achieved on start-up following an extended period of shutdown.	<ul style="list-style-type: none"> <li>a. Insufficient ejector vacuum.</li> <li>b. Leakage at vacuum line connection at outlet of flowmeter, rate control valve, differential pressure regulator, or inlet to ejector.</li> <li>c. Vacuum line(s), if flexible, crimped.</li> <li>d. Leakage around flowmeter gaskets.</li> </ul>	<ul style="list-style-type: none"> <li>a. Refer to Trouble at S.no.6.</li> <li>b. Inspect each connection and remake if necessary.</li> <li>c. Replace vacuum tubing and arrange line(s) to eliminate crimping.</li> <li>d. Inspect and align flowmeter or replace gaskets.</li> </ul>
3. Flowmeter float observed bouncing and/or maximum gas flow cannot be achieved during normal operation.	<ul style="list-style-type: none"> <li>a. Gas inlet filter of vacuum regulator dirty.</li> <li>b. Rate valve dirty.</li> <li>c. Flowmeter dirty.</li> <li>d. Ejector water supply pressure fluctuating too wide (float bounce) or insufficient ejector vacuum.</li> </ul>	<ul style="list-style-type: none"> <li>a. Replace gas inlet filter assembly.</li> <li>b. Clean rate valve.</li> <li>c. Clean flowmeter.</li> <li>d. Correct water supply pressure as necessary.</li> </ul>
4. Flowmeter fails to indicate gas flow during normal operation but there is no out-of-gas indication.	<ul style="list-style-type: none"> <li>a. Rate valve plugged.</li> <li>b. Gas flowmeter plugged.</li> <li>c. Vacuum lines, if flexible, crimped.</li> </ul>	<ul style="list-style-type: none"> <li>a. Clean rate valve.</li> <li>b. Clean gas flowmeter.</li> <li>c. Replace vacuum tubing and re-arrange lines to eliminate crimping.</li> </ul>
5. No gas indication during normal operation.	<ul style="list-style-type: none"> <li>a. Gas supply valve(s) closed.</li> <li>b. Gas supply exhausted.</li> <li>c. Clogging of filter in vacuum regulator.</li> </ul>	<ul style="list-style-type: none"> <li>a. Open gas supply valves.</li> <li>b. Replenish gas supply.</li> <li>c. Replace filter.</li> </ul>

Trouble	Cause	Remedy
6. Insufficient ejector vacuum.	a. Y-strainer in water supply line is dirty reducing available supply pressure. b. Back pressure is greater than value listed for one of the following reasons; i) solution valve, if present, not fully open ii) solution line, if present, partially blocked. iii) back pressure at point of application has increased above its original value. c. Ejector nozzle and/or throat dirty.	a. Clean Y-strainer.  b. Open solution valve, clean solution line.  c. Clean nozzle and/or throat.
7. Loss of gas feed.	a. Dirty or plugged ejector nozzle.  b. Insufficient water pressure to operate ejector. c. No gas supply.	a. Check for vacuum in ejector. Clean nozzle. b. Provide proper water pressure. c. Replenish gas supply.
8. Flooded feeder.	Dirt lodged on the ejector check valve seat.	Clean or replace seat or o-ring.



APPENDIX: 6.4

**STANDARDS RELATED TO CHLORINATORS**

1.	BS: 1500	-	For tonners.
2.	IS: 7681	-	Specification for welded low carbon steel gas cylinders for chlorine gas.
3.	IS: 3224	-	Specification for valve fittings for compressed gas cylinders.
4.	IS: 4263	-	Code of practice for chlorine.
5.	IS: 10553	-	Parts I & II: Requirements for chlorination equipment.
6.	IS: 5844	-	Recommendations for hydrostatic stretch testing of compressed gas cylinders.
7.	IS: 4379	-	Identification of contents of industrial gas cylinders.
8.	IS: 646	-	Specification for liquid chlorine.
9.	IS: 8198 Part 6	-	Code of practice for steel cylinders for liquified chlorine gas.
10.	IS: 5845	-	Code of practice for visual inspection of low pressure welded steel gas cylinders in use.
11.	IS: 8868	-	Periodical inspection interval of gas cylinders in use.
12.	IS: 9200	-	Methods of disposal of unserviceable compressed gas cylinders.
13.	IS: 5903	-	Recommendation for safety devices for gas cylinders.
14.	IS: 3710	-	Filling ratios for low pressure liquifiable gases contained in cylinders.

## CHAPTER 7

# RESERVOIRS INCLUDING SERVICE RESERVOIRS

### 7.1 OPERATION OF RESERVOIRS

The main function of Reservoirs and Service Reservoir (SR) is to cater for daily demands and especially peak demands of water. Operators/managers must be concerned with the amount of water in the storage reservoir and the corresponding water levels at particular times of the day. Procedures for operating the Service Reservoir will depend upon the design of its storage capacity and on the water demand.

#### 7.1.1 NORMAL PROCEDURES FOR OPERATION OF SERVICE RESERVOIR (S.R.)

Service Reservoirs have to be operated as per the design requirements. Normally the service reservoirs are constructed to supply water during periods of high water demand and hence the SRs are filled in low water demand period. At times pumps may be used only for filling the SR before the next supply timing or can be used also during supply hours to maintain the levels in the SR.

In some systems reservoirs are allowed to float at the end of distribution system when pumps are used to pump directly into the distribution system and excess water flows into the SR. In such systems multiple pumps are used to cater to varying demand and pressures in the system.

Small changes in the distribution system such as pipeline extensions or the addition of few more connections will not require additional storage requirement. Major system changes such as addition of larger size of main pipelines and increase in large number of connections may require additional storage.

#### 7.1.2 OPERATION OF SRS DURING ABNORMAL CONDITIONS

Abnormal operating conditions arise:

- Whenever demand for water goes up suddenly due to fire demand, or due to excessive demand on one command area/zone of a system.
- Due to failure or breakdown of water supply of another zone of the distribution system.
- Breakdown or out of service pumps or pipelines or power breakdowns or out of service SRs.

The operator/manager must have a thorough knowledge of the distribution system emanating from the SRs. Closure or adjustment of valves at strategic points in the distribution system can focus or divert the flow of water towards the affected areas. Emergency plans must be developed in advance to cope with such situations. Further details for emergency planning may be seen in Chapter 14 – System Management.

### **7.1.3 STORAGE LEVELS**

Most of the distribution systems establish a pattern of levels for assuring the required supplies at the required pressures. A water usage curve over a 24 hour period should be prepared for each SR. It can be seen from the usage curve that the pattern varies not only during the different times of the day but also during different days of the week especially on week-ends, holidays and festivals. Demand pattern also changes during different times of the year depending on the weather conditions such as summer, winter etc. From the usage curve the operator can better anticipate and be ready for the expected high consumption periods. The maximum water levels to be maintained in the SR at each morning should be known to ensure that the system demands are met for the day.

In case of intermittent supply, timings for supply of water in the areas are fixed in advance. In large command areas, the water can be supplied to sub-zones during particular fixed hours by operation of the necessary valves. The operator should work out a programme for compliance.

### **7.1.4 STORAGE CAPACITY**

Capacity of storage reservoir at different levels can be calculated and charts or tables can be prepared and kept at the SR site. Proper functioning of water level indicators is required to read the water level in the SR and assess its capacity. Usually water levels are read at the same time each day and the readings recorded. Checks of water levels at other times of the day will enable to determine if any unusual consumption conditions have occurred. If any significant increase in consumption is anticipated the operations should ensure a corresponding increase in supply into the SR. Automatic valves are used to prevent overflows from SR and maintain a constant level in the SR as long as the pressure in the distribution system is adequate. Often the pumps feeding into a SR are switched off or switched on as per the water levels in the SR. In some SRs advance warning alarms are provided to signal when water levels in SR are either too low or too high. The operator shall ensure that the automatic operations work as and when needed. Some times time clocks are often used to control the water coming into the reservoir. At some places the overflow is connected to the distribution system; in such cases some mechanism must be in place to indicate that the reservoir has started overflowing.

Routine valve operations are normally done at the SRs. Problems in operation of valves in SRs can also be caused by valve seat getting jammed, and hence cannot be opened, or non seating of valves, and hence cannot be closed properly. Sometimes two valves are fixed in series on the outlet and the downstream valve only is usually operated. Whenever the valve under operation is jammed the upstream valve is closed and the jammed valve is repaired. Such an arrangement enables repair of valves without emptying the SR. In some SRs a by pass line is provided direct from the inlet line to the outlet line for drawing water without feeding the SR. Identification of the valves as to their intended purpose such as inlet, outlet, scour, bye-pass etc. and their direction of opening are to be prominently marked. The operator/manager shall ensure that all valves in a SR are in good working condition and are operated as per the schedule for such operations.

### **7.1.5 STORAGE LEVEL CONTROL**

A simple system used to read and control the levels in SRs is a gauge/water level indicator. Whenever the SR reaches the maximum water level, the operator informs the pump house

to stop pumping. In place of the traditional telephones, mobile phones or dedicated wireless units can also be used. Electrodes, ultrasonic signals or solid state electronic sensors are also used to sense the rise and fall in water levels and send signals to the pumps to be stopped or started through cables or wireless or radio frequencies.

It is also desirable to have an indication of levels of SR in the pump house. Automation of level controls at SRs is to be attempted with caution since most of the authorities require only a small amount of instrumentation and control. It is desirable that only simple level control instruments are chosen keeping in view availability of skilled personnel. However, it is desirable that trained and qualified operators only are permitted to repair the instruments.

### **7.1.6 SAMPLING FOR WATER QUALITY**

Water from all SRs should be regularly sampled especially once, before and after monsoon to determine the quality of water that enters and leaves the SR. Sampling data can help in setting up periodic cleaning of SR. Indicators that help to decide when the tank is due for cleaning is turbidity, excessive colour, taste and odour.

Water quality problems may be of microbiological type which could be caused by loss of residual chlorine due to bacterial contamination. Chemical water quality problems may also occur due to leaching from reservoir lining and coating for RCC and masonry tanks and due to corrosion of steel tanks. Common cause of physical water quality problems includes collection of sediment, rust and chemical precipitates. Water quality in a SR may also deteriorate due to excessively long periods of stagnant conditions. Some times poor design, and improperly applied/and or cured coatings and linings may also cause water quality degradation. Proper investigation is required to find the reasons for water quality degradation, determine the source of the problem and address the same. Wherever seasonal demands fall and the residual chlorine levels get depleted, it may be necessary to add additional chlorination facilities.

## **7.2 PLAN FOR O&M OF SERVICE RESERVOIRS**

The plan for O&M of the service reservoirs shall contain operational procedures, maintenance procedures and the manufacturer's information in respect of the instruments/gauges.

### **7.2.1 PROCEDURES FOR OPERATIONS**

The operational procedures inter-alia will contain:

- Design criteria for the reservoir such as: capacity in liters, size and depth of storage; size of piping of inlet, outlet, scour and overflow; sizes and locations of control valves of inlet, outlet and scour; source of feeding the reservoir; hours of pumping or gravity feeding into the reservoir; rate of flow into the reservoir; hours of supply from the reservoir and quantity to be supplied from the reservoir; areas to be served/ supplied; highest and lowest elevations to be commanded from the SR and the water levels to be maintained in the SR for command of the entire area.
- Structural drawing of the SR and the layout drawing showing the alignment of pipe connections, by pass lines, interconnections and location of valves, flow meters, pressure gauges and alignment of out-fall drain to lead off the scour and overflow water from the reservoir.

- Schedule of suppliers' names, addresses and telephone numbers of the equipment installed in the SR such as valves, flow meters, level indicators etc.
- A spot map showing the location of the piping and valves. The map shall also indicate open or closed positions of valves to be operated. This map shall be preserved by a glass cover or laminated to prevent unauthorised meddling.
- Step by step operating instructions indicating how to operate and control various valves located on the inlets and outlets, so as to ensure the required quantity of water is supplied to the command areas at the desired pressures during the period required to be supplied.
- A record sheet for each valve showing direction for turning, number of turns, inspections, repairs and whether open or closed. The direction of operation of valves shall be clearly marked as "open" or "close".
- The name of the valve and piping such as washout, inlet, outlet, by pass, overflow etc shall be painted clearly and repainted regularly.
- In the case of mechanised operation of valves, the steps to include starting, running and stopping the operations.
- Instruction for situations when valves cannot be operated due to some problems regarding authority to be informed and receive further instructions.

### **7.2.2 MAINTENANCE PROCEDURES**

The maintenance procedures shall contain step by step procedure to cover every piece of equipment used in SRs such as valves and flow meters preferably following the procedures indicated in the manufacturers' catalogues.

#### **(a) Valves**

- All valves should be inspected and operated regularly.
- The manager shall specify frequency of inspection.
- A small amount of penetrating oil is poured down the spindle to lubricate packing gland and soften the packing.
- Valve spindles that develop leaks on turning should be repacked.
- Rust and sediment in the valve is removed by shutting the disc hard in the seat, then opening about a quarter way and closing tightly several times; the increased velocity usually flushes the obstructions away.
- Valve chambers of the SR also require maintenance to ensure that the interiors of chambers are not silted up and also ensure that the covers are in good condition and are in position.

#### **(b) Service Reservoirs**

SRs have to be inspected regularly and the manager can prescribe frequency of inspections. Leakage from structure of SR and through the pipes and valves has to be attended to on priority. It is advisable to resort to pressure grouting to arrest leaks from structures and sometimes an additional coating of cement mortar plastering is also done using water proof compound to arrest leaks from the structure.

Maintenance is concerned with mainly protection against corrosion both externally and internally. Corrosion of roof slab of RCC reservoirs due to the effect of chlorine is also quite common. Internal corrosion is prevented by cleaning and painting at regular intervals. Toxic paints should not be used for painting interior surface of SRs. Anticorrosive painting (epoxy) is also done to the interiors when corrosion due to chlorine is expected.

Painting of steel tanks once in a year and external painting with waterproof cement paint for exteriors of RCC Tanks once in 5 years is usually done. The inside of painted SR shall be disinfected before putting into use for a period sufficient to give chlorine residuals of at least 0.2 mg/l.

### **7.3 CLEANING OF SERVICE RESERVOIRS**

Routine inspection is the best way to determine when a tank requires maintenance and cleaning. A visual inspection can be made from the roof manhole with water level lowered to about half full or less. Alternatively a detailed inspection can be made after draining the tank and then cleaning or washing. Best time of the year to take up cleaning of SRs is during the period of lowest water consumption.

The following activities are normally involved in cleaning of a tank/SR:

- Make alternate arrangement for water supply to consumers served by the SR.
- Close the inlet line before commencing cleaning of SR.
- Draw the water from the SR till 200-300 mm water is left in the SR.
- Close the outlet valve so that no water will be used while the tank is being cleaned.
- Collect sample of water and silt/mud accumulated in the Tank and get the biological analysis and for presence of snails and worms. If snails and worms are found find the source and eliminate it.
- Drain and dispose off the remaining water and silt.
- Wash the interior of tank walls and floor with water hose and brushes.
- Inspect the interior of walls and ceiling of tank for signs of peeling off or deterioration.
- Apply disinfectant (Supernatant of Bleaching powder) to the walls and floor before start of filling the tank/SR.
- Frequency of cleaning of SR depends on the extent of silting, development of bio films and results from water quality monitoring.

### **7.4 PERSONNEL**

Recommended minimum O&M staff for SR s is contained in the Manual on Water Supply and Treatment. The required personnel have to be trained in the maintenance of the valves, flow meters, water level indicators etc; training to include fault location, dismantling and assembling after repairs and replacement of the parts of the valves, flow meters and water level indicators.

The supervisory personnel (managerial staff) have also to be trained in supervision of the maintenance.

## **7.5 SPARES AND TOOLS**

### **7.5.1 SPARES**

The maintenance procedures shall contain a list of spares which are likely to be damaged due to wear and tear and have to be replaced in a SR. This list will also indicate the minimum quantity at which replenishment should be made. The list of probable spares to be kept in stock may include the following:

- Spare check nuts and spindle rods and assorted bolts, nuts and washers for the flangs.
- Gaskets for flanged joints for all sizes of sluice valves installed in the SR.
- Spare pulleys.
- Threads, floats and indicators for water level indicators.
- Spare manhole covers, spare fly proof mesh for ventilators and
- Consumables like the gland rope, grease, cotton waste.

### **7.5.2 TOOLS**

The necessary tools to repair and correct the routine problems and for facilitating repairs and replacements in a SR have to be identified and provided to the maintenance staff.

Some of the tools for the maintenance work in a SR are:

- Key rods for operation of all sluice valves.
- Hooks for lifting manhole covers.
- Pipe wrench of appropriate sizes (200, 300 or 450 mm).
- DE spanner set, Ring spanner set.
- Screw Drivers, Pliers.
- Hammers, Chisels.
- Excavation tools such as crow bars, spades, iron baskets and
- House keeping accessories such as long brooms and coir brushes.

### **7.5.3 LIST OF AVAILABLE SPARES AND TOOLS**

A list consumables such as gland rope and list of spares such as spindle rods or stems, check nuts or wedge nuts and a list of suggested Tools available at each SR site shall be prepared and shown in the premises of each SR.

## **7.6 MANUFACTURER'S INFORMATION**

For each SR compilation shall be made which contains the information about the equipment used in the SR such as sluice valves, Butterfly (BF) valves, air valves, water level indicators, pressure gauges, flow meters, water level indicators etc. The information for the equipment shall include manufacturer's name, address telephone number etc. and also the technical information furnished by the manufacturers. The test certificates, inspection reports and warranty certificates of these equipment shall also be kept along with the manufacturer's information.

## **7.7 RECORDS AND REPORTS**

### **7.7.1 RECORD SYSTEM**

A record system has to be developed which should be realistic and apply to the operating problems involved at the particular SR site. The most efficient way to keep records is to plan what data is essential and then prepare the formats followed by the persons to fill the data, frequency and to whom the record is to be sent for review and report. Sample records to be maintained at a SR site are given below for guidance.

### **7.7.2 RECORDS TO BE KEPT ON THE OPERATIONS**

Note the following:

- Water levels in the SRs (for all compartments) at hourly intervals.
- Time and relevant operation of control valves with time of opening and closure or throttling position of the valves.
- Hourly flow meter readings both on the inlets and outlets.
- Hourly residual chlorine readings of inflow water and outflow water.
- The man-hours spent on routine operations at the SR in previous year and the cost thereof.

### **7.7.3 MAINTENANCE RECORD**

Maintain record on each of the following maintenance/repair works along with the cost of materials and labour.

- When the gland ropes of the valves at the SR were changed.
- When the spares of the valves were changed.
- When the manhole covers were changed/replaced.
- When the water level indicator was repaired or replaced.
- When the reservoir was last cleaned.
- When the out-fall drain for scour and overflow was last cleaned.
- When the ladder was changed.
- When the structure of the reservoir was last repaired to attend to structural defects or arrest leakage.
- When the reservoir was last painted.
- When the piping at the reservoir was last painted.
- Total cost of repairs and replacements at the SR in previous year along with break up of material cost and labour cost with amount spent on outside agencies for repairs and replacements.

### **7.7.4 REPORTS**

With the accumulation of all essential data a report can be prepared evaluating the O&M of the facility. The report can identify the deficiencies in the SR and its appurtenances and



then plan future repairs to the structure or valves and other equipment or for replacement of defective valves or other equipment or additions to the storage capacity where the existing capacity is inadequate.

## 7.8 CHECKS TO BE CARRIED OUT AT SRS

A programme has to be prepared for each SR which shall contain procedures for routine tasks, checks and inspections at intervals viz. Daily, weekly, quarterly semi annually or annually. This plan shall fix responsibility, timing for action, ways and means of completing the action as to when and who should take the action and mention the need to take this actions. Simple checklists for use by the managerial staff can be prepared to ensure that the O&M staff have completed the tasks assigned to them.

### 7.9.1 CHECK LISTS FOR CLEAR WATER SUMP AND RESERVOIR

S. No.	Checks required/undertaken	Status	Frequency of reporting*
1.	Proper closure of washout valves; any abrupt stoppage during operation.		
2.	Proper operation of inlet valves; any abrupt stoppage during operation.		
3.	Proper operation of outlet valves; any abrupt stoppage during operation.		
4.	Proper operation of bye pass valves; any abrupt stoppage during operation.		
5.	Does any valve pass water even after closure.		
6.	Leaks through valves; glands and bolts and nuts.		
7.	Leaks through pipes and joints at SR.		
8.	Status of valve chambers and their covers.		
9.	Status of finial ventilators; fly proof mesh intact or is to be replaced.		
10.	Status of manhole covers; are they corroded?		
11.	Functioning of water level indicators.		
12.	Functioning of flow meters.		
13.	Status of ladders and railing; are they corroded?		
14.	Check whether quality of the water in the SR is OK.		
15.	Possibility of SR water getting polluted.		
16.	Check for the need for cleaning and disinfecting the SR.		
17.	Check for the presence of residual chlorine in the water stored in SR.		
18.	Check for signs of corrosion of interior of roof due to chlorine.		

<b>S. No.</b>	<b>Checks required/undertaken</b>	<b>Status</b>	<b>Frequency of reporting*</b>
19.	Check for structural damages of the SR.		
20.	Check for Leaks through the structure of the SR.		
21.	Status of interconnecting pipe work? Is it corroded?		
22.	Status of lightning arrestor.		
23.	Status of out-fall drains of scour and overflow at SR.		
24.	Availability of:		
	Spares		
	Consumables		
	Tools		
25.	Check for need for painting.		
26.	Check for availability of drawings and designs of the SR.		

\* To be decided by the respective water utilities.

## CHAPTER 8

# DISTRIBUTION SYSTEM

### 8.1 OBJECTIVE OF A DISTRIBUTION SYSTEM

The overall objective of a distribution system is to deliver wholesome water to the consumer at adequate residual pressure in sufficient quantity at convenient points and achieve continuity and maximum coverage at affordable cost. To attain this objective the organisation has to evolve operating procedures to ensure that the system can be operated satisfactorily, function efficiently and continuously, and as far as possible at lowest cost.

Routine and emergency operating procedures should be in written form and understandable by all operators of the authority to act in emergencies. Further, specific operational procedures are required for inspecting, monitoring, testing, repairing and disinfecting the system as well as for locating the buried pipes and valves. System records and maps should be updated and have sufficient details of the system facilities, their condition, routine maintenance that is needed and done, problems found and corrective actions taken. Analysis of the records will enable the organisation to evaluate how well the installations are functioning and how effective its services are and hence assess their adequacy to meet the needs of the consumers.

### 8.2 NORMAL OPERATIONS

Normally, the operations are intended to maintain the required supply and pressure throughout the distribution system. Critical points are selected in a given distribution system for monitoring of pressures by installation of pressure recorders and gauges. These pressures are either measured manually and transmitted to the control station or automatically measured and transmitted by telemetry to control station. In the direct pumping systems, whenever water pressures in the distribution system or water levels in the Service Reservoir (SR) drop below the minimum required levels, pumps would be manually or automatically started. In an intermittent water supply system, pumps and valves are operated during fixed hours. These pumps will run till the maximum levels in SR and maximum pressures in the distribution system are reached. Operators are required to ensure the accuracy of the measuring instruments for pressures and levels so that the pumps operate or stop at the proper levels. Sometimes, online Booster pumps are introduced to work on line to start whenever the desired pressures fall below the required pressures. Both upstream and downstream pressures are sensed and transmitted to the booster pumping station for automatic starting or stopping of the pumps when the actual pressures are below or above the desired pressures.

## **8.3 ISSUES CAUSING PROBLEMS IN THE DISTRIBUTION SYSTEM**

### **8.3.1 INTERMITTENT SYSTEM**

The distribution system is usually designed as a continuous system but often operated as an intermittent system. Intermittent supply creates doubts in the minds of the consumers about the reliability of water supply. This leads to limited use of the water supplied, which does not promote personal hygiene at times. During the supply period the water is stored in all sorts of vessels for use in non-supply hours, which might contaminate the water. Often, when the supply is resumed, the stored water is wasted and fresh water again stored. During non-supply hours polluted water may enter the supply mains through leaking joints and pollute the supplies. Further, this practice prompts the consumers to always keep open the taps of both public stand posts and house connections leading to wastage of water whenever the supply is resumed. Intermittent systems and systems which require frequent valve operations are likely to affect equitable distribution of water mostly due to operator negligence.

### **8.3.2 NON-AVAILABILITY OF REQUIRED QUANTITY OF WATER**

Failure of source or failure of power supply may cause reduced supplies. Normally, the distribution reservoirs are designed for filling in about 8 hours of pumping and whenever the power supply is affected the pumping hours are reduced and hence the distribution reservoirs are not filled up leading to reduced supply hours and hence reduced quantity of water.

### **8.3.3 LOW PRESSURE AT SUPPLY POINT**

Normally peak demand is considered ranging from 2 to 3, whereas the water supply is given only for a different duration, leading to large peak factors and hence affecting the pressures in the distribution system. This is a common with most water supply systems.

### **8.3.4 LEAKAGE OF WATER**

Large quantity of water is wasted through leaking pipes, joints, valves and fittings of the distribution systems either due to bad quality of materials used, poor workmanship, corrosion, age of the installations or through vandalism. This leads to reduced supply, loss of pressure and deterioration in water quality.

### **8.3.5 UNAUTHORISED CONNECTIONS**

Illegally connected users will contribute to the reduction in service level to authorized users/ consumers and deterioration of quality of water. Sometimes, even legally connected users draw water by sucking through motors causing reduction in pressures.

### **8.3.6 EXTENSION OF AREA OF DISTRIBUTION SYSTEM**

Due to extension of service area without corresponding extension of distribution mains, the length of house connections will be too long leading to reduction in pressures.

### **8.3.7 AGE OF THE SYSTEM**

With age there is considerable reduction in carrying capacity of the pipelines due to incrustation, particularly unlined CI, MS and GI pipes. In most of the places the consumer pipes get corroded and leaks occur resulting in loss of water and reduced pressure and pollution of supplies.

### **8.3.8 LACK OF RECORDS**

System maps, designs of the network and reservoirs and historic records of the equipment installed in the distribution system are often not available, whereas some minimum information is required to operate and maintain the system efficiently.

## **8.4 OPERATION SCHEDULE**

### **8.4.1 MAPPING AND INVENTORY OF PIPES AND FITTINGS IN THE WATER SUPPLY SYSTEM**

Availability of updated distribution system maps with contours, location of valves, flow meters and pressure gauges or tapping points is the first requirement for preparation of operation schedule. The agency should set up routine procedures for preparing and updating the maps and inventory of pipes, valves and consumer connections. The maps shall be exchanged with other public utilities to contain information on other utility services like electricity, communications etc.

The activities involved in mapping are:

- Establishment of consultative process with management of other utility services like electricity, communications etc.
- Definition of maps such as layout, scale, representation of pipes, valves, connections etc.
- Establishment of procedures for storage and retrieval and updating of maps and inventory information including intersections.
- Setting up procedures for collecting map information in the field including verification in the field for compliance of the as built drawings with design.
- Setting up procedures for updating maps when any changes are made in the distribution system.

### **8.4.2 PROCEDURE FOR PREPARATION AND UP-DATING OF MAPS**

#### **8.4.2.1 CONTENTS OF MAPS**

Comprehensive maps prepared for a scale of 60m/cm to 120 m/cm are used for O&M of distribution system. They provide an overall view of the system with location of reservoirs, pumping stations, valves and hydrants etc. Valve location maps apart from indicating their location also show the direction to open the valve, number of turns to open, make of valve and date of fixing of valve. At times, plan and profile drawings are also available which show the depth of pipe, pipe location vertical and horizontal and distance from reference point. Hydraulic gradient contour maps are also prepared to indicate the pressures in the system in peak demand period. They can be used for identifying high pressure or problem areas with low pressures.

#### **8.4.2.2 FIELD SURVEY**

Existing maps are used or conventional survey is employed for preparation and up-dation of maps. As an alternative to traditional survey and map preparation, 'total station method' is gaining popularity. Total station instruments can be used for survey and mapping of towns where data is not readily available.

### **8.4.2.3 GIS MAPS**

Geographic Information System (GIS) is a computer program that combines mapping with detailed information on physical structures with geographic areas. GIS has also compatibility with auto-cad design systems. The remote sensing maps can be used to prepare base maps of the utilities by using GIS. The GIS creates a database within a mapped area such as streets, valve chambers/manholes, pipe networks and pumping stations. The attributes can be address, number of valve chamber/manhole, pipe length, diameter, invert and quadrant (coordinates) and can also include engineering information, maintenance information and inspection information. The utility staff will get facility to update the maps and retrieve information geographically. These maps can be used to inform the maintenance crew to locate the place of work. The utility can use a work order system for new/repair works so that after completion of the work like a line is added or a valve is fixed or a new connection is given, the work order can be used by the map unit for up-dation of the map and the attributes also. These maps are used to indicate layers of maps for water lines, sewers, power cables, telecom cables etc.

### **8.4.3 ROUTINE OPERATIONS OF THE WATER SUPPLY DISTRIBUTION SYSTEM**

The efficiency and effectiveness of a water supply system depends on the operating personnel's knowledge of the variables that affect the continuity, reliability, and quantity of water supplied to consumers. The operational staff should be able to carry out changes in the hydraulic status of the system as required depending on those variables promptly and effectively. Routine operations shall be specified which are activities for adjusting the valves and operation of pumps to match the prevailing conditions (flows, pressures, levels and operation of pumps).

Valve and pump operations will have to be controlled as per a schedule. The schedule shall contain procedures for operating the distribution system. It should contain procedures to obtain, process, and analyze the variables related to water flows, pressures and levels as well as the consequences of manipulating control devices, such as operation of valves and or pumps so that the hydraulic status of the system can match the demand for water. When operators change their shifts information on valve closure and opening must be exchanged.

### **8.4.4 OPERATIONS IN OTHER THAN NORMAL CONDITIONS**

Operations other than routine viz. during breakdowns and emergencies have to be specified and should be carried out in specific circumstances when normal conditions change i.e. when flows, pressures and levels and operation of pumps change.

### **8.4.5 MEASUREMENT OF FLOWS, PRESSURES AND LEVELS**

It will be necessary to monitor regularly operational data concerning flows, pressures and levels to assess whether the system is functioning as per requirements. Analysis of data may reveal over drawal of water to some reservoirs and or bulk consumers. At such places appropriate flow control devices may be introduced to limit the supplies to the required quantity. A list of priority points in water supply system have to be identified such as installation of meters to measure flows, pressures and levels. A detailed map showing location for each measuring point has also to be prepared. The degree of sophistication of the devices used at each measuring point with regard to indication, integration, recording, transmission

and reception of data depends mainly on the skills of the O&M personnel available with the agency and affordability of the agency.

#### **8.4.5.1 EVALUATION OF HYDRAULIC CONDITIONS**

A continuous evaluation of the hydraulic conditions of the water supply system can be done by the O&M personnel after obtaining the data on water volumes and flows at various points in the system, the water pressures and levels in the reservoirs and comparing with expected performance. This evaluation shall lead to identification of operational problems and or system faults. Depending on the type of problems actions have to be initiated to ensure that the system functions as per the requirement.

#### **8.4.5.2 SYSTEM PRESSURES**

Maintenance of a continuous positive pressure at all times (during supply timings) to consumers is the main concern of O&M. Negative pressures can cause contamination of water supplies especially in intermittent supplies. Very high pressures may damage the pipelines and valves, which can be corrected with pressure reducing valves. Complaints from consumers about low pressures have to be promptly investigated if necessary by measuring pressures with pressure gauges. Low pressures may be under the following circumstances:

- Purposefully or accidentally a line valve is left closed or partly closed or blockage due to any material causing loss of pressure.
- Too high velocities in small pipelines.
- Low water levels in SR.
- Failure of pumps/booster pumps (either due to power failure or mechanical failure) feeding the system directly.

#### **8.4.5.3 SIMULATION OF NETWORK**

Operations have to be planned for specific circumstances such as failure at source, failure of pumps, leakages or bursts or sudden changes in demand etc. Criteria have to be determined on the basis of analysis of the effects of particular operations on the hydraulic configuration of the water supply system. These effects can be seen in simulated operating conditions. Mathematical simulation models can be developed from basic data on the network such as length, size, flow, characteristics of pumps, valves, reservoir levels etc. This approach can be very useful for analysing the effects of variables on large and complex distribution networks/ water supply systems.

#### **8.4.5.4 SAMPLING FOR QUALITY OF WATER**

The agency operating the water supply system is charged with the primary responsibility of ensuring that the water supplied to the consumer is of an appropriate quality. To achieve this objective it is necessary that the physical, chemical and bacteriological tests are carried out at frequent intervals. The minimum number of samples to be collected from the distribution system should be as prescribed in the Table 15.1 of Chapter 15 of the Manual on “Water Supply & Treatment”. Samples should be taken at different points on each occasion to enable overall assessment. In the event of epidemic or danger of pollution more frequent sampling may be

required, especially for bacteriological quality. For each distribution system a monitoring programme has to be prepared showing the location of sampling points. Based on historic records of a system it will be possible for the manager of the system to decide locations for bacteriological sampling and residual chlorine testing.

Possible water quality problems and causes and remedies are given in Table 8.1.

**TABLE 8.1: WATER QUALITY PROBLEMS, CAUSES & REMEDIES**

S. No.	Problem	Possible Cause	Suggested remedies
1.	Taste and Odour	High chlorine residual.	Lower chlorine dosage
		Biological growth or microorganisms in dead ends and reservoir.	Chlorinate, flush mains and clean the reservoir
2.	Turbidity	Silt or clay in suspension.	Flushing or proper operation of WTP
		Microorganisms	Same as above
		Floc carryover	Same as above
3.	Colour	Decay of vegetable matter	Chlorination
		Microscopic organisms	Chlorination
4.	Positive coliform results	Contamination in distribution system	Locate and remove source of contamination
		Cross connection	Install backflow prevention such as double reflex valves
		Negative pressure	Maintain positive pressure after disinfection
		Improper disinfection	Improve chlorination process

## 8.5 MANAGEMENT IN TIMES OF WATER SHORTAGE

The objective of developing a programme for managing in times of shortage of water is to reduce the excessive use of water particularly when the source is limited due to adverse seasonal conditions. Basically it involves that a water conservation policy is developed and implemented among water consumers. The following activities can be considered while formulating such a water management project:

- Installation of accurate water meters and establishment of a realistic tariff structure to encourage water conservation and prevent wastage of water.
- Introduction of restrictions on use of flushing, showers and other household fittings.
- Introduction of devices to limit water consumption in flushing of toilets.
- Enforcement of restrictions on use of treated water for watering lawns, cooling, construction, washing of vehicles etc.
- Encouragement and/or enforcement of the reuse of treated industrial effluents and municipal wastewater.
- Development and implementation of public education programmes to encourage water conservation.



## **8.6 SYSTEM SURVEILLANCE**

Surveillance of distribution system is done to detect and correct.

- Sanitary hazards.
- Deterioration of distribution system facilities, [to detect].
- Encroachment of distribution system facilities by other utilities such as sewer and storm water lines, power cables, telecom cables etc. and
- Damages of the system facilities by vandalism. [detecting and correcting].

In addition, checks are carried out under special circumstances for assessing damage of the system after flooding of streets following a heavy storm. All these checks are done for above ground water facilities such as valves and valve chambers or exposed pipelines. Some less frequent inspection of underground pipelines will also be required, wherein critical areas of the distribution system should be patrolled routinely so that the water utility can watch out for early warning of any adverse conditions of the distribution system. Any activity or situation that might endanger the water facility or water quality shall be investigated and corrective action is to be taken. Surveillance shall also include looking for unauthorised construction activity on or near the utility's pipelines, which may pose a physical threat to the mains. Any digging or excavation or blasting near the mains shall be closely supervised by the utility staff. Surveillance of Valve chambers and valves shall be done as noted in para 6.6 of this chapter.

## **8.7 MAINTENANCE SCHEDULE**

A maintenance schedule is required to be prepared to improve the level of maintenance of water distribution networks and house connections through improved co-ordination and planning of administrative and field work and through the use of adequate techniques, equipment and materials for field maintenance.

- The schedule has to be flexible so that it can achieve team action with the available vehicles and tools.
- Co-ordination of activities is required for spares and fittings, quality control of materials used and services rendered.
- Training of maintenance staff shall include training to achieve better public relations with consumers apart from the technical skills.

### **8.7.1 ACTIVITIES IN MAINTENANCE SCHEDULE**

Following activities are to be included in the schedule:

- Establishment of procedures for setting up maintenance schedules and obtaining and processing the information provided by the public and the maintenance teams.
- Formation of maintenance teams for each type of service with provision for continuous training.
- Establishment of repair procedures for standard services.
- Specification of appropriate tools.
- Allocation of suitable transport, tools and equipment to each team.

- Establishment of time, labour and material requirement and output expected; time required and other standards for each maintenance task, and
- Monitoring the productivity of each team.

### **8.7.2 PREVENTIVE MAINTENANCE SCHEDULE**

A preventive maintenance schedule for Servicing of Valves and Maintenance of Valve Chambers, Maintenance of the pipelines: may include the tasks, set priorities, issue of work orders for tasks to be performed, list of scheduled tasks not completed, record of when the tasks are completed and maintaining a record of tools, materials, labour and costs required to complete each task.

#### **8.7.2.1 SERVICING VALVES**

Seating of valves which are subject to operations several times is likely to become leaky or pass the flow downstream even after closing tight. Periodical servicing will be required for valves on hydrants and public taps, flow meters and pressure gauges. Corrosion of valves is a main problem in some areas and can cause failure of bonnet and gland bolts. Leaks from spindle rods occur and bonnet separates from the body. Stainless steel bolts can be used for replacement and the valve can be wrapped in polyethylene wrap to prevent corrosion.

#### **8.7.2.2 MANUFACTURERS CATALOGUES**

The manufacturer's catalogues may be referred and comprehensive servicing procedures shall be prepared for periodical servicing. These procedures shall contain manufacturer's name, address, telephone number etc. and also the technical information furnished by the manufacturer of the equipment used in the distribution system such as sluice valves, Butterfly (BF) valves, air valves, pressure gauges, flow meters, etc. The test certificates inspection reports and warranty certificates of this equipment shall also be kept along with the manual.

#### **8.7.2.3 LIST OF SPARES**

A list of spares required for the distribution system shall be prepared and the spares shall be procured and kept for use. The list should indicate the minimum level at which action for replenishments should be initiated. The list of probable spares to be kept in stock may include the following:

Spare check nuts and spindle rods and assorted bolts, nuts and washers for the flanged joints, gaskets for flanged joints for all sizes of sluice valves installed in the distribution system, spare manhole covers and consumables like the gland rope, grease, cotton waste, spun yarn, pig lead and lead wool.

#### **8.7.2.4 LIST OF TOOLS**

The necessary tools to properly repair and correct both the routine problems and for facilitating repairs and replacements in a distribution system have to be identified and provided to the maintenance staff.

Some of the tools for the maintenance work in a distribution system are: Key rods for operation of all sluice valves, hooks for lifting manhole covers, pipe wrench of appropriate sizes ( 200, 300 or 450 mm ), Double ended (DE) spanner set, Ring spanner set, Screw Drivers,

Pliers, Hammers, Chisels, caulking tools for lead and spun yarn, ladles and pans for melting and pouring lead joints, excavation tools such as crow bars, spades, iron baskets, buckets and de-watering pumps.

#### **8.7.2.5 MAINTENANCE OF VALVE CHAMBERS FOR APPURTENANCES**

Valve chambers shall be checked to ensure that they are not damaged, nor filled up with earth nor buried in pavement. Covers of valve chambers are stolen or broken up by vandalism or by accident resulting in damage to the valves or may lead to accidental fall of a person into the open valve chamber. Such situations have to be corrected on priority. Road improvement works require constant attention of water utility staff since the valves may be lost or at times the valve chambers in the roads have to be reconstructed to match the renewed road surface.

#### **8.7.3 MAINTENANCE SCHEDULE FOR PIPELINES**

##### **8.7.3.1 Main Breaks**

Pipeline bursts/main breaks can occur at any time and the utility shall have a plan for attending to such events. This plan must be written down, disseminated to all concerned and the agency must always be in readiness to implement the plan immediately after the pipe break is reported. After a pipe break is located, a decision is to be taken as to which valve is to be closed to isolate the section where the break has occurred. Every consumer (some important consumers may be having an industrial process dependent on water supply which cannot be shut down as fast as the water supply lines are cut off) should be notified about the break and informed about the probable interruption in water supply and also the estimated time of resumption of water supply. After the closure of valve, the dewatering/mud pumps are used to drain the pipe break points. The sides of trenches have to be properly protected before the workers enter the pit. The damaged pipe is removed, and the accumulated silt is removed from inside the pipe and the damaged pipe is replaced and the line is disinfected before bringing into use. After every pipe break a report shall be prepared in regard to the cause of such break, the resources required for rectification and the time and cost required for repairing etc. so that the agency can follow up with measures for avoiding such breaks and also modify their plan to address such breaks in future.

##### **8.7.3.2 Deterioration of Pipes**

Pipes deteriorate on the inside due to corrosion and erosion and on the outside due to corrosion from aggressive soil and water/moisture. Depending on the material of pipes, these are subjected to some deterioration, loss of water carrying capacity, leaks, corrosion and pitting, tuberculation, deposition of sediment and slime growth. Preventive maintenance of distribution system assures the twin objectives of preserving the bacteriological quality of water in the distribution system and providing conditions for adequate flow through the pipelines. Incidentally, this will prolong the effective life of the pipeline and restore its carrying capacity. Some of the main functions in the management of preventive maintenance of pipelines are assessment, detection and prevention of wastage of water from pipelines through leaks, maintaining the capacity of pipelines, cleaning of pipelines and relining. The topic of assessment of leaks is dealt in detail in Chapter 15 on Water Audit and Leakage Control in this manual.

### **8.7.3.3 Flushing of Pipelines**

Flushing is done to clean the distribution lines by removing impurities or sediment that may be present in the pipe. Routine flushing of terminal pipelines is often necessary to avoid taste and odour complaints from consumers. It is advisable that a programme for flushing is prepared and followed so that water mains are flushed before consumers start complaining. The routine for flushing can be prepared by taking into consideration the consumer complaints and type of deposits found while cleaning. Since in distribution system flushing is not the only solution for water quality problems, proper operation of treatment process and cleaning of service reservoirs supplying water to distribution system shall also be planned along with the flushing of distribution system. Flushing is usually done during low water demand, when the weather is favourable. Prior planning and good publicity with public will allow the flushing to proceed quickly and without confusion.

### **8.7.3.4 Cleaning of Pipelines**

Mechanical cleaning devices such as swabs and pigs are some times used if flushing does not improve the water quality. Scrapers or brushes are used in pipelines with hardened scales or extensive tuberculation. Sometimes scrapers and brushes are used before taking up lining works. The topics of cleaning of pipelines including cleaning and swabbing are dealt in Chapter 10 of Manual on "Water Supply & Treatment".

### **8.7.3.5 Cement Mortar lining**

The present trend is to use Cement Mortar lined Ductile Iron (DI) pipes or Mild Steel (MS) pipes so that they will not lose their carrying capacity with use and age. Still many new pipelines are proposed with unlined metallic pipes and there are several existing pipelines with bare metal surface such as CI or MS. With passage of time these pipelines deteriorate and require rehabilitation. Cement mortar stifles corrosion through its ability to develop high alkalinity. The application of cement mortar lining to pipe in place is done by a lining machine, containing a device that projects cement mortar against the pipe wall. Directly behind this device are mechanically driven rotating trowels, which give the surface smooth finish. In-situ Cement Mortar lining of existing metallic water mains has been beneficial where:

- Pipe carrying capacity may reduce due to tuberculation.
- Water quality is affected due to release of corrosion products from the pipes to the water, and
- Leaks occur through joints and pipe walls.

## **8.8 LEAKAGE CONTROL**

Wastage of water in the system and distribution network occurs by way of leakage from pipes, joints & fittings, reservoirs and overflow from reservoirs & sumps. The objective of leakage control programme is to reduce the wastage to a minimum and minimize the time that elapses between the occurrence of a leak and its repair. The volume of water lost through each leak should be reduced by taking whatever action is technically and economically feasible to ensure that the leak is repaired as quickly as possible. To achieve this, the organisation shall prescribe

procedures for identifying, reporting, repairing and accounting for all visible leaks. It will be beneficial for the agency if the procedures involve the conscious and active participation of the population served by the agency apart from its own staff. For details on detection and leakage control, please refer chapter 13.0. Water Audit and Leakage Control. The Management has to process the data and evaluate the work on detection and location of leaks and for dissemination of the results and initiate actions to control the overall problem of water loss. Interim measures for reduction/control of leakage can be initiated by controlling pressures in the water distribution system where feasible.

### **8.8.1 LEAKAGE THROUGH HOUSE CONNECTIONS**

Leakage can be controlled at the point of house connection and in the consumer pipe by adopting correct plumbing practices and improving the methods used for tapping the main and giving house connection and strict quality control on the pipe material used for house connection. An analysis of leaks in house connections and investigation of reasons for leaks in the house connections shall be carried out to initiate action on reducing the leakage through house connections.

### **8.8.2 PROCEDURES FOR REPORTING VISIBLE LEAKS**

The water utility has to establish procedures whereby the population served by the agency can notify the visible leaks. The agency staff can also report visible leaks found by them while carrying out other works on the water supply system. Utility has to establish procedures for prompt repair of leaks and for attending efficiently and accurately to the leaks. Critical areas where leaks often occur have to be identified and appropriate corrective measures have to be implemented.

### **8.8.3 PROCEDURES FOR DETECTING INVISIBLE LEAKS**

Establishment of procedures for detecting and locating non-visible leaks shall be compatible with the technological, operational and financial capability of the agency. Selection and procurement of equipment for detection and location of leaks must take into account the cost effectiveness and the financial capability of the Organisation.

## **8.9 CROSS CONNECTIONS**

### **8.9.1 CROSS CONNECTIONS**

Contaminated water through cross connections of water supply lines with sewers and drains is a problem prevailing widely. Intermittent supply further aggravates the problem since, during non-supply hours polluted water may reach the supply mains through leaking joints, thus polluting the supplies. In certain instances, when there are extremely high water demands, the pressures in the supply mains are likely to fall below atmospheric pressure, particularly when consumers start use of pumps with direct suction from supply mains. Regular survey has to be undertaken to identify potential areas likely to be affected by cross connections and back-flow. All field personnel should be constantly alert for situations where cross connections are likely to exist. After identifying the cross connections, remedial measures are taken up which include: providing horizontal and vertical separation between the water main and the sewer/drain, (refer to para 10.11.1 of Chapter 10 of Manual on "Water Supply

& Treatment”), providing a sleeve pipe to the consumer pipes crossing a drain, modifying the piping including changing corroded piping with non-corrodible piping, providing double check/non return valves at the consumer end etc.

### **8.9.2 CHLORINE RESIDUAL TESTING**

A minimum chlorine residual of about 0.2 mg/l at the selected monitoring point is often maintained to ensure that even a little contamination is destroyed by the chlorine. Hence, absence of residual chlorine could indicate potential presence of heavy contamination. If routine checks at a monitoring point are carried out, required chlorine residuals and any sudden absence of residual chlorine should alert the operating staff to take up prompt investigation. Immediate steps to be taken are:

- Re-testing for residual chlorine.
- Checking chlorination equipment.
- Searching for source of contamination, which has caused the increased chlorine demand.
- Immediate stoppage of supplies from the contaminated pipelines.

### **8.10 MONITORING SYSTEM PERFORMANCE**

Normally the managers of O&M of water utilities monitor levels in service reservoirs, pressures and flows in the distribution system and operation of pumps such as hours of pumping, failure of pumps and monitor water quality by measuring residual chlorine. The manager usually uses telephone line or wireless unit to gather the data, maintain records, analyses, uses his discretion gained with experience and takes decisions to ensure that the system is operating with required efficiency. Manual collection of data and analysis may not be helpful in large undertakings if water utilities have to aim at enhanced customer service by improving water quality and service level with reduced costs. In such cases Monitoring system performance can be done with use of Telemetry and SCADA which are discussed in Chapter 11 – Water Meters and Instrumentation including Flow Meters.

### **8.11 PLUMBING PRACTICES**

The internal plumbing system of the consumer shall conform to the National Building Code and also particularly to the bye laws of concerned water utility/local authority.

#### **8.11.1 QUALITY OF PIPE MATERIAL FOR HOUSE CONNECTION**

The water utility shall ensure that the connection and communication pipe from the street main up to the consumer premises is laid as per correct plumbing practices and adopt improved methods for tapping the main. Strict quality control is required on the pipe material used for house connection. The bye Laws shall lay down rules for defining the ownership and responsibility for maintaining the point of connection and the communication pipe. In several utilities the communication pipes are leaking since they are corroded; however these are not replaced by the consumer or by the utility particularly where the O&M responsibility for consumer pipe rests with the consumers.

### **8.11.2 CONTAMINATION THROUGH HOUSE CONNECTION**

While laying the consumer connection pipes there is a need to avoid contamination of water supplies. This can be achieved by maintaining horizontal and vertical separation between the water supply communication pipe and the sewer/drain, (refer to para 10.11.1 of Chapter 10 of manual on “Water Supply & Treatment”). In some instances a sleeve pipe may be required to be provided to the consumer pipes crossing a drain. It is always recommended to provide a non-corrodible pipe material for the consumer connection. Contamination by possible back flow can also be prevented by ensuring provision of double check/non-return valves at the consumer end.

### **8.11.3 RULES FOR CONSUMER CONNECTIONS**

The water utility shall formulate rules for sanction of consumer connection, tapping the mains and laying the connection piping. Water utility shall undertake inspection of the consumer premises before releasing the connection to ensure that the internal plumbing system of the consumer conforms to the National Building Code. Water utility shall supervise the process of drilling/tapping of the main for giving connection and laying of the consumer piping. The process of submission of applications for connections by consumers and carrying out the connection work through licensed plumbers is also prevalent in some utilities. In such cases the utility shall formulate procedures for licensing the plumbers including the qualifications to be possessed by the plumber, facilities and tools to be available with the plumber for the work to be undertaken by the plumber. The utility shall closely observe the quality of materials used and works done by him and he should act as per procedures laid down in the bye laws for approval of the connection works, renewal or cancellation of the plumbers’ licenses or any other requirement depending on their performance or non performance.

## **8.12 RECORDS AND REPORTS**

### **8.12.1 RECORD SYSTEM**

A record system has to be developed which should be realistic and apply to the operating problems involved in the distribution system. Management must be clear as to why the data/information is collected, as to who will review the data and who will respond to the results of review. The most efficient way to keep records is to plan what data is essential and then prepare the formats followed by the persons concerned for filling of the data, frequency and to whom the record is to be sent for review and report.

Sample records to be maintained are given below for guidance:

- Updated system map.
- Pressure and flow readings at selected monitoring points.
- Persistent low pressure or negative pressure areas.
- Age of pipes/quality of pipes.
- Pipelines to be replaced.

- Presence of corrosive water in the system.
- Water budget for each zone served by one SR.
- Number of connections given.
- Number of meters out of order.
- Status of fire hydrants and public taps.
- Quantity measured at outlet of reservoir.
- Quantity distributed/measured or billed.
- Source of leaks and persistent leak points.
- Status of bulk meters - function or not.
- Status of consumer meters.
- Facilities for repairs of consumer meters.
- Number of unauthorised connections.
- Residual chlorine levels at the pre-selected monitoring points.
- Bacteriological quality of the water sampling points.
- Persistent areas where residual chlorine is absent/where bacteriological samples are unwholesome.
- Record on carrying out repairs on the following works and its cost:
  - ◆ The pipe line leaks or replacement of pipes.
  - ◆ Change of gland ropes of the valves in distribution system.
  - ◆ Replacement of parts.
  - ◆ Replacement of manhole covers.
- Record on man hours spent on routine operations in the distribution system in the previous year and the cost thereof.
- Record on total cost of repairs and replacements in previous year along with break up of material cost and labour cost with amount spent on outside agencies for repairs and replacements.
- Record on when the exposed piping was last painted and the cost of materials and labour cost thereof.
- Record on the unserved areas - extension of pipelines- need for interconnections.

### **8.12.2 REPORTS**

With the accumulation of all essential data a report can be prepared evaluating the O&M of the facility. The report can identify the deficiencies in the system and its appurtenances and then plan future repairs to the network or valves and other equipment or for replacement of defective valves or other equipment or additions and extensions to the distribution network.



## 8.13 CHECKS TO BE CARRIED OUT IN DISTRIBUTION SYSTEM

### 8.13.1 PROGRAMME FOR CARRYING OUT CHECKS

A programme has to be prepared for each zone of the distribution system which shall contain procedures for routine tasks, checks and inspections at intervals viz. daily, weekly, quarterly semi-annually or annually. This plan shall fix responsibility, timing for action, ways and means of completing the action as to when and who should take the action and mention the need to take these actions. Simple checklists for use by the managerial staff can be prepared to ensure that the O&M staff has completed the tasks assigned to them.

### 8.13.2 CHECK LIST

S. No.	Checks required/undertaken	Status	Suggested frequency of reporting
1.	Check whether the Operation of valves is smooth without any abrupt stoppage during closure.		
2.	Check whether closure of a valve results in complete stoppage of flow or if any flow passes the valve (passing valve).		
3.	Check for status of scouring and then proper closure of washout valves.		
4.	Check for leaks through pipes.		
5.	Check for leakage through valves at gland, bolts or any other place.		
6.	Check for leaks at the appurtenances.		
7.	Check for any signs of corrosion of pipelines.		
8.	Check for the status of Manhole covers over the chambers; are they corroded.		
9.	Inspect for any possibilities of pollution of the distribution system water stored.		
10.	Status of out-fall drain for scour and overflow.		
11.	Assess the need for painting of the piping work.		
12.	Check for availability of spares for valves and pipes and jointing materials.		
13.	Review the method of giving consumer connections in the field.		
14.	Preparation of water budget for each zone served by one reservoir.		
15.	Number of connections given.		
16.	Number of meters out of order.		
17.	Status of hydrants and PSPs.		
18.	Status of Distribution System.		

<b>S. No.</b>	<b>Checks required/undertaken</b>	<b>Status</b>	<b>Suggested frequency of reporting</b>
19.	Review of pressures.		
20.	Review of flows.		
21.	Age of pipes/C value of pipes.		
22.	Corrosive water.		
23.	Study of inflows and outflows.		
24.	Identify source of leakage.		
25.	Metering.		
26.	Status of bulk metering and consumer.		
27.	Review facilities for repair of consumer meters.		
28.	Unauthorised connections if any.		
29.	Status of fire hydrants and PSPs.		
30.	Availability of updated system map.		
31.	Need for any interconnections.		

## CHAPTER 9

# DRINKING WATER QUALITY MONITORING AND SURVEILLANCE

### 9.1 INTRODUCTION

Drinking water quality monitoring and surveillance is the continuous monitoring of public health along with vigilant assessment and control of safe potable water supply.

### 9.2 IMPORTANCE OF WATER QUALITY

Safe potable water is the first step to promote good health of the community. Experience has shown that community health and water quality is directly related to each other and an improvement of drinking water quality is followed by an improvement in the community's health. Man made activities; rapid industrialization and agrochemical contamination increasingly affect the quality of water resources. Moreover, infant mortality, mostly from diarrhoeal and other water borne and water related diseases (*Annexure 9.1*) are of great concern in underdeveloped as well as developing countries. In spite of significant achievements in water supply and sanitation coverage, many factors render good quality water unsafe by the time it reaches the consumer. Poor operation management and unsatisfactory sanitary practices are the major key areas responsible for water contamination. Water quality management and surveillance practices ensure safe water supply to consumers.

### 9.3 DEFINITION

While describing water quality, certain terms are frequently used, which are to be clearly understood and correctly used. Some of the definitions are given below:

**Pollution** is the introduction into water of substance in sufficient quantity to affect the original quality of water, make it objectionable to sight, taste, smell or make it less useful.

**Contamination** is the introduction into water of toxic materials, bacteria or other deleterious agents that make the water hazardous and therefore unfit for human use.

**Potable Water** that is satisfactory for drinking purposes from the standpoint of its chemical, physical and biological characteristics.

**Palatable Water** that is appealing to the sense of taste, sight and smell. Palatable water need not always be potable.

**Parts per million (ppm) or milligrams per litre (mg/l)** these terms are used to express the concentrations of dissolved or suspended matter in water. The parts per million (ppm) is a weight to weight or volume to volume relationship. Except in highly mineralized water, this

quantity would be same as milligram per litre. This is preferable, since it indicates how it is determined in the laboratory.

*pH of water* an expression of the Hydrogen ion concentration. Alkaline water is with pH of above 7 and acidic water has pH of below 7; whereas water with pH 7 is neutral.

*Toxic* is harmful, destructive or deadly poisonous.

*Physiological effect* having effect on the normal functions of the body.

*Pathogens* disease-producing organisms.

*Bacteria* a group of universally distributed, essentially unicellular microorganisms lacking chlorophyll.

*Virus* the smallest form capable of producing infection and diseases in human beings.

*Coliform Bacteria* group of bacteria predominantly inhabiting the intestine of human beings and animals, but also occasionally found elsewhere. Used to indicate presence of faecal pollution.

*Enteric* having its normal habitat in the intestinal tract of human beings or animals.

*Chlorine Residual* chlorine remaining in the water at the end of a specified period.

*Chlorine Demand* the difference between the amount of chlorine added to water and amount of residual chlorine remaining in the water at the end of a specified period.

## **9.4 WATER SUPPLY AND SURVEILLANCE AGENCIES**

Water supply agency is responsible for safe water supply to consumers. The main objectives of water quality monitoring are:

1. To determine the quality of water in its natural state in view of its present and future needs
2. To assess the suitability of water for required use
3. To find out the pathways for pollution, if any

Monitoring of water quality by water supply agency involves laboratory and field testing of water samples collected from various points in the water supply system, including the source, water purification plants, service reservoirs distribution systems and consumer end, representative of the condition of water at the point and time of collection. Continuous water quality monitoring involves good operating practices and preventive maintenance, as well as the regular routine testing, and monitoring of water quality to ensure compliance with standards.

Surveillance is an investigative activity undertaken by a separate agency, to identify and evaluate factors posing a health risk to drinking water. Surveillance requires a systematic program of surveys that combine water analysis and sanitary inspection of institutional and community aspects, and reporting system. Sanitary inspection of water supply system should cover the whole system including water sources, rising mains, treatment plants, storage reservoirs, and distribution systems; to identify most common risks and shortcomings in the water supply. Moreover, surveillance is concerned with all sources of water used for domestic purpose by the population, whether supplied by a water supply agency or collected from other

individual sources. So it is important to inspect and analyze all sources of water used and intend to be used for human consumption.

Surveillance agency should communicate to the water supply agency and pinpoint the risk areas and give advice for remedial action. It should also maintain good communication and cooperation with water supply agency for detection of risk areas and remedial action for betterment of water supply. *Annexure 9.2* gives functions and responsibilities of agencies for water quality monitoring and surveillance.

## **9.5 PLANNING AND IMPLEMENTATION**

Systematic planning, keeping in view the fundamental objectives, is necessary for successful implementation of drinking water quality control program.

### **9.5.1 GENERAL CONSIDERATION AND STRATEGIES**

Quality control activities should be initiated as per the norms of national guidelines for each water supply system on a continuous basis.

Surveillance agency should carry out periodic surveillance of all aspects of water quality safety including sanitary inspection and spot checks and result should be reported to the concerned water supply agency to implement remedial action when and where necessary.

Water supply surveillance can be planned in progressive manner considering the availability of resources. It should start with a basic program, which could generate useful data to plan advanced surveillance as resources, and conditions permit. The initial pilot scale program should cover minimum basic strategies including fewer water quality parameters that provide reasonable degree of public health protection and should be widely applicable. Careful planning of training and resource provision is very essential right from the beginning of the project.

### **9.5.2 LEGAL AND INSTITUTIONAL BASIS**

#### **9.5.2.1 Legislative Framework**

Laws and bylaws prevailing in local bodies should be strictly implemented.

#### **9.5.2.1 Institutional Framework**

Water-quality surveillance requires an institutional framework that reflects its objectives and functions and gives key responsibilities to the relevant bodies. At the center of this framework major responsibility for monitoring and surveillance is shared between two agencies whose activities should be mutually exclusive and complementary.

Intersectoral cooperation is required in all activities related to the promotion and surveillance of water quality, from the planning stage, to the actual supply of water, the monitoring and surveillance of water quality, and the implementation of preventive and remedial measures. In the beginning itself, both the agencies should, in consultation with one another, agree on a program on drinking water quality monitoring and surveillance.

## **9.6 SURVEILLANCE PROGRAM**

Surveillance activities differ from region to region; between urban and rural communities; and according to the types of water supply. They should be adapted to local conditions; availability

of local finances, infrastructure and knowledge. Water supply provider and surveillance agencies, depending on resources available with them, will develop the program for monitoring and surveillance of drinking water quality. Following factors should be taken into consideration while implementation of surveillance activities.

- The type and size of water supply systems.
- The existing and available equipment.
- Local employment practices and the level of training.
- Opportunities for community participation.
- Accessibility of systems keeping in view of geographical and climatological conditions.
- Communication and transport facilities available.

Surveillance program can be phased out in three distinct phases - Initial, Intermediate and Advance.

#### **Initial phase**

- Identify agencies and develop collaboration.
- Finalize institutional requirements.
- Prepare inventories of water supply system.
- Preliminary training for staff.
- Assess and identify priority areas for sample collections.
- Develop methodologies for water quality analysis.
- Commence routine surveillance in priority areas.
- Limit water analysis to critical parameters only.
- Establish reporting, filling and communication systems.
- Identify community roles and promote participation.

#### **Intermediate phase**

- Establish and expand systematic routine surveillance.
- Expand analytical capability.
- Train staff.
- Use draft standard methods for analysis and field works.
- Establish data based archive.
- Identify common problems and improve activities accordingly.
- Use legal enforcement where possible.
- Involve community.

#### **Advanced phase**

- Establish routine surveillance for all health parameters at defined intervals.
- Use guidelines as given in Manual on Water Supply and Treatment.
- Give advance training to staff.

- Use full network of local, regional and central laboratories.
- Improve water services on the basis of local priorities, hygiene awareness and enforcement of standards.
- Involve communities.
- Disseminate data at local, regional and national level.

## **9.7 INFORMATION MANAGEMENT**

The flow of information between and within the water supply and surveillance agencies is necessary to maximize the quality of service to consumer and protection of public health. The report provided by the surveillance agency to water supply provider should include:

1. The summary reports of condition of water supply and water quality analysis.
2. Highlight those aspects, which are considered inadequate and needs action.
3. Recommendation of remedial action in case of emergency.

The report should not be limited to complain about failures but the water supply and surveillance agencies should coordinate their activities to ensure good quality of water to consumers. Such a report should specify actions in order of priorities for intervention based on public health criteria. If consistently, unsatisfactory results are reported in a particular area, the cause for the same should be investigated and remedial measures taken, such as repair of leakage, replacement of corroded and leaking consumer pipes etc.

Local laboratory under surveillance agency should maintain detailed field reports regarding inspections and water analysis of all water supplies available in the area. It should include the results of all inspections and analysis. The local surveillance office should report to the relevant supply agency as soon as possible after field visits. The information should also be passed on to regional authorities to allow follow-up; if recommendations for remedial action are not implemented. However, there must be a rapid means of reporting in case of emergency.

The consumers have the right to know about the quality of water being supplied to them. Therefore, the agencies responsible for monitoring should develop strategies for informing public the health-related results obtained by them along with recommendations for action (e.g. boiling during severe faecal contamination, household water storage education etc.) through publicity, pani-panchayats etc.

Local government should ensure that the agency that supplies drinking water to the area complies with the quality standards.

## **9.8 SUPPORT STRUCTURE**

Monitoring and surveillance programmes require laboratory network, offices, transport, financial support and adequate staffing.

### **9.8.1 COMMUNITY BASED MONITORING AND SURVEILLANCE**

Community participation is an essential component of the monitoring and surveillance framework. As the primary beneficiaries community can play an important role in surveillance activity. They are the people who may first notice the problems in water supply and report it to concern agency or take remedial action if possible. Establishing a genuine partnership

with the community creates a climate of trust and understanding, which generates interest and enthusiasm. It also provides a good foundation for other educational activities such as promotion of good hygiene practices.

The community based monitoring and surveillance can be carried out in two ways:

1. Selection of community volunteers, including women, to undertake surveillance activities after training.
2. Providing encouragement to local worker to carry out certain jobs pertaining to surveillance.

In both the cases, preliminary training is necessary for field workers to identify sanitary hazards associated with the water supply, as well as regarding reporting system. Health department or water supply agency should help in providing necessary training while community water committee or health committee can supervise the work. The community participation includes:

- Assisting field workers in water sample collection, including sample location points, existing damaged net works, causing/likely to cause contamination of drinking water.
- Assisting in data collection.
- Monitoring water quantity, quality, and reporting findings to surveillance staff regularly.
- Ensuring proper use of water supply.
- Setting priorities for sanitation and hygiene and educate community members.
- Under take simple maintenance and repair work.
- Refer problems which require special attention.
- Disseminate results and explain the implications with respect to health with the objective to stimulate involvement in actions to keep water clean, safe and wholesome.

### **9.8.2 TRANSPORT**

The preferred means of transport varies widely depending on climatic condition, distance, and road condition. The main factor to be taken into account in choosing transport is to send samples to the laboratory as quickly as possible in ice, never exceeding 24 hours.

In remote areas motorcycle and in developed areas four-wheelers may be used.

### **9.8.3 LABORATORY NETWORK**

Water quality laboratory is the main backbone of water quality surveillance. A well-located and well-equipped analytical laboratory with competent staff is very essential to evaluate the efficiency of water utility services in terms of water quality. Water samples should be analyzed for priority parameters as per local problems.

In principle, water samples should be analyzed as fast as possible to avoid deterioration of sample quality, especially for microbiological analysis. For more effective coverage laboratory facilities can be categorised in two stages; Basic laboratories, State/Regional laboratories. (*Annexure 9.3*)

### **9.8.4 FINANCIAL SUPPORT**

Sufficient allocation of fund should be made for maintaining/monitoring water quality and its surveillance, keeping in view, size of water works, area covered, etc.



### **9.8.5 STAFFING**

Staff requirements for water supply monitoring and surveillance program vary widely according to the plant size, ecological and economical conditions. *Annexure 9.4 (a) and 9.4(b)* shows the possible suggestions for water quality monitoring and surveillance staff.

### **9.9 SURVEILLANCE ACTION**

Surveillance action comprise of:

1. Investigative action to identify and evaluate all possible factors associated with drinking water, which could pose a risk to human health.
2. Ensure preventive action to be taken to prevent public health problem.
3. Data analysis and evaluation of surveys.
4. Reporting to concerned authorities.

### **9.10 SANITARY SURVEY**

Sanitary survey is periodic audit of all aspects of all water supply system. Systematic program of sanitary survey includes sanitary inspection, water quality analysis, and evaluation of data and reporting.

#### **9.10.1 NATURE AND SCOPE**

Sanitary survey is an on-site inspection and evaluation of all conditions, devices and practices used in water supply system, which pose an actual or potential danger to the health and well-being of consumer by trained persons. It is a fact-finding activity, which identifies actual sources of contamination as well as point out inadequacies in the system that could lead to contamination.

The two important activities of sanitary survey are sanitary inspection and water quality analysis; which are complementary to one another. The inspection identifies potential hazards, while analysis indicates actual quality of water and intensity of contamination.

#### **9.10.2 SANITARY INSPECTION**

Sanitary inspection covers the inspection of water system, including the source, transmission mains, treatment plants, storage reservoirs and distribution system. Basically it is a fact-finding review to uncover deficiencies and inadequacies, which could lead to contamination of water. Sanitary inspection is indispensable for the adequate interpretation of laboratory results. It provides essential information about the immediate and ongoing possible hazards associated with a community water supply. It is an essential tool to pinpoint target areas for remedial action, required to protect and improve the water supply system.

#### **9.10.3 SANITARY INSPECTION REPORT**

The sanitary inspection report shall cover the following:

1. Identify potential sources and points of contamination of the water supply.
2. Quantify the hazards attributed to the source and supply.
3. Provide a clear, graphical means of explaining the hazards to the operator/user.

4. Provide clear recommendations for taking remedial actions, to protect and improve the supply.
5. Provide basic data for use in systematic, strategic planning for improvement.

Moreover inspection report should not be restricted to water quality but should take into account other service condition such as coverage, cost, condition and quantity. Such surveys are important from the point of view of operation and maintenance. *Annexure 9.5* shows suggested inspection forms for different water sources.

#### **9.10.4 WORK CHART FOR SANITARY SURVEY**

For collection of adequate information and follow-up work, proper work chart should be prepared considering local requirement. Following should be taken care of:

1. Prior knowledge of source, and type of water supply; and map of distribution system.
2. Notify the visit in advance, where the assistance of community members is needed.
3. Carry prescribed forms and necessary accessories, like sample bottle, sample carry box, analysis kit etc.
4. Verify basic data with community.
5. Interview community members for drinking water supply service.
6. Verify information gathered by observation during survey.
7. Inspection and water sampling should not be haphazard, should follow specific guideline.
8. Water samples should be analyzed immediately for residual chlorine and thermotolerant coliform, or transported quickly to laboratory in iced boxes.
9. Complete the sanitary report on site, and send it immediately to appropriate authority for follow-up remedial action if necessary.
10. Undertake appropriate small repairs at the time of survey in remote areas such as washer changing for leaking taps.
11. For pictorial forms, each risk point should be circled and given to member of water committee for follow-up action.

#### **9.10.5 TIME AND FREQUENCY**

No new public water supply should be approved without sanitary inspection', to provide sufficient information to indicate the suitability of the source and the amount of treatment required before the water can be considered suitable for human consumption. Physical, bacteriological, and chemical analysis should be carried out initially. The physical and bacteriological analysis can be followed at regular intervals, while chemical analysis can be carried out after fairly long time, as the substances are unlikely to be changed with time.

Water quality analysis of surface sources should be carried out frequently through out the year as its parameters vary greatly due to rainfall, man made as well as industrial activities, seasonal changes etc.

Sanitary surveys should be undertaken frequently by water supply department. The frequency of inspection and analysis largely depends on community size and local water

quality problems. *Annexure 9.6a, 9.6b, 9.6c(1) and 9.6c(2)* suggests the minimal round of surveys by water supply and surveillance agency.

## **9.11 WATER SAMPLING AND ANALYSIS**

Periodic drinking water analysis is necessary to ensure safe quality water supply. Water samples should be analyzed for various microbiological and physicochemical contaminants. However, the authenticity of water analysis greatly depends on the sampling procedure.

The objective of sampling is to collect a small portion of water which can be easily transported to laboratory, without contamination or deterioration and which should accurately represent the water being supplied. It should cover locations which are most venerable in the supply system.

For recommended sampling procedures and guideline values regarding physical and chemical parameters, kindly refer to Manual on Water Supply and Treatment, III Edition, May 1999, Government of India, Ministry of Urban Development, New Delhi.

## **9.12 DATA ANALYSIS, INTERPRETATION AND REPORTING**

Data analysis and interpretation are fundamental components of surveillance process. It aims at generation of data, which contributes to protect public health by promoting adequate, safe, potable water supply to communities.

### **9.12.1 DATA ANALYSIS**

Evaluation of community water supply requires consideration of number of factors, such as quality, quantity, coverage, continuity of water supply and never the least, its production cost.

#### **9.12.1.1 QUALITY**

Quality of water supplied to communities is an important consideration for human health and well being. Remedial and preventive measures also form an important part of water supply quality maintenance. *Annexure 9.7* gives details about the suggested guidelines for the same. Water quality data, generated and summarized by surveillance agencies are useful tools to promote improvement and design action strategies for quality water supplies in compliance with national standards.

#### **9.12.1.2 QUANTITY**

Along with quality, quantity of supplied water to the community plays an important role for maintenance and improvement of public health. Personal and domestic hygiene greatly depends on per capita quantity of water supply to the consumers. In case of inadequate quantity of water supply, community may use alternate source of water, some of which may be not be safe and affect the public health.

#### **9.12.1.3 COVERAGE**

Coverage, from the point of view of the water supply agency, is expressed as the percentage of the total population served; it may be by domestic connection, by public standposts, and by point sources such as wells, handpumps and springs.

Therefore, it is essential to undertake wider survey of the various water sources, the estimated population served by each source, and relative risk associated with each of source. Such information is a useful guideline for water supply program and funding strategies.

#### **9.12.1.4 COST**

Cost plays a vital role for adequate quality water supply. In periurban areas as well as some pockets of urban and metropolitan cities, water is purchased from vendors to cater the shortage of water supply, and in such cases the public health is at risk. As the cost involved in monitoring is very little in comparison to total cost of operation and maintenance, there should not be any financial restraint for this activity.

#### **9.12.1.5 CONTINUITY**

In most of the piped water supply system, continuous 24 hrs water supply is not feasible due to constrain of many factors. Generally twice a day water supply at full pressure to consumers is adequate; keeping the main line charged for 24 hrs to take care of in pipe-recontamination, which may be potentially hazardous to the consumers. Surveillance data regarding bacteriological analysis at non-peak hours is a good indicator of the in-pipe recontamination due to leakage.

Household storage is necessary for intermittent water supply, which may lead to an increase risk of contamination during such storage and associated handling. In such cases surveillance data on hygiene and subsequently hygiene education is important.

Information collected during surveillance will be of greater use for planning of hygiene awareness program.

### **9.13 DATA INTERPRETATION**

Assessment of sanitary situation as well as microbiological analysis data together, gives an overall picture of health risk assessment.

#### **9.13.1 ASSESSMENT OF SANITARY SITUATION**

Sanitary surveillance data generates the information regarding specific points of risk to the water supply. Such information can be used in various ways to facilitate the improvement of community water supplies.

Sanitary inspection data interpretation can be used to:

1. Identify most important source(s) of pollution amongst the number of noted potential sources.
2. Identify simple remedial measures that can be undertaken on the sight or at local level.
3. Identify recurrent problems, which require repeated remedial action and define strategies, which provide permanent solution to the problem, which may need external assistance.
4. Pinpoint the importance of adequate training requirement related to water supply practices in the locality or region concerned.

#### **9.13.2 ASSESSMENT OF MICROBIOLOGICAL WATER QUALITY**

Microbiological quality data can be divided into number of categories depending on the level

of contamination associated. *Table 9.1* below shows the suggested classification scheme based on increasing order of magnitude of faecal contamination. Suggested color scheme will be useful for pictorial inspection forms.

The level of faecal contamination may vary widely between successive samples due to seasonal influence such as rainfall where water supplies are unchlorinated. In piped water supply, the samples taken at various points in the whole system sometimes may defer in water quality. The point showing, higher faecal coliform count (>100/100ml) is a sure indication of a sewer water contamination, which may be due to cross contamination or caused by leak in the pipe line. Sanitary inspection data may support the suspicion. Remedial action should be taken immediately.

**TABLE 9.1: EXAMPLE OF CLASSIFICATION AND COLOUR-CODE SCHEME FOR THERMO-TOLERANT COLIFORM OR E. COLI IN WATER**

Count per 100 ml	Category and Colour code	Remarks
0	A (blue)	In conformity with WHO guidelines
1-10	B (green)	Low risk
10-100	C (yellow)	Intermediate risk
100-1000	D (orange)	High risk
> 1000	E (red)	Very high risk

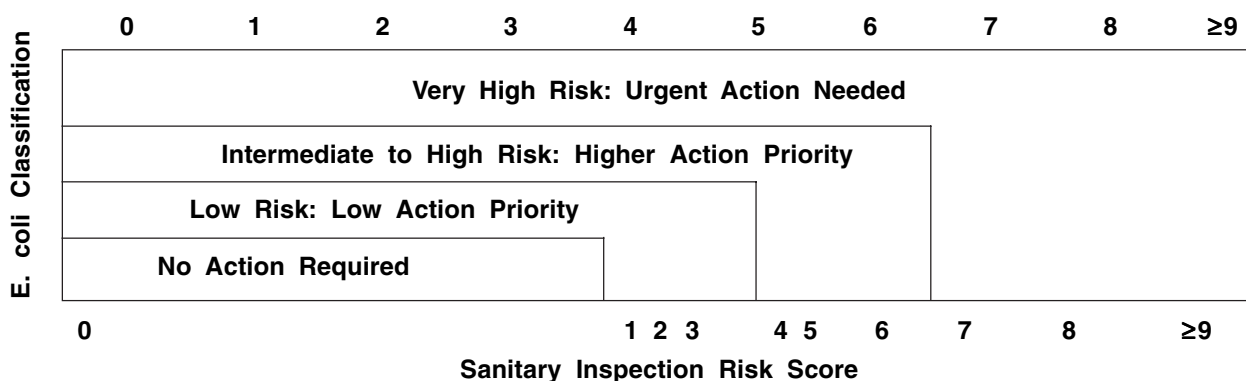
### 9.13.3 RISK ASSESSMENT

Microbiological analysis represents the single time moment whenever sanitary inspection takes account of the previous history as well as the present situation. Therefore, the examination of the faecal grading together with the sanitary inspection risk score gives a meaningful risk assessment.

*Fig. 9.1* illustrates risk analysis keeping in view combined faecal coliform grading and sanitary inspection risk score.

It is expected that greater risk of contamination is likely to be associated with higher grade of contamination. However, a high sanitary risk score associated with low level of faecal contamination still requires urgent action, as it indicates the outburst of contamination any time and preventive action is needed immediately.

**FIG. 9.1: EXAMPLE OF ASSESSMENT OF PRIORITY OF REMEDIAL ACTIONS BY RISK ANALYSIS SANITARY INSPECTION RISK SCORE**



ANNEXURE 9.1

**WATER RELATED DISEASES AND PREVENTIVE STRATEGIES**

<b>Classification</b>	<b>Transmission</b>	<b>Examples</b>	<b>Preventive Strategies</b>
Water-borne (Water-borne diseases can also be washed)	Disease is transmitted by indigestion (Faecal – Oral route)	<ul style="list-style-type: none"> <li>• Diarrhoea</li> <li>• Cholera</li> <li>• Typhoid</li> <li>• Hepatitis (A &amp; E)</li> </ul>	<ul style="list-style-type: none"> <li>- Improve quality of drinking water.</li> <li>- Prevent casual use of other unimproved sources.</li> <li>- Improve sanitation.</li> </ul>
Water washed (Water scarce)	<ul style="list-style-type: none"> <li>• Infections of the intestinal track.</li> <li>• Skin or eye infections.</li> <li>• Infections caused by lice or mites.</li> </ul>	<ul style="list-style-type: none"> <li>• Scabies</li> <li>• Trachoma</li> <li>• Conjunctivitis</li> <li>• Amoebiasis</li> <li>• Giardiasis</li> </ul>	<ul style="list-style-type: none"> <li>- Increase water quantity.</li> <li>- Improve accessibility and reliability of domestic water supply.</li> <li>- Improve hygiene.</li> <li>- Improve sanitation.</li> </ul>
Water based	The pathogen spends part of its life cycle in an animal, which is water based. The pathogen is transmitted by indigestion or by penetration of the skin.	<ul style="list-style-type: none"> <li>• Guinea worm</li> <li>• Schistosomiasis</li> </ul>	<ul style="list-style-type: none"> <li>- Decrease need of contact with infected water.</li> <li>- Control vector host populations.</li> <li>- Improve quality of water (for some types)</li> <li>- Improve sanitation (for some types)</li> </ul>
Water related Insect-vector	Spread by insects that breed or bite near water.	<ul style="list-style-type: none"> <li>• Malaria</li> <li>• Filariasis</li> <li>• River blindness</li> </ul>	<ul style="list-style-type: none"> <li>- Improve surface water management.</li> <li>- Destroy insect breeding sites.</li> <li>- Use mosquito netting.</li> <li>- Use insecticides</li> </ul>

Source: 'Water – Quality or Quantity?', "Running Water", International Technology Publication 1999, Page 77.

ANNEXURE 9.2

**FUNCTIONS AND RESPONSIBILITIES OF AGENCIES FOR WATER  
QUALITY MONITORING AND SURVEILLANCE**

Agency	Function	Responsibilities
Surveillance Agency 1. Ministry of Health/Rural Development 2. State PHED/Rural Development 3. Local Health Authority, CMO/Health Officer 4. Pollution Control Board	Surveillance of drinking water quality	<ul style="list-style-type: none"> <li>- To ensure that the drinking water is free from health hazards.</li> <li>- To find out what is wrong.</li> <li>- Assist in setting things right for both rural and urban systems.</li> </ul>
Water Supplying Agency 1. State PHED/Water Boards/Urban Development 2. Urban Local Bodies/Authority 3. Autonomous Agencies	Supply of potable water	<ul style="list-style-type: none"> <li>- To provide water in sufficient quantity and potable quality to the population at sufficient pressure.</li> </ul>
Pollution Control Board, Central/State	Controlling pollution at water source	<ul style="list-style-type: none"> <li>- To protect the raw water sources from being unduly polluted at Country/State level.</li> </ul>

## ANNEXURE 9.3

**SUGGESTED WATER QUALITY MONITORING LABORATORY  
NETWORK AND THEIR ACTIVITIES**

S.N.	Level	Activities
1.	<b>Basic laboratory</b> a. Primary health centre/Village level	1. Residual chlorine 2. Turbidity 3. Priority parameters as per local water quality problems, preferably through field kits.
	b. Municipal/District level (Plant capacity > 200 mld)	1. Bacteriological tests (Routine) 2. Physico-Chemical tests (Routine) 3. Biological tests (Routine) 4. Other laboratory testing works
2.	<b>State/Regional level laboratory</b>	1. Bacteriological tests (Advanced) 2. Physico-Chemical tests (Advanced) 3. Biological tests (Advanced) 4. Other laboratory testing works

Note: For the capacity less than 200mld, Refer to Manual on Water Supply and Treatment, III Edition (Revised and up dated), 1999.



ANNEXURE 9.4a

**SUGGESTED LABORATORY SERVICE INFRASTRUCTURE FOR MONITORING WATER QUALITY**

S.No.	Level	Minimum Recommended Staff	Remarks
1.	<b>Basic Laboratory</b> a. Primary Health Center/Village Level	1. Lab. Assistant/Technician 2. Lab. Attendant	For routine bacteriological and physico-chemical tests, the samples should be sent to municipal/district level laboratory periodically.
	b. Municipal/District Level (Plant capacity >200 mld)	1. Chief Analyst 2. Chemist 3. Bacteriologist 4. Assistant Chemist 5. Lab. Assistant/Technician 6. Lab. Attendants 7. Driver 8. Helper	Wherever Water Treatment Plant Laboratory is existing
2.	<b>State/Regional Level Laboratory</b>	1. Chief Analyst (Higher Scale) 2. Chemist 3. Bacteriologist 4. Biologist 5. Assistant Bacteriologist 6. Assistant Biologist 7. Lab. Assistant/Technician 8. Lab. Attendants 9. Driver 10. Helper	

Note: 1. Kindly refer to Manual on Water Supply and Treatment, III Edition, May 1999.

2. The level and the no. of the personnel shall be decided by the respective agencies depending on magnitude of problems and resources available.

## ANNEXURE 9.4b

## SUGGESTED WATER QUALITY SURVEILLANCE TEAM

S.No.	Level	Minimum Recommended Staff	Remarks
1.	<p><b>Basic Laboratory</b></p> <p>a. Primary Health Center/Village Level</p> <p>b. Municipal/District Level (Plant capacity &gt;200 mld)</p>	<p>3. Health/Sanitary Inspector</p> <p>4. Laboratory Assistant/Technician</p> <p>5. Lab. Attendant</p> <p>A – Class (5-10 lakhs or greater)</p> <p>1. Senior Health Officer</p> <p>2. Zonal Health Officer</p> <p>3. Chief Health/Sanitary Inspector</p> <p>4. Health/Sanitary Inspector</p> <p>5. Chemist</p> <p>6. Bacteriologist</p> <p>7. Lab Assistant</p> <p>8. Lab Attendant</p> <p>B – Class (1-5 lakhs)</p> <p>1. Health Officer</p> <p>2. Health/Sanitary Inspector</p> <p>3. Chemist</p> <p>4. Lab. Assistant/technician</p> <p>5. Lab. Attendant</p> <p>C – Class (&lt; 1 lakhs)</p> <p>1. Chief Health/Sanitary Inspector</p> <p>2. Health/Sanitary Inspector</p> <p>3. Lab. Assistant/technician</p> <p>4. Lab. Attendant</p>	<p>For periodical testing, samples shall be sent to District or State Health Laboratory</p> <p>For periodical testing, samples shall be sent to District or State Health Laboratory</p>
2.	<b>State/Regional Level Laboratory</b>	Staff as per existing State Medical and Health Deptt. norms	

Note: 3. The level and the no. of the personnel shall be decided by the respective agencies depending on magnitude of problems and resources available.

ANNEXURE 9.5a  
**CHECK POINTS**

Type of facility **Protected Spring Source**

1. General information: Health Center .....
- Village .....
2. Address .....
3. Water authority/community representative signature .....
4. Date of visit .....
5. Water sample taken ..... Sample no. .... Total Coliform/faecal Coliform .....

S.N.	Particulars for Assessment	Risks
1.	Is the spring source unprotected and therefore open to surface contamination?	Y/N
2.	Is the masonry protecting the spring source faulty?	Y/N
3.	If there is a spring box, is there an unsanitary inspection cover in the masonry?	Y/N
4.	Does the spring box contain contaminating silt or animals?	Y/N
5.	If there is an air vent in the masonry, is it unsanitary?	Y/N
6.	If there is an overflow pipe, is it unsanitary?	Y/N
7.	Is the area around the spring unfenced?	Y/N
8.	Can animals have access to within 10 m of the spring source?	Y/N
9.	Does the spring lack a surface water diversion ditch above it or if present, is it nonfunctional?	Y/N
10.	Are there any latrines uphill of the spring?	Y/N

Total score of risks...../10

Contamination Risk Score: 9-10 = Very High, 6-8 = High, 3-5 = Intermediate, 0-2 = Low

Results and Recommendations

The following important points of risks were noted: ..... (list no. 1-10)

And the authority advised on remedial action

Name and Signature of Inspector:.....

## ANNEXURE : 9.6a

**SUGGESTED MINIMUM SAMPLING FREQUENCY AND  
NUMBER FROM DISTRIBUTION SYSTEM**

Population Served	Maximum interval between successive sampling	Minimum no. of samples to be taken from entire distribution system
Upto 20,000	One month	One sample per 5,000 of population per month
20,000-50,000	Two weeks	
50,000-1,00,000	Four days	
More than 1,00,000	One day	One sample per 10,000 of population per month

## ANNEXURE : 9.6b

**SUGGESTED MINIMUM ANNUAL FREQUENCY OF  
SANITARY INSPECTIONS**

Source and mode of supply	Community	Water supply agency	Surveillance agency
Dug well (without windlass)	6	–	1
Dug well (with windlass)	6	–	1
Dug well (with hand pump)	4	–	1
Shallow and deep tube well with hand pump	4	–	1
Rainwater catchment	4	–	1
Gravity spring	4	–	1
Piped supply: ground water sources (springs and wells) with or without chlorination	–	1	1
<i>Treated surface source of piped supply, with chlorination</i>			
< 5,000 population	12	1	1
5,000-20,000 population	–	2	1
20,000-50,000 population	–	12	1
50,000-1,00,000 population	–	24	2
>1,00,000 population	–	48	2

**SUGGESTED MINIMUM SAMPLING FREQUENCY FOR  
WATER QUALITY CONTROL MONITORING**

S.L.	Size and Source	Frequency	PARAMETERS					Heavy Metals & Pesticides	Problem Parameters As, Cr <sup>6+</sup> , Fe & Mn, Fluoride	Remarks
			Residual Chlorine	Physical	Chemical	Bacteriological	Biological			
1	2	3	4	5	6	7	8	9	10	11
1.	< 50,000 Population	i. Daily	√							From source & distribution system
	a. Ground Water (Tube Well, Sanitary Well, Bore Well)	ii. Quarterly		√	√	√			√	
	b. Ground Water (Hand Pump)	Twice a year		√	√	√			√	In summer & rainy season
2.	>50,000 upto 1,00,000 Population	i. Daily	√							From source and distribution system
	a. Ground Water (Tube Well, Sanitary Well, Bore Well)	ii. Monthly				√				
	b. Ground Water (Hand Pump)	iii. Quarterly		√	√				√	
		Twice a year		√	√	√			√	In summer & rainy season
3.	>1,00,000 Population									From source & distribution system
	a. Ground Water (Tube Well, Sanitary Well, Bore Well)	i. Daily	√							
		ii. Monthly				√				

1	2	3	4	5	6	7	8	9	10	11
		iii. Quarterly		√	√				√	
		iv. Annually						√		
	b. Ground Water (Hand Pump)	i. Twice a year		√	√	√			√	In summer & rainy season
		ii. Annually						√		
4.	Surface water									
	a. Raw water, source and intake point	i. Daily		√	√					
		ii. Weekly				√				
		iii. Annually						√	√	
		iv. Occasional (As & when required)					√			
	b. Sedimentation tank after clarifier	i. Daily		Turbidity only						
		ii. Weekly				√				
		iii. Occasional (As & when required)								
	c. Filtered water	i. Daily		Turbidity only			√			
		ii. Weekly				√				
	d. Clear water storage reservoirs	i. Daily	√	√	√					
		ii. Weekly				√				
	e. Distribution system	i. Daily	√							
		ii. Weekly				√				
		iii. Monthly		√	√					

Note: 1. Refer to the Manual on Water Supply and Treatment, III Edition, Ministry of Urban Development, New Delhi, May 1999, Appendix 15.9, for minimum tests to be performed.

2. Parameters and frequency are general in nature and in case of special situations, they can be altered according to the local conditions by the local authority.

ANNEXURE : 9.6c(2)

**SUGGESTED MINIMUM SAMPLING FREQUENCY FOR WATER QUALITY CONTROL SURVEILLANCE**

S.L.	Size and Source	Frequency	PARAMETERS							Remarks	
			Residual Chlorine	Physical	Chemical	Bacteriological	Biological	Heavy Metals & Pesticides	Problem Parameters As, Cr <sup>6+</sup> , Fe & Mn, Fluoride		
1	2	3	4	5	6	7	8	9	10	11	
1.	< 50,000 Population a. Ground Water (Tube Well, Sanitary Well, Bore Well)	i. Weekly	√								From source & distribution system
		ii. Twice a year		√	√					√	In summer & rainy season
	b. Ground Water (Hand Pump)	Twice a year		√	√	√				√	Preferably in summer
2.	>50,000 upto 1,00,000 Population c. Ground Water (Tube Well, Sanitary Well, Bore Well)	i. Weekly	√								From source and distribution system
		ii. Quarterly				√					
		iii. Twice a year		√	√					√	In summer & rainy season
	d. Ground Water (Hand Pump)	Annually		√	√	√			√	Preferably in summer	
3.	>1,00,000 Population e. Ground Water (Tube Well, Sanitary Well, Bore Well)	i. Weekly	√								From source & distribution system
		ii. Quarterly				√					

1	2	3	4	5	6	7	8	9	10	11
		iii. Twice a year		√	√				√	In summer & rainy season
		iv. Annually						√		
	f. Ground Water (Hand Pump)	Twice a year		√	√	√		√	√	In summer & rainy season
4.	Surface water									
	g. Raw water, source and intake point	i. Fortnightly				√				
		ii. Quarterly		√	√					
		iii. Annually						√	√	
		iv. Occasional (As & when required)					√			
	h. Filter	i. Monthly				√				
	i. Clear water storage reservoirs	ii. Fortnightly	√			√				
		iii. Monthly								
	j. Distribution system	i. Weekly	√							
		ii. Monthly								
		iii. Quarterly			√	√	√			

Note: Refer to the Manual on Water Supply and Treatment, III Edition, Ministry of Urban Development, New Delhi, May 1999, Appendix 15.9, for minimum tests to be performed. Parameters and frequency are general in nature and in case of special situations, they can be altered according to the local conditions by the local authority.



ANNEXURE 9.7

REMEDIAL AND PREVENTIVE MEASURES FOR PROTECTION OF WATER SUPPLIES

Source and Mode of Supply	Evidence or Information available	Immediate remedial measures available	Preventive action
1 Open dug wells	2 Pollution usually expected to occur	3 a. Clean well if necessary and disinfect with bleaching powder. b. Boiling of drinking water, use of chlorine tablets or bleaching powder and/or filters in the home is recommended.	4 Well is protected by raising a pucca wall all around and cover. It is preferable to provide hand pumps and promote community education and participation.
Unpiped supplies from tube well or hand pumps	Findings of sanitary inspection, unsatisfactory localized epidemic of enteric infection	Confirm bacteriological quality analysis and if necessary, recommend use of disinfectant (Bleaching powder) or a. Recommend use of boiling water, chlorine tablets or bleaching powder and/or filters in the home b. Confirm bacterial quality c. Conduct a detailed sanitary inspection to ensure effectiveness of remedial measures against shortcomings found earlier	Eliminate pollution source and/or repair tube wells and/or hand pumps if found necessary in sanitary inspection. a. Promote community education and participation. b. Feedback information on remedial action and sanitary survey results to the water supply agency, to check whether the remedial actions followed are appropriate.
Untreated pipe water supply	Findings of sanitary inspection unsatisfactory Unsatisfactory bacteriological quality of water at source	Confirm bacteriological quality and if necessary recommend boiling of water or use of disinfectant or filters a. Disinfect (chlorinate) water supply if feasible, recommend boiling or use of chlorine tablets at home b. Conduct a detailed sanitary inspection and correct the shortcomings found	Eliminate pollution sources and/or repair systems if found necessary in sanitary inspections Protect the source and its catchment area

1	2	3	4
	<p>Unsatisfactory bacteriological quality of water in the distribution system</p>	<p>a. Disinfect (chlorinate) water supply or recommend boiling or use of chlorine tablets at home b. Conduct a detailed sanitary inspection of distribution system and rectify the shortcomings</p>	<p>Frequent and improved supervision of the distribution system and prompt repair and good maintenance are essential, especially for intermittently operated system.</p>
	<p>Localized epidemic of enteric infection</p>	<p>a. Take samples for bacteriological analysis. Without waiting for its result, immediately chlorinate water supply so that the tail end has minimum 0.5 mg/l of free residual chlorine. Recommend boiling and use of chlorine tablets at home b. Conduct a detailed sanitary inspection of source and distribution system and rectify the shortcomings found.</p>	
<p>Treated pipe water supply</p>	<p>Findings of sanitary inspection of source, treatment plant, distribution systems is unsatisfactory</p>	<p>Confirm bacteriological quality and if necessary, recommend boiling or use of disinfectant (Bleaching powder) home</p>	<p>a. Frequent and improved supervision of the whole system is necessary, careful operations and maintenance is essential, especially for intermittent systems. b. Ensure routine sanitary inspections and feedback information to the water supply agencies.</p>

1	2	3	4
	<p>Unsatisfactory bacteriological quality of water after treatment or in the distribution system</p> <p>Localized epidemic of enteric infection</p>	<p>a. Ensure 0.5 mg/l free residual chlorine at tail end. Recommend boiling and use of chlorine tablets</p> <p>b. Conduct a detailed sanitary inspection of whole water supply system and rectify the shortcomings found</p> <p>a. Take samples for bacteriological analysis. Without waiting for its result, immediately chlorinate water supply so that the tail end has minimum 0.5 mg/l of free residual chlorine. Recommend boiling and use of chlorine tablets at home</p> <p>b. Conduct a detailed sanitary inspection of source and distribution system and rectify the shortcomings found.</p>	<p>a. Frequent and improved supervision of the whole system is necessary, careful operations and maintenance is essential, especially for intermittent systems.</p> <p>b. Ensure routine sanitary inspections and feedback information to the water supply agencies.</p>
			<p>a. Eliminate pollution source</p> <p>b. Frequent and improved supervision of the whole system is necessary, careful operations and maintenance is essential, especially for intermittent systems.</p> <p>c. Ensure routine sanitary inspections and feedback information to the water supply agencies.</p>

## CHAPTER 10

# REPAIR OF PIPE LINE

It is one of the most important responsibilities of a Water Undertaking to properly maintain the transmission and distribution mains in order to prevent waste and provide a constant pressurized flow of potable water to the consumers. It is equally important to prevent damage to the public property which could arise for not properly repairing a defective pipe. Proper planning and implementation of remedial measures will avoid leakages and breakdowns.

### 10.1 CAUSES OF FAILURE IN PIPELINE

For proper planning for the operation of the repair work it is necessary to assess the probable causes of failure. Following guidelines outline some of the factors to be duly considered to ensure protection of pipes from damage/failure.

#### 10.1.1 HANDLING AND STORAGE OF PIPES

1. Damage during transport of the piping material.
2. Defective stacking and storage.
3. Damage to the pipe wall and coating.
4. Cracks in pipe during careless unloading and pipes striking against each other.
5. Weathering effect due to unfavorable environment.
6. Mixing up of different classes of pipes and their jointing materials.

#### 10.1.2 LAYING OF PIPELINE

1. Deviation from proper laying procedures.
2. Improper bedding
3. Loss of support of bedding after laying.
4. Slipping of trench sides.
5. Sinking of soil after laying.
6. Poor quality of backfill material.
7. Improper compaction of trench backfill and its subsequent settling.
8. Excessive overburden on piping trenches, not taken care of during the design of pipeline.
9. Point loads coming on the pipe through the backfill.
10. Excessive vibrations due to traffic during the laying of pipeline.

### **10.1.3 JOINTING OF PIPES**

1. Defective jointing material.
2. Direct strike on the body of the pipe with any sharp edge, while jointing.
3. Slipping of jointing material like rubber ring or lead etc.

### **10.1.4 CHARACTERISTICS OF SOIL**

1. Corrosive nature of soil causing damage to the external surface of the pipe.
2. Extremes of climate: frost heave or clay shrinkage.
3. Loss of support or anchorage (horizontal or vertical), both in case of pipes embedded and those laid above ground level.
4. Movement of soil due to filled soil, mining.
5. Movement of soil while work of laying pipes or other activities like laying of cables etc. is taken up.
6. Changes in soil moisture or water table conditions.

### **10.1.5 EXCESSIVE TEMPERATURE CHANGES**

1. Expansion: severe compression, end crushing.
2. Contraction: pull out or separation of joint.
3. Freezing: pipe blockages and splits.

### **10.1.6 INTERNAL PRESSURE**

1. Excessive test pressure.
2. Pressure surge, water separation, vacuum.
3. Extending pipe connections without proper precautions.

### **10.1.7 AGGRESSIVE WATER**

Damage to the internal surface of pipe as well the lining material.

### **10.1.8 GALVANIC ACTION**

## **10.2 SPECIAL OBSERVATIONS ON FAILURE OF PIPES**

### **10.2.1 PIPE BARREL**

Certain failures connected with the deterioration of the barrels of pipe are given below.

#### **10.2.1.1 Brittle type fractures**

These may be found in rigid and semi-rigid materials such as cast iron, asbestos cement and PVC.

These are characterized by relatively clean, sharp-edged splits or cracks. These may occur as circumferential breaks or longitudinal cracks which may run straight but more often irregularly curved along the pipe barrel.

### **10.2.1.2 Ductile type failures**

These occur in polyethylene and ductile iron. These are usually found as relatively short splits or tears with irregular edges which are often associated with some local swelling around the break.

### **10.2.1.3 Blow Outs**

These are localized failures which only occasionally occur and are usually associated with high pressure, e.g. pumping surges in weakened brittle materials.

### **10.2.1.4 Pinholes**

These may be caused by an impurity or inclusion in the wall of the pipe wall or, more often, by localized chemically or electrically induced corrosion which thins and weakens the pipe wall until a small plug is blown out by internal pressure. Pinholes often enlarge quite quickly due to erosion around the edges of the hole. Pin holes are frequently found within the metallic group of pipes.

### **10.2.1.5 Generalised Deterioration**

More generalized deterioration of pipe barrel may be due to a manufacturing defects but is usually the result of some form of chemical attack. The overall effect is reduction in wall strength depending on the material group. Some of the examples are the graphitization of iron mains, sulphate attacks on AC and concrete, lime leaching from cement lining by soft waters and solvent attacks on the polymeric group of materials leading to softening or delamination of composites such as GRP.

## **10.2.2 FAILURE AT PIPE JOINTS**

Some of the points for consideration are given below:

### **10.2.2.1 General**

1. Failures may occur due to originally careless installation practices causing displacements of the seal and/or eventual separation of the mating surfaces.
2. Stress cracking of pipe material around the joint.
3. Biodegradation of the sealing components.

### **10.2.2.2 Flanged connections**

Stress cracking of the flange can occur due to unequally tightened bolts. Such a situation arises during ground movement or the forceful activation of a valve or hydrant.

### **10.2.2.3 Crushing of pipe ends**

Cracking may occur due to crushing of pipe ends when they touch or bind and are then subjected to high compressional or bending forces.

### **10.2.2.4 Lead joints**

Hardening of lead in association with joint movement may lead to 'weeping' which gradually develops into a more serious leak.

### **10.2.2.5 Sealing rings or gaskets**

Many mechanical joint designs rely upon the compression of sealing rings or gaskets which have varying compositions and different resiliences. The physical breakdown (e.g. biodegradation) or change of resilience with time can lead to leaking joints. The loss of compression combined with corrosion of pressure rings or collars or the bolts may aggravate the breakdown.

## **10.3 REPAIR ACTION PLAN**

### **10.3.1 GENERAL PROCEDURE**

Following procedure may be followed:

1. Internal mobilization.
2. Detection of pipe failure: Inspection of site
3. Notification of interruption in water supply and related issues.
4. Location and demarcation
5. Repair planning
6. Repair work: Selection of most appropriate method for repair.
7. Testing of 'dry' repair.
8. Restoration
9. Completion
10. Hygiene
11. Notice of restoration and completion

### **10.3.2 IMPLEMENTATION OF ACTION PLAN**

#### **10.3.2.1 Monitoring of Internal Mobilization**

Some of the important activities relating to the mobilization of the internal activities are summarized below;

##### ***(a) Senior Level Management***

Necessary information to the Senior Level Management may be submitted and their interim approval sought. Details approval can follow in due course of time.

##### ***(b) Operation and maintenance staff of the running water supply system***

The entire staff must be made fully aware of the likely activities required to be undertaken so as to ensure minimum possible interruption in the system.

##### ***(c) Alternative arrangement***

Alternative arrangement for water supply may be planned and duties of staff fixed accordingly.

##### ***(d) Existing installations***

The operation of the water supply system with regard to Intake, Headworks, Pumping machinery, Treatment Plant, Piping system etc. must be co-related with the proposed repair work.

**(e) Mobilization of men**

Necessary staff may be arranged for the following duties;

1. Location of section;
2. Isolation of section;
3. Scouring of section;
4. Arranging transport, material, machinery, equipment, tools, pipes, fittings etc.
5. Other miscellaneous duties.

**(f) Manpower, material, machinery, transport, lighting, safety measures, communication, pipes with fittings and specials etc. for the repairing operation.**

These details are variable and depend upon various factors as per the local situation. Some of the factors to be considered are;

- i) The importance, utility and function of the affected pipeline with the piping net work.  
This may be the only transmission main of the system. It may be one of the two or many parallel transmission mains. It may be initial portion of the distribution system serving as the only main to supply water to the rest of the area to be served. It may be a distribution pipe serving only a part of the system.
- ii) Size and material of the affected pipe.  
These are very important factors which determine the magnitude of the repair to be undertaken.
- iii) Depth of the pipeline. Deeper pipes require more labour work for repairing.
- iv) Subsoil water table.  
If the pipe is laid much below the local water table, additional work will be required to dewater the trenches excavated for repair.
- (v) Other unforeseen factors.

Depending on these factors the requirement of manpower, material, machinery, tools, equipments, pipes, specials, fittings etc. is to be worked out. Given below is a list to meet the requirement of a big transmission main which is a life for the water supply system. This may be considered as a guideline only. Exact requirement may be worked out depending upon the local conditions.

**Man power**

Designation	Manager	Supervisor	Fitters	Welders	Crane operator	Excavator operator	Truck operator	Jeep operator
Number	1	1	3	3	1	1	1	1

Designation	Emergency Van operator	Electrician	Mechanic	Helper	Semi-skilled	Pump operator
Number	1	1	1	1	8	1



## Material

Electrodes, Gaskets, Rubber insertion, Bolts and nuts, Gland rope, Manila rope, Pig lead, Cotton waste, Wooden sleepers, PVC hose pipe, Canvas hose, Engine oil, Wire slings, Grease, M.S. Plates, Diesel, Kerosene, Fire wood, Cement, Sand, Spun yarn, Hard crete, M seal, Sand bags.

## Machinery

Machinery	Crane mobile	Excavator	Pumpset (Electric)	Portable Diesel pumpset	Welding generator	25KVA generator	Lighting generator
Number	1	1	2	2	1	1	1

Machinery	Welding set	Mud pump	Gas Cutting set	Pressure Grouting machine	Flexible grinder	Hand drilling
Number	2	2	2	1	1	1

## Transport

Vehicle	Truck	Jeep	Emergency breakdown van
Number	1	1	1

## Tools

Scour rod with lever, motor driven pipe cutter with extra cutters, H.T.wire cutter, sheet cutter, screw jacks, hammers, spades, buckets, baskets, crow bars, hammers, showels, caulking tools (spun caulking, cement caulking, lead caulking), power wrenches 36 in. to 15 in., adjustable spanner 18 in. to 12 in., chain tong 36 in. long, ring spanner set, DE spanner set, screw drivers, cutting plier, knife, nose plier, knife, chisels, lead pan with sport and bucket, Temporary platforms, files, bench vice and pipe vice.

## Pipe Specials

MS gap special, ms barrels, ms split collars (different types available), ms girder, ms angle.

## Communication

Wireless set, mobile wireless set, cell phone, pager.

## Lighting

Flood lighting, tube light fittings, wire, 3 core cable, insulation tape, main switch, fuse wire, kit kats, welding cable, emergency lights, torch lights, gas lights.

## Safety Equipment

First aid box, helmets, headlight, gum shoes, hand gloves (rubber, leather), gas masks, oxygen cylinder.

## **Amenities**

Tents, water cans, jugs and glasses, tarpaulins, electric heaters, rain coats, food (tea and snacks, meals)

### **10.3.2.2 Detection of Pipe Failure**

1. Inspect site and ascertain the nature of the failure.
2. Assess any possible damage or dispute that may arise and take steps to face such situations.
3. Investigate the access to the site so as to plan the arrangement of plant and equipment.
4. Assess urgency of repair, availability of men and equipment, effect on consumers and fix time and day of repair.
5. Locate isolating valves for proper control of requisite activities required for repair work.
6. Depending upon the seriousness of the leakage or burst, the likely effect on the local supplies, decision may be taken on
  - i) maintenance of supplies as long as possible
  - ii) prevention of possible contamination of the pipeline and
  - iii) quick location of the actual position of the pipeline.
7. Establish control and communication network after deciding the time of repair work to be undertaken.
8. Ascertain the sensitivity of the affected area and take steps to avoid undesirable situations.
9. Issue notification and warnings of the likely interruptions.
10. Mobilise men, material and equipment for repairs.

### **10.3.2.3 Notification**

Issue notices to the affected consumers and the departments looking after other affected facilities like telephones, cables, electric lines etc.

Such notifications may be by mobile loud speakers, hand bills, telephones, local media channels etc.

The contents of the notification will be as under:

- Time of closure and affected area;
- A brief and simple reason for interruption;
- An estimated time of restoration of supplies;
- Contact point for any problems;
- Advice on conservation, flushing, boiling, etc.

### **10.3.2.4 Location and extent of failure**

#### ***(a) Location of the failure***

Make use of local knowledge, plan, experience in locating the failure. Depending on the local conditions, if need be, leak detectors may be used.

***(b) Protective signs***

Before undertaking any excavation work, all protective measures may be taken including signs, lighting etc. Traffic rules must be complied with. All local utilities must be located and marked and liaison kept with local representatives of these affected utilities.

***(c) Excavation***

The conventional methods of excavation may be supplemented with more mechanized processes keeping in view the existence and location of the water main.

***(d) Shuttering and support***

Pay due attention to safety below ground by providing support to trench sides and any exposed pipes and cables.

***(e) Extent of failure***

The full extent of damage, both to pipe work and any support works, should be assessed.

***(f) Work space***

Ample workspace should be created to allow for:

- i) detailed inspection around the pipe.
- ii) provision of sump for continuous operation of a drainage pump
- iii) movement of men with jointing material and equipment to be used safely and effectively.

***(g) Provide safe dewatering system and discharge points***

The discharge of any dewatering apparatus should be checked to ensure free outflow and to avoid any danger or inconvenience caused by flooding.

***(h) Control by Valves***

Ensure effective operation of repair work by proper control of valves which should be in perfect working condition.

**10.3.2.5 Repair planning**

***(a) Note details of existing pipe***

The full details of the failed pipe and/or fitting should be noted including material type, approximate age, class and general condition. Reasons for failure should be established as accurately as possible and recorded. Check actual external dimensions of the pipe and determine any tendency to ovality for effective repair.

***(b) Type of repair—wet or dry***

A 'wet' repair is defined as a repair which can be achieved while maintaining a nominal pressure in the pipeline. Split collars or identical fittings can be installed in this way if the conditions are favourable.

A 'dry' repair is defined as one in which the main is completely isolated and drained out. 'Cut out' repairs necessitating the removal of a section of the pipe and/or joints will require 'dry' main on which to work and the pipeline should be drained out.

*(c) Extent of repair work and availability of repair fittings and tool*

The replacement pipe and/or repair fittings should be selected and their dimensions marked on the pipeline. For a 'dry' repair a final check should be made that all the required fittings and materials are available and are compatible before any attempt to cut the same is made.

*(d) Bedding material*

Assess and make available the bedding material if required.

*(e) Report to Control*

When ready to start repair, inform 'control'.

**10.3.2.6 Repair work**

*(a) Repair of small, local defects - 'wet repair'*

For small local defects such as pinholes a single split collar or wraparound clamp may be all that is required. The repair can be carried out as a 'wet' or 'dry' operation. In case of 'wet' repair care should be taken to maintain a steady, gentle flow so as not to dislodge the sealing elements.

*(b) Cut out – 'dry repair'*

For a more extensive damage e.g. a longitudinal fracture, a section of pipe is cut out and replaced by the use of two appropriate couplers. If full extent of the fracture is not clearly defined cuts should be made at least 300mm beyond each end of the visible crack or defect and in case of any doubt the full length of damaged pipe should be replaced. This necessitates cutting out the joint at both ends of the affected pipe, thus the repair normally requires two replacement pipe sections and three couplers.

*(c) Replacement repairs- following observations are important*

- Carryout correct measurements and give allowance for expansion;
- All cuts should be made clean and square;
- In A.C. pipes, cuttings should be avoided;
- All cut edges should be prepared (scraped, deburred, chamfered etc.) to the manufacturer's recommendations.
- Both exposed ends of the existing pipe should be similarly treated;
- Couplers should have their sealing rings lubricated if recommended;
- Correct expansion gaps should be allowed;
- Good alignment is essential particularly if narrow couplers are used;
- All couplers and collars should be centralized;
- Tighten all bolts evenly;
- Do not over tighten bolts or compression joints;
- Restore any damaged coatings on the parent pipe;
- Ensure full protection to the bolts and any exposed bare metal before burial.

***(d) Record of repair***

While the repair is still visible the details of repair should be recorded.

***(e) Record of pipe***

Record the following items:

- i) any visible damage to the pipe;
- ii) state of protective system or coating;
- iii) depth of cover
- iv) description of the soil/backfill.

**10.3.2.7 Testing of 'dry' repairs**

***(a) Give additional support to repaired pipe portion, if necessary;***

All wet slurry should be removed to the extent possible, and the bottom of the excavation should be filled and the exposed pipe work rebedded, with suitable material sufficiently compacted to give adequate support to the invert and lower quadrants of the pipe and any fittings.

***(b) Renew bedding and compact***

Additional material may be placed to support the repaired pipeline when under test pressure, but it is advisable to leave all joints visible in case of leakage.

***(c) Arrange air bleeding and slowly refill isolated section***

Refilling the isolated section of the main with water should be done slowly and from one direction only. Arrangements should be made for the expulsion of the air by means of any convenient air valves, hydrants, washouts or taps. The repaired pipe is subjected to a pressure equivalent to the normal working pressure. The repaired pipe should remain under such working pressure until it is adjudged to be satisfactory. Some minor re-tightening of the joints may be necessary due to slight expansive movement of the assembly on being subjected to increase in pressure.

***(d) Control*** – Report situation to 'Control'.

**10.3.2.8 Restoration**

***(a) Restore valves and the system in accordance with the original operational plan***

The repaired section of main is reintroduced to the system by restoring all valves to their original status.

***(b) Checking restoration***

The restoration of the supplies to the normal situation supplied at important points should be checked.

***(c) Removal of temporary supplies***

All standby pipes, temporary supplies and emergency tankers should be removed.

***(d) Notification***

Notification and acknowledgments should be made wherever necessary.

### **10.3.2.9 Hygiene**

During the execution of the repair work hygienic conditions must be made to prevail at various stages till the completion of work.

#### ***(a) Site cleanliness***

During the repair work the area should be kept as clean as possible. All debris and contaminants should be removed from the site and the contamination of the trench from plant, equipment or any other potentially hazardous materials must be avoided.

#### ***(b) Storage of tools and equipment***

All pipes, fittings, tools, equipment and vehicles to be used on site should be regularly maintained and cleaned.

Equipment used for disinfection and sampling should be kept for this purpose and regularly maintained.

#### ***(c) Prevention of contamination during repair work***

Clean and spray with disinfectant, on all surfaces that come into contact with potable water including the broken main, repair fittings and replacement pipe. Ensure that the contaminants do not enter the main where it is cut for repair.

After completing the repair, flush the main at the nearest hydrant to remove any dirt etc.

#### ***(d) Disinfection procedure***

For small repairs which do not require the main to be cut, the fracture should be cleaned and this along with the repair collar should be sprayed with disinfectant.

For more major repairs requiring cut out, every care must be taken to prevent contamination.

### **10.3.2.10 Completion**

#### ***(a) Finishing touches***

Wherever joints have been left exposed for testing purposes these should be restored to their original position. The bolts, bare metal surfaces etc. should be properly protected prior to side fill.

#### ***(b) Side filling work should be suitably accomplished***

The dug material should be returned to the trench and placed in layers. The first side fill layer should be placed and compacted under the lower quadrants of the pipe and up to the springing level of the pipe. Successive layers of up to 100 mm thickness may then be placed and compacted to a maximum height above the crown of 250 mm. Light vibrating machinery may be used but not directly above the pipe or the fittings.

#### ***(c) Clear site***

On completion of the work all materials and protective barriers should be removed from site and the working area left clean and tidy. All records should be completed and submitted.

### 10.3.2.11 Notice of Completion

Notice of completion or interim or permanent reinstatement must be given within a reasonable period. Location of works and other relevant details should also be given.

## 10.4 REPAIR METHOD FOR DIFFERENT TYPES OF PIPES

Some of the methods of repair for different types of pipes are given in the following tables.

**TABLE 1**

MATERIAL		CAST IRON
Burst	Action	Repair
Joint failure	Enclose joint Two couplers	Special joint clamp Two couplers and new section
Brittle failure	Remove section/joint Enclose failure	Two couplers and new section Repair collar or clamp
Corrosion	Remove section/joint Rehabilitation technique Enclose failure	Two couplers and new section Sliplining etc. Repair collar or clamp

**TABLE 2**

MATERIAL		DUCTILE IRON
Burst	Action	Repair
Joint failure	Enclose joint Remove section/joint	Special joint clamp Two couplers and new section
Extensive pinholing	Rehabilitation technique Remove section/joint	Sliplining etc. Two couplers and new section
Ductile failure	Remove section/joint Enclose burst	Two couplers and new section Repair collar or clamp
Localised pinholing	Enclose burst	Repair collar or clamp

**TABLE 3**

MATERIAL		STEEL
Burst	Action	Repair
Extensive pin holing	Rehabilitation Technique Remove section/joint	Slip lining etc. Two couplers and new section
Joint failure	Remove section/joint Enclose joint	Two couplers and new section Special joint clamp
Isolated pin holing	Enclose burst	Patch and weld Repair collar or clamp

**TABLE 4**

<b>MATERIAL ASBESTOS CEMENT</b>		
<b>Burst</b>	<b>Action</b>	<b>Repair</b>
Surface softening	Remove complete pipe length	New pipe section and fittings
Longitudinal cracking	Remove complete pipe length	New pipe section and fittings
Joint failure	Remove complete pipe length Enclose joint	New pipe section and fittings Joint repair clamp
Circumferential failure	Enclose burst	Repair collar or calmp

**TABLE 5**

<b>MATERIAL PRESTRESSED CONCRETE</b>		
<b>Burst</b>	<b>Action</b>	<b>Repair</b>
Surface softening	Remove complete length/joint or cracking	Two couplers and new pipe section
Joint failure	Remove complete length/joint Enclose joint	Two couplers and new pipe section Special joint clamp

**TABLE 6**

<b>MATERIAL POLYETHYLENE/P.V.C.</b>		
<b>Burst</b>	<b>Action</b>	<b>Repair</b>
Fast crack propagation	Remove damaged section	Two couplers and new section
Brittle failure	Remove damaged section Enclose burst	Two couplers and new section Repair collar or clamp
Joint failure	Cut out joint	Two couplers and new section

**TABLE 7**

<b>MATERIAL GLASS REINFORCED PLASTIC PIPES (GRP)</b>		
<b>Burst</b>	<b>Action</b>	<b>Repair</b>
Joint failure	Enclose joint Replace joint	Joint clamp Repair collar or clamp
Delamination	Remove section Enclose failure	Two couplers and new section Repair collar or clamp
Fracture/damage	Remove section Enclose failure	Two couplers and new section Repair collar or clamp



## **10.5 REPAIR PROBLEMS SPECIFIC TO PRESTRESSED CONCRETE PIPES**

The most difficult and time consuming repair problems relate to PSC Pipes, particularly the bigger diameter pipes. Some of the cases connected with the damage and leakage of such pipes along with their suggested methods are discussed below:

### **10.5.1 EXTENSIVE DAMAGE TO A PSC PIPE LENGTH**

Sometimes the damage is so extensive that the entire length of a pipe needs replacement. The replacement is done by inserting a steel pipe which shall be fabricated in three pieces. One piece shall consist of a spigotted machine end, another of steel shell and the third a spigotted machine end. The middle portion shall be of steel barrel with an integral manhole. This man hole may be meant for temporary use only so as to be covered and rewelded suitably after the repairing operation has been satisfactorily carried out. The thickness of steel plate used for this purpose shall be equal to the design thickness plus 2 mm extra to take care of corrosion. A minimum of 10 mm may, however, be used. The burst pipe may be broken by taking due precautions and replaced with this set of three pieces. The two machine ends shall be fixed as per normal procedure for laying PSC pipes. The steel barrel shall be introduced in between and duly welded internally and externally.

### **10.5.2 DAMAGE RESTRICTED TO A SMALL LENGTH ONLY**

Sometimes the damage is along a length of 1 m to 1.5 m only and the remaining portion of the pipe remains in a sound condition. To make the damaged portion functional, two plain M.S. Barrels shall be inserted into the pipe, to suit the internal diameter with a gap of 25 mm. on either side of the pipe, 50 mm less than the internal diameter of the pipe, to facilitate jointing with jute and cement mortar. The barrels shall have 2 nos. 12 mm dia. M.S. rings to fix over the shell at the ends. At least 500 mm of overlap on either side of the pipe, length wise, is provided for jointing.

After following the normal procedure (as already discussed at length), break the damaged portion of the pipe to the extent (length wise) of cracks developed in the pipe for more than half of the pipe (diameter wise).

Cut the H.T. wires core reinforcement.

Clean the pipe internally, remove the broken debris and dewater the pipe.

Insert one piece of the M.S. Barrel, duly fabricated with a temporary manhole for entry into the pipe for internal caulking, welding etc.

Shift barrel to one side so as to facilitate the insertion of the second barrel.

Join the two pieces and weld the joint internally and externally.

Keep the barrel in position by covering the damaged portion duly keeping at least 500 mm of overlap for jointing with P.S.C. pipe.

Insert the M.S. ring at the ends and place at 150 mm from the outer ends of the barrels and tag weld the rings to the barrel to caulk the jute firmly.

Caulk both the ends of the barrel with spun yarn for 3 layers and with cement mortar 1:1 duly mixing quick setting cement solution.

Clean the pipe internally and paint with epoxy paint.

Close the manhole made on the M.S. pipe by welding and strengthening the joint with additional plates.

Weld angles on the barrel and support the edges of the PSC pipe.

Caulk the joints with cement mortar and cover the MS barrel with cement mortar.

Embed the damaged portion of the pipe in cement concrete to avoid movement of the M.S. barrel during surge.

(As alternatives to the above procedure, there are other methods in use, depending upon the local conditions and the diameters of the pipes).

Follow other prescribed procedure for completion.

### **10.5.3 LEAKAGE THROUGH SOCKET/SPIGOT JOINT DUE TO DISPLACEMENT OF RUBBER JOINT**

The joint has to be exposed. A medium leakage can be attended without taking the shut down by pushing the rubber gasket to the original position with the help of wooden caulking tools and also inserting lead pieces in the joint. Afterwards, caulking with cement mortar 1:1 will further strengthen the joint. The entire joint has to be caulked with cement mortar.

### **10.5.4 LEAKAGE THROUGH DAMAGED SOCKET**

Such leakage can be attended only by taking shut down and draining the pipe line. The joint shall be exposed by excavating the trench around the joint. The crack and joint shall be filled with lead wool, quick setting cement mortar and the stepped split collar fixed over the joint and filled with cement slurry or cement mortar mixed with quick setting solution.

### **10.5.5 LEAKAGE THROUGH CIRCUMFERENTIAL CRACK**

Such leaks can be attended by providing split collars after arresting the leakage through crack either on running line or by availing shut down.

Materials required for attending the leakage are lead wool, M seal, cement mortar, special adhesives like araldite and plain split collar.

### **10.5.6 LEAKAGE THROUGH HOLE**

The hole can be covered with a plate and bolted to a flat inserted through the hole. The hole shall be covered with a lead washer under the plate and annular gap to be filled with m-seal compound or other suitable sealing material.

If the hole is very close to the joint, a plane cover or a stepped split collar can be fixed and caulked with cement mortar after caulking the joint with lead pieces or lead wool.

## **10.6 GENERATION OF DATA AND LIFE CYCLE ANALYSIS**

Record of repair carried out with costs should be maintained systematically. This will help in assessing the useful life of different materials of pipelines. This data will be useful in carrying out Life Cycle Cost analysis of competing materials and take decision regarding replacements.

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# CHAPTER 11

## OPERATION AND MAINTENANCE OF PUMPING MACHINERY

### 11.1 INTRODUCTION

#### 11.1.1 GENERAL

Pumping machinery and pumping station are very important components in a water supply system. Pumping machinery is subjected to wear, tear, erosion and corrosion due to their nature of functioning and therefore are vulnerable for failures. Generally more number of failures or interruptions in water supply are attributed to pumping machinery than any other component. Therefore, correct operation and timely maintenance and up-keep of pumping stations and pumping machinery are of vital importance to ensure uninterrupted water supply. Sudden failures can be avoided by timely inspection, follow up actions on observations of inspection and planned periodical maintenance. Downtime can be reduced by maintaining inventory of fast moving spare parts. Efficiency of pumping machinery reduces due to normal wear and tear. Timely action for restoration of efficiency can keep energy bill within reasonable optimum limit. Proper record keeping is also very important.

Obviously due attention needs to be paid to all such aspects for efficient and reliable functioning of pumping machinery. This chapter discusses procedures for operation and maintenance and addresses pertinent issues involved in O&M of pumping machinery and associated electrical and mechanical equipment.

#### 11.1.2 COMPONENTS IN PUMPING STATIONS

The components in pumping station can be grouped as follows.

- i) *Pumping machinery*
  - Pumps and other mechanical equipment, i.e. valves, pipe work, vacuum pumps
  - Motors, switchgears, cable, transformer and other electrical accessories
- ii) *Ancillary Equipment*
  - Lifting equipment
  - Water hammer control device
  - Flowmeter
  - Diesel generating set

- iii) *Pumping station*
  - Sump/intake/well/tubewell/borewell
  - Pump house
  - Screen
  - Penstock/gate

### **11.1.3 TYPE OF PUMPS**

Following types of pumps are used in water supply systems.

- i) Centrifugal pumps
- ii) Vertical turbine pumps
  - Oil lubricated
  - Self water (pumped water) lubricated
  - Clear water lubricated
- iii) Submersible pumps
  - Vertical borewell type pump-motor set
  - Monobloc open well type pump-motor set
- iv) Jet pumps
- v) Reciprocating pumps

### **11.1.4 COVERAGE IN THE CHAPTER**

The chapter covers following aspects regarding operation and maintenance of components of pumping station and pumping machinery.

- i) *Pumping Machinery*
  - Operation including starting and stopping of pumps and associated electrical and mechanical equipment
  - Preventive maintenance
  - Trouble shooting
  - Inventory of spares, oil and lubricants
  - Tools and testing equipments
  - Inspection and testing
  - Record keeping
- ii) *Ancillary equipment*
  - Operation, maintenance and testing of
    - \* lifting equipment
    - \* water hammer (surge) control device

iii) *Pumping station*

- Maintenance of following,
  - \* Screen
  - \* Penstock/gate
  - \* Pump house
- Housekeeping

## 11.2 OPERATION OF THE PUMPS

### 11.2.1 IMPORTANT POINTS FOR OPERATION

Important points as follows shall be observed while operating the pumps.

- (a) Dry running of the pumps should be avoided.
- (b) Centrifugal pumps have to be primed before starting.
- (c) Pumps should be operated only within the recommended range on the head-discharge characteristics of the pump.
  - If pump is operated at point away from duty point, the pump efficiency normally reduces.
  - Operation near the shut off should be avoided, as the operation near the shut off causes substantial recirculation within the pump, resulting in overheating of water in the casing and consequently, in overheating of the pump.
- (d) Voltage during operation of pump-motor set should be within  $\pm 10\%$  of rated voltage. Similarly current should be below the rated current as per name plate on the motor.
- (e) Whether the delivery valve should be opened or closed at the time of starting should be decided by examining shape of the power-discharge characteristic of the pump. Pump of low and medium specific speeds draw lesser power at shut off head and power required increases from shut off to normal operating point. Hence in order to reduce starting load on motor, a pump of low or medium specific speed is started against closed delivery valve.

Normally the pumps used in water supply schemes are of low and medium specific speeds. Hence, such pumps need to be started against closed delivery valve.

The pumps of high specific speed draw more power at shut off. Such pumps should be started with the delivery valve open.

- (f) The delivery valve should be operated gradually to avoid sudden change in flow velocity which can cause water hammer pressures.

It is also necessary to control opening of delivery valve during pipeline - filling period so that the head on the pump is within its operating range to avoid operation on low head and consequent overloading. This is particularly important during charging of the pumping main initially or after shutdown. As head increases the valve shall be gradually opened.

- (g) When the pumps are to be operated in parallel, the pumps should be started and stopped with a time lag between two pumps to restrict change of flow velocity to minimum and to restrict the dip in voltage in incoming feeder. The time lag should be adequate to allow to stabilize the head on the pump, as indicated by a pressure gauge.
- (h) When the pumps are to be operated in series, they should be started and stopped sequentially, but with minimum time lag. Any pump, next in sequence should be started immediately after the delivery valve of the previous pump is even partly opened. Due care should be taken to keep the air vent of the pump next in sequence open, before starting that pump.
- (i) The stuffing box should let a drip of leakage to ensure that no air is passing into the pump and that the packing is getting adequate water for cooling and lubrication. When the stuffing box is grease sealed, adequate refill of the grease should be maintained.
- (j) The running of the duty pumps and the standby should be scheduled so that no pump remains idle for long period and all pumps are in ready-to run condition. Similarly unequal running should be ensured so that all pumps do not wear equally and become due for overhaul simultaneously.
- (k) If any undue vibration or noise is noticed, the pump should be stopped immediately and cause for vibration or noise be checked and rectified.
- (l) Bypass valves of all reflux valve, sluice valve and butterfly valve shall be kept in closed position during normal operation of the pumps.
- (m) Frequent starting and stopping should be avoided as each start causes overloading of motor, starter, contactor and contacts. Though overloading lasts for a few seconds, it reduces life of the equipment.

### 11.2.2 UNDESIRABLE OPERATIONS

Following undesirable operations should be avoided.

i) *Operation at Higher Head*

The pump should never be operated at head higher than maximum recommended. Such operation results in excessive recirculation in the pump, overheating of the water and the pump. Another problem, which arises if pump is operated at a head higher than the recommended maximum head, is that the radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft which may cause failure of the pump shaft. As a useful guide, appropriate marking on pressure gauge be made. Such operation is also inefficient as efficiency at higher head is normally low.

ii) *Operation at Lower Head*

If pump is operated at lower head than recommended minimum head, radial reaction on the pump shaft increases causing excessive unbalanced forces on shaft which may cause failure of the pump shaft. As useful guide, appropriate markings on both pressure gauge and ammeter be made.

Such operation is also inefficient as efficiency at lower head is normally low.

iii) *Operation on Higher Suction Lift*

If pump is operated on higher suction lift than permissible value, pressure at the eye of impeller and suction side falls below vapour pressure. This results in flashing of water into vapour. These vapour bubbles during passage collapse resulting in cavitation in the pump, pitting on suction side of impeller and casing and excessive vibrations. In addition to mechanical damage due to pitting, discharge of the pump also reduces drastically.

iv) *Throttled operation*

At times if motor is continuously overloaded, the delivery valve is throttled to increase head on the pump and reduce power drawn from motor. Such operation results in inefficient running as energy is wasted in throttling. In such cases, it is preferable to reduce diameter of impeller which will reduce power drawn from motor. For detailed discussion, refer to para 16.3.16, Chapter 16 on "Energy Audit and Energy Conservation."

v) *Operation with Strainer/Foot Valve Clogged*

If the strainer or foot valve is clogged, the friction loss in strainer increases to high magnitude which may result in pressure at the eye of the impeller falling below water vapour pressure, causing cavitation and pitting similar to operation on higher suction lift.

The strainers and foot valves should be periodically cleaned particularly during monsoon.

vi) *Operation of the Pump with Low Submergence*

Minimum submergence above the bellmouth or foot valve is necessary so as to prevent air entry into the suction of the pump which gives rise to vortex phenomenon causing excessive vibration, overloading of bearings, reduction in discharge and efficiency. As a useful guide the lowest permissible water level be marked on water level indicator.

vii) *Operation with Occurrence of Vortices*

If vibration continues even after taking all precautions, vortex may be the cause. All parameters necessary for vortex-free operation should be checked. Chapter 11 in Manual on Water Supply and Treatment discusses these aspect in details.

### **11.2.3 STARTING THE PUMPS**

#### **11.2.3.1 Checks before starting**

Following points should be checked before starting the pump.

- Power is available in all 3 phases.
- Trip circuit for relays is in healthy state
- Check voltage in all 3 phases.

The voltage in all phases should be almost same and within  $\pm 10\%$  of rated voltage, as per permissible voltage variation.

- Check functioning of lubrication system specifically for oil lubricated and clear water lubricated VT pumps and oil lubricated bearings.

- Check stuffing box to ensure that it is packed properly.
- Check and ensure that the pump is free to rotate.
- Check overcurrent setting if the pump is not operated for a week or longer period.
- Before starting it shall be ensured that the water level in the sump/intake is above low water level and inflow from the source or preceding pumping station is adequate.

### 11.2.3.2 Starting and Operation of Pumps

Procedures for starting and operation of different types of pumps are as follows.

#### (a) *Centrifugal Pump (of low and medium specific speed)*

- To start a centrifugal pump, the suction pipes and the pump should be fully primed irrespective of the fact whether the pump is with positive (flooded) suction or suction lift.

The centrifugal pump with positive suction can be primed by opening valve on suction side and letting out air from the casing by opening air vent.

Centrifugal pump on suction lift necessitates close attention to prime the pump fully. To achieve this, the suction pipe and the pump casing must be filled with water and entire air in suction piping and the pump must be removed. If vacuum pump is provided, the pump can be primed by operating vacuum pump till steady stream of water is let out from delivery of vacuum pump. In absence of vacuum pump, priming can be done by pouring water in casing and evacuating air through air vent or by admitting water from pumping main by opening bypass of reflux valve and delivery valve. Check all joints in the suction pipe and fittings.

- Close the delivery valve and then loosen slightly.
- Switch on the motor, check that direction of rotation is correct. If the pump does not rotate, it should be switched off immediately.
- Check vacuum gauge if the pump operates on suction lift. If the pointer on gauge gradually rises and becomes steady the priming is proper.
- Pressure gauge should be observed after starting the pump. If the pump is working correctly the delivery pressure gauge should rise steadily to shut off head.
- When the motor attains steady speed and pressure gauge becomes steady, the delivery valve should be gradually opened in steps to ensure that the head does not drop below recommended limit. (in the absence of recommendations, the limit shall be about 85% of duty head for centrifugal pump).
- Check that ammeter reading is less than rated motor current.
- Check for undue vibration and noise.
- When in operation for about 10-15 minutes, check the bearing temperature, stuffing box packing, and leakage through mechanical seal and observe vibrations, if any.
- Voltage should be checked every half an hour and should be within limit.



**(b) Vertical Turbine Pump (of low and medium specific speed)**

- i) Close delivery valve, and then loosen slightly.
- ii) If pump is oil-lubricated, check the oil in the oil tank and open the cock to ensure that oil is flowing at the rate of 2-4 drops per minute.  

If the pump is self water-lubricated and length of column assembly is long (15 m or above), external water shall be admitted to wet and lubricate the line shaft bearings before starting the pump.

If the pump is external clear water lubricated, the clear water lubricating pump should be started before starting main pump.
- iii) Open the air vent in discharge/delivery pipe.
- iv) Switch on the motor and check correctness of direction of rotation. If the pump does not rotate, it should be switched off immediately.
- v) Check that oil is flowing into the pump through the sight glass tube. The number of drops/min. should be as per manufacturer's recommendations (normally 2-4 drops/minute).  

For clear water lubricated pump, check that lubricating clear water is passing into the column assembly.
- vi) Check pressure gauge reading to ensure that pump has built up the required shut off head.
- vii) When the motor attains steady speed and pressure gauge becomes steady, the delivery valve should be gradually opened in steps to ensure that the head does not drop below recommended limit. (In absence of recommendation, the limit shall about 75% of duty head for VT & submersible pump).
- viii) If steady water stream is let out through air vent, close the air vent.
- ix) Check that ammeter reading is less than rated motor current.
- x) Check for undue vibration and noise.
- xi) When in operation for about 10-15 minutes, check bearing temperature, stuffing box packing and observe vibration if any.
- xii) Voltage should be checked every half an hour and should be within limit.

**(c) Submersible Pumps**

Starting of a submersible pump is similar to vertical turbine pump except that steps ii, v, and xi are not applicable and since motor is not visible, correctness of direction of rotation is judged from pressure gauge reading which should indicate correct shut off head.

**(d) Jet Pump**

The procedure for starting jet pumps is similar to centrifugal pump except that priming by vacuum pump is not possible. Priming needs to be done by filling the pump casing and suction line from external source or by pouring water.

(e) *Vacuum Pump*

The procedure for starting vacuum pump is similar to centrifugal pump except that priming is not necessary and valves on both suction & delivery side of vacuum pump should be fully open.

(f) *Reciprocating Pump*

The steps stipulated for centrifugal pump are equally applicable for reciprocating pump. However exceptions as follows are applicable.

- The pump should be started against partially open delivery valve.
- The pump should never be started or operated against closed delivery valve.

#### **11.2.4 STOPPING THE PUMP**

##### **11.2.4.1 Stopping the Pump under Normal Condition**

Steps to be followed for stopping a pump of low and medium specific speed are as follows:

- i) Close the delivery valve gradually (sudden or fast closing should not be resorted to, which can give rise to water hammer pressures).
- ii) Switch off the motor.
- iii) Open the air vent in case of V.T. and submersible pump.
- iv) Stop lubricating oil or clear water supply in case of oil lubricated or clear water lubricated VT pump as applicable.

##### **11.2.4.2 Stopping after Power Failure/Tripping**

If power supply to the pumping station fails or trips, actions stated below should be immediately taken to ensure that the pumps do not restart automatically on resumption of power supply. Though no-volt release or undervolt relay is provided in starter and breaker, possibility of its malfunctioning and failure to open the circuit cannot be ruled out. In such eventuality, if the pumps start automatically on resumption of power supply, there will be sudden increase in flow velocity in the pumping main causing sudden rise in pressure due to water hammer which may prove disastrous to the pumping main. Secondly, due to sudden acceleration of flow in the pumping main from no-flow situation, acceleration head will be very high and the pumps shall operate near shut off region during acceleration period which may last for few minutes for long pumping main and cause overheating of the pump. Restarting of all pumps simultaneously shall also cause overloading of electrical system.

Hence, precautions are necessary to prevent auto-restarting on resumption on power. Following procedure should be followed.

- i) Close all delivery valves on delivery piping of pumps if necessary, manually as actuators can not be operated due to non-availability of power.
- ii) Check and ensure that all breakers and starters are in open condition i.e. off-position.
- iii) All switches and breakers shall be operated to open i.e. off-position.

- iv) Open air vent in case of V.T. or submersible pump and close lubricating oil or clear water supply in case of oil lubricated or clear water lubricated V.T. pump.
- v) Information about power failure should be given to all concerned, particularly to upstream pumping station to stop pumping so as to prevent overflow.

### **11.3 PREVENTIVE MAINTENANCE OF PUMPING MACHINERY**

Lack of preventive and timely maintenance or poor maintenance can cause undue wear and tear of fast moving parts, and premature failure of the equipment. Such premature failure or breakdown causes immense hardship to the consumers and staff, and avoidable increase in repair cost. The shortcomings in maintenance can also result in increase in hydraulic and power losses and low efficiency. Inefficient running of the pump increases burden of power cost. Importance of preventive maintenance, therefore, need not be overstressed.

Appropriate maintenance schedule and procedure need to be prescribed for all electrical and mechanical equipment based on manufacturers' recommendations, characteristics of the equipment, site and environment conditions i.e. temperature, humidity, dust condition, etc. The maintenance schedule also need to be reviewed and revised in the light of experience and analysis of failures and breakdown at the pumping station. The preventive maintenance schedule shall detail the maintenance to be carried out at regular intervals i.e. daily, monthly, quarterly, half yearly, annually etc. or operation hours. The schedule shall also include inspections and tests to be performed at appropriate interval or periodicity.

General guidelines for maintenance schedules for pumps and associated electrical and mechanical equipment are enlisted below. The guidelines should not be considered as total, full-fledged and comprehensive as characteristics of equipment and site conditions differ from place to place. For example, in dust laden environment or places where occurrence of storms are frequent, blowing of dust in motor, renewal of oil and grease in bearing shall have to be done at lesser intervals than specified in general guideline.

#### **11.3.1 MAINTENANCE OF PUMPS**

##### **11.3.1.1 Daily Observations and Maintenance**

###### *(a) Daily Maintenance*

- Clean the pump, motor and other accessories.
- Check coupling bushes/rubber spider.
- Check stuffing box, gland etc.

###### *(b) Routine observations of irregularities*

The pump operator should be watchful and should take appropriate action on any irregularity noticed in the operation of the pumps. Particular attention should be paid to following irregularities.

- i) Changes in sound of running pump and motor
- ii) Abrupt changes in bearing temperature.
- iii) Oil leakage from bearings

- iv) Leakage from stuffing box or mechanical seal
- v) Changes in voltage
- vi) Changes in current
- vii) Changes in vacuum gauge and pressure gauge readings
- viii) Sparks or leakage current in motor, starter, switch-gears, cable etc.
- ix) Overheating of motor, starter, switch gear, cable etc.

**(c) Record of operations and observations**

A log book should be maintained to record the hourly observations, which should cover the following items.

- i) Timings when the pumps are started, operated and stopped during 24 hours.
- ii) Voltage in all three phases.
- iii) Current drawn by each pump-motor set and total current drawn at the installation.
- iv) Frequency.
- v) Readings of vacuum and pressure gauges.
- vi) Motor winding temperature.
- vii) Bearing temperature for pump and motor.
- viii) Water level in intake/sump.
- ix) Flowmeter reading.
- x) Daily PF over 24 hours duration.
- xi) Any specific problem or event in the pumping installation or pumping system e.g. burst in pipeline, tripping or fault, power failure.

**11.3.1.2 Monthly Maintenance**

- i) Check free movement of the gland of the stuffing box; check gland packing and replace if necessary.
- ii) Clean and apply oil to the gland bolts.
- iii) Inspect the mechanical seal for wear and replacement if necessary.
- iv) Check condition of bearing oil and replace or top up if necessary.

**11.3.1.3 Quarterly Maintenance**

- i) Check alignment of the pump and the drive. The pump and motor shall be decoupled while correcting alignment, and both pump and motor shafts shall be pushed to either side to eliminate effect of end play in bearings.
- ii) Clean oil lubricated bearings and replenish with fresh oil. If bearings are grease lubricated, the condition of the grease should be checked and replaced/replenished to the correct quantity. An anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be between one third to half. A fully packed housing will overheat the bearing and will result in reduction of life of the bearing.

- iii) Tighten the foundation bolts and holding down bolts of pump and motor mounting on base plate or frame.
- iv) Check vibration level with instruments if available; otherwise by observation.
- v) Clean flow indicator, other instruments and appurtenances in the pump house.

#### 11.3.1.4 Annual Inspections and Maintenance

A very thorough, critical inspection and maintenance should be performed once in a year. Following items should be specifically attended.

- i) Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. corrosion, wear and scratches. Check end play. Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture.
- ii) Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.
- iii) Examine shaft sleeves for wear or scour and necessary rectification. If shaft sleeves are not used, shaft at gland packings should be examined for wear.
- iv) Check stuffing box, glands, lantern ring, mechanical seal and rectify if necessary.
- v) Check clearances in wearing ring.

Clearances at the wearing rings should be within the limits recommended by the manufacturer. Excessive clearance reduces discharge and efficiency of the pump. If the wear is only on one side, it is indicative of misalignment. The misalignment should be set right, and the causes of misalignment should be investigated. When the clearances have to be restored, general guidelines detailed in table 11.1 below shall be followed. Normally, if the clearance in wearing rings increase by about 100% for small pumps and 50-75% for large pumps the rings shall be renewed or replaced to restore to the original clearance.

The tolerances given in the table are to be strictly followed. For example, while machining the internal diameter of the casing wearing ring of basic size, say 175 mm, the limits for machining would be 175.00 minimum and 175.05 maximum. For the corresponding outer diameter at the hub of the impeller or impeller ring, the basic

**TABLE 11.1: WEARING RING DIAMETRICAL CLEARANCE AND TOLERANCE**

Inside diameter of wearing ring (mm)	Diametral clearance (mm)	Machining Tolerance (mm)
Upto 100	0.30	.050
101-150	0.35	
151-200	0.40	
201-300	0.45	0.075
301-500	0.50	
501-750	0.55	
751-1200	0.65	0.100
1201-2000	0.75	0.125

size will be with a clearance of 0.4 mm, i.e. 174.60 mm and the machining limits will be 174.60 mm maximum and 174.55 minimum.

Taking into consideration that part dismantling of the pump is involved in checking wearing ring clearance and as it is not advisable to dismantle vertical turbine pump every year, the frequency for checking wearing ring in case of V.T. pump shall be once in two years or earlier if discharge test indicates discharge reduction beyond limit of 5% - 7%.

- vi) Check impeller hubs and vane tips for any pitting or erosion.
- vii) Check interior of volute, casing and diffuser for pitting, erosion, and rough surface.
- viii) All vital instruments i.e. pressure gauge, vacuum gauge, ammeter, voltmeter, wattmeters, frequency meter, tachometer, flowmeter etc. shall be calibrated.
- ix) Conduct performance test of the pump for discharge, head and efficiency.
- x) Measures for preventing ingress of flood water shall be examined. Ingress of flood water in sump, well, tubewell or borewell shall be strictly prevented. Seal cap shall be provided above tubewell/borewell.
- xi) Check vibration level.

#### **11.3.1.5 Overhaul of Pump**

It is difficult to specify the periodicity or interval for overhaul in the form of period of service in months/years or operation hours, as deterioration of pump depends on nature of service, type of installation i.e. wetpit or drypit, quality of water handled, quality of material of construction, maintenance, experience with particular make & type of pump etc.

However generally, following operational hours may be taken as broad guidelines for overhauling.

- Submersible pump – 5000 – 6000 hours
- Vertical turbine pump – 12000 hours
- Centrifugal pump – 15000 hours

#### **11.3.1.6 Problems in Long Column Pipes in VT Pump**

Very long column pipes in VT pump at river intake or intake well constructed in impounded reservoir are required to be provided due to large fluctuations in water level from minimum water level in summer to high water level in monsoons. Such long column pipes (if length exceeds about 15 m) usually cause problem of fast wearing of line- shafts bearings in case of water lubricated pumps. Such longer suspended assembly is also more prone to rotation or swinging of column assembly due to vortices.

Precautionary measure as follows may be taken

- (a) Prevention of premature wear of water lubricated bearings in column pipes  
Water lubricated bearings usually are of rubber or neoprene and wear fast if dry running, occurs during starting of VT pumps. Therefore to avoid dry running water is admitted from external source (usually a tank near the pump provided for the purpose) into the column pipe for about 3-4 minutes so as to wet the bearing before starting the pump.

(b) Preventing rotation or swinging in column assembly

A cone as shown in the figure 11.1 (C) or splitter as shown in figure 11.1 (G) shall be provided underneath bellmouth.

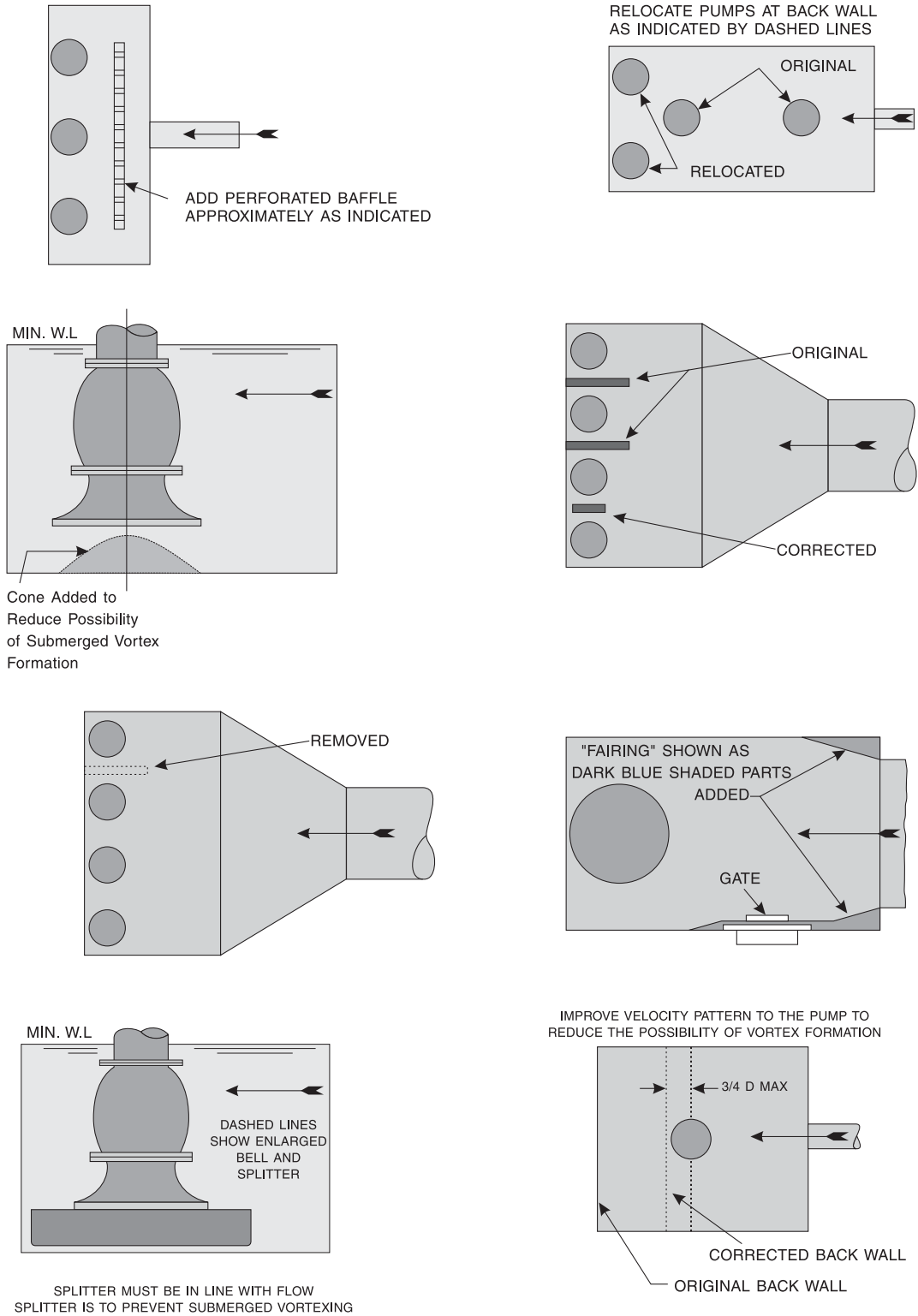


FIG 11.1 REMEDIAL MEASURES FOR VORTEX-FREE OPERATION IN EXISTING SUMPS

Under no circumstances the column assembly be tied or fixed at any point other than discharge head from which it is suspended, as such measure shall result in misalignment.

#### **11.3.1.7 Sludge Water/Filter Wash Recirculation Pump**

Due attention should be paid for proper selection of the pump and material of construction, to avoid operation problems and premature wear due to abrasive material in pumped water. The impeller should, preferably, be of stainless steel of grade CF 8 M and wearing ring of CF 8. The pump should preferably be VT type.

#### **11.3.1.8 History Sheet**

History sheet of all pumps shall be maintained. The history sheet shall contain all important particulars, records of all maintenance, repairs, inspections and tests etc. It shall generally include the following.

- i) Details of the pump, rating, model, characteristic curves, performance test report etc.
- ii) Addresses of manufacturer & dealer with phone & fax number and e-mail addresses.
- iii) Date of installation and commissioning.
- iv) Brief details and observations of monthly, quarterly and annual maintenance and inspections.
- v) Details of breakdown, repairs with fault diagnosis, replacement of major components i.e. impeller, shaft, bearings, wearing rings.
- vi) Results of annual performance test including discharge and efficiency.
- vii) Yearly operation hours of the pumps.
- viii) Brief findings of energy audit.

### **11.3.2 MAINTENANCE SCHEDULE FOR MOTORS**

#### **11.3.2.1 Daily Maintenance**

- i) Clean external surface of motor.
- ii) Examine earth connections and motor leads.
- iii) Check temperature of motor and check whether overheated. The permissible maximum temperature is above the level which can be comfortably felt by hand. Hence temperature observation should be taken with RTD or thermometer. (Note: In order to avoid opening up motors, a good practice is to observe the stator temperature under normal working conditions. Any increase not accounted for, by seasonal increase in ambient temperature, should be suspected).
- iv) In case of oil ring lubricated bearing.
  - Examine bearings to check whether oil rings are working.
  - Note bearing temperature.
  - Add oil if necessary.
- v) Check for any abnormal bearing noise.



### **11.3.2.2 Monthly Maintenance**

- i) Check belt tension. In case where this is excessive it should immediately be reduced.
- ii) Blow dust from the motor.
- iii) Examine oil in oil lubricated bearing for contamination by dust, grit, etc. (this can be judged from the colour of the oil).
- iv) Check functioning and connections of anti-condensation heater (space heater).
- v) Check insulation resistance by meggering.

### **11.3.2.3 Quarterly Maintenance**

- i) Clean oil lubricated bearings and replenish fresh oil. If bearings are grease lubricated, the condition of the grease should be checked and replaced/replenished to correct quantity. An anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be between one third to half. A fully packed housing will overheat the bearing and will result in reduction of life of the bearing.
- ii) Wipe brush holders and check contact faces of brushes of slip-ring motors. If contact face is not smooth or is irregular, file it for proper and full contact over slip rings.
- iii) Check insulation resistance of the motor.
- iv) Check tightness of cable gland, lug and connecting bolts.
- v) Check and tighten foundation bolts and holding down bolts between motor and frame.
- vi) Check vibration level with instrument if available; otherwise by observation.

### **11.3.2.4 Half Yearly Maintenance**

- i) Clean winding of motor, bake and varnish if necessary.
- ii) In case of slip ring motors, check slip-rings for grooving or unusual wear, and polish with smooth polish paper if necessary.

### **11.3.2.5 Annual Inspections and Maintenance**

- i) Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. wear and scratches. Check end-play. Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture.
- ii) Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.
- iii) Blow out dust from windings of motors thoroughly with clean dry air. Make sure that the pressure is not so high as to damage the insulation.
- iv) Clean and varnish dirty and oily windings.  
Revarnish motors subjected to severe operating and environmental conditions e.g., operation in dust-laden environment, polluted atmosphere etc.
- v) Check condition of stator, stamping, insulation, terminal box, fan etc.

- vi) Check insulation resistance to earth and between phases of motors windings, control gear and wiring.
- vii) Check air gaps.
- viii) Check resistance of earth connections.

#### **11.3.2.6 History Sheet**

Similar to history sheet of pump, history sheet of motor should be maintained. The history sheet should contain all important particulars, records of periodical maintenance, repairs, inspections and tests. It shall generally include the following:

- i) Details of motor, rating, model, class of duty, class of insulation, efficiency curve, type test result and type test certificate etc.
- ii) Date of installation and commissioning.
- iii) Addresses of manufacturer & dealer with phone & fax number and e-mail addresses.
- iv) Brief details of monthly, quarterly, half yearly and annual maintenance and observations of inspections about insulation level, air gap etc.
- v) Details of breakdown, repairs with fault diagnosis.
- vi) Running hours at the time of major repairs.

#### **11.3.3 VALVES**

Following 5 types of valves are generally used in pumping installation

- a) Foot valve.
- b) Sluice valve.
- c) Knife gate valve.
- d) Reflux (non-return) valve.
- e) Butterfly valve.

Maintenance as follows shall be carried out.

- a) *Foot Valve*
  - ◆ Clean foot valve once in 1-3 months depending on ingress of floating matters.
  - ◆ Clean flap of the foot valve once in 2 months to ensure leakproof operation.
  - ◆ Inspect the valve thoroughly once in a year. Check for leakage through foot valve after priming and observing level in volute casing.
- b) *Sluice valve and Knife gate valve*
  - ◆ Check gland packing of the valve at least once in a month. It should be ensured that packings inside the stuffing box are in good trim and impregnated with grease. It may be necessary to change the packing as often as necessary to ensure that the leakage is within limit.
  - ◆ Grease should be applied to reduction gears and grease lubricated thrust bearing once in three months.

- ◆ Check tight closure of the valve once in 3 months.
  - ◆ A valve normally kept open or closed should be operated once every three months to full travel of gate and any jamming developed due to long disuse shall be freed.
  - ◆ Inspect the valve thoroughly for flaws in guide channel, guide lugs, spindle, spindle nut, stuffing box etc. once in a year.
  - ◆ Important DON'T for valve is that it should never be operated with oversize handwheel or cap or spanner as this practice may result in rounding of square top and handwheel or cap or spanner may eventually slip.
  - ◆ An important DON'T for valve is that it should never be operated under throttled i.e. partially open condition, since such operation may result in undue chatter, wear and failure of valve spindle.
- c) *Reflux (non-return) valve*
- ◆ Check proper operation of hinged door and tight closure under no-flow condition once in 3 months.
  - ◆ The valve shall be thoroughly inspected annually. Particular attention should be paid to hinges and pins and soundness of hinged door.
  - ◆ Condition of dampening arrangement should be thoroughly examined once in year and necessary maintenance and rectification as per manufactures' instructions shall be carried out.
  - ◆ In case of dampening arrangement, check for oil leakage and replace oil once in a year.
- d) *Butterfly valve*
- ◆ Check seal ring and tight shut-off once in 3 months.
  - ◆ Lubricate gearing arrangement and bearing once in 3 months.
  - ◆ Inspect the valve thoroughly including complete operations once in a year.
  - ◆ Change oil or grease in gearing arrangement once in a year.
- e) *General*
- ◆ Operate bypass valve wherever provided once in 3 months.
  - ◆ Flange adapter/dismantling joint provided with valve shall be loosened and retightened once in 6 months to avoid sticking.

### **11.3.4 VALVE ACTUATORS**

#### **11.3.4.1 Quarterly Maintenance**

- ∞ Declutch and operate manual handwheel.
- ∞ Check oil level and top up if required.
- ∞ Regrease the grease lubricated bearing and gear trains as applicable.

- ∞ Check insulation resistance of the motor.
- ∞ Check for undue noise and vibration and take necessary rectification measures.
- ∞ Tighten limit switch cams and check for setting and readjust if necessary.

#### **11.3.4.2 Annual Inspections and Maintenance**

- ∞ Examine all components and wiring thoroughly and rectify as necessary.
- ∞ Change oil or grease in gear box and thrust bearing.
- ∞ Check condition of gears & replace gears if teeth are worn out.

#### **11.3.5 L.T. STARTERS, BREAKERS AND PANEL**

Note: Circuit diagram of starter/breaker should be pasted on door of switch gear and additional copy should be kept on record.

##### *i) Daily*

- ∞ Clean the external surface.
- ∞ Check for any spark or leakage current.
- ∞ Check for overheating.

##### *ii) Monthly*

- ∞ Blow the dust and clean internal components in the panel, breaker and starter.
- ∞ Check and tighten all connections of cable, wires, jumpers and bus-bars. All carbon deposits shall be cleaned.
- ∞ Check relay setting.

##### *iii) Quarterly*

- ∞ Check all connections as per circuit diagram.
- ∞ Check fixed and moving contacts and clean with smooth polish paper, if necessary.
- ∞ Check oil level and condition of oil in oil tank. Replace the oil if carbon deposit in suspension is observed or colour is black.
- ∞ Check insulation resistance.
- ∞ Check condition of insulators.

##### *iv) Yearly*

- ∞ Check and carry out servicing of all components, thoroughly clean and reassemble.
- ∞ Calibrate voltmeter, ammeter, frequency meter etc.

#### **11.3.6 H.T. BREAKERS, CONTACTORS AND PROTECTION RELAYS**

Note: Circuit diagram of breaker/relay circuit should be pasted on door of switch gear and additional copy should be kept on record.

Maintenance schedule specified for L.T. breakers is also applicable to H.T. breakers and contactors. In addition, following important points shall be attended for H.T. breakers and contactors.

i) *Monthly*

- ☞ Check spring charging mechanism and manual cranking arrangement for operation.
- ☞ Clean all exposed insulators.
- ☞ Check trip circuit and alarm circuit.
- ☞ Check opening & closing timing of breaker.

ii) *Quarterly*

- ☞ Check control circuits including connections in marshalling boxes of breakers and transformer.
- ☞ Check oil level in MOCB/LOCB/HT OCB and top up with tested oil.

iii) *Yearly/Two yearly*

- ☞ Testing of protection relay with D.C. injection shall be carried out once in a year.
- ☞ Servicing of HT breaker and contactor shall be carried out once in 2-3 years.
- ☞ Check dielectric strength of oil in breaker and replace if necessary.
- ☞ Check male & female contacts for any pitting and measure contact resistance.

### **11.3.7 CAPACITORS**

#### **11.3.7.1 Pre-requisites for Satisfactory Functioning of Capacitors**

Ensure following points :

- i) A capacitor should be firmly fixed to a base.
- ii) Cable lugs of appropriate size should be used.
- iii) Two spanners should be used to tighten or loosen capacitor terminals. The lower nut should be held by one spanner and the upper nut should be held by the another spanner to avoid damage to or breakage of terminal bushings and leakage of oil.
- iv) To avoid damage to the bushing, a cable gland should always be used and it should be firmly fixed to the cable-entry hole.
- v) The capacitor should always be earthed appropriately at the earthing terminal to avoid accidental leakage of the charge.
- vi) There should be a clearance of at least 75 mm on all sides for every capacitor unit to enable cooler running and maximum thermal stability. Ensure good ventilation and avoid proximity to any heat source.

- vii) While making a bank, the bus bar connecting the capacitors should never be mounted directly on the capacitor terminals. It should be indirectly connected through flexible leads so that the capacitor bushings do not get unduly stressed.
- ix) Ensure that the cables, fuses and switchgear are of adequate ratings.

#### **11.3.7.2 Operation and Maintenance of Capacitors**

- i) The supply voltage at the capacitor bus should always be near about the rated voltage. The fluctuations should not exceed  $\pm 10\%$  of the rated voltage of the capacitor.
- ii) Frequent switching of the capacitor should be avoided. There should always be an interval of about 60 seconds between any two switching operations.
- iii) The discharge resistance efficiency should be assessed periodically by sensing, if shorting is required to discharge the capacitor even after one minute of switching off. If the discharge resistance fails to bring down the voltage to 50V in one minute, it needs to be replaced.
- iv) Leakage or breakage should be rectified immediately. Care should be taken that no appreciable quantity of impregnant has leaked out.
- v) Before physically handling the capacitor, the capacitor terminals shall be shorted one minute after disconnection from the supply to ensure total discharging of the capacitor.
- vi) Replace capacitor if bulging is observed.

#### **11.3.8 TRANSFORMER & TRANSFORMER SUBSTATION**

Maintenance schedule as follows shall be applicable for transformer and sub-station equipments e.g. lightning arrestor, A.B. switch, D.O. or horn gap fuse, sub-station earthing system etc.

##### **11.3.8.1 Daily Observations and Maintenance**

- i) Check winding temperature and oil temperature in transformer and record. (For large transformers above 1000 kV, the temperature should be recorded hourly).
- ii) Check leakages through CT/PT unit, transformer tank and HT/LT bushings.
- iii) Check colour of silica gel. If silica gel is of pink colour, change the same by spare charge and reactivate old charge for reuse.

##### **11.3.8.2 Monthly Maintenance**

- i) Check oil level in transformer tank and top up if required.
- ii) Check relay contacts, cable termination, connections in marshalling box etc.
- iii) Check operation of AB switch and DO fuse assembly.
- iv) Clean radiators free from dust and scales.
- v) Pour 3-4 buckets (6 to 8 buckets in summer) of water in earth pit. *The frequency of watering shall be increased to once in a week in summer season.* The water for earthing shall preferably contain small amount of salt in solution.
- vi) Inspect lightning arrestor and HT/LT bushing for cracks and dirt.

#### **11.3.8.3 Quarterly Maintenance**

- i) Check dielectric strength of transformer oil and change or filter if necessary.
- ii) Check insulation resistance of all equipments in sub-station, continuity of earthings and earth leads.
- iii) Check operation of tap changing switch.

#### **11.3.8.4 Pre-Monsoon and Post-Monsoon Checks and Maintenance**

- i) Check insulation resistance of transformer.
- ii) Test transformer oil for dielectric strength, sludge etc. If necessary, filtration of oil shall be carried out before monsoon.
- iii) Oil shall be tested for dielectric strength after monsoon.

#### **11.3.8.5 Half-Yearly Maintenance**

- i) Check dielectric strength of transformer oil in CT/PT and filter or change oil if necessary.
- ii) Check contact faces of AB switch and DO/HG fuse; apply petroleum jelly or grease to moving components of AB switch.

#### **11.3.8.6 Annual Inspections and Maintenance**

- i) Measure resistance of earth pit. Resistance shall not exceed 1 ohm.
- ii) Check bus bar connections, clean contact faces, change rusted nut bolts.
- iii) Calibrate the protection relay for functioning. Check relay setting and correct if necessary.
- iv) Ensure that sub-station area is not water-logged. If required necessary earth fillings with metal spreading at top shall be carried out once in a year.  
Check drainage arrangement to prevent water logging in substation area and cable trenches.
- v) Test transformer oil for acidity test.

#### **11.3.8.7 Special Maintenance**

- i) Painting of transformer tank and steel structure of sub-station equipments shall be carried out after every two years.
- ii) The core of transformer and winding shall be checked after 5 years for transformer upto 3000 kVA and after 7–10 years for transformers of higher capacity.

#### **11.3.9 D.C. BATTERY**

Maintenance schedule as under shall be applicable for D.C. Batteries.

- i) *Daily* : Check voltage and specific gravity of the batteries and battery supply for the tripping circuit.
- ii) *Monthly* : Check the battery charging & fuses and clean contact faces.
- iii) *Monthly* : Apply petroleum jelly or grease to battery terminals.

- iv) *Quarterly* : Check to ensure that battery is not overcharged/under charged.
- v) *Yearly* : Check rectifier, diode, rheostat motor thoroughly.

### **11.3.10 LIFTING EQUIPMENT**

Relevant points in the maintenance schedule as follows shall be applicable for lifting equipments, depending on the type of lifting equipment i.e. chain pulley block, monorail (travelling trolley and chain pulley block), manually operated overhead crane and electrically operated travelling crane.

- i) *Quarterly* :
  - Check oil level in gear box and top up if required.
  - Check for undue noise and vibration.
  - Lubricate bearings and gear trains as applicable.
  - Check insulation resistance of motors.
- ii) *Half yearly* :
  - Clean limit switches.
  - Clean all electrical contacts.
- iii) *Yearly* :
  - Change oil in gear box.
  - Conduct load test of crane for rated load or at least for maximum load required to be handled. All fast moving components which are likely to wear should be thoroughly inspected once in a year and if necessary shall be replaced.

### **11.3.11 WATER HAMMER CONTROL DEVICES**

Maintenance requirements of water hammer devices depends on type of water hammer control device, nature of its functioning, water quality etc. Type of water hammer control devices used in water pumping installations are as follows :

- Surge tank
- One-way surge tank
- Air vessel (air chamber)
- Zero velocity valve and air cushion valve.
- Surge anticipation valve (surge suppressor)
- Pressure relief valve.

General guidelines for maintenance of different types of water hammer control devices are as follows:

#### **11.3.11.1 Surge Tank and One-Way Surge Tank**

- *Quarterly* : Water level gauge or sight tube provided shall be inspected, any jam rectified, all cocks and sight tube flushed and cleaned.
- *Yearly* : The tank shall be drained and cleaned once in a year or earlier if frequency of ingress of foreign matter is high.



- *Valve maintenance* : Maintenance of butterfly valve, sluice valve and reflux valve shall be attended as specified for valves on pump delivery in para 9.3.3.
- *Painting* : Painting of tanks shall be carried out once in 2 years.

#### **11.3.11.2 Air-Vessel**

- *Daily* :
  - Check air-water interface level in sight glass tube.  
The air water level should be within range marked by upper and lower levels and shall be preferably at middle.
  - Check pressure in air receiver at interval of every 2 hours.
- *Quarterly* :
  - Sight glass tube and cock shall be flushed.
  - All wiring connections shall be checked and properly reconnected.
  - Contacts of level control system and pressure switches in air supply system shall be cleaned.
- *Yearly* :
  - The air vessel and air receiver shall be drained, cleaned and dried.
  - Internal surface shall be examined for any corrosion etc. and any such spot cleaned by rough polish paper and spot-painted.
  - Probe heads of level control system shall be thoroughly checked and cleaned.
- *Accessories* :
  - Maintenance of panel, valves and air compressor etc. shall be carried out as specified for respective appurtenances.

#### **11.3.11.3 Zero-Velocity Valves and Air Cushion Valve**

Foreign matters entangled in valve shall be removed by opening all handholes and internal components of the valves including ports, disk, stem, springs, passages, seat faces etc. should be thoroughly cleaned and checked once in 6 months for raw water and once in a year for clear water application.

#### **11.3.11.4 Surge Anticipation Valves**

Pilot valves and tubes shall be flushed and cleaned every month

#### **11.3.11.5 Pressure Relief Valve**

The spring shall be checked and freed from jam every month.

#### **11.3.12 AIR COMPRESSOR**

- i) *Daily* :
  - Clean external surface.
  - Check oil level and top up if necessary.

- ii) *Monthly* :
  - Clean oil filter
  - Clean air filter
- iii) *Quarterly* :
  - Check condition of oil and change if dirty.
  - Check grease in bearing housing and replenish/change if necessary.
  - Check condition of oil in air filter and change if dirty.
- iv) *Half yearly* :
  - Change oil.
  - Change oil filter element.
  - Thoroughly clean air filter.
  - Clean bearing and bearing housing and change grease/oil.
- v) *Yearly* :
  - Thoroughly check all components, piping valve etc. and rectify if necessary.

## **11.4 MAINTENANCE OF PUMPING STATION**

Maintenance as follows shall be carried out for screens, penstock/gate, sump/intake/well and pump house including civil works.

### **11.4.1 SCREENS**

- i) Screen should be cleaned at a frequency depending on ingress load of floating matters. The frequency in monsoon season shall be more than that in fair season. However, cleaning frequency should be atleast once in a week, or, if head loss in screen exceeds 0.20 m.
- ii) Care should be taken to remove and dump the screening far away from the pump house.
- iii) Lubricate wheels and axle of wheel burrows.
- iv) The screen, catch tray and screen handling arrangement shall be thoroughly inspected once in six months and any item broken, eroded, corroded shall be rectified.

### **11.4.2 PENSTOCK / SLUICE GATE**

- i) *Monthly* :
  - The penstock/sluice gate normally remains in open position and closed only when inflow is to be stopped. Since floating matters may adhere to the gate and may accumulate in the seat, it should be operated once in a month. In order to ensure that gate remains free for operation

ii) *Yearly* :

- The gate should be thoroughly inspected once in a year preferably after monsoon and components found worn out shall be replaced. Particular attention shall be paid to the seats of the frame and gate.
- The gate should be closed to check the leakages. For this purpose, the sump/intake shall be partly dewatered so that differential head is created on the gate and leakage test at site can be performed.

#### **11.4.3 SUMP/INTAKEWELL**

- i) All foreign floating matters in the sump/intake shall be manually removed at least once in a month and shall be disposed off away from pump house.
- ii) Desilting of intake/sump shall be carried out once in year preferably after monsoon. Care should be taken to dump the removed silt away from pump house.
- iii) It is generally observed that reptiles like snakes, fish, etc. enter intake particularly in monsoon. The intake should be disinfected.
- iv) The sump/intake should be fully dewatered and inspected once in a year.
- v) It is advisable to undertake leakage test of sump once in a year. For this purpose, the sump shall be filled to FSL and drop in water level for reasonably long duration (2-3 hours) should be observed. If leakage is beyond limit, rectification work shall be taken.

#### **11.4.4 PUMP HOUSE**

- i) The pump house should be cleaned daily. Good house keeping and cleanliness are necessary for pleasant environment.
- ii) Entire pump house, superstructure and sub-structure shall be adequately illuminated and well ventilated. Poor lighting, stale air etc. create unpleasant environment and have an adverse effect on will of the staff to work.
- iii) Wooden flooring and M.S. grating wherever damaged should be repaired on priority.
- iv) It is observed that at many places, roof leaks badly and at times the leakage water drips on the panel/motor which is dangerous and can cause short circuit and electric accidents. All such leakages should be rectified on priority.
- v) All facilities in sub-structure i.e. stair case, floors, walkways etc. should be cleaned daily.
- vi) Painting of civil works should be carried out at least once in two years.

### **11.5 PREDICTIVE MAINTENANCE**

Predictive maintenance is the term used to examine and predict likely failure of components. As this requires experience, anticipation, good judgment and expertise and involves costs for repairs for predicted failures, it can be adopted at important, vital and large pumping stations.

### **11.5.1 PUMPS AND BEARINGS**

Some factual evidence i.e. declining of pump performance, excessive noise or bearing temperature, increase of vibration can indicate that the pump probably needs to be overhauled or bearing need to be replaced.

Efforts should be made to rectify noise and vibration level by critical study and adopting measures for rectifications. If noise or vibration still persists, the pump should be dismantled and thoroughly checked.

If significant reduction in discharge is suspected, performance test at site shall be conducted with calibrated instruments and the results of the tests are compared with initial results of new pump. After fully ascertaining that the performance has considerably declined, decision to overhaul may be taken.

In some installations particularly if raw water is corrosive or contains grit or sand, the pump may become prematurely due for overhaul due to deterioration caused by corrosion or erosion. In such cases, the decision for overhaul should be based on circumstantial evidence i.e. previous history. As a long term solution, the manufacturer should be consulted for use of better material of construction for affected components.

### **11.5.2 ELECTRICAL EQUIPMENT**

Weakening of insulation and failure of winding can be predicted by measuring insulation resistance and judging trend of weakening of insulation. The predictive maintenance test is recommended for following components of electrical machinery.

- |  |     |           |
|--|-----|-----------|
| i) Motor winding and insulation        | ... | Quarterly |
| ii) Transformer winding and insulation | ... | Annual    |

For condition monitoring of motors polarisation index shall be checked. The polarisation index is ratio of meggar value after 10 minutes and meggar value after 1 minute. The measurement should be taken with help of motorized meggar. For a healthy motor from insulation resistance point of view, the value of PI shall be more than 1.25.

## **11.6 FACILITIES FOR MAINTENANCE AND REPAIRS**

Facilities as follows should be provided for maintenance, inspection and repairs in the pumping installation.

- Adequate stock of consumables and lubricants
- Adequate stock of spare parts
- Tools and testing instruments
- Lifting equipment
- Ventilated and illuminated adequate space for repairs

### **11.6.1 CONSUMABLES AND LUBRICANTS**

Adequate stock of gland packing, belts, gaskets, lubricating oil, greases, transformer oil, insulation tape, sealing compound, emery paste etc. shall be maintained. The consumables and lubricants shall be of proper quality and grade. Quantity shall be decided depending on consumption and period required to procure and replenish the stock.

### 11.6.2 SPARE PARTS

Adequate stock of spare parts should be maintained to avoid downtime due to non-availability of spares. Generally spares required for one-two years maintenance as per list below shall be kept in stock. The list should not be considered as full fledged and comprehensive and should be updated and revised in light of manufacturers' recommendations and previous history of repairs undertaken.

- Set of wearing rings
- Shaft sleeves
- Bearings
- Gland packings and gaskets
- Coupling bushes and bolts
- Line shaft bearings and spiders
- Line shaft
- Pump shaft
- Shaft enclosing tube
- Tube tensioning plate
- Gland nut
- Lantern ring
- Coupling for line shaft
- Slip ring unit
- Carbon brushes
- Fixed and moving contacts
- Lugs
- Gland for cable termination
- Fluorescent tubes and lamps
- Fuses
- Impeller
- Rotating assembly of pump (for large pumping installation)

### 11.6.3 TOOLS AND TESTING INSTRUMENTS

The pumping installation should be equipped with all necessary tools, testing instruments and special tools required for repairs and testing. Their quantity and special tools depend on size and importance of installation. Generally following tools and testing instruments shall be provided.

#### a) Tools

- Double ended spanner set and ring spanner set.
- Box spanner set
- Hammers (of various sizes and functions)
- Screw driver set
- Chisel
- Nose plier, cutting plier
- Files of various sizes and smooth/rough surfaces
- Adjustable spanner
- Pipe wrenches
- Bearing puller
- Torque wrench
- Clamps for column pipes, tube and line shaft.
- Specials tools such as grinder, blower, drilling machine.
- Tap and die set.
- Bench vice

- Special tools for breakers
- Crimping tool
- Heating stove for heating sleeves.

**b) Test instruments**

- Insulation tester
- Tongue tester
- AVO meter
- Test lamp
- Earth resistance tester
- Wattmeter, CT and PT
- Dial gauge
- Tachometer

**11.6.4 LIFTING AND MATERIAL HANDLING AIDS**

Following lifting and material handling aids shall be kept in the pump house.

- Chains
- Wire rope
- Manila rope
- Chain pulley block and tripod.
- Other lifting equipment
- Hand cart
- Ladder

**11.6.5 SPACE**

A well ventilated and illuminated adequate space shall be earmarked for repairs. Minimum facilities such as work table, bench-vice etc. shall be provided.

**11.7 TROUBLE SHOOTING OF PUMPS AND ELECTRICALS**

Trouble shooting check charts for the following equipments are enlisted below.

- Pumps (Centrifugal, jet, VT, submersible, vacuum, reciprocating).
- Electric motor
- Capacitors
- Starters, breakers and control circuits
- Panels
- Cables
- Transformer
- Batteries
- Air compressor

## 11.7.1 TROUBLE SHOOTING FOR CENTRIFUGAL / JET / VT / VACUUM / SUBMERSIBLE PUMPS

### 11.7.1.1 Trouble & Causes

#### (a) Centrifugal Pump

Trouble	Possible Causes (numbers as per list below)	List of Causes
<ul style="list-style-type: none"> <li>• Pump does not deliver water. (water not delivered to not completely filled with water).</li> </ul>	1, 2, 3, 5, 6, 7, 9, 10, 15, 18, 21, 23, 26, 28, 29, 30, 31, 33, 40, 41, 42.	<ol style="list-style-type: none"> <li>1. Pump not fully primed i.e. pump or suction pipe discharging end i.e. reservoir/WTP).</li> <li>2. Pressure at eye of impeller has fallen below vapour pressure causing cavitations (Check for clogging on suction side. If no clogging is observed take action as against Sr. No. 3).</li> </ol>
<ul style="list-style-type: none"> <li>• Insufficient discharge delivered.</li> </ul>	2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 16, 17, 18, 20, 21, 23, 24, 27, 28, 29, 30, 31, 33, 39, 40, 41.	<ol style="list-style-type: none"> <li>3. Suction lift too high. (Reduce suction lift after calculating permissible suction lift from NPSHA and NPSHR).</li> </ol>
<ul style="list-style-type: none"> <li>• Insufficient pressure developed.</li> </ul>	2, 3, 4, 21, 23, 24, 26, 27, 28, 33, 39.	<ol style="list-style-type: none"> <li>4. Excessive amount of air in liquid.</li> </ol>
<ul style="list-style-type: none"> <li>• Pump loses prime after starting.</li> </ul>	4, 5, 6, 7, 10, 16, 17, 18.	<ol style="list-style-type: none"> <li>5. Air pocket in suction line (Check whether any point in suction line is above centre line of pump and if so, lower the line).</li> </ol>
<ul style="list-style-type: none"> <li>• Pump requires excessive power.</li> </ul>	22, 25, 28, 33, 37, 38, 49, 53, 54, 55, 56, 58	<ol style="list-style-type: none"> <li>6. Air leaks into suction line.</li> </ol>
<ul style="list-style-type: none"> <li>• Stuffing box leaks excessively.</li> </ul>	34, 36, 44, 45, 46, 47, 48, 50, 51, 52.	<ol style="list-style-type: none"> <li>7. Air leaks into pump through stuffing boxes or mechanical seal.</li> <li>8. Net opening area of foot valve less.</li> </ol>
<ul style="list-style-type: none"> <li>• Gland packing has short life.</li> </ul>	11, 12, 34, 36, 44, 45, 46, 47, 48, 49, 50, 51, 52.	<ol style="list-style-type: none"> <li>9. Foot valve/strainer partially or fully clogged or silted up.</li> <li>10. Suction bell mouth or foot valve insufficiently submerged. (Lower the inlet for adequate submergence for vortex-free operation as stipulated in para 11.2 of chapter 11 of Manual on Water Supply and Treatment).</li> </ol>
		<ol style="list-style-type: none"> <li>11. Water-seal pipe clogged.</li> </ol>

- Bearing has short life. 17, 20, 32, 34, 35, 36, 37, 39, 41, 44, 48, 51, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63.
  - Pump vibrates or noisy at all flows. 10, 17, 19, 20, 22, 33, 34, 35, 36, 37, 38, 40, 41, 43, 45, 46, 47, 48, 51, 52, 53, 55, 56, 57, 58, 59, 60, 61, 62, 63, 65.
  - Pump vibrates or noisy at low flow. 1, 2, 3, 9, 10, 17, 20, 21, 27, 39.
  - Pump vibrates or noisy at high flow. 25, 28
  - Pump oscillates axially. 38
  - Coupling fails. 34, 36, 38, 60, 62
  - Pump overheats and/or seizes. 1, 2, 3, 11, 12, 17, 20, 24, 26, 27, 31, 34, 36, 37, 38, 44, 45, 46, 47, 48, 49, 50, 53, 54, 55, 56, 57, 58.
  - Pump rotates in reverse direction on shutdown or after power failure or tripping. 14, 64
12. Seal cage improperly mounted in stuffing box, preventing sealing, fluid from entering space to form the seal.
  13. Circular motion in suspended suction pipe observed. (The problem indicate occurrence of vortex. Take remedial action as per C or G in Fig. 11.1).
  14. Foot valve leaks.
  15. Flap of foot valve jammed.
  16. Concentric taper in suction line causing air pocket (Replace with eccentric taper).
  17. Occurrence of vortex in intake, sump or well (Check whether all parameters for vortex-free operation are satisfied. Take recommended remedial measures as per Fig. 11.1).
  18. Casing not air-tight and therefore breathing in.
  19. Short bend/elbow on suction side.
  20. Inadequate clearance below suction bell mouth. (Raise bellmouth to achieve recommended bottom clearance for vortex-free operation as per para 11.2 of manual on water supply & treatment).
  21. Speed too low for pump driven by diesel engine.
  22. Speed too high for pump driven by diesel engine.
  23. Wrong direction of rotation.
  24. Total head of system higher than design head of pump.
  25. Total head of system lower than pump design head.
  26. Static head higher than shut off head of pump.
  27. Pump characteristics unsuitable for parallel operation of pumps.
  28. Burst or leakage in pumping main.
  29. Pumping main partially or fully clogged.
  30. Air trapped in pumping main.
  31. Malfunctioning of line valve causing partial or full closure.



Trouble	Possible Causes	List of Causes
		<ul style="list-style-type: none"> <li>32. Capacity of thrust bearing in adequate.</li> <li>33. Foreign matter in impeller.</li> <li>34. Misalignment.</li> <li>35. Foundations not rigid or broken/loose foundation bolts or supporting structural member (RCC/ structural steel beams) not rigid [Dismantle existing foundation and cast new foundation. Strengthen supporting RCC/structural steel beams].</li> <li>36. Pump (impeller) shaft bent.</li> <li>37. Rotating part rubbing on stationary part.</li> <li>38. Pump shaft bearing (bush bearing or antifriction bearing) worn.</li> <li>39. Wearing rings worn.</li> <li>40. Impeller damaged.</li> <li>41. Impeller locking pin or collet loose.</li> <li>42. Pump shaft or transmission shaft broken.</li> <li>43. Transmission shaft bent (not true).</li> <li>44. Shaft or shaft sleeves worn or scored at the packing.</li> <li>45. Gland Packing improperly installed.</li> <li>46. Incorrect type of gland packing for operating conditions.</li> <li>47. Shaft running off centre because of worn bearing or misalignment.</li> <li>48. Rotor out of balance, causing vibration.</li> <li>49. Gland too tight, resulting in no flow of liquid to lubricate gland.</li> <li>50. Failure to provide cooling liquid to water cooled stuffing boxes.</li> <li>51. Excessive clearance at bottom of stuffing box between shaft and casing, causing interior packing to be forced into pump.</li> </ul>

Trouble	Possible Causes	List of Causes
		52. Dirt or grit in sealing liquid leading to scoring of shaft or shaft sleeve.
		53. Excessive thrust caused by mechanical failure inside the pump or by the failure of the hydraulic balancing device if any.
		54. Excessive grease or highly viscous oil in anti-friction bearing housing or lack of cooling causing excessive bearing temperature.
		55. Lack of lubrication causing overheating and abnormal friction in anti-friction bearing, bush bearing or transmission shaft bearing.
		56. Improper installation of anti-friction bearing (damage during assembly, incorrect assembly of stacked bearings, use of unmatched bearings as a pair etc.).
		57. Dirt in bearings.
		58. Rusting of bearing from water in housing.
		59. Mechanical seal worn out.
		60. Coupling bushes or rubber spider worn out or wear in coupling.
		61. Base plate or frame not properly leveled.
		62. Coupling unbalance.
		63. Bearing loose on shaft or in housing.
		64. Reflux valve (NRV) does not close to tight closure during shut down or after power failure or tripping.
		65. Critical speed close to normal speed of pump.

(b) Jet Pump

The troubles and causes for centrifugal pump are generally applicable for jet pumps except troubles regarding cavitation.

(c) V.T. Pump

Trouble	Possible Causes (numbers as per list below)	List of Causes
• Pump does not deliver water. (water not delivered to discharging end i.e. reservoir/WTP).	1, 3, 4, 8, 10, 11, 13, 15, 16, 17, 18, 27, 28.	1. Pressure at eye of impeller has fallen below vapour pressure.
• Insufficient discharge delivered.	1, 3, 4, 5, 6, 7, 8, 10, 11, 14, 15, 16, 17, 18, 19, 25, 26, 27, 48.	2. Excessive amount of air in liquid. 3. Strainer partially or fully clogged or silted up. 4. Inlet bell mouth or suction case insufficiently submerged.
• Insufficient pressure developed.	1, 2, 8, 10, 12, 13, 14, 15, 19, 25.	5. Circular motion in suspended column-pipes of V.T. pump observed. (The problem indicate occurrence of vortex. Take remedial action as per C or G in Fig. 11.1. If not corrected, the column pipe may crack).
• Pump requires excessive power.	9, 12, 15, 19, 23, 24, 35, 40, 41, 42, 44.	6. Occurrence of vortex in intake, sump or well. (Check whether all parameters for vortex-free operation are satisfied. Take recommended remedial measures as per Fig. 11.1).
• Stuffing box leaks excessively.	20, 22, 30, 31, 32, 33, 34, 36, 37, 38, 48.	7. Inadequate clearance below suction bell mouth. (Raise bell mouth to achieve recommended bottom clearance for vortex-free operation as per para 11.2 of manual on water supply & treatment).
• Gland packing has short life.	20, 22, 30, 31, 32, 33, 34, 36, 37, 38.	8. Speed too low for pump driven by diesel engine.
• Pump vibrates or noisy at all flows.	1, 5, 6, 7, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 31, 32, 33, 34, 37, 39, 41, 42, 43, 44, 45, 46, 47, 49, 50, 51, 52, 53, 54, 57.	9. Speed too high for pump driven by diesel engine. 10. Wrong direction of rotation. 11. Total head of system higher than design head of pump.
• Pump vibrates or noisy at low flow.	1, 3, 4, 14, 25.	12. Total head of system lower than pump design head.
• Pump vibrates or noisy at high flow.	12, 15.	13. Static head higher than shut off head of pump. 14. Pump characteristics unsuitable for parallel operation of pumps.

- Bearing has short life.
    - 1, 5, 6, 7, 20, 21, 22, 23, 25, 27, 30, 34, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54.
  - Pump overheats and/or seizes.
    - 1, 5, 6, 7, 11, 13, 14, 18, 20, 22, 23, 24, 30, 31, 32, 33, 34, 35, 36, 39, 40, 41, 42, 43, 44.
  - Coupling fails.
    - 20, 22, 24, 29, 46, 53.
  - Pump rotates in reverse direction on shutdown or after power failure or tripping.
    - 55, 56.
15. Burst or leakage in pumping main.
  16. Pumping main partially or fully clogged.
  17. Air trapped in pumping main.
  18. Malfunctioning of line valve causing partial or full closure.
  19. Foreign matter in impeller.
  20. Misalignment.
  21. Foundations not rigid or broken/loose foundation bolts or supporting structural member (RCC/ structural steel beams) not rigid.
  22. Pump (impeller) shaft bent.
  23. Rotating part rubbing on stationary part.
  24. Pump shaft bearing (bush bearing or antifriction bearing) worn.
  25. Wearing rings worn.
  26. Impeller damaged.
  27. Impeller locking pin or collet loose.
  28. Pump shaft or line shaft broken.
  29. Line shaft bent (not true).
  30. Shaft or shaft sleeves worn or scored at the packing.
  31. Gland Packing improperly installed.
  32. Incorrect type of gland packing for operating conditions.
  33. Shaft running off centre because of worn bearing or misalignment.
  34. Rotor out of balance, causing vibration.
  35. Gland too tight, resulting in no flow of liquid to lubricate gland.
  36. Failure to provide cooling liquid to water cooled stuffing boxes.
  37. Excessive clearance at bottom of stuffing box between shaft and casing, causing interior packing to be forced into pump.
  38. Dirt or grit in sealing liquid leading to scoring of shaft or shaft sleeve.

39. Excessive thrust caused by mechanical failure inside the pump or by the failure of the thrust bearing.
40. Excessive grease or highly viscous oil in anti-friction bearing housing or lack of cooling causing excessive bearing temperature.
41. Lack of lubrication causing overheating and abnormal friction in anti-friction bearing, bush bearing or line shaft bearing.
42. Improper installation of anti-friction bearing (damage during assembly, incorrect assembly of stacked bearings, use of unmatched bearings as a pair etc.).
43. Dirt in bearings.
44. Rusting of bearing from water in housing.
45. Mechanical seal worn out.
46. Coupling bushes worn out or wear in coupling.
47. Discharge head or not properly levelled
48. Water leaking out from stuffing box in discharge head of V.T. Pump.
49. Screw bearings of Line shaft loose or worn out (in case of oil lubricated V.T. pump).
50. Rubber bearings (in case of water lubricated V.T. pump) worn out.
51. Spiders holding shaft enclosing tube or line shaft loose or broken.
52. Line shaft screw bearing loose in joint with shaft enclosing tube.
53. Coupling unbalance
54. Bearing loose on shaft or in housing.
55. Pins of non-reverse ratchet striking up, tooth broken or worn.
56. Reflux valve (NRV) does not close to tight closure during shut down or after power failure or tripping.
57. Critical speed close to normal speed of pump.

#### (d) Vacuum Pump

The troubles and causes for centrifugal pump are generally applicable for vacuum pump except that priming is not necessary and troubles regarding cavitation are not applicable.

Normally vacuum generating capacity of vacuum pump is limited to 600 mm of Hg, i.e. 8.13 m. Hence top of vacuum pump should not be above 8.0 m from water level in the sump.

#### (e) Submersible Pump

Trouble	Possible Causes (numbers as per list below)	List of Causes
<ul style="list-style-type: none"> <li>Pump does not deliver water (water not delivered to discharging end i.e. reservoir/WTP).</li> </ul>	2, 4, 5, 7, 10, 11, 12, 22, 23.	<ol style="list-style-type: none"> <li>Excessive amount of air in liquid.</li> <li>Suction case insufficiently submerged. (Lower the pump for adequate submergence for vortex-free operation as stipulated in para 11.2 of chapter 11 of Manual on Water Supply and Treatment).</li> </ol>
<ul style="list-style-type: none"> <li>Insufficient discharge delivered.</li> </ul>	2, 3, 4, 5, 8, 9, 10, 11, 12, 22.	<ol style="list-style-type: none"> <li>Occurrence of vortex in intake, sump or well. (Check whether all parameters for vortex-free operation are satisfied. Take recommended remedial measures as per Fig.11.1).</li> </ol>
<ul style="list-style-type: none"> <li>Insufficient pressure developed.</li> </ul>	1, 4, 5, 7, 8, 9, 14, 20.	<ol style="list-style-type: none"> <li>Wrong direction of rotation.</li> </ol>
<ul style="list-style-type: none"> <li>Pump requires excessive power.</li> </ul>	6, 9, 14, 18, 19, 26.	<ol style="list-style-type: none"> <li>Total head of system higher than design head of pump.</li> </ol>
<ul style="list-style-type: none"> <li>Ingress of pumped water into motor.</li> </ul>	27	<ol style="list-style-type: none"> <li>Total head of system lower than pump design head.</li> </ol>
<ul style="list-style-type: none"> <li>Pump vibrates or noisy.</li> </ul>	6, 8, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30, 32.	<ol style="list-style-type: none"> <li>Static head higher than shut off head of pump.</li> <li>Pump characteristics unsuitable for parallel operation of pumps.</li> </ol>
<ul style="list-style-type: none"> <li>Pump rotates in reverse direction on shutdown or after power failure or tripping.</li> </ul>	31.	<ol style="list-style-type: none"> <li>Burst or leakage in pumping main.</li> <li>Pumping main partially or fully clogged.</li> <li>Air trapped in pumping main.</li> <li>Malfunctioning of line valve causing partial or full closure.</li> </ol>

13. Sandy or muddy water pumped from bore/tube well. (In case of muddy water, close delivery valve and open scour valve till clear water is pumped out. In case of sandy water, close delivery valve partially until clear water is pumped out).
  14. Foreign matter in impeller.
  15. Misalignment.
  16. Foundations not rigid or broken/loose foundation bolts or supporting structural member (RCC/ structural steel beams) not rigid.
  17. Pump (impeller) shaft bent.
  18. Rotating part rubbing on stationary part.
  19. Pump shaft bearing (bush bearing or antifriction bearing) worn.
  20. Wearing rings worn.
  21. Impeller damaged.
  22. Impeller locking pin or collet loose.
  23. Pump shaft broken.
  24. Shaft running off centre because of worn bearing or misalignment.
  25. Rotor out of balance, causing vibration.
  26. Excessive thrust caused by mechanical failure inside the pump or by the failure of the thrust plate/bearing.
  27. Mechanical seal worn out.
  28. Wear in coupling.
  29. Frame not properly leveled
  30. Coupling unbalance
  31. Reflux valve (NRV) does not close to tight closure during shut down or after power failure or tripping.
  32. Critical speed close to normal speed of pump.
-

## 11.7.2 TROUBLE SHOOTING FOR RECIPROCATING PUMP

Symptom	Possible Cause (as per list below)
Liquid end noise	1, 2, 7, 8, 9, 10, 14, 15, 16
Power end noise	17, 18, 19, 20
Overheated power end	10, 19, 21, 22, 23, 24
Water in crankcase	25
Oil leak from crankcase	26, 27
Rapid packing or plunger wear	11, 12, 28, 29
Pitted valve or seats	3, 11, 30
Valve hanging up	31, 32
Leak at cylinder-valve hole plugs	10, 13, 33, 34
Loss of prime	1, 4, 5, 6

### 11.7.2.1 Suction Troubles

1. Insufficient suction pressure
2. Partial loss of prime
3. Cavitation
4. Lift too high
5. Leaking suction at foot valve
6. Acceleration head requirement too high

### 11.7.2.2 System Problem

7. System shocks
8. Poorly supported piping, abrupt turns in piping, pipe size too small, piping misaligned.
9. Air in liquid
10. Overpressure or overspeed
11. Dirty liquid
12. Dirty environment
13. Water hammer

### 11.7.2.3 Mechanical Troubles

14. Broken or badly worn valves
15. Packing worn
16. Obstruction under valve
17. Loose main bearings
18. Worn bearings
19. Low oil level



20. Plunger loose
21. Tight main bearings
22. Inadequate ventilation
23. Belts too tight
24. Driver misaligned
25. Condensation
26. Worn seals
27. Oil level too high
28. Pump not set level and right
29. Loose packing
30. Corrosion
31. Valve binding
32. Broken valve spring
33. Loose cylinder plug
34. Damaged O-ring seal

### 11.7.3 TROUBLE SHOOTING FOR DELIVERY PIPES, HEADER AND NRV

S.No.	Trouble	Cause	Remedy
1.	Undue thrust on pump foundation and bend in delivery pipe causing shearing or uprooting of foundation bolts of pumps and thrust on common header.	Dismantling joint is not properly designed, to counter thrust at the elbow in the pump.	Provide dismantling joint of proper design. The design should ensure that it has long tie-bolts connecting rigid flanges and thus taking up the pull caused by thrust at pump.
2.	Cracks in welded jointed of individual delivery and common header.	The cracks are caused due to thrust at dead end of common header.	Provide thrust blocks at dead (free) end of common header.
3.	Reflux valve (NRV) closes with slam and high noise in the event of shut-down or power failure or tripping.	<ul style="list-style-type: none"> <li>• The reflux valve is not designed for non-slam in closure.</li> </ul>	<ul style="list-style-type: none"> <li>• Replace with reflux valve designed for non-slam closure.</li> <li>• Taken up issue of old valve to valve manufacturer.</li> </ul>

### 11.7.4 TROUBLE SHOOTING FOR ELECTRIC MOTOR

S.No.	Trouble	Cause	Remedy
1.	Hot bearings	<ul style="list-style-type: none"> <li>• Bent or sprung shaft.</li> <li>• Excessive belt pull.</li> <li>• Misalignment</li> <li>• Bent or damaged oil rings.</li> <li>• Oil too heavy or too light.</li> <li>• Insufficient oil level</li> <li>• Badly worn bearings</li> <li>• Bearing loose on shaft or in bearing housing</li> <li>• Insufficient grease</li> <li>• Deterioration of grease or lubricant contaminated</li> <li>• Excessive lubricant</li> <li>• Overloaded bearing</li> <li>• Broken ball or rough races.</li> </ul>	<ul style="list-style-type: none"> <li>• Straighten or replace shaft.</li> <li>• Decrease belt tension</li> <li>• Correct coupling alignment.</li> <li>• Replace or repair oil rings</li> <li>• Use recommended oil. Use of oil of too light grade is likely to cause the bearings to seize.</li> <li>• Fill reservoir to proper level when motor is at rest.</li> <li>• Replace bearings.</li> <li>• Remetal shaft/housing or replace shaft or bearing housing.</li> <li>• Maintain proper quantity of grease in bearing.</li> <li>• Remove old grease, wash bearings thoroughly with kerosene and replace with new grease.</li> <li>• Reduce quantity of grease. Bearing should not be more than two-third filled.</li> <li>• Check alignment, side thrust and end thrust.</li> <li>• Clean housing thoroughly and replace bearing.</li> </ul>
2.	Motor dirty	<ul style="list-style-type: none"> <li>• Ventilation passage blocked. Windings coated with fine dust or lint (dust may be cement, sawdust, rock dust, grain dust and the like).</li> <li>• Bearing and brackets coated inside.</li> <li>• Rotor winding coated with fine dust/cement</li> </ul>	<ul style="list-style-type: none"> <li>• Dismantle entire motor and clean all windings and parts by blowing off dust, and if necessary, varnish.</li> <li>• Clean and wash with cleaning solvent.</li> <li>• Clean and polish slip ring. Clean rotor and varnish</li> </ul>
3.	Motor stalls	<ul style="list-style-type: none"> <li>• Motor overloaded</li> <li>• Low voltage</li> <li>• Open circuit</li> <li>• Incorrect control resistance of wound motor</li> <li>• Mechanical locking in bearings or at air gap.</li> </ul>	<ul style="list-style-type: none"> <li>• Check any excessive rubbing or clogging in pump</li> <li>• Correct voltage to rated value.</li> <li>• Fuses blown, check overload relay, starter and push button.</li> <li>• Check correct sequence; Replace broken resistors.</li> <li>• Dismantle and check bearings. Check whether any foreign matter has entered air gap and clean.</li> </ul>

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|----|---|---|---|
| 4. | Motor does not start                      | <ul style="list-style-type: none"> <li>• No supply voltage or single phasing or open circuit or voltage too low.</li> <li>• Motor may be overloaded</li> <li>• Starter or switch/breaker contacts improper</li> <li>• Initial starting torque of load too high.</li> <li>• Rotor defective</li> <li>• Poor stator coil connection</li> <li>• Mechanical locking in bearings or at air gap.</li> </ul> | <ul style="list-style-type: none"> <li>• Check voltage in each phase.</li> <li>• Start on no load by decoupling. Check for cause for overloading.</li> <li>• Examine starter and switch/breaker for bad contact or open circuit. Make sure that brushes of slip ring motor are making good contact with the rings.</li> <li>• If of squirrel cage type and with auto-transformer starter, change to a higher tap. If of slip ring type, lower the starting resistance.</li> <li>• Check for broken rings.</li> <li>• Remove end shields, check end connections</li> <li>• Dismantle and repair. Clean air gap if choked.</li> </ul> |
| 5. | Motor runs and then                       | <ul style="list-style-type: none"> <li>• Power supply system faulty. bearings or at air gap.</li> <li>• Overload replay trips.</li> </ul>   | <ul style="list-style-type: none"> <li>• Check for loose connections or single phasing in switches, breakers, starter, bus-bars and conductor.</li> <li>• Examine overload relay setting. Ensure that the relay is set correctly to about 140-150% of load current. Check whether dashpot is filled with correct quantity and grade of oil.</li> </ul>  |
| 6. | Motor does not accelerate to rated speed. | <ul style="list-style-type: none"> <li>• Voltage too low at motor terminals because of line drop.</li> <li>• Improper connection.</li> </ul>  | <ul style="list-style-type: none"> <li>• Consult manufacturer whether suitable for design duty and load.</li> <li>• Check voltage, change tapping on transformer.</li> <li>• Check that all brushes are riding on rings. Check secondary connections. Leave no lead poorly connected.</li> </ul>  |
| 7. | Motor takes too long to accelerate.       | <ul style="list-style-type: none"> <li>• Broken rotor bars</li> <li>• Excess loading</li> </ul>   | <ul style="list-style-type: none"> <li>• Look for cracks near the rings.</li> <li>• Reduce load. (Note that if motor is driving a heavy load or is starting up a long line of shafting, acceleration time will be more)</li> </ul>  |

	<ul style="list-style-type: none"> <li>• Timer setting of starter not correct.</li> <li>• Defective squirrel cage rotor.</li> <li>• Applied voltage too low.</li> </ul>	<ul style="list-style-type: none"> <li>• Check whether timer setting of star – delta or autotransformer starter is less than acceleration time required for the torque of driven equipment.</li> <li>• Replace with new rotor.</li> <li>• Correct the voltage by changing tap on transformer. If voltage is still low, take up the matter to power supply authority.</li> </ul>
8. Wrong rotation	<ul style="list-style-type: none"> <li>• Wrong sequence of phases</li> </ul>	<ul style="list-style-type: none"> <li>• Inter change connections of two leads at motor or at switchboard for two phases.</li> </ul>
9. Motor overheats while running	<ul style="list-style-type: none"> <li>• Check for overload</li> <li>• End shields may be clogged with dust, preventing proper ventilation of motor.</li> <li>• Motor may have one phase open.</li> <li>• Unbalanced terminal voltage</li> <li>• Weak insulation</li> <li>• High or low voltage</li> <li>• Rotor rubs on stator bore</li> </ul>	<ul style="list-style-type: none"> <li>• If overloaded, check and rectify cause for over loading. Overloading may be due to system fault, e.g. if pipeline bursts, the pump may be operating at low head causing overload of motor. Vortices in sump also may cause overload.</li> <li>• Blow off dust from the end shields.</li> <li>• Check to make sure that all leads are well connected.</li> <li>• Check for faulty leads, connections from transformer.</li> <li>• Check insulation resistance, examine and revarnish or change insulation.</li> <li>• Check voltage of motor and correct it to the extent possible.</li> <li>• Replace worn bearings.</li> <li>• Check for true running of shaft and rotor.</li> </ul>
10. Motor vibrates after connections have been made	<ul style="list-style-type: none"> <li>• Motor misaligned</li> <li>• Weak foundations or holding down bolts loose</li> <li>• Coupling out of balance</li> <li>• Driven equipment unbalanced.</li> <li>• Defective ball or roller bearings</li> </ul>	<ul style="list-style-type: none"> <li>• Realign</li> <li>• Strengthen base plate/ foundation; tighten holding down bolts.</li> <li>• Balance coupling</li> <li>• Balance rotating elements of driven equipment on dynamic balancing machine.</li> <li>• Replace bearing</li> </ul>

		<ul style="list-style-type: none"> <li>• Bearings not in line</li> <li>• Rotor unbalanced</li> </ul>	<ul style="list-style-type: none"> <li>• Line up properly</li> <li>• Rebalance rotor on dynamic balancing machine.</li> </ul>
		<ul style="list-style-type: none"> <li>• Single phasing</li> </ul>	<ul style="list-style-type: none"> <li>• Check for open circuit in all phases.</li> </ul>
		<ul style="list-style-type: none"> <li>• Excessive end play</li> </ul>	<ul style="list-style-type: none"> <li>• Adjust bearing or add washer.</li> </ul>
		<ul style="list-style-type: none"> <li>• Resonance from supporting structure or foundation or vibration of adjoining equipment</li> </ul>	<ul style="list-style-type: none"> <li>• Seek consultation from expert.</li> </ul>
11.	Unbalanced line current on polyphase motor during normal operation	<ul style="list-style-type: none"> <li>• Unbalanced terminal voltage.</li> </ul>	<ul style="list-style-type: none"> <li>• Check leads and connections.</li> </ul>
		<ul style="list-style-type: none"> <li>• Single phase operation.</li> </ul>	<ul style="list-style-type: none"> <li>• Check for open contacts or circuit in all phases.</li> </ul>
		<ul style="list-style-type: none"> <li>• Poor rotor contacts in control wound rotor resistance.</li> </ul>	<ul style="list-style-type: none"> <li>• Check control devices.</li> </ul>
		<ul style="list-style-type: none"> <li>• Brushes not in proper position in wound rotor.</li> </ul>	<ul style="list-style-type: none"> <li>• See that brushes are properly seated.</li> </ul>
12.	Scraping noise	<ul style="list-style-type: none"> <li>• Fan rubbing air shield or striking insulation.</li> </ul>	<ul style="list-style-type: none"> <li>• Check for cause and rectify.</li> </ul>
		<ul style="list-style-type: none"> <li>• Loose on bed plate</li> </ul>	<ul style="list-style-type: none"> <li>• Tighten holding down bolts</li> </ul>
13.	Magnetic noise	<ul style="list-style-type: none"> <li>• Air gap not uniform</li> </ul>	<ul style="list-style-type: none"> <li>• Check and correct bracket fits or bearing.</li> </ul>
		<ul style="list-style-type: none"> <li>• Stator stamping loose</li> </ul>	<ul style="list-style-type: none"> <li>• Retighten stamping.</li> </ul>
		<ul style="list-style-type: none"> <li>• Loose bearings</li> </ul>	<ul style="list-style-type: none"> <li>• Correct or replace bearing.</li> </ul>
		<ul style="list-style-type: none"> <li>• Rotor unbalance</li> </ul>	<ul style="list-style-type: none"> <li>• Rebalance on dynamic balancing machine.</li> </ul>
		<ul style="list-style-type: none"> <li>• Crack in rotor bar</li> </ul>	<ul style="list-style-type: none"> <li>• Replace</li> </ul>
14.	Motor sparking at slip rings	<ul style="list-style-type: none"> <li>• Motor may be overloaded.</li> </ul>	<ul style="list-style-type: none"> <li>• Reduce the load</li> </ul>
		<ul style="list-style-type: none"> <li>• Brushes may not be of correct quality and may not be sticking in the holders.</li> </ul>	<ul style="list-style-type: none"> <li>• Use brushes of the grade recommended and fit properly in the brush holder.</li> </ul>
		<ul style="list-style-type: none"> <li>• Slip ring dirty or rough.</li> </ul>	<ul style="list-style-type: none"> <li>• Clean the slip rings and maintain in smooth glossy appearance and free from oil and dirt.</li> </ul>
		<ul style="list-style-type: none"> <li>• Slip rings may be ridged or out of turnness.</li> </ul>	<ul style="list-style-type: none"> <li>• Turn and grind the slip rings in a lathe to a smooth finish.</li> </ul>
15.	Leakage of oil or grease on winding	<ul style="list-style-type: none"> <li>• Thrust bearing oil seal damaged</li> </ul>	<ul style="list-style-type: none"> <li>• Clean the spilled oil on winding. Replace oil seal.</li> </ul>
		<ul style="list-style-type: none"> <li>• Excessive oil, grease in bearing.</li> </ul>	<ul style="list-style-type: none"> <li>• Reduce quantity to correct extent. Grease should be filled upto maximum half space in bearing housing.</li> </ul>

### 11.7.5 TROUBLE SHOOTING FOR CAPACITORS

S.No.	Trouble	Cause	Remedy
1.	Leakage of heclor*	<ul style="list-style-type: none"> <li>Leaking welds &amp; solders.</li> <li>Broken insulators</li> </ul>	<ul style="list-style-type: none"> <li>Repair by soldering.</li> <li>Replace insulators.</li> </ul>
2.	Overheating of unit	<ul style="list-style-type: none"> <li>Poor ventilation</li> <li>Over voltage</li> </ul>	<ul style="list-style-type: none"> <li>Arrange for circulation of air either by reinstalling in a cooler and ventilated place or arrange for proper ventilation.</li> <li>Reduce voltage if possible, otherwise switch off capacitors.</li> </ul>
3.	Current below normal value	<ul style="list-style-type: none"> <li>Low voltage</li> <li>Element fuses blown</li> <li>Loose connections</li> </ul>	<ul style="list-style-type: none"> <li>Correct the voltage.</li> <li>Replace capacitor</li> <li>Tighten carefully</li> </ul>
4.	Abnormal bulging	<ul style="list-style-type: none"> <li>Gas formation due to internal arcing</li> </ul>	<ul style="list-style-type: none"> <li>Replace the capacitor</li> </ul>
5.	Cracking sound	<ul style="list-style-type: none"> <li>Partial internal faults.</li> </ul>	<ul style="list-style-type: none"> <li>Replace the capacitor</li> </ul>
6.	HRC Fuse blowing	<ul style="list-style-type: none"> <li>Short, external to the units.</li> <li>Over-current due to over voltage and harmonics</li> <li>Short circuited unit.</li> <li>kVAR rating higher.</li> </ul>	<ul style="list-style-type: none"> <li>Check and remove the short.</li> <li>Reduce voltage and eliminate harmonics.</li> <li>Replace the capacitor.</li> <li>Replace with bank of appropriate kVAR.</li> </ul>
7.	Capacitor not discharging	<ul style="list-style-type: none"> <li>Discharge resistance low</li> </ul>	<ul style="list-style-type: none"> <li>Correct or replace the discharge resistance.</li> </ul>
8.	Unbalanced current	<ul style="list-style-type: none"> <li>Insulation or dielectric failure.</li> </ul>	<ul style="list-style-type: none"> <li>Replace capacitor unit.</li> </ul>

\*Leakage of Heclor from terminals, insulators or lid etc. is not a serious trouble. After cleaning, the nuts should be tightened carefully, araldite shall be applied if necessary and the capacitor should be put into circuit. If the leakage still continues, refer the matter to manufacturer.

### 11.7.6 TROUBLE SHOOTING FOR STARTERS, BREAKERS AND CONTROL CIRCUITS

S.No.	Trouble	Cause	Remedy
1.	Starter/breaker not switching on	<ul style="list-style-type: none"> <li>Non availability of power supply to the starter/breaker</li> <li>Overcurrent relay operated</li> <li>Relay reset not operating</li> <li>Castle lock is not locked properly</li> </ul>	<ul style="list-style-type: none"> <li>Check the supply</li> <li>Reset the relay</li> <li>Clean and reset relay</li> <li>Remove lock and lock it properly</li> </ul>
2.	Starter/breaker not holding on ON-Position	<ul style="list-style-type: none"> <li>Relay contacts are not contacting properly</li> <li>Latch or cam worn out</li> </ul>	<ul style="list-style-type: none"> <li>Check and clean the contacts</li> <li>Readjust latch and cam.</li> </ul>
3.	Starter/breaker tripping within short duration due to operation of overcurrent relay	<ul style="list-style-type: none"> <li>Overcurrent relay setting incorrect.</li> </ul>	<ul style="list-style-type: none"> <li>Check and reset to 140-150% of normal load current.</li> </ul>

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| 4. Starter/breaker not tripping after overcurrent or short circuit fault occurs | <ul style="list-style-type: none"> <li>• Moderate short circuit on outgoing side.</li> <li>• No or less oil in dashpot.</li> <li>• Dashpot oil not of proper grade.</li> <li>• Sustained overload</li> <li>• Loose connection</li> <li>• Lack of lubrication to mechanism</li> <li>• Mechanism out of adjustment</li> <li>• Failure of latching device</li> <li>• Mechanical binding.</li> <li>• Relay previously damaged by short circuit.</li> <li>• Heater assembled incorrectly.</li> </ul>          | <ul style="list-style-type: none"> <li>• Check and remove cause for short circuit.</li> <li>• Fill oil upto level mark.</li> <li>• Check and use oil of correct grade.</li> <li>• Check overcurrent setting.</li> <li>• Check for short circuit or earth fault.</li> <li>• Examine cause of overload and rectify.</li> <li>• Clean and tighten.</li> <li>• Lubricate hinge pins and mechanisms.</li> <li>• Adjust all mechanical devices i.e., toggle stops, buffers, springs as per manufacturer's instructions.</li> <li>• Examine surface, clean and adjust latch. If worn or corroded, replace it.</li> <li>• Replace overcurrent relay (and heater, if provided)</li> <li>• Replace overcurrent relay and heater.</li> <li>• Review installation instructions and correctly install the heater assembly.</li> </ul> |
| 5. Overheating  | <ul style="list-style-type: none"> <li>• Relay not operating due to: <ul style="list-style-type: none"> <li>* Blown fuse</li> <li>* Loose or broken wire</li> <li>* Relay contacts damaged or dirty</li> <li>* Damaged trip coil</li> <li>* C.T. damaged</li> </ul> </li> <li>• Poor condition of contacts.</li> <li>• Contacts out of proper alignment</li> <li>• Contacts burnt or pitted</li> <li>• Loose power connection.</li> <li>• Sustained overcurrent or short circuit/earth fault.</li> </ul> | <ul style="list-style-type: none"> <li>* Replace fuse.</li> <li>* Repair faulty wiring; ensure that all screws are tight.</li> <li>* Replace damaged contacts.</li> <li>* Replace coil.</li> <li>* Check and repair/replace.</li> <li>• Clean and polish contacts.</li> <li>• Align the contacts.</li> <li>• Clean the contacts with smooth polish paper or if badly burnt/pitted, replace contacts. (contacts shall be cleaned with smooth polish paper to preserve faces. File should not be used.)</li> <li>• Tighten the connection.</li> <li>• Check cause and rectify.</li> </ul>  |

6.	Overheating of auto transformer unit	<ul style="list-style-type: none"> <li>• Poor ventilation at location of starter/breaker.</li> <li>• Winding design improper.</li> </ul>	<ul style="list-style-type: none"> <li>• Improve ventilation.</li> <li>• Rewind.</li> </ul>
7.	Contacts chatter	<ul style="list-style-type: none"> <li>• Transformer oil condition poor.</li> <li>• Low voltage</li> </ul>	<ul style="list-style-type: none"> <li>• Replace transformer oil in auto-transformer unit.</li> <li>• Check voltage condition. Check momentary voltage dip during starting. Low voltage prevents magnet sealing. Check coil voltage rating.</li> </ul>
	Contacts welding	<ul style="list-style-type: none"> <li>• Poor contact in control circuit</li> <li>• Defective or incorrect coil.</li> </ul>	<ul style="list-style-type: none"> <li>• Check push button station, (stop button contacts), auxiliary switch contacts and overload relay contacts and test with test lamp.</li> <li>• Check for loose connections in control circuits.</li> <li>• Replace coil. Rating should be compatible for system nominal voltage.</li> </ul>
8.	Contacts welding	<ul style="list-style-type: none"> <li>• Abnormal inrush of current</li> <li>• Low voltage preventing magnet from sealing</li> <li>• Short circuit</li> </ul>	<ul style="list-style-type: none"> <li>• Check for grounds &amp; shorts in system as well as other components such as circuit breaker.</li> <li>• Check and correct voltage.</li> <li>• Remove short circuit fault and ensure that fuse or circuit breaker rating is correct.</li> </ul>
9.	Short push button and/ or over heating of contacts.	<ul style="list-style-type: none"> <li>• Filing or dressing.</li> <li>• Interrupting excessively high current</li> <li>• Discoloured contacts caused by insufficient contact pressure, loose connections etc.</li> <li>• Dirt or foreign matter on contact surface.</li> <li>• Short circuit.</li> </ul>	<ul style="list-style-type: none"> <li>• Do not file silver tips. Rough spots or discolouration will not harm tips or impair their efficiency.</li> <li>• Check for short circuit, earth fault or excessive motor current.</li> <li>• Replace contact springs, check contact for deformation or damage. Clean and tighten connections.</li> <li>• Clean with carbon tetrachloride.</li> <li>• Remove fault &amp; check fuse or breaker rating whether correct.</li> </ul>
10.	Coil open circuit	<ul style="list-style-type: none"> <li>• Mechanical damage</li> <li>• Burnt out coil due to over voltage or defect.</li> </ul>	<ul style="list-style-type: none"> <li>• Examine and replace carefully. Do not handle coil by the leads.</li> <li>• Replace coil.</li> </ul>



11.	Magnets & other mechanical parts worn out/broken	<ul style="list-style-type: none"> <li>• Too much cycling.</li> <li>• Dust and dirt or mechanical abuse.</li> </ul>	<ul style="list-style-type: none"> <li>• Replace part and correct the cause of damage.</li> </ul>
12.	Noisy magnet (humming)	<ul style="list-style-type: none"> <li>• Defective coil</li> <li>• Magnet faces not mating correctly.</li> <li>• Dirt oil or foreign matter on magnet faces.</li> <li>• Low voltage</li> </ul>	<ul style="list-style-type: none"> <li>• Replace coil</li> <li>• Replace magnet assembly. Hum may be reduced by removing magnet armature and rotating through 180°.</li> <li>• Clean magnet faces with carbon tetrachloride.</li> <li>• Check system voltage and voltage dips during starting.</li> </ul>
13.	Failure to pick-up and/or seal	<ul style="list-style-type: none"> <li>• Low voltage</li> <li>• Coil open or shorted.</li> <li>• Wrong coil.</li> <li>• Mechanical obstruction</li> </ul>	<ul style="list-style-type: none"> <li>• Check system voltage and voltage dips during starting.</li> <li>• Replace coil.</li> <li>• Check coil voltage rating which must include system nominal voltage and frequency.</li> <li>• With power off, check for free movement of contact and armature assembly. Remove foreign objects or replace contactor.</li> </ul>
14.	Failure to drop out	<ul style="list-style-type: none"> <li>• Poor contact in control circuit.</li> <li>• Gummy substances on pole faces or in mechanism.</li> <li>• Voltage not removed from control circuit.</li> <li>• Worn or rusted parts causing binding e.g. coil guides, linkages.</li> <li>• Residual magnetism due to lack of air gap in magnetic path.</li> <li>• Improper mounting of starter.</li> </ul>	<ul style="list-style-type: none"> <li>• Check and correct.</li> <li>• Clean with carbon tetrachloride.</li> <li>• Check control circuit.</li> <li>• Replace contactor.</li> <li>• Replace contactor.</li> <li>• Review installation instructions and mount properly.</li> </ul>
15.	Failure to reset	<ul style="list-style-type: none"> <li>• Broken mechanism worn parts, corrosion dirt etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Replace overcurrent relay and heater.</li> </ul>
16.	Open or welded control circuit contacts in over current relay.	<ul style="list-style-type: none"> <li>• Short circuit in control circuit with too large protecting fuses.</li> <li>• Misapplication, handling too heavy currents.</li> </ul>	<ul style="list-style-type: none"> <li>• Rectify short circuit in general. Fuses over 10A rating should not be used.</li> <li>• Check rating and rectify.</li> </ul>
17.	Insufficient oil in breaker/ starter ( if oil cooled)	<ul style="list-style-type: none"> <li>• Leakage of oil</li> </ul>	<ul style="list-style-type: none"> <li>• Locate point of leakage and rectify.</li> </ul>
18.	Oil dirty	<ul style="list-style-type: none"> <li>• Carbonisation of moisture from atmosphere</li> </ul>	<ul style="list-style-type: none"> <li>• Clean inside of tank and all internal parts. Fill fresh oil.</li> </ul>
19.	Moisture present in oil	<ul style="list-style-type: none"> <li>• Condensation of moisture from atmosphere</li> </ul>	<ul style="list-style-type: none"> <li>• -do-</li> </ul>

### 11.7.7 TROUBLE SHOOTING FOR PANELS

S.No.	Trouble	Cause	Remedy
1.	Overheating	<ul style="list-style-type: none"> <li>• Bus bar capacity inadequate.</li> <li>• Loose connection</li> <li>• Improper ventilation</li> </ul>	<ul style="list-style-type: none"> <li>• Check and provide additional bars in combination with existing bus-bars or replace bus-bars.</li> <li>• Improper ventilation</li> <li>• Improve ventilation</li> </ul>
2.	Insulator cracked	-	<ul style="list-style-type: none"> <li>• Replace the insulator</li> </ul>

### 11.7.8 TROUBLE SHOOTING FOR CABLES

S.No.	Trouble	Cause	Remedy
1.	Overheating	<ul style="list-style-type: none"> <li>• Cable size inadequate.</li> </ul>	<ul style="list-style-type: none"> <li>• Provide a cable in parallel to existing cable or higher size cable</li> <li>• Increase clearance between cable.</li> </ul>
2.	Insulation burning at	<ul style="list-style-type: none"> <li>• Improper termination in lug termination</li> </ul>	<ul style="list-style-type: none"> <li>• Check size of lug and whether properly crimped and correct.</li> <li>• Check whether only few strands of cable are inserted in lug. Insert all strands using a new or higher size lug if necessary.</li> </ul>

### 11.7.9 TROUBLE SHOOTING FOR TRANSFORMER

S. No.	Fault	Trouble shooting Procedure	Cause	Remedy
1.	Abnormal noise	Listen to the noise at various points of the transformer and find out the exact location by means of a solid piece of wood or insulating materials placed on body of transformer tank at various points. This helps in from the inside of determining whether the noise originated from the inside of the transformer or is only an external one.	a) External Noise: A loose fixing bolt/nut of the transformer.  a) Noise originating small transformer, the transformer. In the case of old transformer, possibly due to the windings having become slightly slack.	a) Tighten the fixing bolts and nuts and such other loose metallic parts.  b) In the case of such facilities are available open the transformer and take up any slackness by placing shim of insulated boards. In case of big transformers it will be necessary to contact the manufacturer or transformer repairer.
2.	High Temperature	<ul style="list-style-type: none"> <li>• The temperature rise of the transformer during 10-24 hours of operation is</li> </ul>	a) Transformer is over loaded. b) Transformer	a) Reduce the load to the rated load. b) Improve the

	<p>observed. The input current, oil temperature are noted down at intervals of half an hour and tabulated.</p>	<p>room is not properly ventilated.</p>	<p>ventilation of the transformer room to achieve effective air cooling.</p>
		<p>c) Dielectric strength of transformer oil low.</p> <p>d) Certain turns in the winding are short circuited.</p>	<p>c) Filter transformer oil and improve dielectric strength to 40 kV minimum.</p> <p>d) Major repairs are necessary and should be taken up in consultation with an experienced Electrical Engineer and transformer repairer.</p>
	<ul style="list-style-type: none"> <li>• The transformer becomes hot in a relatively short period; transformer oil escapes from the conservator or there is even appearance of gas. In the case of built-in buchholz relay, accumulation of inflammable gas accompanied by the alarm signal of the relay</li> <li>• Abnormal heating of one terminal</li> </ul>	<p>The transformer has a major defect</p>	<p>Take action for major repairs in consultation with an experienced Electrical Engineer and transformer repairer.</p>
<p>3. Tripping of circuit breaker or blowing of fuses.</p>	<p>–</p>	<p>Poor termination either inside or outside the transformer.</p>	<p>a) External contacts should be checked up and put in order especially in the aluminium bus bars.</p> <p>b) If heating persists, action for major repairs should be taken in consultation with an experienced Electrical Engineer.</p>
		<p>a) Short circuit in the windings.</p> <p>b) Damage in the insulation of the winding or of one terminal</p>	<p>Action for major repairs should be taken in consultation with an experienced Electrical Engineer and transformer repairer.</p>

4. Buchholz relay contains only air.	Due to leakage, the transformer has lost so much oil that even conservator and Buchholz relay is drained off.	<ul style="list-style-type: none"> <li>a) Locate the leakage, switch off the transformer leakage socket and weld the transformer tank or replace the packing.</li> <li>b) Fill with dry oil till the oil level appears on the oil level indicator. All terminals should be properly cleaned before switching on.</li> </ul>
5. Frequent change of silicagel colour	<ul style="list-style-type: none"> <li>a) Breather leakage</li> <li>b) Breather oil level low.</li> <li>c) Absorption of moisture.</li> </ul>	<ul style="list-style-type: none"> <li>a) Replace packing.</li> <li>b) Check oil seal. Top up oil level.</li> <li>c) Moisture to be removed completely.</li> </ul>
6. Oil leak at joints/ bushing/drain valve	<ul style="list-style-type: none"> <li>a) Defective packing.</li> <li>b) Loose tightening</li> <li>c) Uneven surface</li> <li>d) Bushing cracked</li> </ul>	<ul style="list-style-type: none"> <li>a) Replace packing.</li> <li>b) Tighten properly</li> <li>c) Check and correct it.</li> <li>d) Replace bushing along with washer.</li> </ul>
7. Low insulation resistance	<ul style="list-style-type: none"> <li>e) Drain, valve not fully tight.</li> <li>a) Moisture absorption by winding.</li> </ul>	<ul style="list-style-type: none"> <li>e) Tighten valve and plug.</li> <li>a) Heat the windings, by operating transformer on no-load, and check whether insulation resistance improves. If no-improvement is observed after operation for 5-6 hours, filter the oil.</li> </ul>
8. Water inside tank	<ul style="list-style-type: none"> <li>b) Contaminated oil</li> <li>c) Presence of sludge</li> <li>a) Defects of joints</li> <li>b) Moisture condensation.</li> </ul>	<ul style="list-style-type: none"> <li>b) Replace with proper oil.</li> <li>c) Filter or replace the oil.</li> <li>a) Rectify the defect</li> <li>b) Drain water and dry the moistures from winding.</li> </ul>

		c) Oil mixed with water when topping up	c) Heat the winding on no-load. Recheck dielectric strength and filter if necessary.
9.	Overheating of cable ends and cable terminals	Loose connections	Check and tighten the connections.
10.	Neutral ground conductor (earth strip) burnt.	a) Loose connections. b) Heavy fault current.	Replace the grounding conductor.

### 11.7.10 TROUBLE SHOOTING FOR BATTERIES

Battery troubles revealed in service may be due to inadequate maintenance, incorrect operation and incorrect charging. Many battery troubles can be traced to charging source, undercharging or excessive overcharging eventually leads to battery trouble.

S.No.	Trouble	Cause	Remedy
1.	Readings of specific gravity and voltage very erratic even after equalising charge for at least 48 hrs.	<ul style="list-style-type: none"> <li>Battery life is over.</li> </ul>	<ul style="list-style-type: none"> <li>Check the following               <ul style="list-style-type: none"> <li>* Age of battery.</li> <li>* Capacity.</li> <li>* Appearance of plates.</li> <li>* Depth of sediments below plates.</li> </ul> </li> </ul>
2.	Several cells showing low charge voltage at the end of extended charge.	<ul style="list-style-type: none"> <li>Internal short circuit.</li> </ul>	<ul style="list-style-type: none"> <li>Open cells and examine for damage or displaced separators, lead particles between plates or buckled plates.</li> </ul>
3.	Battery overheats	<ul style="list-style-type: none"> <li>Poor contacts or badly welded joints.</li> </ul>	<ul style="list-style-type: none"> <li>Clean and tighten all bolted connections, reweld doubtful welded joints.</li> </ul>
4.	Battery damp and dirty, wood trays deteriorated or metal work corroded.	<ul style="list-style-type: none"> <li>Poor maintenance, over topping, or lid sealing compound cracked.</li> </ul>	<ul style="list-style-type: none"> <li>Keep battery dry and clean. Do not overtop when adding water. Clear away all traces of acid and old sealing compound from cell lids.</li> </ul>
5.	Hydrometer test (at 80°F) show less than 1.200 specific gravity		<ul style="list-style-type: none"> <li>Battery should be recharged. Give high rate discharge test for capacity. If cell test OK recharge and adjust gravity of all cells uniformly. Check operation and setting of voltage regulator, make a thorough check of the electrical system for short circuits, loose connections, corroded terminals etc.</li> </ul>

### 11.7.11 TROUBLE SHOOTING FOR AIR COMPRESSOR

S.No.	Trouble	Cause	Remedy
1.	Compressor does not start	<ul style="list-style-type: none"> <li>• Dirty contacts</li> <li>• Loose electrical connections or faulty wiring.</li> </ul>	<ul style="list-style-type: none"> <li>• Clean the contacts on all switches and controls.</li> <li>• Tighten connections. Check wiring and rewire if necessary.</li> </ul>
2.	Compressor noisy	<ul style="list-style-type: none"> <li>• Loose or misaligned coupling.</li> <li>• Insufficient clearance between piston and valve plate.</li> <li>• Motor or compressor bearing worn out.</li> <li>• Loose or misaligned belts.</li> <li>• Loose foundation bolts or hold down bolts.</li> <li>• Improper support or isolation of piping.</li> </ul>	<ul style="list-style-type: none"> <li>• Check alignment &amp; tightness.</li> <li>• Replace worn parts.</li> <li>• Replace bearing.</li> <li>• Check alignment &amp; tension. Belt slack should be at the top.</li> <li>• Tighten bolts.</li> <li>• Provide sufficient right angle bends in piping to absorb vibration &amp; support firmly with suitable hangers.</li> </ul>
3.	Pipe rattle	<ul style="list-style-type: none"> <li>• Inadequately supported piping or loose pipe connections.</li> <li>• No muffler in discharge line or muffler improperly located.</li> </ul>	<ul style="list-style-type: none"> <li>• Support pipes or check pipe connections.</li> <li>• Install or move muffler closer to compressor.</li> </ul>
4.	Compressor will not load.	<ul style="list-style-type: none"> <li>• Low oil pressure</li> <li>• Capacity control valve struck open.</li> <li>• Unloader element struck.</li> </ul>	<ul style="list-style-type: none"> <li>• See item 5.</li> <li>• Repair or replace.</li> <li>• Repair</li> </ul>
5.	Oil pressure lower than normal or no oil pressure.	<ul style="list-style-type: none"> <li>• Low oil charge</li> <li>• Faulty oil gauge</li> <li>• Defective oil pressure regulator.</li> <li>• Clogged oil suction strainer.</li> <li>• Broken or worn oil pump.</li> <li>• Worn compressor bearings.</li> </ul>	<ul style="list-style-type: none"> <li>• Add oil</li> <li>• Check and replace</li> <li>• Repair or replace.</li> <li>• Clean</li> <li>• Replace pump assembly.</li> <li>• Replace</li> </ul>

## 11.8 SAFETY ASPECTS

### 11.8.1 GENERAL SAFETY ASPECTS

Following safety precautions should be observed while working in a pump house.

- i) No electric live part shall be kept exposed. Particular care should be taken not to keep the motor terminals, starter door, panel door etc. in open condition.
- ii) Guard for pump – motor coupling and for extended shaft shall be provided.
- iii) Top cover of the VHS (vertical hollow shaft) motor shall not be unnecessarily kept in dismantled condition.

- iv) Helmet, gumboots, hand gloves, torch and emergency lamp etc. shall be provided to the workers.
- v) Shock proof rubber matting shall be kept in front of panel and starters.
- vi) Discharging devices shall also be provided to work safely on HT side of transformer.
- vii) Fire fighting equipment suitable for electrical fire shall be provided. The fire extinguisher shall be thoroughly checked and recharged once in a year.
- viii) Damaged wooden flooring, damaged grating etc. shall be repaired on priority.
- ix) Safety railing shall be provided above all openings, unwallled edges of flooring and all such places vulnerable for falling or slipping of staff.
- x) First aid box shall be kept at visible and accessible place. The first aid box shall be checked once in a month and all used items shall be replenished.
- xi) Staff shall be trained in the following aspects to enhance safety awareness and skills to handle safety aspects.
  - Fire fighting
  - Safety procedures and practices in electrical work
  - First aid (general)
  - First aid for electric shock.

### **11.8.2 SAFETY PROCEDURES & PRACTICES IN ELECTRICAL WORK**

Following Indian Standards (IS) detail comprehensive guidelines for safety in electrical installation.

- IS 5216 (Part I) – General
- IS 5216 (Part II) – Life Saving Technique
- IS 5216 (Part III) – Safety Posters
- IS 5216 (Part IV) – Special guidance for safety in electrical work in hazardous areas.

General guidelines and precautions as follows should be observed for safe working in electrical installations.

#### **11.8.2.1 Work on Low and Medium Voltage Mains and Apparatus**

1. Unless a person is authorized to work on live low and medium voltage mains and apparatus, all mains and apparatus to be worked upon shall be isolated from all sources of supply, before starting the work, proved dead, earthed and short-circuited.
2. For earthing and short-circuiting, only recognized methods should be used. Measures such as removing fuses shall be taken against the inadvertent energizing of the mains and apparatus.
3. Only competent, experienced and authorised persons shall work on live mains and apparatus, and such persons should take all safety measures as required under the Indian Electricity Rules, 1956.
4. Warning boards shall be attached on or adjacent to the live apparatus and at the limits of the zone in which work may be carried out.

5. Immediately before starting work, rubber hand gloves shall be thoroughly examined to see whether they are in sound condition. Under no circumstances shall a person work with unsound hand gloves, mats, stools, platforms or other accessories and safety devices.

### **11.8.2.2 Work on High Voltage System in Transformer Substation**

All high voltage mains and apparatus shall be regarded as alive and a source of danger and treated accordingly unless it is positively known to be dead and earthed.

No person shall work on high voltage mains or apparatus unless covered by a permit-to-work and after proving the mains dead except for the purpose of connecting the testing apparatus, etc. which is specially designed for connecting to the live parts. Incoming high voltage power supply shall be disconnected by opening AB switch/GOD. As additional precaution, the DO fuses or HG fuses shall be disconnected. Breaker on HV side shall be kept in open (off) position.

### **11.8.2.3 General Precautions in Electrical Installations**

It is always necessary to observe the following rules as precautionary measures in electrical installations.

- i) Try to avoid work on live mains which should be switched off before working.
- ii) If it is not possible to switch off the mains, make sure before working that your hands or feet are not wet and insulated footwear and rubber hand gloves are worn.
- iii) Place yourself in a safe and secure position to avoid slipping, stumbling or moving backward against live conductors or apparatus. Do not rely for protection upon the care assumed to be exercised by others.
- iv) In the event of near approach of a lightning storm, all outdoor work on electrical system should be stopped.
- v) Make a habit of being cautious. Be on the lookout for danger notice plates, danger flags, warning boards and signals etc. Warn others when they seem to be in danger near live conductor or apparatus.
- vi) Never speak to any person working upon live mains or apparatus, unless the person doing the work is aware of your presence and that you are working on electrical system.
- vii) In order to rescue a person who has got an electric shock, if there is no other insulator available for rescuing, use your feet rather than hands.
- viii) When attending electrical work, be sure that the floor is covered with rubber mat. Concrete floors are dangerously conductive.
- ix) When working on high voltage try to keep your left hand in the pocket i.e. avoid your left hand to get in contact with any live conductor or metallic casing of an apparatus or metal pole or cross arms.
- x) Do not work in such a place where your head is liable to touch the live mains.



### 11.8.3 FIRST AID FOR ELECTRIC SHOCK

Standard printed instructions for first aid against electric shock shall be framed and displayed at prominently visible and accessible location.

In most of the cases the electric shock due to accidents is momentary and the contact with the live wire is imperfect. In such cases breathing stops momentarily, but due to the shock, the victim becomes unconscious, and heart beats become weak. The most urgent and immediate care for the victim is that he should be given immediate artificial respiration in the manner detailed below, and artificial respiration should be continued till the victims starts breathing normally. It should be borne in mind if the artificial respiration is stopped just after the victims recovers, he is liable to become unconscious again. In some cases the artificial respiration need to be continued for 6 to 8 minutes.

#### 11.8.3.1 Artificial Respiration

At the time of accident due to electric shock, proceed as follows.

- i) When any one gets a shock, the first and foremost duty of the observer is to break the contact of the live mains and body either by switching off the main supply, or the body should be rolled away with dry wooden stick. If a stick etc. is not at hand, a dry piece of cloth should be used. Detach the body from the live mains, or if that is also not available, the loose cloth such as coat or shirt of the victim should be pulled without touching his body.
- ii) See if the operator's clothes are smoldering; extinguish the spark first.
- iii) Check up if the patient is breathing or not. If he is not breathing, immediately start artificial respiration as detained below until medical aid arrives.
- iv) Lay the patient so that no pressure on the lungs of the patient is exerted to facilitate artificial respiration.

#### Method – I

Lay the patient as shown in Fig. 11.2. Kneel over the patient's back, and place both the hands on the patient's thin portion of the back near the lowest rib in such a manner that the fingers



FIG. 11.2: ARTIFICIAL RESPIRATION

remain spread on the sides and the two thumbs almost touch each other and are parallel to spine. Now press gradually and slowly for about 3 seconds by leaning your hands forward as shown in Fig. 11.3. The patient should be kept warm.

Now relax the pressure slowly and come to the original kneeling position for about 2 seconds as represented in Fig.11.2. Repeat the process for about 12 to 15 times in a minute so as to expand and contract lungs of the patient to initiate breathing. The process should be continued with great patience and in no case undue force should be used.



FIG. 11.3: ARTIFICIAL RESPIRATION

### Method-II

When the patient has got burns etc. on his chest or anywhere on front side, then the patient should not be laid as in Fig.11.3. Appropriate position of laying in such case is on back as shown Fig.11.4 with a pillow or rolled cloth, mat, bedsheet under his shoulders. The clothes of the patient shall be immediately loosened before starting the process of artificial respiration.



FIG. 11.4: ARTIFICIAL RESPIRATION

- a) Hold the patient just below the elbow and draw his hand over his head until they are horizontal. Keep them in that position for about two seconds. Now bring the patient's hands on to his sides kneeling over the patient's hands so as to compress them down as shown in Fig. 5. After 2 seconds repeat the process again.

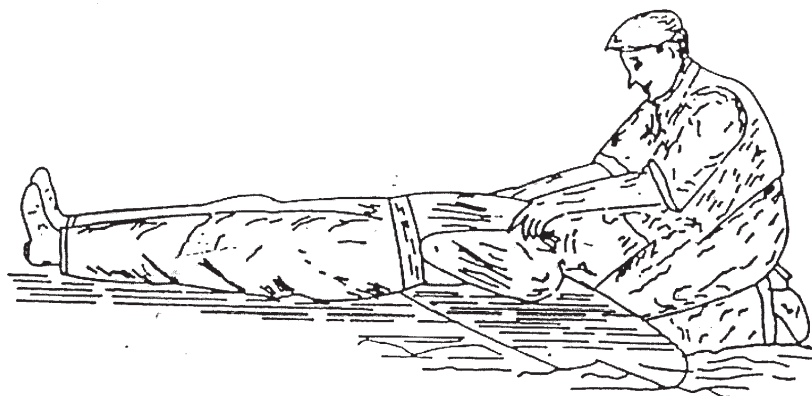


FIG. 11.5: ARTIFICIAL RESPIRATION

- b) If operator has got burns only, the same should be dressed properly. Oil should never be used on the burns. After burns are dressed properly, he may feel better. It is important to note that the one who has received electric shock is liable to get an attack of hyperstatic pneumonia. So it is necessary to keep him warm for at least a day.

## 11.9 DESIRABLE ENVIRONMENT AND AMENITIES IN INSTALLATION

Environment and cleanliness have tremendous impact on willingness or unwillingness of the workers. In order to maintain working environment following guidelines shall be followed.

- Maintain cleanliness in the installation and surrounding. Cleanliness causes pleasant atmosphere for work.
- Appearance of equipment, furniture and walls etc. should be improved by painting, polishing etc. at about 2 years interval.
- The color selected shall be sober and eye-pleasing.
- Good housekeeping is must for sustaining pleasant environment.
- High noise is major irritant and should be kept within limit, by reducing or isolating the noise emitting sources.

Following amenities shall be provided at installations.

- Dress-changing room and locker facilities.
- Clean toilet and running water supply.
- Drinking water facilities.
- Chairs etc. to rest during work.

\* \* \*

CHAPTER 12

# WATER METERS, INSTRUMENTATION, TELEMETRY & SCADA

## 12.1 WATER METERS

### 12.1.1 INTRODUCTION

A water meter is a scientific instrument for accurate measurement of quantity of water distributed to the consumers. It also fulfils the need to know accurately the water produced and distributed.

It differs from flow meter in respect of the following points.

1. It is a quantity meter and not a flow rate meter.
2. Water meter is a mechanical device whereas flow meter may be a mechanical or an electronic device.
3. Water meter is always specified in two accuracies i.e. lower range and upper range accuracies whereas a flow meter it is specified in a single range accuracy.
4. The upper range and lower range accuracies are 2% and 5% of the actual quantity respectively for the water meter whereas it is variable for flow meter as per the customer's requirement.
5. Importance is not given for repeatability and linearity in the case of water meter whereas importance is given in the case of flow meter.

Water meters having sizes from 15 mm to 50 mm as per BIS 779 are considered to be domestic water meters and sizes from 50 mm and above as per BIS 2373 are considered to be Bulk Water Meters.

Water meters are classified according to the operating principle, type of end connections, the standard by which the same are covered, constructional features, method of coupling between the counter and primary sensor, the metrological characteristics etc. (Table 12.1)

### 12.1.2 SIZING OF WATER METERS

Sizing of water meter is done keeping in view the guidelines given in Indian standard IS 2401 and ISO 4064 part-II. In general main considerations are as follows:

1. Water meter has to be selected according to the flow to be measured and not necessarily to suit a certain size of water main.
2. The maximum flow shall not exceed the maximum flow rating.
3. The nominal flow shall not be greater than the nominal flow rating.

## CLASSIFICATION OF WATER METER BASED ON

Semi positive or Piston or Volumetric		Operating Principle			Constructional Features	Consumer Category		Metrological Characteristics
		Inferential or Velocity or Turbine				Domestic Meter as per IS 779	Bulk Meter as per IS 2373	
Available in C&D classes as per ISO 4064	<b>Advantages:</b> 1. Most sensitive 2. Less sensitive to flow disturbances <b>Disadvantages:</b> 1. Water must be free from solid dirt particles 2. Difficult to maintain 3. Difficult to calibrate 4. Failure of rotating part causes failure of water flow through the meter	<b>Single Jet</b> Available from 15 mm to 50 mm as per IS 779 and 15 mm to 100 mm as per ISO 4064 <b>Advantages:</b> 1. Simple & less complicated 2. The cheapest 3. Less loss of pressure <b>Disadvantages:</b> 1. Sensitive to flow disturbances 2. Requires specialized calibration as external regulator is not available 3. Not sustained in hostile flow conditions.	<b>Multi Jet</b> Available from 15 mm to 300 mm as per ISO 779 <b>Advantages:</b> 1. Less sensitive to flow disturbances 2. Can sustain hostile flow conditions 3. External regulator facilitates easy calibration 4. Easy maintenance <b>Disadvantages:</b> 1. More costly than that of single jet 2. More pressure loss	<b>Woltman or Helical Type</b> Available from 50 mm to 500 mm as per BIS and 50 mm to 800 mm as per ISO <b>Advantages:</b> 1. Suitable for higher flows 2. Less pressure loss 3. Robust construction 4. External and internal regulators <b>Disadvantages:</b> 1. Approach conditioning piping is required 2. Not available in metrological classes in BIS. Limited to higher flows.	1. Wet dial meter 2. Dry dial meter 3. Mechanically coupled meter 4. Magnetically coupled meter 5. Straight reading cyclometer 6. Multi pointer meter (Analogue type) 7. Combination of Cyclometer & pointer <b>Advantages of mechanical coupled</b> 1. Not affected by external magnetic field. <b>Disadvantages:</b> 1. Bush leak problems 2. Air escape hole create problem during submergence. 3. Available in class 'A' only <b>Advantages of Magnetically Coupled:</b> 1. Available in Class 'A' as well as Class 'B' 2. More sensitive 3. No condensation of water in resister <b>Disadvantages:</b> 1. Temperable with external magnetic field. 2. In intermitten supply high temperature of water may damage the properties of the magnet.	Available upto size 50 mm Screwed connection Body with Brass of Bronze or Plastic Available in Class 'A' & 'B' in IS	Available from size 50 mm and above Flanged connections Body: cast or steel Not available in classes in IS	Classes A to D as per ISO 4064 Classes A & B as per BIS 779

4. The minimum flow to be measured shall be within the minimum starting flow of the meter.
5. Low head loss, long operating flow range, less bulky and robust meter shall be preferred.

### **12.1.3 INSTALLATION OF WATER METERS**

In order to ensure proper working of the meters, BIS has given guidelines in IS-2401 of 1973 for their installation as per the drawing given in it. At the same time following guidelines should be borne in mind while installing the meters.

1. The water meter being a delicate instrument shall be handled with great care. Rough handling including jerks or fall is likely to damage it and affects its accuracy.
2. The meter shall be installed at a spot where it is readily accessible.  
  
To avoid damages and over run of the meter due to intermittent water supply system, it is always advisable to install the meter, so that the top of the meter is below the level of the communication pipes so that meters always contains water, when there is no supply in the line. Also, the minimum straight length condition as per the drawing shall be observed.
3. The meter shall preferably be housed in a chamber with a lid for protection; it should never be buried underground nor installed in the open nor under a water tap so that water may not directly fall on the meter. It should be installed inside inspection pits, built out of bricks or concrete and covered with lid. It should not be suspended.
4. The meter shall be so installed that the longitudinal axis is horizontal and the flow of water should be in the direction shown by the arrow cast on body.
5. Before connecting the meter to the water pipe, it should be thoroughly cleaned by installing in the place of the water meter a pipe of suitable length and diameter and letting the passage of a fair amount of water flow through the pipe work to avoid formation of air pockets. It is advisable that the level of the pipeline where the meter is proposed to be installed should be checked by a spirit level.
6. Before fitting the meter to the pipeline check the unions nuts in the tail pieces and then insert the washers. Thereafter screw the tail pieces on the pipes and install the meter in between the nuts by screwing. In order to avoid its rotation during the operation, the meter should be kept fixed with suitable non metallic clamps. Care should be taken that the washer does not obstruct the inlet and outlet flow of water.
7. The protective lid should normally be kept closed and should be opened only for reading the dial.
8. The meter shall not run with free discharge to atmosphere. Some resistance should be given in the down side of the meter if static pressure on the main exceeds 10 m head.
9. A meter shall be located where it is not liable to get severe shock of water hammer which might break the system of the meter.

10. Owing to the fine clearance in the working parts of the meters they are not suitable for measuring water containing sand or similar foreign matter and in such cases a filter or dirt box of adequate effective area shall be fitted on the upstream side of the meter. It should be noted that the normal strainer fitted inside a meter is not a filter and does not prevent the entry of small particles, such as sand.
11. Where intermittent supply is likely to be encountered the meter may be provided with a suitable air valve before the meter in order to reduce inaccuracy and to protect the meter from being damaged. At higher altitude, if meter is installed as above the problem will be eliminated.

#### **12.1.4 TESTING AND CALIBRATION OF WATER METERS**

1. The testing & calibration of a water meter is essential before putting it into use as it is a statutory requirement. It is also essential to test it periodically in order to ascertain its performance as during the course of meter working it is likely that its accuracy of measurement may deteriorate beyond acceptable limits.
2. A meter suspected to be malfunctioning is also tested for its accuracy of measurement. The testing is done as per IS6784/ISO4064 part III. A faulty meter if found to be repairable, is repaired and tested and calibrated for its accuracy before installation.

The metering accuracy testing is carried out at  $Q_{min}$ ,  $Q_t$  &  $Q_{max}$ . separately.

Where :

$Q_{min}$  : Lowest flow rate at which the meter is required to give indication within the maximum permissible error tolerance. It is as mentioned in IS779 and is determined in terms of numerical value of meter designation in case of ISO 4064.

$Q_t$  : The flow rate at which the maximum permissible error of the water meter changes in value.

$Q_n$  : Half the maximum flow rate  $Q_{max}$ .

$Q_{max}$  : The higher flow rate at which the meter is required to operate in a satisfactory manner for short periods of time without deterioration.

The accuracy of water meter is divided into two zones i.e. (1) Lower measurable limit in which  $\pm 5\%$  accuracy from minimum flow to transitional flow (exclusive) and (2) Upper measurable limit in which  $\pm 2\%$  accuracy from transitional flow (inclusive) to maximum flow.

3. The procedure for conducting the above test is as follows:

Water meter is fixed on a test bench horizontally or vertically or in any other position for which it is designed and with the direction of flow as indicated by arrow on its body. By adjusting the position of regulating valve on upstream side, the rate of flow is adjusted. At the desired rate of flow, the difference in pressure gauge readings fitted on upstream and downstream side of water meter is noted. The flow is now stopped with regulating valve and measuring chamber is emptied and zero water levels on manometer attached to measuring chamber is correctly adjusted. Initial reading of the water meter from its recording dial is noted. Now the flow at the set rate is passed through the water meter and the discharge is collected in the measuring chamber. After passing the desired quantity of

water through the meter, the flow is once again stopped. The discharge as recorded by measuring chamber is noted. The final reading of water meter is noted. The difference between the initial and final readings of water meter gives the discharge figure recorded by water meter. Now the discharge recorded by measuring tank is treated as ideal. The discharge recorded by water meter is compared with this ideal discharge. If the quantity recorded by water meter is more than the ideal, the meter is called running fast or vice versa. The difference in the quantity recorded by meter from ideal quantity is considered as error. This error is expressed in percentage.

If the limits of error for the meter exceed as specified in the IS concerned the meter is readjusted by the regulator if it is available in the meter. A change in position of the regulating screw will displace the error curve (calibration curve) in parallel to former position. With the closing of the regulating orifice the curve will shift upward while opening the same will lower the curve. If the curve does not get into acceptable limit the meter is not used. Some of the organizations are accepting accuracy limit for repaired water meter double the value of new water meters at respective zones i.e. for upper zone accuracy is  $\pm 4\%$  & for lower zone accuracy is  $\pm 10\%$ .

### **12.1.5 REPAIRS, MAINTENANCE & TROUBLE SHOOTING OF WATER METERS**

The water meters are mechanical devices, which normally deteriorate in performance over time. The fact that a meter does not show outward signs of any damage and has a register that appears to be turning does not mean that the meter is performing in a satisfactory way. It is necessary to ascertain the following preventive cares for water meter after proper installation.

Preventive maintenance:-

1. Proper handling, storage and transportation of water meters.
2. To clean the dirt box or strainer wherever installed.
3. To replace the gaskets, if any.
4. To clean the chamber in which the meter is installed and keep free from flooding, & seepage.
5. To remove the meter for further internal repair/replacement if it does not show correct reading pattern.

Breakdown maintenance:-

Replacement of broken glass, lid and fallen wiper wherever provided:-

These are the only basic breakdowns observed during periodical inspection. If a meter found not working, then it shall be removed immediately and sent to meter service workshop. In meter workshops normally following steps are performed to carry out the repairs.

1. Disassembling of water meters including strainer, measuring unit, regulator, registering device, etc.
2. Clean all disassembled spare parts in detergent solution in warm water.
3. Inspect the cleaned parts and replace worn parts and gaskets, if any.
4. Inspect the meter body spur threads and cover threads.



5. Inspect the sealing surface on meter body and paint the meter body, if necessary.
6. Inspect the vane wheel shaft pinion, bearing & pivot.
7. Inspect the vane wheel chamber.
8. Reassemble the water meter properly after reconditioning.
9. Calibrate & test the repaired water meter for leakage & accuracy as per IS 6784.
10. Make entry in the life register of that water meter for keeping history record.

**TABLE 12.2 TROUBLE SHOOTING OF WATER METERS**

S.No.	Trouble	Cause	Remedy
1.	Meter reads in reverse direction	Might have been installed in reverse direction	Check the arrow on the meter body and install the meter properly, if necessary
2.	Meter not recording	Impeller to register link broken	Remove the meter for servicing and repairs
3.	Continuously moving pointer/digit rotates but no change in indicator	Pointer and drum link missing Drum defect	Remove the meter for servicing and repairs Remove the meter for servicing and repairs
4.	Dial/glass foggy	Climatic condition	Wait for climate change, if it is rainy season
5.	Meter suspected to be slow or fast	Inlet flow disturbance, missing internally defective, deteriorated magnets in case of magnetic meter	Clean the external filter/dirt box where provided and the in-built strainer Ensure full open condition of upstream valve. If doubt persists, remove meter for testing, servicing & repair
6.	Bush/gland leakage	Gland deformity	Remove meter for testing and servicing
7.	Regulator, head, body leakage	Regular washer damaged, loose screw	Remove the meter and repair
8.	Physical damage to meter including broken seal	Improper installation	Remove meter for testing, servicing and repair, physical protection arrangement be made
9.	No water available past the water meter even though inlet side is charged	Semi positive/positive displacement meter with jammed piston	Meter is acting as a stop valve. Remove it for inspection, servicing and repair

In case of smaller size water meters, it is advisable to check cost benefit ratio before getting them repaired.

### **12.1.6 PREVENTION OF TAMPERING OF WATER METERS**

In order to prevent tampering, following precautions should be taken.

1. The water meters, shall be installed properly in the chamber with lock and key or in the C.I. covers with lock and key in order to avoid tampering.
2. The water meters must be sealed properly.
3. The water meters shall not allow reversible flow; it should register flow in forward directions only.
4. The water meter dials should be easily readable without confusions.
5. The lid, glass of water meters must be made up of tough materials as per IS 779 and shall be replaced timely.
6. The wiper or dial as far as possible is avoided.
7. In case of magnetically coupled meters, the proper material to shield magnets must be provided in order to avoid the tampering of such meter by outside magnets in the vicinity of meter.
8. Periodical inspection/checking at site is essential to ensure the proper working of meter.
9. Special sealing arrangements may be necessary and provided for bulk meters whereby unauthorized removal of the meter from the connection can be detected.

In spite of above, to tackle the problems of tampering suitable penalty provisions/clauses shall be there in the rules or the water supply agreement with the consumer. This will also discourage the consumer tendencies of neglecting water meter safety.

### **12.1.7 TREND OF REPLACEMENT OF WATER METERS**

In general, if a water meter goes out of order due to any physical damage or non operation of registration device and is beyond economical repair it should be replaced with immediate effect. In Indian context, the performance of water meter depends upon -

1. the quality of water meter produced by manufacturer and it differs from manufacturer to manufacturer.
2. the design of pipeline & fittings in line with meter;
3. the workmanship & care when handling and installing the meter;
4. the pattern of water passing through the meter;
5. the type of supply of water whether it is continuous or intermittent;
6. the meter maintenance, testing;
7. the proper selection of meter.

The performance of a water meter is required to be watched continuously with suitable history sheets. Any abnormality noticed needs immediate action. Timely removed faulty meter, & specially mechanical type meter, prevents cascade and cumulative damages.

Looking at the amount of transactions involved, bulk meters shall be given priority in replacements. Based on the experience gained for a specification work, a well planned

programme for periodical meter testing, servicing, repairs and replacement wherever necessary shall be designed.

### **12.1.8 AUTOMATIC WATER METERING SYSTEMS**

Water meter is a cash register of a water supply authority. Consumption based water rates require periodic reading of meters except in remote or automated meter reading of meters. Except in remote or automated meter reading these readings are usually done by meter readers visiting consumers premises one by one and noting down the indicator reading by the meter. These readings are recorded manually in books or on cards and later keyed in manually to a customer accounting or billing system. In some cases, meter readers use Hand held Data Entry Terminals to record meter readings. Data from these devices are transferred electronically to a billing system. In other cases, key entry has been replaced by mark-sense card readers or optical scanners.

The environment of meter reading usually is not favourable to the meter reader as most of the water meters are installed in underground chamber; these chambers are filled in many cases with water, reptiles or insects. Often access to these meters is also obstructed when these meters are installed in the consumers' premises. Sometimes manual work is involved for opening the chamber covers. Some consumers connect their electrical earth terminal to water utility pipe which endangers the safety of meter reader. If during the meter reading visit the consumer premises are not accessible the meter reader will have to visit it again which increases the cost of meter reading.

The solution to above difficulties is to install automatic system to read meters and process the results by computer. Because of development in integrated circuit technology and low powered radio trans receivers this system to some extent is simplified.

The data can be captured by the meter readers from the meter in one of the following ways.

1. Manual entry into meter books.
2. Manual entry into portable hand held entry terminals or recorders.
3. Direct electronic entry from meter registers either into portable data terminals or display units from which readings are transcribed in the field.
4. Telemetry link through radio, telephone.

#### **Remote register meters**

This system consists of a coiled spring mechanism wound by the register gears in the meter. A small generator is attached to the spring which trips and upwinds when the meter reaches a certain consumption increment. The spinning of generator sends an electrical pulse to the remote Display unit installed outside. This system is known as electro-mechanical remote registering. The place of this system is being taken by Electronically encoded remote registering. In this type small printed circuit boards are installed between counter wheels of meter register, wiper blades attached to the counter wheels contact discrete positions on the PCBs corresponding to meter reading digits. A small microprocessor determines the positions of the wiper blades on PCB and converts in serially coded output. Similarly non contact type optical-encoded sensing technology is also being used.

In order to collect the data from the site Hand held Data Entry Terminal (HDET) is used. This unit consists of a programmable microprocessor based unit, with memory, key pad, display unit, and battery power supply. It has an interface part so that necessary meter reading route instructions can be down loaded to the unit from a host computer and the meter readings themselves uploaded. The meter reader follows the HDET's instructions.

In a remote electronic meter reading system the output from the encoded register meter is captured through a probe attached to HDET. For reading a meter the probe is connected to a receptacle on the outside of consumer's premises.

Presently there are five different systems of automatic meter reading which are as follows:-

1. Telephone dial outbound:

In this system a meter interface unit is installed on the phone line in the consumer's premises. The utility begins reading by calling a central office access unit which in turn connected to meter interface unit through telephone line. This access is available through dialing i.e. the meter reading is carried out on demand.

2. Telephone dial in bound:

In this system meter interface unit dials the utility's computer at predetermined time and transmits the latest reading.

3. Bi directional telephone dial in/out bound.

It is the combination of two earlier systems. With this system it is possible to read meters at will or to send instructions from the utility control center to meter interface unit as necessary.

4. Cable Television:

In this system at cable hardware end station on address signal is injected for Meter Interface Units (MIU). All MIUS monitor the signals and the unit corresponds to particular address respond and data is transmitted through the cable.

5. Radio:

In this system a radio frequency transmitter is installed at the meter and receiver is either located at fixed location or movable through the vehicle. The dialogues between transmitters and receivers are taking place either in predetermined time or on demand.

Some of the accrued advantages of automatic water metering are as follows:-

- i) Improvement in efficiency of meter reading.
- ii) Reduced operating cost
- iii) Skipping of access problems of meter reading.
- iv) Estimated billing not necessary
- v) Tampering of meter can be detected.
- vi) Back up to customer information services.

### **12.1.9 RELEVANT NATIONAL & INTERNATIONAL STANDARDS**

1. IS 779-1994 : Water meters (Domestic type) – Specification (Sixth revision)
2. IS 2373-1981 : Specifications for water meters (Bulk type) (Third revision)
3. IS : 6784 : Testing of Water meter

- 4. BS : 5728 : Measurement of water flow in close conduits, Part-I : Specifications for meters for cold potable Water
  - : Part – II : Specification for installation requirements for meters
  - : Part – III : Methods for determining principal characteristics of meters
- 5. ISO : 4064 : Measurement of water flow in close conduits, Part-I-Specification for meters for cold potable Water.
  - : Part – II : Installation requirement
  - : Part – III : Test methods and equipment

## **12.2 FLOW METERS**

### **12.2.1 INTRODUCTION**

Various different methods are available for metering flow rate and total flow. Each method has its own specific characteristics, which are directed towards individual installation requirements.

In water industry flow rate meter is termed as flow meter and total flow meter is termed as water meter.

A wide range of standard terms are used to describe the essential performance characteristics of instruments and sensors. Some of these terms are as follows.

#### **1. Accuracy**

It is defined as the difference between the reading of an instrument and the true value of the measured variable expressed as a percentage of either full scale or true value of the measured variable i.e. either in terms of full scale or flow rate of the flow meter.

As far as possible the accuracy should be selected in terms of percentage of flow rate as it remains constant within the rangeability irrespective of variation in flow rate.

#### **2. Range**

The difference between the maximum and minimum values of the physical output over which an instrument is designed to operate normally.

#### **3. Rangeability/Turndown ratio**

Describes the relationship between the range and the minimum quantity that can be measured

#### **4. Linearity**

The degree to which the calibration curve of a device matches a straight line.

#### **5. Resolution**

The error associated with the ability to resolve output signal to the smallest measurable unit.

#### **6. Repeatability**

The quantity which characterises the ability of a measuring instrument to give identical

indications or responses for repeated applications of the same value of the quantity measured under stated conditions of use.

### **12.2.2 TYPES OF FLOW METER**

In water works, normally, following types of flow meters are used. They can be classified in to:

#### **A. Differential Pressure/Head Flow Meter**

1. Orifice Flow Meter
2. Venturi Meter
3. Pitot Tube
4. Annubar (Average pitot tube)

#### **B. Linear Flow Meter**

1. Turbine Wheel Flow Meter
  - Full bore type
  - Insertion type
2. Variable Area Flow Meter (Rotameter)
3. Vortex Flow Meter
  - Full bore type
  - Insertion type
4. Magnetic Flow Meter
  - Full bore or Inline type
  - Insertion type
5. Ultrasonic Flow Meter
  - Doppler type
  - Transit time type

The Advantages and Disadvantages of these Flow Meters are given below.

#### **A. Differential Pressure/Head Flow Meter**

##### **1. Orifice Flow Meter**

###### *Advantages*

- i) It can be used for all fluids except some exceptions
- ii) No moving parts
- iii) Flow rate, indication, integration are easily obtained
- iv) It can be fitted in any configuration of pipeline
- v) Suitable for any pipe diameter
- vi) Signal can be transmitted to long distance
- vii) Good accuracy
- viii) Suitable for extreme temperature and pressure
- ix) Calculation possibilities for unusual situations

***Disadvantages***

- i) Rangeability 4 : 1
- ii) Energy cost in terms of head loss
- iii) Ideal conditions are required for good accuracy
- iv) Suitable for particular range of Reynolds number
- v) Accuracy in terms of span
- vi) Minimum slope for tapping piping has to be maintained i.e. 1:10
- vii) Very long conditioning section required
- viii) Intensive maintenance required
- ix) Edge sharpness of the orifice must be assured.
- x) It requires isolation of pipeline during installation

**2. Venturi Meter**

***Advantages***

As mentioned under orifice meter, and less pressure loss and hence less energy cost.

***Disadvantages***

Same as under Sr. No. i, iii, iv, v, vi & x of orifice flow meter in addition to high capital cost.

**3. Pitot Tube**

***Advantages***

As mentioned under orifice flow meter except at Sr. No. 7. It does not require isolation of pipeline for installation and comparatively capital cost of the flow meter is less. Head loss is also less.

***Disadvantages***

As mentioned under Sr. No. i, iii, v, vi, vii of orifice flow meter in addition to inferiority in accuracy as it being point velocity measurement.

**4. Annubar (Average pitot tube)**

***Advantages***

As mentioned under pitot tube in addition to higher accuracy

***Disadvantages***

As mentioned under pitot tube except inferiority in accuracy i.e. accuracy improves due to averaging of multiported pressures.

**B. Linear Flow Meter**

**1. a. Turbine Wheel Flow Meter (Full bore or Inline)**

***Advantages***

- i) Excellent accuracy, linearity and repeatability
- ii) Usable at extreme temperature and pressure

***Disadvantages***

- i) Suitable for only for low viscosity
- ii) Moving parts and hence wear

- iii) Sensitive to contamination
- iv) Flow profile sensitive and needs conditioning section
- v) Affected by overloading, danger of over speeding
- vi) Sensitive to vibration
- vii) Isolation of pipeline is required for installation.

**b. Turbine wheel flow meter (Insertion type)**

*Advantages*

- i) Isolation of pipeline is not required
- ii) Low cost

*Disadvantages*

- i) Inferior accuracy because of point velocity measurement
- ii) Suspended impurities can clog it. In addition to above the disadvantages mentioned under Turbine wheel flow meter (full bore) are also applicable.

**2. Variable Area Flow Meter (Rotameter)**

*Advantages*

- i) In expensive
- ii) No power supply required for local indication
- iii) No conditioning section
- iv) Easy maintenance

*Disadvantages*

- i) It requires vertical installation
- ii) Affected by density and temperature of the fluid
- iii) Affected by vibration and pulsation

**3. Vortex Flow Meter**

**a. Full bore or Inline type**

*Advantages*

- i) No moving part
- ii) Robust construction
- iii) Unaffected by temperature, pressure and density changes

*Disadvantages*

- i) Conditioning of long approached section
- ii) Span limitation due to viscosity
- iii) Shedding rate is non linear between 2000 and 10000 Reynolds's number
- iv) Available upto 400 mm size due to constraints of sensitivity
- v) Isolation of pipeline is required for installation

**b. Insertion Vortex Flow Meter**

*Advantages*

- i) Isolation of pipeline for installation is not required
- ii) Less costly than that of full bore

In addition to above the advantages mentioned under full bore vortex flow meter are also applicable.



*Disadvantages*

- i) Inferior accuracy due to point velocity measurement

In addition to above the disadvantages mentioned under full bore vortex meter are applicable except at Sr. No. V.

**5. Magnetic Flow Meter**

**a. Full bore (Inline) Flow Meter**

*Advantages* of full bore magnetic (Inline) flow meter

- i) Unobstructed flow passage
- ii) No moving parts
- iii) No additional pressure drop
- iv) Unaffected by changes in temperature, density, viscosity, electrical conductivity
- v) Flow range setting can be optimised
- vi) Suitable for water containing suspended solids
- vii) Short conditioning section is required as it is insensitive to flow profile
- viii) Measures flow both the directions
- ix) Un- affected by contamination and deposit
- x) Minimum maintenance
- xi) Good linearity
- xii) Smaller diameter flow meter can be used on bigger diameter pipe with the help of reducers having angle not more than  $16^\circ$ .

*Disadvantages*

- i) Air or gas inclusion causes error
- ii) Minimum required conductivity of fluid 0.5 ms/cm.
- iii) Isolation of pipeline is required for installation
- iv) Vacuum creation may detach inner liner

**b. Insertion Magnetic Flow Meter**

*Advantages*

- i) Less costly than that of full bore
- ii) No isolation of pipe line for installation
- iii) Advantages mentioned under Sr. Nos. ii, iv, v, vi, viii, ix, x, xi of full bore magnetic flow meter are applicable.

*Disadvantages*

- i) Inferior accuracy due to point velocity measurement
- ii) Long conditioning section is required
- iii) Sensitive to vibration
- iv) Periodic cleaning of electrode is required

## 6. Ultrasonic Flow Meter

### a. Doppler type Ultrasonic Flow meter

#### *Advantages*

- i) Unobstructed flow passage
- ii) No moving parts
- iii) No pressure drop
- iv) Measures flow in both directions
- v) Installations of individual elements in existing pipe lines possible
- vi) Minimum maintenance
- vii) Economical for large diameter pipe
- viii) Suitable for turbid water

#### *Disadvantages*

- i) Not suitable for clear water
- ii) Accuracy is inferior
- iii) It requires long conditioning section

### b. Transit Time (Time of Flight) Ultrasonic Flow meter

#### *Advantages*

- i) Advantages mentioned under Sr. nos. i, ii, iii, iv, v, vi, vii of Doppler type are applicable
- ii) Accuracy is improved in multipath
- iii) Accuracy is superior in insertion (wetted type) than that of clamp type.

#### *Disadvantages*

- i) It requires long conditioning section
- ii) Not suitable for turbid water or carrying air/gas bubbles.

### 12.2.3 INSTALLATION OF FLOW METER

Every user expects a problem-free installation of the meter and thereafter only accurate reading. Regular monitoring is desirable in order to avoid failures.

The meter is installed in the pipeline using flanged or threaded connections giving due consideration for conditioning sections. It should be seen that stress-free installation is carried out in pipeline. It is essential to install the flowmeter co-axially to the pipeline without protruding any packing or gasket into the water flow stream. In the case of ultrasonic meter the probes are welded on the pipeline which requires care to see that no projection is protruding in the pipeline. In this case onsite calibration is essential. Wherever converters are used with primary elements it should be observed that the connection between them should be protected against lightning strokes and any other interference signal.

The installation on the existing water supply requires shutting down the water supply. This necessitates shortest installation time. The installations are strictly carried out as per manufacturers' recommendations.

In the case of differential pressure type flowmeter the impulse piping requires special care in respect of slope and protection. Similarly long disturbance free straight sections should be provided for uniformity. Installation should be vibration free as moving parts in the flowmeter wherever present will get worn out in addition to the effect on overall accuracy of the flowmeter.

Installation in 'U' shape is essential for intermittent water supply.

Flow meters should be provided with battery backup in order to retain integrator reading during failure of electric supply.

#### **12.2.4 MAINTENANCE OF FLOW METER**

Modern development in the flowmeter measurement is that in most of the equipment a self-monitoring facility is provided with which the maintenance staff monitors the health of the equipment. A number of instruments are enunciating the error conditions.

As long as orifice, Pitot tube, Venturi & Annubar flowmeters are concerned they require regular purging of impulse piping. Similarly the transducers require periodical checking of zero and range setting. For the orifice it is essential to check sharpness of the edge as in the case of its deterioration or damage the flowmeter reading may vary upto 20%.

Ultrasonic Flowmeter and Magnetic flowmeters being self-monitoring, they give information regarding deviation in accuracy or failure of probe or electrode. Whenever cleaning of probes or electrodes is required, those should be cleaned as per manufacturers' recommendation.

Turbine meter should be checked for bearing wear out periodically as presence of air in the liquid may damage the bearing because of overspeeding.

Where deposits are to be expected in any flowmeter, the same should be regularly inspected and cleaned as per the experience gained during the course of time. As these deposits affect the accuracy of the measurement, Vortex meter, Magnetic flowmeter, Ultrasonic flowmeter, may show erroneous reading in the presence of deposits. In an intermittent water supply the corrosion rate of the pipe increases due to chlorine and air. The formation of incrustation & subsequent descaling affect flowmeter working especially differential pressure type, turbine meters.

#### **12.2.5 CALIBRATION OF FLOW METERS**

Flow calibration is essential to

- i) Confirm performance of flowmeter
- ii) Quality control
- iii) Comply with statutory or legal requirements
- iv) Provide traceability of measurement and confidence in resultant data.

The calibration is normally carried in the flow laboratory with the help of one of the following methods.

- i) Gravimetric
- ii) Volumetric
- iii) Prover
- iv) Master or reference meter
- v) Tow tank – current meter calibration

There are two philosophies of flow meter calibration. One is that it is better to have a fixed calibration system with all the associated technical back up and with the flow meters being brought to the calibration system, the other favours calibrating in situ leaving the flow meters in their installed condition and using a portable calibrator. The former will generally provide

the more accurate calibration but the latter has the advantage that site specific effects such as proximity to hydraulic disturbances can be taken into account. It is necessary to decide carefully to adopt the option.

There is often no choice but to carry out in situ calibration where

- i) flow cannot be shut off
- ii) site specific conditions have to be accounted for
- iii) the meter is so large that removal, transport and testing costs would be prohibitive.

The major constraint with in situ calibration technique is that the high accuracy laboratory calibration can not be matched in the field and accuracies of  $\pm 2\%$  to  $\pm 5\%$  is all that can be achieved and such field tests are called confidence checks rather than absolute calibrations. Such checks are often the precursor to removal of flow meter for laboratory calibration or replacement.

For field test following methods can be used.

- i) Clamp on devices
- ii) Thermodynamic method
- iii) Velocity area methods (insertion meters)
- iv) Tracer methods
- v) Flow simulators

Normally the manufacturers of the flowmeters provide laboratory calibration of the flow meters in their works. Some of the Government agencies also provide laboratory calibration vis. Fluid Control Research Institute (FCRI), Palghat, Central Water & Power Research Station (CWPRS), Pune and Institute for Design of Electrical Measuring Instruments (IDEMI), Mumbai

### 12.2.6 CONCLUSION

The present flow meter market is a challenging one to the purchaser. Unless the site problems are known, it is very difficult to select the flowmeter to serve the purpose from performance point of view. If the flowmeter is selected and installed properly, the maintenance will get reduced drastically.

This is an age where 'energy audit' is gaining wide acceptance in view of the spiraling energy cost. Thus, correct and accurate measurement of inputs (electrical power) and outputs (flow measurement in water works) need to be given due weightage and importance in all water works installations for effective and productive utilization of precious potable water resources.

*Details of Various Flow Meters in respect of following features are given in respective tables.*

Average Accuracies	:	Table – 12.3
Broad areas of applications	:	Table – 12.4
Performance factors	:	Table – 12.5
Installation constraints	:	Table – 12.6
Fluid property constraints	:	Table – 12.7
Economic factors	:	Table – 12.8
Installation & maintenance	:	Table – 12.9
Common problems encountered	:	Table – 12.10
Applicable standards for flow meters	:	Table – 12.11

**TABLE 12.3**  
**AVERAGE ACCURACIES OF VARIOUS FLOW METERS**

Sr. No.	Type of flow meter	Accuracy %
1.	Square edge orifice	±1S
2.	Venturi	±1S
3.	Pitot	±2S
4.	Annubar	±1S
5.	Turbine	±0.5R
6.	Rotameter	±2S
7.	Vortex	±1R
8.	Magnetic	±0.5R
9.	Doppler	±2S
10.	Transit time	±1R

Legends : S : in terms of full scale  
R : in terms of flow rate.

**TABLE 12.4**  
**BROAD AREAS OF APPLICATION OF FLOW METER FOR LIQUID**

	A	B	C	D
Orifice	0	+	0	0
Venturi	0		0	0
Variable Area	0	0		
Anubar	0		0	0
Turbine	0		0	*
Insertion turbine	0		0	0
Vortex	0			
Insertion Vortex	0		0	0
Electro Magnetic	0	0	0	0
Insertion Electro Magnetic	0		0	0
Doppler	0		+	+
Transit time	0	+	0	0

Legends : 0 is suitable, generally applicable  
+ is worth considering, sometimes applicable  
\* is worth considering, limited availability  
**or tends to be expensive.**  
A blank indicates unsuitable;

C: Large liquid flows  
( $> 1.7 \times 10^4$  L/min.)  
D: Large water pipes  
( $> 500$  mm dia)

liquids (temp. $>200^\circ\text{C}$ )

not applicable.

A: General liquid application

(< 50 CP)

B: Low liquid flows (<2 L/min)

**TABLE 12.5**  
**PERFORMANCE FACTORS OF FLOW METER**

Sr. No.	Type of the flow meter	Linearity %	Repeatability %	Rangeability	Pressure drop at maximum flow	Flow parameter measured
1.	Orifice	0.25% FS to 1%FS	± 0.2% FS	3 or 4:1	3-4	R
2.	Venturi	0.25% FS to 1% FS	± 0.2% FS	3 or 4:1	2	R
3.	Variable area	± 1% FS to ± 5% FS	± 0.5% FS to ± 1% FS	1% FS	10:1	3R
4.	Anubar	0.5%R to 1%R	± 0.05% R to ± 0.2% R	4 to 10:1	1/2	Vm
5.	Turbine	± 0.15% R to ± 1% R	± 0.02% R to ± 0.5% R	5 to 10:1	3	R
6.	Insertion Turbine	± 0.25% R to ± 5% R	± 0.1% R to ± 2% R	10 to 40:1	1-2	Vp
7.	Vortex	± 1% R	± 0.1% R to ± 1% R	4 to 40:1	3	R
8.	Insertion Vortex	± 2% R	± 0.1% R	15 to 30:1	1	Vp
9.	Electro Magnetic	± 0.2% R to ± 1% R	± 0.1% R to ± 0.2% FS	10 to 100:1	1	R
10.	Insertion Elec. Mag.	± 2.5% R to ± 4% R	± 0.1% R	10:1	1	Vp
11.	Doppler	No data	± 0.2% FS	5 to 25:1	1	Vm,R
12.	Transit time	± 0.2 R to ± 1% R	± 0.2% R to ± 1% FS	10 to 300:1	1	R

Legends: R : Flowrate                      Vp : Point velocity                      NS : Not specified  
T : Volume flow                      % R : Percentage flowrate                      1 : Low  
Vm : Mean velocity                      % FS : Percentage fullscale                      5 : High



**TABLE 12.8**  
**ECONOMIC FACTORS OF FLOW METERS**

Type	Installation cost	Calibration cost	Operation cost	Maintenance cost	Spares cost
Orifice	2-4	1	3	2	1
Venturi	4	1-4	2	3	3
Variable area	1-3	2	2	1	1
Anubar	2	3	2	2	2
Turbine	3	4	3	4	4
Insertion Turbine	2	3	2	2	3
Vortex	3	3	3	3	3
Insertion Vortex	2	3	2	3	3
Electromagnetic	3	3	1	3	3
Insertion Ele. Mag.	2	3	2	3	2
Doppler	1-3	1	1	3	2
Transit time (time of flight)	1-3	3	1	3	2

Legends : 1 : Low    5 : High

**TABLE 12.9**  
**INSTALLATION & MAINTENANCE OF FLOW METERS**

Type	Installation	Pipeline ahead of meter	Maintenance during operation	Self monitoring	Service
Turbine meter	Flanged connections electrical installation	Conditioning section	Maintenance free, monitor, possible foreign lubrication	Not possible	–
Vortex meter	Flanged connections or water installation, electrical	Conditioning section installation	Maintenance free	Error monitoring	Electronic monitor functions and test values
Differential pressure meters	Primary in flanges, impulse piping, convertor power supply	Long conditioning sections	Regular monitoring	Not possible	Direct measurement at primary
Variable area meter	Flanged or threaded connections	No restrictions	Maintenance free	Constant appearance	–
Electromagnetic flow meter	Flanged connections, electrical connections	No condition- ing section	Maintenance free	Monitoring with error announcements	Electronic control func- tions & test simulator
Ultrasonic meter	Flanged connections or welding nipples, electrical installation.	Long conditioning section	Maintenance free	Signals for signal loss	–



**TABLE 12.10**

**COMMON PROBLEMS ENCOUNTERED IN FLOW METER PERFORMANCE**

Sr. No.	Problems	Causes	Flow Meter	Remedial Action
1.	Erratic reading	Operated below lower range having limited rangeability of flow meter	Differential pressure type	Replace flow meter
		Operated below lower range having limited rangeability of flow meter	Linear flow meter	Change range setting
		Less static pressure	D.P. type	Remove air trap
		Clogged impulse piping	D.P. type	Clear the choke up
		Air trapped in impulse piping	D.P. type	Remove air trap
		Frequent air trap in impulse piping	D.P. type	Change impulse piping slope to minimum 1: 10, If still the problem persists change the flow meter.
		Damaged impulse piping	D.P. type	Rectify impulse piping
2.	Unsteady reading : (oscillating)	$\beta$ ratio more than 0.65	D.P. type	Redesign orifice
		Pulsating flow	D.P. & Linear type	Condition the flow
3.	Inaccurate reading	Pipeline internally incrustated	D.P. & Linear type	Clean the internal surface of pipeline
		Scaling is formed at tapping points	D.P. type	Clean the tapping points
		Orifice edge gets blunt	D.P. type	Replace orifice plate
		Flow meter down stream is opened within the range of 50 times dia pipe length	D.P. type	Extend the down stream pipeline beyond 50 dia length
		Unsymmetrical formation of vena contract due to large diameter of throat in relation to static pressure	D.P. (orifice type)	Redesign the orifice
		Mismatch between flow meter & pipeline	D.P. & Linear type	Remove the mismatch
		Absence of sufficient conditioned approach pipeline	D.P. & Linear type	Provide sufficient conditional approach pipeline
		Foreign particles such as pieces of concrete, bricks, debris etc. are gathered at upstream of orifice	D.P. (Orifice)	Remove them
		Flanged coupling used with flow meter leaking	D.P. & Linear type	Rectify the leakage
		Pipeline may not be cylindrical within the range of 0.3% of the diameter of the pipe	D.P. & Linear type	Replace the pipe length of 2 times dia immediate upstream of the flow meter
		Pipeline partially filled	D.P. & Linear type	Install valve down stream of the flow meter for throttling

**TABLE 12.11**  
**APPLICABLE STANDARDS FOR FLOW METERS**

BS:7405:1991 of	:	Selection and application of flow meters for the measurement of fluid flow in enclosed conduits.
BS:1042	:	Methods for the measurement of Fluid flow in pipes – Orifice plates, Nozzles and Venturi Tubes.
BS:5792:1980	:	Specification for Electro Magnetic flow meters.
BS EN ISO :6817-1997	:	Measurement of conductive liquid flow in closed conduits- Method using Electro magnetic flow meters.
ISO Recommendation –R541 1967(E)	:	Measurement of fluid flow by means of orifice plates and nozzles.
ISO 9104-91/BS 7526 : 1991	:	Measurement of fluid flow in closed conduits – Method of evaluating the performance of electro magnetic flow meter for liquid.
BS : 6199 : 1991/ISO9368/1990	:	Measurement of liquid flow in closed conduits using weighing and volumetric methods.
IS : 4477 (Part-2) 1975	:	Methods of measurement of fluid flow by means of Venturi meters: Part-2 Liquids.
IS 2951 : 1965	:	Recommendations for estimation of flow of liquids in closed conduits part I: Head loss in straight pipes due to frictional resistance.
IS 2952 : Part I - 1964	:	Recommendations for methods of measurements of fluid flow incompressible fluids.
IS 14615 Part I	:	Measurement of fluid flow by means of pressure Differential devices – part I : Orifice plates, nozzles and venturi tubes inserted in circula.
IS 9115 – 1979	:	Method for estimation of incompressible fluid flow in closed conduits by Bend meters.

## **12.3 INSTRUMENTATION**

### **12.3.1 LEVEL MEASUREMENT**

#### **12.3.1.1 Introduction**

Instrumentation facilitates coordination of various water parameters, which are essential for optimization of water supply & treatment plant. One of the important parameters amongst them is water level measurement, which is carried out at various locations vis. water reservoir, inlet chamber, open channel, alum feeding tank, lime tank, filter beds, air vessel, sump well etc.

This measurement is accomplished in water works by two following ways.

- A. Direct Method
- B. Inferential Method

Their merits, demerits as well as uses are given below in brief.

## A. DIRECT METHOD

Hook Type Level Indicator	Sight Glass	Float Type Indicator
<b>Advantages</b> i. Low cost ii. Simple	i. In expensive ii. Corrosion resistive iii. Simple	i. Level can be read at convenient place ii. Operates over large temperature range iii. Very accurate
<b>Disadvantage</b> i. Only local reading ii. Human error may encountered in reading	i. Only local reading ii. Accuracy and readability depend on cleanliness of glass and fluid iii. It is fragile	i. They are tailored to tank geometry ii. Requires a certain amount of mechanical equipment
<b>Uses</b> i. Inlet channel level	i. Filter bed level ii. Reservoir level iii. Head loss in filter	i. Filter bed ii. Final water reservoir iii. Sump well iv. Lime tank

## B. INFERENCE METHOD

Hydrostatic Pressure Gauge Type & Pressure Bulb Type	Displacer Level Type	Electrical Method (Capacitance Type)	Ultrasonic
<b>Advantages</b> i. Easy maintenance ii. Simple to adjust iii. With pressure bulb type remote reading possible iv. Reasonably accurate	i. Excellent accuracy ii. Possible at remote places	i. Good accuracy ii. Possible at remote places iii. Very sensitive iv. Suitable for highly corrosive media	i. Good accuracy ii. Possible at remote places iii. Suitable for liquid as well as bulk products
<b>Disadvantage</b> i. Instrument must be installed at base reference level for gauge type ii. Pressure bulb type relatively costly	i. Limited range ii. High cost iii. Requires stilling chamber iv. Requires a significant amount of mechanical equipment	i. Affected by dirt & other contaminants ii. Affected by temperature	i. Affected by foam ii. Not suitable for high temperature & pressure
<b>Uses</b> i. Delivery head of the pump (pressure gauge type) ii. Clear or raw water reservoir iii. Sump level	i. Clear water reservoir ii. Raw water reservoir	i. Raw water reservoir ii. Clear water reservoir	i. Raw water as well as clear water level i.e. inlet channel sump level etc. ii. Lime tank iii. Sludge level

### **12.3.1.2 MAINTENANCE OF LEVEL MEASURING INSTRUMENTS.**

#### **Sight Glasses**

- After closing top and bottom valves remove the glass and clean with soap water using brush. Clean with fresh water. Assemble the parts again in proper order.

#### **Float Operated Instrument**

- Guide cable wound round a pulley should be lubricated. Other moving parts should also be lubricated.
- Zero setting should be checked. Float should be checked from corrosion point of view.

#### **Hydrostatic Pressure Instruments (Pressure Gauge Type)**

- Check for Zero setting after disconnecting from the system and purging out.
- Check for the leakages from the connection after reconnecting it.

#### **Pressure Bulb Type**

- Check for zero setting. Check for air leakages from the bulb by applying soap water.
- Check coupling from corrosion point of view.
- Clean the bulb with fresh water.
- Check for the correctness of the signal by moving the bulb in the water.

#### **Displacer, Electrical or Ultrasonic Instrument**

- Clean the instrument and check for zero and range setting.

### **12.3.2 PRESSURE MEASUREMENT**

#### **12.3.2.1 Introduction**

In water supply network pressure parameter plays very important role in order to get sufficient water to the consumers. Similarly in flow measurement by differential pressure type flow meter, differential pressure measurement across the primary element is the main physical parameter to inter link with flowing fluid.

This pressure or differential pressure measurement is accomplished with the help of following methods in water works.

- A. Manometers
- B. Elastic Pressure Transducer
- C. Electrical Pressure Transducer

The advantages and disadvantages of the instrument of pressure measurement normally used in waterworks are given below.

## A. MANOMETERS

U Tube Manometers	Well Type Manometers	Inclined Manometers
<b>Advantages</b> i. Simplest ii. Low cost	i. Zero reference setting is possible ii. Low cost	i. More sensitive ii. Low cost
<b>Disadvantage</b> i. No fixed reference ii. Large & bulky iii. Need for levelling iv. No over range protection	i. Accuracy inferior to U tube manometer ii. Large & bulky iii. Need for levelling iv. No over range protection	i. Large & bulky ii. Need for levelling iii. No over range protection
<b>Uses</b> i. For measurement of differential pressure in D.P. type flow meter & calibration of D.P. type transducers	i. For calibration of D.P. type flow meters & measurement of differential pressure in D.P. type flow meter	i. For measurement of very small pressure differences

## B. Elastic Pressure Transducer : Commonly used

Bourdon tube type pressure gauge :

### Advantages

- i) Low Cost
- ii) Simple construction
- iii) Time tested in applications
- iv) Availability in a wide range
- v) Adaptability to electronic instruments
- vi) High accuracy in relation to cost

### Disadvantages

- i) Low spring gradient below 3 kg/cm<sup>2</sup>
- ii) Susceptibility to shock and vibration
- iii) Susceptibility to hysteresis
- iv) Accuracy in terms of full scale deflection

### Uses

- i) Pump delivery & suction
- ii) Water supply distribution network
- iii) Air receivers
- iv) Chlorinators
- v) Pump cooling water.

### C. Electrical Pressure Transducer

In this category following types are there

1. Strain gauge pressure transducer
2. Potentio metric pressure transducer
3. Capacitive pressure transducer
4. Variable reluctance pressure transducer
5. Piezo electric pressure transducer

The advantages & disadvantages of electrical pressure transducers commonly used in water works are as follows.

Potentio metric Transducer	Capactive Pressure Transducer	Variable Reluctance Type
<b>Advantages</b> i. Widely used in Industry as these are simpler and less expensive ii. Easy compatibility with the requirement	i. Short response time ii. Vibration proof iii. Extremely sensitive iv. It can measure static as well as dynamic changes	i. Excellent linearly ii. Good repeatability iii. Low hysteresis iv. High sensitivity
<b>Disadvantage</b> i. Finite resolution ii. Wear out early iii. Noise signal is generated	i. Sensitivity changes with temperature	i. Relatively large size ii. More nos. of components iii. More maintenance
<b>Uses</b> i. Where less accuracy is required	i. Distribution network ii. In process instrumentation	i. Distribution network ii. In process instrumentation

#### 12.3.2.2 Calibration of Pressure Measuring Instruments

Pressure instrument calibration is the process of adjusting the instruments output signal to match a known range of pressure. All instruments tend to drift from their last setting. This is because springs stretch, electronic components undergo slight changes on the atomic level and other working parts sag, bend or lose their elasticity.

The calibration procedure includes Zero, Span and linearity adjustments. The pressure is varied with the help of pneumatic calibrator so as to give desired pressures to the instrument. The settings are carried out on the instrument for zero and span adjustment on the basis of applied pressures. For carrying out linearity setting various pressures between zero and maximum range of the instruments are applied and adjusted the output of the measuring instrument with the help of controls provided in the instrument.

In the case of pressure gauges the calibration is carried out by means of dead weight tester.

In absence of pneumatic calibrator the air can be supplied to the instrument with proper pressure regulator and pressure is measured with the help of manometer so as to calibrate the instrument.

The calibration should be checked every 3,6 or 12 months depending upon the use and accuracy expected.

Maintenance of pressure instruments is essential for their proper working and accurate reading. It also improves the life and reliability of the instruments.

### 12.3.2.3 Preventive Maintenance

The manufacturer of the instrument gives the instructions in the manual supplied along with the instruments. These instructions explain how to maintain the instrument. Generally these consist of following categories.

#### 1. Visual Inspection

Any damage to piping or wiring of the instrument observed should be immediately rectified. It avoids entry of foreign bodies into the system and further damage to the instrument.

#### 2. Venting or Blow down

Liquid lines are generally clogged subsequently if those are not vented periodically. Similarly air or gas in the liquid columns gives wrong readings. In order to avoid such incidents it is essential to blow down the instrument piping periodically on the basis of experience gained in the field.

#### 3. Cleaning and Lubrication

Instruments with mechanical linkages undergo wear and misalignment. Dirt may clog the linkages, causing the mechanism to become less flexible. If not attended these kind of faults,

**TABLE 12.12**  
**A TYPICAL TROUBLE SHOOTING CHART FOR PRESSURE & LEVEL MEASURING INSTRUMENT (ELECTRONIC TRANSMITTER TYPE)**

Fault	Possible Causes	Corrective Action
Low output Or zero output Or High output Or Erratic output	Power Supply	Check output of power supply Check for short and multiple grounds Check polarity of connections Check loop impedance
	Pressure tapping	Check the pressure connection Check for leakage or blockage Check for entrapped air or gas in the line
	Transmitter	Check for shorts in sensor leads Check connector to transmitter Check for amplifier assembly by replacing it with spare one.
	Sensing element	Check sensing element for its working by gently tapping it.
Tapping by hand gently the mechanism sensor does not respond	Mechanical	Check mechanical linkage Check for dirt finding Excessive wear, misalignment For dirt clean and lubricate as per manufactures recommendations Realign Mechanical parts if necessary For wear replace the worn-out components
	Electrical	Replace electrical/electronic subassemblies and perform calibration

the instrument may breakdown subsequently. This clogging can be removed by cleaning and working of the instrument can be improved by lubrication as per manufacturer's recommendations. Dust can be removed from the panels as well as from the instruments with the help of air blower. If auto test facility is provided on the instrument by the manufacturer the same can be used to check the performance of the instrument daily. If any kind of fault occurs, in such instrument, the same is identified and displayed by the instrument itself.

### 12.3.3 WATER QUALITY PARAMETER MONITORING

#### 12.3.3.1 Introduction

In water works various treatment processes are carried out in order to supply potable water. The parameters of the water which are normally used for monitoring are as follows :

- Turbidity
- pH
- Residual Chlorine

These parameters are monitored either by means of on-line instruments or by analytical laboratory instruments or both. Their relative advantages and disadvantages are as follows.

#### 12.3.3.2 Turbidimeter

Online	Laboratory Type
<p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>i. Turbidity continuously monitored</li> <li>ii. Can be hooked up for automation</li> <li>iii. Can be set for giving alarm if minimum and maximum limits of turbidity are exceeded.</li> <li>iv. Human error in sampling is eliminated</li> </ul>	<ul style="list-style-type: none"> <li>i. Low cost</li> <li>ii. Simple to use</li> <li>iii. Portable</li> <li>iv. Easy maintenance</li> </ul>
<p><b>Disadvantages</b></p> <ul style="list-style-type: none"> <li>i. High cost</li> <li>ii. High Maintenance is required</li> <li>iii. Periodical calibration is required</li> <li>iv. It is not portable</li> </ul>	<ul style="list-style-type: none"> <li>i. Does not monitor continuously</li> <li>ii. Human error may encounter</li> <li>iii. Low accuracy</li> </ul>
<p><b>Maintenance</b></p> <ul style="list-style-type: none"> <li>i. Clean chamber &amp; lense with fresh water</li> <li>ii. Microprocessor based instrument has self calibration facility which is useful for periodical calibration</li> <li>iii. Clean sources of light</li> </ul>	<ul style="list-style-type: none"> <li>i. Clean sampling tube with fresh water</li> <li>ii. Bulb, standard sample tubes and lense should be cleaned with soft cotton</li> <li>iii. Calibrate before carrying out measurement</li> <li>iv. Calibrate with standard samples of 100 NTU, 10 NTU &amp; 1 NTU or calibrate with formazin standard solution</li> </ul>



### 12.3.3.3 pH METER

Online	Laboratory Type
<p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>i. Continuously monitored</li> <li>ii. Can be hooked up for automation</li> <li>iii. Can be set for giving alarm for specified limits</li> <li>iv. Human error in sampling is eliminated</li> </ul>	<ul style="list-style-type: none"> <li>i. Low cost</li> <li>ii. Simple to use</li> <li>iii. Portable</li> <li>iv. Easy maintenance</li> </ul>
<p><b>Disadvantages</b></p> <ul style="list-style-type: none"> <li>i. High cost</li> <li>ii. Periodical calibration is required</li> <li>iii. High maintenance cost (replacement of electrodes)</li> <li>iv. It is not portable</li> </ul>	<ul style="list-style-type: none"> <li>i. Does not monitor continuously</li> <li>ii. Human error may encounter</li> <li>iii. Low accuracy</li> </ul>
<p><b>Maintenance</b></p> <ul style="list-style-type: none"> <li>i. Clean electrode with soap water or clean with 5% concentrated H<sub>2</sub>SO<sub>4</sub> and 6% concentrated H<sub>2</sub>O<sub>2</sub></li> <li>ii. Calibrate periodically with standard solution of 4 pH and 7 pH</li> <li>iii. Replace electrodes if dried up</li> </ul>	<ul style="list-style-type: none"> <li>i. Clean sampling electrode with distilled water</li> <li>ii. Calibrate the instrument with three standards samples i.e. 4 pH, 7 pH &amp; 9.2 pH</li> <li>iii. Prepare standard samples from readily available capsules</li> <li>iv. Calibration may last from 4 days to 7 days</li> </ul>

### 12.3.3.4 Residual Chlorine Meter

Online	Laboratory Type (Lovibond Type)
<p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>i. Continuously monitored</li> <li>ii. Can be hooked up for automation</li> <li>iii. Can be set for giving alarm for specified limits</li> <li>iv. Human error in sampling is eliminated</li> </ul>	<ul style="list-style-type: none"> <li>i. Low cost</li> <li>ii. Simple to use</li> <li>iii. Portable</li> <li>iv. Easy maintenance</li> </ul>
<p><b>Disadvantages</b></p> <ul style="list-style-type: none"> <li>i. High cost</li> <li>ii. Periodical calibration is required</li> <li>iii. High maintenance cost (replacement of membrane)</li> <li>iv. It is not portable</li> <li>v. It requires electricity</li> </ul>	<ul style="list-style-type: none"> <li>i. Does not monitor continuously</li> <li>ii. Human error in sampling may encounter</li> <li>iii. Low accuracy</li> </ul>
<p><b>Maintenance</b></p> <ul style="list-style-type: none"> <li>i. Clean membrane if it gets clogged</li> <li>ii. If membrane is damaged replace it with new one</li> <li>iii. Fill up electrolyte if necessary</li> <li>iv. Calibrate it using DPD.</li> </ul>	<ul style="list-style-type: none"> <li>i. Clean tubes with distilled water</li> <li>ii. Calibration is not required as it being a comparator</li> </ul>

## **12.4 AUTOMATION**

### **12.4.1 INTRODUCTION**

In small and medium plants the supervision and coordination of various activities can be carried out by the operator manually. However for large plant it becomes cumbersome to supervise, operate, coordinate, control and protect it. It is preferably to use sophisticated instrumentation and control system. The task of controlling is achieved by programmable logic controller or digital computer.

The process of monitoring the parameter, comparing it with the set values, manipulating the signal and sending the instructions to concerned equipment for taking action is known as automation. Automation entails the replacement or elimination of intermediate components of a system or steps in a process, especially those involving human intervention or decision making, by technologically more advance ones.

### **12.4.2 AUTOMATION OF TUBE WELLS**

#### **12.4.2.1 General**

In some of the cases automation is found to be very useful & efficient even when the number of parameters involved in controlling in the system are less. The fine example of it is the automation of tube wells in remote areas. It is being easily achieved without using P.L.C. The functioning of a pumping set automatically as and when required as per the availability of power supply is carried out without the help of pump operator as described in the following paras.

#### **12.4.2.2 How the Automation is Made**

For Operation of the tube well electric switch gear is used. In this electric switch gear the starter is a main component. Starter has two buttons visible on the body of it. One button is green and another is Red. Green button is used for starting the pumping set while Red button is used for closing the pumping set. Green button is normally known as 'NO' (Normally Open) and Red button is known as 'NC' (Normally Close). Whenever any pumping set is to be started Green button is pushed to complete the circuit and energize the no volt coil to make the main contactor functional which in turn operates the motor. In manual operation this starting & closing of the tubewells are done by the pump operator when the tubewells are required to run round the clock. This can be achieved by short circuiting the connections of the Green button i.e. NO is converted into NC. This results into all the time complete circuit giving voltage to no volt coil. So long power is available the tubewell remains functioning. Whenever there is any tripping or power shut down, the tubewell remains non-functional. In this case there is no need of any pump operator but for cluster of tubewells an electrician is needed to keep a watch on the smooth functioning of electric switch gear and pumping sets. For automation of tube wells a healthy switch gear is required which should have all protection devices for the pumping set. The details of such switch gear are given below:

### a. Automation Switch Gear:

Automation switch gear in the shape of a Panel Board or Feeder Pillar should have the following components:

- Starter of some standard make.
- Volt meter- 0 to 500 volts
- Ammeter of required Capacity
- Circuit breaker of required capacity
- Energy meter
- Capacitor of required capacity.
- Protection device for single phasing & reverse phasing (current sensing or voltage sensing)
- Selector Switch.

Now a days protection devices are available on the market which have an in-built system of prevention of dry run alongwith single phasing and reverse phasing protection. It is recommended that this device should be used along with the automation switch gear. The technical specifications of this device are given below:

#### Supply Voltage:

1. System : 220 – 240/380 – 415 – 440 V. AC +/- 10%@50/60 Hz.
2. Auxiliary : 110/240/380/415 – 440 V. AC +/- 10%
3. Output Relay : ICO 5 A at 240 V. AC
4. Trip setting :
  - i) Unbalance : 50% of motor current + 5% (fixed)
  - ii) Under current : 75% of set current +/- 5% (fixed)
  - iii) Overload : Above 120% of set current (fixed)
5. Trip type delay (seconds)
  - i) On phase failure : 4 to 7 (fixed)
  - ii) For dry running : Less than 2 seconds
  - iii) For overloading : As per inverse time characteristics
6. Resetting : Auto/manual/remote
7. CTS : As per full current load (20/40/.... )

### b. The Method of Installing the Protection Device in the System

*A line diagram of installing the devices in the system is given at Fig. 12.1*

In the diagram shown above the main supply 3 phase marked as RYB (colour based) will be controlled through proper rating of main switch or 3 pole circuit breaker. This 3 phase supply will pass through the device with CTS (Current Transformer Sensor) as shown in the diagram. In the diagram it has been indicated that 1st and 3rd phase (R&B) are passing

ANNEXURE - I

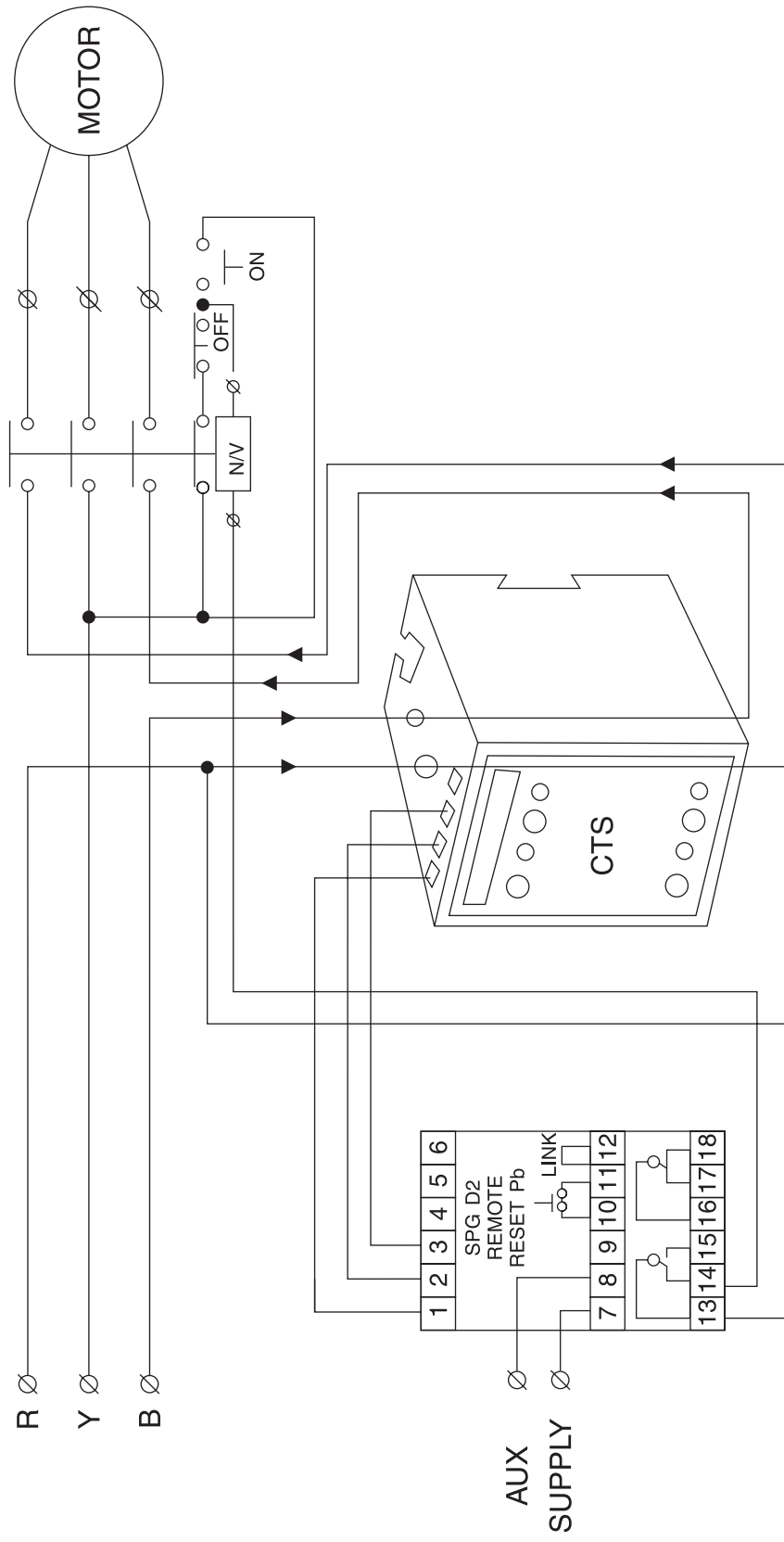


FIG. 12.1: AUTOMATION OF TUBEWELL

through the specified CTS and remaining 2nd phase (Y) is directly connected to no volt coil through relay. A link from phase (R) through the protection device is connected to 2nd point of the no volt coil. Hence after installation this device it will protect the pumping set running with unbalance of motor current, under current i.e. 75% of rated current (dry running condition) and overloading upto 120% of the rated current which may be single phasing also. This device is normally current sensing device.

In case the above mentioned device is not available or is not to be used due to some economic reasons then the conventional single phasing preventor can be used with the automation switch gear. This is normally voltage sensing device. The line diagram is shown at Fig. 12.2.

## ANNEXURE - II

CONVENTIONAL SINGLE PHASING PREVENTER  
(VOLTAGE SENSING TYPE)

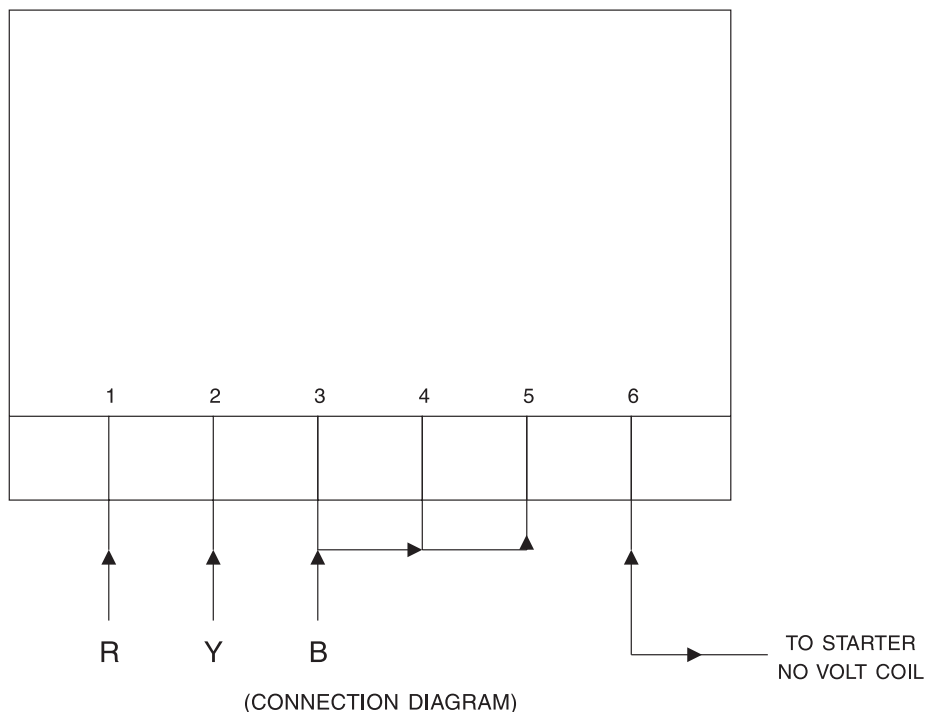
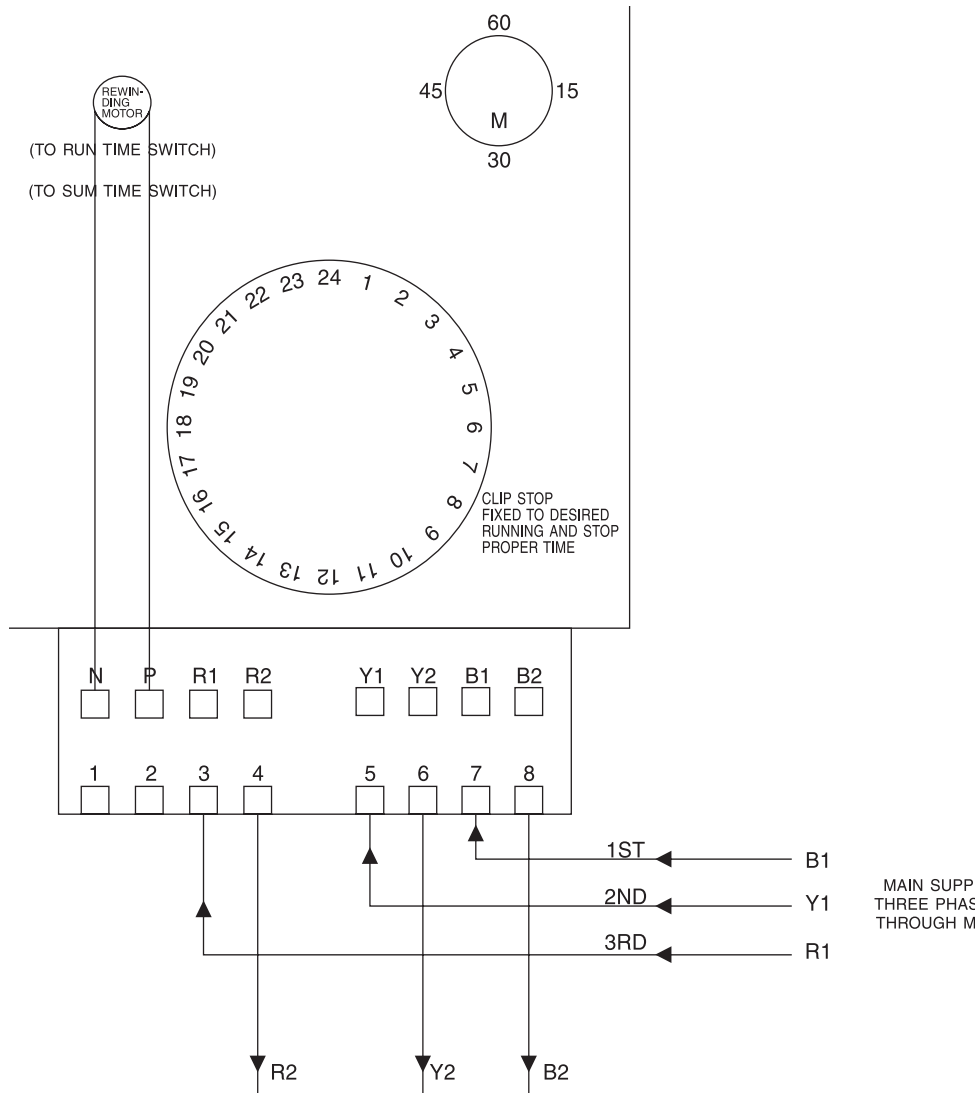


FIG. 12.2: USE OF PROTECTION DEVICE

### c. Use of Time Switch with Automation Electric Switchgear

Time switch (timer) is a device to control the operation of the pumping set as and when required. There are certain distribution areas where supply of water is done directly through tubewells. Wherever round the clock water supply is given in the area there is no need of time switch and only conventional electric panel as mentioned in earlier paras will be used. Wherever intermittent water supply for few hours is needed through tubewells then the installation of time switch is required alongwith the electric switch gear to control the operation of tubewell. This time switch will make and break the power supply to starter for a pre-set period of operation of the tubewell. The period

between the make and break is the period for operation of tubewell. The make and break period of operation is adjusted with the help of dogs provided on the operating time disc of the time switch. The time disc operated with the help of a energy spring which gets its energy by rewinding the spring. This rewinding system is automatic which is done when the power is available. The circuit diagram of installation of time switch is given at Fig. 12.3.



#### d. Selection of Type of Relay

It is recommended that whenever there are no or lesser power trippings starters preferably with manual reset relay should be used so that whenever pumping set trips due to single phasing, unbalancing or overloading then it should not start functioning again automatically. It should restart only after the checking by the electrician. He will reset the relay and start the pumping set. If any abnormal condition is there with the pumping set, he will again close the pumping set, put the remark in the log book and will intimate further the concerned supervisor about the probable cause of the abnormal condition of the pumping set.

Although automatic reset relays are available with the starters but for automatic operation of the tubewell manual reset relays are more beneficial. It has been proved practically that automatic reset relays result in more burning of motors in comparison to manual reset relays. However where power trippings are more, there the use of automatic reset relays may be considered to avoid the larger loss of water production.

### 12.4.3 Problems and Remedial Measures

Sr. No.	Problems	Remedial Measures
1	Whenever there is pumping set shut down due to overloading, single phasing or unbalancing of phases, normally the pumping set remains un-operational (due to manual reset relay) till it is checked and restarted by the electrician. This causes the loss in production of water.	Bulk meters for measuring the inflow at water collection point should be provided. By noticing the inflow rate the operator on duty at collection point must know that from how many tubewells he is getting that rate of flow and accordingly he should intimate the Engineer-Incharge concerned to take corrective measures.
2	Due to reverse phasing the pumping set remains un-operational till it is checked and restarted by the electrician. This causes the loss in production of water.	Bulk meters for measuring the inflow at water collection point should be provided. By noticing the inflow rate the operator on duty at collection point must know that from how many tubewells he is getting that rate of flow and accordingly he should intimate the Engineer, Incharge concerned to take corrective measures.
3	Due to lack of knowledge of the circuits it has been noticed that the electricians by pass the single phasing devices and connect the pumping set directly with the starter. This has resulted frequent burning of motors.	The electricians in charge for checking of tubewells should be given practical training about the circuit diagrams and the functioning of the all components of the automation switchgears. This should be followed by refresher courses after a period of two years.
4	Due to non-availability of spare parts in time, it has been noticed that electricians make direct connections with circuit breakers or ICTP switches thus operating the tubewells directly by circuit breaker/ICTP switches. This has resulted into more burning of motors and electrical accidents also.	Sufficient stock of all moving parts like contact points, no volt coils, contactors blocks, spare parts kits etc. be kept at the levels of Engineer incharge store.
5	Normally preventive maintenance is ignored and dust blowing is not done. This results in failure of automation devices.	There should be regular preventive maintenance as per recommendations of manufacturer. Dust blowing with the help of air blower should be a regular practice and it should be at least once a week. This should be done by the electrician. This will prolong the life of the switch gear.
6	Non-functioning of check valve (non-return valve) in the delivery side of the pump and non-functioning of NRV of pumping set may cause back flow of water of rising main into tubewell when pump set is not functioning. This condition also causes frequent burning of motors.	Both the non-return-valves, one of delivery side & another of pumping set should always be kept functioning & back flow of water into tubewell should not be allowed.

## **12.5 TELEMETRY AND SCADA SYSTEMS**

### **12.5.1 MANUAL MONITORING**

Normally the Managers of O&M of water utilities monitor levels in Service reservoirs, pressures and flows in a distribution system and on operation of pumps such as hours of pumping and failure of pumps and monitor water quality by measuring residual chlorine. The manager usually uses the telephone line or wireless unit to gather the data, uses his discretion gained with experience and takes decisions to ensure that the system is operating with required efficiency. Manual collection of data and analysis may not be helpful in large undertakings if water utilities have to aim at enhanced customer service by improving water quality and service level with reduced costs. This is possible if the management acquires operational data at a very high cost.

### **12.5.2 TELEMETRY**

The inspection, monitoring and control of O&M of a water utility can be automated partially through telemetry. Telemetry enables regular monitoring of the above data on real time basis and the data is provided to anyone in the organization who can review the data and take a decision. In a Telemetry system probes/sensors will be used which will sense and generate signals for the level, pressure and flow in a given unit and transmit the signals by radio/by Telephone. Normally radio link is used and telephone line with modem is used as spare communication. Microwave satellite or fiber- optic transmission systems are also used for data transmission. The water pumping stations may communicate via a cable buried with the pipe. However there may be locations where the main power may not be available and hence solar panels with a battery charger are used to power the remote terminal unit (RTU) and the radio. In urban areas RTU s can communicate on cell phones and or packed radio networks. For remote locations satellite technology is also available.

#### **12.5.2.1 Data for collection by telemetry**

The data includes levels in Service reservoirs, pressures and flows in a distribution system, flows/quantity of delivered into a SR and data on operation of pumps such as Voltage, amperes, energy consumed, operating times and down times of pumps and chlorine residuals. In a telemetry system up-to the minute real time information is gathered from remote terminal unit located at the water treatment plant, reservoir, flow meter, pumping station etc. and transmitted to a central control station where the information is updated, displayed and stored manually or automatically.

#### **12.5.2.2 Processing data from telemetry**

The meter readings from reservoirs is useful information for managing the distribution system and helps in preventing overflow from reservoirs. However the effectiveness of Telemetry in pumping operations is dependent on reliability of instrumentation for measuring flows, pressures, KWh meters, etc. Standard practice is to calculate pump efficiency and water audit calculations on a monthly basis. Telemetry can also be used to supervise water hammer protection system wherein the pump failures are linked to initiate measures to prevent occurrence of water hammer.



### **12.5.3 SCADA SYSTEMS**

Instead of manual review of data collected by telemetry and initiating action manually, if telemetry is extended to include actions based on the data for remote control of pumps and other equipment then such a system is known as SCADA. Supervisory Control and Data Acquisition (SCADA) is a computer aided system which collects, stores and analyses the data on all aspects of O&M. The operating personnel can retrieve the data and control their operations and sometimes the system itself is programmed to control the operations on the basis of the acquired data. SCADA enhance the efficiency of the O&M personnel who are better informed about the system and hence are in full control of the operations. Whether in a telemetry system or a SCADA system up-to the minute real time information is gathered from remote terminal unit located at the water treatment plant, reservoir, flow meter, pumping station etc. and transmitted to a central control station where the information is updated, displayed and stored manually or automatically. In a SCADA system the information is linked to a supervisory system for local display, alarm annunciation etc. which may be linked to remote control of pumping operations or operation of valves etc.

#### **12.5.3.1 Data collected in SCADA**

SCADA systems will have probes/sensors which will sense and generate signals for the level, pressure and flow in a given unit and transmit the signals for storage and analysis in the computer. The signals are transmitted by radio, by Telephone, microwave satellite or fiber-optic transmission systems. The signals transmitted are stored as data, analysed and presented as information. SCADA systems can include the network diagrams of the distribution system of which detailed sketches of a particular area can be viewed by the operator if necessary to observe the current operating data such as flow, pressure, level or residual chlorine. SCADA systems in Water distribution are programmed for collection and processing of following information.

- to monitor levels in Service reservoirs, pressures and flows in a distribution system
- to monitor and store data on levels in SRs, or flows/quantity of delivered into a SR or pressures of distribution system and generate alarms for threshold values of levels, flows and pressures to initiate operation of valves and pumps
- to monitor and store data on operation of pumps such as Voltage, amperes, energy consumed, operating times and down times of pumps
- to measure and record chlorine residuals and generate alarms at thresh hold values of residual chlorine in the distribution systems.

#### **12.5.3.2 Analysis of Data from SCADA**

SCADA systems can be designed to analyse the data and provide daily, weekly, monthly and or Annual reports or schedules. It also helps in monitoring the inventories on spare parts and plan requirement of spares. Responses for different scenarios such as seasonal changes or any emergencies can be programmed into SCADA. The information stored in the SCADA can be easily retrieved and analysed. Typical information that could be generated in the system include : Consumption patterns linked to the weather conditions, plots on pressures against

flows, electrical energy consumption linked to consumer demands, record on system leaks, record on pump failures, areas with less chlorine residuals etc.

### **12.5.3.3 Limitations of SCADA**

Before installing a SCADA the utility staff should visit facilities with SCADA and discuss with the utility managers and then decide the scope of SCADA to be provided in their utility. The objective of SCADA should be to make the job of operator easier, more efficient and safer to make their facilities performance more reliable and cost effective. There is no doubt that SCADA enables better capacity utilization and help in improved service levels at low operating cost. The following limitations are to be kept in view before embarking on an ambitious program of providing SCADA. SCADA designing calls for careful planning and requires a phased implementation, particularly dependent on appropriate training of utility staff and their willingness to adopt the new technology.

Availability of power supply is very essential to efficient functioning of the system. Wherever possible the RTU for flow meter or pressure sensor is provided power from electricity mains via a battery that acts as a buffer in case of mains failure. There may be metering locations for flow and pressure sensors without any source of power close by. In such cases Solar power may be one alternative. Initially installations at such locations may operate well but they are always subject to poor after sales service by vendors, vandalism and theft.

Ultimate improvement in water supply distribution system cannot be achieved through advanced application of technology like SCADA. The utility staff should have reached a reasonable level of managerial capabilities even with conventional methods of monitoring and control by adopting a holistic approach when the SCADA may further enhance their capabilities; but SCADA by itself is not the answer for poor or inefficient management.

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## 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

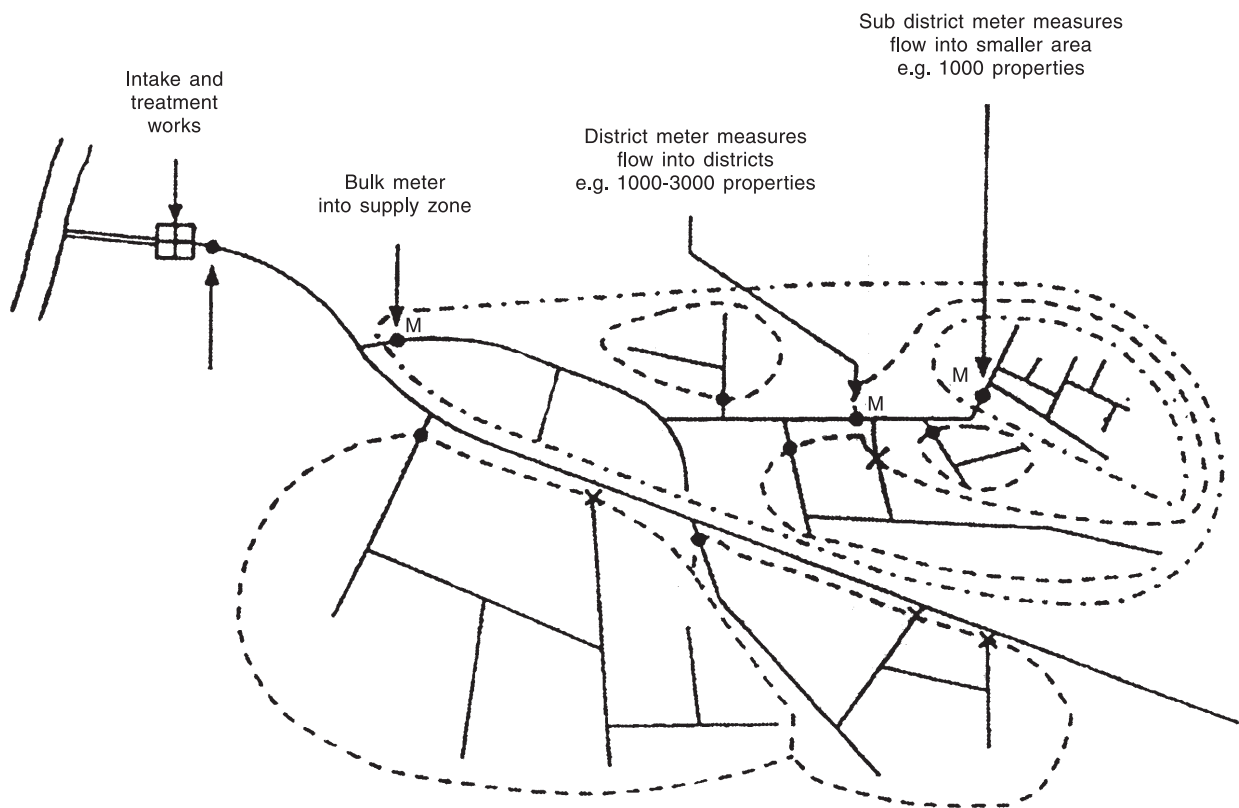
The size of the meter can be determined by:

- 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

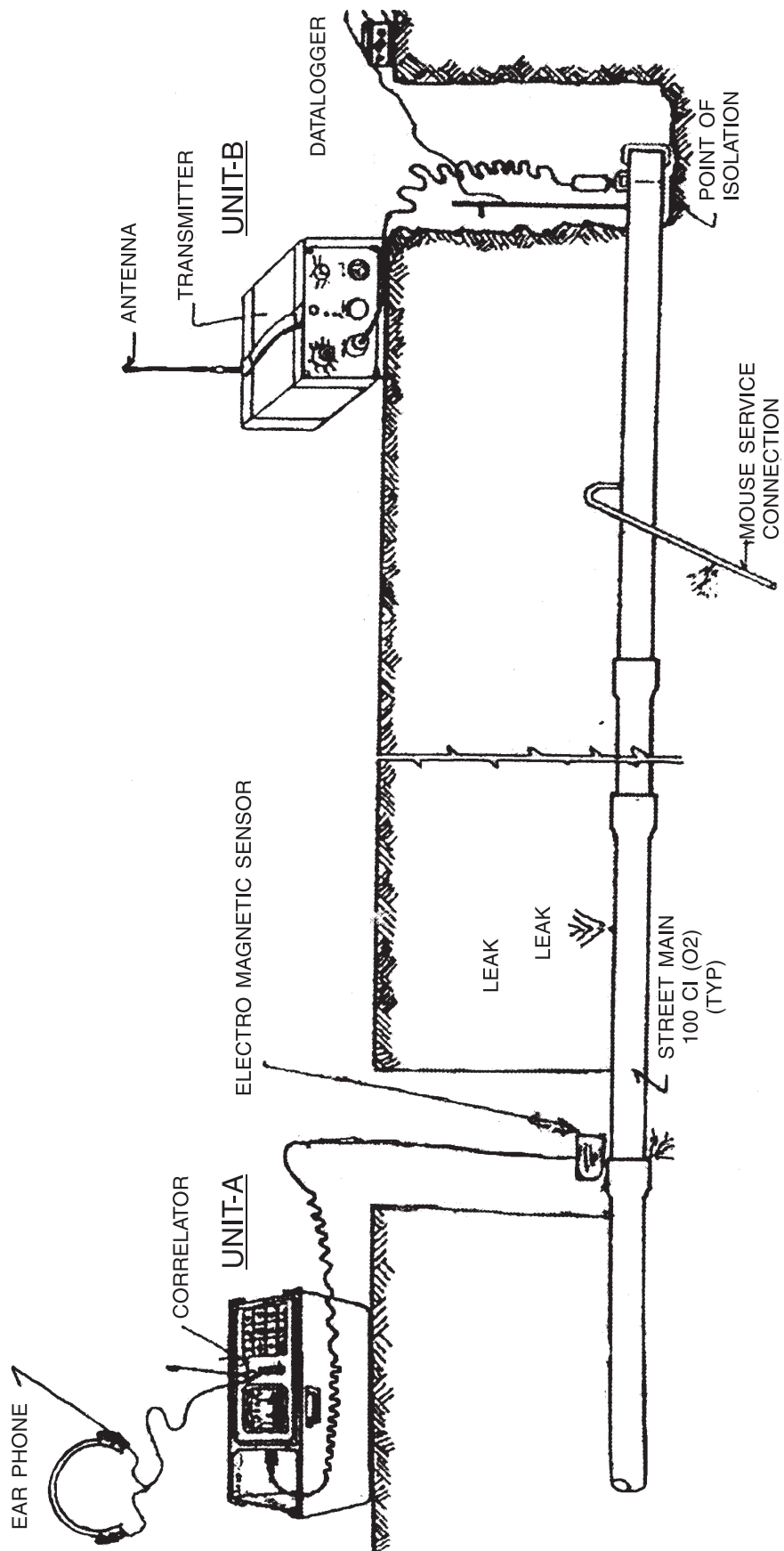
To minimize the possibility of human error, operator involvement in calculation is limited to merely operating the measurement "start key". This initiates the measurement procedure and automatically determines the leak position on the integral display, combined with the measurement curve and the operating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

## **15.11 ASSESSMENT OF LEAKAGE**

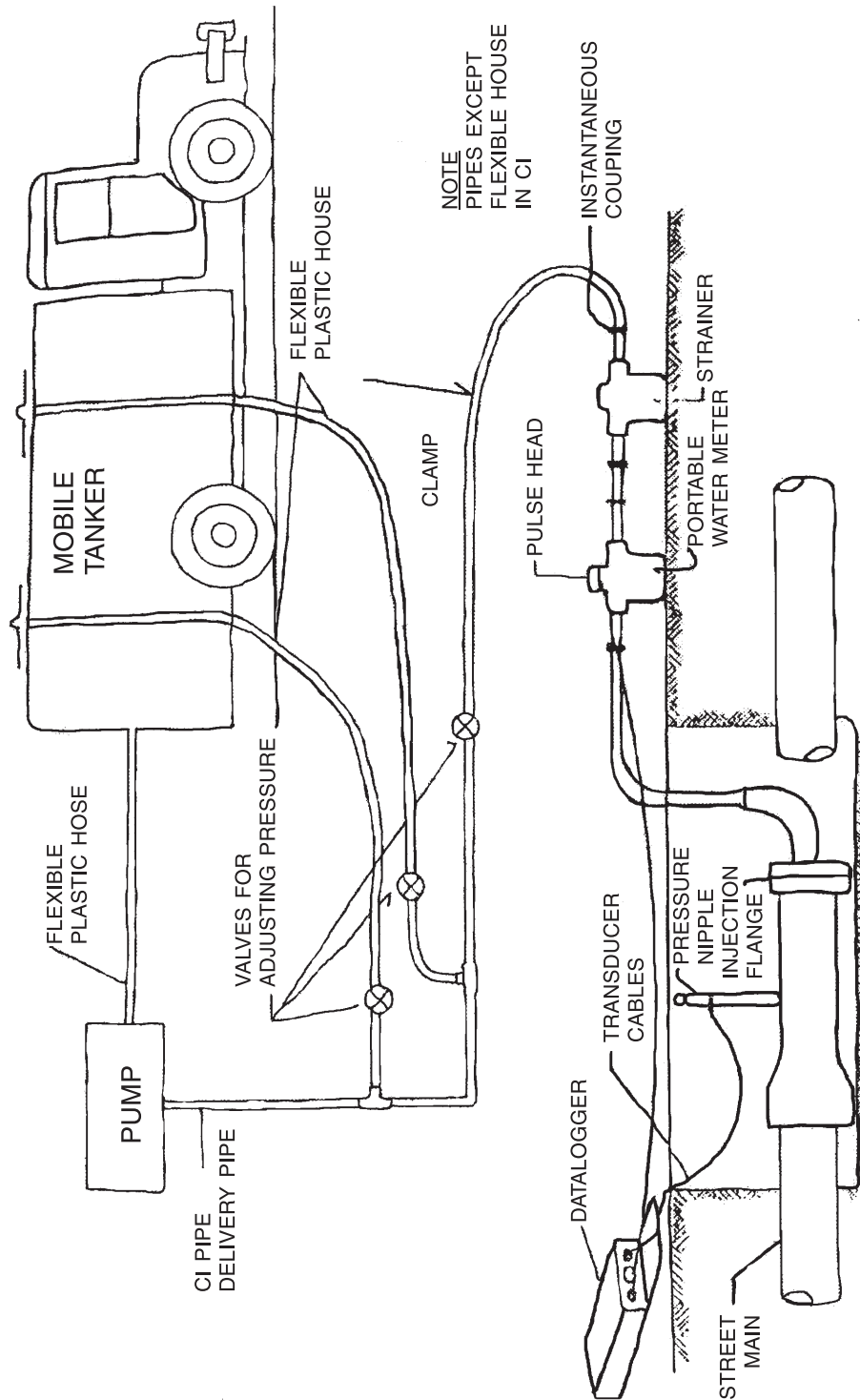
To conduct tests for assessment of leak the following equipment are needed:

- 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**

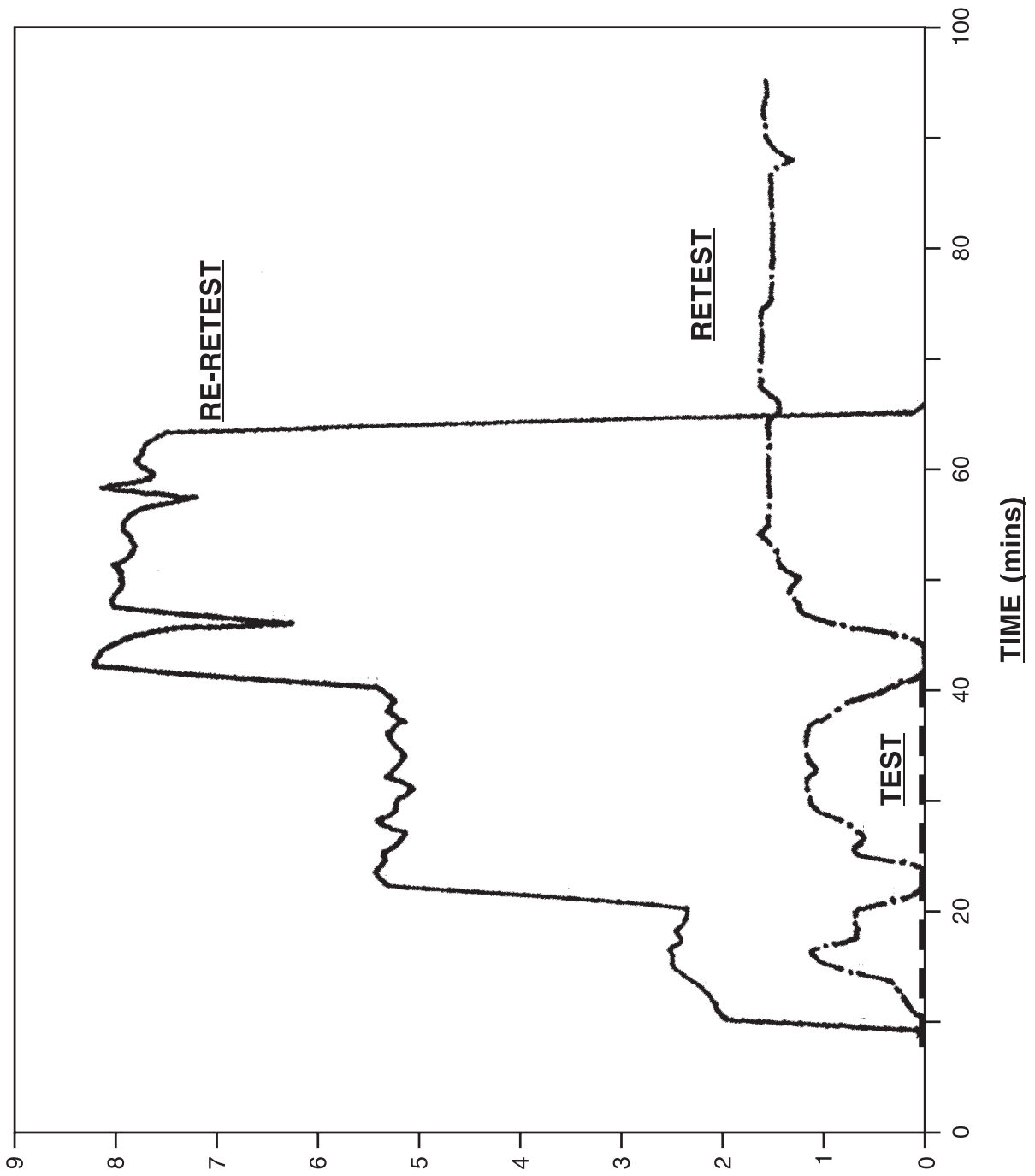
The term district metering is used to describe the method whereby flow meters are installed on all major supply lines and strategic points within the distribution system. The meters are then used to monitor the overall performance of the system establishing average daily flows into various districts.

District meter areas ideally consists of 2000 to 5000 properties.

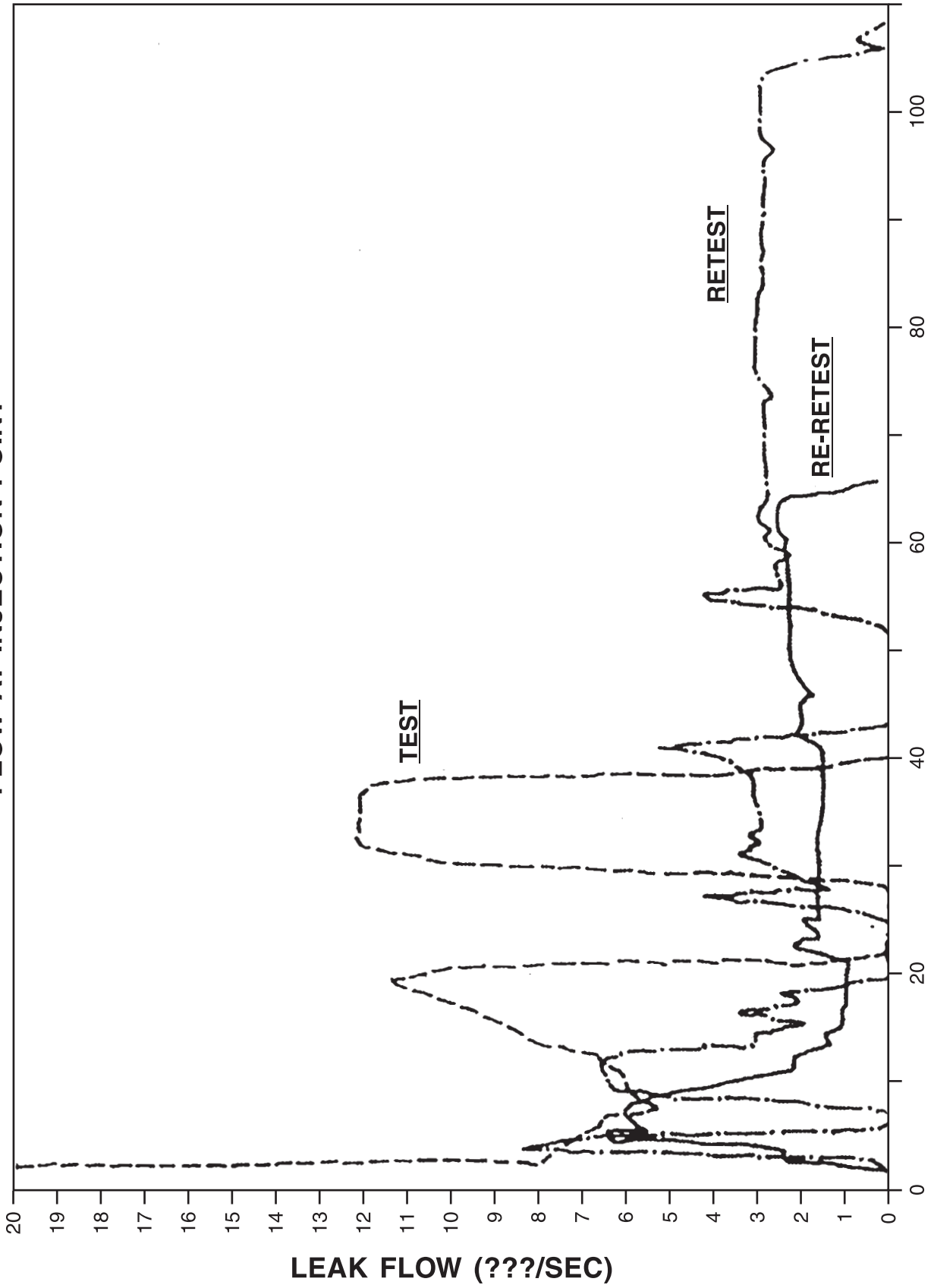
Size of the district meter should be such that it is capable of recording night flow without loss of accuracy and also must be capable of supplying peak flow without introducing serious head loss.

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.

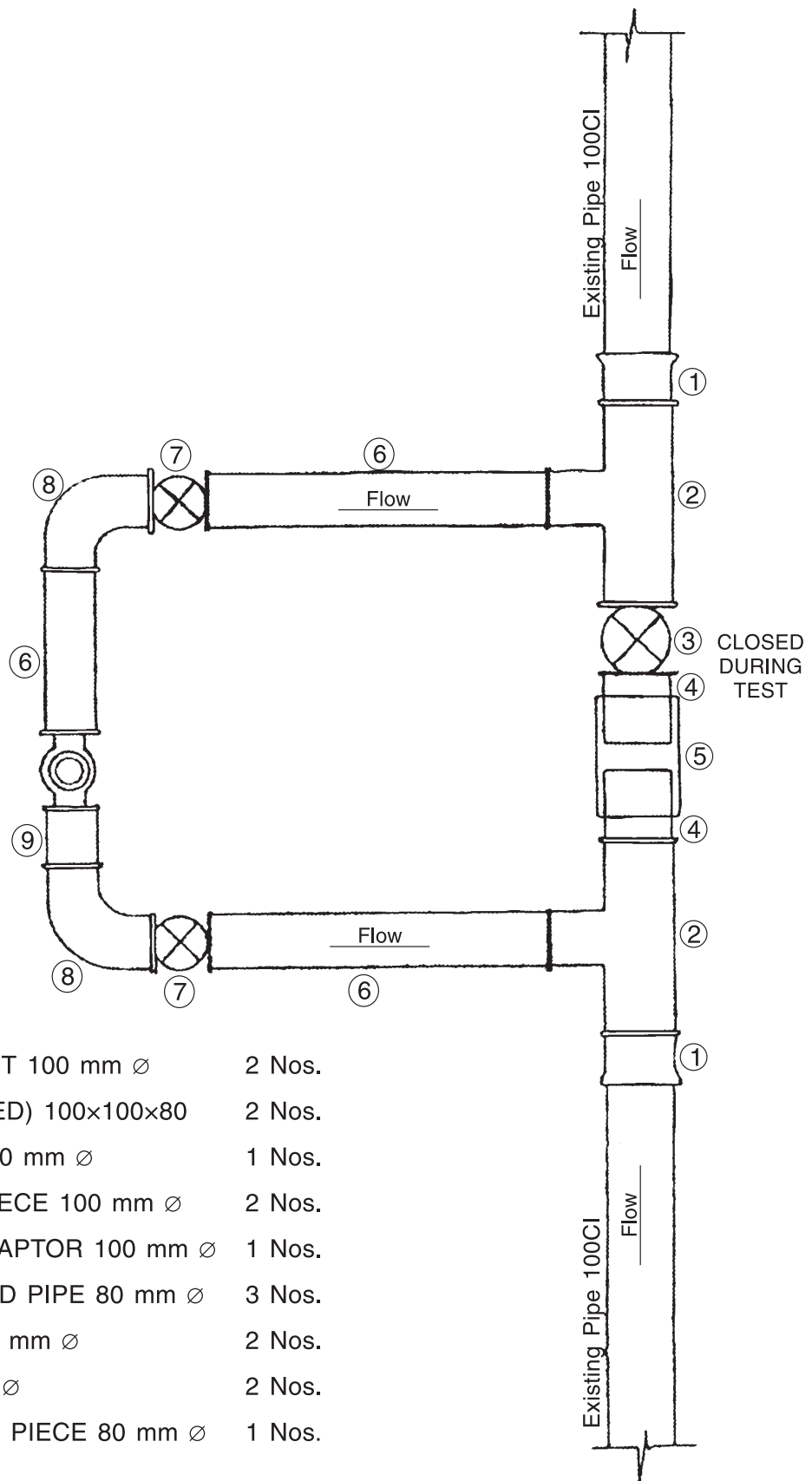
## **15.12 ACCEPTED NORMS FOR EXPRESSION OF LEAKAGE**

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

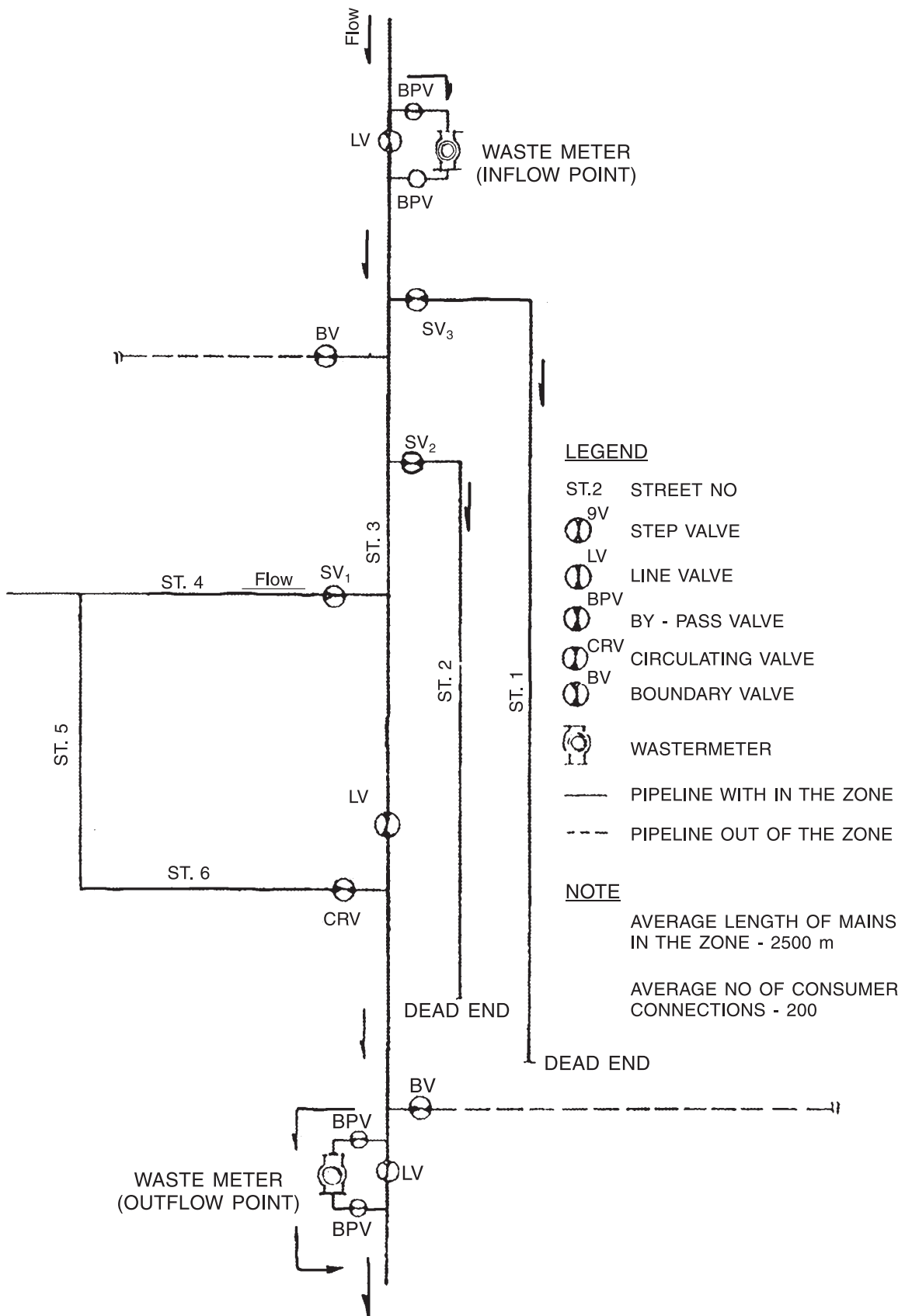
- i) Litres/household/hour for urban areas and for whole systems.
- ii) Litres/Kilo Meter of main/hour for rural areas.

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. |



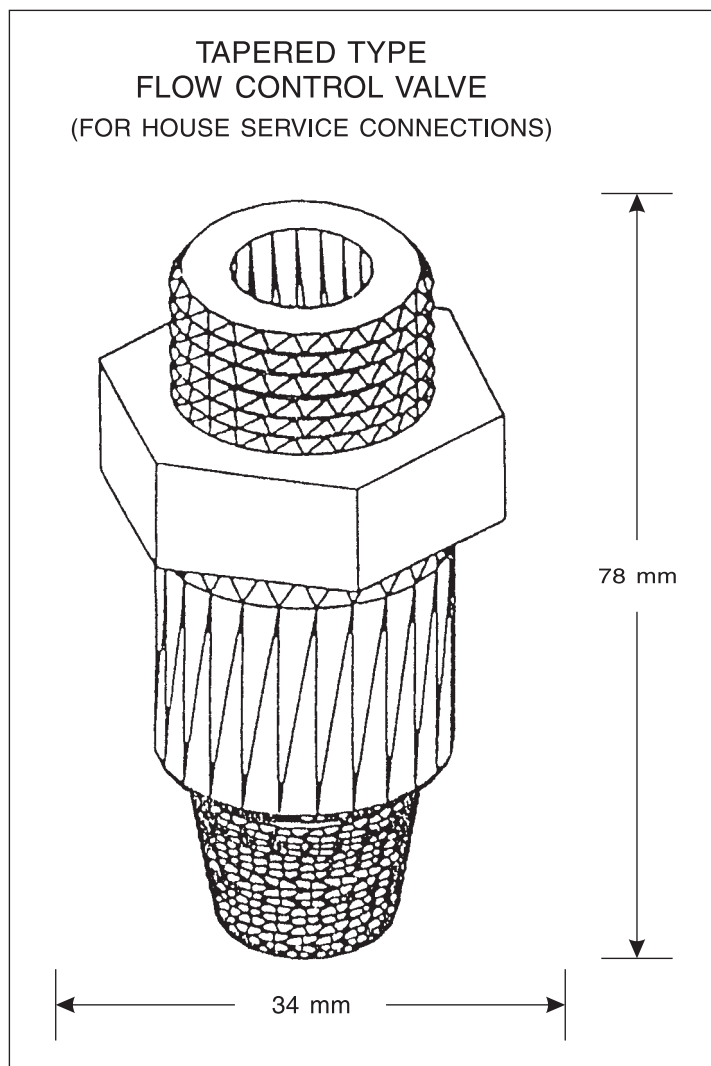


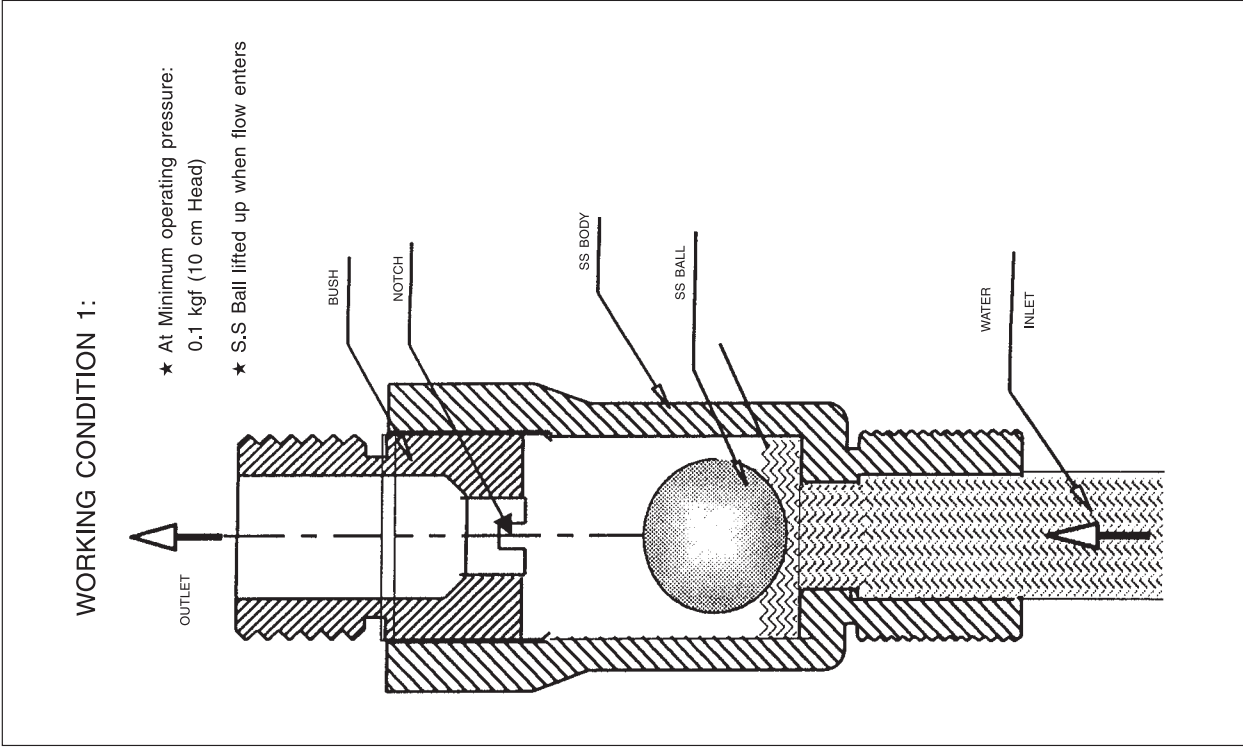
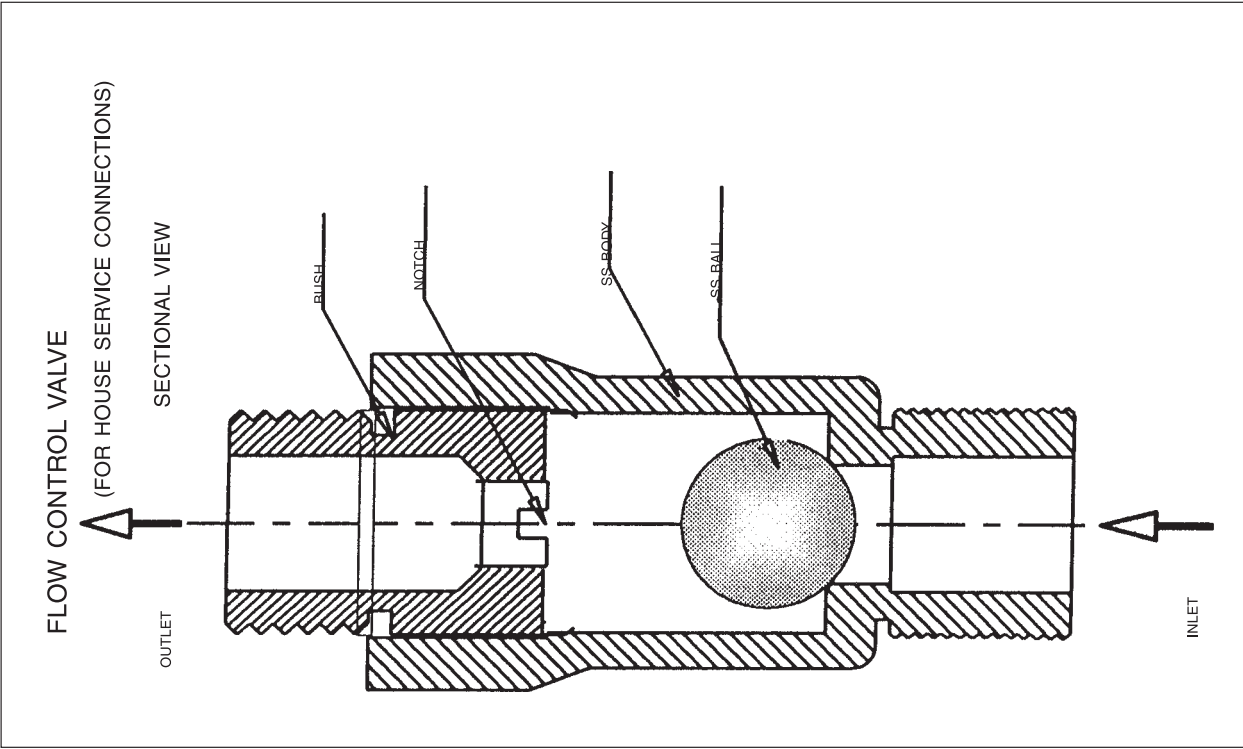
### 15.13 PREVENTION OF UFW IN CONSUMER CONNECTION

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.

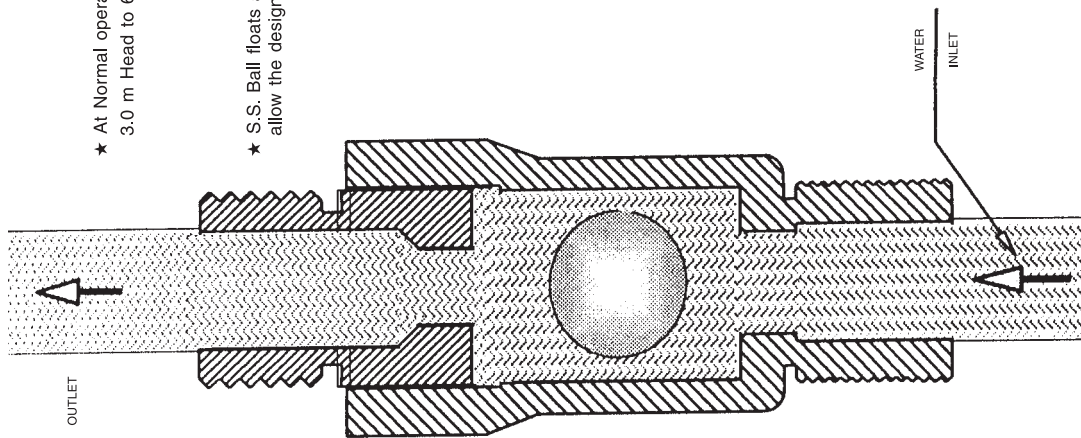
This arrangement is simple economical & free from tampering. As the insertion of this device may not be agreeable to the residents, the process of installation of this device needs to be accomplished tactfully.





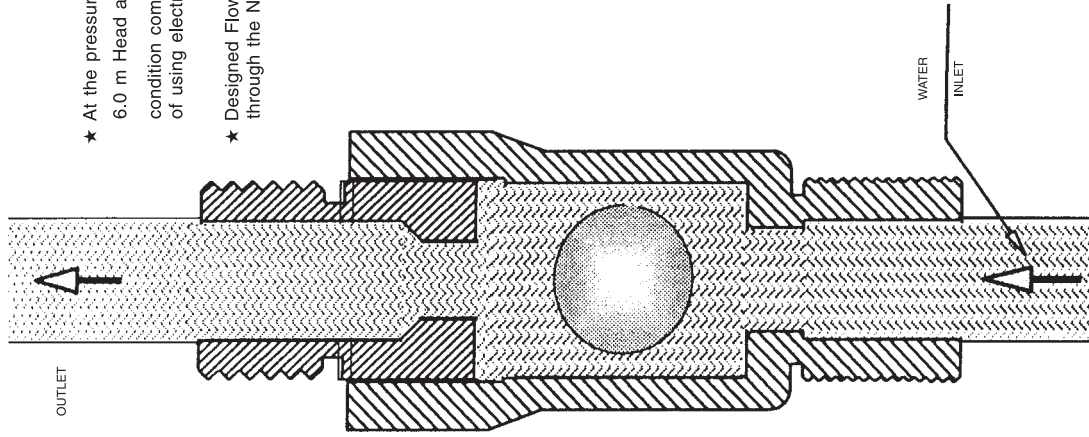
WORKING CONDITION 2:

- ★ 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

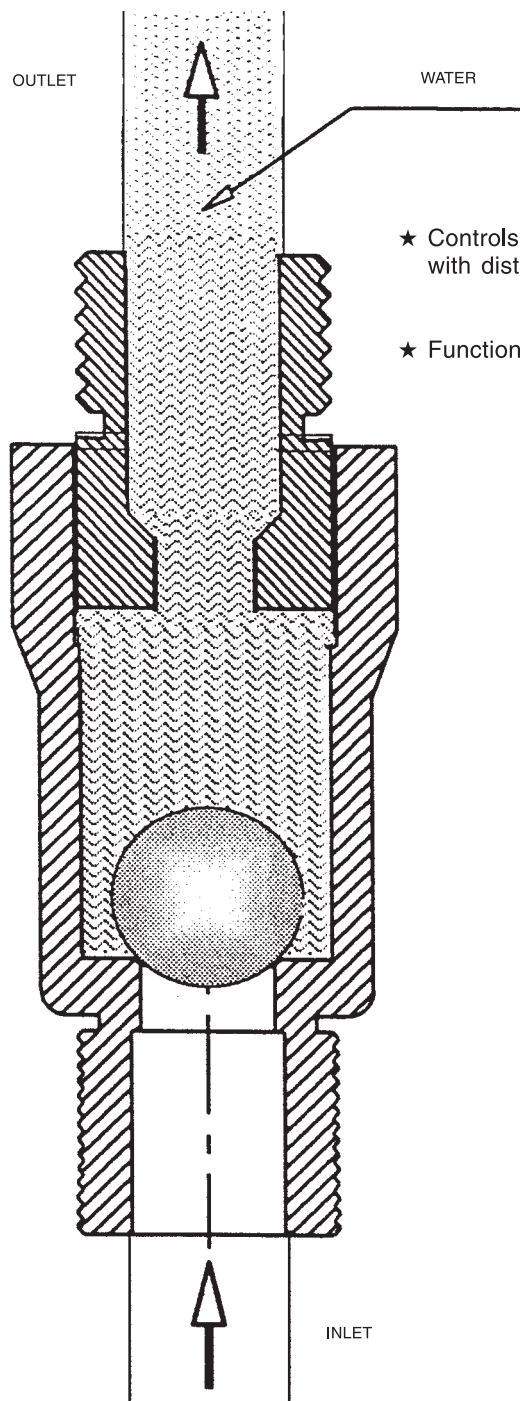


WORKING CONDITION 3:

- ★ 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



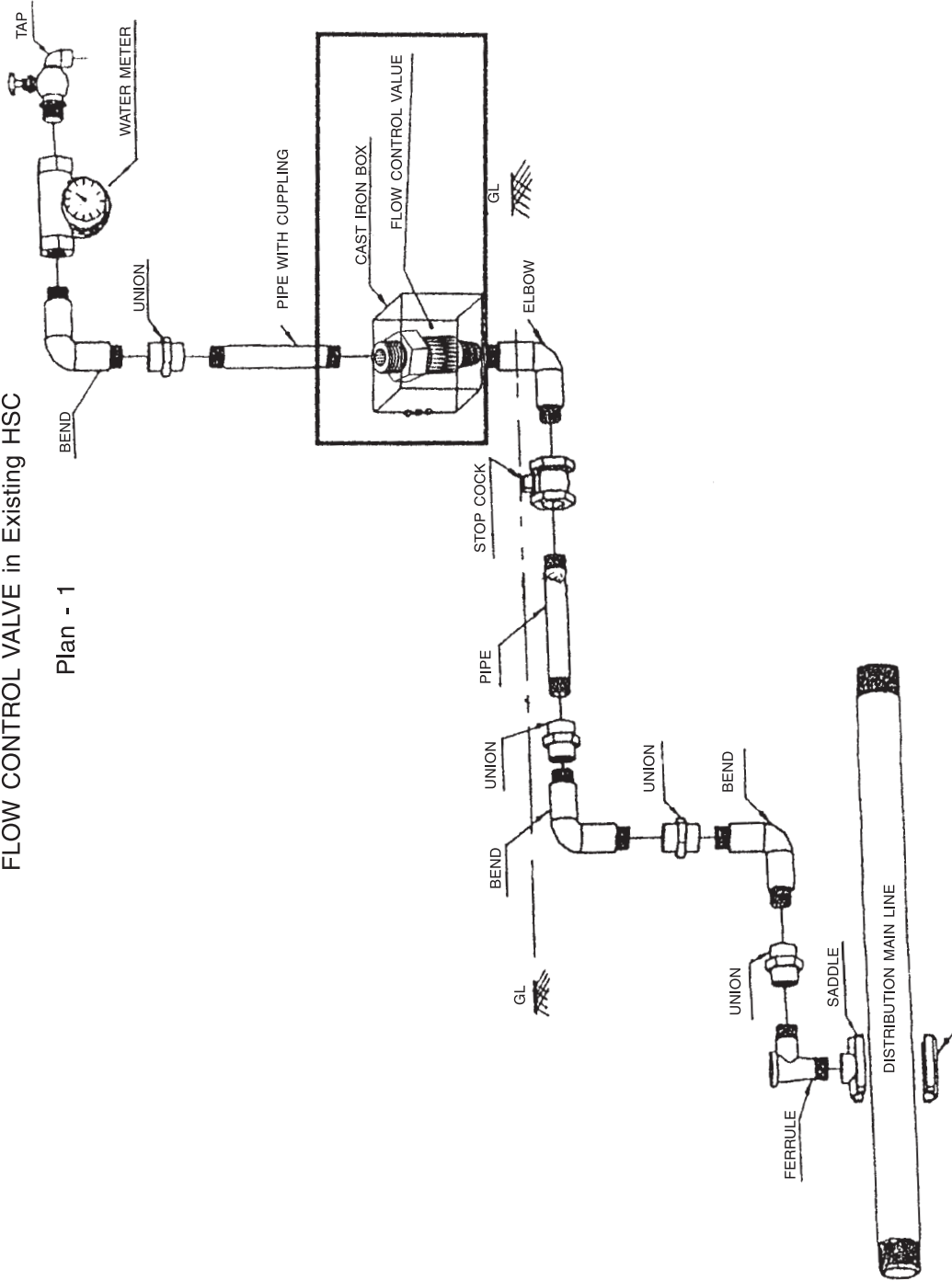
WORKING CONDITION 4:



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

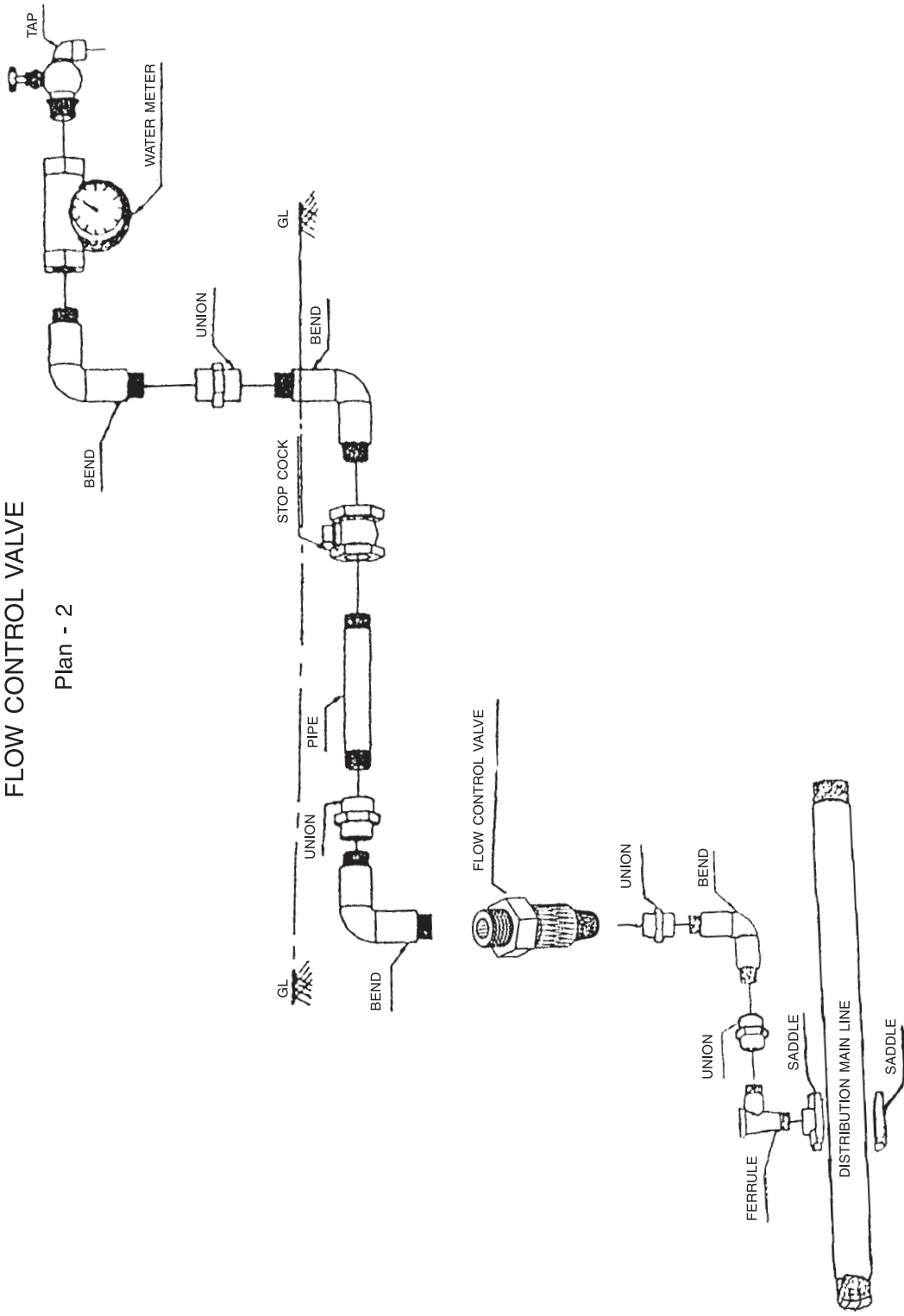
Fixing Details for MALE TYPE STAINLESS STEEL  
FLOW CONTROL VALVE in Existing HSC

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**

	<b>Nature of Complaint</b>		
	<b>Defective Water Supply</b>	<b>Water Leak</b>	<b>Water pollution</b>
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  $367.34 \times 0.97$  i.e. 356.32 kW and  $551.01 \times 0.975$  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  $178.16 \times 0.86$  i.e. 153.22 kW and  $179.07 \times 0.86$  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.

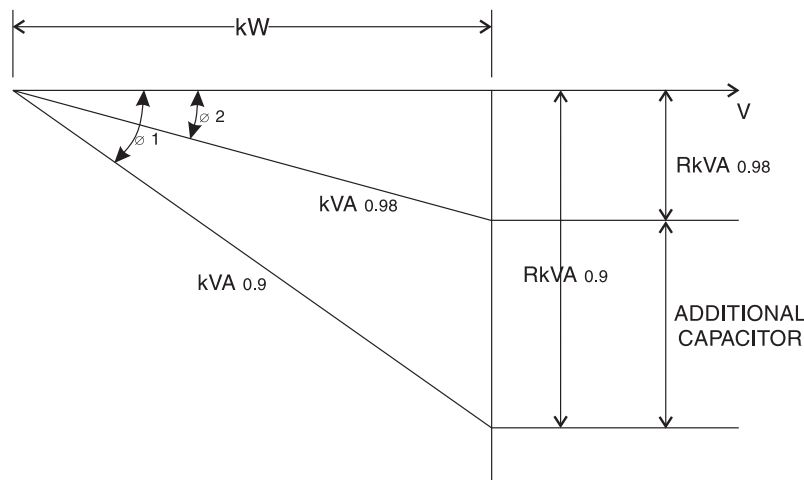


FIG. 16.1: CORRECTION OF POWER FACTOR

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

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

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

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

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

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

As copper losses  $\propto$  (current)<sup>2</sup>,

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

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.

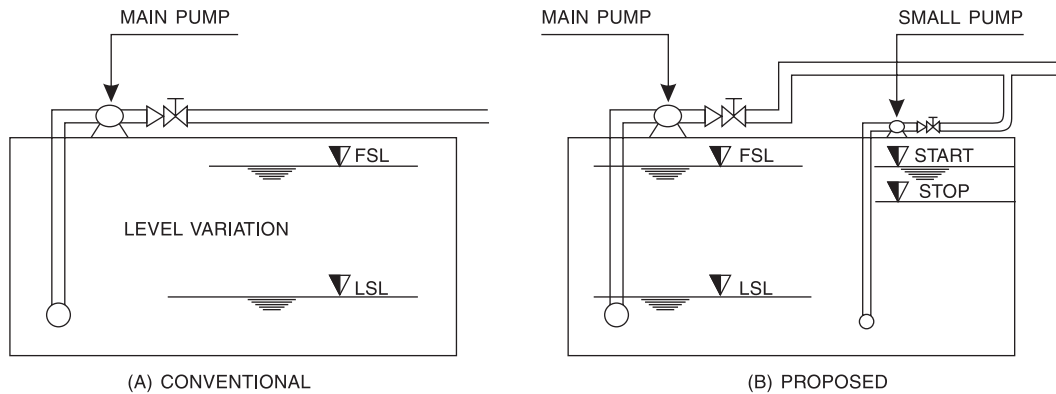


FIG. 16.2: CONVENTIONAL AND PROPOSED PUMPING INSTALLATION IN SUMP

- 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.

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

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

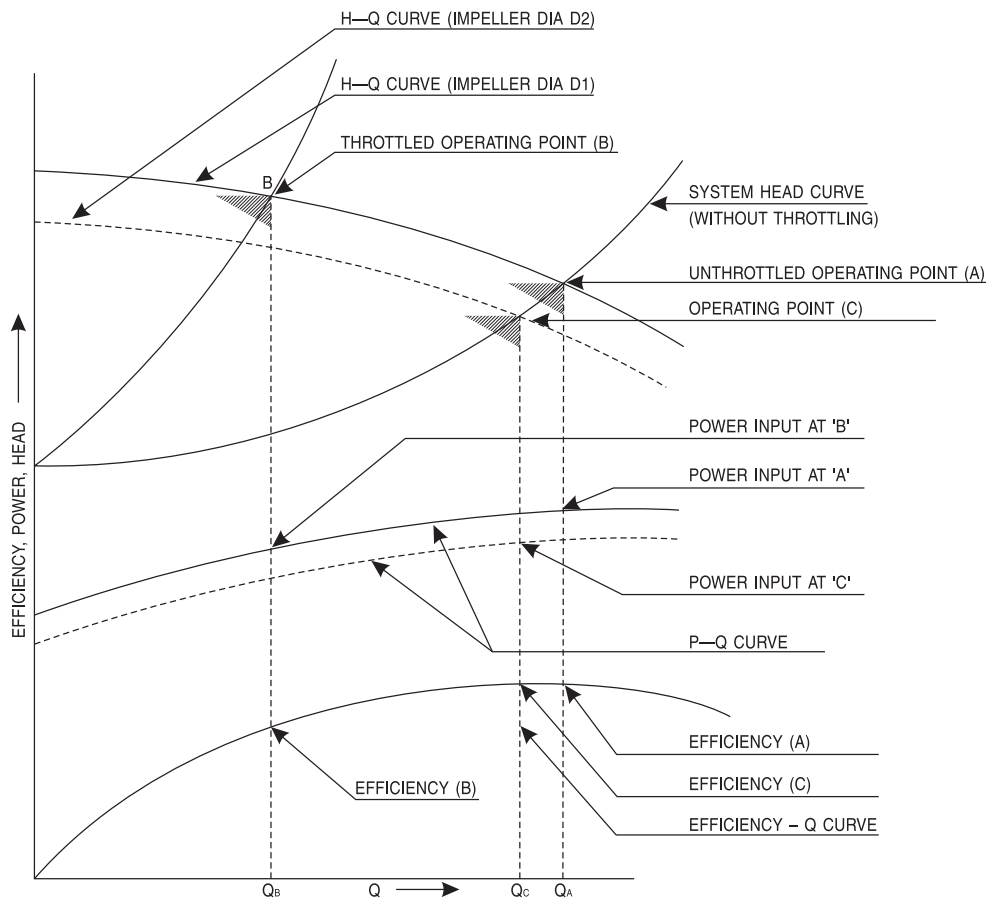


FIG. 16.3: EFFECT OF THROTTLING AND TRIMMING IMPELLER

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.

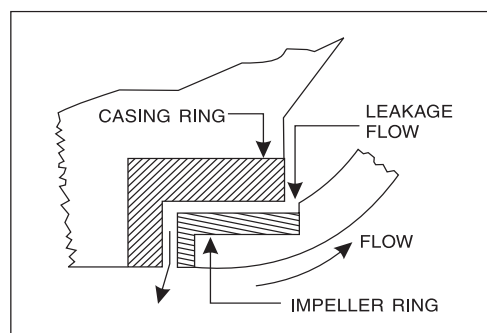


FIG. 16.4: A TYPICAL WEARING RING

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

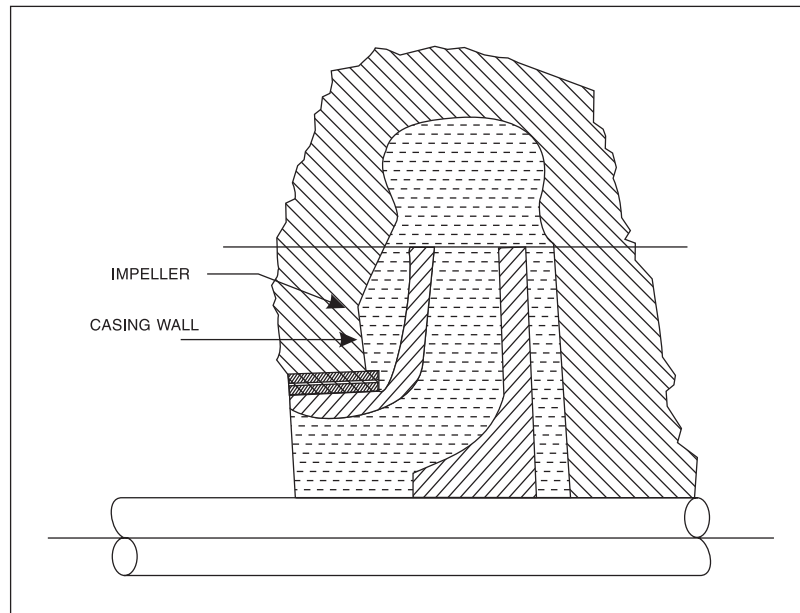


FIG. 16.5: IMPELLER AS A DISK

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, m<sup>3</sup>/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.

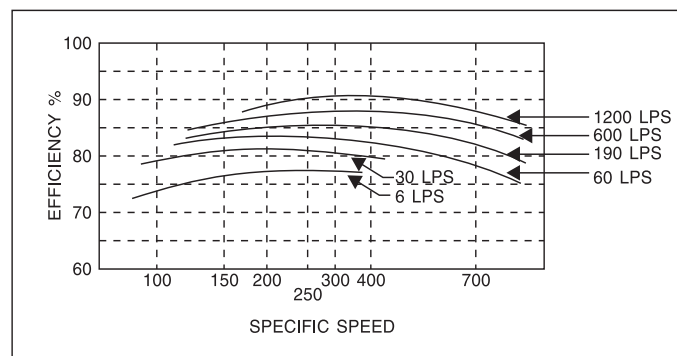


FIG. 16.6: PUMP EFFICIENCY VERSUS SPECIFIC SPEED & DISCHARGE

#### 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.

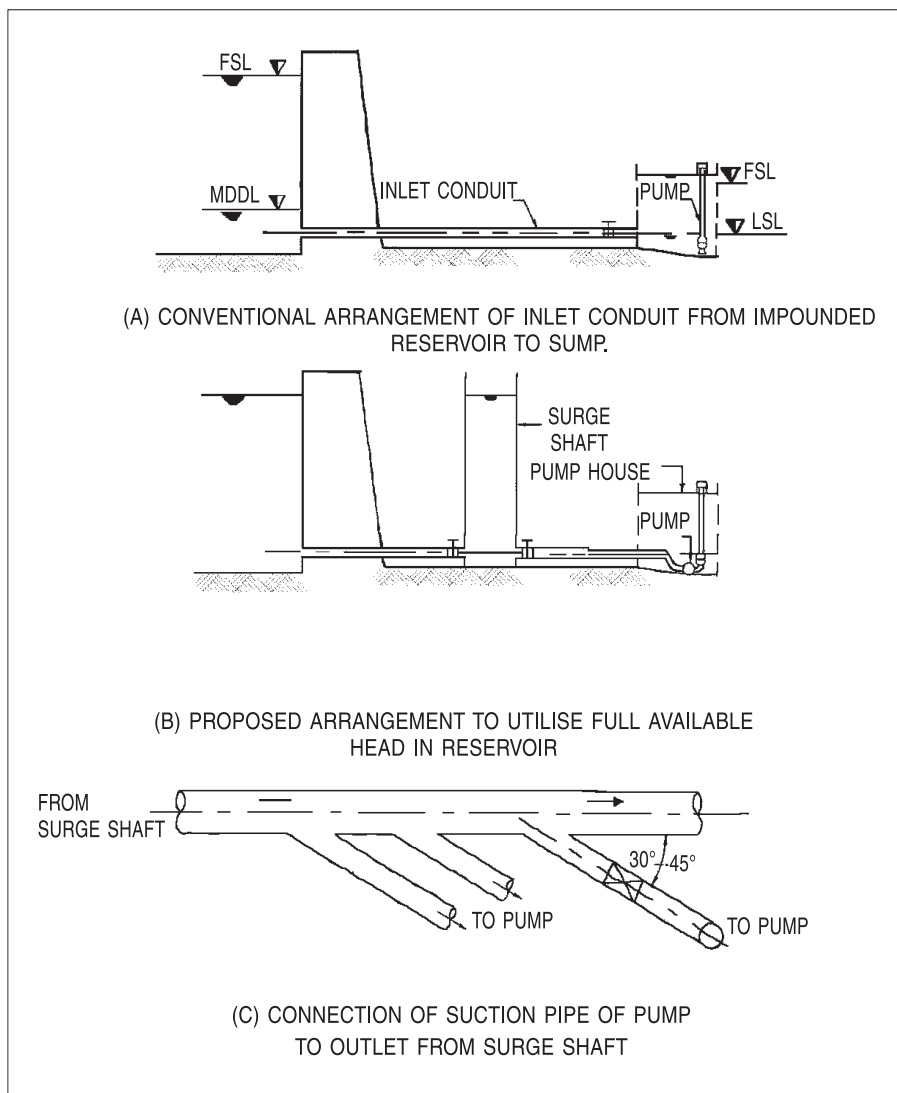


FIG. 16.7: INTAKE FROM IMPOUNDED RESERVOIR

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.

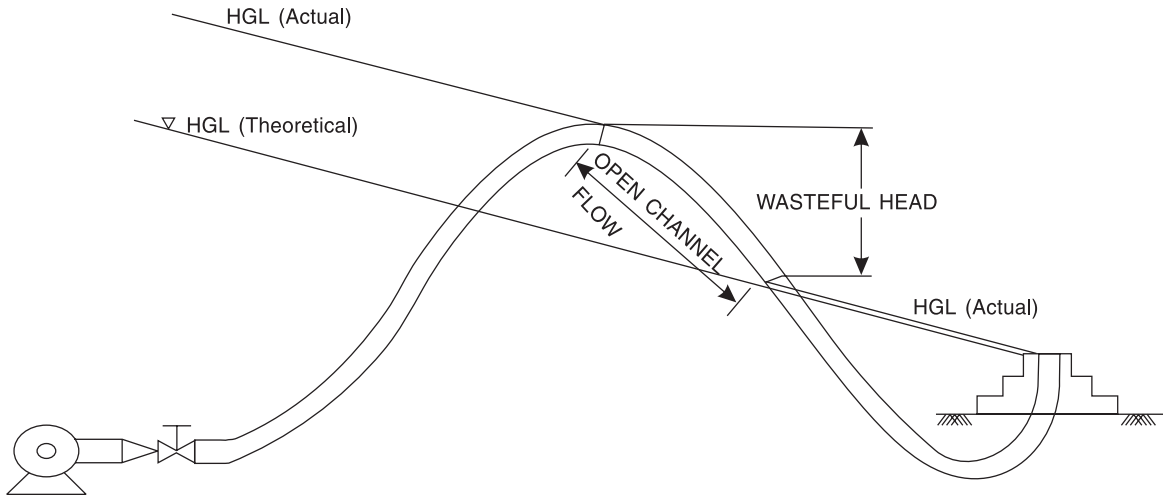


FIG. 16.8: HGL CUTTING AT HUMP OPEN CHANNEL FLOW

### 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.

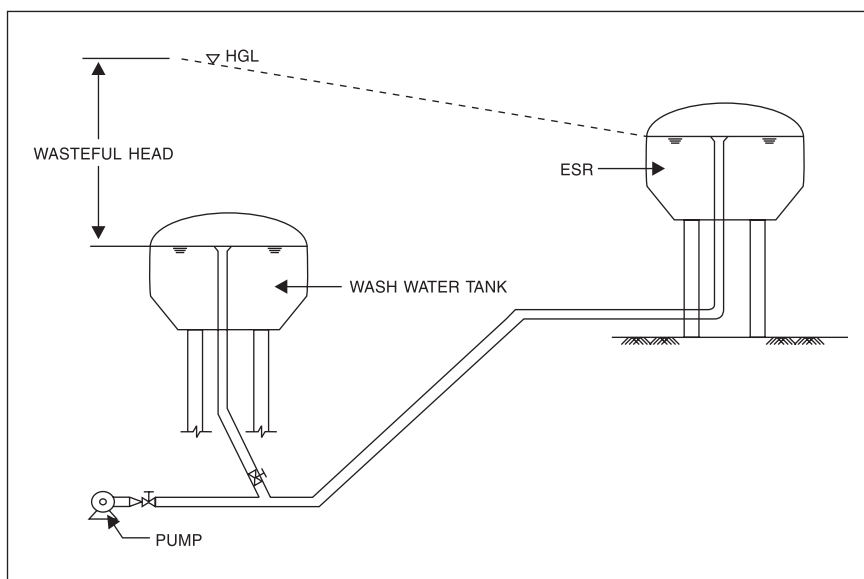


FIG. 16.9: FEEDING WASH WATER TANK FROM PURE WATER RISING MAIN

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	• Plant Capacity	300 ML/day
	• Wash Water quantity required	2.5 %
		i.e. 7.5 ML/day
	• Head on main pump	33 m
	• Efficiency of main pump	0.75
	• Head for wash water pump	15 m
	Therefore, wasteful head	(33-15)
	Energy wasted per day	18 m

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

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.

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## CHAPTER 17

# HUMAN RESOURCES DEVELOPMENT

### 17.1 NEED FOR HUMAN RESOURCE DEVELOPMENT

Adequate and safe drinking water supplies and appropriate sanitation facilities form a sound basis for improvement in community health. Maximum health benefits will be achieved only when the water supply and sanitation facilities operate continuously and to full capacity in conformity with the acceptable standards of quantity and quality. If the O&M tasks are to be carried out effectively and efficiently there is a need for strengthening the technical, operational and managerial capabilities of the O&M managers and staff. The management orientation shall change and the management shall become service oriented and be prepared to run the organisation on a commercial basis. The management must be able to motivate the staff to perform better. It is essential that the organization responsible for O&M has well qualified, experienced, efficient staff. Human resource development through training programmes, career plans and adequate salary system should be given special emphasis to improve the knowledge and skills of the staff. This objective is achieved by first developing proper job description and undertaking training schemes for the O&M managers and personnel. This chapter covers the following topics on Human Resources Development in water supply sector:

- Job description
- Training needs assessment
- Training for capacity building
- Training for refreshing skills
- Training of trainers
- Training in outside institutions
- Long term training needs
- Short term training needs
- On-the-job training
- Quantification of training
  - ◆ Categories
  - ◆ Number
  - ◆ Frequency
  - ◆ Duration

- Training Schedule
- Yearly programme
- Institutions
- Training budget

## **17.2 JOB DESCRIPTION**

### **17.2.1 CATEGORIES OF O&M STAFF**

The O&M function is performed by (a) operating staff and (b) supervisory staff. While the former actually runs the system, the latter monitor the operations and provide managerial support. The O&M staff should know the procedures for routine tasks to be performed by them and supervision and inspection managers should know the checks and inspections to be carried out by them at specified intervals to monitor and evaluate the status of operation and maintenance. The supervision or inspecting officers have to ensure that the operation and maintenance staffs perform their assigned duties promptly and properly. While in most of the cities, a large work force has been already created over a number of years and is being used for O&M of the systems; the suitability of skills and experience has not necessarily been tested.

### **17.2.2 JOB DESCRIPTION**

The managers of water utilities deal with planning, organization and finance in water supply and sanitation. They will also be required to formulate programmes and implement activities aimed at improving the effectiveness of operation and maintenance practices. This job description is quite general in nature and the water utilities should have well defined duties and responsibilities at various levels of employees.

As a first step to preparation of job descriptions, an O&M plan or programme containing procedures to be adopted or actions to be taken is prepared for each piece of equipment in the system and the person to carry out this action is to identify. The job description of operating personnel shall clearly define the limits up to which these personnel can carry out normal maintenance. The job description of the Supervisor/Manager shall include the requirement that they shall ensure that the operating personnel conform to these limits and thus ensure the safety of the equipment. (Sample job requirements are given in Annexure-17.I).

## **17.3 TRAINING NEEDS ASSESSMENT**

### **17.3.1 TRAINING**

Training is a planned process to modify attitude, knowledge or skill through learning experience to achieve effective performance in activity and to develop abilities of the individual to satisfy the current and future needs of the organization.

The personnel who are already available or chosen to carryout the actions contained in the O&M programme may have to be trained through special courses or by “on the job training” to ensure that these personnel are thoroughly trained to carryout the actions listed in the plan of maintenance. This training is essential to prevent experimentation by operating

personnel to meddle with equipment since often these operating personnel may not be capable to take up the required maintenance. On the job training is preferred to classroom training. The supervisors can be trained initially; they can later train their operators. A systematic plan of action of any training programme include:

- Identification and assessment of the need for planned training.
- Defined training objectives.
- Appropriate strategy for training.
- Provision for assessing effectiveness of training.

### **17.3.2 TRAINING NEEDS IDENTIFICATION**

#### **17.3.2.1 Objective of Training Needs Identification**

The objectives of training needs identification are:

- To identify a profile of the training needs and interests of the employees.
- To gather information on the climate, culture and communication links of the work place.
- To make recommendations for a training initiative that would be the basis for a strategic plan for employee development.

#### **17.3.2.2 Process of Identification of Training Needs**

The basic process of identifying training needs involves the following steps:

- Determine what is required or expected in the job.
- Determine the degree to which this requirement is being met.
- Determine whether training can bridge the gap between what is required in the job and the present knowledge, skills, attitudes or behaviour of the employees.

#### **17.3.2.3 Data Collection**

Data on the assessment of training needs can be collected in the following ways:

- Discussions with the officials and employees, supervisors and top management.
- Observing the employees, their work, work flow and relationships.
- Review of records and reports, particularly the reports if any which provide the reaction of the consumers to the services provided by the utility, organization structure, organization policies, records of past trainings etc.

#### **17.3.2.4 Analysis of data**

The analysis of the data is carried out with a view to make the assessment of training needs for various levels as below:

- Needs for the organization as a whole – corporate needs
- Needs for departments/teams within the organization – group needs
- Needs for individual employees – individual needs

There is a need for a i) Job analysis and ii) A person analysis for carrying out a training need analysis.

**17.3.2.4 I. Job analysis**

The information is obtained on the following aspects :

- Problems faced by jobholders in learning basic skills and applying them successfully in work.
- Weakness in performance of existing jobholders due to gap in knowledge, lack of skills or motivation.
- Areas where competence levels are not up to standards required.
- Areas where future changes in work process or methods or job responsibilities indicate training needs.
- How training is carried out at present.

A job analysis work sheet is shown below:

What has to be done?	Why?	How?	How well?
To .....	In order to .....	With whom? Where? Process or Procedure? What equipment or facilities?	Quantity? Output required? Results needed? Quality?

**17.3.2.4. II. Person analysis**

The information obtained from person analysis is:

- Details of job holders with adequate knowledge and skill for the job.
- Effectiveness of a person in putting his work to practice.
- Behavioural changes and work efficiency of job holders after attending training programmes.
- Level of job satisfaction.

A person analysis work sheet is shown below:

Personal particulars	Detailed information		
	Essential	Useful	Not necessary
Educational/Training/Experience			
Sex, Age			
Occupation			
Affiliation/ Special interests/Aptitudes			
Languages			
Attitudes, beliefs			
Knowledge of subject			
Authority			



### 17.3.2.5 Presentation of results of the training need analysis

From the training need analysis described above; the present knowledge and skill of jobholders of the organization can be arrived at. A table showing results of training needs is shown below:

Job requirement	Trainee's current knowledge & skills				
	Excellent	Good	Fair	Poor	Nil
1.					
2.					
3.					
4.					
Etc.					

Training needs are identified from the above information, taking the identified training needs as indicators, training objectives can be listed out to arrange the training.

### 17.4 TRAINING FOR ENHANCEMENT / REFRESHING SKILLS

The purpose of any training programme is to provide individuals with skills necessary for them to perform their assigned duties effectively and efficiently. After ascertaining the skills of the job holders, it has to be decided as to whether trainings to enhance the skills or refreshing the skills are to be arranged.

- *Employees creative model:*
  - ◆ Organizations provide trainings for enhancement of skills to encourage personal advancement.
- *Organizational strategy model:*
  - ◆ Basic skills are identified as a critical component in achieving corporate goals, for refreshing the skills of work for increasing production and efficiency.
- *Problem centered model:*
  - ◆ The need for basic skills training was identified as a specific issue or difficulty faced by the organization.

### 17.5 TRAINING OF TRAINERS

Training of trainers plays a key role in how effectively a trainer can operate to satisfy the needs of the trainees. Trainer's training is a specific programme set out to enable new trainers to learn the basic techniques and approaches of training or to enable existing trainers to develop the training skills they already possess. Some of the specific objectives of trainer's training in water supply sector are:

- To explain the necessity and objectives of training in water supply, operation and maintenance.
- To practice participatory learning activities.
- To carry out systematic training needs identification or training needs assessment.

- To demonstrate appropriate technology for urban and rural water supply.
- To prepare and review curriculum for various categories of trainees.
- To select and use appropriate audio visual aids in training programmes.

With the new or improved skills of trainers, they (trainers) are able to arrange training programmes to enable others (trainees) to develop skills, knowledge and attitudes. (Some specific training needs for a water utility are listed in Annexure 17.2).

## **17.6 TRAINING IN OUTSIDE INSTITUTIONS**

Off-the-job training can take place in institutions outside the organization, which are specially equipped and staffed for training.

- It is the best way to acquire knowledge on advanced or latest office procedures, planning and monitoring, project implementations methods, quality assurance methods and proper maintenance of schemes.
- Use of systematic training techniques, special equipments and trained trainers.
- Basic skills and knowledge can be acquired quickly and often economically.
- Training courses cover standard theory and practice which are easily translated from general to be particular.
- Useful to implant highly specialized knowledge and advanced skills.

List of a few training Institutions is presented in Para 17.3.

## **17.7 LONG-TERM TRAINING NEEDS**

Long-term training needs will largely be addressed by deputing staff to undergo formal educational programmes in water supply and sanitations (regular/distance learning) as well as specifying recruitment criteria for new entrants.

- Universities, Technical Colleges, Public/Private Sector institutes offer formal programmes leading to degree/diploma in Water Supply.
- Evaluations of short-term training programmes will lead to assessment of long term training needs.
- Existing staff of organization can undergo formal programmes by distant learning.
- Long-term training needs addresses the future demands of the organization.

## **17.8 SHORT-TERM TRAINING NEEDS**

Short-term training needs are for the existing staff of the organization that are likely to be met by short courses or other similar interventions.

- Specific training needs identified can be met by appropriate short-term training programmes.
- This improves competence of employees.

Proper job analysis and training analysis can identify short-term training needs. Short-term training needs can mostly be attended to by means of in-house training programmes.

## 17.9 ON-THE-JOB TRAINING

Depending on the place or location where training takes place, training can be called on-the-job training if the trainee gets training while working on the job assigned to him. The trainee in the physical and social environment of the work place is simultaneously involved in the process of acquiring knowledge.

- The trainee requires little specialized attention in terms of extra equipment and manpower.
- It helps to develop and practice specific managerial/technical/administrative skills needed in operation and maintenance of Water Supply System.
- The trainee works, learns and develops expertise at the same time concepts and theory are put into practice immediately.
- Gives guidance to supervisors and instructs new employees in performing their tasks.
- It is considered to be an acceptable means to train officials in new developments and new systems when they are introduced.

For example, a mechanic/plumber may be given field experience in Pump Houses and small water supply schemes to operate and maintain them. This helps them –

To Skill Development	Learns how to do it
Practical knowledge	Learns when to do it
Education	Learns what to do
Hands on experience	Knows the impact

## 17.10 QUANTIFICATION OF TRAINING

The training programmes can be quantified in terms of category of staff being trained, the number of staff members who also can be accommodated in a training programme, how often this training has to be given (frequency) and the duration of each course.

### 17.10.1 Category of trainees

- ◆ Executive Officers.
- ◆ Supervising staff.
- ◆ Administration and establishment staff.
- ◆ Last grade servants.
- ◆ Training for grass root level personnel.

### 17.10.2 Category of the training course

- ◆ Technical/Public Health Engineering.
- ◆ General Management.
- ◆ Finance.
- ◆ Operation and Maintenance.
- ◆ Industrial/Personal Relations.
- ◆ Computer application/IT.

### **17.10.2.1 Number, frequency & duration**

The number of trainees in a particular training course, how frequently that course is offered and duration of the course are factors used to quantify the training programmes.

## **17.11 INCENTIVES FOR EFFICIENT PERFORMANCE**

There is a need to provide for incentives and awards to recognize and encourage those employees whose performance has been found to be exceptionally efficient. This will enthruse other employees also to strive to improve their work efficiency. The HRD budget should provide for the incentives and awards.

## **17.12 TRAINING SCHEDULE AND YEARLY PROGRAMME**

The change from a crisis type of O&M to a planned O&M can be undertaken gradually or in a relatively short period of time depending on the resources available. The change should be planned and coordinated with a schedule of training. The training schedule should ensure that each staff member gets training periodically and training should be made mandatory for all the staff members of the utility.

A tentative action plan for the year (or yearly programme) can be prepared in advance. Each and every staff member will get training periodically and it shall be made mandatory. This action plan would give the yearly programme of various training courses. It gives the following:

- Course group, title.
- Category and number of participants.
- Duration (including date on which training is to be held).

## **17.13 TRAINING INSTITUTIONS**

External training facilities for a substantial proportion of the staff and personnel engaged in supply of drinking water are available at both the national and local level. Such training facilities are being used by many of the Water Authorities.

### **17.13.1 INTERNATIONAL TRAINING NETWORK (ITN)**

There exist a number of institutions coming under an International Training Network (ITN) established for the implementation of HRD activities. In India the following institutions are in the network:

- i) All India Institute of Hygiene & Public Health, Kolkata (ITN Centre).
- ii) Gujarat Jalseva Training Institute, Gandhinagar.
- iii) Environmental Sanitation Institute, Ahmedabad.
- iv) S.J. College of Engineering, Mysore.
- v) Gandhigram Rural Institute, Gandhigram.
- vi) Institute of Engineering & Rural Technology, Allahabad.
- vii) Motilal Nehru National Institute of Technology, Allahabad.

## 17.13.2 NATIONAL EDUCATION/TRAINING FACILITIES

### 17.13.2.1 Masters Degree in Public Health/Environmental Engineering

Post Graduate programmes are recommended/sponsored by the Ministry of Urban Development for inservice engineers working in water supply and sanitation agencies including urban local bodies. The name of the recognised institutes for in service engineers for P.G.C. are:

	Institute	Course Duration (Months)
1.	All India Institute of Hygiene & Public Health, Kolkata	24
2.	V.J.T.I., Mumbai	24
3.	National Institute of Technology, Nagpur.	24
4.	Indian Institute of Technology, Delhi	24
5.	Sri Jayachamrajendra College of Engineering, Mysore.	24
6.	Motilal Nehru National Institute of Technology, Allahabad.	24
7.	Shri G.S. Institute of Technology & Science, Indore.	24
8.	Indian Institute of Technology, Powai, Mumbai.	24
9.	Malaviya National Institute of Technology, Jaipur.	24
10.	Anna University, Chennai.	24
11.	Indian Institute of Technology, Kharagpur	24

### 17.13.2.2 Management education at degree/diploma level

Management Courses are offered inter-alia, at the following five management Institutes:

1. Indian Institute of Management - Ahmedabad
2. Indian Institute of Management - Bangalore
3. Indian Institute of Management - Kolkata
4. Indian Institute of Foreign Trade - New Delhi
5. International Management Institute - Delhi
6. Administrative Staff College of India - Hyderabad

### 17.13.2.3 National Institute for Training in Industrial Engineering (NITIE)

Short term non-residential and residential courses are held by the National Institute for Training in Industrial Engineering (NITIE). The courses are from five days to two weeks' duration and are held at five centers. Courses held in Mumbai are residential. Courses held in Bangalore, Delhi, Hyderabad and Madras are non-residential.

### 17.13.2.4 Central Public Health and Environmental Engineering Organisation (CPHEEO)

Refresher Courses are conducted by various recognized institutes under the sponsorship of the CPHEEO, by the Ministry of Urban Development under the Public Health Engineering Training Programme. The courses being offered are in Annex 17.3.

### **17.13.2.5 National Environmental Engineering Research Institute (NEERI), Nagpur**

NEERI is a research Institute primarily engaged on research and development work in the field of public health and environmental engineering. Training & consultancy services are offered by this Institute in the following areas :

Water Treatment and Supply.

Sewage Treatment and Disposal.

Industrial Waste Treatment.

Stream Sanitation.

Industrial Hygiene and Air Pollution.

Rural Sanitation.

### **17.14 NEED FOR SEPARATE HRD/TRAINING BUDGET**

It is preferable to have a separate Budget for HRD for each utility. While preparing budget for each training, one should plan and budget for the following items:

- The professional/registration fee.
- Honorarium and travel expenses for the trainer/faculty.
- Accommodation for Trainer(s).
- Ground Transportation for Trainer(s).
- Training Rooms.
- Library facilities.
- Audio-Visual Equipment (OHP, TV, VCR etc.).
- Snacks & tea (refreshment).
- Travel expenses for trainees for field visit.
- Stationery articles.
- Computer time; stationery; etc. for computer aided training courses.
- Incentives and awards for improvement in work efficiency.

A typical worksheet for developing a Training Budget is given below:

### WORKSHEET I: DEVELOPING A TRAINING BUDGET

Questions to consider	Cost	Comments
<b>Event fees:</b>		
Is there a registration fee, course fee, or tuition fees for the event?		
<b>Trainer or Consultant Fees:</b>		
What is the trainer's or consultant's hourly, daily, or weekly fee?		
Does the trainer or consultant charge for preparation time? If so, how much?		
<b>Materials:</b>		
Are there course materials associated with the training? How much do they cost? Does each trainee need a copy, or can they share?		
Will the training require printing or photocopying of materials? If so, how much will these services cost? Are they included in the trainer's fees?		
Will the trainer need audio or visual aids (e.g., overhead projector and slides, VCR and TV)? How much will it cost to purchase or rent these items?		
Will you need to purchase other assorted materials (e.g., name tags, paper and pens, files, or computer stationary)? If so, what will they cost?		
How much will refreshments cost? How will you pay for them?		
<b>Space:</b>		
Where will you hold the training? What will the space cost?		
Will you provide on-site care? Are the necessary space and resources available? What will this cost?		
<b>Travel:</b>		
Will the training require staff to travel? Will they need to stay over? How much will this cost, including mileage, per diem, and lodging?		
If the trainers are from out of town, what will their travel, lodging, and per diem expenses total? Are their travel costs covered separately or included in the contract?		
If volunteers are included in the learning event, will they have transportation or parking expenses? Are they eligible for reimbursement?		
<b>Staff Time/Substitutes:</b>		
Will some employees involved in the training need to be replaced by substitute staff? How much will the substitutes cost?		
If follow-up training or assistance will be needed, what will this cost?		
<b>Other:</b>		
Accommodation for the out station trainees		

Budget for Training is frequently expressed as a percentage of the total payroll. On an average 2 to 2.5% is preferred, out of which 75% can be spent for in-house training and rest can be utilized for training in external institutions.

## JOB REQUIREMENTS

### 1. Responsibility of Senior Management

- (a) The senior management shall define the role of the agency and set out strategies for long term objectives. They should be in close contact with other agencies involved in infrastructure services and work for coordination with government and private agencies in design, construction, O&M, monitoring and evaluation of the functioning of the agency.

Their responsibilities will be to:

- Establish delivery mechanisms and type and level of service for water supply to the population in their service area and determine priorities and define areas for expansion of coverage.
- Determine and administer staffing structure, service conditions, job descriptions, salary levels, performance standards, staff training and promotions.
- Ensure efficient use of funds and control construction and O&M costs (preferably to link to per unit of water produced).
- Set targets for achieving excellence in quality, quantity, continuity, cost, and set tariff levels keeping in view the social equity and agency's need for financial self-sufficiency.
- Promote dissemination of information and seek support and acceptance of the agency's programmes and plans by public and private bodies.
- Initiate actions for conservation of water.
- Work with other water users such as agriculture, industry and other drinking water supply agencies for managing the water resources by proper water allocations amongst all users.
- Carry out a situation analysis of technological capacity, government policies, sources of funding which affect the O&M.
- Prepare an inventory of the installations and equipment.
- Reduce amount of water wasted or not accounted for.
- Institute water conservation practices.
- Adopt appropriate technologies to minimise O&M costs.
- Ensure quality control in the purchase and installation of materials and equipment and thus ensure prolonged useful life of materials and equipment through preventive maintenance.
- Raise the productivity of workforce.
- Draw up plans to explore, exploit, and manage water resources in coordination with appropriate agencies.
- Monitor plans for prevention and control of pollution of water at source.



- Consolidate programmes formulated by middle and operational management levels and prepare a long term plan for O&M with targets set for each unit for the coverage, output, productivity and cost.
- (b) Determine the technical, economic and organisational feasibility of the O&M plan, adjustments where necessary, and carry out cost benefit analysis or undertake socio-economic studies or other studies if found necessary.
- (c ) Arrange for dissemination of O&M plan with other agencies, authorities and public.
- (d) Approve the long term plan and prepare programme for investment and implementation of the long term plan for O&M and set targets for implementation of long term plan for O&M and allocate resources as per priorities, set targets, monitor and re-allocate resources where necessary to ensure that the targets set in the plan are achieved.
- (e) Encourage programmes of a strategic nature and have potential for research and development and adaptation of new technologies and approaches.
- (f) Create enabling environment in adaptation by the agency of technical, regulatory and political changes.
- (g) Prepare contingency plans for continued service delivery in emergency situations.

## **2. Responsibility of Middle Management**

- (a) Middle management should contribute in the formulation of a long term plan for O&M and also for preparing projects for expanding the facilities and making them work effectively. For achieving this they should,
  - i) update system data, select design criteria and decide how to meet the technical standards and social needs in the most cost effective way,
  - ii) formulate and implement programmes for increasing productivity,
  - iii) formulate and implement programmes for exploitation and management of water resources and provide data to senior management for formulation and implementation of pollution control programmes.
- (b) Middle management should be responsible for defining the type of service and coverage, deciding the capacity of treatment, transmission, storage and distribution of water and formulate medium term programmes for O&M. These programmes should aim at:
  - Expanding coverage of service.
  - Making best use of existing physical, financial and human resources.
  - Improving quality of services provided.
  - Reducing and controlling of water loss.
  - Rehabilitation (as part of preventive maintenance) component parts of water supply installations and equipment with a view to extend their useful life.
  - Reducing costs and raising productivity in the agency's O&M programmes.
  - Controlling production and quality of drinking water.
  - Supervising the O&M of water supply.

- Monitoring of pollution of water sources.
  - Promoting awareness of and educating users about the proper use of drinking water services.
- (c) Middle management shall determine the technical, economic and organisational feasibility of the O&M plan. They should determine priorities and set targets for implementation of long term plan for O&M.
- (d) Middle management will consolidate all the short term O&M plans prepared by the operational management level and submit it to senior management to ensure that it is compatible with the long term plan and they will monitor and re-allocate resources where necessary to ensure that the targets set in the plan are achieved.

### **3. Responsibility of Operational management**

Operational management is primarily responsible for short term planning and also participate in formulating medium term and long term O&M plans. Operational management has responsibilities in the planning, design and construction work as well as O&M of the agency's equipment. They also propose medium term activities to provide water supply and participate with middle management in defining objectives, strategies and resources both to extend the coverage of service and ensure full use of them. They should also evaluate the feasibility of medium term investments for O&M. In line with long term and medium term programmes for O&M they should formulate short term objectives, targets and programmes. They will assess the resources required and allocate them, monitor and evaluate the performance in the following areas:

- Studies and designs needed for rehabilitation of the installations or for expansion of the services.
- Maintain the units under operation so that they will work efficiently and last as long as possible.
- Measurement of water flow rates, pressures and levels (Macro metering).
- Diagnosis process by way of simulation or otherwise for the working of distribution system.
- Introduce process for reducing and controlling leakages.
- Update the distribution system plans/maps.
- Processes for improvements of house connections and domestic plumbing.
- Processes for production and quality control of water.

### **JOB DESCRIPTION**

Based on the above identified responsibilities for various management levels, the suggested job descriptions are given below:

#### **I. Senior Management level (Director/Chief Engineer)**

1. To assist the Agency in designing and developing appropriate organizational structure and formulation of policies pertaining to operations and maintenance of water supply and sewerage.

2. To initiate perspective planning for augmentation of water supply, strengthening of sewerage system and improvement of sewage treatment.
3. To provide professional leadership in formulation of projects pertaining to augmentation storage treatment and distribution of water supply collection treatment and disposal of sewage.
4. To provide technical guidance in achieving the desired level as well as quality of service.
5. To provide leadership and guidance to the heads of various service circles in achieving the organisational goals.
6. To develop data base management culture pertaining to monitoring, review and coordination of control systems in operations and maintenance.
7. To prepare contingency plans for lean monsoon/drought years.
8. To undertake periodic inspection of sources, prescribe operation schedules for meeting floods/emergencies and ensure implementation.
9. To coordinate with external organisations such as electricity Boards, roads and communications, railways, telecom, pollution control, revenue, industries and industrial infrastructure departments to ensure smooth interface operations.
10. To schedule and organise periodic inspections of the dams by panel of experts on dam safety and ensure appropriate documentation of the panel reports.
11. To ensure timely preparation and approval of the annual budget plans.
12. To ensure timely processing of requisition for allocation of funds.
13. To develop procedures as well as ensure implementation of material vendor rating.
14. To prescribe methods and ensure implementation of inventory control.
15. To cause preparation of type designs.
16. To ensure updating of the existing plans.
17. To prescribe norms for evaluation and registration of contractors.
18. To cause preparation of model bid documents for execution of works as well as procurement of goods.
19. To prescribe methods and ensure implementation for evaluation of tenders.
20. To coordinate with other Chief Engineers in preparation of manpower plans and training plans.

## **II. Senior/Middle Management level (Superintending Engineer)**

1. To undertake program planning for implementation of agency's policies on procurement of materials, maintenance, repair and operations, contract services, tooling, equipment and supplies etc.
2. To supervise the interdivisional task assignment and monitor performance.
3. To initiate activity planning pertaining to the following functions and ensure effectiveness of implementation in the service jurisdiction. (a) augmentation of

storage, treatment and distribution of water supply; and (b) collection, treatment and disposal of sewerage services.

4. To prescribe norms of implementation and monitor the operations pertaining to quality assurance.
5. To prescribe procedures for generating data on service delivery and monitor their implementation.
6. To coordinate with external organisations, such as Electricity Board/Agency, City Municipal Corporation, Roads & Buildings Department, Urban Development Authority, Housing Agency, Telecom, Revenue & Public Health Engineering Department for resolving interface problems.
7. To undertake performance review of the subordinate units, and provide direction and guidance to the heads of the units, in achieving the performance targets pertaining to the following elements: a) inspection of level of service delivery; (b) service interruptions; (c) quality assurance;
8. To formulate, implement, monitor and review procedures pertaining to the following:
  - (a) Provision of advance information to consumers on service interruptions;
  - (b) Assignment of quota of connections for water supply division wise and subdivision wise: so as to be in conformity with the available capacity;
  - (c) Procurement, storage and issue of materials, tools, plant and equipment;
  - (d) Safety and security of properties materials, tools. plants and equipment by servicing schedules for various machines, tools, plants and equipment;
  - (e) Preparation of utility plans;
  - (f) Formats and procedures for generation of management control data;
  - (g) Preventive maintenance & leak detection;
  - (h) Water quality etc.,
9. To monitor the implementation and to effect suitable revision of contingency plans for service delivery during lean and drought years;
10. To monitor implementation of agreed staff welfare measures.

### **III. Middle/Operational Management level (Executive Engineer)**

1. To cause preparation of water distribution plans - source wise and area wise.
2. To ensure preparation and periodic updating of plans of the service area-subdivisions/zones and sections/reservoirs.
3. To implement the procedures pertaining to advance notification on likely occurrence of floods/interruptions in water supply to public.
4. To ensure timely preparation of budget estimates of annual maintenance and maintain cash books.
5. To implement the procedures pertaining to requisitioning of funds, processing, scrutinizing, approval and obtaining sanction thereof.

6. To ensure that procedures are followed for prompt and timely payments to agencies for works done/supplies made.
7. To ensure that the expenditure on O&M is maintained as per the heads of accounts indicated.
8. To ensure implementation of prescribed procedures for indenting and receipt of materials from stores division for operation and maintenance.
9. To ensure implementation of procedures in acquisition of cash, undertake scrutiny of accounts and accord authorization.
10. To cause for the audit of accounts, at the end of monthly accounting period and arrange for addressing the audit authorization.
11. To cause preparation of O&M establishment's salary claims, processing, approval, disbursement and maintenance of pay rolls, in accordance with the approved procedures.
12. To undertake periodic review of manpower availability at the concerned service sub-divisions and sections and effect staff transfers if necessary to conform to requirements.
13. To arrange for shoes, raincoats, uniforms and safety gear etc., for operation and maintenance staff as per the requirement.
14. To cause preparation, scrutiny and accord sanctions for maintenance of vehicles used in operation and maintenance or to arrange for hiring of vehicles for O&M.
15. To formulate proposals for hiring private water tankers and to implement the approved proposals.
16. To cause preparation of normal/emergency operation schedules of each source and ensure implementation.
17. To undertake periodic inspection of sources, especially the spill ways, gates and emergency gates, sand bag stocks, etc., to ensure implementation of prescribed norms. To ensure that prescribed procedures are followed for removal of any carcasses and drift wood etc. from reservoirs.
18. To take personal charge of operations and provide guidance to the personnel in critical areas during high intensity floods.
19. To evolve methodologies for collection of flood flow information and ensuring data collection, documentation and dissemination of data.
20. To coordinate inspections of dam safety committees and ensure compliance with their recommendations in accordance with prescribed procedure.
21. To schedule the statutory inspections by the electrical inspectorate and ensure implementation of their suggestions.
22. To arrange for energy audit and ensure that power is conserved.
23. To arrange that generator sets are procured for use in power cut periods as per prescribed procedures.

24. To undertake water demand forecasting/projections.
25. To undertake periodic inspection of subordinate offices and evaluate their state of effectiveness.
26. To prepare and ensure implementation of inspection schedules for store materials, small tools, plant and machinery.
27. To generate data on MIS from subordinate offices for processing or transmit to the concerned for processing.
28. To undertake surprise checks of bulk water meters of industrial, commercial and other large water consumers and ensure that reading, billing and collection is done properly and ensure that deliberate under billing, pilferage and unauthorised use of water is avoided.
29. To undertake a trend analysis of water supplied, bills demanded and amount collected.
30. To coordinate with external organisations, such as Electricity Agency, city Municipal Corporation, Roads & Buildings Department, Urban Development Authority, Housing Agency, Telecom, Revenue & Public Health Engineering Department for resolving interface problem.
31. To prescribe methods and norms in respect of quality assurance, organise, implement and monitor their implementation.
32. To cause preparation, maintenance and implementation of all staff welfare measures.
33. To meet the guide line values for water quality control, water quality monitoring, preventive maintenance and leak detection etc.
34. To assess training needs for all categories of field staff involved in water treatment, water quality control and monitoring, O&M of treatment plant, distribution system net work etc. and prepare training schedule for imparting training with in the department and or outside and forward detailed proposal to the heads of the department with financial implications.

#### **IV. Middle/Operational Management (Deputy Assistant to the Executive Engineer)**

1. To monitor, review and reschedule of inflows into service reservoirs and sumps, in accordance with delivery schedules in the relevant service area.
2. To monitor supply pressures with a view to identify problems and their removal.
3. To monitor the implementation of water quality control.
4. To monitor the leakage rectification.
5. To monitor the pollution cases.
6. To monitor, guide and supervise maintenance and other works.
7. To initiate timely check measurement of works.
8. To monitor the quality of filling for road cuttings of leakage rectification.
9. To verify conformity with bye-laws for regulating sanction of new consumer connections, and arrange for onward transmission where necessary.

10. To monitor the service section performance and render guidance to the section officers in problem resolution through weekly meetings.
11. To guide service area section officers in organising staff review meetings at section level.
12. To guide service area section officers in organising of consumer meetings at section level.
13. To carryout periodic physical verification of materials, tools and plants.
14. To verify and initiate corrective actions on the level of O&M staff strength.
15. To monitor the performance of concerned revenue collection center.
16. To coordinate with City Municipal Corporations and Electricity Agencies to resolve interface problems.
17. To monitor the maintenance, status of log books and other records in the concerned section and pumping stations and render technical guidance for oil operation and maintenance.
18. To schedule and carry out periodic service inspection and initiate corrective action on the status of: (a) Chlorination Plants; (b) Switch gear and HRC fuses; (c) Emergency lighting points; (d) Requirement and availability of tools; (e) Vibration levels of motors/pumps; (f) pump alignments; (g) General condition of base plates and foundation bolts; (h) Pressure gauges on suction/delivery; (i) Voltmeters/ Ammeters; (j) Conservation of energy of power factor meters and performance of capacitors; (k) Replacement of oils/lubricants; (l) By-pass valves in delivery sluice valves; (m) History register of each machine with specific reference to entries on supplier details and service specifications and implementation; (n) Fire fighting equipment; (o) First aid kits; (p) Safety equipment like rubber mats, hand gloves, helmets, gas masks etc.; (q) Weed control and metalling at substations; (r) Clearance between trees and overhead power lines; and (s) Ventilators, manhole covers and ladders at reservoirs.
19. To schedule and monitor the implementation of cleaning and weed removal schedules at reservoirs/sources.
20. To monitor the implementation of procedures for storing and issue of materials.
21. To carryout periodic preventive checks against encroachments on foreshore areas at the sources.
22. To ensure effective regulation of visitors at the source premises.
23. To undertake periodic inspection to identify spots/areas of degeneration and ensure timely repair, rebuilding and maintenance of affected areas, pertaining to the following (a) Spillway gates including the wire ropes, pulleys and the operating parts; (b) Emergency gates including the wire ropes, pulleys and the operating parts; (c) Upstream paving; (d) Down stream aprons, revetment and leakage; (e) Bunds-Status of consolidation, growth of weeds and vegetation etc.; (f) Lighting at surplus release points; (g) Raw water conduits and trunk lines - special focus on sections

vulnerable to pilferage encroachment and unauthorised modifications, and pollution;  
(h) Sluice valves and air valves, approach roads, cross drainage works.

24. To formulate and obtain approval for flood regulation measures and train the staff in carrying out various operations in emergency.
25. To take direct charge of flood regulation at reservoirs and areas that may be flooded.
26. To undertake periodic inspection and initiate corrective action of the following: (a) Raw water conduits and trunk lines; (b) Verification and prevention measures pertaining to pilferage; (c) Encroachment and unauthorised modifications on main pipelines; (d) Pollution spots; (e) Status of all sluice valves and air valves and expansion joints; (f) Condition of approach roads; (g) Cross drainage works before and after monsoon.
27. To monitor alum dosage, consumption and stock of alum at treatment plants.
28. To monitor chlorine dosage, consumption and stock of chlorine at treatment plants.
29. To formulate and monitor periodic cleaning of all Tanks.
30. To monitor the movement of water tankers.
31. Undertake periodic assessment of service delivery in the concerned sections, identify the factors causing deficiency in service levels and initiate measures for maintaining the required service levels.
32. Cause preparation of inventories of assets/estate by value and age.
33. Monitor status of functioning of zonal flow meters and need for servicing them.
34. Prepare section wise requirement of funds (annual budget) and compile and forward to division.
35. Prepare proposals for extension of service to new layouts.
35. To cause preparation, maintenance and implementation of all staff welfare measures
36. To analyse the work turned out by staff and identify the cases where overtime is paid and initiate remedial measures to avoid payment of overtime.
37. Undertake review of consumer complaints, monitor the lead time for addressing the complaints and initiate measures to reduce the lead time in attending to consumer complaints.

**V. Section Officer/Asst. Engineer or Junior Engineer (To assist the Sub-divisional Officer or to Manage a survey section) (Operational Management)**

1. To formulate and ensure implementation of action plans for equitable supply of water in service areas.
2. To schedule, implement, monitor and revise the service delivery timings in the areas concerned to be in tune with consumer convenience.
3. To monitor and undertake appropriate measures to improve supply pressures and reconciliation between the demand & supply of water.
4. To ensure implementation of prescribed measures on quality control standards in the service area.



5. To cause timely detection and rectification of leakages in the concerned service area.
6. To ensure implementation of procedures for detection and monitoring pollution cases and to undertake appropriate measures for immediate rectification of both repairs.
7. To supervise the progress of various ongoing works in the service area and ensure implementation of the prescribed norms on quality.
8. To inspect, measure, record and ensure timely submission of bills for payment.
9. To undertake periodic performance review of contractors and vendors and analyse information to effect appropriate rating.
10. To ensure proper maintenance of contractor ledger.
11. To undertake periodic review and ensure updating of utilities and system plans:
12. To ensure balance between the available capacity of the system demand and sanctions for new service connections.
13. To undertake inspection and authorise road cuttings for leakage rectification or as necessary and ensure refilling as per the prescribed norms.
14. To undertake preparation of discharge tables and other connected technical reports.
15. To ensure implementation of preventive maintenance schedules on chlorination plant and equipment and ensure operations free of leakages or other defects or break downs.
16. To ensure implementation of prescribed maintenance schedules and safe operations of safety and fire fighting equipment.
17. To undertake scheduling of meter reading in the service area, ensure billing, prompt ledger entries and service of bills to consumers.
18. To identify problems in employee welfare through periodic staff meetings.
19. To organise consumer meets in service area, identify consumer problems and deficiencies in service delivery and ensure corrective follow up action.
20. Undertake inspection visits in the service area during water supply timing and note the visible leaks, leaking valves, cross connections, absence of residual chlorine, missing inspection chambers' covers etc. and initiate measures to attend to these.
21. To take part in water quality control, water sampling etc.

#### **VI. Senior Level-Finance & Accounts**

1. To cause maintenance of proper accounts and other records in relation thereto to be kept, and cause preparation of annual and periodical statements of accounts (balance sheets, revenue and expenditure account, and schedules) in such forms as may be prescribed by regulations.
2. To cause timely preparation and presentation of annual, quarterly and monthly accounting reports like balance sheets, income and expenditure accounts, funds flow statements etc.
3. To ensure implementation of accounts system and procedures and timely preparation of periodical accounting statements and reports at office of the Agency.

4. To design and implement financial procedures and policies.
5. To cause quarterly/monthly/financial reports and forecasts.
6. To establish sound pricing policies.
7. To organise effective systems of pre-audit and payments and to arrange receipts of recoverable and to cause proper accounting of cash and bank transactions.
8. To arrange institutional finance and manage public issues.
9. To liaise with Government and various lending agencies and ensure compliance with the requirements of Government and lending institutions.

#### **VII. Middle Level Finance & Accounts**

1. Maintaining cash book and bank books.
2. Sending copy of cash/bank book to agency office.
3. Prompt posting of ledgers (day by day).
4. Posting of sub-ledgers within set date.
5. Bank reconciliation statements.
6. Action on the reconciled items.
7. Monthly trial balance.
8. Monthly balance-sheet income & expenditure account.
9. Monthly cash forecast (for the next month).
10. Cash flow statement.
11. Monthly work wise schedules.
12. Monthly schedule of sub-ledgers.
13. Monthly requisition of funds (for the next month).
14. Monthly statements of receipts, payments, income & expenditure comparing actual figures with budget.

#### **VIII. Manager Material Accounting**

1. Maintenance of (computerised) stock accounts of the agency, material wise, scheme wise, section wise, stock point wise and contractor wise.
2. Arranging data entry of stores receipts, issues and uses of stock points and sections.
3. Custody and issue of stationery of stores accounting forms and reconciling the data entered with stationery issued.
4. Reconciliation of materials accounts and communication with Divisions/Sections regarding un-reconciled balances and effecting rectification.
5. Ensuring implementation of stock valuation procedures for closing stocks and for stocks issued to works and consumption.
6. Preparation and submission of materials at site accounts and reports.

## **IX. Manager – Revenue Accounts**

1. Collection of data from bill/cash collection counters at specified intervals and incorporation in the common data base.
2. Arrange for checking of cash collections counter-wise with remittances in the banks.
3. Preparation of consolidated revenue accounts including ledgers, demands, debtors statements.
4. Quantitative billing analysis and reconciliation.
5. Preparation and submission of analyzed divisions reports to managing director and concerned officers.
6. Monitoring collection of dues from major consumers and pursuing divisions for collections and demands.
7. Compilation of statements of collection counters and reconciliation with bank accounts, arranging data entry, computerised reconciliation and feed back to systems of collection counters.
8. Prompt reporting to the management of any deviations from the norms of demand, collection, billing and balances and of any abnormalities.

## **X. Manager – Personnel & Training**

1. To assist the agency in formulating personnel training policies.
2. To cause preparation of manuals on service regulations for facilitating effective implementation of personnel policy.
3. To cause preparation of standing orders to guide the officers and employees in carrying out respective duties and responsibilities and ensure easy access to them by all the concerned.
4. To develop and update the data base on the following elements of personnel management in the agency.
  - i) Manpower, inventories including employee turnover.
  - ii) Salaries and & wage structures.
  - iii) Employee training inventories and calendars.
  - iv) Manpower distribution - by cadre, sanctioned strength and actual.
  - v) Implementation of performance appraisals as well as individual performance summaries.
  - vi) Status of implementation of measures on employee welfare and social security.
  - vii) Disciplinary proceedings litigation and redressal of grievances.
  - viii) Sanctions on gratuities, pensions and other terminal benefits.
  - ix) Promotions, empaneling and implementation of relevant schemes.
  - x) Medical and Health Service coverage.
  - xi) Accidents
  - xii) Housing & Estate management.

5. To undertake liaison activities for building rapport with various departments of the State Government.
6. To monitor the progress of proceedings involving the agency, pending in courts, tribunals and other statutory agencies.
7. To ensure implementation of pertinent provisions under trade union and industrial disputes acts and other labour laws.
8. To undertake constitution of medical advisory committees, arrange for documentation indexing and retrieval at call, of the proceedings thereof.
9. To take initiative in regard to procurement of books, journals and magazines and servicing the agency's membership in professional associations.
10. To ensure compliance with the schedules for budget preparation revision, preparation of revised estimates pertaining to personnel functions, submission for approval by all the units down the line.
11. To undertake scheduling of welfare meetings and ensure compliance by the units down the line, ensure follow up action on the minutes of the meetings held.
12. To organise awareness improvement programmes on fire accidents, hazards, safety and first aid.
13. To organise consumer contact programmes and public relations campaigns.
14. To assist the agency in the preparation of agenda for Agency meetings and follow up action on the minutes of the meetings.
15. To convene the meeting of training coordination committee. Prepare agenda for discussions and record the minutes thereof.
16. To prepare training calendars and develop deputation programs.
17. To develop organisational linkages with institutions of higher learning in the neighbourhood, outside the city, and the country.
18. To undertake scientific assessment of availability, adequacy and cost of using the existing resources.
19. To develop a training need inventory.
20. To develop training capsules for in-house training.
21. To arrange for effective utilisation of training facilities available in house.
22. To undertake preparation of lists of resource persons in regard to subjects related to training programs.
23. To develop methods for identifying and developing in-house training capabilities.
24. To develop/up date MIS.
25. To develop GIS.

**XI. Public Relation Officer & Staff Welfare Officer**

1. To develop rapport with media services.
2. To maintain liaison with local police and administration in times of emergency.
3. To bring out a house journal highlighting the activities of the Agency.

4. To assist the management in organising important functions.
5. To arrange for press and other media meets.
6. To organise customers meets and provide feed back to management.
7. To maintain cordial industrial Relations.
8. To help the management in conducting negotiations with Employees /workers unions.
9. Follow up action on the implementation of memorandum of understanding between management and unions.
10. Resolving Inter-union disputes.
11. Redressal of grievances of various employees association and works unions.
12. To ensure that the policies and programmes of the Management are properly communicated to various Associations and unions.
13. To implement the rules and regulations on Medical & Health Services.
14. To implement rules and regulations pertaining to prevention of fire hazards and adoption of safety and security measures.
15. To implement procedures for receiving and disposal of grievances of the employees.
16. To implement rules and regulations on staff welfare measures, terminal benefits and other compensation benefits.

## **XII. Senior Technicians**

To guide, monitor and control various categories of technical staff in performance of highly skilled level of work.

### **Mechanical**

1. To undertake operations and maintenance of laying, jointing and testing of pipelines and sewers including specials, valves, meters etc.
2. To undertake operations and maintenance pertaining to filter beds, washing of beds, valves, flash mixers, flocculators/clarifier machinery and alum mixing machinery, wash water pumpsets, flow meters, pressure gauges and chlorination equipment.
3. To undertake maintenance of cranes, air tech machines, bucket machines, tackles, winches and hoists.
4. To undertake operation and maintenance of welding machines and accessories and Oxygen cutting torches.
5. To undertake operation and maintenance of hand tools for drilling, threading, fitting, pipe bending and maintenance of log book.

### **Electrical**

1. To undertake recording and mounting, removal, dismantling, repairing, servicing and re-assembly of switches, switchgears, starter, motors, blowers, generators, compressors and battery charge equipment.

2. To undertake preparation of layout diagram for domestic and industrial wiring energising low and medium voltage machine control panels as per I.E. rules.
3. To undertake installations wiring testing fault finding and rectification and connecting industrial and street light fittings.
4. To undertake operation and maintenance pertaining to transformers, Boosters, fault rectification, jointing of HV underground cables, drawing overhead service lines to undertake operation and maintenance of meggers insulation testers, continuity tests, frequency meters, power factor meters.
5. To undertake operation and maintenance of fire fighting and first aid kits.
6. To undertake maintenance of log book and to undertake operation and maintenance of wireless equipment, receipt and transmission of messages, detection of minor faults and rectification and operation of fax machine.

### **Civil**

1. To guide, monitor and control various categories of technical staff.
2. To maintain check lists on progress of work and quality control.
3. To collect samples of water and analyse for residual chlorine.
4. To verify flow calculations of water supply connections.

### **XIII. Junior Technician**

To undertake operations and maintenance requiring skilled level of ability.

#### **Mechanical**

1. To undertake operations and maintenance of laying, jointing, testing of pipelines and sewers including specials, valves, meters, etc.
2. To undertake operations and maintenance pertaining to filter beds, washing of beds, valves, flash mixers, flocculator/clarifier machinery and alum mixing machines, wash water pumpsets, flow meters, pneumatic and pressure gauges and chlorination equipment.
3. To undertake operation and maintenance of cranes, air tech machines, sewer cleaning bucket machines, tackle winches and hoists.
4. To undertake operation and maintenance of welding machines and accessories, oxygen cutting torches.
5. To undertake operation and maintenance of hand tools for drilling, threading, fitting, pipe bending and maintenance of log book.

#### **Electrical**

1. To undertake operations pertaining to mounting, removal, dismantling, repairing, servicing and re-assembly of switches, switchgear, starters, motors, blowers, generators, compressors, battery charging equipment.
2. To undertake preparation of layout diagrams for domestic and industrial wiring, energising low and medium voltage machines, control panels as per I.E. rules.

3. To undertake operations and maintenance pertaining to wiring and testing of installations, fault finding and rectification and connecting industrial and street light fittings.
4. To undertake operation and maintenance pertaining to transformers and boosters. Fault rectification and joining high voltage underground cables and drawing overhead service lines.
5. To undertake operation and maintenance of meggers, insulation and continuity testers, frequency meters, power factor meters, volt meters, flow meters, fire fighting equipment and first aid kits.
6. To undertake maintenance of log books of all machinery and equipment.
7. To undertake operation and maintenance of wireless equipment, receipts and transmission of messages, detection of minor faults and rectification, operation of fax machines.

#### **Civil**

1. To guide, monitor and control various categories of technical staff. To maintain check lists on progress and quality control.
2. To collect samples of water to analyse.
3. To assist the management in maintenance of records, reports and accounts.
4. To assist the management in preparation of estimates.
5. To prepare a consolidated list of consumer wise readings and submit to the manager in charge.
6. To detect faults in domestic water meter.
7. To identify sources of pollution in and around consumer meter and assist to schedule and undertake periodic visits of the (Metering) premises of domestic and commercial category of consumers for recording the meter readings.

#### **Transport**

1. To drive heavy vehicle, operating crane, air tech machine and excavator.
2. Forklift, trippers, road rollers, paver - grader.

### **XIV. Skilled Employee**

Work not requiring judgement but simple levels of mechanical ability and dexterity.

#### **Mechanical**

Assisting the technicians in carrying out simple operations pertaining to operation and maintenance of water pipe lines, valve cleaning, greasing and lubricating of pumps and motors, excavator, vehicles and other mechanical equipment, borewells, fitting, smithy, welding, tinkering and moulding, carpentry, and other works.

#### **Electrical**

Assisting the technicians and also carrying out operation of pumps, motors installation up to 440 volts, operation of valves, cleaning, greasing and lubrication, changing of fuse

on LT side, wiring connections at terminals, receiving of telephone calls at pumping installation contacting the APSEB fuse call Office, maintenance of log book first aid, operation of fire fighting equipment.

### **Civil**

Assisting the technicians and carrying out simple operations to operate and maintain, cleaning repairing, test ware, general assistance in the laboratories, carpentry, Masonry, painting, carrying of survey instruments, keeping of level staves, surveying and general assistance to surveyor, recording of water level, receiving registering and communicating messages.

## **XV. Unskilled Employee**

All types of manual work not requiring any special training or aptitude and independent judgement. The tasks under the category are simple and entail physical labour of varying intensities.

Operations pertaining to excavation, de-watering, de-silting, assisting the skilled workers in carrying, handling, loading, stacking of materials, tools and equipment, general purpose cleaning including machines, tools, equipment, pipelines, couplings, water meters, filters and valves etc.

Dusting, sweeping and washing.

Gardening, maintaining, spraying and dusting of pesticides etc., cleaning, preparing test-ware, waste disposal and general assistance to lab technicians.

Cleaning of vessels, crockery and other kitchen equipment, linen washing and door keeping and attending to office errands.

Performing the relevant technical functions in the workshop, assisting the skilled worker in operation of valves and cleaning of water pumps.

Watch and ward (day and night) not requiring the use of fire arms.

Receiving telephone calls and paging, carrying files, notes, books, courier etc.

### **House Keeping**

*Utilities:* cooking and maintenance of crockery and other kitchen equipment, linen changing, attending to the guest requirements door keeping, gardening, watering, grass cutting, mowing, manuring, spraying of pesticides.

Women personnel unskilled employees shall be employed only for gardening, house keeping, attending manual duties in offices, carrying materials, lab attendants and such other work not involving heavy physical labour.

The unskilled employees are interchangeable from one function to other.



ANNEXURE 17.2

**TRAINING NEEDS  
SUBJECTS/PERFORMANCE AREAS IDENTIFIED  
FOR ORGANISING TRAINING INPUTS**

**I. Chief Engineer**

1. Corporate policy and management, personnel.
2. Management Information System – Automation.
3. Personnel management - Organisational development - Management of Urban utilities.
4. Bilateral/Multilateral funding and management.
5. Financial management - commercial pattern.
6. Project management.
7. Systems Engineering.
8. Contracts - application of specifications.
9. Quality engineering.
10. Material planning and control.
11. Construction management.
12. Environmental impact assessment.

**II. Superintending Engineer**

1. Corporate planning.
2. Organisational behaviour.
3. Industrial relations.
4. Personnel management and industrial relations.
5. Management Information system – applications.
6. Human resource development.
7. Project planning & control – computer applications.
8. Computer aided designing.
9. Standardisation of designs.
10. Quality circles.
11. Material Planning and control techniques.
12. Preparation of manual on servicing and repair and testing of Electrical and mechanical equipment.
13. Unaccounted for water management.
14. Analysis of industrial effluents.
15. Construction management.

16. Water audit.
17. Rehabilitation of structures.
18. Leakage rectification and cleaning of pipelines.
19. Programme planning and budgeting systems.
20. Bilateral/Multilateral funding – issues and problems.
21. Import procedures.
22. Commercial accounting.
23. Basic financial management.

### **III. Other Engineers**

1. Construction management.
2. Project preparation – feasibility studies.
3. Project report writing.
4. Dam Safety – monitoring, and evaluation techniques.
5. Leak detection, rectification techniques.
6. Capacity estimation of impounding reservoirs.
7. Updating of codes standards.
8. Unaccounted for water management.
9. Water audit.
10. Construction quality control.
11. Laying, jointing testing and commissioning of pipelines.
12. Pipe network analysis.
13. Tooling for operations, maintenance and repair.
14. Civil structures – maintenance management.
15. Pollution – detection, prevention and control – techniques and applications.
16. Preparation of discharge tables for flow in pipes.
17. Maintenance management.
18. Energy audit.
19. Basic instrumentation.
20. Project estimates – preparation and documentation.
21. Systems engineering - simulation/modeling.
22. Hydrographic survey techniques – application.
23. Material testing and certification.
24. Total station survey – computerised analysis and mapping of survey data.
25. GIS methods Preparation and updation of maps.

26. Swabbing and cleaning of pipelines.
27. Rehabilitation of structures.
28. Office management – automation.
29. Industrial relations.
30. Fire fighting and first aid.
31. Material (stock accounting).
32. MS office – Computer applications in office management.
33. Human resource development.
34. Management Information Systems (MIS) in urban utilities.
35. Basic financial management.
36. Commercial accounting – accounting in Public utilities.
37. Planning and Monitoring of metering and billing for water.
38. Basic business accounting.
39. Financial analysis – techniques.
40. Budgeting – Principles and applications.
41. Management accounting.
42. Stores accounting.
43. Costing, budgeting and accounting.
44. Financial ratio analysis.

#### **IV. ALL TECHNICAL AND NON-TECHNICAL OFFICERS (other than engineers)**

1. Introduction to MIS – (Application to respective functions).
2. Maintenance, manuals – updating.
3. Engineering Drawing.
4. Work execution – measurement recording and billing.
5. Water quality testing and control.
6. Preparation of estimates.
7. Sewer cleaning techniques.
8. Scouring and cleaning techniques.
9. Data collection and statistical analysis.
10. Computer applications.
11. Introduction to MIS (Application in respective functions).
12. Personnel management.
13. Labour laws and industrial relations.
14. General management – introduction.

15. Office management – automation.
16. Metering, billing and customer services.
17. Commercial accounting – procedures.
18. Budgeting and Audit – procedures.
19. Capital budgeting – procedures.
20. Costing, cash flow and credit management – Procedures.
21. Stores accounting – procedures.
22. Book keeping and accounts.
23. Preparation of budgets.
24. Materials (stock) accounting.
25. Management accounting.
26. Costing, budgeting and accounting.

## **SPECIFIC TRAINING COURSES**

### **1. UTILITY PLANS**

To make detailed plans/sketches indicating water supply lines with pipe size, material, date of installation, number of connections between road junctions, tapping for bulk consumers, flow rates with ground contours relative to local source of supply, superimpose location of sluice valves duly indicating normally closed/open positions, scour valves, air valves, reflex valves, bulk meters, borewells, public stand posts, areas susceptible for low pressure, fire hydrants etc.

Prepare detailed assignment to individual function plans when there are a number of inter connections – duly indicating the location of each in the main plan.

Develop schedules for updating the utility plans;

Gain technical familiarity with the plans already prepared;

Identify the gaps and fill the gaps as necessary.

### **2. MANAGEMENT INFORMATION SYSTEM**

1. To assist the participants in identifying the data needs for water supply and prepare:
  - i) Utility plans;
  - ii) Operation plans;
  - iii) Maintenance plan;
  - iv) Quality control plan;
  - v) Consumer inventories, revenue data sheets;
  - vi) Layouts and individual units, specific focus on multistoried buildings and public institutions;

- vii) Demographic;
- viii) Data on unserved areas within zone;
- ix) Vacant government and private lands suitable for locating, reservoirs, treatment plants and pumping stations;
- x) Man power, requirements – available deployment – turnover workload;
- xi) Location and status of serviceability borewells, PSP's etc.;
- xii) Number and status of serviceability of tankers;
- xiii) Inventories of mechanical and electrical equipment available and status of serviceability, servicing schedule, scales of spares for operation voltages and energy requirements;
- xiv) Implementation of development plants by local municipality/Roads and Buildings Department;
- xv) Spots vulnerable to fire hazards, accidents etc.;
- xvi) Likely spots vulnerable to pollution and types of pollution;
- xvii) Areas/location susceptible to low Pressures;
- xviii) Location and population resident in slums;
- xix) Data on consumption of power and emerging power factor;
- xx) Develop data, records, type designing, compile and analyse, draw inference for decision making.

3. Storage and retrieval of data on call.

4. Maintenance of registers and inspection notes.

### **3. PIPE NETWORK ANALYSIS**

- i) Familiarize the participants with design parameters of pipelines.
- ii) Calculation for deriving pipe size in case of dead end as well as loops and water connections.
- iii) Methods of calculating systems capacity.

### **4. STATISTICAL QUALITY CONTROL**

Familiarising the participants with: statistics, statistical methods, sampling, sampling techniques, statistical application in analysis, matrix analysis forecasting trend analysis, rating.

Methods of sample collection in water supply works, soils, concrete and building materials and reliability analysis.

### **5. COMPUTERS IN ENGINEERING APPLICATIONS**

*Familiarize the participants with:*

Computer applications in engineering

CAD and CAM, MS Project & MIS

## **6. LAYING, JOINTING AND TESTING OF WATER SUPPLY PIPE LINES**

- i) To develop skills in leak detection,
- ii) Assessment of soil characteristics,
- iii) Bedding, of pipes – usage of jacking equipment,
- iv) Usage of tripods, pulley blocks,
- v) Usage of winches and hooks,
- vi) Types of joints and jointing material,
- vii) Hydraulic testing equipment and anchorages, test pumps and pressure gauges and valves,
- viii) Tools, hand tools/machine tools, assessment of requirement and servicing,
- ix) Trench refilling techniques,
- x) Thrust blocks, anchor blocks,
- xi) Testing for valve alignments, rubber insert/gasket, lubrication. Use of torque wrench,
- xii) Flange alignments,
- xiii) Appurtenances,
- xiv) Protection against pollution,
- xv) Fixation of pipe levels with reference to scouring of pipelines,
- xvi) Welding techniques, filter material, blow torches, nozzles, fluxes, electrodes, compatibility, welding temperatures,
- xvii) Anti corrosive measures,
- xviii) Dewatering pumps,
- xix) Shoring and strutting techniques,
- xx) Rock cutting techniques, detonators, drilling equipment and compressors.

## **7. Material Specification and Application**

- i) To familiarise with codes in use, control of specification and testing,
- ii) Identification of material, classification, stocking,

## **8. Civil Engineering Structures, Maintenance & Rehabilitation**

- i) To familiarise condition monitoring of roofs, foundation failures, preservation of wood work, electrical fixtures, sanitary fittings, plastering, colouring, anti-termite treatment, protection of iron and steel structures,
- ii) To arrest leakages in water retaining structures,
- iii) Rehabilitation of corrosion affected structures,
- iv) Repairs of manhole covers and frames,
- v) Repairs to expansion joints,

## **9. Detection of Pollution of water supplies – prevention and control**

- i) To familiarise with tools/equipment for detection of pollution and usage of same for tracing pollution,
- ii) Techniques for assessing magnitude of pollution,
- iii) Methods of control and contingency planning for isolating polluted system and alternate supply routes,
- iv) Fouling with storm water drains.

### **Technical Training in Operation and Maintenance**

Laying, Jointing and Testing techniques for pipelines, including detection of leaks and identification of various types of leakages.

Maintenance and repairs of valves and valve chambers.

Maintenance of pumps, motors, and electrical systems, identification of trouble shooting and rectification.

Maintenance of chlorinators.

Maintenance of water treatment plants.

Road cutting and restoration techniques.

Collection of samples, analysis, water quality standards.

Safety procedures.

Fire-fighting and first-aid.

Customer relation.

Repair and maintenance of water meters and flow meters.

Maintenance of Instrumentation in automation.

## ANNEXURE 17.3

**MINISTRY OF URBAN DEVELOPMENT  
GOVT. OF INDIA**

**CPHEEO  
LIST OF REFRESHER COURSES SPONSORED BY THE MINISTRY**

Sl. No.	Name of the Refresher Course	Place	Conducting Agency	Duration
1.	Water Works Supervisors Course	Nasik Road	R&T.C., M.J.P.	4 weeks
2.	—do—	Trivandrum	K.W.A.	4 weeks
3.	—do—	Palasuni Bhubaneswar	P.H. Deptt.	4 weeks
4.	Water Supply System Management	Chennai	TWAD Bd.	1 week
5.	—do—	Nasik Road	R & T.C., M.J.P.	10 days
6.	Pipes & Conduits	Nasik Road	—do—	12 days
7.	—do—	Mumbai	C.T.I. & R.C. M.C.G.B.	9 days
8.	New Development in Water Treatment	Kolkata	AIIH & PH	10 days
9.	Structural Design on Water Treatment Plants and other Related Structure	Nagpur	V.N.I.T.	1 week
10.	Water Treatment Plant Design	Nagpur	V.N.I.T.	1 Week
11.	Public Health Engineering Structures	Chennai	TWAD Bd.	9 days
12.	Waste Stabilisation Pond Practices	Kolkata	AIIH & PH	1 week
13.	—do—	Chennai	TWAD Bd.	-do-
14.	Filter Operation	Nasik Road	R&T.C., M.J.P.	10 days
15.	—do—	Chennai	C.M.W.S.S. Board	12 days
16.	Care & use of Chlorinators	Mumbai	C.T.I. & R.C., M.C.G.B.	1 week
17.	—do—	Chennai	CMWSS Bd.	-do-
18.	Water analysis	Kolkata	AIIH & PH	4 weeks
19.	Waste water analysis	—do—	-do-	-do-
20.	Water & waste water analysis	Jaipur	P.H.E.D.	-do-
21.	—do—	Chennai	TWAD Bd.	-do-
22.	Solid waste management	Kolkata	AIIH & PH	10 days
23.	Solid waste management	Bhopal	AIIISG	1 week
24.	Municipal solid waste management	Allahabad	MNNIT	-do-
25.	Preventive maintenance and leak detection in Water distribution system	Nasik Road	R&T.C., M.J.P.	10 days



Sl. No.	Name of the Refresher Course	Place	Conducting Agency	Duration
26.	—do—	Mumbai	C.T.I. & R.C. M.C.G.M.	10 days
27.	—do—	Chennai	T.W.A.D. Board	10 days
28.	Corrosion control	Chennai	C.M.W.S.S. Board	1 week
29.	Project planning and Preparation	Indore	SGSIT & S	10 days
30.	Recycling and reuse of wastes	-do-	-do-	10 days
31.	Computer application in PHE structures design	-do-	-do-	10 days
32.	Sewage works supervisors course	Chennai	C.M.W.S.S. Board	2 weeks
33.	Low cost sanitation	Poonamallee Chennai	I.P.H.	1 week
34.	—do—	Jaipur	R.I.L.S.G.	-do-
35.	Sewer maintenance and cleaning	-do-	-do-	9 days
36.	Computer application for water distribution	Mysore	S.J.C.E.	-do-
37.	System management and water treatment plant design			
38.	Computer aided design of Water supply & sewer network	New Delhi	AILSG	10 days
39.	Computer application for water Distribution system Management	Mumbai	A.I.L.S.G.	10 days
40.	Computer aided Design of Water and Waste Water treatment plants	Allahabad	MNNIT	1 week
41.	Scientific source Finding	Gandhinagar	G.J.T.I.	1 week
42.	Maintenance & management Related to municipal water works	Kolkata	I.P.H.E.	12 days
43.	—do—	Chennai	TWAD Bd	1 week
44.	Surface drainage in medium and small towns	Bhopal	AILSG	1 week
45.	Laying of water mains & sewer lines	Chennai	CMWSS Bd.	1 week
46.	Ground water	Kolkata	I.P.H.E.	1 week
47.	Water supply & sanitation to buildings	Kolkata	I.P.H.E.	1 week
48.	Operation and maintenance of W.S. and sanitation projects	Kolkata	AIIH & PH	10 days
49.	Water quality surveillance	Mysore	S.J.C.E.	12 days

Sl. No.	Name of the Refresher Course	Place	Conducting Agency	Duration
50.	Positive preventive maintenance of water supply and sewerage system	Bhopal	AILLSG	1 week
51.	Pumping & non pumping mains for water supply system-design, Operation and maintenance	-do-	-do-	1 week
52.	Total quality management in Water supply system	-do-	-do-	1 week
53.	Water supply from ground water sources-Quantity/Quality and ground water recharge	-do-	-do-	-do-
54.	Preparation of water supply projects	-do-	-do-	-do-
55.	Tenders & contract	-do-	-do-	-do-
56.	Pump and pumping machinery for Public Health Engineering Jobs	Kolkata	IPHE	-do-

### ABBREVIATIONS

1.	R&T.C	Research & Training Center
2.	M.J.P	Maharashtra Jeevan Pradhikaran
3.	K.W.A.	Kerala Water Authority
4.	P.H. Deptt.	Public Health Department
5.	T.W.A.D. Bd.	Tamil Nadu Water Supply and Drainage Board
6.	A.I.I.H. & P.H.	All India Institute of Hygiene and Public Health
7.	M.N.N.I.T.	Motilal Nehru National Institute of Technology
8.	V.N.I.T.	Visvesvaraya National Institute of Technology
9.	C.T.I. & R.C.	Civic Training Institute and Research Centre
10.	M.C.G.B.	Municipal Corporation of Greater Bombay
11.	P.H.E.D.	Public Health Engineering Department
12.	A.I.L.S.G.	All India Institute of Local Self Govt.
13.	S.G.I.T. & S.	Shri G.S. Institute of Technology and Science
14.	C.M.W.S.S.B	Chennai Metropolitan Water Supply and Sewerage Board
15.	I.P.H.	Institute of Public Health
16.	I.P.H.E.	Institution of Public Health Engineers
17.	R.I.L.S.G.	Rajasthan Institute of Local Self Govt.
18.	S.J.C.E.	Sri Jayachamarajendra College of Engineering
19.	G.J.T.I.	Gujarat Jalseva Training Institute

## CHAPTER 18

# PUBLIC AWARENESS & CUSTOMER RELATION

### 18.1 OBJECTIVE OF PUBLIC AWARENESS PROGRAMME

The objective of a water supply agency is to provide adequate supply of safe, good quality potable water at a reasonable cost and serve its consumers in a prompt and courteous manner. The consumers must be made to understand that potable water is not a free commodity and that it is a value-added commodity with cost implications. The quality of people's lives often depends on what the water utilities do and how they do it. The objective of any programme for public awareness is to achieve better customer relations, greater water conservation, and enhanced organisational credibility. This chapter discusses the need for public awareness with regard to water supply system maintained by local body. It also deals with the various aspects that are to be considered to improve the local public awareness by involving individually or with the voluntary organisation groups.

### 18.2 SCOPE OF A PUBLIC AWARENESS PROGRAMME

Scope of a public awareness programme is :

1. To enable the public to understand the operational dynamics of the water supply system.
2. To promote civic consciousness.
3. To understand and appreciate the water distribution strategies.
4. To inculcate consumer responsibility.
5. To establish good reputation for quality/service.
6. To inform and to obtain approval of public for various improvement measures thus creating a feeling of close participation.
7. To educate them on the basic rights of consumers and efforts undertaken by water utility/local body to ensure their basic rights.

### 18.3 PROCESS OF BUILDING UP PUBLIC AWARENESS

It is necessary to identify the audience such as community leaders, school children, or the average customer. It is advisable to prepare the publicity material to suit the target audience. Its public communication policy shall involve the elected Civic Body, Consumer Action Groups etc. The agency shall try new and imaginative ways of involving local communities in its plans and programmes thus according the public, its due pride of place.

### **18.3.1 DEFINING THE LOCAL COMMUNITY CONCERNED**

- Geographic or administrative boundaries.
- Major media in the locality concerned (newspapers, radio/televisions, local speakers, and town meetings).
- Customers and stake holders/local residents.

### **18.3.2 IDENTIFYING EXISTING LOCAL COMMUNITY CONTACTS**

- Elected officials (Joint Council/Sub Committee/Ward Committee members of local body).
- Prominent civic leaders.
- Clubs and associations (Chamber of Commerce, Consumer Service Committee consisting Consumer Association and Consumer action groups).
- Voluntary Organisations, Residents Association, etc.
- Industry Consumers.
- Schools/Colleges.
- Professional bodies (Doctors, Lawyers etc.).
- NGO, Community based organisations, Ward committees.

### **18.3.3 LISTING OUT THE MESSAGES TO BE COMMUNICATED**

- Status position of water supply.
- Service related issues such as temporary suspensions of services due to construction, maintenance and augmentation of supply.
- Changes in policy, launching of new schemes etc.
- Adoption of a Citizen's Charter containing objectives, mission statement, facts about the organisation, growth profile, achievements, commitments, major schemes to be implemented, service standards, customer assistance etc.
- Quality assurance related messages.
- Leak detection and repair works.
- Functioning of Information and Facilitation counters, customer assistance, grievances handling and redressal system, feed back from the public, Vigilance Committee, Consumer Service Committee.
- Billing and collection procedures/queries, tariff related issues, collection drives and special camps, levy of surcharge, reconciling of accounts.
- Need for rain water harvesting and artificial recharge.
- Extraction of ground water.
- Drought management - mobile lorry supply.
- Consumers survey - to issue questionnaire and obtain feed back from the consumer about the services of organisation at regular intervals for refining the service standards.
- Celebration of National Festivals, functions, World Water Day.

### **18.3.4 SELECTION OF COMMUNICATION METHODS**

A variety of media and communication methods exist, each with its own advantages and disadvantages. The use of several media at the same time can reinforce the messages. Person to person contact from community members who are already convinced of the message's truth is usually the most effective means of communication. The following are the some of the consumer friendly measures that could be effectively used for Public Awareness Programme for attaining complete transparency in operations.

- Fact sheets/brochures/pamphlets/handbills/Bill boards.
- Telephones/Telex/FAX/computer based Interactive Voice Response System (IVRS) dialing service.
- Visual Aids-Radio/T.V./Films/Video.
- Modern Electronic/Computer aids-E-mail.
- Hosting a web site.
- Slide/speech presentations.
- Small group meetings, Conferences, Seminars, Congresses.
- Community newsletters and oral communications, direct letter correspondences.
- News releases, advertising.
- Press meet and tours.
- Participation in Exhibition, Trade Fair.
- Open house meetings by involving Voluntary organisation, Residents Association and concerned interested group.
- In-house House journal to provide information to employees and stakeholders and to motivate to write articles/stories/lyrics/related subject.

### **18.4 BUDGET FOR PUBLIC AWARENESS CAMPAIGN**

The authorities shall list out the various aspects of public awareness programme as mentioned above and work out cost implications for implementing the Awareness Programme. With proper evaluation and necessary modifications if any, it would be possible to make the programme a success. Further, a form of planning and reporting is needed to monitor and control the public awareness activity.

### **18.5 FORMATION OF PUBLIC RELATIONS UNIT**

The following services may be offered under public relations Information & Facilitation:

- i) Registration and redressal of public complaints with feed back from complainant with help of reply cards, maintenance of suggestion books for customers to record their suggestions/remarks on the function of public relations counter.
- ii) Guidance to the public for new water connections and assistance for filling up of application form.

- iii) Guidance to the public for new assessment for water tax, name changes, annual value changes, classification changes and other tax and charges matters.
- iv) Guidance to the public to meet the concerned officer to make their representations and redressal of their grievances.
- v) Information regarding disruption of water supply due to urgent repair works.
- vi) Supply of self explanatory application form for the use of consumers that would help the consumer to tick and submit application with required enclosure to obtain various services such as new water connections, new assessments, name changes, annual value changes, classification changes, reconciliation of wrong demand, payment of water charges in installment, etc.
- vii) Supply of pamphlet on procedure on complaint registration and redressal.
- viii) Obtaining feed back from the consumers in redressal of their complaints/grievances.
- ix) Supply of Citizen's Charter to consumer to know the service standards of the organisation and also assurances for adherence to such service standards.
- x) Supply of pamphlet on rain water harvesting methods, procedures, and approximate estimate.
- xi) Creation of a single window system for redressal of grievances.
- xii) A separate telephone line should be available round the clock to record complaints for addressing them.

It will be better if one could have four digit telephone numbers for easy remembrance.

## **18.6 COURTEOUS BEHAVIOUR OF PUBLIC RELATIONS**

Since public relation and field staff are at the cutting edge level they should be properly trained. Courteous behaviour towards the public by public relation staff will give a better image of the utility in the minds of public. Since the first impression of the consumer is always the best impression it is necessary to impress on the consumer at the very first contact itself. Public relation staff should follow simple guidelines while answering telephone calls from consumers to create a positive image in the minds of public.

### **18.6.1 SUGGESTED GUIDELINES FOR ANSWERING CALLS**

- i) The staff at the telephone shall answer the call promptly say by third or fourth ring.
- ii) The agency's staff at the telephone shall identify himself/herself and let the caller know whom the caller is talking to.
- iii) The staff at the telephone shall not conduct side conversation and minimise distractions so that the caller can be given full attention avoiding repetition of names, addresses etc.
- iv) The staff at the telephone shall minimise transfers of the calls to other concerned officers.

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### **18.6.2 ANSWERING CONSUMER ENQUIRIES**

The staff at the telephone of the Public Relations Counter shall:

- Be familiar with the information of the services and policies of the utility.
- Learn to listen rather than interrupt the caller.
- Avoid technical jargon/unnecessary high sounding terms while talking to the caller.
- Summarise the caller's problem and repeat it to the caller for confirmation.
- Make every effort to promise specific action on the caller's complaint.

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# CHAPTER 19

## SAFETY PRACTICES

### 19.1 INTRODUCTION

As in any utility or industry, dangers are associated with Water Supply System Operation and Maintenance. There is therefore a need for safety practices. Physical injuries, cuts, bruises, and infection are common. However serious injuries necessitating long layoff, loss of limbs, eyesight, death due to accident or electrocution may also occur though not so frequently.

Adoption of safe practices and use of safety equipment may largely minimise occupational hazards.

Accidents do not happen – **they are caused.**

### 19.2 ACCIDENT INJURIES AND DEATHS IN WATER SUPPLY SYSTEMS

Figures of accidents/injury in various water works organisations or in utility concerns may be collected and included to show the extent of accidents. This can be in the following form or any other forms as available:

<i>Utility</i>	<i>Rates of accidents</i>
	<i>OR</i>
<i>No. of employees</i>	<i>Accident frequency rates</i>
Injury Frequency Rate F.R. =	$\frac{\text{Number of injuries} \times 1,000,000}{\text{Man-hours worked}}$
Severity rate S.R.	$= \frac{\text{Number of days lost} \times 1,000,000}{\text{Man-hours worked}}$

### 19.3 IDENTIFICATION OF ACCIDENTS

#### 19.3.1 SOURCE

In developing a safety programme it is necessary to know the source of accidents. It is then possible to take precautions and corrective action. Besides knowledge of accidents in the utility itself, review of records or information at other water supply systems or in other utilities is helpful. Record of injuries/accidents maintained by the concerned department of labour, industries or factory department of the state can also be consulted. Other sources of information are safety manuals, insurance company brochures etc.

The main dangers at a water works system include, but are not limited to, the following:

- (a) Physical injuries arising from handling objects, falling objects, lifting objects, falls, tools and equipment,



- (b) Stepping on or striking objects,
- (c) Machinery,
- (d) Infections,
- (e) Toxic gases,
- (f) Chemicals,
- (g) Fire,
- (h) Electrical shock,
- (i) Too much noise,
- (j) Collapse of trenches during repair of water mains.

### 19.3.2 LOCATION

The above dangers may exist at several locations in a water works system. These include, inter alia:

Intakes, Pumping stations, Transmission mains, Distribution system, Water Treatment plants, Storage places which include chemical hazards, large open filters, handling of materials, cleaning of internal sewerage system, septic tanks etc., mechanical & electrical hazards.

The person responsible for the safety programme should constantly on the alert for hazards, which may cause an injury to a workman.

### 19.3.3 TYPES OF INJURIES

To draw up a safety programme, it is important to know the type of injury that is most prevalent in water supply systems. The general injuries occurring in water supply systems are:

Bruises, cuts, sprains, fractures, burns, eye irritation and injuries, shocks, irritation by gases and other occupational diseases, deaths, permanent disabilities, temporary total disabilities

Statistical data of major type of accidents, which occur in Water Supply System in the country, have not been well documented. Some data which may serve as a rough guide to understand the overall injury pattern at one of the water utility in the country is given in Table 19.1

**TABLE 19.1**  
**STATISTICAL DATA OF MAJOR TYPE OF ACCIDENTS**

Cause of Accident	Percentage
Over exertion	20
Chemicals/gases	15
Fall on same level	11
Struck by falling object	10
Struck by moving object	9
Electrical shock injuries	8
Failure to wear safe attire	6
Caught in/on in between moving objects	5
Burns	4
Horseplaying, mischief making	4
Insect/animal bite	3
Others	5

### **19.3.4 COST COMPONENTS**

#### **Cost components of Accident**

The cost component of accidents include the following:

- Compensation paid to workers and/or affected persons.
- Medical expenses incurred on the injured/accident persons.
- Cost of repairing or replacement of equipment.
- Loss of production and consequential payment of overtime/damages.
- Legal expenses.
- Industrial relations.
- Loss of good will and reputation.
- Resiting of injured person on resumption and/or additional cost of hiring a new person including training cost.

### **19.4 SAFETY PROGRAMME**

#### **19.4.1 INTRODUCTION**

Safety practices require good management. For years, there may be minor injuries like cuts and bruises, but suddenly there could be a loss of limb, eyesight or even death.

Safety organisation is what you make of it. It may be a full-fledged safety organization with a Safety Officer with necessary staff. It could be only the person in charge of the plant with a few personnel picked out for special assignments. Everybody on the job knows what can happen under certain conditions but each is busy with his own duties and responsibilities. However, a safety officer works at safety full time. A Safety Committee may also be constituted. Whether you need a full time safetyman or not depends on the size of the Undertaking/organisation. *However, we need full-time attention to Safety.*

#### **19.4.2 SAFETY PRACTICE PROGRAMME**

##### **19.4.2.1 Preliminary step**

A safety programme is a must for a water supply system. It must have the full cooperation of the management; otherwise it will not be successful. A safety officer who can devote part-time or full time to the job in a large organisation may be designated as responsible for the programme. In a smaller organisation, that person may be the officer in charge of the plant.

##### **19.4.2.2 Records**

Keeping injury records is necessary for a safety programme. It is also mandatory in some of the Acts or Rules and Regulations framed by the Government. With records, the programme is given direction and will succeed.

For maintenance of records, standard forms are available. The formats could include items such as:

- (a) Accident report
- (b) Description of the accident

- (c) Doctor's report
- (d) Action taken
- (e) Accident analysis

Frequency rate and severity rate may be worked out as in para 19.2

A summary of types and causes of accidents should be prepared periodically; A suggestive format is given in Table 19.2

**TABLE 19.2**  
**SUMMARY OF TYPES AND CAUSES OF ACCIDENTS**

Type of injury	Primary cause of injury										
	Unsafe Act	Chemical	Falls	Handling Objects	Heat	Machinery	Falling Objects	Electrical	Striking	Misc.	Total
Fractures											
Sprains											
Eye Injuries											
Cuts											
Bruises											
Burns											
Miscellaneous											

There must be a review of all reports by the foreman/supervisor, safety officer and management. There must be recommendations to avert such accidents. A follow-up is necessary to see that proper action has been taken.

**19.4.2.3. Searching out hazards**

Hazards can be removed and will give increase in safety and will cost little time and money to correct. Some methods are:

- To examine records for conditions and situations that has caused accidents. Recall circumstances that led to the accidents. See if you can put your finger on some of the sore spots in your building, equipment or bad practices that are occurring.
- See what parts of the body are injured in the accidents. Protective gear may be required.
- Look around and inspect in an organised manner. Take help of your supervisors. Dig around for potential causes of personal injury and fire and health hazards.
- Be on the watch for unsafe practices and doing the job the wrong way. Always be on the watch.
- Reduce risks in the workplace, equipment and materials. With the supervisory staff you can cut down the amount of personal handling of tools and materials. It may be cheaper to buy power equipment.
- See that the work is done in the right and safe way.

#### **19.4.2.4 Motivation and training**

- For a good safety record, all individuals must be educated in safety measures. They must have conviction that accidents can be prevented. A safety programme must start on the new operator who has been freshly recruited or transferred from another work site. He must be exposed to the importance of safety, proper reporting and policies. Copies of Safety Practices should be supplied to him. Deeper training can be given to him subsequently after a few months. In the case of an individual who has been transferred, only the specific safety requirements in the new job are to be explained to him.
- Training will include how to perform the job. The plant supervisor must train the individuals in all aspects of plant safety. This will include dangers of electrical hazards, fire hazards, handling of tools and proper maintenance of tools to prevent accidents. Special instructions for specific work in confined environment such as pits, manholes, gas etc. must be given.
- The training must be continuous and not a one-time affair. During refresher education, case studies can be discussed. Victims of injuries can give their experience on how the accident happened. Safety posters placed at strategic points around the plant are a constant reminder and contribute to the continuing education.
- Proper guidance and use of tools, equipment must be given. Supervisors must continually check on proper use of tools. They must also see that the methods adopted are right and also safe.
- Motivate people to work safely when they are not being watched. Positive approaches like recognition of safety record, competitive interests etc. can be tried. Importance of good personal relations, a high morale and a sensitive management to the needs and interests of people plays a vital role in the programme of Safety Practices.

### **19.5 OPERATOR PROTECTION**

#### **19.5.1 PERSONAL SAFETY EQUIPMENT**

The first step in controlling an unsafe condition is to remove the hazard mechanically. A secondary measure of protection is to provide personal protective equipment to the workman. Study of records has indicated the large number of injuries to various parts of the body. Personal safety equipment is designed to help protect the person's eyes, face, head, nose throat, lungs, ears, hands, feet and body. Such safety equipment cannot protect the worker from unsafe actions or conditions. It can only supplement safe work or work habits.

##### **19.5.1.1 Head protection**

- All personnel working in any areas where there may be danger from falling, flying tools or other objects must wear approved hard hats. Such hats should be according to the relevant BIS. Special insulated hard hats must be worn when working around high voltage to protect from electrical shock.
- It is advisable to have detachable cradle and sweat bands for two reasons (1) to permit easy replacement of cradles and sweat bands and (2) to make possible assignment of

one helmet to several workers each with his own cradle and sweat band for sanitary reasons.

- Once broken, the crown of a hard hat cannot be effectively repaired. It must be replaced.

#### **19.5.1.2 Face and Eye Protection**

- Impact Goggles must be worn to protect against flying objects. They can be spectacle or cup goggles.  
Spectacle goggles must have rigid frame to hold lenses in proper position before the eyes. Frames must be corrosion resistance and simple in design for cleaning and disinfection.  
Cup goggles should have cups large enough to protect the eye socket and to distribute impact over a wide area of facial bones.
- Chemical Goggles and Acid Hoods for protection against splashes of corrosive chemicals. A hood treated with chemical-resistance material having a glass or plastic window gives good protection. There should be a secure joint between the window and the hood material.
- Face Shields can be used against light impact. Plastic shields should be non-inflammable, free from scratches or other flaws, which introduce distortions.
- Welding Masks must be used from splashes and radiation produced by welding.
- Protective Creams are used to protect the skin from contamination and penetration by oils, greases, paints, dust etc.

#### **19.5.1.3 Hands and Lower Arms**

- Protective sleeves, gloves and finger pads are used for different types of hazards and jobs.
- Rubber and asbestos gloves should be long enough to come well above the wrist, leaving no gap between the glove and coat or shirtsleeve.
- Gloves or mittens having metal parts for reinforcements should never be used around electrical equipment.
- Linemen and electricians working on energized or high voltage electrical equipment require specially made and tested rubber gloves.

#### **19.5.1.4 Body protection**

Overalls are sufficient for most jobs. Always use rubber aprons when working with chemicals. When working on ladders or scaffolding use extreme caution to prevent falls.

#### **19.5.1.5 Legs and Feet**

- Leggings are provided where leg protection is necessary and are in the same category as coats, frocks and aprons, kneepads made of cloth, padding, rubber, cork are used on jobs where kneeling is required.

- Ordinary work shoes are acceptable for many jobs. They should have nonskid soles to prevent slips. Safety shoes are required where there is danger of dropping tools or materials on the feet. Toe guards have been designed for the men to wear when operating machines as air hammers, concrete breakers etc. For working on electrical equipment suitable safety shoes must be used.

#### **19.5.1.6 Respiratory Equipment**

In all dusty areas, effective filter masks shall be used to guard against the specific hazard. Hose Mask should be used by men entering tanks or pits where there may be dangerous concentrations of dust, vapor, gases or insufficient oxygen. Hose mask with blower and the airline respirator are used where the hazard is immediate i.e., hasty escape would be impossible or could not be made without serious injury if there is failure of the equipment.

Oxygen or Air Breathing Apparatus i.e. self-contained oxygen breathing equipment using cylinders or bottles of compressed oxygen or air is used where required. This is a must when the length of the hosepipe on on-line supply of oxygen exceeds more than 45 m.

Gas Masks - Canisters consist of a face piece connected by a tube to a canister. Chemicals in the canister purify contaminated air. No one chemical has been found to remove all gaseous contaminants. It does not supply oxygen and can be used where there is sufficient oxygen.

#### **19.5.1.7 Ear Protection**

Where noise levels are high and exceeds specified limits, effective ear-pads or earplugs must be used

#### **19.5.1.8 Training**

Supplying the appropriate equipment to the worker does not solve the problem. The employee must know when, how and where to use the equipment provided as well as its limitations. This requires that the men must be trained.

### **19.5.2 PERSONAL HYGIENE PRACTICES**

Every employee must practice personal cleanliness to prevent body infections. A clean plant is safer, both from physical accidents and infection. Hands must be washed with soap after working and before eating or smoking.

Use the first-aid kit for immediate treatment of minor cuts, bruises and scratches.

### **19.5.3 PROPER USE OF TOOLS**

Some of the basic tool rules are:

- (a) Always select the right tool for the job. Screwdrivers are not prying bars. Pliers are not wrenches.
- (b) Repair or replace broken or worn tools regularly.
- (c) Never use tools on or near moving machinery.
- (d) Be sure you have enough room, if the tool should slip.
- (e) Be sure you have good footing to prevent slipping.

- (f) Wear well fitted gloves except when hammering.
- (g) Never wear rings or loose clothing around moving machinery.
- (h) Always wear goggles whenever using any impact tools, power grinder or sharpener.
- (i) After using each tool, wipe, clean and replace in carrier or work belt. A greasy wrench can be dangerous.
- (j) Do not lay tools on top of ladders or where they may fall on someone working below.
- (k) Always use non-sparking tools on any job where explosive gases could be present.

## **19.6 SAFETY IN PLANT MAINTENANCE**

### **19.6.1 MAINTENANCE HAZARDS**

Plant maintenance also called housekeeping or cleaning up is an important function of the treatment plant and essential for plant equipment. Maintenance requires an operator to handle machinery, manual and power tools, repair electrical equipment, enter pits, sumps, manholes etc. All these functions can pose a hazard and cause injury, fire, disease or death.

Fixed safety features are designed or built into the structures. However there are instances where the maintenance engineer may alter or augment the existing structure. Prompt effective maintenance can prevent many accidents.

### **19.6.2 CLEANING**

Keeping the entire plant clean will provide a much nicer place to work. Just keeping the working areas free of tripping hazards will add safety in the plant. Cleaning should be performed when others are not exposed to danger or inconvenience. Wet floors become slippery. Use notices to warn people.

Provide and use trashcans for used oily rags. Hazardous waste, acids and caustics should be cleaned up immediately.

Doorways, aisles, stairways and work places must be kept free of rubbish to reduce hazards of tripping and fire.

### **19.6.3 PAINTING**

Regular painting is done at most plants. The following considerations must be kept in mind:

- When working with toxic paints i.e. containing lead, zinc or organics, be sure to clean your hands before eating or handling food.
- Avoid exposing your skin to solvent and thinners and try not to use compounds such as carbon tetrachloride.
- When spray painting, use a respirator to avoid inhaling fumes.
- No smoking or open flames of any kind should be allowed around the area being painted.
- When painting or cleaning the spraying equipment avoid closed containers where heat is involved. At a certain temperature called the flash point, spray or vapours could ignite and burn the operator or start fires. Always clean the spray equipment in an area with sufficient ventilation.

- Be very careful when using scaffolding or ladders. They must be strong and in good repair.
- Rags containing paint or oil should be placed in a closed container to avoid fires.

#### **19.6.4 ACCESS TO EQUIPMENT**

Safe access to equipment will reduce dangers from falls. Ramps and step stairs provide the safest means. Slope of ramps and rise of steps should not be excessive. Step stairs should have hand railings and the tread at least 9 inches (25 cms).

Vertical ladders should be discouraged. However, they are commonly employed. A vertical ladder of 10ft (3m) or more in length should be equipped with a hoop cage to enable the operator to regain his hold in case of a slip. Rungs of vertical ladders should not be less than 30 cms (12 in) or more than 40 cms (15 in) vertically. Minimum width should be 25 cms (9 in): preferably 30 cms to 40 cms.

Adequate workspace around equipment is important.

#### **19.6.5 GUARDS, RAILS, FENCING, ENCLOSURES, SHIELDS**

These are designed to prevent, slipping, falling or contacting machinery when in operation. If they are missing they should be repaired or replaced. When removed for repairs, put a temporary safety line. Protective devices must be replaced promptly.

Settling tanks, basins, manholes, sumps and other underground structures must be provided with railings or fencing. Safety belts must be used where necessary.

#### **19.6.6 LIGHTING**

Adequate glare free lighting should be provided especially in the vicinity of steps and vulnerable places. Flood lighting should be provided at suitable places for safety and security of the complex.

#### **19.6.7 VENTILATION**

Ventilation is a major factor in water supply systems. This can be secured by:

- (a) By open exterior windows or door louvres.
- (b) By fresh air intakes and mechanical exhaust fans/ducts.
- (c) By use of forced-draft fans.
- (d) By use of portable air compressors or air blowers.

#### **19.6.8 SAFETY FROM EQUIPMENT**

When maintaining and operating equipment, the following precautions should be taken:

- Always stop the machine before removing any guard.
- Personally lock out all power before starting any equipment maintenance. Put a warning sign and tag on the lockout.
- Do not unlock any power, which has been closed by others.
- Block any counter balance or weighted machine to prevent dead movement.
- Have enough help and hoisting gear to handle heavy equipment safely.
- Block up under any heavy equipment when on jacks or hoists before starting work.



- Keep tools in a kit bag or belt (not on the floor).
- Keep goggles handy. Use them wherever needed.
- Don't be in a hurry. Haste makes accidents.
- An authorized person should handle overhead travelling cranes. Circuit breakers, limit switches, hook and wire should be checked. Only standard hand signals, known to all, should be used. When loads are to be moved give a warning and make sure everyone is in a safe position. Hard helmets must be used.
- When using portable power tools use safety protective devices when operating grinding, chipping, buffing or pavement breaking equipment. Extension cords provide a tripping hazard. When working in damp or wet conditions use rubber mats. Electric tools should be grounded. For pneumatic tools use safety clamps and connectors. Electrical cords and air hoses should be kept away from oils, chemicals or sharp objects.
- Portable electric lamps should not be more than 24 volts and should conform to I. E. regulations.
- In gas or electric welding, the operator must be trained. Fire protection and personal protection practices must be followed. Storage of gas cylinders must be done with the same care as those of other gases in a water supply system.
- All safety valves in the system must be regularly inspected according to the maintenance schedule.
- Where forklifts are used, do not permit anybody, except the operator, to ride on it. Make sure the warning signals are operating. Check brakes. Make sure the forklift load is stacked properly before lifting or moving.

#### **19.6.9 LUBRICATION SAFETY**

1. Avoid lubricating machinery when it is running. If you have to do so, ensure that the lubricating point is at 30 cms. away from the moving part or the lubricant should be piped outside a guard.
2. Wipe spilled oil or grease immediately.
3. Never point a grease gun at anyone. Never squirt grease into your hands.

#### **19.6.10 SAFETY IN CONFINED SPACES**

Any place where oxygen deficiency or dangerous air contamination can occur and where ready ingress or egress for removal of a person is not available can be defined as a confined space. Some of such places are pits, manholes, basins and tanks. Accumulation of gases and vapours in confined spaces can produce explosive mixtures.

Oxygen deficiency occurs when oxygen is removed or when another gas displaces it. Oxygen is removed from air when it is used up due to bacterial action; by the oxidation of metals; combustion and when inert or toxic gases displace it.

When oxygen in air is reduced to less than 17%, shortness of breath takes place and further reduction leads to loss of consciousness. Death occurs at 10% or less. Toxic gases cause injury or death by their own action.

Safety checks must be carried out when working in such spaces. More information is available in the Manual of Sewerage and Sewage Treatment issued by the Ministry of Urban

Development, Government of India in Chapter 8 (8.9-Hazards; 8.10-Precautions; and 8.11-Safety Equipment).

When working in confined spaces ensure that sufficient air changes as required takes place.

## 19.7 HAZARDS IN CHEMICAL HANDLING — GASES

Gases commonly used in water treatment in this country are listed in Table 19.3

They are supplied in cylinders or drums. Some chemicals are generated at the plant itself. Exposure to the liquid form of the gases causes damage to human tissues such as skin burn. Most gases are heavier than air and displace air-containing oxygen. It is therefore important to have proper ventilation and use the right type of respirator.

**TABLE 19.3**  
**GASES USED IN WATER TREATMENT PLANTS**

Name and Formula	Common Name	Available Forms	Specific Gravity	Flammability	Colour	Odour	Containers
Chlorine, Cl <sub>2</sub>	Liquid Chlorine	Liquid-Gas	1.468@ 0°C	None	Greenish Yellow	Irritating	Cylinder One-ton
Carbon Dioxide, CO <sub>2</sub>	Dry Ice	Liquid-Gas	0.914	None	Colourless	Odourless	Bulk Liquid under pressure

### 19.7.1 CHLORINE

Chlorine is considered as a hazard in the water industry. Chlorine gas is poisonous to humans. It is very corrosive when in contact with water. Extreme care must be taken when working with chlorine to prevent accidental injury to operators. Small amount can cause severe coughing and irritation of the nose, throat and lungs.

Precautions to be taken when handling Chlorine are given in Chapter 8 Disinfection

### 19.7.2 CARBON DIOXIDE

Carbon Dioxide has limited use in water treatment plants but it is dangerous and causes suffocation due to lack of oxygen. Therefore, when using carbon dioxide keep in mind the safety requirements. Since the gas is a heavy vapour, it does not tend to diffuse away rapidly. Persons must be on guard when entering pits, manholes, wells etc.

First aid involves moving the victim to fresh air, giving resuscitation and getting medical attention.

## 19.8 HAZARDS IN CHEMICAL HANDLING — ACIDS

The antidote to all acids is neutralisation. Most often large amount of water will serve the purpose. If acid is swallowed, then lime water or milk of magnesia may be needed. If vapours are inhaled, first aid usually consists of providing fresh air, artificially restoring breathing or supplying oxygen. Baking soda is used to neutralise acid falling on the skin.

Many acids are used in water treatment. However in this country, Sulphuric acid is extensively used. The properties of Sulphuric acid are shown in Table 19.4:

**TABLE 19.4**

Name, and Formula	Common Name	Available Forms	Specific Gravity	Flam-mability	Color	Odor
Sulphuric Acid, H <sub>2</sub> SO <sub>4</sub>	Oil of Vitriol; Vitriol	Solution	1.841	N/A	Clear	Odonrless

### 19.8.1 SULPHURIC ACID

1. Sulphuric acid is the most dangerous chemical handled at the plant. The main hazard is from contact. Fumes are dangerous but normally at room temperatures, there are not many fumes.
2. Always use protective clothes and equipment. Contact with the acid on body tissue results in severe burns immediately. Immediate flooding with water is essential.
3. Clean the acid spill immediately. Do not leave the area until it is well marked or guarded. Neutralise the acid with soda ash and then flush it down the drain.

First aid is speed in removing sulphuric acid from the body. Continue irrigation with running water and alternating applications of mild alkaline solutions (bicarbonate of soda). Irrigate eyes with large amounts of water. If swallowed, do not induce vomiting but encourage patient to wash out his mouth with large amount of water and then drink as much water as possible. Get medical help immediately.

### 19.9 HAZARDS IN CHEMICAL HANDLING – BASES

The bases used in water treatment are known as hydroxides. They are used to raise pH. Compounds of sodium, calcium and ammonia are strong bases. Silicate, carbonate and hypochlorite are weak bases. Table 19.5 lists some of the basic compounds used in water treatment in this country.

**TABLE 19.5  
BASES USED IN WATER TREATMENT**

Name and Formula	Common Name	Available Forms	Spec.Grav. or lbs/cu ft	Flamma-bility	Color	Odor	Contai-ners
Calcium Hydroxide and Calcium Oxide Ca(OH) <sub>2</sub> or CaO	Hydrated Lime or Quick-lime	Dry Powder, Lump	50-70	N/A	White	Dust	Bags, Bulk, Trucks
Sodium Hydroxide, NaOH	Caustic, Lye	Lump, Liquid, Flake	1.524	May Cause Flammable Conditions	Opaque White	Toxic, Pungent	Drums, Bulk, Trucks
Sodium Silicate, Na <sub>2</sub> SiO <sub>2</sub>	Water Glass	Liquid	1.35-1.42	N/A	Opaque	N/A	Drums, Bulk Trucks

### **19.9.1 CALCIUM HYDROXIDE (HYDRATED LIME)**

1. Lime has a great affinity for water and a great deal of heat is evolved when the two come in contact. Storage in damp places may cause a fire in nearby flammable materials. Calcium hydroxide (hydrated lime) is less troublesome than calcium oxide (quicklime).
2. They should be stored in a cool, dry place. In damp places fire may be caused in nearby flammable material. Also do not mix dry quicklime with other chemicals that contain water of crystallisation like alum or ammonium sulphate
3. Persons exposed to lime dust must be protected with personal protective equipment. Prolonged exposure to lime dust causes dermatitis especially at points of perspiration. Face shields, chemical goggles must be used when inspecting lime slakers.
4. First aid for lime burns is about the same for any caustic burn - Thorough flooding with water.

### **19.9.2 SODIUM HYDROXIDE (CAUSTIC SODA)**

1. Dry caustic soda should be stored in a dry place where it will not be exposed to moisture, liquid caustic in steel covered tanks.
2. Workers are exposed to splash and mist. They must wear protective equipment like safety goggles, face shields, rubber gloves aprons, boots and cotton overalls.
3. First aid is the same as for any caustic burn. Irrigate well with water.

### **19.9.3 SODIUM SILICATE**

1. Sodium silicate is a liquid. Although non-toxic, non-inflammable and non-explosive it presents the same hazards to the skin and eyes as other base compounds.
2. Avoid prolonged contact with the skin. Wash with plenty of warm water. Use face shield and rubber gloves when working with the solution. Use goggles.

## **19.10 HAZARDS IN CHEMICAL HANDLING – SALTS**

The various salts (chemicals) used in water treatment in this country are given in Table 19.6.

### **19.10.1 ALUMINIUM SULPHATE (ALUM) AND FERROUS SULPHATE**

1. These materials should be stored in a clean dry place, for moisture has a tendency to cake the material.
2. Handlers should wear protective clothing and protective cream on exposed skin surfaces because these chemicals can cause irritation to the skin and mucous membranes and serious injury to the eyes. Use the same precautions for liquid solutions, with added protection for the eyes.
3. Do not use compressed air to clean dry feed machines and equipment. Keep covers on feeding equipment.
4. Remember that mixtures of dry alum and quicklime can explode. Ferrous sulphate dust is more corrosive to equipment, and, when moist, is a good conductor of electricity.

**TABLE 19.6**  
**SALTS USED IN WATER TREATMENT**

Name, Formula	Common Name	Available Forms	Density, lbs/cu ft	Flammability	Color	Odor	Containers
Aluminum Sulphate, $Al_2(SO_4)_3 \cdot 14H_2O$	Alum, Filter Alum	Liquids, Powder, Lump	1.69 38-67	None	Ivory	N/A	Bags, Tank Truck, Bulk
Ferric Chloride, $FeCl_3$	Ferrichlor, Chloride of Iron	Syrup, Liquid, Lump	60-90	None	Dark Brown, Yellow	N/A	Carboys, Tank Cars
Ferric Sulphate, $Fe_2(SO_4)_3$	Ferrifloc, Ferrisul	Powder, Granule	70-72	None	Red-Brown	N/A	Bags, Drums
Ferrous Sulphate, $FeSO_4 \cdot 7H_2O$	Coppras, Green Vitriol	Crystal, Granule, Lump	63-66	None	Green	N/A	Bags, Drums, Bulk
Sodium Aluminate, $NaAlO_2$	Soda Alum	Dry Crystal, Liquid	(27°)	None	White, Green-Yellow	N/A	Bags, Bulk
Copper Sulphate, $CuSO_4$	Blue Vitriol, Blue Stone	Crystal, Lump, Powder	60-90	None	Blue	None	Bags, Drums
Sodium Chlorite, $NaOCl$	Technical Sodium Chlorite	Powder, Flake, Liquid	70 dry	Oxidizer	Light Orange	None	Tank Truck, 100 lb-Drums
Potassium Permanganate, $KMnO_4$	Permanganate	Crystal, Powder	90-100	Oxidizer	Purple	None	Drums, Bulk

Ferrous sulphate dryers can also corrode essential instruments or equipment in the vicinity of dusty conditions. Electrical equipment in the area should be of the dust-proof type and frequently cleaned

5. First aid for skin irritations and mild burns should be the same as for any acid burn. Scrub with plenty of warm water and soap, followed by a good shower as soon as possible. For any irritation of the mouth and nasal passages, irrigate freely with warm water. If the material is in the eyes, flush with large quantities of warm water, and consult a physician.

### 19.10.2 FERRIC CHLORIDE

1. This is a very corrosive compound and should be treated as you would treat any acid.
2. The salt is highly soluble in water, but in the presence of moist air or light, it decomposes to give off hydrochloric acid, which may cause other problems regarding safety. When handling liquid ferric chloride, normal precautions should be taken to prevent

splashing, particularly if the liquid is hot. Use a face shield to protect your eyes and rubber aprons to protect clothing.

3. First aid for eyes exposed to the liquid is that the eyes must be flushed out immediately for 15 minutes with large amounts of water. Ferric chloride should also be washed off the skin with water, as prolonged contact will cause irritation and staining of the skin.

### **19.10.3 FERRIC SULPHATE**

1. Because of its acidic nature, operators using this compound should be provided with protection suitable for dry or liquid alum.
2. Use protective clothing and a respirator. Avoid prolonged exposure to the dry form because of its acidic reaction with moisture on the skin, eyes and throat.
3. First aid for exposure to the eyes requires the eyes to be flushed immediately with lots of water. The skin should also be flushed with large amounts of water. Prolonged contact may cause irritation.

### **19.10.4 SODIUM ALUMINATE**

1. There are few hazards with this compound, but as with other chemicals, you should use precautions when handling it.
2. Use respiratory protection when handling the dry compound to prevent the inhalation of dust.

First aid for eyes that are exposed is to flush with water; keep the skin clean with water.

## **19.11 SAFETY IN CHEMICAL HANDLING – POWDERS**

### **19.11.1 ACTIVATED CARBON**

1. One of the greatest dangers in carbon storage is the fire hazard. Storage bins for dry bulk carbon should be of fireproof construction, and equipped with carbon dioxide equipment or water spray for fire control.
2. Bag storage should be in a clean dry place, in single or double rows with access aisles around every stack for frequent fire inspections, and to facilitate removal of any burning carbon.
3. Smoking should be prohibited at all times in the carbon handling and storage areas. Keep carbon away from heated pipes, or any possible fire hazard such as electric motors or electric wiring.
4. Dust-proof motors and explosion-proof electrical equipment that can be kept dust-tight should be used. Damp carbon dust is a conductor of electricity and can short circuit electrical equipment.
5. Dust masks should be worn when handling carbon, and good dust collecting equipment should be used. When loading carbon bins or hoppers, the personnel should also wear dust-proof goggles, a cap, and loose clothing tied at the wrists and ankles.

### (a) Controlling fires

Activated carbon burns like ordinary charcoal, without smoke or flame, and glows with intense heat. Such fires are sometimes difficult to detect, and when found, are hard to handle. A fire in a large storage bin or stack may burn for some time before being discovered. The smell of charred paper from the bags, or an area of scorched paint on the side of the hopper is indication that a fire is in progress.

Burning carbon should never be doused with a large stream of water, as the steam produced will scatter burning carbon in all directions. A fine spray or fog nozzle works much better. In working with a carbon fire in a confined area, remember there is danger from carbon monoxide, so air-supplied hoods or self-generating oxygen masks should be available.

Most activated carbon has sufficient oxygen adsorbed in the material so that it can burn in the absence of air. Carbon will start to burn if a temperature of 350 to 450 degrees Fahrenheit is reached, depending on the type of material and the fineness of grinding. The best way to combat the fire is to reduce the surrounding carbon below this ignition point, by soaking with water from spray nozzles

## 19.12 FIRE PROTECTION

Very little attention is paid to fires. Three elements cause a fire – fuel, oxygen and a means of ignition. If any one is missing, there is no fire. Fire fighting is based on removing one of these elements. In any fire, only the cause or fuel for burning varies.

### 19.12.1 CLASSIFICATION OF FIRES

TABLE 19.7

Class of Fire	Description	Extinguishing medium	IS No.
A	Fires involving ordinary combustible materials like wood, paper, textiles etc. where the (constant air pressure) cooling effect of water is essential for the extinction of fires.	Water Soda acid type, Water type (gas pressure), Water type	934 940 6234
B	Fire in flammable liquids like oils, solvents, petroleum products, varnishes, paints etc. where a blanketing effect is essential.	Foam Carbon dioxide Dry Powder	933 2878 2171 4308
C	Fires involving gaseous substances under pressure where it is necessary to dilute the burning gas at a very fast rate with an inert gas or powder.	Carbondioxide Dry powder	2878 2171 4308
D	Fires involving metals like blanketing aluminium, zinc, potassium etc. where the burning metals is reactive to water and which requires special extinguishing media or technique.	Dry powder Special dry powder for metal fire.	2171 4861
E	Fires involving electrical equipment where the electrical non-conductivity of the extinguishing media is of first equipment importance.	Carbon dioxide Dry Chemical powder when electrical is de-energised, same as for Classes A and B.	2878 2171 4308

Note: "E" type category has been recently removed.

## 19.12.2 FIRE EXTINGUISHERS

There is no one extinguisher that is effective for all fires, so it is important that you understand the class of fire you are trying to control. One must be trained in the use of the different types of extinguishers, and the proper type should be located near the area where that class of fire may occur. A preventive maintenance program for fire extinguishers requires a considerable amount of time from the operator and requires a system of record keeping.

### Types of fire extinguishers

#### (a) Stored Pressure, Cartridge Operated, Water Pump Tank, and Soda-Acid

These are suitable for Class A fires. Proper maintenance is essential and a schedule should be drawn up.

1. The method of operation for a stored pressure extinguisher is simply to squeeze the handle or turn a valve. The maintenance is also simple: check air pressure and recharge the extinguisher as needed.
2. For the cartridge type, the maintenance consists of weighing the gas cartridge and adding water as required. To operate, turn upside down and bump.
3. To use the water pump tank type of extinguisher, simply operate the pump handle. For maintenance, one has only to discharge the contents and refill with water annually or as needed.
4. The soda-acid type must be turned upside down to operate; it also requires annual recharging.

#### (b) Foam Type

Foam type of extinguishers will control Class A and Class B fires well. They, like soda-acid, operate by turning upside down and require annual recharging.

The foam and water type extinguishers should not be used for fires involving electrical equipment. However, they can be used in controlling flammable liquids such as gasoline, oil, paints, grease and other Class B fires.

#### (c) Carbon Dioxide (CO<sub>2</sub>)

Carbon Dioxide extinguishers are common. They are easy to operate, just pull the pin and squeeze the lever. For maintenance, they must be weighed at least semi-annually. Many of these extinguishers will discharge with age. They can be used on a Class C (electrical) fire. All electrical circuits should be switched off, if possible, before trying to control this type of fire. A carbon dioxide extinguisher is also satisfactory for Class B fires, such as gasoline, oil and paint, and may be used on surface fires of the Class A type.

#### d) Chemical Extinguishers

Chemical extinguishers are either (1) cartridge operated (2) stored pressure. These are recommended for Class B and C fires and may work on small surface Class A fires.

1. The cartridge-operated extinguishers only require you to rupture the cartridge, usually by squeezing the lever. The maintenance is a bit more difficult, requiring weighing of the gas cartridge and checking the condition of the dry chemical.



2. For the stored-pressure extinguishers, the operation is the same as the CO<sub>2</sub> extinguisher. Just pull the pin and squeeze the lever. The maintenance requires a check of the pressure gauges and condition of the dry chemical.

### **19.12.3 DANGER POINTS**

The danger points are:

- Unattended storage rooms where combustibles are present
- Workshops with cleaning liquids, oil and soaked rags
- Laboratories with chemicals, heaters, burners
- Offices where much paper is present.

### **19.12.4 PREVENTION**

1. Emphasis should be on good housekeeping. A clean environment raises morale and reduces tendency for slovenliness and carelessness.
2. Rubbish and waste not properly cared for is the biggest fire hazard.
3. Oil-soaked waste or rags should be stored in metal cans and covered.
4. Additions, alterations must be of non-combustible materials.
5. Combustibles must be kept away from heating equipment or where flames are present.
6. Proper check and maintenance of electrical equipment and wiring should be carried out.
7. Automatic fire-alarm systems should be installed in fire-prone areas.
8. Fire extinguishers and fire fighting equipment must be installed and maintained regularly.
9. Avoid careless use of matches, blow torches, Bunsen burners or smoking.

### **19.12.5 FIRE DUE TO CHEMICALS**

1. Sodium Chlorite, being used for odour control in waterworks becomes explosive and a fire hazard in presence of organic matter. Even a spark or sunlight can set it off. When spilled on a wooden floor, fire is caused with the scuff of a shoe. Spillage on clothes has resulted in locker fires. Fires can be controlled by soda ash or sand— never water. It should be stored by itself far removed from organics, sulphur or acid.
2. Activated carbon is another fire hazard and has been discussed in 18.11- Safety in Chemical Handling – Powders.

## **19.13 SAFETY FROM ELECTRICAL HAZARDS**

Refer to Chapter 11 para 11.8.2 – Safety practices in Electrical works

### **19.13.1 GENERAL RULES**

1. Only trained and qualified persons should be allowed to operate and maintain electrical equipment.
2. When servicing any electrical appliance, kill, lockout and tag all power coming to it.

3. Be sure of proper footing so that you don't fall onto a live wire. Always make sure that the wire is not live. Use a pencil type tester.
4. Hand tools must have insulated handles. Insulated mats must be provided before electrical controls.
5. Ensure that all electrical systems, equipment etc. are properly grounded.
6. Remove metallic rings, watches, eye glasses. Don't use metallic tape measures or metal ladders.
7. Always mount and protect wires and cables to prevent tripping by persons.
8. Electrical controls should be in good working order, easy to reach and plainly identified.
9. Be sure there is someone to help in case of emergency. Don't become careless or overconfident.

### **19.13.2 ELECTRICAL FIRST AID**

1. Immediately free the victim from the live conductor by use of a dry wooden stick, (such as a broom or shovel handle), piece of rubber hose or plastic pipe, or other nonconductor. Never grab the victim or the wire with bare hands, or you will suffer the same consequences.
2. If unconscious or not breathing, artificial respiration should be started immediately and continued until relieved by doctors or professional. Please refer to 9.8.3.1 in Chapter 9.
3. Protect from shock by keeping the victim warm and quiet.

## **19.14 SAFETY IN THE LABORATORY**

Safety in handling and storage of chemicals has already been discussed in the preceding sections — Hazards in Chemical Handling 19.9 to 19.11 Operators do not experience a great deal of exposure to hazardous laboratory conditions. However proper practices must be followed to avoid accidents.

### **19.14.1 SAMPLING SAFETY**

1. Never take field samples with bare hands. Always wear gloves.
2. Do not climb over or go inside guardrails. Use poles, ropes, dippers, or other long distance samplers.
3. When collecting gas samples, do not open tank cover completely. Install a sampling port, if needed.
4. Wear an effective gas mask when taking gas samples.

### **19.14.2 HOUSEKEEPING**

- General cleanliness and correct storage of chemicals and equipment are important for accuracy as well as safety in the laboratory. Basic rules include:

1. Follow a daily general clean up schedule in the laboratory. Dirty glassware or clothing can encourage infection. Put all chipped, cracked or broken glassware into containers marked 'Broken Glass only'.
2. Have a special spot for storing each piece of equipment. After each use, clean, disinfect, and return to its rack.
3. Never work in a poorly ventilated room. Keep the laboratory well lighted. Do not crowd the laboratory. Have plenty of room.
4. Always clean up and discard any spills at once.
5. All workbenches or tables should have chemical resistant tops, or be painted with chemical resistant paint frequently.
6. Do not store any other equipment in the laboratory.

### **19.14.3 SAFETY WITH CHEMICALS**

1. Keep working amounts of chemicals stored out in the lab to a minimum.
2. All bulk chemicals should be stored in original containers, in a separate fire proof store room. Larger bulk containers should always be on the floor.
3. Have individual bulk siphons to transfer chemicals from bulk storage to working stock bottles.
4. All chemicals storage jars should stand on wide shelves with retaining rails to prevent their accidentally being pulled or jarred off.
5. Strong and/or highly corrosive acid and base storage jars should stand in lead, plastic, or ceramic individual trays deep enough to contain the contents if the jar should break.
6. All chemical storage should be as low as possible and never more than shoulder height.
7. Clearly label all chemicals with common and chemical names, formula, strength, and date prepared or received. Replace these labels as needed to keep them legible.
8. Add red "Skull and Cross bones" labels to all containers of toxic chemicals.
9. Workers familiar with their properties must carefully dispose of used chemicals. They must not be flushed down the drain without due consideration of their effect on the sewer system.
10. Keep highly reactive chemicals stored far apart.
11. Perform all work that involves volatile acids, bases or solvents in a hood. Be very cautious with nitric acid. Do not add it to substances that are easily oxidised or nitrated. This can cause a fire or explosion. Other examples are: nitric acid with acetone; with benzene and toluene; with acetic acid.

### **19.14.4 SAFETY WITH EQUIPMENT**

1. Only trained experienced technicians should operate laboratory equipment, especially pressure units.
2. Exact, clear operating procedures, for autoclaves, water stills, and any other special pressure equipment will be permanently posted near same.

3. Valves and switches on such equipment shall be clearly numbered in their order of use. All electrical equipment must be well grounded. Inspect all electrical cords for wear or cracks in insulation, and replace as necessary.
4. Manufacturer's operations, warranty, service, and safety instructions shall be kept in a permanent file.
5. All equipment shall be set up away from gas and electric service switches or valves.

#### **19.14.5 SAFETY WITH GLASS**

1. Wear gloves any time you are working with glass.
2. Hold rod or tube in contact with stopper and twist to insert.
3. Wear full or wrap-around goggles or a face shield when working glass.
4. Always support glass units with several padded clamps firmly anchored.
5. Properly shatter and discard all chipped or cracked glassware.

#### **19.14.6 SAFETY IN LABORATORY PROCEDURES**

1. Never pipette by mouth. Always use a bulb.
2. Know your procedure and follow a check list.
3. Always wear safety glasses or goggles in the laboratory.
4. Never wear contact lenses in the lab.
5. Have a viewing window so visitors won't enter the laboratory.
6. Always wear a rubber apron when working with chemicals or running any reaction.

#### **19.14.7 FIRST AID AND FIRE PREVENTION IN THE LABORATORY**

1. Have an adequate supply of a good eyewash at all times.
2. Keep several fire blankets in an easily accessible location.
3. Special fire extinguishers, clearly labelled and checked for monthly charge, for chemical and electrical use should be openly mounted.
4. Emergency numbers for fire and medical help should be clearly and permanently posted above every phone.
5. All employees, and especially laboratory technicians, should have extensive, regularly refreshed, first aid training.

### **19.15 SAFETY PRACTICES DURING REPAIR AND OPERATION OF WATER MAINS**

#### **19.15.1 PLANNING**

A safety practice during construction and maintenance of the water distribution system has two major aspects — preparation and planning and operation. Usually previous methods are followed and these are revised on past experience. However, if we want to complete routine or special jobs successfully, we must plan them. This will eliminate possible hazards.

Proper maps of the system must be maintained and studied. A study of the character of the area in which the work is to be carried out is an accident prevention item.

### **19.15.2 TRAFFIC CONTROL**

1. Warning signs must be placed well ahead of the work area. Signs, barricades and used tyres can be used.
2. Vehicles can be parked between work area and the coming traffic.
3. Use red warning lights or flashers during the night.
4. Use a flag man for one way operation.
5. Traffic police must be informed and their help taken.

### **19.15.3 SAFETY PRACTICES IN REPAIR AND LAYING OF PIPES**

1. Excavations should be closely watched. Type of soil must be studied and necessary precautions taken to provide adequate side slopes or to shore up the trench. The proximity of poles and buildings must be taken into consideration.
2. All soil must be stacked at least three feet from the edge of the trench.
3. Repair of broken mains is a hand job. The ground is usually saturated or washed out. Care must be taken to protect other utilities especially electric cables which can be dangerous. Welding must be done in dry conditions.
4. The workmen must use safety hats and other protective equipment.
5. Only one trained and experienced man should give signals to a crane operator.
6. The inspection of the equipment to be used should be done before it is sent to the site. In case of a burst main, the advance crew should carry plans showing the location of valves to be closed, barricading equipment, signage, valve and chamber keys etc. Portable pumps to drain out the water should also be sent.
7. The pipe for replacement must be blocked to prevent it from rolling. Proper equipment should be used when lowering it into the trench. Sufficient men should also be engaged.
8. When the job is completed, cleaning up must be done to prevent hazards to others.

### **19.16 SAFETY IN VEHICLE OPERATION**

1. Make sure that the vehicle is in proper order including brakes etc.
2. Only licensed drivers should be engaged on the operation of vehicles. One or two drivers should preferably handle each vehicle only.
3. Simple forms should be used to report any unsafe condition by the driver.

### **19.17 FIRST AID**

1. The ideal goal is to have every person trained in First Aid and Cardiac Pulmonary Resuscitation (C.P.R.). A more realistic approach is to two persons in each crew and shift. This training can be imparted through the Red Cross, Fire departments or other organisations.

2. These crew medics can be made responsible for keeping all first-aid kits well stocked. They could serve as instructors for the rest of the fellow workers.
3. First-aid kits must be prominently displayed at various points at the plant and in the vehicles. Special attention must be given to the most hazardous areas like laboratories, workshops, chemical handling facilities etc.

### **19.18 CONCLUSION**

We must remember that everyone is responsible for safety. A Safety Programme is a must for the management. Many accidents occur due to the human factor. Ultimate responsibility may be that of management but the operator cannot also be relieved of his responsibility. The operators decision-making abilities and general behaviour (response time, sense of alarm etc.) are important. Be on the lookout for factors that disrupt the flow of action between the operator's natural senses and actions and the tools and machines.

The operator has a greater understanding of the operator-machine interface. The operator is the appropriate person to indicate the human factor involvement to the cause of accidents.

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## CHAPTER 20

# PUBLIC-PRIVATE PARTNERSHIP

### 20.1 INTRODUCTION

Providing safe drinking water is an essential basic service to be rendered by any civic body interested in ensuring quality of life of its residents. Predominant problems in Urban Water Supply Service are :

- Intermittent and irregular supply.
- Inefficient and inequitable utilization of resources (water, capital and human).
- High level of fiscal dependence.
- Supply and norm-based organisational and technical design of urban water systems.
- Low responsiveness to consumer needs and preferences.
- High costs to be borne by the consumer particularly by the poor.
- High levels of unaccounted water leading to only partial cost recovery of O&M cost and with no scope for capital investment.
- Huge money is to be invested by the municipalities for putting up/developing water treatment plants, water transmission and distribution networks.
- The water supply sector is both financially and operationally weak.

#### 20.1.1 PRESENT METHOD OF FINANCING

At present the government provides the finance to the municipalities for improving the water supply service. Due to paucity of funds the municipalities are often faced with lack of cash and high indebtedness and hence money has been the major constraint for the municipalities for improving /providing these basics services. A frank assessment of the time frame required for the local bodies to improve the basic services of water supply and with their meager budgetary provisions shows that there is a need for alternative options which can ensure sustainable services in much shorter times. As an alternative to traditional management and funding, most suitable option is to bring in private management and finance into provision and development of urban basic services including water supply with the objective of improving provision of these basic services.

#### 20.1.2 SCOPE FOR PRIVATE SECTOR PARTNERSHIP

A priority issue for most towns and cities will be first to improve the management and accountability of water distribution system through Private Sector Partnership (PSP) to make the service market oriented, efficient and demand responsive. Investment in other areas should

then be determined by the private operator who should have financial incentives for meeting desired service standards at least cost, ensuring that low cost rehabilitation, efficiency enhancement and demand management measures precede capital intensive source development, reservoirs, treatment plants or pumping stations.

## **20.2 NEED FOR REFORMS**

### **20.2.1 Need for Sector Reforms**

There is a need for a radical reform of urban infrastructure sector and particularly in water supply and sanitation sector to ensure that the quality of services in the urban areas, particularly to the urban poor is improved. Traditional mechanisms, relying on unreliable flows of insufficient public funds to finance piecemeal projects cannot fill the urban infrastructure gap. Hence reform of the urban water supply sector is particularly urgent because without such reform, fiscal resources will continue to be used sub-optimally and urban population will continue to spend significant portions of their time and income in coping with the costs of poor service, depriving themselves of their full economic and civic potential. The situation is also complex because :

- Water is an essential service.
- Water is a local issue with local solution, but failure to tackle them successfully can have regional and national implications.
- There is a need to introduce the reform agenda.
- The private sector can play a positive and long – lasting role, and
- Reforms must be properly sequenced and managed, applying key lessons from reforms in other sectors.

### **20.2.2 STATUS OF REFORMS**

While recognizing that urban reforms are state subjects, the Government of India (GOI ) through the Ministry of Urban Development and Poverty Alleviation is facilitating these reforms, including designing and disseminating among others, a model Municipal Act, important guidelines for private sector partnership in urban water and sanitation services and overall framework for GOI support. Within the framework, the ministry has proposed the “Urban Challenge Fund” and the “Pooled Finance Mechanism” to catalyse urban change through an active partnership with the states and their towns and cities through a combination of strategic engagements, capacity and regulatory support, and fiscal incentives. These will be further complemented by the “Urban Reform Incentive Fund” under the Ministry of Finance (GOI).

### **20.2.3 Constitutional Provisions**

The 74th Constitutional amendment encourages state governments to transfer responsibility for Water Supply Services (WSS) to Urban Local Bodies and gives them an opportunity to develop an Urban WSS sector policy to start far reaching reforms. Though the constitutional amendment empowers the people to manage their affairs and hence places the responsibility for provision and management of water supply services on the people,



the local bodies still depend on the governments for provision of funds for improving the water supply service.

#### **20.2.4 KEY PRINCIPLE FOR POLICY FRAMEWORK**

A publicly endorsed policy framework would give decision makers the mandate for systematic reform and private partnership. Various initiatives are required for creation of an enabling environment among all the stakeholders for private partnership as a viable alternative. To create such an environment there is a need to assure the under privileged and weaker sections of society of the continued government support (subsidies) and dispel the fears of retrenchment and salary cuts of the present employees even if the services are provided and managed by the private sector. The key principles for such reform policy framework are to :

- Introduce public service obligations, prudent financial constraints and accountability obligations for urban local bodies/service providers/water utilities.
- Commercialise service providers under transparent governance structures – professional management, insulation from political influence, revenue adequacy and suitable and auditable accounts and performance measures.
- Establish an autonomous and competent economic regulator when there is a clear demand for its services and the political will for its empowerment.
- Put in place specific incentives and regulations to improve services for the poor.
- Create a flexible demand – responsive industry structure.
- Encourage private sector partnership, prioritizing distribution system management, operation, maintenance and planning.
- Set service charges that reflect costs with better targeted public subsidies.
- Create an enabling legal, regulatory and institutional environment; delineate the roles of state and local regulatory agencies and establish an empowered Sector Reform Team to facilitate the reforms.
- Urban Local Bodies/Water Utilities would restructure the service providers, assess costs, tariff and subsidy requirements for better services, prepare for and execute the envisaged form of Private Sector Partnership and manage the Private Sector Partnership contract (with support from State institutions).

#### **20.3 SUITABILITY OF PRIVATE SECTOR PARTNERSHIP CONTRACTS**

Benefits from PSP will grow, as increasing responsibility and risks are transferred to the private partner. Hence simple service management contracts generate less benefits compared to performance based management contracts, leases, concessions and divestitures. Concession contracts are best suited for most urban areas as they mobilize capital and high quality human resources but may be unfeasible till market conditions are better developed. However management contracts can be expedient and cost effective if used as a leverage for a deeper form of private sector partnership. Hence the private partners in such contacts shall have sufficient rights and responsibilities to improve services and prepare for a deeper form of PSP.

Any form of PSP should contain a clear obligation to improve services to the poor. PSP transactions should be executed in a transparent and competent manner, with the assistance of qualified transaction advisers. Maximising competition from qualified bidders is one of the surest ways of assuring the best outcome to the consumers. Capacity must continue to be strengthened at the local and state levels so that utility performance is monitored effectively and the PSP contracts are managed efficiently to ensure quality of economic regulation.

## **20.4 LEGAL FRAMEWORK**

An act with legal provisions is required for creation of an authority for approval of private sector partnership projects, with specific authority to negotiate, accept or reject the PSP proposals submitted by the bidders. Any act shall also include provision for creation of a regulatory authority independent of private sector participants and the Government, not only for regulating the tariffs but also for ensuring that the private sector participants are discharging their obligations as per their contracts. This is also required to ensure expansion and upgradation of facility in future.

## **20.5 SUBSIDIES TO THE POOR**

The economically disadvantaged consumers may not be able to pay the full cost of the water. What is the minimum quantity required for sustaining and how much is spent for providing this quantity and what is the least amount that the poor/low use consumer will be able to pay and hence how much of the costs can be mobilised from the poorest and how much is to be shared by those who can afford to pay? There is a need for coming out with the policy for continuation of subsidies to the under privileged sections of society who require the support of the Government for getting drinking water supply service even if the service is managed by private firm.

## **20.6 COMPETITIVE BIDDING**

Due to the procedural formalities, often a lot of time and effort are spent on finding finances from international financial lending institutions. Since the funding is not focussed on privatization their grant processes are generally too slow to meet the requirements of fast track projects involving water supply service. Regulatory authority can compare the alternatives available for implementation of a project. If any utility desires to take up improvements to its water supply system to achieve increased coverage and better service levels, it has two alternatives namely traditional funding or private financing.

### **20.6.1 TARIFF CHARGES FOR TRADITIONAL FUNDING**

Any utility can approach the Government for funds by Plan provisions and/or procure loans from LIC, HUDCO and International and Bilateral funding agencies. Due to limited availability of such funds, the investment for improvement projects may spill over longer periods i.e. about 5 to 7 years. Accordingly the technical estimates and financial projections will be prepared for O&M costs and probable tariff charges to be recovered from users by the utility can be worked out to cater for meeting the O&M costs, debt servicing and depreciation plus some capital, reserve for extension of service .

### **20.6.2 TARIFFS FOR PRIVATE FINANCING**

As an alternative to traditional funding, a suitable option is to bring in private finance into provision and development of water supply. The utility can accept without bidding and by negotiation of proposals submitted by private firms if their tariffs are comparable with those from the alternative with traditional funding.

### **20.7 ADVANTAGES OF PRIVATE PARTNERSHIP**

- Investments by private firms may be quick and prompt and await shorter period as compared to traditional government funding, thus ensuring early completion of improvements in water supply.
- Through increased investment and greater focus on customer service the private firm will be able to ensure that they will provide adequate quantity of water of required quality with better service.
- With enormous potential for expansion of the facilities, the private firm may enhance the efficiency of service.
- Consumers are kept informed by publication of performance data.
- Private firms are more flexible in their approach to solve related problems.
- The private firm does not have the constraint of working within yearly budgetary allocations usually seen in public sector funding and hence can borrow money as required which they can spend efficiently and in a timely manner.
- It is possible that there could be a gradual change in work culture of the employees resulting in a more flexible structure that would allow individuals to show more initiative.

### **20.8 CONSTRAINTS OF PRIVATE PARTNERSHIP**

- In the process of private partnership there will be a natural aversion to change from the people themselves or from public representatives.
- The utility may be having fears of losing its clout where providing a water connection by the civic body is considered as their prerogative.
- The utility and the consumers/users may have fears that they will have no control over the pricing for the services to be provided by the private firm.
- It is inevitable that there are always those sections of the society who are less privileged for whom water supply service is either free or heavily subsidised by Govt. and hence may object to private partnership.
- The employees will have fears in respect of their existing benefits of Government employees like pension rights, retrenchment, salary cuts and more importantly the loss of the identity of a government servant or civic employee.
- The taking over of part of a public service by the private sector will require a well-defined contract in order to safe guard all parties, including government, but primarily the consumer who would be the main beneficiary. The hand-over process at the end

of a private sector arrangement needs to be defined, at least in outline, when the initial deal is made.

## **20.9 ISSUES FOR PRIVATE PARTNERSHIP**

- Since the utilities depend on the governments for provision of funds for improving the water supply service, the responsibility for providing this basic service has shifted from government to utility; this is a vital issue since the 74th Constitutional amendment which empowers the people to manage their affairs and hence places the responsibility for provision of these services on the local body.
- The utility shall give sufficient thought to all aspects and frankly assess as to how it is doing the job of providing the water supply and sewerage services and how soon it can improve the services with available/Government funds.
- The utility can also weigh the advantages and drawbacks of entrusting these services to a private firm as against management by the utility and then decide freely.
- It will also be necessary for the utility and Government to dispel the fears of the employees in respect of their existing benefits like pension rights, retrenchment, salary cuts and more importantly the loss of the identity of a Government servant or civic employee.

## **20.10 CONCLUSION**

- The decision as to whether private partnership is a viable option or not, or which solution will be the best for a specific utility can only be taken on a case by case basis considering the technical, environmental and economic conditions.
- It is important to note that the private firm despite having better resources can function effectively only on a sensible economy of scale.
- A routine customer satisfaction survey may be necessary to reveal whether majority of customers are willing to pay for an improved service and if they want better value for their money.

## ANNEXURE: 20.1

**KEY RESPONSIBILITIES UNDER VARIOUS PRIVATE SECTOR  
PARTNERSHIP OPTIONS**

Option	Asset Ownership	Operation & Maintenance	Capital Investment	Commercial Risk	Duration years	Remarks
Service contract	Public	Public & private	Public	Public	1-2	Specific activities like Meter installation or reading, monitoring losses, repairs to pipes or collection of bills
Management contract	Public	Private	Public	Public	3-5	Fixed fees based or combination of fees plus bonus; private operator may assume commercial risks associated with tariff collection from all or specific consumer groups and for reducing specific costs if provided with sufficient authority. Government must ensure timely access to capital.
Lease	Public	Private	Public/with limited private	Shared	8-15	Private operator assumes risks/rewards of efficiency and revenue improvements (and if given authority over key decisions). Private party finances working capital & limited rehabilitation, administratively as complex as concession contract. Typically suited where operating expertise and small capital investments can generate substantial efficiency gains.
Concession	Public	Private	Private	Private	25-30	Usually awarded to qualified bidder proposing the lowest tariff to operate the utility and meet performance targets. Require secure access to adequate water resources; high quality of technical,

						financial and market information needed to prepare a credible bid; administratively complex requiring competent & independent regulation.
BOT/BOO	Private & public	Private	Private	Private	20-30	Typically used for bulk water supply, water or wastewater treatment plants etc. 'Capital risk usually borne by the state government or state utility.
Divestiture	Private or private & public	Private	Private	Private	Indefinite (license may set term)	Regulation-intensive; however, reduced role of Government in asset ownership may justify higher costs of competent and fair regulation.

Build - Operate - Transfer and Build Own – Operate

Note : In practice, hybrids are also possible for example :

management contracts where the private operator takes on some commercial risks

leases in which private sector is responsible for some investments

Though not advisable, majority privately owned joint venture companies set up to operate and sometimes invest in the water utility under a lease or concession arrangement

## ANNEXURE : 20.2

### SUGGESTED ROAD MAP FOR PRIVATISATION

#### Type of Contracts : *Management Contract*

- Private Sector operator responsible for managing water service by providing Key management personnel.
- Water supply facilities/assets remain with utility.
- Existing Utility Employees are deputed to the operator for the duration of contract. Contract can be for 1 to 5 years and can be for whole services, specific functions such as distribution or in specific geographical areas.
- Private Sector operator is given authority and made responsible for the service delivery.
- Reimbursement to operator is through fixed fees plus incentive/penalty; fixed fees may include some future repairs/maintenance.
- In larger contracts an independent regulatory authority will be required to regulate the pricing and guide, mediate, control and settle the disputes between the public and private operators.
- Certain minimum collection revenue and total operating costs are agreed to, beyond which incentive/penalty applies.

- Amount collected is credited to the account of the utility.
- Private Sector operator is responsible for operation and normal repairs and maintenance, which are well defined, beyond which is classified as capital, and to account of the utility.
- To prevent deliberate avoidance of repairs and maintenance a Proportion of unspent normal repairs and maintenance amount is reimbursed to municipality at the end of contract or every year.

### **Advantages**

- Assets remain with utility.
- Technical know how is transferred from operator to utility.
- Management expertise is available.
- Short duration and gives flexibility to utility.

### **Disadvantages**

- No capital investment from operator.
- No working capital by operator, so commercial risk in billing & collection remains with utility.
- Operator performance is affected by municipality's inability to invest.
- Short duration and hence operator refuses to take long term view.
- No penalty if operator just walks away.

### **Delegated Management contract**

- Private Sector operator responsible for managing water & wastewater services including commercial risk in billing & collection.
- Water supply and wastewater facilities/assets remain with utility.
- Existing utility Employees are normally transferred to the operator for the duration of contract.
- Contract may be for about 10 years and usually covers the whole services in the entire geographical areas.
- Operator is given authority and made responsible for the service delivery of measurable levels of service.
- Operator relies on amount collected which is retained by the Operator.
- Operator injects working capital.
- Operator has to earn extra by maximising revenue and optimising costs.
- Profit sharing is agreed to beyond a financial return.
- Operator is not responsible for any capital investment.
- Capital expenditure is well defined as above a monetary value.

- Penalties for non compliance with agreed levels of service
- Utility sets the tariff including the operators expenses and capital investment
- Utility reviews tariffs periodically with changing legislation and priorities
- This contract is useful when:
  - Little capital is required
  - Utility must control capital costs
  - Utility has alternative financing options

### **Advantages**

- Assets remain with utility.
- Technical know how is transferred from operator to utility.
- Management expertise is available, real control is available due to operator's financial involvement.
- Long term planning is necessary since contracts are > 10 years.
- Duration gives flexibility to utility.
- Working capital provided by operator.
- Commercial risk in billing & collection remains with operator.
- Some financial penalty is at risk if operator just walks away.

### **Disadvantages**

- No capital investment from operator and hence all capital is to be found by the utility.
- Operator performance is affected by utility's inability to make capital investments.
- Utility's flexibility reduced due to long term contract.

### **Concession Contract**

- Private sector assumes responsibility for the complete provision of effective water services.
- Private sector provides all capital funding to meet existing and future demand for agreed levels of service.
- Water supply facilities/assets remain with utility.
- Existing utility Employees are transferred to the operator on agreed terms for the duration of contract.
- Due to greater financial involvement contract can be for 25 to 30 years.
- Usually covers the entire geographical areas supplied by utility and covers water service.
- Operator is given authority and made responsible for the service delivery of measurable levels of service.



- Operator relies on amount collected which is retained by the Operator.
- Operator uses the existing assets without heavy capital investments.
- Operator has to earn extra by maximising revenue and optimising costs.
- Profit sharing is agreed to beyond a financial return.
- Penalties for non compliance with agreed levels of service.
- Utility sets the tariff including the private sector investments and operators expenses.
- Utility reviews tariffs periodically with changing legislation/priorities.
- This contract is useful when:  
Superior levels of service are required at reduced cost to customers where previous service was at an economic tariff.

### **Advantages**

- Both existing and new assets remain with utility.
- Technical know how is transferred from operator to utility management, expertise is available, real control is available due to operator's large financial involvement.
- Working capital provided by operator.
- Commercial risk in billing & collection remains with operator.
- All capital investments are made by the private operator and as a result the performance also lies in his hands.
- A substantial financial penalty is incurred if private operator just walks away.
- Long term planning is essential as contracts are for more than 25 years.

### **Disadvantages**

- Utility's flexibility reduced due to long term contract.
- Very few operators would come forward to make such a huge investment.

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## ABBREVIATIONS

ARDC	–	Agriculture Refinance & Development Corporation
AUWSP	–	Accelerated Urban Water Supply Programme
BOOT	–	Build, Operate, Own and Transfer
CCCSC	–	Chamber of Commerce, Consumer Service Committee
CPR	–	Cardiac Pulmonary Resuscitation
CWR	–	Clear Water Reservoir
FCRI	–	Fluid Control Research Institute
GEC	–	Groundwater Estimation Committee
GIS	–	Geographic Information System
HDET	–	Hand held Data Entry Terminal
HUDCO	–	Housing and Urban Development Corporation
IEC	–	Information Education and Communication
IMD	–	Indian Meteorological Department
IPHE	–	Institution of Public Health Engineers
LIC	–	Life Insurance Corporation
NABARD	–	National Bank for Agriculture & Rural Development
NEERI	–	National Environmental Engineering Research Institute
NITIE	–	National Institute for Training in Industrial Engineering
NTU	–	Nephelometric Turbidity Unit
O&M	–	Operation & Maintenance
PHED	–	Public Health Engineering Department
PSP	–	Public Stand Posts
RILSG	–	Rajasthan Institute of Local Self Govt.
SCADA	–	Supervisory Control and Data Acquisition
UFW	–	Unaccounted for Water
WSSB	–	Water Supply & Sanitation Boards
VCCSC	–	Vigilance Committee, Consumer Service Committee