

GOVERNMENT OF TELANGANA
RURAL WATER SUPPLY AND SANITATION
DEPARTMENT



MISSION BHAGIRATHA



OPERATION AND MAINTENANCE GUIDELINES
TELANGANA DRINKING WATER SUPPLY PROJECT
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CHAPTER – 1

INTRODUCTION AND STRATEGY

1.1 General Roles and Responsibilities of Water Supply Departments

1. The Rural Water Supply and Sanitation Department is the nodal agency for the implementation of the Rural Water Supply and Sanitation Programme in the rural areas of the state. The Rural Population of the thirty districts of Telangana excluding GHMC is about 216 Lakhs spread over in 24,248 habitations. Drinking water facilities are provided through various means such as bore wells fitted with hand pumps, Single Village Schemes (SVS), and Multi Village Schemes (MVS). As per the 73rd constitutional amendment, all rural water supply schemes are to be maintained by the local bodies (VWSCs/GPs/ZPs) with technical support from RWS&S Department.
2. The Public Health and Municipal Engineering Department of Telangana is the nodal agency for implementation of Water Supply and Sanitation programmes in Urban Local Bodies excluding the Greater Hyderabad Municipal Corporation (GHMC) and Urban and Rural Local Bodies within ORR of Hyderabad. The operation and maintenance of the water supply schemes is the responsibility of the urban local body with the technical support of PH&ME Department.
3. Hyderabad Metro Water Supply and Sewerage Board (HMWS&SB) is the nodal agency for implementation of water supply and sewerage facilities in GHMC and surrounding habitations within ORR of Hyderabad. The operation and maintenance of the water supply and sewerage schemes is the responsibility of HMWS&SB in the GHMC and surrounding area within ORR.
4. **Status of Rural Water Supply in Telangana:** The status of rural drinking water supply as on April 2015 is far below the national average. While full coverage (55 LPCD) is available to 37 per cent of rural Indian habitations, only 30 per cent of habitations of Telangana are fully covered. Further 64 per cent of Telangana habitations are partially covered against 58 per cent all over India. In respect of quality problems, 6 per cent of habitations in Telangana are affected, against total 5.2 per cent of habitations in India

Table 1 Status of Water Supply in Telangana (2015)

A	The infrastructure available in the Rural areas	
1	Hand pumps fitted to bore well	1,57,709
2	Single Village Schemes (SVS)	24,966
3	Multi Village Schemes (MVS)	160
4	Water Quality Testing Laboratories	76
B	Status of rural habitations as on 1.4.2015	
1	Fully covered habitations (FC)	7480
2	Partially covered habitations (PC)	15980
3	Quality affected habitations (QA)	1342

In accordance with the new state development goals, Telangana has envisioned providing of 100 LPCD of water to every household in rural areas, 135 LPCD in Nagarpanchayats and 150 LPCD in Municipal corporations on sustainable basis on full saturation mode.

Accordingly, **Telangana Drinking Water Supply Project (TDWSP) later called as “Mission Bhagiartha”** is launched in the year 2014 as one of the Flagship programmes to cater to domestic water needs of the rural, urban areas and to some extent industrial needs duly integrating the existing assets and ongoing projects in Rural and Urban areas out side the ORR of Hyderabad. The Government contemplated to implement the Project in a time frame of four years and felt need to establish a **Corporation** to enable to mobilize the requisite funds for implementing the Project

5. **Telangana Drinking Water Supply Corporation (TDWSCL)** is new company owned and formulated by the Government vide G.O.Ms. No.17 Dt. 30.01.2015 for implementation, operate and maintainance of the Telangana Drinking Water Supply Project.

The broad objectives of the Company:

- To mobilize the requisite funds through loans from the Financial Institutions, Commercial Banks, Mercantile Banks, International Funding Agencies and supported by State and Central Grants.

- To provide safe drinking water in all rural and urban areas in the State of Telangana by taking up drinking water supply projects to cater the needs of Rural and Urban people as per norms fixed by Government with all related infrastructure like laying of pipelines, approach roads, buildings, WTPs, electrical sub stations, godowns, electrical lines, erection of pumping sets with electrical motors etc.
- To develop, construct, erect, install sewerage systems and treatment plants in rural areas.
- To supply bulk drinking water at entry point of the rural and urban areas and maintain the drinking water supply projects outside the GP/ULBs.
- To fix, revise whenever necessary and to collect the tariff for the bulk drinking water supply as per the policy guidance of the Government.
- The staff required by the Corporation shall be drafted mainly from RWS&S department and PHED on deputation. However based on the need there shall be flexibility to draft staff on deputation from other departments like PR, R&B, Revenue and Energy. The Corporation can also engage required personnel from open market as per need.

6. Role of RWS&S, PHED, HMWS&SB and the Corporation as per G.O.Ms.No17 Dt.30.01.2015:

The functional areas of the departments connected and the Corporation shall be as follows:

- The Corporation will limit its activities to the extent of 'Telangana Drinking water Supply Project' and connected Sewerage Treatment Plants initially till further orders of the Government.
- The Engineer-in-Chief, Rural Water Supply & Sanitation Department shall continue to execute the ongoing sanctioned works/programme including MVS, SVS Schemes, World Bank, NABARD, HUDCO, Finance commission, Drought, Floods etc., outside the Outer Ring Road of Hyderabad City. It shall complete all the ongoing works pertaining to the Rural areas inside Outer Ring Road and handover to the newly formed Corporation.
- The Hyderabad Metro Board shall deal with drinking water supply and Sewerage aspects within Outer Ring Road. However it shall complete its entire ongoing urban drinking water works outside Outer Ring Road and handover to the new Corporation after completion for O&M.

- The Public Health Engineering dept shall continue to execute all its ongoing sanctioned works/programme including Sewerage Treatment Plants in municipalities and Municipal Corporations.
- All new schemes pertaining to the Mega Drinking water supply Project outside Outer Ring Road shall be taken up by the new Corporation.
- The intra village or intra Municipal works shall be taken up by the respective Local bodies with the technical assistance of the respective line departments as per instructions of the Government from time to time.

1.2 Mission Bhagiratha (Telangana Drinking Water Supply Project)

1.2.1 Project Development Objective

- To provide safe, adequate, sustainable and treated drinking water for entire rural and urban areas of the State.
- To provide water to industries to the extent possible through the same project to promote industrial growth and socio-economic development.

1.2.2 Scope and Strategy

- The Mission Bhagiratha has been planned to cover domestic water demand of all the rural areas and urban areas (excluding with in ORR of the Greater Hyderabad Municipal Corporation, which will be covered by HMWS&SB). The project planned to consider the water demand of all institutions, commercial entities, industries, etc. in addition to domestic needs.
- The Mission Bhagiratha is being integrated utilizing existing/ ongoing projects providing water supply from surface water sources.
- It is being planned to cover all the habitations in the state with drinking water through the Mega Project through main bulk trunk lines, sub-trunk lines, village network wherever necessary by integrating all the existing infrastructure and ongoing schemes so as to provide 100 LPCD of drinking water at the door step of every household in the rural areas.
- For Urban Local Bodies water will be supplied as bulk water at specified locations identified and mutually agreed. Bulk metering system will be planned to ensure accountability on the part of local bodies. Further treatment/ disinfection needed and service distribution will be under the scope of respective Local Body.

- Similarly the treated water will be supplied to rural habitations also as bulk supply from the Project and bulk metering system will be planned for accountability at GP level as per the policy.
- Up to 10% of the total demand allocated for Industrial supply through bulk connections as part of the project
- The project scope also includes construction of intra village service reservoirs and improvement of Distribution Network in rural areas only.

1.2.3 Water Draw and Sources

- The project contemplates to draw additional raw water about 60.75 TMC (@ 2048) from various reservoirs and rivers of the Godavari and Krishna Basins in addition to the existing/ ongoing schemes drawl. I&CAD Department vide Memo No.8026/ARB/WRG/GRC/16-1 Dt.29.09.2016 has accorded necessary permission for the same.
- **Krishna Rivers and their tributaries and reservoirs** - **24.98 TMC**
(Jurala Project, Srisaillam Project, Nagarjuna sagar, Udayasamudram, Tail Pond, Paliar Reservoir, Wyra Reservoir)
- **Godavari Rivers and their tributaries and reservoirs** - **35.77 TMC**
(SRSP, Singur Dam, Kadem Project, Komarambeem Project, LMD, MMD, Yellampally Reservoir, Godavari River, Chalivagu, Bheemghanpur, Ghanpur reservoir)

1.2.4 State Initiatives

- Mission Bhagiratha declared as Flagship programme
- Telangana Drinking Water Supply Corporation Limited (TDWSCL) formed with Hon'ble Chief Minister as Chairman.
- Right of User (RoU) Act for laying of pipelines in Private Land

1.2.5 Implementation Status

- Project investigated, designed and estimated by RWS&S Department
- WAPCOS (a GOI undertaking) appointed as state technical consultant for vetting of DPRs, Project Management, Quality Control and Supervision of Mission Bhagiratha works.
- Telangana State power generation corporation (TS Genco) appointed as technical consultant for vetting the designs of Electro Mechanical works.

- All the intake structures, WTPs, Transmission Pipelines, Electro-Mechanical works were entrusted are targeted to be completed by 2018. Intra-village works are being entrusted.
- The defect liability for the intake structures, WTPs and Transmission system is 5 years from the date of commissioning and for Electro-Mechanical Works the defect liability period is 10 years from the date of commissioning.

1.2.6 Salient features

The broad features of the Mission Bhagiratha are as follows:

○ No of segments	-	26
○ No of Constituencies	-	99
○ No of Mandals	-	547
○ No of ULBs covered with bulk supply	-	63
○ Habitations	-	24,248 (out side ORR)
○ Rural house holds	-	49,19,007
○ Urban house holds	-	12,82,545

Assets being constructed as part of the project:

○ Intake Structures	-	19 No
○ Rapid Sand Filters	-	50 Nos (3,349 MLD)
○ Transmission Pipeline	-	48,856 Km
▪ Mild Steel	-	1,420
▪ Ductile Iron	-	14,796
▪ PCCP	-	269
▪ BWSCP	-	372
▪ HDPE	-	31,999
OHBRs/GLBRs	-	733 No
Sumps	-	405 No
○ OHSRs	-	18504 Nos
○ Intra -Distribution Network	-	51,180 Km
○ Major Pumping Supply Stations	-	141 No

1.3 Introduction O&M

The large investments made to construct Water Supply Systems intended to provide facilities for drinking water in rural areas are becoming unproductive in the sense that the main objective for which they have been installed is not achieved mainly on account of poor Operation & 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 organizations are not able to ensure that the maintenance staff follows valid practices to achieve proper maintenance. 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 are some of the reasons for the present status of the rural water supply sector. It has been observed that lack of attention to the important aspect of Operation & Maintenance of Water Supply Schemes leads to deterioration of the intended life of the system, thus necessitating premature replacement of many system components. As such, even after creating such assets by investing huge investments, they are unable to provide the desired services to the community, as they either remain defunct or underutilized most of the time.

In an engineering sense, operation refers to hourly and daily operations of the components of a system such as structures, plant, machinery and equipment (valves, safety devices 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 organizations 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 organizations also incorporate heads of expenditure under maintenance for cost of spare parts and cost of labour or contract amount for repairs and replacements.

1.3.1 Sector Organization

Water supply and sanitation is treated as a State subject as per the Constitution of India and, therefore, the states are responsible for the planning, implementation, operation and cost recovery of water supply and sanitation projects. At the local level, the responsibility is entrusted by legislation to the local bodies like Gram Panchayat / Village water & sanitation committee (VWSC) in Rural Sector.

The Rural Water Supply & Sanitation Department, Government of Telangana is the principal agency at the State level for planning and implementation of water supply programme and provides technical assistance to PRIs in rural areas.

The Ministry of Drinking Water and Sanitation, Government of India formulates policy guidelines in respect of Rural Water Supply & Sanitation Sector and provides technical assistance to the States & Rural Local Bodies (GPs/VWSC) wherever needed. The expenditure on rural water supply is met by Ministry of Drinking Water and Sanitation under National Rural Drinking Water Programme (NRDWP) as well as State Government and also with loans from National/ International financial institutions.

Now the state Government have formulated special purpose vehicle i.e TDWSCL for the implementation of the 'Mission Bhagiratha' by raising loans from the various financial Institutions/ Commercial Banks. TDWSCL shall maintain and operate all the water supply schemes up to the bulk storage point of the habitations/ local bodies. TDWSCL may collect the Tariffs for bulk supply of water to the ULBs, Rural Habitations and Industries. TDWSCL shall make strategy for the bulk connections and Tariff.

1.4 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 villages often leads to their dysfunction or deterioration of the useful life of the systems necessitating premature replacement of many components, incurring huge losses. As such even after creating such assets by investing millions of rupees, they failed to provide the proper services effectively to the community for which they have been constructed and became dysfunctional or remained underutilized most of the time.

Some of the key issues contributing to the poor Operation & Maintenance (O&M) have been Identified as follows:

- Lack of finance, equipment, material, and inadequate data on Operation & Maintenance

- Inappropriate system design and inadequate Workmanship
- Multiplicity of agencies, overlapping responsibilities.
- Inadequate skill of operating staff
- Illegal tapping of water
- Inadequate training of personnel.
- Lesser attraction of maintenance jobs in career planning.
- Lack of performance evaluation and regular monitoring.
- Inadequate emphasis on preventive maintenance
- Lack of O & M manual.
- 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 for O & M of water supply schemes.

1.5 Necessity for Manual

Telangana Government has been take up 'Mission Bhagiratha' as flagship programme with a goal to supply safer, protected, sustainable and reliable treated water to every door step of the state with saturation mode . Accordingly large scale water infra structure is being created under 'Mission Bhagiratha' programme, like constructing new intake structures, Raw Water Pumping Mains, WTPS, Power Sub Stations, Clear Water Pumping Mains, Transmission pipelines, Pumping Stations, OHBRS, GLBRs, Sumps, OHSRs, Distribution system, etc. In order to operate and maintain such a large scale systems in a proper manner, it is felt by the RWS&S Department to make a manual covering bulk transmission system and distribution system within the habitation.

1.6 Scope of Manual

This Operation and Maintenance manual covers technical Operation & Maintenance issues of Source, Intake structure, Pumping mains, Gravity Mains, WTPS, Structures, Pumping Stations, Electro-Mechanical Equipment, Instruments, Distribution System,etc. However this manual does not include the operation & and maintenance policy.

As per the 73rd Amendment to the Constitution, all the rural water supply schemes are to be operated and maintained by local bodies (VWSCs/GPs/Z.Ps). Therefore, this operation and maintenance manual has been prepared to facilitate/ institutionalize the operation and maintenance system of rural water supply schemes.

1.7 O&M Management

O&M management is a critical component of the overall program. The management function should bind the distinct parts of the program into a cohesive entity. The overall program should contain five very distinct functions for strengthening organization: **Operations, Maintenance, Engineering, Training, and Administration**—
OMETA

Beyond establishing and facilitating the OMETA links, O&M managers have the responsibility of interfacing with other department managers and making their case for ever-shrinking budgets. Their roles also include project implementation functions as well as the need to maintain persistence of the program and its goals.

Developing the Structure Five well-defined elements of an effective O&M program include those presented above in the OMETA concept (Meador 1995). While these elements, Operations, Maintenance, Engineering, Training, and Administration, form the basis for a solid O&M organization, the key lies in the well-defined functions each brings and the linkages between organizations. A subset of the roles and responsibilities for each of the elements is presented below; further information is found in Meador (1995).



1.7.1 Operations & Maintenance

- **Administration** – To ensure effective implementation and control of operation activities.
- **Conduct of Operations** – To ensure efficient, safe, and reliable process operations.
- **Equipment Status Control** – To be cognizant of status of all equipment.
- **Operator Knowledge and Performance** – To ensure that operator knowledge and performance will support safe and reliable plant operation.
- **Maintenance Administration** – To ensure effective implementation and control of maintenance activities.

- **Work Control System** – To control the performance of maintenance in an efficient and safe manner such that economical, safe, and reliable plant operation is optimized.
- **Conduct of Maintenance** – To conduct maintenance in a safe and efficient manner.
- **Preventive Maintenance** – To contribute to optimum performance and reliability of plant systems and equipment.
- **Maintenance Procedures and Documentation** – To provide directions, when appropriate, for the performance of work and to ensure that maintenance is performed safely and efficiently.

1.7.2 Engineering Support

- **Engineering Support Organization and Administration** – To ensure effective implementation and control of technical support.
- **Equipment Modifications** – To ensure proper design, review, control, implementation, and documentation of equipment design changes in a timely manner.
- **Equipment Performance Monitoring** – To perform monitoring activities that optimize equipment reliability and efficiency.
- **Engineering Support Procedures and Documentation** – To ensure that engineering support procedures and documents provide appropriate direction and that they support the efficiency and safe operations of the equipment.

1.7.3 Training

- **Administration** – To ensure effective implementation and control of training activities.
- **General Employee Training** – To ensure that plant personnel have a basic understanding of their responsibilities and safe work practices and have the knowledge and practical abilities necessary to operate the plant safely and reliably.
- **Training Facilities and Equipment** – To ensure the training facilities, equipment, and materials effectively support training activities.
- **Operator Training** – To develop and improve the knowledge and skills necessary to perform assigned job functions.
- **Maintenance Training** – To develop and improve the knowledge and skills necessary to perform assigned job functions.

The personnel who are already available or chosen to carry out the actions contained in the program 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.

Village Water and Sanitation Committees can be actively involved to periodically attend to the problems, carry out the Operation & Maintenance functions and also inform the department on improvements needed and future course of planning, upkeep of utilities, encourage the people to remit water charges regularly and encourage hygienic habits.

1.7.4 Administration

- **Organization and Administration** – To establish and ensure effective implementation of policies and the planning and control of equipment activities.
- **Management Objectives** – To formulate and utilize formal management objectives to improve equipment performance.
- **Management Assessment** – To monitor and assess station activities to improve all aspects of equipment performance.
- **Personnel Planning and Qualification** – To ensure that positions are filled with highly qualified individuals.
- **Industrial Safety** – To achieve a high degree of personnel and public safety.

1.7.5 Ten Steps to Operational Efficiency

Step 1: Strive to *increase management awareness* and appreciation of the operations and maintenance program/department.

- Consider developing a maintenance mission statement and requesting/ requiring management sign-off.
- Consider developing a maintenance plan and requesting/ requiring management sign-off.
- Begin the development of the OMETA linkages.
- Develop key points of contact within other departments that can participate in the O&M mission.

Step 2: Commit to begin *tracking Operations and Maintenance activities*.

- Need to understand where O&M time is spent.
- Need to understand where O&M amount is spent.

- Consider (strongly) establishing or enhancing a Computerized Maintenance Management System and commit to its implementation and use.

Step 3: Through tracking begin to *identify your troubled equipment and systems*.

- Make a list of these systems and prioritize them.

Step 4: Commit to ***addressing at least one of these troubled systems***.

- Begin base-line/ tracking the system. - System operations and history. -System maintenance and history. -System costs, time to service, downtime, resulting overtime, etc.

Step 5: Commit to ***striving for Operational Efficiency of this system***.

- Strive to understand how to properly operate this system.
- Define and complete operator training needs.
- Strive to understand how to properly maintain this system
- Define and complete maintenance training needs.

Step 6: Commit to ***purchasing or contracting for some form(s) of diagnostic, metering, or monitoring equipment***.

Step 7: Commit to ***trending the collected tracking and diagnostic data***.

- Take to time to understand the data.
- Look for and develop “project opportunities.”
- Develop appropriate cost justification metrics.

Step 8: Select, request funding for, and ***complete first “Operational Efficiency” project***.

- Start small, pick a project that will be a winner.
- Carefully document all findings.
- Present success in terms management will understand.

Step 9: Strive to ***highlight this success – capitalize on visibility opportunities***.

- Consider writing an internal success story/case study.
- Submit finding to trade publication or industry conference.

Step 10: Commit to ***choosing the next piece of equipment...go to Step 3***.

Steps 1 and 2 are ONGOING ACTIVITIES.

1.7.6 Why Maintenance

Maintenance of the facilities is essential in preventing component failure, extending the useful life of the facilities, and minimizing disruptions in services. Good maintenance involves the following:

- Timely quick repair/ replacement of any failed component;
- Up-to-date training of maintenance personnel;
- Adequate inventory of parts and tools needed for repairs;
- Efficient mobilization practices in emergencies; and
- Valve exercising (single most important form of preventive maintenance for reliability of service).

There are two general types of maintenance: Preventive and Reactive (or Repair) maintenance.

1.7.6.1. Preventive Maintenance

Preventive or routine maintenance involves tasks and activities carried out according to pre-established schedules to ensure the quality and reliability of operating facilities. It is based on rational considerations such as the manufacturer's recommendations for servicing equipment, industry standards and practices (which are based on collective experience),

1.7.6.2. Unscheduled Maintenance

Unscheduled maintenance (also called Emergency or Repair maintenance) is a reactive Intervention forced on the Utility when equipment, components, or parts either break down or malfunction. The activities and tasks are unplanned and generally unexpected, thus taking the nature of emergencies. They tend to be disruptive, inefficient, and often costly - not only to undertake but also in terms of lost revenues and goodwill. These occur most frequently when preventive maintenance has been poor or inadequate, after accidents and natural force major events, and when aging facilities are kept in service without replacement beyond their useful life.

All unscheduled maintenance situations need to be analyzed and the causes of the malfunction or breakage recorded. These records are important as they help in deciding whether part or all of a network or plant should be upgraded or replaced, and serve as a guide in future procurement decisions.

1.7.7 How to Develop an Effective O& M Plan

O & M Plans are often prepared by engineers and managers; however, they must be certain that they obtain information from persons actually experienced in plant operation and maintenance. The procedures must be described in terms and language which are readily

accepted and understood by the operators. Because of the technical nature of the water treatment process, a basic level of knowledge and understanding by the operators must be assumed. The experienced operator will usually refer to the O & M Plan for confirmation of normal operation and maintenance procedures and as a reference guide for unusual operating conditions. The entry level operator should frequently refer to the O & M Plan for guidance and instruction.

1.8 How can a village improve its O&M?

Efficient and effective operation depends upon sound village water supply strategies made up of

- (a) water safety plans to ensure good quality water,
- (b) standard operating procedures including who will do what and when, and to identify associated annual expenses and revenues; and
- (c) service improvement plans to set out future investments to ensure improved, sustainable service delivery.

1.8.1 Water safety plans

Water Safety Plans shift the focus from end-of-pipe testing to improved operational management, with water quality testing used to verify outcomes. They provide a means of prioritizing improvement programmes based on health outcomes. Most importantly, water safety plans address bacteriological contamination which is the biggest water quality related threat to public health, especially infant growth and mortality.

A water safety plan is developed by surveying the water supply system from source to storage/ treatment to distribution to household (also known as a sanitary survey). This helps to identify risks of contamination and corresponding operational control measures to reduce those risks. The controls have to be monitored to check that they are working, specifying how often the check should be carried out, and identifying who is responsible for checking. If a control is deemed to have failed remedial action should be taken.

It is also essential to establish a mechanism to check for the possible hazardous material contamination in the impounded reservoirs like adding foods to fish and fauna which may be grown officially/ unofficially. The necessary guidelines shall be issued to the concerned authorities to prevent the hazardous contamination to the water bodies where fish culture practices are there. There shall be a mechanism and guidelines to handle the emergency situation arising due to possible hazardous poisoning in the water. It is also essential to

frequently check the water bodies used for the drinking water for possible contamination from sewerage water, fertilizers, industrial wastes, etc.

1.8.2 Standard operating procedures

Standard operating procedures are essential to identify what local operators should do in terms of routine operation and maintenance related to water sources, storage and treatment units, and distribution systems including connections for formulating annual budgets of operating expenses, income and annual surplus/ deficit. Someone with good experience and analytical skills would be needed to train operators and assist them when problems arise.

Often the tasks required can overwhelm a local operator who has only basic skills and limited experience, but by providing basic orientation in terms of what to do and when, the operator can quickly gain hands on experience and build confidence to do the job well. Likewise, the operator's fees and incentives can be made transparent and this also helps to improve their performance levels.

1.8.3 Service improvement plans

Service improvement plans are important to define management improvements, service delivery improvements and actions to improve accounts, billing and revenue collection. The benefits and costs need to be considered and priorities set (such as immediate, this year or next year).

1.9 Objectives of Operation and Maintenance

The primary objective of an efficient operation and maintenance plan for 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 possible on a sustainable basis.

The minimum requirements for good operation and maintenance include:

- Preparation of a plan for operation and maintenance.
- Providing required personnel appropriate mechanism to operate and maintain.
- Providing Capacity building programmers' for the O&M personnel
- Availability of spares and tools for ensuring maintenance.
- Preparation and regular updating of GIS based maps of the system
- Preparation of a water audit and leakage control plan
- Maintaining MIS records on the system including history of equipment, costs, life etc.
- Action Plan for energy audit for saving on energy

- Establishing a sound financial management system for availability of funds for O & M
- System Evaluation

1.10 Operation and Maintenance Plan

A program or a plan has to be prepared for operation and maintenance of every segment 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/ checkslips for routine tasks, checks and inspections at intervals viz. daily, weekly, quarterly, semi-annually or annually etc.

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 are to 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 scrupulously and also will be the basis for supervision and inspection and also can be used for evaluation of the status of operation and maintenance and performance of O&M staff..

If the labour costs for operation and maintenance are high compared to replacement cost, the latter course of action will be preferable. The officers 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.

The Operation & Maintenance 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 organizational 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.

1.11 Tools & Spares

The availability of spare parts for repairs and replacements is to be ensured by ordering and delivery of spare parts by organizing 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 manufacturer's 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.

1.12 Plan for Water Audit and Leakage Control

The availability of potable water (underground and surface) is very limited, There are considerable losses in the water produced and distributed through leakages in pipelines, valves, public taps un authorized service connection etc. the percentage of unaccounted for water (UFW/NRW) ranges from 30 to 55 % .Thus, huge quantum of water is being wasted which also leads to reduction in water as well as revenue losses. Therefore it become essential to plan the conservative use of water i.e. water auditing/ leakage control through metering, improved O & M practices and awareness intervention.

1.13 Plan for Efficient Use Of Power

Power charges can 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 systematic energy audit which can identify the possible means to save energy and reduce power consumption apart from use of star rating equipment/ Power capacitors.

1.14 Plan for Sound Financial Management System

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 revenue through preparing annual budget, based on realistic estimates.

The full cost recovery of O&M cost through user charges may be adopted as per the prevailing state government policies. However, Gram Panchayats should have their own water tariff structure depending upon the O&M expenditure and socio-economic condition of the users.

Presently as per NRDWP guideline 15% of NRDWP funds can be used by the state/ UTs on O&M of rural drinking water supply scheme. The funding pattern for this will be on 50:50 basis between the Centre and state.

1.15 Plan for Information Education Communication (IEC) Conservative Use of Water

The IEC activities is a very essential part for conservative use of water. The awareness for conservative use of water can be generated among consumer by plays, electronic media, print media and by mouth publicity. The utility organization should prepare Information-Education-Communication material and use the services of voluntary organization/ NGOs to create awareness among the public and consumers.

1.16 Role of Voluntary /Non-Government Organization (NGOs)

The Role of Voluntary /Non-Government organization (NGOs) can be important especially in the creation of public awareness on issues like water conservation, proper use of water by people and the need to pay price for water at affordable level. Water user's committee may be formed by active involvement of NGOs to periodically review the local problems, advice the agencies on improvements needed and upkeep of utilities within their jurisdiction and also encourage the people to remit water charges regularly and encourage hygienic habits.

1.17 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 component 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 data.

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.

1.18 Water Budgeting and Security Plan for storage of Water in the reservoirs

In advance next five year water requirements of various categories of bulk consumers like rural habitations/ULBs/Industries shall be estimated and shall be consolidated source wise. The possibility of the water supply based on the infrastructure available shall also be ascertained. The total raw water to be drawn from the each reservoir shall be estimated at least for next 5 years and shall be intimated to I&CAD Department the minimum storage shall be available time to time and minimum drawdown to be maintained in the reservoir to lift the water. In certain balancing reservoirs which are fed from canals/lift irrigation schemes, in advance water requirements to be planned and intimated to I&CAD authorities to plan to feed the sources accordingly. A mechanism shall be established for interaction between I&CAD and TDWSCL.

Continuously the water levels in the intake arrangements shall be monitored and recorded. Where drawdown is affected due to drought conditions to lift the water temporary arrangements to lift the water based on the necessity shall be planned in advance and necessary budget provisions shall be prepared.

Based on the availability of water, in such draught situations where unable to provide the designated supply, the same shall be rationalized based on priority of the consumers.

During drought situations the depletion of water may be possible and also some times water may not available. In such a situation alternative arrangements shall be planned in advance and necessary budget provisions shall be made.

CHAPTER 2

OPERATION AND MAINTENANCE OF SOURCE

2.1 Objectives

The objectives of operation and maintenance for 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. The source is generally located at the suitable location at the impounding reservoir. The reservoirs are under the control of irrigation department.
6. For sustainability of source shall be maintained at all times. Prior intimation shall be given to the concerned department after assessing the depletion in advance.
7. There should be least possible expenditure on the repair and maintenance of the water sources.
8. Proper record of the water sources should be maintained so that their time to time performance could be known.
9. 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.
10. The necessary contour maps shall be obtained or prepared for all possible sources of water like rivers, reservoirs, lakes, canals, wells, and springs etc which is taken as source. The maps already available should be updated from time to time.

Under Mission Bhagiratha the sources are surface water and in particular intake structures. Therefore Operation and Maintenance of Intake Structure and other associated civil structures are discussed in this chapter.

However the operation and maintenance of sub-surface, such as Bore wells/Tube wells, dug wells, Infiltration Wells and Infiltration Galleries etc. may be referred to the relevant chapters of O&M Manual of Central Public Health and Environmental Engineering Organization (CPHEEO) and/or O&M Manual of Ministry of Rural Water Supply and Sanitation, Government of India.

2.2 Intake Structures

2.2.1 General

An intake is a structure placed in a surface water source to permit to draw water and discharge into a pipe line through which will flow into the water works system. Types of intake structures consist of intake towers, submerged intakes, intakes pipes or conduits, movable intakes and shore intakes. Intakes structure constructed at rives and impounding reservoirs nearer the dams are necessarily protected against wave action, floods, navigation, pollution and other interferences with the proper functioning of the intakes. Intake towers are used for drawing large quantity of water from lakes, reservoirs and rivers in which there is either or both a wide fluctuations 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.

2.2.2 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, 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) Minimizing 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

2.2.3 Operation and Maintenance of Intake Well

1. 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.
2. De-silting of intake/sump shall be carried out once in year preferably after monsoon.
3. Care should be taken to dump the removed silt away from pump house.

4. It is generally observed that reptiles like snakes, fish, etc. enter intake particularly in monsoon. The intake should be disinfected.
5. The sump/intake should be fully dewatered and inspected once in a year.
6. Operating criteria, equipment manufacturer's operating instructions and standard operating procedures should be bound into a manual and used for reference by operators and shall be placed in pump house. If written references are not available for a particular facility, they should be prepared with the assistance of knowledgeable operators, engineers and manufacturers.
7. Dos and DoNots shall be listed out and exhibited on the wall, which shall be visible for operator.
8. Screens should be regularly inspected, maintained and cleaned,
9. Mechanical or hydraulic jet cleaning devices should be used to clean the screens.
10. Intake structures and related facilities should be inspected, operated and tested periodically at regular intervals.
11. Proper service and lubrication of intake facilities is important
12. Operation of Gates and Valves.

2.2.4 Causes of Faulty Operation

Some of the causes of faulty operation are as under:

1. Settlement or shifting of supporting structures which could cause binding of gates and valves,
2. Worn, corroded, loose or broken parts,
3. Lack of use,
4. Lack of lubrication,
5. Vibration,
6. Improper operating procedures,
7. Design errors or deficiencies,
8. Failure of power source or circuit failure
9. Vandalism

2.2.5 Record keeping

The records to be maintained shall include the following aspects:

1. A history of operations and maintenance performed on intake facilities,
2. When and under what conditions failure or malfunctions occurred.

2.2.6 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 station wise operating procedure.

2.3 Maintenance of Other Civil Structures

2.3.1 Pump House

1. The pump house should be cleaned daily. Good housekeeping and cleanliness are necessary for pleasant environment.
2. 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.
3. Wooden flooring and M.S. grating wherever damaged should be repaired on priority.
4. 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.
5. All facilities in sub-structure i.e. stair case, floors, walkways etc. should be cleaned daily.
6. Painting of civil works should be carried out at least once in two years.

2.3.2 Unlined Canal/Channel Transmitting Raw Water

1. All grass should be scraped and weed removed from the silted bed
2. Silt deposited should be removed
3. Bed should be leveled and their gradient regularized.
4. Berms should be kept straight by trimming
5. Both edges of the bank especially the inner one should be neatly aligned and should be free from holes, weeds.
6. Ensure there is no Seepage through the banks

2.3.3 Lined Canals/ Channels Transmitting Raw Water

1. Cavity or pockets or any activity detected behind the lining should be carefully packed with sand or other suitable material. Care should be taken to ensure that the lining does not get damaged or displaced.
2. Damaged portion of lining should be removed and replaced with fresh lining of good

quality by preparing a thoroughly compacted sub-grade before laying fresh sub-grade. The cracks in the lining should be filed with standard sealing compound. An effective sealing may be obtained by cutting 'V' groove along the face of the cracks before filing with sealing compound. Packing with powdered clay upstream of the cracks may seal minor crack on the lining.

3. Displaced portion of the joint filter should be removed and fresh filter material may be packed
4. The choked pressure release pipes should be cleaned by intermittent application of air and water by rodding.
5. Subsoil water level should be observed regularly especially after rainy season. If there is rise, adequacy of the pressure release system or other remedial measures like humps, regulators etc. provided for the safety of the lining should be reviewed.
6. Seepage through embankments if any should be observed from time to time and remedial measure should be taken.
7. Silt deposition if any noticed should be flushed out during non-Monsoon period when the water is silt free.

CHAPTER 3

OPERATION AND MAINTENANCE ASPECTS FOR TRANSMISSION OF WATER

3.1 General

3.1.1 Objectives

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.

Frequent scouring of pipelines duly operating the scour valves should be operated in periodic manner to ensure non-depositing of foreign materials.

3.1.2 Normal Conditions

3.1.2.1 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.

3.1.2.2 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 in 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.

3.2 Transmission through Pipes

In case of gravity transmission line, where direct feeding into OHSRs is envisaged, then it should be ensured for the design head and discharge. All valves installed in the transmission main should be inspected daily to ensure that there is no leakage otherwise leakage should be attended. If attending leakage requires, stoppage of flow through pipes the same can be attended on a pre-fixed monthly shutdown day.

3.2.1 Problems in Transmission Mains

3.2.1.1 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.

3.2.1.2 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.

3.2.1.3 Air Entrapment

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.

3.2.1.4 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. Hence care should be taken to avoid rapid closure of valve and also to ensure that the provided surge protection system is working properly and well maintained.

3.2.1.5 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.

3.2.1.6 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 preferably with latitude & longitude about the location of pipes, valves, size of pipes and valves and the direction of flow etc. is required, to operate and maintain the system efficiently.

3.2.2 Operation Schedule

3.2.2.1 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 tapings 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. The 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 updating 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. GPR survey can also be used where in the alignment along with appurtenances can be located and updated on google earth/ maps. It is preferable to have a GIS base information system for storage, retrieval and analysis.

3.2.2.2 Normal Operations of the water supply transmission 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 for operation of pumps to match the prevailing conditions (flows, pressures, levels and operation of pumps).

Pump operations will have to be controlled as per a schedule. It should contain procedures to obtain, process, and analyse the variables related to water flows, pressures and levels. Operation of pumps have to be done, such that the hydraulic status of the system can match the required capacity of the system for transmission of water. When operators change their shifts important information must be exchanged.

3.2.2.3 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, levels and operation of pumps change.

3.2.2.4 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 pressure availability of salient points and water flows into the reservoirs, flow meter readings on main lines and branches 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.

3.2.2.5 System Pressures

Maintenance of continuous positive pressures in the transmission mains 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:

- purposefully or accidentally a line valve is left closed or partly closed or blockage may occur due to any material causing loss of pressure,
- higher velocities than design peak velocities in pipelines and in suction-delivery piping at pumps ,
- low water levels in Balancing Reservoir (OHBR/BPT/GLBR/sump) feeding into the transmission mains,
- Failure of pumps either due to power failure or mechanical failure feeding the transmission system.

3.2.2.6 Sampling for Quality of Water

The agency operating the water supply system is assigned with the primary responsibility of ensuring that the water supplied to the consumer is of potable 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 published by CPHEEO. 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.

3.2.2.7 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. Additional 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 pipelines which may pose a physical threat to the mains and structures. 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 below under Maintenance Schedule.

3.2.3 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 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 comprise not only the technical skills, but also include training to achieve better public relations with consumers.

3.2.3.1 Activities in Maintenance Schedule

Following activities are to be included in the schedule:

- Develop and conduct a surveillance programme for leaks in pipelines, pipe joints and valves,
- Develop and conduct a water quality surveillance programme,
- Develop and conduct a programme for locating and repairing leaks including rectifying cross connections if any, arrange for flushing, cleaning and disinfecting the mains,
- 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,
- Establish repair procedures for standard services and with provision for continuous training of the team members,
- Procure appropriate machinery, equipment and tools for repair of leaks and replacement of pipes and valves,
- Allocate suitable transport, tools and equipment to each maintenance team,
- Establish time, labour and material requirement and output expected time and other standards for each maintenance task, and
- Arrange for monitoring the productivity of each team.

3.2.3.2 Preventive maintenance

A preventive maintenance schedule has to be prepared for:

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

3.2.3.2.1 Activities for preventive maintenance

(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 required for proper repair and correct both the routine problems and 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 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.

3.2.4 Maintenance of Pipelines

3.2.4.1 Main Breaks

Pipeline bursts/main breaks can occur at any time and the utility shall have a contingency 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. 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.

3.2.4.2 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.

3.2.4.3 Flushing and Cleaning 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.

Mechanical cleaning devices such as swabs and pigs are sometimes 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 necessity for systematic and periodic cleaning of pipelines is borne out by the fact that the carrying capacity of the pipes gets reduced due to growth of slimes, incrustations or deposits. Flushing and swabbing of pipes, which are simple and inexpensive can go a long way in maintaining the capacity.

The old cast iron and steel pipes which are cleaned can be protected from further incrustations or corrosion by cement lining. Insertion of a plastic pipes has also been practiced with success.

(a) Flushing

Water at high velocity is allowed to flow in the pipe and finally escape through a scour valve or hydrant. The minimum velocity to be induced varies from 90 to 120 cm/s and it is to be ensured that the flows are in one direction and the dirty water does not enter the cleaned sections. Flushing can only remove loose deposits of small size and not the slimy layers, large sized deposits and hard incrustations. Flushing also disentangles microscopic biological growths which, if left unattended, are likely to grow further and create problems. The period of flushing is determined by the quality of outgoing water in hydrants or valves. Usually this amounts to the flushing out of a volume of water equal to twice the capacity of the pipe length under consideration. About 100 to 300 m length of pipe can be flushed in one operation

(b) Swabbing

The swab used is made of polyurethane foam of cylindrical shape and 30 to 60 cm long with varying diameters. It is soft and flexible, highly compressible and can retain the original shape when released from compression. Two varieties are available, one soft and the other relatively hard.

This swab is pushed into the pipe by the momentum of the flowing water. As the swab moves, it sweeps out the loose and slimy layer adhering to the inside of the pipelines and the deposits are carried away by the flowing water. Swabbing is not successful for dealing with hard deposits.

Swabs are slightly larger in diameter than the pipe to be cleaned. In certain cases with heavily incrustated pipes, swabs of the same diameter as the pipe are used initially. For pipe diameters of

75 to 100 mm, the swab diameter is usually 25 mm larger in size while for larger diameter pipe it is 50 to 75 mm larger.

For cleaning pipelines of 150 mm diameter or less, the following procedure is adopted. In distribution systems, where hydrants are connected vertically above a main without a duck-foot bend, the insertion of swab and its expulsion from the pipe are carried out at the hydrants. In situations, where the hydrants are laterally connected to the main, insertion of the swab has to be either through an existing valve in the line or by pumping water under pressure through the hydrant. The exit can be through another hydrant or a tee connected to the other end of the pipe and kept open.

The length of the main to be cleaned is isolated by valves. The swab is dipped in bleaching powder solution of strength 50 mg/l of chlorine prior to insertion. After insertion, the hydrant valve is dosed or the valve body is covered. Water is allowed into the pipe by opening the valve near the hydrant and keeping the exit hydrant valve open, while the valve on the other side of pipe is kept closed. This ensures water flows in one reach only between the point of insertion and point of exit of the swab.

The movement of swab depends on the rate of flow or velocity of flush in the pipe which usually should not be less than 30 cm/s. If swab gets stuck or blocked in the pipe, water can be passed from the opposite direction in the pipe to release it.

As a permanent measure, tee-branches can be provided near the junction points of the pipe network preceded by the valves. These tee connections are covered by blank flanges. The tee can be vertical or horizontal and the outlet end with blank flanges can be enclosed in a chamber. Whenever swabbing or flushing is desired, the blank flange can be opened after closing the downstream valve and allowing the water and swab to escape through the tee.

Mechanical cleaning devices such as swabs and pigs are sometimes 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.

3.2.4.4 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 strives corrosion through its ability to develop high alkalinity. Insitu cement mortar lining of existing metal water mains has been beneficial where:

- Pipe carrying capacity has reduced 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.

3.2.5 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.

3.2.5.1 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.

3.2.5.2 Procedures for reporting 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. 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.

3.3 Repairing Pipe Leaks

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.

3.3.1 Causes of Failure In Pipelines

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.

3.3.1.1 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 while in transport..
5. Weathering effect due to unfavourable environment.
6. Mixing up of different classes of pipes and their jointing materials.

3.3.1.2 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 pipe trenches which was not taken care 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.

3.3.1.3 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

3.3.1.4 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 laying pipes or other activities like laying of cables etc. is taken up.
6. Changes in soil moisture or water table conditions.

3.3.1.5 Excessive Temperature Changes

1. Expansion: severe compression, end crushing.
2. Contraction: pull out or separation of joint.
3. Freezing: pipe blockages and splits

3.3.1.6 Internal Pressure

1. Excessive test pressure.
2. Pressure surge, water separation, vacuum.
3. Extending pipe connections without proper precautions.

3.3.1.7 Aggressive Water

Damage to the internal surface of pipe as well the lining material.

3.3.1.8 Galvanic Action

3.3.2 Special Observations on Failure of Pipes

3.3.2.1 Pipe Barrel

Certain failures connected with the deterioration of the barrels of pipe are given below.

3.3.2.1.1 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

3.3.2.1.2 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.

3.3.2.1.3 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.

3.3.2.1.4 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.

3.3.2.1.5 Generalized 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.

3.3.2.2 Failure at Pipe Joints

Some of the points for consideration are given below:

3.3.2.2.1 General

1. Failures may occur due to 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.

3.3.2.2.2 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.

3.3.2.2.3 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.

3.3.2.2.4 Lead joints

Hardening of lead in association with joint movement may lead to 'weeping' which gradually develops into a more serious leak.

3.3.2.2.5 Sealing rings or gaskets

Many mechanical joint designs rely upon the compression of sealing rings or gaskets which have varying compositions and different resiliencies. 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.

3.3.3 Repair Action Plan

3.3.3.1 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

3.3.3.2 Implementation of action plan

3.3.3.2.1 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, Head works, 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

Different types of man power are required depending upon the magnitude of repair, material of pipe line to be repaired, time limit for repair and restoration of the leakages, and man power generally required on monthly basis and requirement on appointment instantly for the repair of job work.

The Requirement of man power is area specific and type of operation such as valve operation and operation of pumps, SCADA and other operations. Number of OHSRs to be covered and levels of OHSRs, Distances of OHSRs and their locations, such as located near the city, town or forest area. The automatic control of control valves if provided and the AMR meters if provided will reduce the requirement of manpower.

The no. of personnel required may be arrived by trial and error basis and taking into account of mode of transport being provided to the linemen (Operator).

The general type of manpower required are (1) Manager (2) Supervisor (3) Fitters (4) Crane operator (5) Excavator operator (6) Truck operator (7) Jeep operator (8) Emergency van operator (9) Electrician (10) Mechanic (11) Helper (12) pump operator (12) Semiskilled labour (13) Unskilled labour

Material

Different types of material that are required depending upon the magnitude of repair, material of pipe line to be repaired, time limit for repair and restoration of the leakages are, 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, Hardcrete, M seal, Sand bags.

Machinery

Different types of machinery that are required depending upon the magnitude of repair, material of pipe line to be repaired, time limit for repair and restoration of the leakages are, (1) Crane mobile (2) Excavator (3) Pumpset (Electrical) (4) Portable diesel pumpset (5) Welding Generator (6) Welding sets and rods (7) Mud Pump (8) Gas cutting set (9) Pressure Grouting Machine (10) Flexible Grinder (11) Hand Drilling

Transport

(1) Vehicle – Truck (2) Vehicle-Jeep (3) Emergency breakdown van.

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)

3.3.3.2.2 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.

3.3.3.2.3 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, and 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.

3.3.3.2.4 Location and extent of failure

(a) Location of the failure

Make use of local knowledge, plan, and 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:

- Detailed inspection around the pipe.
- Provision of sump for continuous operation of a drainage pump
- 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) Operation of Valves in repairs/replacements

Ensure effective operation of repair work which should be in perfect working condition by proper on/off of valves for water flow passing.

3.3.3.2.5 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'.

3.3.3.2.6 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;
- 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:

- any visible damage to the pipe;
- state of protective system or coating;
- depth of cover
- Description of the soil/backfill.

3.3.3.2.7 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 re-bedded, 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.

The Nipple used for release of air while hydraulic testing of pipeline is a source of leakage at a later date. These nipples have to be removed the hole plugged or the nipple used shall be properly plugged with corrosion protection.

(d) Control – Report situation to 'Control'.

3.3.3.2.8 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.

3.3.3.2.9 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 major repairs requiring cut out, every care must be taken to prevent contamination.

3.3.3.2.10 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.

3.3.3.2.11 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.

Some of the methods of repair for different types of pipes are given in the following tables:

MATERIAL	DUCTILE IRON	
Burst	Action	Repair
Joint Failure	Enclose Joint Remove Section/ Joint	Special Joint Clamp Two couplers and new section
Extensive Pin holing	Rehabilitation Technique Remove Section/ Joint	Slip lining etc. Two couplers and new section
Ductile Failure	Remove Section/ Joint Enclose Burst	Two couplers and new section Repair collar or clamp
Localized Pin holing	Enclose Burst	Repair collar or clamp

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

MATERIAL	PRESTRESSED CONCRETE(PSC)/ PCCP	
Burst	Action	Repair
Surface Softening	Remove complete length / Joint or cracking	Two couplers and new pipe section with machine end.
Joint Failure	Remove complete length / Joint Enclose Joint	Two couplers and new pipe section. Special Joint Clamp with machine end.

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 Slip lining etc. Repair collar or clamp

MATERIAL	ASBESTOS CEMENT	
Burst	Action	Repair
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 clamp

MATERIAL	POLYETHYLENE/ P.V.C	
Burst	Action	Repair
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

MATERIAL	GLASS REINFORCED PLASTIC PIPES (GRP)	
Burst	Action	Repair
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

3.3.4 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.

3.3.5 After the Leak Is Repaired

1. Open the control valve to allow water to flow into the repaired section;
2. Observe carefully to verify if the leak is completely sealed;
3. After sealing, backfill the excavation and restore the surface to its former condition;
4. Apply the disinfection procedures.

3.4 Disinfecting Pipelines after Repairs

After a repair job, it is essential to disinfect the repaired sections of the water distribution system with chlorine or chlorine containing compounds.

Important aspects of operation and maintenance of distribution system are detection and prevention of wastage due to leakage. The object is to control the waste within reasonable limits.

3.4.1 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:

1. Re-testing of residual chlorine,
2. Checking chlorination equipment at the start of the transmission system,
3. Searching for source of contamination along the transmission system which has caused the increased chlorine demand,
4. Immediate rectification of source of contamination.

3.4.2 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 areas 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 and casing of pipelines to avoid pollution.

3.4.2.1 Horizontal Separation

A water main should be laid such that there is at least 3m separation, horizontally from any existing or proposed drain or sewer line. If local conditions prevent this lateral separation, a water main may be laid closer to a storm or sanitary sewer, provided that the main is laid in a separate trench, or on an undisturbed earth shelf located on one side of the sewer at such an elevation that the bottom of the water main is at least 0.5 m above the top of sewer.

3.4.2.2 Vertical Separation

In situations where water mains have to cross house sewer, storm drain, or sanitary sewer, it should be laid at such an elevation that the bottom of the water main is 0.5 m above the top of the drain or sewer with the joints as remote from the sewer as possible. This vertical separation should be maintained for a distance of 3m on both sides measured normal to the sewer or drain it crosses.

3.5 Checks to be carried out in transmission system

A programme has to be prepared for each 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.

S. No.	Checks required/undertaken	Status	Suggested frequency of reporting
1.	Check whether the on/off 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 status of Air valve and isolation Sluice valves for leakages.		
5.	Check for leaks through pipes		
6.	Check for leakage through valves at gland, bolts or any other place		
7.	Check for leaks at the appurtenances including expansion joints		
8.	Check for any signs of corrosion of pipelines		
9.	Check for the status of manhole covers over the chamber covers; are they corroded		
10.	Inspect for any possibilities of pollution of the transmission system		
11.	Check status of out-fall drain for scour valves and chances of contamination at scours		
12.	Assess the need for painting of the exposed piping work		
13.	Check for availability of spares for Valves, expansion joints and pipes and jointing materials		
14.	Carry out review of pressures		

15.	Carry out review of flows		
16.	Check age of pipes /C value of pipes		
17.	Check for corrosive water		
18.	Study inflows and outflows into the reservoirs linked to the transmission system		
19.	Identify source of leakage		
20.	Metering		
21.	Status of bulk metering		
22.	Review facilities for repair of meters		
23.	Availability of updated system map		

CHAPTER 4

OPERATION AND MAINTENANCE OF PUMPING MACHINERY

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 upkeep 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.

4.1 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
 - Flow meter
 - Diesel generating set
- iii) Pumping station
 - Sump/intake/well/tube well/bore well
 - Pump house
 - Screen
 - Penstock/gate

4.1.1 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 bore well type pump-motor set
 - Monobloc open well type pump-motor set
- iv. Jet pumps
- v. Reciprocating pumps

4.2 Operation of the Pumps

Important points as follows shall be observed while operating the pumps.

4.2.1 Important Points for Operation

- (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 + 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 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 valves, sluice valves and butterfly valves 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.

Additional Points for Operation of the Pumps

(a) Submersible pumps:

- Correct rotations
- Pump is below static water level before starting, and continues to be below draw down level throughout the operation.

(b) Centrifugal pumps:

- Correct rotations
- Pump is properly primed before starting if pump suction is negative.

(c) Vertical turbine pumps

- Pumps properly primed before starting
- Air vent to be fully opened before starting
- Correct rotation of pump.
- Pump should not be operated, if ratchet pins are missing
- Bowl assembly is completely submerged

(d) Inventory of materials for pumps

- Submersible pumps: Impellers
- Centrifugal pumps: Impellers, diffusers, bearings, gland packing
- Vertical turbine pumps: thrust bearings, gland packing, head shaft, intermediate shaft, bearing spider, bowl assemble, impeller etc.
- Motors: Bearings
- MCC: Relay, tripping circuit, fuses.
- Transformer: Oil

4.2.2 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 12.3.16, Chapter 12 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.

4.2.3 Starting the Pumps

4.2.3.1 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 + 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 over current 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.

4.2.3.2 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.

- iv. Check vacuum gauge if the pump operates on suction lift. If the pointer on gauge gradually rises and becomes steady the priming is proper.
- v. 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.
- vi. 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).
- vii. Check that ammeter reading is less than rated motor current.
- viii. Check for undue vibration and noise.
- ix. 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.
- x. 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.

4.2.4 Stopping the Pump

4.2.4.1 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.

4.2.4.2 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 under volt 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 cannot 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.

4.3 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 needs 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 guidelines.

4.3.1 Maintenance of Pumps

4.3.1.1 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.

- Changes in sound of running pump and motor
- Abrupt changes in bearing temperature.
- Oil leakage from bearings
- Leakage from stuffing box or mechanical seal
- Changes in voltage
- Changes in current
- Changes in vacuum gauge and pressure gauge readings
- Sparks or leakage current in motor, starter, switch-gears, cable etc.
- 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.

- Timings when the pumps are started, operated and stopped during 24 hours.
- Voltage in all three phases.

- Current drawn by each pump-motor set and total current drawn at the installation.
- Frequency.
- Readings of vacuum and pressure gauges.
- Motor winding temperature.
- Bearing temperature for pump and motor.
- Water level in intake/sump.
- Flowmeter reading.
- Daily PF over 24 hours duration.
- Any specific problem or event in the pumping installation or pumping system e.g. burst in pipeline, tripping or fault, power failure.

4.3.1.2 Monthly Maintenance

- Check free movement of the gland of the stuffing box; check gland packing and replace if necessary.
- Clean and apply oil to the gland bolts.
- Inspect the mechanical seal for wear and replacement if necessary.
- Check condition of bearing oil and replace or top up if necessary.

4.3.1.3 Quarterly Maintenance

- 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.
- 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.
- Tighten the foundation bolts and holding down bolts of pump and motor mounting on base plate or frame.
- Check vibration level with instruments if available; otherwise by observation.
- Clean flow indicator, other instruments and appurtenances in the pump house.

4.3.1.4 Annual Inspections and Maintenance

A very thorough, critical inspection and maintenance should be performed once in a year.

Following items should be specifically attended.

- 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.
- Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.
- 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.
- Check stuffing box, glands, lantern ring, mechanical seal and rectify if necessary.
- 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 4.1 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 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%.

Table 4.1 Wearing Ring Diametral Clearance and Tolerance

Inside diameter of wearing ring (mm)	Diameter clearance (mm)	Machining Tolerance (mm)
Upto 100	0.30	0.050
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

- Check impeller hubs and vane tips for any pitting or erosion.
- Check interior of volute, casing and diffuser for pitting, erosion, and rough surface.
- All vital instruments i.e. pressure gauge, vacuum gauge, ammeter, voltmeter, wattmeters, frequency meter, tachometer, flowmeter etc. shall be calibrated.
- Conduct performance test of the pump for discharge, head and efficiency.
- 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.
- Check vibration level.

4.3.1.5 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. wet pit or dry pit, 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

4.3.1.6 Problems in Long Column Pipes in V.T 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 or splitter as shown in figure 4.1 shall be provided underneath bell mouth.

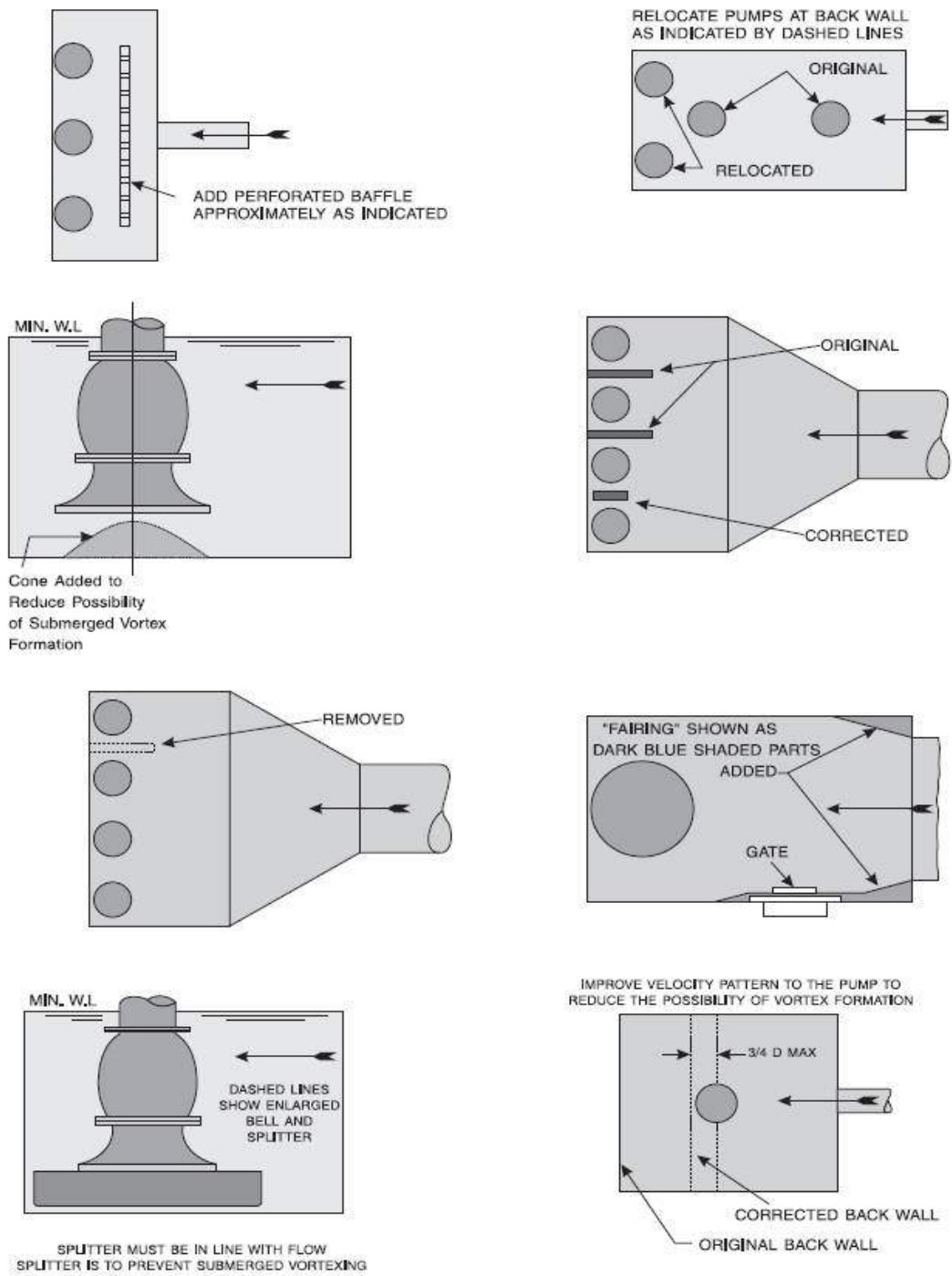


Fig 4.1: Remedial Measures for Vortex Free Operation in Existing Sumps

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.

4.3.1.7 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.

4.3.1.8 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.

4.3.2 Maintenance Schedule for Motors

4.3.2.1 Daily Maintenance

- Clean external surface of motor.
- Examine earth connections and motor leads.
- 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).
- In case of oil ring lubricated bearing.
 - Examine bearings to check whether oil rings are working.
 - Note bearing temperature.
 - Add oil if necessary.

- Check for any abnormal bearing noise.

4.3.2.2 Monthly Maintenance

- Check belt tension. In case where this is excessive it should immediately be reduced.
- Blow dust from the motor.
- Examine oil in oil lubricated bearing for contamination by dust, grit, etc. (this can be judged from the colour of the oil).
- Check functioning and connections of anti-condensation heater (space heater).
- Check insulation resistance by meggering.

4.3.2.3 Quarterly Maintenance

- 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.
- 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.
- Check insulation resistance of the motor.
- Check tightness of cable gland, lug and connecting bolts.
- Check and tighten foundation bolts and holding down bolts between motor and frame.
- Check vibration level with instrument if available; otherwise by observation.

4.3.2.4 Half Yearly Maintenance

- Clean winding of motor, brake and varnish if necessary.
- In case of slip ring motors, check slip-rings for grooving or unusual wear, and polish with smooth polish paper if necessary.

4.3.2.5 Annual Inspection and Maintenance

- 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.
- Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.
- 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.
- Clean and varnish dirty and oily windings.

Re-varnish motors subjected to severe operating and environmental conditions e.g., operation in dust-laden environment, polluted atmosphere etc.

- Check condition of stator, stamping, insulation, terminal box, fan etc.
- Check insulation resistance to earth and between phases of motors windings, control gear and wiring.
- Check air gaps.
- Check resistance of earth connections.

4.3.2.6 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:

- Details of motor, rating, model, class of duty, class of insulation, efficiency curve, type test result and type test certificate etc.
- Date of installation and commissioning.
- Addresses of manufacturer & dealer with phone & fax number and e-mail addresses.
- Brief details of monthly, quarterly, half yearly and annual maintenance and observations of inspections about insulation level, air gap etc.
- Details of breakdown, repairs with fault diagnosis.
- Running hours at the time of major repairs.

4.3.3 Valves

Following 5 types of valves are generally used in pumping installation

- Foot valve.
- Sluice valve.
- Knife gate valve.
- Reflux (non-return) valve.
- 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 leak proof 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 packing 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.
- It is important for valve that it should never be operated with oversize hand wheel or cap or spanner as this practice may result in rounding of square top and hand wheel or cap or spanner may eventually slip.
- It is also important for valve, 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.

4.3.4 Valve Actuators

4.3.4.1 Quarterly Maintenance

- Declutch and operate manual hand wheel.
- Check oil level and top up if required.
- Re-grease 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.

4.3.4.2 Annual Inspection 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.

4.3.5 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.

4.3.6 H.T Breakers, Contractors 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.

4.3.7 Capacitor

4.3.7.1 Pre-requisites for Satisfactory Functioning of Capacitor

Ensure following points:

- A capacitor should be firmly fixed to a base.
- Cable lugs of appropriate size should be used.
- 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.

- To avoid damage to the bushing, a cable gland should always be used and it should be firmly fixed to the cable-entry hole.
- The capacitor should always be earthed appropriately at the earthing terminal to avoid accidental leakage of the charge.
- 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.
- 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.
- Ensure that the cables, fuses and switchgear are of adequate ratings.

4.3.7.2 Operation and Maintenance of Capacitors

- The supply voltage at the capacitor bus should always be near about the rated voltage. The fluctuations should not exceed + 10% of the rated voltage of the capacitor.
- Frequent switching of the capacitor should be avoided. There should always be an interval of about 60 seconds between any two switching operations.
- 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.
- Leakage or breakage should be rectified immediately. Care should be taken that no appreciable quantity of impregnant has leaked out.
- 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.
- Replace capacitor if bulging is observed.

4.3.8 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.

4.3.8.1 Daily Observations and Maintenance

- Check winding temperature and oil temperature in transformer and record. (For large transformers above 1000 kV, the temperature should be recorded hourly).
- Check leakages through CT/PT unit, transformer tank and HT/LT bushings.

- Check colour of silica gel. If silica gel is of pink colour, change the same by spare charge and reactivate old charge for reuse.

4.3.8.2 Monthly Maintenance

- Check oil level in transformer tank and top up if required.
- Check relay contacts, cable termination, connections in marshalling box etc.
- Check operation of AB switch and DO fuse assembly.
- Clean radiators free from dust and scales.
- 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.
- Inspect lightning arrestor and HT/LT bushing for cracks and dirt.

4.3.8.3 Quarterly Maintenance

- Check dielectric strength of transformer oil and change or filter if necessary.
- Check insulation resistance of all equipments in sub-station, continuity of earthings and earth leads.
- Check operation of tap changing switch.

4.3.8.4 Pre-Monsoon and Post-Monsoon checks and Maintenance

- Check insulation resistance of transformer.
- Test transformer oil for dielectric strength, sludge etc. If necessary, filtration of oil shall be carried out before monsoon.
- Oil shall be tested for dielectric strength after monsoon.

4.3.8.5 Half-Yearly Maintenance

- Check dielectric strength of transformer oil in CT/PT and filter or change oil if necessary.
- Check contact faces of AB switch and DO/HG fuse; apply petroleum jelly or grease to moving components of AB switch.

4.3.8.6 Annual Inspection and Maintenance

- Measure resistance of earth pit. Resistance shall not exceed 1 ohm.
- Check bus bar connections, clean contact faces, change rusted nut bolts.
- Calibrate the protection relay for functioning. Check relay setting and correct if necessary.
- 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.

- Test transformer oil for acidity test.

4.3.8.7 Special Maintenance

- Painting of transformer tank and steel structure of sub-station equipments shall be carried out after every two years.
- 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.

4.3.9 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, and rheostat motor thoroughly.

4.3.10 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.

4.3.11 Water Hammer Control Devices

Maintenance requirements of water hammer devices depend 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 :

4.3.11.1 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.
- Painting: Painting of tanks shall be carried out once in 2 years.

4.3.11.2 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.

4.3.11.3 Zero Velocity Valves and Air Cushion Valve

Foreign matters entangled in valve shall be removed by opening all hand holes 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.

4.3.11.4 Surge anticipation valves

Pilot valves and tubes shall be flushed and cleaned every month

4.3.11.5 Pressure relief valve

The spring shall be checked and freed from jam every month.

4.3.12 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.

4.4 Maintenance of Pumping Station

Maintenance as follows shall be carried out for screens, penstock/gate, sump/intake/well and pump house including civil works.

4.4.1 Screens

- 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.
- Care should be taken to remove and dump the screening far away from the pump house.
- Lubricate wheels and axle of wheel burrows.
- 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.

4.4.2 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.

4.4.3 Sump / Intake Well

- 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.
- 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.
- It is generally observed that reptiles like snakes, fish, etc. enter intake particularly in monsoon. The intake should be disinfected.
- The sump/intake should be fully dewatered and inspected once in a year.

- 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.

4.4.4 Pump House

- The pump house should be cleaned daily. Good house keeping and cleanliness are necessary for pleasant environment.
- 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.
- Wooden flooring and M.S. grating wherever damaged should be repaired on priority.
- If 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.
- All facilities in sub-structure i.e. stair case, floors, walkways etc. should be cleaned daily.
- Painting of civil works should be carried out at least once in two years.

4.5 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.

4.5.1 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.

4.5.2 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 polarization index shall be checked. The polarization 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.

4.6 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

4.6.1 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.

4.6.2 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
- Coupling bushes and bolts

- Line shaft
- Shaft enclosing tube
- Gland nut
- Lantern ring
- Shaft sleeves
- Slip ring unit
- Gland pickings and gaskets
- Fixed and moving contacts
- Rotating assembly of pump (for large pumping installation)
- Coupling for line shaft
- Carbon brushes
- Bearings
- Line shaft bearings and spiders
- Lugs
- Gland for cable termination
- Pump shaft
- Fluorescent tubes and lamps
- Fuses
- Tube tensioning plate
- Impeller

4.6.3 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

4.6.4 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

4.6.5 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.

4.7 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

4.7.1 Trouble Shooting for Centrifugal Submersible Pumps

4.7.1.1 Trouble & Cause

(a) Centrifugal Pump

Trouble	Possible Causes (numbers as per list below)	List of Causes
<ul style="list-style-type: none"> • Pump does not deliver water. (water not delivered to not completely filled with water). 	<p>1, 2, 3, 5, 6, 7, 9, 10, 15, 18, 21, 23, 26, 28, 29, 30, 31, 33, 40, 41, 42.</p>	<ol style="list-style-type: none"> 1. Pump not fully primed i.e. pump or suction pipe discharging end i.e. reservoir/WTP). 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).
<ul style="list-style-type: none"> • Insufficient discharge delivered. 	<p>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.</p>	<ol style="list-style-type: none"> 3. Suction lift too high. (Reduce suction lift after calculating permissible suction lift from NPSHA and NPSHR).
<ul style="list-style-type: none"> • Insufficient pressure developed. 	<p>2, 3, 4, 21, 23, 24, 26, 27, 28, 33, 39.</p>	<ol style="list-style-type: none"> 4. Excessive amount of air in liquid.
<ul style="list-style-type: none"> • Pump loses prime after starting. 	<p>4, 5, 6, 7, 10, 16, 17, 18.</p>	<ol style="list-style-type: none"> 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).
<ul style="list-style-type: none"> • Pump requires excessive power. 	<p>22, 25, 28, 33, 37, 38, 49, 53, 54, 55, 56, 58</p>	<ol style="list-style-type: none"> 6. Air leaks into suction line. 7. Air leaks into pump through stuffing boxes or mechanical seal.
<ul style="list-style-type: none"> • Stuffing box leaks excessively. 	<p>34, 36, 44, 45, 46, 47, 48, 50, 51, 52.</p>	<ol style="list-style-type: none"> 8. Net opening area of foot valve less. 9. Foot valve/strainer partially or fully clogged or silted up.
<ul style="list-style-type: none"> • Gland packing has short life. 	<p>11, 12, 34, 36, 44, 45, 46, 47, 48, 49, 50, 51, 52.</p>	<ol style="list-style-type: none"> 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).
		<ol style="list-style-type: none"> 11. Water-seal pipe clogged.

- 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. 4.1).
 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. 4.1).
 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"> 32. Capacity of thrust bearing in adequate. 33. Foreign matter in impeller. 34. Misalignment. 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]. 36. Pump (impeller) shaft bent. 37. Rotating part rubbing on stationery part. 38. Pump shaft bearing (bush bearing or antifriction bearing) worn. 39. Wearing rings worn. 40. Impeller damaged. 41. Impeller locking pin or collet loose. 42. Pump shaft or transmission shaft broken. 43. Transmission shaft bent (not true). 44. Shaft or shaft sleeves worn or scored at the packing. 45. Gland Packing improperly installed. 46. Incorrect type of gland packing for operating conditions. 47. Shaft running off centre because of worn bearing or misalignment. 48. Rotor out of balance, causing vibration. 49. Gland too tight, resulting in no flow of liquid to lubricate gland. 50. Failure to provide cooling liquid to water cooled stuffing boxes. 51. Excessive clearance at bottom of stuffing box between shaft and casing, causing interior packing to be forced into pump.

Trouble	Possible Causes	List of Causes
		<ul style="list-style-type: none"> 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. 4.1. 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. 4.1).
• 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.
• Pump vibrates or noisy at low flow.	1, 3, 4, 14, 25.	11. Total head of system higher than design head of pump.
• Pump vibrates or noisy at high flow.	12, 15.	12. Total head of system lower than pump design head. 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, 41,15. Burst or leakage in pumping main.
42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54. 16. Pumping main partially or fully clogged.

17. Air trapped in pumping main.
- Pump overheats and/or seizes. 1, 5,6, 7, 11, 13, 14, 18, 20, 22, 23, 24, 30,31, 18. Malfunctioning of line valve causing partial or full closure.
32, 33, 34, 35, 36, 39, 40, 41, 42, 43, 44.

19. Foreign matter in impeller.
- Coupling fails. 20, 22, 24, 29, 46, 53.

20. Misalignment.
21. Foundations not rigid or broken/loose foundation bolts or supporting structural member (RCC/ structural steel beams) not rigid.
- Pump rotates in reverse direction on shutdown or after power failure or tripping. 55, 56.

22. Pump (impeller) shaft bent.
23. Rotating part rubbing on stationery 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
• Pump does not deliver water (water not delivered to discharging end i.e. reservoir/WTP).	2, 4, 5, 7, 10, 11, 12, 22, 23.	1. Excessive amount of air in liquid. 2. 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).
• Insufficient discharge delivered.	2, 3, 4, 5, 8, 9, 10, 11, 12, 22.	3. 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.4.1).
• Insufficient pressure developed.	1, 4, 5, 7, 8, 9, 14, 20.	4. Wrong direction of rotation.
• Pump requires excessive power.	6, 9, 14, 18, 19, 26.	5. Total head of system higher than design head of pump.
• Ingress of pumped water into motor.	27	6. Total head of system lower than pump design head.
• Pump vibrates or noisy.	6, 8, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30, 32.	7. Static head higher than shut off head of pump. 8. Pump characteristics unsuitable for parallel operation of pumps.
• Pump rotates in reverse direction on shutdown or after power failure or tripping.	31.	9. Burst or leakage in pumping main. 10. Pumping main partially or fully clogged. 11. Air trapped in pumping main. 12. Malfunctioning of line valve causing partial or full closure.

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 stationery 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.
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4.7.2 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

4.7.2.1 Suction Troubles

- Insufficient suction pressure
- Partial loss of prime
- Cavitation
- Lift too high
- Leaking suction at foot valve
- Acceleration head requirement too high

4.7.2.2 System Problem

- System shocks
- Poorly supported piping, abrupt turns in piping, pipe size too small, piping misaligned.
- Air in liquid
- Overpressure or overspeed
- Dirty liquid
- Dirty environment
- Water hammer

4.7.2.3 Mechanical troubles

- Broken or badly worn valves
- Packing worn
- Obstruction under valve
- Loose main bearings
- Worn bearings

- Low oil level
- Plunger loose
- Tight main bearings
- Inadequate ventilation
- Belts too tight
- Driver misaligned
- Condensation
- Worn seals
- Oil level too high
- Pump not set level and right
- Loose packing
- Corrosion
- Valve binding
- Broken valve spring
- Loose cylinder plug
- Damaged O-ring seal

4.7.3 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"> • The reflux valve is not designed for non-slam in closure. 	<ul style="list-style-type: none"> • Replace with reflux valve designed for non-slam closure. • Taken up issue of old valve to valve manufacturer.

4.7.4 Trouble Shooting for Electric Motor

S.No.	Trouble	Cause	Remedy
1.	Hot bearings	<ul style="list-style-type: none"> Bent or sprung shaft. Excessive belt pull. Misalignment Bent or damaged oil rings. Oil too heavy or too light. Insufficient oil level Badly worn bearings Bearing loose on shaft or in bearing housing Insufficient grease Deterioration of grease or lubricant contaminated Excessive lubricant Overloaded bearing Broken ball or rough races. 	<ul style="list-style-type: none"> Straighten or replace shaft. Decrease belt tension Correct coupling alignment. Replace or repair oil rings Use recommended oil. Use of oil of too light grade is likely to cause the bearings to seize. Fill reservoir to proper level when motor is at rest. Replace bearings. Remetal shaft/housing or replace shaft or bearing housing. Maintain proper quantity of grease in bearing. Remove old grease, wash bearings thoroughly with kerosene and replace with new grease. Reduce quantity of grease. Bearing should not be more than two-third filled. Check alignment, side thrust and end thrust. Clean housing thoroughly and replace bearing.
2.	Motor dirty	<ul style="list-style-type: none"> Ventilation passage blocked. Windings coated with fine dust or lint (dust may be cement, sawdust, rock dust, grain dust and the like). Bearing and brackets coated inside. Rotor winding coated with fine dust/cement 	<ul style="list-style-type: none"> Dismantle entire motor and clean all windings and parts by blowing off dust, and if necessary, varnish. Clean and wash with cleaning solvent. Clean and polish slip ring. Clean rotor and varnish
3.	Motor stalls	<ul style="list-style-type: none"> Motor overloaded Low voltage Open circuit Incorrect control resistance of wound motor Mechanical locking in bearings or at air gap. 	<ul style="list-style-type: none"> Check any excessive rubbing or clogging in pump Correct voltage to rated value. Fuses blown, check overload relay, starter and push button. Check correct sequence; Replace broken resistors. Dismantle and check bearings. Check whether any foreign matter has entered air

gap and clean.

4. Motor does not start

- No supply voltage or single phasing or open circuit or voltage too low.
- Motor may be overloaded
- Starter or switch/breaker contacts improper
- Initial starting torque of load too high.
- Rotor defective
- Poor stator coil connection
- Mechanical lockings in bearings or at air gaps
- Check voltage in each phase
- Start on no load by decoupling. Check for cause for overloading
- 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.
- If of squirrel cage type and with auto transformer starter, change to a higher tap. If of slip ring type, lower the starting resistance
- Check for broken rings.
- Remove end shields, check end connections.
- Dismantle and repair, clean air gap if choked.

5. Motor runs and then

- Power supply system faulty. bearings or at air gap.
- Overload relay trips.
- Check for loose connections or single phasing in switches, breakers, starter, bus-bars and conductor.
- 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.

6. Motor does not accelerate to rated speed.	Voltage too low at motor terminals because of line drop.	<ul style="list-style-type: none"> • Consult manufacturer whether suitable for design duty and load. • Check voltage, change tapping on transformer • Check that all brushes are riding on rings. Check secondary connections. Leave no lead poorly connected.
	<ul style="list-style-type: none"> • Improper connection. • Broken rotor bars 	<ul style="list-style-type: none"> • Look for cracks near the rings.
7. Motor takes too long to accelerate.	<ul style="list-style-type: none"> • Excess loading 	<ul style="list-style-type: none"> • 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)
	<ul style="list-style-type: none"> • Timer setting of starter not correct. • Defective squirrel cage rotor. • Applied voltage too low. 	<ul style="list-style-type: none"> • Check whether timer setting of star – delta or autotransformer starter is less than acceleration time required for the torque of driven equipment. • Replace with new rotor. • Correct the voltage by changing tap on transformer. If voltage is still low, take up the matter to power supply authority.
8. Wrong rotation	<ul style="list-style-type: none"> • Wrong sequence of phases 	<ul style="list-style-type: none"> • Inter change connections of two leads at motor or at switchboard for two phases.

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|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 9. Motor overheats while running | <ul style="list-style-type: none"> • Check for overload
 • End shields may be clogged with dust, preventing proper ventilation of motor. • Motor may have one phase open. • Unbalanced terminal voltage
 • Weak insulation
 • High or low voltage
 • Rotor rubs on stator bore | <ul style="list-style-type: none"> • 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. • Blow off dust from the end shields.
 • Check to make sure that all leads are well connected. • Check for faulty leads, connections from transformer. • Check insulation resistance, examine and revarnish or change insulation. • Check voltage of motor and correct it to the extent possible. • Replace worn bearings. • Check for true running of shaft and rotor. |
| 10. Motor vibrates after connections have been made | <ul style="list-style-type: none"> • Motor misaligned • Weak foundations or holding down bolts loose
 • Coupling out of balance • Driven equipment unbalanced.
 • Defective ball or roller bearings
 • Bearings not in line • Rotor unbalanced
 • Single phasing
 • Excessive end play | <ul style="list-style-type: none"> • Realign • Strengthen base plate/ foundation; tighten holding down bolts. • Balance coupling • Balance rotating elements of driven equipment on dynamic balancing machine. • Replace bearing
 • Line up properly • Rebalance rotor on dynamic balancing machine • Check for open circuit in all phases.
 • Adjust bearing or add washer |

		<ul style="list-style-type: none"> • Resonance from supporting structure or foundation or vibration of adjoining equipment 	<ul style="list-style-type: none"> • Seek consultation from expert.
11.	Unbalanced line current on polyphase motor during normal operation	<ul style="list-style-type: none"> • Unbalanced terminal voltage. • Single phase operation. • Poor rotor contacts in control wound rotor resistance. • Brushes not in proper position in wound rotor. 	<ul style="list-style-type: none"> • Check leads and connections. • Check for open contacts or circuit in all phases. • Check control devices. • See that brushes are properly seated.
12.	Scraping noise	<ul style="list-style-type: none"> • Fan rubbing air shield or striking insulation. • Loose on bed plate 	<ul style="list-style-type: none"> • Check for cause and rectify. • Tighten holding down bolts
13.	Magnetic noise	<ul style="list-style-type: none"> • Air gap not uniform • Stator stamping loose • Loose bearings • Rotor unbalance • Crack in rotor bar 	<ul style="list-style-type: none"> • Check and correct bracket fits or bearing. • Retighten stamping. • Correct or replace bearing. • Rebalance on dynamic balancing machine. • Replace
14.	Motor sparking at slip rings	<ul style="list-style-type: none"> • Motor may be overloaded. • Brushes may not be of correct quality and may not be sticking in the holders. • Slip ring dirty or rough. • Slip rings may be ridged or out of turnness. 	<ul style="list-style-type: none"> • Reduce the load • Use brushes of the grade recommended and fit properly in the brush holder. • Clean the slip rings and maintain in smooth glossy appearance and free from oil and dirt. • Turn and grind the slip rings in a lathe to a smooth finish.
15.	Leakage of oil or grease on winding	<ul style="list-style-type: none"> • Thrust bearing oil seal damaged • Excessive oil, grease in bearing. 	<ul style="list-style-type: none"> • Clean the spilled oil on winding. Replace oil seal. • Reduce quantity to correct extent. Grease should be filled upto maximum half space in bearing housing.

4.7.5 Trouble Shooting for Capacitors

Sl no.	Trouble	Cause	Remedy
1.	Leakage of heclor*	<ul style="list-style-type: none"> Leaking welds & solders Broken insulators 	<ul style="list-style-type: none"> Repair by soldering Replace insulators
2.	Overheating of unit	<ul style="list-style-type: none"> Poor ventilation Over voltage 	<ul style="list-style-type: none"> Arrange for circulation of air either by reinstalling in a cooler and ventilated place or arrange for proper ventilation Reduce voltage if possible, otherwise switch off capacitors
3.	Current below normal value	<ul style="list-style-type: none"> Low voltage Element fuses blown Loose connections 	<ul style="list-style-type: none"> Correct the voltage Replace capacitor Tighten carefully
4	Abnormal bulging	<ul style="list-style-type: none"> Gas formation due to internal arcing 	<ul style="list-style-type: none"> Replace the capacitor
5	Cracking sound	<ul style="list-style-type: none"> Partial internal faults 	<ul style="list-style-type: none"> Replace the capacitor
6	HRC fuse blowing	<ul style="list-style-type: none"> Short, external to the units Over-current due to over voltage and harmonics Short circuited unit. kVAR rating higher. 	<ul style="list-style-type: none"> Check and remove the short Reduce voltage and eliminate harmonics Replace the capacitor Replace with bank of appropriate kVAR
7	Capacitor not discharging	<ul style="list-style-type: none"> Discharge resistance low 	<ul style="list-style-type: none"> Correct or replace the discharge resistance
8	Unbalanced current	<ul style="list-style-type: none"> Insulation or dielectric failure 	<ul style="list-style-type: none"> Replace capacitor unit

* 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

4.7.6 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"> • Non availability of power supply to the starter/breaker • Relay reset not operating • Castle lock is not locked properly 	<ul style="list-style-type: none"> • Check the supply • Reset the relay • Clean and reset relay • Remove lock and lock it properly
2.	Starter/breaker not holding on ON-Position	<ul style="list-style-type: none"> • Relay contacts are not contacting properly 	<ul style="list-style-type: none"> • Check and clean the contacts
3.	Starter/breaker tripping within short duration due to operation of overcurrent relay	<ul style="list-style-type: none"> • Overcurrent relay setting incorrect. • Moderate short circuit on outgoing side. • No or less oil in dashpot • Dashpot oil not of proper grade • Sustained overload 	<ul style="list-style-type: none"> • Check and reset to 140% of normal load current. • Check and remove cause for short circuit • Fill oil upto level mark • Check and use oil of correct grade • Check overcurrent setting • Check for short circuit or earth fault. • Examine cause of overload & rectify
4.	Starter/breaker not tripping after over current or short circuit fall occurs	<ul style="list-style-type: none"> • Loose connection • Lack of lubrication to mechanism • Mechanism out of adjustment • Failure of latching device • Mechanical binding • Relay previously damaged by short circuit • Heater assembled incorrectly • Relay not operating due to: <ul style="list-style-type: none"> Blown fuse Loose or broken wire Relay contacts damaged or dirty Damaged trip coil 	<ul style="list-style-type: none"> • Clean and Tighten • Lubricate hinge pins and mechanism • Adjust all mechanical devices i.e toggle stops, buffers, springs as per manufacturers instructions • Examine surface, clean and adjust latch. If worn or corroded replace it • Replace overcurrent relay (& heater if provided) • Replace overcurrent relay and heater • Review installation instruction & correctly install the heater assembly • Repair fuse • Repair faulty wiring; ensure that all screws are tight • Replace damaged contacts • Replace coil

	C.T. damaged	Check and repair/replace
5. Overheating	<ul style="list-style-type: none"> • Poor condition of contacts • Contacts out of proper alignment • Contacts burnt or pitted • Loose power connection • Sustained overcurrent / short circuit 	<ul style="list-style-type: none"> • Clean and polish contacts • Align the contacts • 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. • Tighten the connection • Check cause and rectify
	<ul style="list-style-type: none"> • Poor ventilation at location of starter/breaker. 	<ul style="list-style-type: none"> • Improve ventilation.
6. Overheating of auto transformer unit	<ul style="list-style-type: none"> • Winding design improper. • Transformer oil condition poor 	<ul style="list-style-type: none"> • Rewind. • Replace transformer oil in auto-transformer unit.
7. Contacts chatter	<ul style="list-style-type: none"> • Low voltage • Poor contact in control circuit • Defective or incorrect coil. 	<ul style="list-style-type: none"> • Check voltage condition. Check momentary voltage dip during starting. Low voltage prevents magnet sealing. Check coil voltage rating. • Check push button station, (stop button contacts), auxiliary switch contacts and overload relay contacts and test with test lamp. • Check for loose connections in control circuits. • Replace coil. Rating should be compatible for system nominal voltage.

8.	Contacts welding	<ul style="list-style-type: none"> • Abnormal inrush of current Low voltage preventing magnet from sealing • Short circuit 	<ul style="list-style-type: none"> • Check for grounds & shorts in system as well as other components such as circuit breaker. • Check and correct voltage. • Remove short circuit fault and ensure that fuse or circuit breaker rating is correct.
9.	Short push button and/ or over heating of contacts.	<ul style="list-style-type: none"> • Filing or dressing. • Interrupting excessively high current • Discoloured contacts caused by insufficient contact pressure, loose connections etc. • Dirt or foreign matter on contact surface. • Short circuit. 	<ul style="list-style-type: none"> • Do not file silver tips. Rough spots or discolouration will not harm tips or impair their efficiency. • Check for short circuit, earth fault or excessive motor current. • Replace contact springs, check contact for deformation or damage. Clean and tighten connections • Clean with carbon tetrachloride. • Remove fault & check fuse or breaker rating whether correct.
10.	Coil open circuit	<ul style="list-style-type: none"> • Mechanical damage • Burnt out coil due to over voltage or defect. 	<ul style="list-style-type: none"> • Examine and replace carefully. Do not handle coil by the leads. • Replace coil.

- | | | |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11. Magnets and other mechanical parts worn out | <ul style="list-style-type: none"> • Too much cycling • Dust and dirt or mechanical abuse | <ul style="list-style-type: none"> • Replace part and correct the cause of damage. |
| 12. Noisy magnet(humming) | <ul style="list-style-type: none"> • Defective coil • Magnet faces not mating correctly | <ul style="list-style-type: none"> • Replace coil • Replace magnet assembly. Hum may be reduced by removing magnet armature and rotating through 180° |
| | <ul style="list-style-type: none"> • Dirt oil or foreign matter on magnet faces • Low voltage | <ul style="list-style-type: none"> • Clean magnet faces with carbon tetrachloride • Check system voltage and voltage dips during starting. |
| 13. Failure to pick up and/or seal | <ul style="list-style-type: none"> • Low voltage | <ul style="list-style-type: none"> • Check system voltage and voltage dips during starting. |
| | <ul style="list-style-type: none"> • Coil open or shorted | <ul style="list-style-type: none"> • Replace coil |
| | <ul style="list-style-type: none"> • Wrong coil | <ul style="list-style-type: none"> • Check coil voltage rating which must include system nominal voltage and frequency |
| | <ul style="list-style-type: none"> • Mechanical obstruction | <ul style="list-style-type: none"> • With power off, check for free movement of contact and armature assembly. Remove foreign objects or replace contactor. |
| | <ul style="list-style-type: none"> • Poor contact in control circuit | <ul style="list-style-type: none"> • Check and correct |

14. Failure to drop out	<ul style="list-style-type: none"> • Gummy substances on pole faces or in mechanism • Voltage not removed from control circuit • Worn or rusted parts causing binding e.g coil guides, linkages • Residual magnetism due to lack of air gap in magnetic path • Improper mounting of starter 	<ul style="list-style-type: none"> • Clean with carbon tetrachloride • Check control circuit • Replace contactor • Review installation instruction and mount carefully
15. Failure to reset	<ul style="list-style-type: none"> • Broken mechanism worn parts, corrosion dirt etc 	<ul style="list-style-type: none"> • Replace overcurrent relay and heater
16. Open or welded control circuit contacts in over current relay	<ul style="list-style-type: none"> • Short circuit in control circuit with too large protecting fuses • Misapplication, handling too heavy currents 	<ul style="list-style-type: none"> • Rectify short circuit in general. Fuses over 10A rating should not be used. • Check rating and rectify
17. Insufficient oil in breaker/ (if oil cooled)	<ul style="list-style-type: none"> • Leakage of oil 	<ul style="list-style-type: none"> • Locate point of leakage and rectify
18. Oil dirty	<ul style="list-style-type: none"> • Carbonisation of moisture from atmosphere 	<ul style="list-style-type: none"> • Clean inside of tank and all internal parts. Fill fresh oil
19. Moisture present in oil	<ul style="list-style-type: none"> • Condensation of moisture from atmosphere 	<ul style="list-style-type: none"> • Clean inside of tank and all internal parts. Fill fresh oil

4.7.7 Trouble Shooting for Panels

Sl no.	Cause	Trouble	Remedy
1.	Overheating	<ul style="list-style-type: none"> • Bus bar capacity inadequate • Loose connection • Improve ventilation 	<ul style="list-style-type: none"> • Check and provide additional bars in combination with existing bus bars / replace bus bars • Improve ventilation
2.	Insulator cracked		<ul style="list-style-type: none"> • Remove insulator

4.7.8 Trouble Shooting for Cables

Sl no.	Cause	Trouble	Remedy
1.	Overheating	<ul style="list-style-type: none"> • Cable size inadequate • Loose connection 	<ul style="list-style-type: none"> • Provide a cable in parallel to existing cable or higher size cable • Increase clearance between cable
2.	Insulator burning at	<ul style="list-style-type: none"> • Improper termination in lug termination 	<ul style="list-style-type: none"> • Check size of lug and whether properly crimped or correct • Check whether only few strands of cables are inserted in lug. Insert all strands using a new or higher size lug if necessary.

4.7.9 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	<p>a) External Noise: a loose fixing bolt/nut of the transformer</p> <p>b) Noise originating small transformer, due to the transformer. In case of old transformer possibly due to windings becoming slightly slack</p>	<p>a) Tighten the fixing bolts/nuts and such other loose metallic parts</p> <p>b) In the case of small transformer such facilities are available open the transformer and take up any slackness by pacing shim of insulated boards. In the case of big transformer it will be necessary to contact the manufacturer</p>
2.	High temperature	The temperature rise of the transformer during 10-24 hrs operations is observed. The input current, oil temperature are noted down at intervals of half an hour and tabulated	<p>a) transformer is overloaded</p> <p>b) transformer room is not properly ventilated</p> <p>c) Dielectric strength of transformer oil low</p>	<p>a) reduce the load to the rated load</p> <p>b) Improve the ventilation of transformer room to achieve effective air cooling</p> <p>c) Filter transformer oil and improve dielectric strength to 40 kV minimum</p>

		d) certain turns in windings are short circuited	d) major repairs are necessary and should be taken up in consultation with an experienced electrical engineer and transformer repairer.
	The transformer becomes hot in a relatively shorter 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	The transformer has major defect	Take action for major repairs in consultation with an experienced electrical engineer and transformer repairer
	Abnormal heating of one terminal	Poor termination either inside or outside the transformer.	a) External contacts should be checked up and put in order especially in the aluminium bus bars. b) If heating persists, action for major repairs should be taken up in consultation with an experienced electrical engineer
3.	Tripping of circuit breaker or blowing of fuses	a) short circuit in the windings b) damage in the insulation of the winding or of one terminal	action for major repairs should be taken up in consultation with an experienced electrical engineer
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	a) Locate the leakage, switch off the transformer leakage socket and weld the transformer tank or replace the packing b) Fill with dry oil till the oil level appears on the oil level indicator. All terminals should be properly cleaned before switching on.

- | | | | |
|----|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | | b) Fill with dry oil till the oil level appears on the oil level indicator. All terminals should be properly cleaned before switching on. |
| 5. | Frequent change of silicagel colour | a) Breather leakage
b) Breather oil level low.
c) Absorption of moisture. | a) Replace packing.
b) Check oil seal. Top up oil level.
c) Moisture to be removed completely. |
| 6. | Oil leak at joints/ bushing/drain valve | a) Defective packing.
b) Loose tightening
c) Uneven surface
d) Bushing cracked
e) Drain, valve not fully tight. | a) Replace packing.
b) Tighten properly
c) Check and correct it.
d) Replace bushing along with washer.
e) Tighten valve and plug. |
| 7. | Low insulation resistance | a) Moisture absorption by winding.

b) Contaminated oil
c) Presence of sludge | 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.
b) Replace with proper oil.
c) Filter or replace the oil. |
| 8. | Water inside tank | a) Defects of joints
b) Moisture condensation. | a) Rectify the defect
b) Drain water and dry the moistures from winding. |

		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.

4.7.10 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.

Sl.no	Trouble	Cause	Remedy
1	Readings of specific gravity and voltage very erratic even after equalising charge for at least 48 hrs.	• Battery life is over.	<ul style="list-style-type: none"> • Check the following <ul style="list-style-type: none"> * Age of battery. * Capacity. * Appearance of plates. * Depth of sediments below plates.
2	Several cells showing low charge voltage at the end of extended charge.	• Internal short circuit.	Open cells and examine for damage or displaced separators, lead particles between plates or buckled plates
3	Battery overheats	Poor contacts or badly welded joints	• Clean and tighten all bolted connections, reweld doubtful welded joints.
4	Battery damp and dirty, wood trays deteriorated or metal work corroded.	poor maintenance, over topping, or lid sealing compound cracked.	• Keep battery dry and clean. Do not overtop when adding water. Clear away all traces of acid and old sealing compound from cell lids.
5	Hydrometer test (at 80°F) show less than 1.200 specific gravity		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.

4.7.11 Trouble Shooting for Air Compressor

Sl.no	Trouble	Cause	Remedy
1	Compressor does not start	<ul style="list-style-type: none"> • Dirty contacts 	Clean the contacts on all switches and controls.
		Loose electrical connections or faulty wiring.	Tighten connections. Check wiring and rewire if necessary.
2	Compressor noisy	<ul style="list-style-type: none"> • Loose or misaligned coupling. 	<ul style="list-style-type: none"> • Check alignment & tightness.
		<ul style="list-style-type: none"> • Insufficient clearance between piston and valve plate. 	<ul style="list-style-type: none"> • Replace worn parts.
		<ul style="list-style-type: none"> • Motor or compressor bearing worn out. 	<ul style="list-style-type: none"> • Replace bearing.
		<ul style="list-style-type: none"> • Loose or misaligned belts. 	<ul style="list-style-type: none"> • Check alignment & tension. Belt slack should be at the top.
		<ul style="list-style-type: none"> • Loose foundation bolts or hold down bolts. 	<ul style="list-style-type: none"> • Tighten bolts.
		<ul style="list-style-type: none"> • Improper support or isolation of piping 	<ul style="list-style-type: none"> • Provide sufficient right angle bends in piping to absorb vibration & support firmly with suitable hangers.
3	Pipe rattle	<ul style="list-style-type: none"> • Inadequately supported or loose pipe connections. 	<ul style="list-style-type: none"> • Support pipes or check pipe connections.
		<ul style="list-style-type: none"> • No muffler in discharge line or muffler improperly located 	<ul style="list-style-type: none"> • Install or move muffler closer to compressor.
4	Compressor will not load.	<ul style="list-style-type: none"> • Low oil pressure 	<ul style="list-style-type: none"> • See item 5.
		<ul style="list-style-type: none"> • Capacity control valve struck open. 	<ul style="list-style-type: none"> • Repair or replace.
		<ul style="list-style-type: none"> • Unloader element struck 	<ul style="list-style-type: none"> • Repair
5	Oil pressure lower than normal Or no oil pressure.	<ul style="list-style-type: none"> • Low oil charge 	<ul style="list-style-type: none"> • Add oil
		<ul style="list-style-type: none"> • Faulty oil gauge 	<ul style="list-style-type: none"> • Check and replace
		<ul style="list-style-type: none"> • Defective oil pressure regulator. 	<ul style="list-style-type: none"> • Repair or replace.
		<ul style="list-style-type: none"> • Clogged oil suction strainer. 	<ul style="list-style-type: none"> • Clean
		<ul style="list-style-type: none"> • Broken or worn oil pump. 	<ul style="list-style-type: none"> • Replace pump assembly.
		<ul style="list-style-type: none"> • Worn compressor bearings. 	<ul style="list-style-type: none"> • Replace

4.8 Safety Aspects

4.8.1 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, unwallied 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.

4.8.2 Safety Procedures and 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.

4.8.2.1 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.

4.8.2.2 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.

4.8.2.3 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.

4.8.3 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.

4.8.3.1 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 detailed 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. 4.2. 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 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. 4.3. 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.4.2. 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 4.2 : Artificial Respiration



Fig 4.3 : 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.4.3. Appropriate position of laying in such case is on back as shown Fig.4.4 with a pillow or rolled cloth, mat, bed sheet under his shoulders. The clothes of the patient shall be immediately loosened before starting the process of artificial respiration.

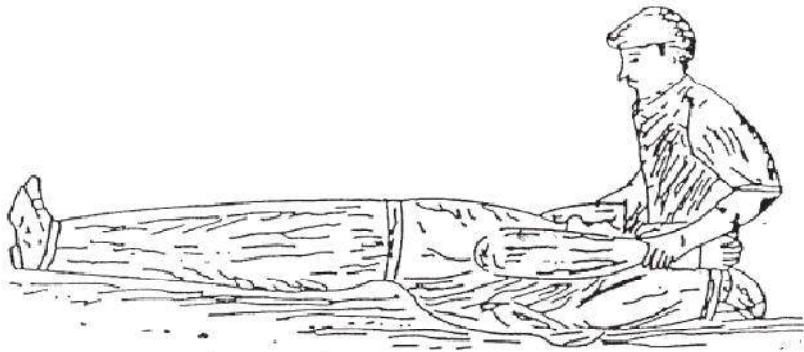


Fig 4.4 : Artificial Respiration

- 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. 4.5. After 2 seconds repeat the process again.

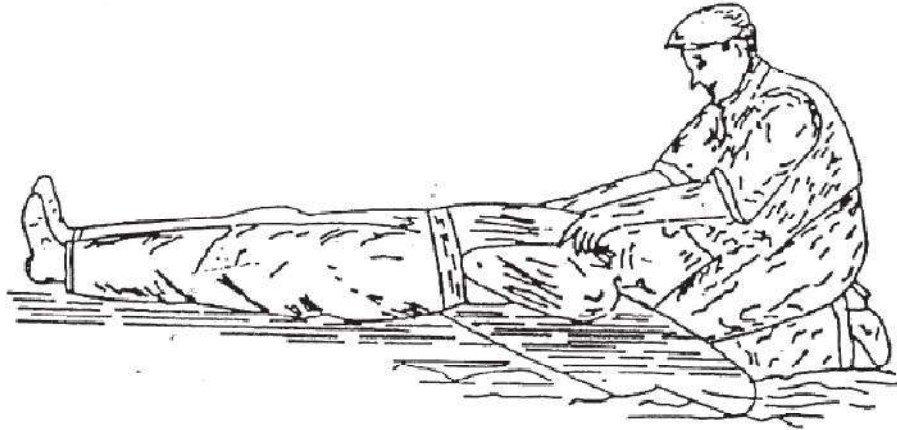


Fig 4.5 : Artificial Respiration

- 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.

4.9 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 year's interval.
- The colour 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.

LOG BOOK

TIME	Pump No						Flow Meter Reading		Air Vessel Level	System Voltage (V)	Line Pressure (kg/sqcm)	Reservoir Water Level (ft)	Battery Charger DC Voltage	Battery Charger DC Current	REMARKS
	Total Running Hours			Pumping Delivery Pressure (kg/sqcm)	Pumping Bearing Temperature (Deg)	Motor Bearing Temperature (Deg)	Motor Winding Temperature (Deg)	Inlet Flow							
	Ammeter Reading (A)		Frequency (Hz)												
	R	Y		B											
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CHAPTER 5

OPERATION AND MAINTENANCE OF 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 includes 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 mainly comprise of Coagulation and Flocculation has been discussed under Rapid Sand Filters section 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 Drinking water quality requirements

Drinking water shall comply with the requirements as given in Tables 5.1 and 5.2 as detailed below:

Table 5.1

RECOMMENDED GUIDELINES FOR PHYSICAL AND CHEMICAL PARAMETERS			
Sl.No.	Characteristics	*Acceptable	** Cause for Rejection
1	Turbidity (NTU)	1	10
2	Colour (Units on Platinum cobalt scale)	5	25

3	Taste and Odour	Unobjectionable	Objectionable
4	pH	7.0 to 8.5	<6.5 or > 9.2
5	Total Dissolved Solids (mg/l)	500	2000
6	Total Hardness (as CaCO ₃)(mg/l)	200	600
7	Chlorides (as Cl) (mg/l)	200	1000
8	Sulphates (as SO ₄) (mg/l)	200	400
9	Fluorides (as F) (mg/l)	1	1.5
10	Nitrates (as NO ₃) (mg/l)	45	45
11	Calcium (as Ca) (mg/l)	75	200
12	Magnesium (as Mg) (mg/l)	≤ 30	150
If there are 250 mg/l of sulphates, Mg content can be increased to a maximum of 125 mg/l with the reduction of sulphates at the rate of 1 unit per every 2.5 units of sulphates			
13	Iron (as Fe) (mg/l)	0.1	1
14	Manganese (as Mn) (mg/l)	0.05	0.5
15	Copper (as Cu) (mg/l)	0.05	1.5
16	Aluminium (as Al) (mg/l)	0.03	0.2
17	Alkalinity (mg/l)	200	600
18	Residual Chlorine (mg/l)	0.2	>1.0
19	Zinc (as Zn) (mg/l)	5	15
20	Phenolic compounds (as Phenol) (mg/l)	0.001	0.002
21	Anionic detergents (mg/l) (as MBAS)	0.2	1
22	Mineral Oil (mg/l)	0.01	0.03

TOXIC MATERIALS			
23	Arsenic (as As) (mg/l)	0.01	0.05
24	Cadmium (as Cd) (mg/l)	0.01	0.01
25	Chromium (as hexavalent Cr) (mg/l)	0.05	0.05
26	Cyanides (as CN) (mg/l)	0.05	0.05
27	Lead (as Pb) (mg/l)	0.05	0.05
28	Selenium (as Se) (mg/l)	0.01	0.01
29	Mercury (total as Hg) (mg/l)	0.001	0.001
30	Polynuclear aromatic hydrocarbons (PAH) ($\mu\text{g/l}$)	0.2	0.2
31	Pesticides (total, mg/l)	Absent	Refer to WHO guidelines for drinking water quality Vol 1-1993
RADIO ACTIVITY+			
32	Gross Alpha activity (Bq/L)	0.1	0.1
33	Gross Beta activity (Bq/l)	1	1

NOTES

*The figures indicated under the column 'Acceptable' are the limits upto which water is generally acceptable to the consumers.

**Figures in excess of those mentioned under 'Acceptable' render the water not acceptable, but still may be tolerated in the absence of an alternative and better source but upto the limits indicated under column "Cause for Rejection" above which the sources will have to be rejected.

+ It is possible that some mine and spring waters may exceed these radio activity limits and in such cases it is necessary to analyze the individual radio-nuclides in order to assess the acceptability or otherwise for public consumption.

The analysis for the above parameters can be referred from IS 10500-2012

Table 5.2

BACTERIOLOGICAL QUALITY OF DRINKING WATER^a	
Organism	Guideline value
All water intended for drinking	
E coli or thermotolerant coliform bacteria ^{b,c}	Must not be detectable in any 100ml sample
Treated water entering the distribution system	
E coli or thermotolerant coliform bacteria ^b	Must not be detectable in any 100ml sample
Total coliform bacteria	Must not be detectable in any 100ml sample
Treated water in the distribution system	
E coli or thermotolerant coliform bacteria ^b	Must not be detectable in any 100ml sample
Total coliform bacteria	Must not be detectable in any 100ml sample. In case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12 month period.
Source: WHO guidelines for Drinking Water Quality Vol 1-1993	
^a Immediate investigative action must be taken if either <i>E.coli</i> or total coliform bacteria are detected. The minimum action in the case of total coliform bacteria is repeat sampling; if these bacteria are detected in the repeat sample, the cause must be determined by immediate further investigation.	
^b Although <i>E.coli</i> is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory test must be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies, particularly in tropical areas where many bacteria of no sanitary significance occur in almost all untreated supplies.	
^c It is recognized that, in the great majority of rural water supplies in developing countries, faecal contamination is widespread. Under these conditions, the national surveillance agency should set medium term targets for progressive improvement of water supplies, as recommended in volume 3 of W.H.O. <i>guidelines for drinking-water quality 1993</i> .	

5.3 Types of Filtration Plants

The types of Filtration Plants are as follows:

- A) Slow Sand Filter Plant
- B) Rapid Sand Filter Plant
- C) Other types of Filter Plants, which are not used commonly, are:
 - 1) Pressure filters-used as small treatment plant in Industries.

2) 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 which can entrap such undesirable material prior to the storage structures of the treatment units.

Figure shows typical flow pattern of a conventional treatment plant

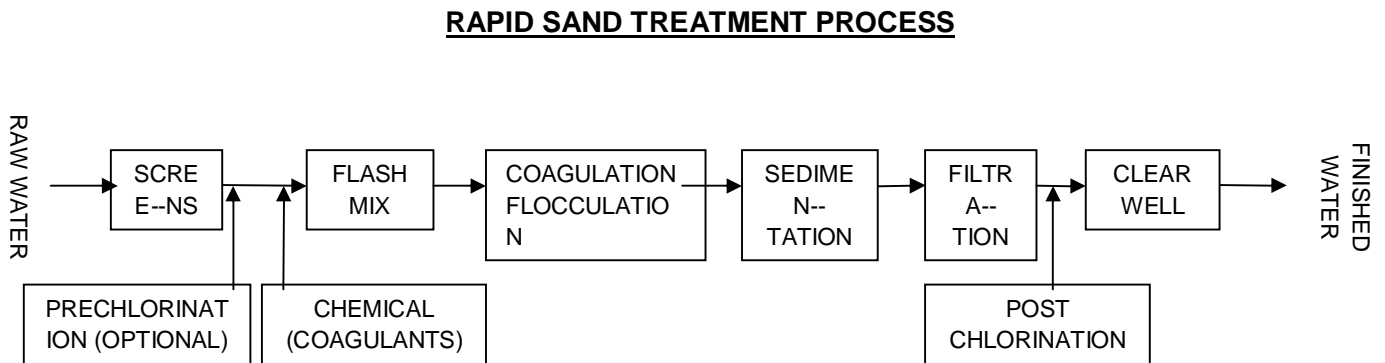


Fig 5.1 : Conventional Filtration Process

5.4 Rapid Sand Filtration Plants

The pre-treatment units which form essential parts of a Rapid sand filtration unit and include:

1. Aeration
2. Pre-sedimentation (optional),
3. Coagulation and flocculation with rapid mixing facilities and
4. Sedimentation
5. Filtration unit

5.4.1 Aeration /Pre-sedimentation

5.4.1.1 Aeration

Aeration is a unit process in which air and water are brought into intimate contact. Aeration is used for the following purposes:

- To add oxygen to raw water for imparting freshness.
- Oxidation of iron and manganese of raw water
- Reduction of Carbon dioxide Ammonia and hydrogen Sulphide and other volatile substances causing taste and odour.
- Effective method of bacteria control.

There are two main types of aerators depending upon the mechanics of aeration:

- a) Those forming drops or thin sheets of water exposed to the atmosphere i.e. water is exposed to come in contact with the ambient air; and
- b) Those forming small bubbles of air which rise in the water i.e. air is brought in contact with the water, by providing external source of air.

Spray, water-fall or multiple tray, cascade and mechanical aerators can be considered under type (a), while diffusion aerators fall under type (b).

The most common in use is cascade aerator, where water is allowed to flow downwards after spreading over inclined surface in thin sheets and the turbulence is secured by allowing the water to pass through a series of steps or baffles. The number of steps is usually 4 to 6. Care should be taken such that there is no spilling of water away from the structure.

5.4.1.2 Pre-sedimentation

Sedimentation without coagulation and flocculation as part of the pretreatment process is known as pre-sedimentation and removal of coarse suspended matter (such as grit) depends merely on gravity. This type of sedimentation typically takes place in a reservoir, grit basin, debris dam, or sand trap at the beginning of the treatment process.

While sedimentation with coagulation/flocculation is meant to remove most of the suspended particles from the water before the water reaches to the filters, pre-sedimentation removes most of the sediment from the water at the pre-treatment stage and it reduces the load on the coagulation/flocculation basin and on the sedimentation chamber, as well as reducing the volume of coagulant chemicals required to treat the water.

5.4.2 Coagulation and Flocculation

5.4.2.1 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.

Coagulation is the process by which particles become destabilized and begin to clump together. It is an essential component in the water treatment operation.

Flocculation is the second stage of the formation of settleable particles (or flocs) from destabilized colloidal sized particles and is achieved by gentle and prolonged mixing.

Table 5.3 : CHEMICAL COAGULANTS

Name	Formula	Coagulant Primary/Aid
Non Ferric Alum	$Al_2(SO_4)_3 \cdot 24H_2O$	Primary
Poly Aluminium Chloride	$\{Al_2(OH)_2Cl_{3.3}\}_{15}$	Primary
Ferric Chloride	$FeCl_3 \cdot 6H_2O$	Primary
Calcium Hydroxide	$Ca(OH)_2$	Primary/Aid
Calcium Oxide	CaO	Primary/Aid

The most commonly used coagulant is non 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.

5.4.2.2 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 under dosing 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.

5.4.2.3 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 5.4.

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

Table 5.4 : Jar test data sheet

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

5.4.2.4 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 (e.g. Convergent and Divergent flow, Hydraulic Jump)
- 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.

5.4.2.5 Chemicals Handling and Feeding

The chemicals are introduced into the water for the purposes of coagulation and flocculation, disinfection, softening, corrosion control, algae control and fluoridation, in general, chemicals are added as solutions or dilute suspensions. As the treatment is a continuous process, the flow of chemicals is regulated and measured continuously through chemical feeders which can be either solution feed type or the dry feed type. The installation of chemical feeders obviously promotes the uniform distribution of chemicals and eliminates wastage, livery chemical feeder should be arranged and positioned in such a way that checking of dosing rate can be made at regular intervals to verify the discharge rate.

5.4.2.6 Solution Feed

Preparation of the solution of the chemical in water in desired strength is the first step and is carried out in the solution tanks. This solution is fed to the raw water through controlled feeders which are of gravity or pressure type. The selection of the proper type of feeders and the point of application are important. For example, when mixing is done in a channel, it should be at a number of points in the cross-section of maximum turbulence. Also as different chemicals are to be fed at different points, the location at which the chemicals are fed is important to derive maximum efficiency.

5.4.2.7 Solution Tanks

There should be at least two tanks for each chemical feed. The capacity of each tank should generally be such as to hold 8 hours requirement at the maximum demand of chemical at the design flow. Dissolving trays or boxes and also adequate facilities for draining the solution tanks should be provided.

The solution tank may be constructed either of masonry, plain or reinforced cement concrete. Coating with bituminous paint may be adequate for alum tanks while for tanks for handling other corrosive chemicals, suitable lining of rubber, PVC or Epoxy resin may be necessary to resist corrosion.

The chemical solution tanks should be located in or as near the chemical storage godown as possible to avoid unnecessary lifting and handling of chemicals. These tanks should preferably be located at a suitable elevation, to facilitate gravity feed of the chemical solution.

5.4.2.8 Dissolving Trays or Boxes

The chemicals after being carefully weighed, are placed into the dissolving trays which vary in size to suit the capacity of the treatment plant. The trays or boxes may be constructed of wood, cast iron or cement or cement concrete with slots or perforations both at the sides and at the bottom, These may be placed either inside or just above the solution tanks.

For small tanks, a pipe perforated with small holes to provide a spray of water to help in dissolving chemicals, may be placed above these trays. For plants of medium and large size, dissolving boxes should preferably be constructed of concrete with a pipe manifold having holes either at bottom or at sides for dissolving chemicals.

5.4.2.9 Preparation of Solutions

It is essential to ensure that all the chemicals are dissolved before the solution is put into operation and the homogeneity of the prepared chemical solution is maintained. This can be achieved by proper mixing either by compressed air or by mechanical agitation.

A knowledge of the solubility characteristics of the chemical as well as the solution strength that are used in normal practice, will facilitate the choice of feed equipment. The solution strength of alum which is the most widely used coagulant shall not be more than 5% for manual operations and 10% for other operations with efficient mixing. It may be desirable to dilute down to 1% prior to addition.

The chemical solution is conveyed from the solution tanks to the point of application by means of chemical feed lines. These should be as short and straight as possible.

Liquid Alum

Liquid alum contains 5.8 to 8.5% water soluble alumina as against 17% for crystalline alum, but is lower priced. Since its use also avoids construction of solution tanks, it may be economical in large plants especially if the waterworks are within a reasonable trucking distance of alum producing works. Acid-proof equipment such as rubber-lined or stainless steel tanks and piping is necessary for transport, handling and storage.

5.4.2.10 Solution Feed Devices

Solution feed devices are used to regulate the doses of chemical fed into water. The rate of flow of the chemical solution of known strength prepared in the solution tank is measured by means of either an orifice rotameter, positive displacement pump or by weirs. The solution feed equipment should be simple in operation and corrosion resistant.

The constant head orifice is the most common device used for measuring the rate of flow of solution. It is usually contained in a unit consisting of corrosion resistant, constant level box with a float valve and an orifice. The orifice can be of either variable size or constant size, the

adjustment in the latter being made by using the required size to give the desired rate of flow. The unit should also be capable of adjustment to allow setting for various depths of solution in the box.

In large systems, automatic control of chemical feed could be practiced which assures that the quantity of chemical measured is not prone to human errors. The principle must be based upon the measurement of some attributes of the water such as the rate of flow, pH, colour, conductivity, chlorine residual.

Since the flow of water can fluctuate, it is necessary to maintain the flow of chemical in a fixed proportion to the flow of water for which a proportional feed device is necessary. Measurement of the water can be done in a number of ways, the simplest: possibly being the tipping bucket or a pump with positive meter which provides a positive method of measurement, but is applicable to the smaller installations only. The more common measuring device is a weir, venturi tube or orifice plate.

The most satisfactory method of control is one that depends upon the matching of two factors, one of which is associated with the primary measuring unit (control) and the other with the flow of chemical. For example, a venturi tube will produce a differential pressure bearing known relationship to the flow of water through it. If it is desired to control the flow of a chemical solution, then some similar measurement associated with the flow of a chemical solution must be compared with the differential pressure and means provided for adjusting the flow of chemical so that the two factors so compared are mutually in equilibrium. Such a system is basically stable.

5.4.2.11 Solution Feeders

There are several types of solution feeders, some of which are discussed below:

(a) Pot Type chemical Feeders

The pot type chemical feeder is a simple type of equipment for feeding alum or alkali into water. The chemical, in large crystal or lump form, is charged into the feeding pot. A special orifice fitting, placed in the raw water line, contains an orifice plate which creates a pressure differential in pipes which connect the chemical pot into the orifice fitting,

This pressure differential causes a small stream of water to flow from the high pressure side of the orifice plate through a pipe and a regulating valve, into the bottom of the chemical feeding pot and this forms an equivalent stream of the chemical solution, formed in the pot, to flow out of the top of the pot into the raw water line on the low pressure side of the orifice plate.

Since the same pressure differential acts across the regulating valve as across the orifice, the flow through the regulating valve, at any setting, is a definite fraction of the flow through the

orifice. Consequently, the rates of flow of the small stream of chemical fed to the raw water are directly proportional to the rates of flow of the raw water. These find use in small plants because they do not permit a uniform feed rate and the feed rate cannot be also checked. Sediment tanks are usually employed with these feeding lines.

(b) Pressure Solution chemical Feeders

Pressure solution, chemical feeders are much more accurate than the pot type chemical feeders. In these a chemical solution of a definite strength is made by dissolving a weighed amount of chemical in a specified volume of water in the chemical solution tank. This batch of chemical solution, when, required, is charged into the displacement tank through the bottom. As the specific gravity of the chemical solution is higher than that of water, the water in the displacement tank is displaced upwardly to waste through a valve.

A sight glass at the side of the feed tank has in it a glass float, which is so constructed that it floats in the heavy chemical solution but sinks in water. This float indicates, at all times, the level of the chemical solution thus notifying the operator when recharging is necessary.

A special orifice fitting, placed in the raw water line, contains an orifice plate which creates a pressure differential in the pipes connecting the displacement feed tank to the orifice fitting. This pressure differential causes a small stream of water to flow from one side of the orifice plate. The greater part of this stream flows through a secondary orifice and the smaller through an adjustable needle valve into the top of the displacement feed tank, where it displaces downwardly an equivalent stream of the heavier chemical solution.

Since the same pressure differential acts across the primary orifice and across the needle valve, the flow through the needle valve at each setting is a constant fraction of the flow through the primary orifice. As the rates of flow of the chemical solution are directly proportional to the rates of flow of the raw water, this type of feed is applicable to water supplies of varying flow rates and pressure. Sediment tanks are usually employed with pressure solution chemical feeders to keep sediment out of the feeding line. In cases, where corrosive chemicals are handled, special pressure solution chemical feeders are employed.

(c) Gravity Orifice chemical feeders

The gravity orifice chemical feeder is limited in application to those cases where the flow rate of the water being treated is constant. The solution from the chemical solution tank flows by gravity, through a strainer and through a float valve, into the orifice box.

The float valve keeps the chemical solution in the orifice box always at the same level so that the adjustable orifice operates under constant head. By gravity, the chemical solution flows from the orifice box through the adjustable orifice to the point of application.

To stop and start the chemical and water simultaneously, a float switch may be used in the settling basin to operate a solenoid-operated valve on the orifice box discharge and an electrically controlled valve on the raw water line. Thus the flows of raw water and chemical solution are stopped whenever the level of the water in the basin has reached a certain height. When the level has fallen a certain distance, the float switch closes an electric circuit thus starting simultaneously the flows of raw water and chemical solution.

Instead of being connected to an electrically controlled valve in the raw water line, the float switch may be connected so as to start or stop a raw water pump simultaneously with the starting or stopping of the chemical feeder.

The amount of chemical solution fed to the raw water may be varied over a wide range by means of the adjustable orifice located in the orifice box.

Instead of the chemical solution flowing by gravity to the point of application, it may be discharged into a pump suction box from which it is pumped to the point of application.

(d) Reciprocating Pump chemical Feeders

This method of feeding chemical employs a motor-driven reciprocating chemical pump. The pump withdraws a chemical solution or suspension of suitable strength, from a tank and discharges the solution or suspension to the point of application under any desired pressure. The feeding pump may be designed to treat either a variable or a constant flow of water.

The chemicals to be fed are prepared in solution tanks. If the chemical to be fed is relatively insoluble, a high speed motor-driven agitator maintains uniform suspension throughout the full depth of the tank. If the chemical forms a clear solution, a dissolving basket is furnished and the mechanical agitator is omitted.

(i) Variable rate proportional feeders

If the rate of flow of water being treated varies, proportional feeding of chemicals is necessary. This is carried out by accurately measuring the amount of chemical fed by the pump. This pump is a proportioning and metering device which delivers a definite volume of chemical with each stroke. A water meter with an electrical contactor is placed in the raw water line. The contactor closes a circuit every time a given volume of water flows through the meter. The closing of the circuit energizes the motor of the reciprocating pump, which then operates to deliver a given volume of chemical until an electric time switch breaks the circuit, thereby stopping the pump. The cycle repeats itself approximately every thirty seconds, at maximum flow, with the pump operating for approximately twenty seconds after each contact. The amount of chemical fed is thus accurately proportioned to the flow of water regardless of variations in the rate of flow, because both the volume of water treated between meter contacts and the volume of chemical

added to treat the water are accurately measured. However this suffers from the disadvantage that, particularly when used with alum solutions, the water is subject to an overdose and no-dose sequence. It is better to have the chemical pump run continuously and to modulate the stroke of the pump either manually or with a mechanical device.

For a number of chemicals fed simultaneously, one meter control serves to operate any number of pumps.

(ii) Constant rate feeding for uniform flow

If the flow of water being treated is constant, the chemical pump operates continuously at the set dosage. When the flow of water ceases, the chemical pump is stopped automatically so as to shut off the flow of chemicals. When the flow of water begins again, the chemical feeding is automatically resumed.

5.4.2.12 Adjustment of feeding rates

Two methods are available for adjusting the rate of chemical feeding. Firstly, the length of the pump stroke can be changed to vary the rate of feeding of a given strength of solution over a wide range. Secondly, the strength of the chemical solution or suspension in the chemical tank can be changed when a new chemical charge is made up so as to provide a different chemical dosage for the same setting of the chemical pump.

The method of adjustment of chemical feeding rate varies with the type of proportioning pump used. The single feed pump varies the feeding rate by a simple screw adjustment, which changes the length of the plunger stroke. The duplex pump varies its feeding rate by screwing the adjusting coupling toward the liquid end of the pump to increase the capacity or away from the end to decrease the capacity.

The reciprocating chemical pumps can be provided with ball check valves on both, suction and discharge, thus assuring maximum efficiency of displacement, non-clogging and self cleaning features, elimination of air binding and the minimizing of wire drawing of valve seats. The check valves are readily opened, to inspect the ball checks and seats, without disconnecting either suction or discharge piping.

5.4.2.13 Chemical Storage

The chemical store should be of damp proof construction, properly drained. Special precautions against flooding should also be taken.

For chemicals purchased in bags or cakes, storage by piling on the floor of the store room may be arranged. A height of stack not exceeding 2 m is recommended. Hygroscopic chemicals should be obtained in moisture-proof bags and stored in air-tight containers.

All plants, particularly small ones, should keep on hand at all times, a supply of chemicals sufficient to provide a safety factor. A storage of 3 months is advisable but this again depends upon the location of the plant as well as the source of supply, transport facilities and the arrangement made with the suppliers for the supply of chemicals,

In cases where the major storage is provided at a place away from the feed equipment, a week's storage space should be provided near the plant.

Dampness may cause severe caking even in chemicals such as aluminium sulphate which usually are free from such troubles. Quick lime gradually expands on prolonged storage and may even burst the containers if kept too long.

Chemicals such as powdered activated carbon which are likely to cause dust problems should preferably be stored in separate rooms.

Storage of acid materials near alkalis is undesirable as their contact generates considerable heat resulting in combustion. This is also true of oxidising chemicals such as chloride of lime mixed with activated carbon. Hence they should be isolated. It is advisable to store chlorine cylinders separately as gaseous chlorine in contact with activated carbon leads to severe fire hazards.

5.4.2.14 Handling Of Chemicals

Ordinarily a 50 kg container with cakes can be handled by a single person when aided by small hand carts. Heavy containers should be handled with the aid of mechanical contrivances such as trucks, monorail pulley, cranes and other special equipments.

Sufficient space with access should be provided for handling bulk storages allowing for negotiating of vehicles and cranes likely to be used.

5.4.2.15 Flocculation

5.4.2.15.1 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. Settling tanks should be capable of giving settled water having turbidity not exceeding 20 and preferably less than 10 NTU. Following points should be considered during the operation of the flocculation basins.

5.4.2.15.2 Clari-flocculator

The flocculators may be circular, square or rectangular. circular clari-flocculator partitioned with baffle walls are preferred. 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 flocs, which have already formed. If the floc is broken up nothing is accomplished and the filter gets overloaded.

5.4.2.15.3 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.

5.4.2.15.4 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 CPHEEO Manual of Water supply and Treatment (1999 edition).

5.4.2.16 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.

5.4.2.17 Coagulation – Flocculation Process Action

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

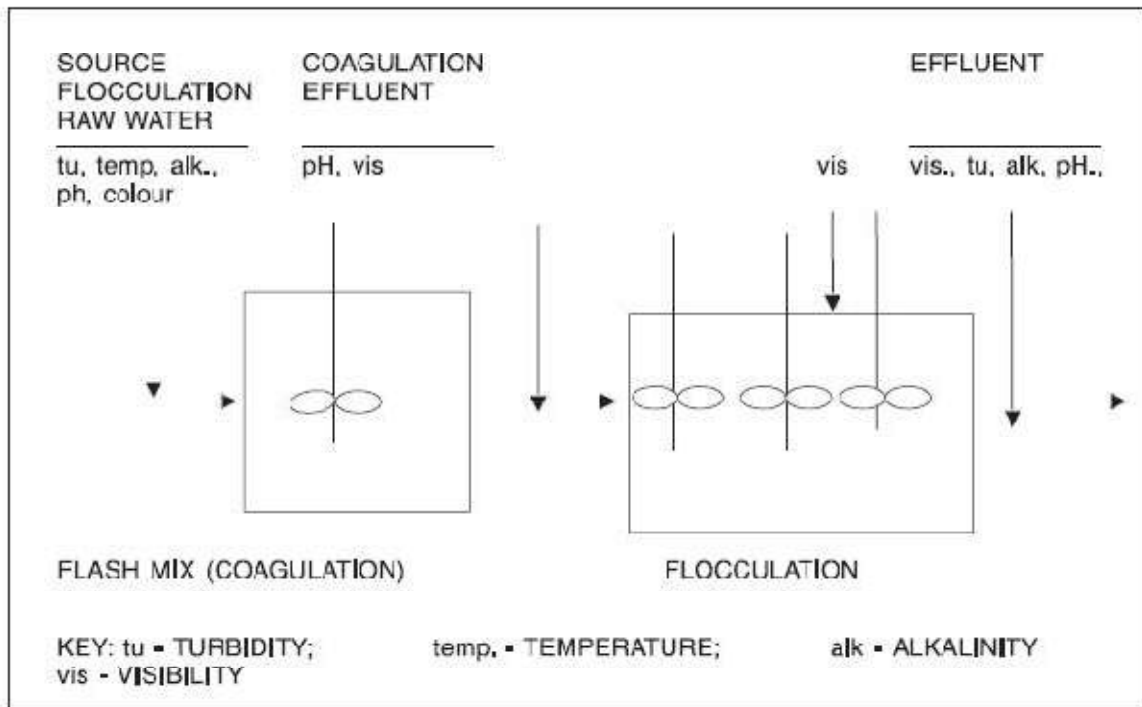


Fig 5.2 Coagulation – Flocculation Process Monitoring Guidelines

5.4.2.18 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 5.5 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.

5.4.2.19 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 5.5 COAGULATION – FLOCCULATION PROCESS TROUBLESHOOTING

Source Water Quality Changes	Operator Actions	Possible Process Changes
Turbidity Temperature	<ol style="list-style-type: none"> 1. Perform necessary analyses to determine extent of change. 2. Evaluate overall process performance. 3. Perform jar tests. 4. Make appropriate process changes (see right-hand column-Possible Process Changes). 5. Increase frequency of process monitoring. 	<ol style="list-style-type: none"> 1. Adjust coagulant dosage. 2. Adjust flash mixer/flocculator mixing intensity. 3. Add coagulant aid or filter aid. 4. Adjust alkalinity or pH. 5. Change Coagulant(s)
Coagulation Process Effluent Quality Changes	Operator Actions	Possible Process Changes
Turbidity Alkalinity pH	<ol style="list-style-type: none"> 1. Evaluate source water quality. 2. Perform jar tests. 3. Verify process performance: <ol style="list-style-type: none"> (a) Coagulant feed rate(s), (b) Flash mixer operation. 4. Make appropriate process changes. 	<ol style="list-style-type: none"> 1. Adjust coagulant dosage. 2. Adjust flash mixer intensity (if possible). 3. Adjust alkalinity or pH. 4. Change Coagulant(s).

Flocculation Basin Floc Quality Changes	Operator Actions	Possible Process Changes
Floc formation	<ol style="list-style-type: none"> 1. Observe floc condition in basin: <ol style="list-style-type: none"> (a) Dispersion, (b) Size, and (c) Floc strength (breakup). 2. Evaluate overall process performance. 3. Perform jar tests <ol style="list-style-type: none"> (a) Evaluate floc size, settling rate and strength. (b) Evaluate quality of supernatant; clarity (turbidity), pH, and color. 4. Make appropriate process changes. 	<ol style="list-style-type: none"> 1. Adjust coagulant dosage. 2. Adjust flash mixer/ flocculator mixing intensity. 3. Add coagulant aid. 4. Adjust alkalinity or pH. 5. Change Coagulant(s).

5.4.2.20 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).

5.4.2.21 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 manufacturer's 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.)
8. Close basin Isolation gates or install stop-logs.

9. 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.

5.4.2.22 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.

5.4.2.23 Water Sampling

Automatic sampling pumps have to be provided at the following locations to pump the water to laboratory for evaluating the physical, chemical, Bacteriological and Biological parameters.

- (a) Raw water at the inlet works.
- (b) Clarified water at filter inlet.
- (c) Clear water at filter outlet/clear water sump inlet

For conducting Bacteriological and Biological tests samples have to be collected at the respective locations physically.

5.4.3 Sedimentation

5.4.3.1 Sedimentation Basin

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 CPHEEO Manual on "Water Supply and Treatment" published by Ministry of Urban Development. (1999 edition).

5.4.3.2 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).

5.4.3.3 Sludge Handling

(a) Sludge characteristics

Water treatment sludge are typically alum sludge, 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 pumped operationally, this must be considered when establishing the frequency of the operation of sludge removal equipment.

(b) Sludge Removal Systems

Sludge is normally removed under hydrostatic pressure through pipes. The size of the pipe will depend upon the flow and the quantity of suspended matter. It is advisable to provide telescopic sludge discharge arrangement for easy operation and for minimising the wastage of water. For non-mechanised units, pipe diameters of 200 mm or more are recommended. Pipe diameters of 100 to 200 mm are preferred for mechanised units with continuous removal of sludge with hydrostatic head. In circular tanks, where mechanical scrapers are provided, the floor slopes should not be flatter than 1 in 12 to ensure continuous and proper collection of sludge

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 re-suspension 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).

(c) Desludging Control and Plant

The desludging system and control shall be located in the central control house as appropriate.

(l) Control

(i) The system shall be designed to carry out the following operations:

(a) intermittent desludging alone

(b) continuous desludging alone (Bleeding)

(c) intermittent and continuous desludging simultaneously.

(d) Pumping of sludge from sludge receiving tank into the sludge drying beds.

(ii) Facilities for sequential sludge discharge shall be provided. Manual override facilities both for initiation of a discharge sequence and for operation of individual valves shall be provided. Valves controlled automatically on an intermittent basis shall be electrically operated straight through type or eccentric plug type, and shall be arranged to be "fail safe" (e.g. on power, discharge valves shall close) and initiate an audible and visual alarm state at the Filter control Block . It shall be possible to open the valve manually by using a lever or similar, under fail-safe conditions. Each electrically valve shall be provided with a manually operated guard valve and a manual bypass facility.

(iii) Continuous desludging of clarifiers shall be by adjustable bellmouth devices with cast iron bodies and bronze guides. The devices shall be provided with operating headstocks and suitably located position indication scales and arranged to operate in parallel with the intermittent desludging valves.

(iv) During the periods of temporary shutdown, it is required that sludge scraping and sludge evacuation equipment shall continue to run until all heavy solids have been removed from the system which could otherwise compact during the shutdown period and cause difficulties on start up.

(II) Hydraulic design

The total hydraulic design capacity of the sludge withdrawal and discharge system shall not be less than 2.5% by volume of the Max. Water Flow.

(III) Clearing of Blockages

(i) Compressed air and pressure water shall be used to facilitate purging of sludge pipes and pockets in the event of blockages.

(ii) Compressed air/ flushing water connection of at least 25 mm diameter shall be provided upstream of each sludge pocket isolating and guard valves on the pneumatically operated sludge discharge valve(s).

d) Sludge Disposal

Disposal of waste from the water treatment plants has become increasingly important with the availability of technology and the need for protection of the environment. Treatment of waste solid adds to the cost of construction and operation of treatment plants.

Waste from the Water treatment plants comprise of:

- i) Sludge from sedimentation of particulate matter in raw water, flocculated and precipitated material resulting from chemical coagulation, or residuals of excess chemical dosages, plankton etc.
- ii) Waste from rinsing backwashing of filter media containing debris, chemical precipitates, straining of organic debris and plankton and residual of excess chemical dosages etc.

e) Disposal Method

In continuous sludge removal, the feasibility of discharging of water treatment plant sludge to existing sewer nearby should be considered. The sludge from all the clari-flocculators shall be collected in sludge receiving tank and pumped out into the sludge drying beds and effluent thereon to the nearby drainage system with environmental acceptance or it may be recirculated to inlet channel. The sludge from clarification units using iron and aluminum coagulant can be dewatered by vacuum filtration. However the method of waste disposal shall conform to the pollution control norms.

5.4.3.4 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. If the turbidity is up to 1 NTU clariflocculator may be bypassed. 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.

5.4.3.5 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.

5.4.3.6 Process Action

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.

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 5.6 and Table 5.7 gives a summary of sedimentation process problems and remedial measures.

5.4.3.7 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 5.6 SUMMARY OF ROUTINE SEDIMENTATION PROCESS ACTIONS

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

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

Table 5.7 SEDIMENTATION PROCESS TROUBLESHOOTING

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

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

5.4.3.8 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.

5.4.3.9 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 of specific equipment.

1. Flow meters and gauges.

2. Valves and valves with electrical actuators and with manual override.
3. Control Systems.
4. Water Quality monitors such as turbidity meters.
5. Sludge removal equipment.
6. Sludge pumps.
7. 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.

5.4.3.10 Safety Considerations

(a) Electrical Equipment

1. Avoid electric shock.
2. Avoid grounding yourself in water or on pipes.
3. Ground all electric tools.
4. 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.

(d) 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.

5.4.3.11 Corrosion Control

All metallic parts which are liable to corrosion must be protected.

5.4.3.12 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.

5.4.3.13 Other Categories Sedimentation

5.4.3.13.1 Tube Settlers

Settling efficiency of a basin is primarily dependent upon surface area, and is independent of depth. Attempts have been made to use this concept to achieve better efficiency and economy in space as well as cost. Wide shallow trays inserted within conventional basins with a view to increase the surface area have not met with success. However, very small diameter tubes having a large wetted perimeter relative to wetted area providing laminar flow conditions and low surface loading rate have shown good promise. Such tube settling devices provide excellent clarification with detention times of equal to or less than 10 minutes. Tube configurations can be horizontal or steeply inclined. In inclined tubes (about 60°) continuous gravity drainage of the settleable material can be achieved. At angles greater than 40° the units lose efficiency rapidly whereas with angles less than 60°, sludge will not slide down the floors. Under such situations, hosing down the sediments may have to be resorted to. With horizontal tubes (normally inclined at 5°) auxiliary scouring of settled solid is necessary. While tube-settlers have been used for improving the performance of existing basins, they have also been successfully used in a number of installations as a sole settling unit. It has been found that if one-fifth of the outlet end of a basin is covered with tubes or plate settlers, the effective surface loading on the tank is nearly halved or the flow through the basin can be nearly doubled without impairment of effluent quality.

The tubes may be square, circular, hexagonal, diamond shaped, triangular, rectangular or chevron shaped. A widely used material for their construction is thin plastic sheet (1.5 mm) black in colour, though plastic and asbestos cement pipes have also been used. There are number of proprietor devices such as Lemella clarifier.

5.4.3.13.2 Lamella Settlers

Properly designed and constructed Lamella plate settlers require minimal operator attention.

However, provisions for access and the maintenance should be considered.

i. Access

Lamella plate settlers basically require little maintenance. Access walk ways over the basin area if not provided already needs to be provided during maintenance depending upon the requirement of the maintaining agency.

Walkway either obstructs the installation and removal of plates directly beneath them, or if clear space is provided beneath the walkways, increase the size and construction cost of the sedimentation tank. However effluent channels of the Lamella plate system can be used to provide access to the plates for occasional inspection. Walkover the plate is possible using plywood sheets laid directly on the plates. Access to the sludge collection portion beneath the Lamella plates is also needed. It may be ensured that a door or suitable facility is provided in the basin wall between the flocculation basin and Lamella plates.

ii. Maintenance

Lamella plate equipment sedimentation basin does not require any adjustment by the operating staff. Normal maintenance is dependent on the materials selected for construction. Periodic disassembly of the plate pack system is recommended if painted carbon steel equipment is used. Stainless steel construction however minimizes routine maintenance. If process upset such as coagulant over dose or biological growth occurs, the basin may have to be drained and or plate cleaned with high pressure hose.

5.4.3.13.3 Record Keeping

Daily operations log of process performance and water quality characteristics should be maintained for the following records:

1. Inflow and outflow turbidity and inflow 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).

5.4.4 Filtration (Rapid Sand Filters)

5.4.4.1 Filter unit

Rapid Sand Filter comprises of bed of a sand serving as a single medium granular matrix supported on gravel overlying on under drainage system. The distinctive features of rapid sand filtration as compared to slow sand filtration include careful pretreatment of raw water to effectively flocculate the colloidal particles, use of higher filtration rates with more coarser & uniform filter media to utilize greater depths of filter media to trap influent solid without excessive head loss and also back washing of filter bed by reversing the flow direction to clean the entire depth of filter. Turbidity of 1.0 NTU or less, measured by an accurate instrument, is the best criterion of the stability of effluent of a freshly washed filter. The water standing on the bed at the close of wash should be clear with a turbidity preferably not exceeding 10 NTU.

5.4.4.2 Filter Sand

Filter sand is defined in terms of effective size and uniformity coefficient (D_{60}/D_{10}). Effective size is the sieve size in mm that permits 10% by weight to pass. Uniformity in size is specified by the uniformity coefficient which is the ratio between the sieve sizes that will pass 60% by weight and the effective size.

Check shape size and quantity of filter sand to the followings:

- Sand shall be of hard and resistant quartz or quartzite and free of clay, fine particles, soft grains and dirt of every description.
- Effective size shall be 0.4 to 0.7 mm
- Uniformity coefficient shall not be more than 1.7, nor less than 1.3
- Ignition loss should not exceed 0.7 per cent by weight.
- Soluble fraction in hydrochloric acid shall not exceed 5.0% by weight.
- Silica content should be not less than 90%
- Specific gravity shall be in the range between 2.55 to 2.65.
- Wearing loss shall not exceed 3%

(Refer IS: 8419 (Part 1) 1977 entitled Filtration Media Sand and Gravel for details)

5.4.4.3 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.

The coagulant that are being used for coagulation and flocculation can also be used as coagulants in filters in such circumstances where the clari-flocculator is by passed and the raw water requires a small quantity of coagulant for effective filtration.

Typical treatment processes are shown in figs. 5.3, 5.4, 5.5.

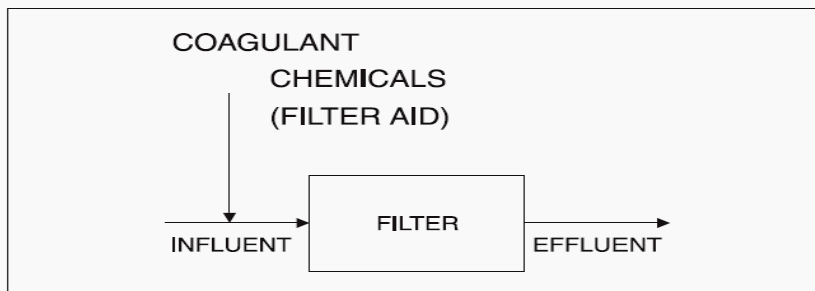


Fig 5.3 Inline Filtration

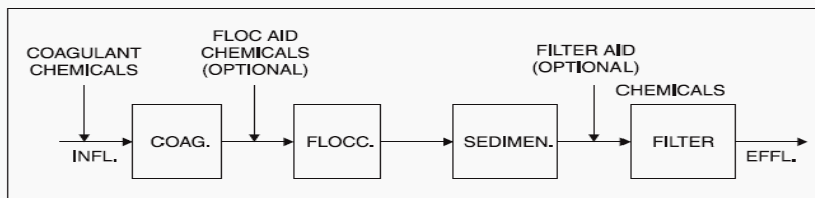


Fig 5.4 Conventional Filtration

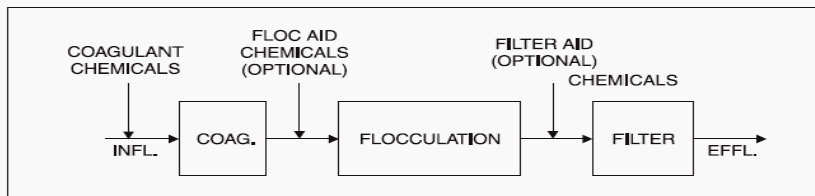


Fig 5.5 Direct Filtration

5.4.4.4 Operation

5.4.4.4.1 Filter Operation

A filter is usually operated until just before clogging or breakthrough occurs or a specified time period has passed (generally 24 hours). Before starting a filter it is backwashed at increasing rates until the sand bed has been stratified vertically by the wash water which carries various sizes of sand to different levels. The filter run of rapid gravity filters depends on several attendant factors. It is necessary to calculate the total loss of head in backwashing to arrive at the pump capacity and staging height of backwash water reservoir. The total loss of head includes loss due to expansion of sand, loss in orifices or under drainage system, loss in incoming pipe and height of wash water gutter with respect to under drainage system. The loss

of head immediately after washing should not exceed 0.3 m. The head loss builds as the filter accumulates dirt during its run. It is usual to allow a filter head loss of 1.8 to 2 m before cleaning such filters. Under no circumstances, a build-up of negative head within the filter media be allowed.

5.4.4.4.2 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.

5.4.4.4.3 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.

5.4.4.4.4 Operation Procedures

(a) The indicators of Normal Operating Conditions

The filter influent and effluent turbidities should be closely watched with a turbidity measuring device. 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 turbidity-meter.

(b) Process Actions

Follow the steps as indicated below:

1. Monitor process performance.
2. Evaluate turbidity and make appropriate process changes.
3. Check and adjust process equipment (change chemical feed rates).
4. Backwash filters.
5. Evaluate filter media condition (media loss, mud balls, cracking).
6. Visually inspect facilities.

(c) Important process activities and Precautions.

Monitoring process performance is a continuous activity. You should look for and attempt to anticipate any treatment process changes or other problems that might affect filtered water quality.

Measurement of head loss built up (Fig.5.6) in the filter media will give you a good indication of how well the solids removal process is performing. Tappings with isolating cocks shall be provided wherever necessary in the pipework to enable the head loss across the valve to be accurately measured. For each filter piezometer tubes shall be mounted on the lower gallery wall adjacent to the restrictor valve so that the head loss across the valve can be read locally. The piezometer tubes and scales shall be provided.

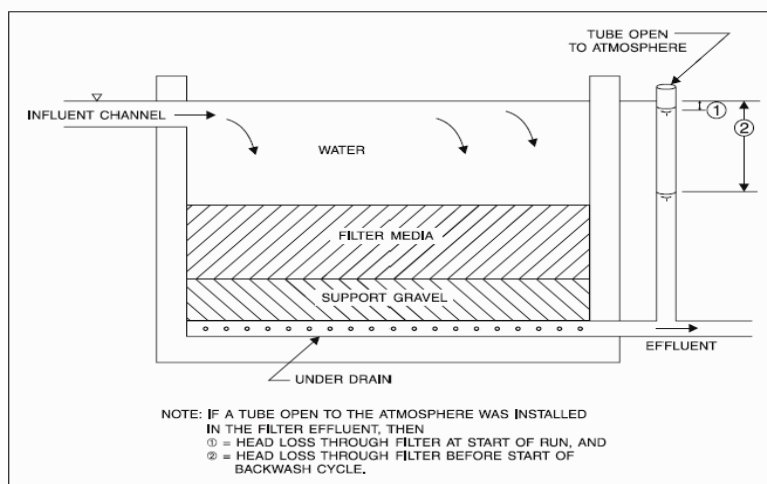


Fig 5.6 Measurement of Head Loss

One of the valves supplied shall be flow calibrated at the manufacturer's works or at an approved centre to produce the following data which will be required during commissioning and subsequent operation of the works;

- (i) Disc angle (no. of turns open)/head loss coefficient (k)
- (ii) A series of curves plotting
- (iii) Disc angle (no. of turns open)/head loss, for required flow ranges plotted at intervals of 1.0MLD.

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.

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.

Monitoring of filter turbidity on a continuous basis with an on-line turbidity-meter is highly recommended. This will provide you with continuous feedback on the performance of the filtration process. In most instances it is desirable to cut off (terminate) filter at a predetermined effluent turbidity level.

A control console for each filter shall be installed in the gallery.

These consoles shall be equipped such that the operator can initiate the backwashing operation manually. The control consoles for each filter shall include the following facilities and indications as a minimum:

- (a) start filter wash cycle - key operated push-button;
- (b) manual/automatic key operated selector switch;
- (c) filter water holding tank full - lamp;
- (d) open/close push-buttons for each actuated valve and penstock;
- (e) open/close indication for each valve and penstock - lamp;
- (f) filter ready for wash - lamp;
- (g) filter washing - lamp;
- (h) filter in service - lamp;
- (i) Filter out of service
- (j) wash water pump tripped - lamp;
- (k) air scour blower tripped - lamp.

Filter backwashing shall be inhibited to prevent two filters washing simultaneously and also to prevent wash initiation when the filtered water holding tank has insufficient water in storage.

Filter washing time cycles shall be manually adjusted to suit the monitored turbidity levels. All the appurtenances such as valves etc should have manual over ride in addition to pneumatic operation or electrical operated.

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.
- 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.
- 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.
- 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.
- 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.
- 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.

(d) Upwash rates

- Filters which have received a preliminary air scour: On completion of the air scour, washwater shall be admitted to the filters at an inflow rate between 400 - 600 lpm/m² for 5 minutes. The facility shall be provided for inflow rates up to 700 lpm/m² for a duration of 6 - 10 minutes and pipework and valves sized accordingly.
- Filters designed for combined air and water washing: At the commencement of the air scour, wash water shall be admitted to the filters at an inflow rate of 400-600 lpm/m² or at such higher rate as the Contractor shall recommend.
- Filters to be backwashed using high velocity water wash only i.e. without either preliminary air scour or a concurrent air scour will not be acceptable.

(e) Upwash water

Wash Water shall be drawn from the clear water reservoir and shall be delivered to the wash water tank constructed independently. Wash water tank of adequate capacity i.e. to wash, two beds at a time shall be provided. The contract includes all necessary wash water pumpsets, wash water pump room , necessary pipe work. Wash water shall be admitted to the filters at the rates offered by the Contractor. The actual rate of wash water flow shall be manually set on a controller.

A summary of routine filtration process action is given in Table 5.8. and Table 5.9 gives Filtration process trouble shooting problems.

5.4.4.5 Record Keeping

Maintain a daily operations log of process performance data and water quality characteristics.

Accurate recording of the following items should be maintained.

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-unit filter run volume).
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).

A typical daily operating record for a water treatment plant is shown in Table 5.10

Table 5.8 SUMMARY OF ROUTINE FILTRATION PROCESS ACTION

Monitor Process Performance and evaluate Water Quality Conditions	Location	Frequency	Possible Operator Actions
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.
Operate Filters and Backwash			
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 5.4.4.4)
Check Filter Media Condition			
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.
Make visual Observations of Backwash Operation			
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.
Check Filtration Process and Backwash Equipment Condition			
Noise, Vibration, Leakage, Overheating	Various	Once per 8-hour shift.	Correct minor problems.
Inspect Facilities			
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.

Table 5.9 FILTRATION PROCESS TROUBLESHOOTING

Source Water Quality Changes	Operator Actions	Possible Process Changes
Turbidity Temperature Alkalinity pH Colour Chlorine Demand	<ol style="list-style-type: none"> 1. Perform necessary analysis to determine extent of change. 2. Assess overall process performance 3. Perform Jar tests. 4. Make appropriate process changes. 5. Increase frequency of process monitoring. 6. Verify response to process changes (be sure to allow sufficient time for change to take effect) 7. Add lime or caustic soda if alkalinity is low. 	<ol style="list-style-type: none"> 1. Adjust coagulant dosage. 2. Adjust flash mixer /floculator mixing intensity. 3. Change frequency of sludge removal (increase or decrease). 4. Adjust backwash cycle (rate, duration). 5. Change filtration rate (add or delete filters). 6. Start filter aid feed. 7. Change coagulant.
Sedimentation Process Effluent Quality Changes		
Turbidity or floc carryover	<ol style="list-style-type: none"> 1. Assess overall process performance. 2. Perform Jar tests. 3. Make appropriate process changes. 	Same as source water quality changes.
Filtration Process Changes/Problem		
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"> 1. Assess overall process performance. 2. Perform Jar tests. 3. Make appropriate process changes. 	<ol style="list-style-type: none"> 1. Adjust coagulant dosage. 2. Adjust flash mixer/floculator mixing Media intensity. 3. Change frequency of sludge removal. 4. Adjust backwash cycle (rate, duration). 5. Manually remove mudballs. 6. Decrease filtration rate (add more filters) 7. Decrease or terminate filter aid. 8. Replenish lost media. 9. Clear under drain openings of media, corrosion or chemical deposits; check head loss. 10. Change coagulant
Filter Effluent Quality Changes		
Turbidity breakthrough Colour pH Chlorine	<ol style="list-style-type: none"> 1. Assess overall process performance. 2. Perform Jar tests. 3. Verify process performance: <ol style="list-style-type: none"> a) Coagulation and Flocculation b) Sedimentation process c) Filtration process. 4. Make appropriate process changes. 	<ol style="list-style-type: none"> 1. Adjust coagulant dosage. 2. Adjust flash mixer/floculator mixing intensity. 3. Change frequency of sludge removal. 4. Start filter aid feed. 5. Decrease filtration rate (add more filters). 6. Change chlorine dosage. 7. Change coagulant.

Table 5.10 FILTER DAILY OPERATING RECORD

No.	Time		Hours operated			Head loss		Kash		Physical condition of filters
	Start	Stop	Today	Previous	Total	Start	Stop	Min.	M.ltrs	
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				

5.4.4.6 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 back washing the filter is as follows: (Fig 5.7)

- Log Length of filter run since last backwash.
- Close filter influent valve (V1)
- Open drain valve (V4)
- Close filter effluent valve (V5)
- Slowly start air wash system (V6)
- Start surface wash system (open V2)
- Slowly start backwash system (open V3 and V6)
- Observe filter during washing process
- When wash water from filter becomes clear, Slowly turn off air wash system

- Slowly turn of backwash system (close V3)
- close surface wash system valve (V2)
- Close drain valve (V4)
- 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.

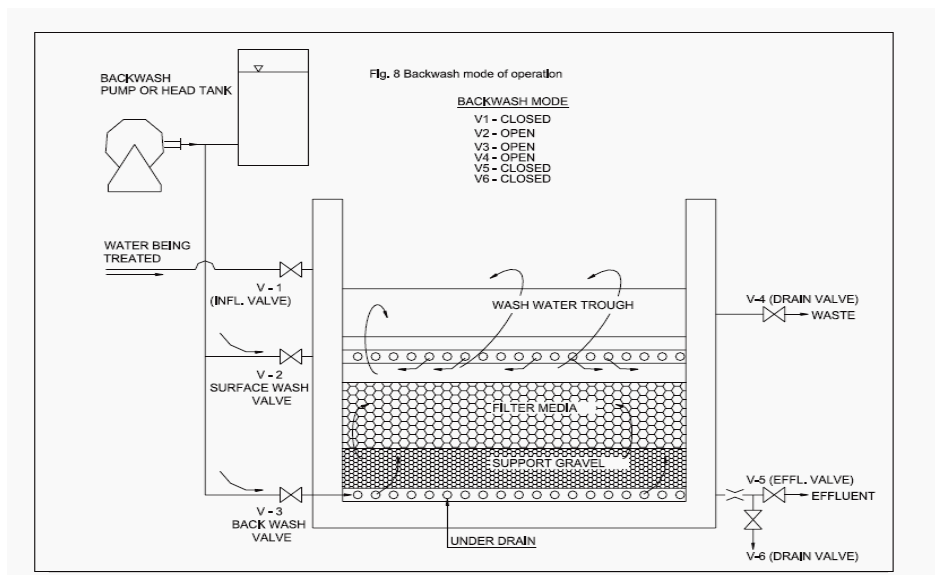


Fig 5.7 Backwash Operation

5.4.4.7 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. Air wash systems
4. Flow meter and level/pressure gauges.
5. Water quality monitors such as turbidimeters etc
6. Process monitors (head loss and water level).
7. Mechanical and electrical filter control systems.

(b) Equipment Operation

Before starting of mechanical equipment, such as a backwash pump and air blower, 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 equipment, refer to manufacturer's instructions.

A **flow meter** with local indication shall be installed in the backwash pipeline feeding the filter blocks. This flow shall also be transferred onto main unit and integration of the same to measure the quantity used for back wash.

Periodic calibration and maintenance of the equipment is necessary.

5.4.4.8 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).

5.4.4.9 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).

5.4.5 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 Check list

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

5.5.1 Plant information

5.5.1.1 Source

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

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

5.5.1.2 Intake

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

5.5.1.3 Treatment process

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

5.5.2 Operation, Maintenance, Records, Etc.

5.5.2.1 Flow

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

5.5.2.2 Flow Meters

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

5.5.2.3 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

5.5.2.4 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.

5.5.2.5 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.

5.5.2.6 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.

5.5.2.7 Records

(a) Inlet flow (Raw water)

1. Quantity measured at the inlet channel and also transmitted to central processing unit for instant flow and cumulative flow day wise
2. The sampling pump pumps the raw water to the laboratory, where the physical and chemical parameters are evaluated.

(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 Unit Filter Run Volume (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).

5.6 Algal Control

5.6.1 Introduction

Algae are unicellular or multi-cellular 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.

5.6.2 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.

5.6.3 Remedial Measures

5.6.3.1 Preventive measures

Preventive measures should, therefore, be based on control of those factors such as

- Reduction of the food supply.
- Change of the environment or exclusion of sunlight though they are not always practicable.

- Clear water reservoirs, service reservoir; and wells may be covered to exclude sunlight, but such a remedy is obviously inapplicable in the case of large reservoirs of raw waters.
- Turbid water prevents light penetration and thereby reduces algal population. Activated carbon (10.5 to 24.5 kg/hectare) reduces algae population by excluding sunlight but the disappearance of activated carbon in the water may support algal growth again.
- To a limited extent, the environmental conditions for the growth of algae may be made unfavorable by proper care in the construction and operation of reservoirs.

5.6.3.2 Control Measures

Adequate records of number, kind and location of algae becomes handy for algal growth control. Algaecide dose used should be harmless to humans, have no effect on water quality, should be inexpensive and readily available and easy to apply. The most commonly used algaecides are copper sulphate and chlorine/ bleaching powder

5.6.4 Copper Sulphate treatment

5.6.4.1 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 5.11 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.

5.6.4.2 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 maximize 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.

5.6.4.3 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.

5.6.5 Chlorine treatment

5.6.5.1 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 algaecide. 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. 5.11. 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 algaecide. 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.

5.6.5.2 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.

5.6.5.3 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 prechlorination 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.

Table 5.11 APPROXIMATE AMOUNT OF COPPER SULPHATE & CHLORINE REQUIRED AS A LETHAL DOSE FOR VARIOUS ALGAE

Organism	Odour, Taste & Colour	Cause of Other	Copper Sulphate Dosage (Mg/L)	Chlorine Dosage (Mg/L)
Diatomaceae:				
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	0.2	–
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
Chlorophyceae:				
Chara	Garlic	Yes	0.1-0.	–
Cladophora	Septic	Yes	0.	–
Closterium	Grassy	–	0.17	–
Coelastrum	–	Yes	0.05-0.33	1.0
Conferva	–	Yes	0.2	–
Desmidium	–	–	2.0	–
Dictyosphaerium	Grassy, Nasturtium, Fishy	–	–	0.5-1.0
Drapamaldia	–	–	0.33	–
Eudorina	Faintly fishy	–	2.0-10.0	–
Entrtomorpha	–	–	0.	–
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.	–
Tetrastrum	–	–	–	1.0
Ulothrix	Grassy	–	0.2	–
Volvox	Fishy	–	0.25	0.3-1.0
Zygnema	–	–	0.	–
Cynophyceae:				
Anabaena	Mouldy, Grassy, vile	–	0.2-0.48	0.5-1.0
Aphanizomenon	Mouldy, Grassy, sweet taste	–	0.12-0.	0.5-1.0
Clathrocystis	Sweet grassy, vile	–	0.12-0.2	0.5-1.0
Coelosphaerium	Sweet grassy	–	0.2-0.33	0.5-1.0
Cylindrospermum	Grassy	–	0.12	–
Gloeocapsa	Red colour	–	0.2	–
Microcystis	Sweet taste	–	0.2	–
Oscillatoria	Musty, spicy	Yes	0.2-0.5	51
Rivularia	Mouldy, grassy	–	–	–

5.6.6 MICRO-STRAINERS

Algae can be removed from water by using micro-strainer. The infested water can be passed through stainless-steel drums with cloths of mesh size ranging from 15-45 µm. Micro-straining 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. Micro straining 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.

OPERATION MAINTENANCE OF WTP AVERAGE PLANT RUNNING PARAMETER

S.No	PARAMETERS	UNITS	VALUE	REMARKS
1	Raw Water Flow	MLD		
2	Clear Water Flow	MLD		
3	Alum Dose	mg/l		
4 (1)	Pre Chlorination Dose	kg/hr		
2	Post Chlorination Dose	kg/hr		
5 (1)	Clarified Water Residual Chlorine	PPM		
2	Clear Water Residual Chlorine	PPM		
6 (1)	Raw Water Turbidity	NTU		
2	Clarified Water Turbidity	NTU		
3	Clear Water Turbidity	NTU		
7(1)	Raw Water pH	Numeric		
2	Clarified Water pH	Numeric		
3	Clear Water pH	Numeric		

8(1)	Raw Water Dissolved Oxygen	mg/l		
2	Clear Water Dissolved Oxygen	mg/l		
9(1)	Raw Water Fluoride	mg/l		
2	Clear Water Fluoride	mg/l		

DAILY REPORT

LABORATORY ANALYSIS OF WATER

Date:

Hour	Raw Water		Clarified Water			Clear Water		
	Turbidity N.T.U	pH Numeric	Turbidity N.T.U	pH Numeric	Rcl ₂ mg/l	Turbidity N.T.U	pH Numeric	Rcl ₂ mg/l
8:00								
12:00								
16:00								
20:00								

	Fluoride (mg/l)	Dissolved Oxygen (mg/l)
Raw Water		
Clear Water		

Unit of Parameter

Turbidity: N.T.U

pH: Numeric

All Others: mg/l

Filter Bed's Number	Time of Washing	Air blowing running time in mins	Backwash water running time in mins	Qty of water consumed in Back Washing in MLD	Remarks
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

SLUDGING CHAMBER NUMBER	DESLUDGING		REMARKS
	TIME	DURATION	
CFL-1			
CFL-2			
CFL-3			
CFL-4			

S. No.	ON DUTY OPERATORS	SHIFT 1	SHIFT 2	SHIFT 3
1	Shift in charge			
2	Chemist			

WEEKLY REPORT

LABORATORY ANALYSIS OF WATER

Date:

	Total Suspended Solids (T.S.S) (mg/l)	Total Dissolved Solids (T.D.S) (mg/l)	Total Alkalinity (mg/l)
Raw Water			
Clear Water			

	COLIFORM COUNT IN 100 ml (MPN) AT 37°C FOR 24 HOURS
Raw Water	
Clear Water	

CHAPTER – 6

DISINFECTION

6.1 General

Disinfection is necessary to ensure that drinking water is free from disease-causing microorganisms, control of odour and for taste. Water disinfection means the removal, deactivation or killing of pathogenic microorganisms. Disinfection is often universally employed by water distribution systems, even when water at the source is deemed already potable, as a precautionary measure to control the spread of waterborne diseases. Disinfection is particularly important because of the risk of external contamination due to leakages, breakages and other types of seepages anywhere throughout the extensive pipe network, and the magnified impact of this risk due to the number of users. Present method of disinfection for the water supply is to be continued and ensured that the tail end point receives residual chlorine of 0.2 ppm or traces of Chlorine.

6.2 Chlorine Disinfection (Chlorination)

Chlorination is the process of adding the element chlorine to water to make it safe for human consumption as drinking water. Chlorine (and its compounds) is the most widely used disinfectant for water systems because of its effectiveness, cheap cost and availability. 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 hypochlorate ions (OCl^-), free available chlorine is hypochlorous acid and hypochlorite ions.

Chlorination has the advantage of oxidizing bacteria and virus even after the point of application due to its residual action. Hence any bacteria introduced to the system after the point of chlorination can still be eliminated by the residual chlorine in the water.

For more details please refer the manual on “water supply and treatment”(1999 Edition) published by CPHEEO.

6.3 Determinants of Chlorine Effectiveness

1. **Contact Time (CT) & Dosage** – Contact time refers to the period of time allowed for the disinfectant to react with the microorganisms that may be in the water. Dosage refers to the amount of chlorine infused in relation to the volume of the water being treated.
2. **The Type of Microorganism** – Chlorine is quite effective in destroying the most significant pathogenic organisms that are dangerous to humans and are commonly borne in water. Different pathogens and parasites, however, have different levels of resistance to it. Thus, the dosages, the CT, and other conditions of the water that

intensify or inhibit the oxidizing action of chlorine such as temperature and pH (acidity or alkalinity) need to be considered in order to be sure that the harmful organisms and undesirable substances are eliminated.

3. **Characteristics of the Source Water** – The nature of the water that requires treatment influences the disinfection. Materials in the water, for example, iron, manganese, hydrogen sulfide and nitrates often react with disinfectants, effectively increasing the chlorine demand. Turbidity of the water also reduces the effectiveness of disinfection.
4. Usually, the tests on the water from a new source are the basis for prescribing the dosage and CT needed to eliminate the harmful and undesirable substances. Additional tests on the water at source need to be conducted when there are indications that the source water characteristics have changed. The possibility of contaminants (whether pathogens or minerals that change its acidity or turbidity) in the path of the water or in the proximity of the spring box or reservoir need to be checked.
5. **Temperature of Water** – Higher temperatures usually increase the speed of reactions and of disinfection.

6.4 Terminology and Definitions

1. **Available Chlorine Content** – is amount of chlorine in a chlorine compound, which determines its potential disinfecting power.
2. **Chlorine Demand** – is the total amount of chlorine needed to oxidize all the materials in the water that react with chlorine within a given period. After all the reactions within that period are completed, the pathogens and undesirable organic substances, as well as the soluble iron, manganese and hydrogen sulfides are deemed to have been destroyed, neutralized, or eliminated. Chlorine demand is the difference between the amount of chlorine added to water and the amount of residual (remaining) chlorine at the end of a specific contact period. If no residual chlorine is detected, it means that the chlorine demand was so great it exhausted the chlorine; thus the chlorine infused into the water (dosage) was insufficient.
3. **Chlorine Residual** – is the total amount of chlorine (combined and free available chlorine) remaining in water at the end of a specific contact period following the infusion of chlorine. The chlorine residual is an important indicator of safe water because as long as the residual chlorine is present in the water, disinfection is a continuing process.
4. **Dosage of Chlorine** – is the quantity of chlorine applied to a specific quantity of water. Dosage is expressed in milligrams per liter (mg/l) of chlorine.

5. **Dosage Rate** – is the amount of chlorine applied per unit time. It is usually in grams/day or kg/day.
6. **Super chlorination** – this means applying chlorine at very much higher than the usual dosages. If a system design or requirements do not allow adequate contact time for the normal dosages of chlorine to eliminate the pathogens and undesirable substances in the water, super chlorination could be resorted to. Super chlorination provides a chlorine residual of 3.0-5.0 mg/l, which is 10 times the recommended minimum breakpoint chlorine concentration. Retention time for super chlorination is approximately 5 minutes.
7. **De chlorination** – removes excessive levels of chlorine from the water. De chlorination is considered a necessary phase after super chlorination in order to remove the odor, taste and the other objectionable traces of excess chlorine in the water. De chlorination commonly involves the use of an activated carbon filter.
8. **Shock Chlorination** (dosage of 200 mg/l for 3-4 hrs) is recommended whenever a well, reservoir or pipeline is new, repaired, or found to be contaminated. This treatment introduces high levels of chlorine to the water. Unlike super chlorination, shock chlorination is a "one time only" occurrence, and chlorine is depleted as water flows or is flushed through the system. If bacteriological problems persists following shock chlorination, the source of the contamination of the system should be determined and eliminated.
9. **Break point chlorination**

The addition of chlorine to ammonia in water produces chloramines which do not have the same efficiency as free chlorine. If the chlorine dose in this water is increased, a reduction in the residual chlorine occurs, due to the destruction of chlorine by the added chlorine. A few possible schemes are as below:



The end products do not represent any residual chlorine. This fall in residual chlorine will continue with further increase of chlorine dose and after a stage the residual chlorine begins to increase in proportion to the added dose of chlorine. This point at which the free residual chlorine appears after the entire combined chlorine residual has been completely destroyed is referred to as breakpoint and corresponding dosage is the

breakpoint dosage. Breakpoint chlorination achieves the same results as super chlorination in a rational manner and can therefore be construed as controlled super chlorination.

6.5 Chlorine Dosage and Demand

6.5.1. Relationship of Chlorine Dosage, Demand and Residual

When chlorine is added to water, some of it is used up immediately by the water and the substances that are in it. This is known as the chlorine demand of the water. There must be sufficient chlorine left to kill bacteria and viruses not just at the reservoir but even in the distribution system.

$$\text{Dosage} = \text{Demand} + \text{Residual}$$

Even if the chlorine demand of a particular source does not change much over the years, it is still good to be vigilant to prevent any serious outbreaks of diseases. An increase in organic matter in the water source will increase chlorine demand. And this means measuring the chlorine demand and residual almost every day to determine the accurate chlorine dosage to be used.

6.5.2. Determining Chlorine Demand

There are two ways of determining the chlorine dosage.

Method 1:

1. Dose the water supply with an arbitrary amount, say 1 mg/l;
2. Wait for 30 minutes and measure the chlorine residual.
3. If residual is zero or less than 0.2 mg/l, increase the dosage until the right residual is obtained.
4. If residual is more than 0.5 mg/l, then the dosage can be reduced.

Method 2:

Use a 1% chlorine solution to conduct the following procedures:

1. Prepare a 1% chlorine solution, the quantity depending upon type of chlorine used (see Table 6.1 below);
2. Take 3 or 4 non-metallic containers of known volume (e.g. 20 liter buckets);
3. Fill the containers with some of the water to be treated and check the pH of the water;
4. Add to each bucket a progressively greater dose of 1% solution with a measuring device:
 - 1st container: 1 ml
 - 2nd container: 1.5 ml
 - 3rd container: 2 ml
 - 4th container: 2.5 ml

5. Wait 30 minutes. (This is essential as this is the minimum contact time for the chlorine to react. If the pH of the water is high, this minimum time will increase);
6. Measure the free chlorine residual in each bucket;
7. Choose the sample which shows a free residual chlorine level between 0.2 mg/l and 0.5mg/l;
8. Extrapolate the 1% dose to the volume of water to be treated;
9. Check chlorine demand at several water distribution points and adjust if required.

6.6 Chlorine/Chlorine Compounds Used in Disinfection

1. **Chlorine** – Chlorine is a poisonous yellow-green gas with a penetrating, pungent odor. It is extracted from chlorides through oxidation and electrolysis. In water, chloride (chlorine compounds) hydrolyses to form a 1% chlorine solution contains 10 grams active chlorine per liter hypochlorous acid and the hypochlorite ion (free available residual chlorine), which are very toxic to bacteria. It is available outside in different capacities filled in gas cylinders
2. **Bleaching Powder or Chloride of Lime** – Bleaching powder or calcium hypochlorite is a chlorinated lime, is a yellow white solid which has a strong smell of chlorine. It is not highly soluble in water, and is preferably used in soft to medium-hard water. Bleaching powder loses strength rapidly whenever it is exposed to moist air so that it should be kept in closed containers. It is available out side as powder packed in bags with different weights.
3. **High-Test Hypochlorite (HTH)** – It is a more stable and stronger compound than bleaching powder. HTH is sold under a number of proprietary names. It is generally sold as tablets.
4. **Sodium Hypochlorite (NaOCl)** – This is a highly corrosive, slightly yellow liquid. It is used extensively in many industries as a disinfectant, deodorizer, bleach, and to neutralize certain undesirable chemicals and compounds used or formed in productions processes. For households, it is supplied as the common households bleach. It is available out side in liquid cans of different capacities.

Table 6.1 shows the percent available chlorine of various chlorine compounds.

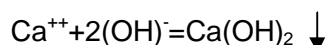
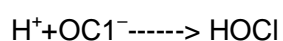
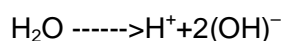
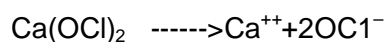
Table 6.1: Percentage of Available Chlorine

Material	Available Chlorine	Quantity to Make a Liter of 1% Chlorine Solution
Chlorine gas	100%	-
Bleaching powder (chloride of lime)	25 – 34%	30 grams (approx) Powder form
Calcium hypochlorite (HTH)	70 – 44%	14 grams (approx) Powder/tablet form
Sodium Hypochlorite (NaOCl)	12 – 15%	80 grams (approx) liquid form

6.7 Disinfection By Bleaching Powder

6.7.1 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.

6.7.2 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 OCl^- , Cl^- , is now ready for use as disinfectant. (See fig. 6.1)

6.7.3 Dosing of Solution

1. 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 dose has to be monitored properly, depending on the desired residual chlorine required in clear water reservoir. The system is shown in figure 6.1

6.7.4 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.

6.8 Electro Chlorinator

6.8.1 Principle of Operation of Electro Chlorinator (Hypo chlorination)

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 hypo chlorite is used as disinfectant.

6.8.2 Description of Electro Chlorinator

The electro chlorinator 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.

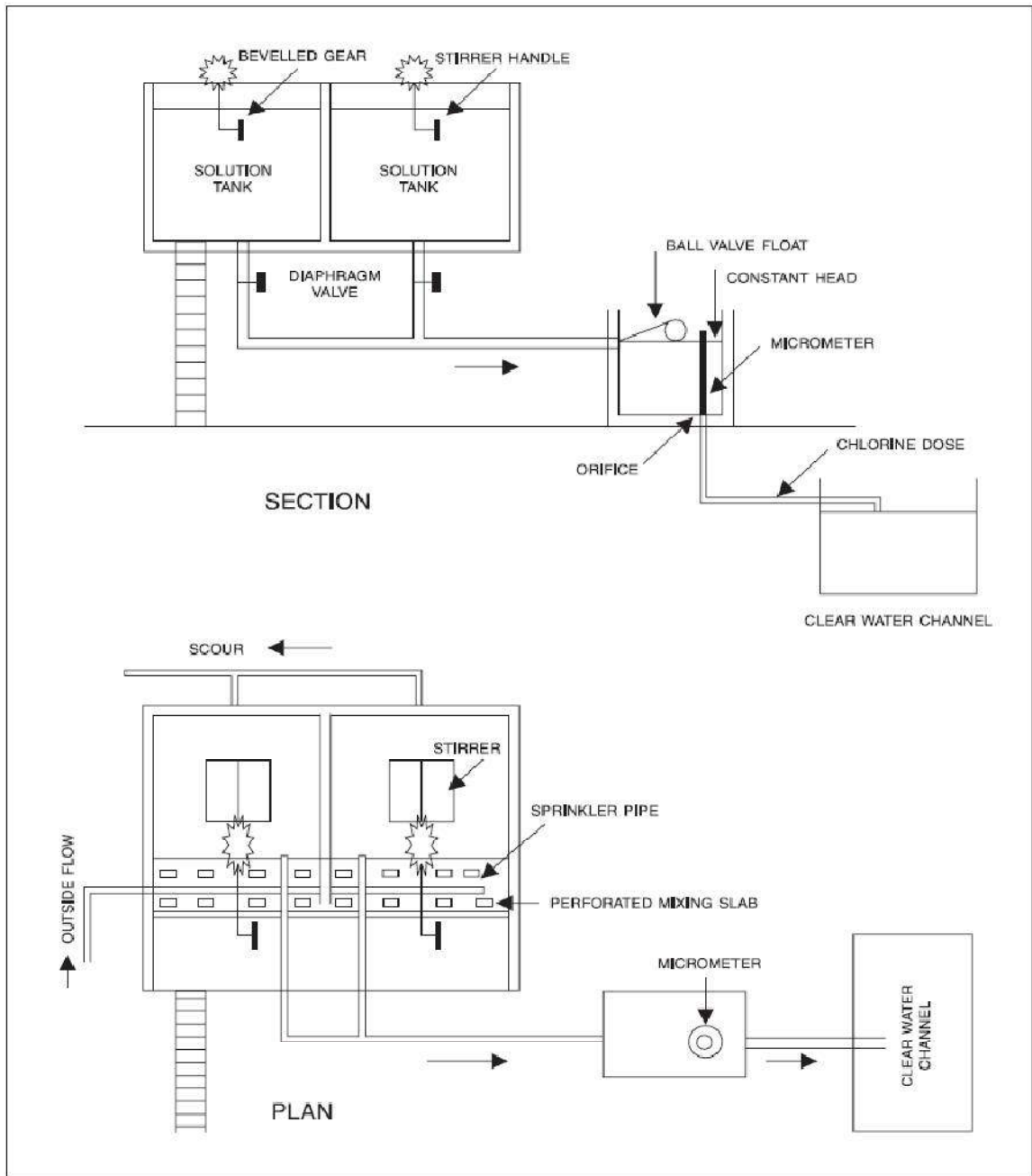


Fig 6.1: Typical bleaching solution dosing

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.

6.8.3 Process Details of Electro Chlorinator

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 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 (H₂O), hydrogen gas (H₂) 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.

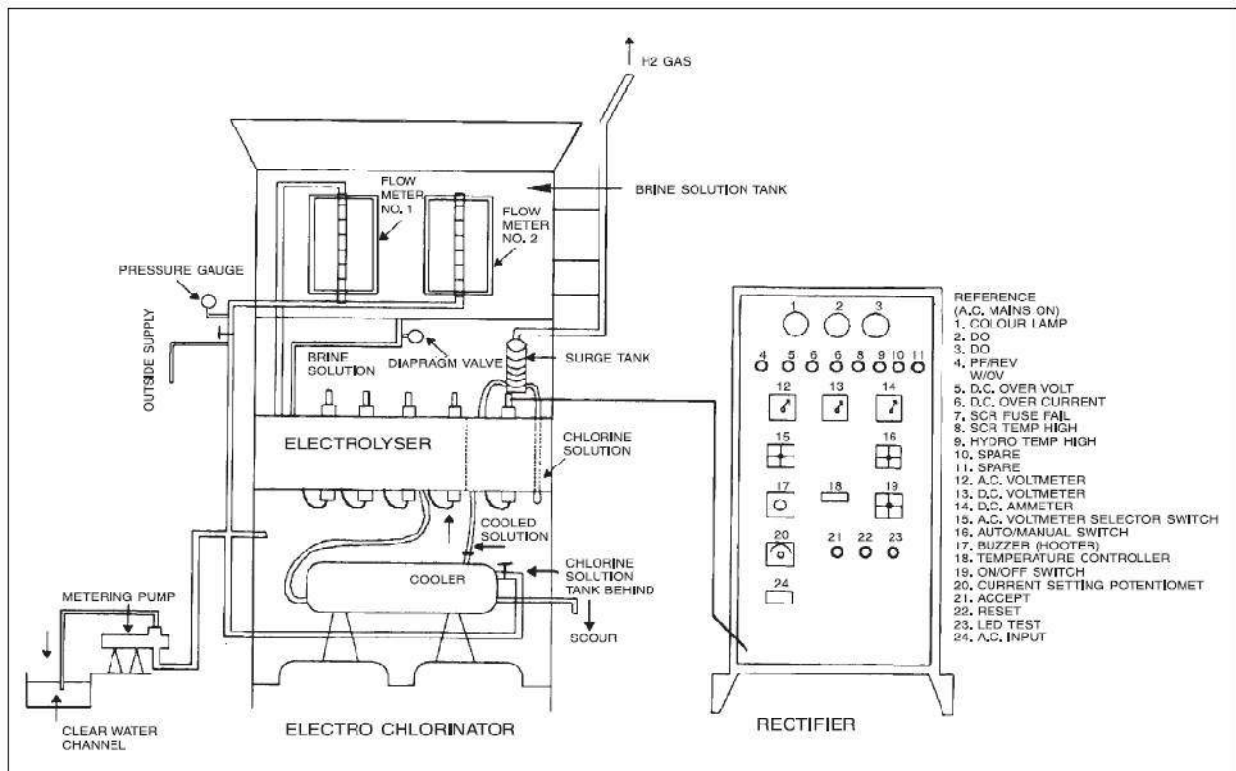


Fig 6.2 Onsite Production of Hypo-Solution from Common Salt

6.8.4 Operation of Electro Chlorinator

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/ cm². 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 + 12⁰C), 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.

6.8.5 Maintenance of Electro Chlorinator

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.

6.9 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.

6.9.1 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 re liquefaction 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).

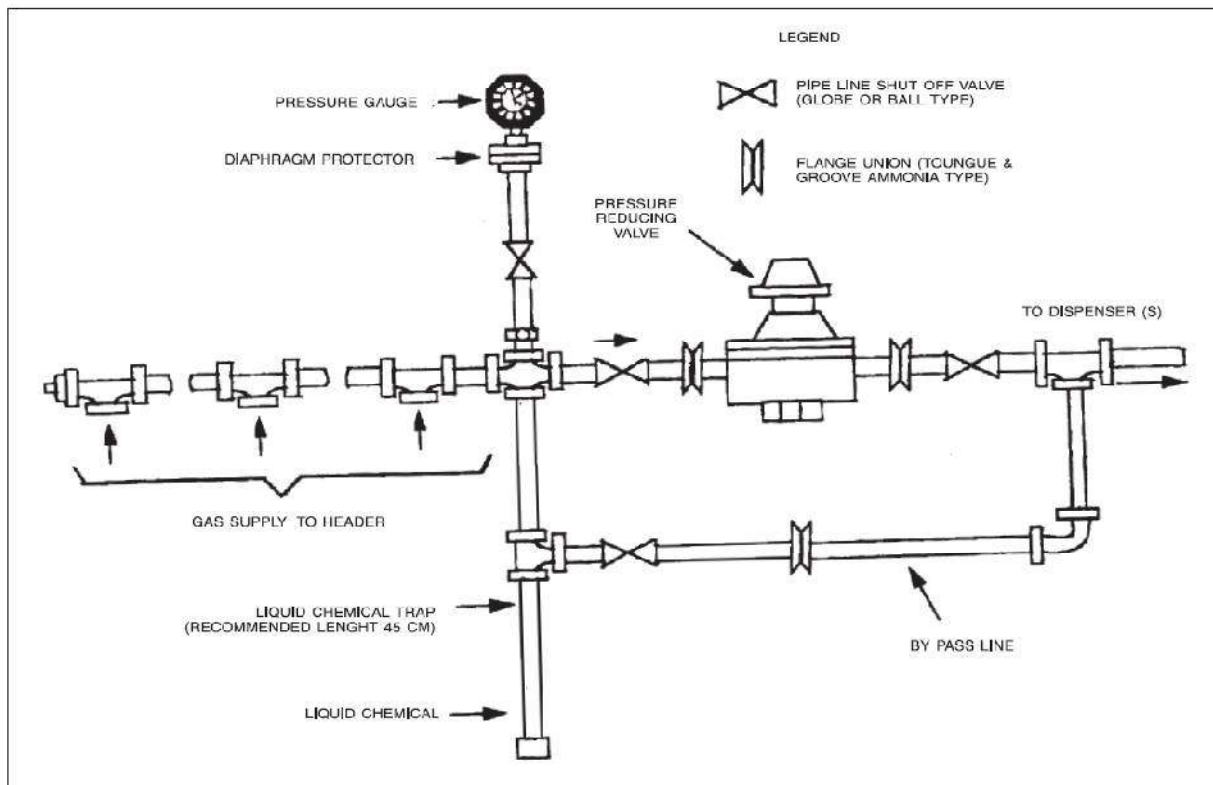


FIG 6.3: GAS SUPPLY SYSTEM

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 - 2.75 kg/cm² 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 reliquefaction of the gas in the header between the last cylinder connected and the chlorinator (Fig.6.5)

6.9.2 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

6.9.2.1 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 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.

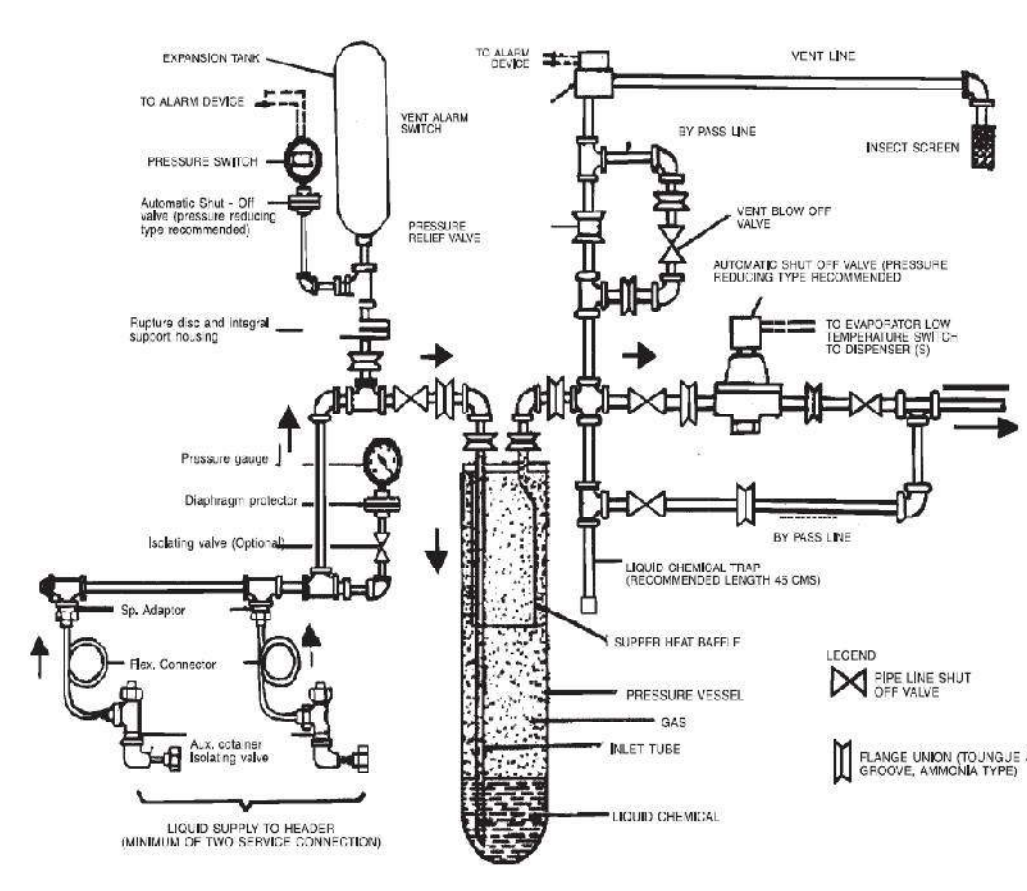


FIG 6.4: LIQUID WITHDRAWAL SYSTEM

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).

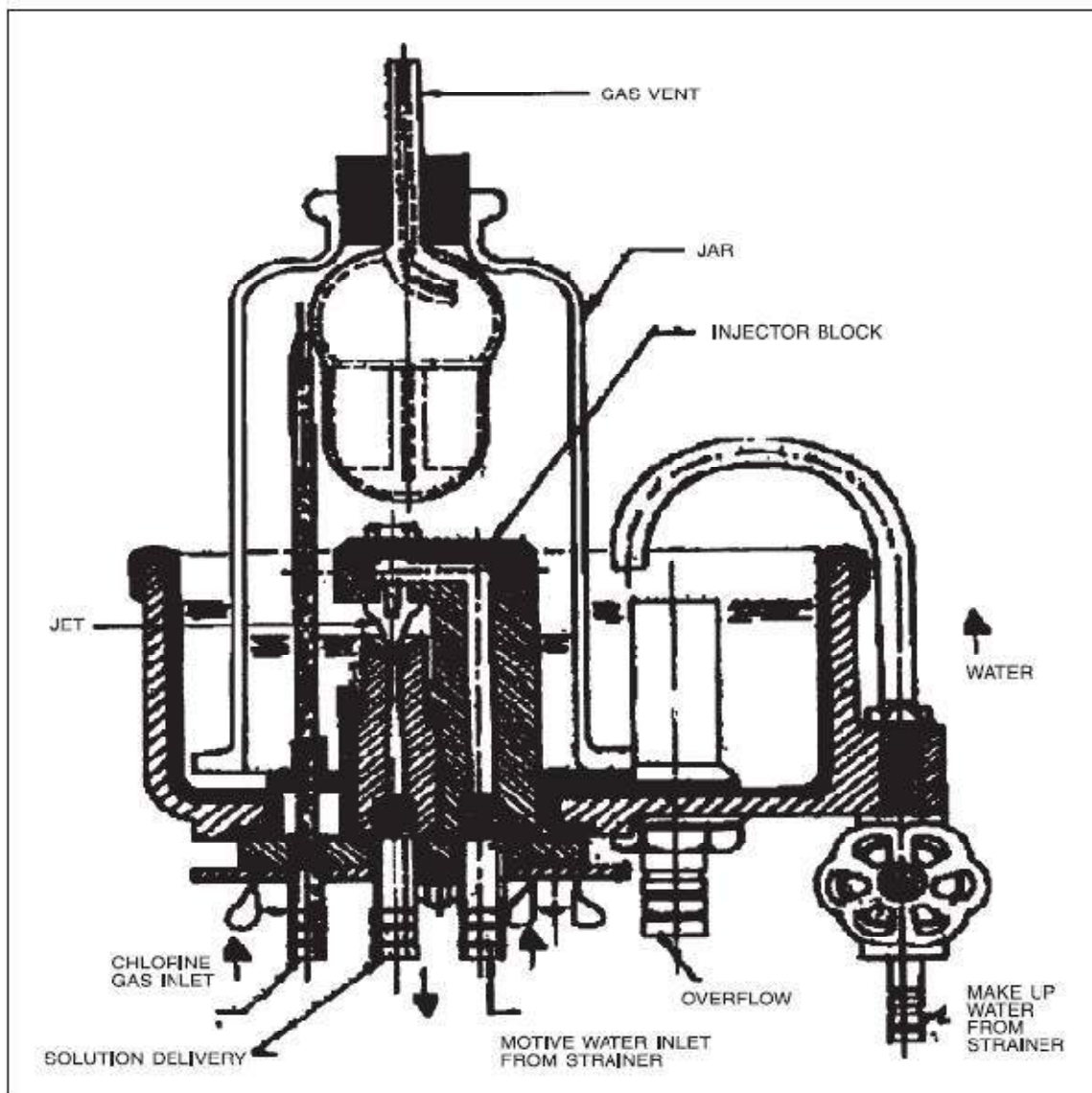


FIG 6.5:CHLORINE GAS APPARATUS
INJECTOR(PRESSURE TYPE) SOLUTIONIZER

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.

6.9.2.2 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.

6.9.2.3 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.

6.9.2.4 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 flow meter (Rotameter), vacuum regulating valve, pressure vacuum relief valve, drain valve and injector assembly (Fig 6.6)

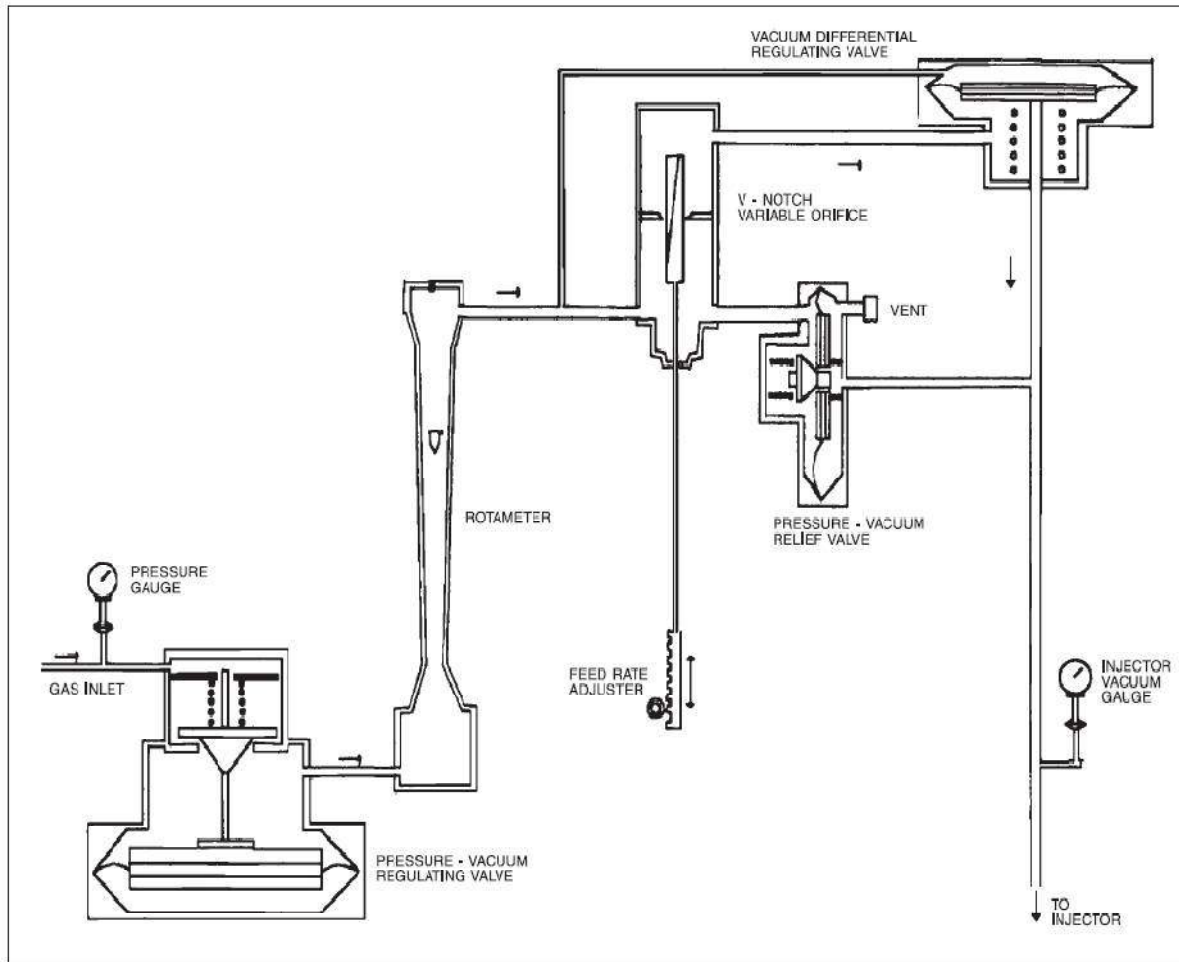


FIG 6.6: TYPICAL CHLORINATOR

If the system is designed for chlorine gas withdrawal, the following procedure for starting up the system is adopted.

6.9.2.5 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.

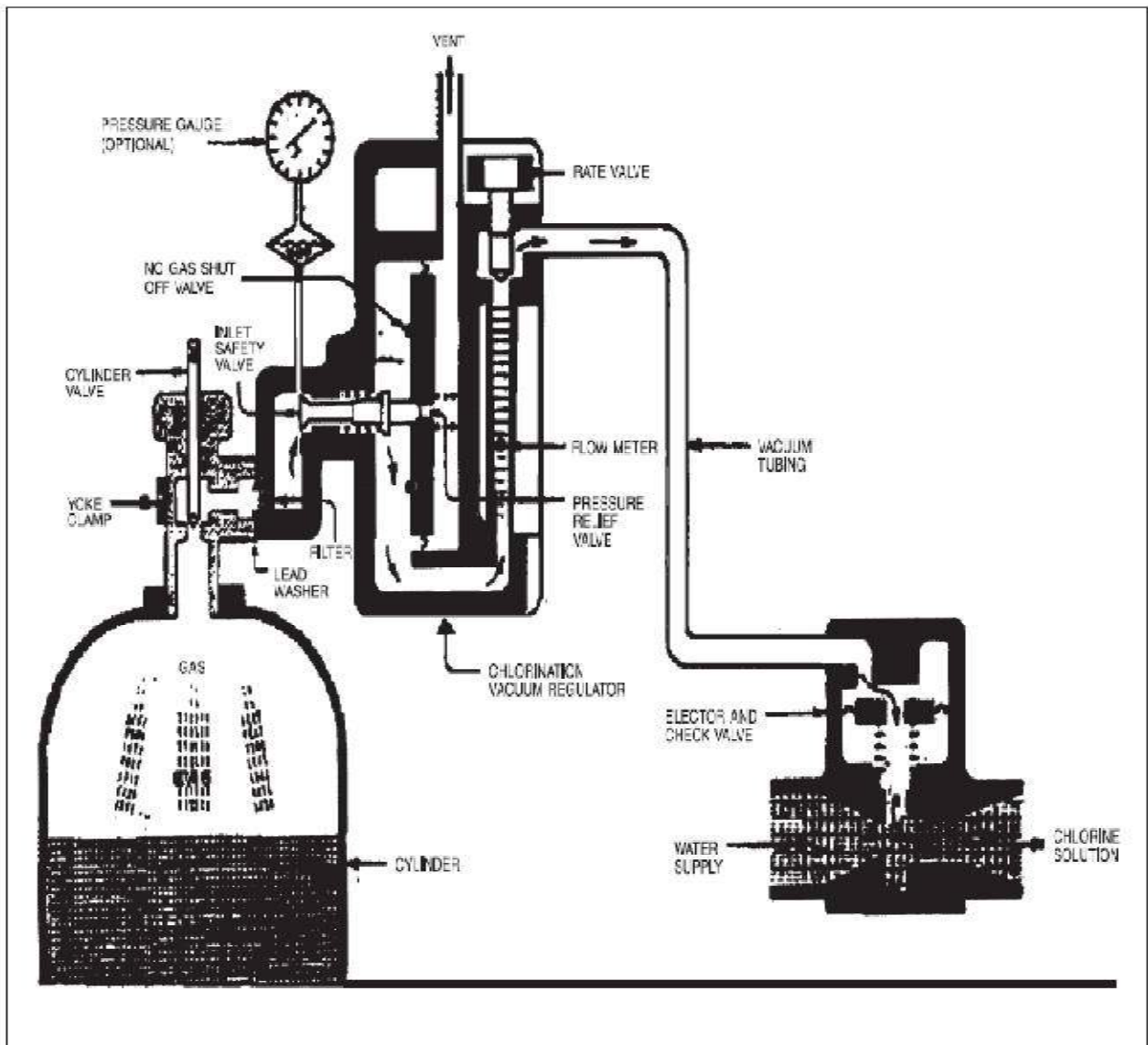


FIG 6.7: CYLINDER MOUNTED CHLORINATOR

6.9.2.6 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 65⁰C temperature, the chlorine pressure reducing valve & shut off valve will open and the system is ready for operation. When water temperature reaches 82⁰C, start the injector water system and follow the procedure mentioned in gas system.

6.9.2.7 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.

6.9.2.8 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.

- (a)
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. 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 6.2 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 6.3 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 6.4 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 ² (max)	0.7 kg/cm ² (max)	More than 0.7 kg/cm ²	More than 0.7 kg/cm ²	More than 0.7 kg/cm ²
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 6.5 Important Facts About Chlorine From Safety Point of View

	Facts	Reasons	Remedy
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 ⁰ 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 ⁰ 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.

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.

6.10 Safety Aspects of Chlorine

6.10.1 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:

6.10.2 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°. The withdrawal rates of Cl₂ at 20°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)

SPECIFICATION OF CHLORINE GAS CYLINDER

Water Capacity (Litres)		84
Gas Capacity (Kg.)		100
Maximum Working Pressure (Kg/Cm ² at 65°C)		19.90
Hydraulic Test Pressure (Kg/Cm ²)		29.85
Nominal Dia	Inside (d)	356
	Outside (D)	368
Approx (mm)		
Nominal Wall Thickness (I) mm		6
Approx Height excluding		988
Valve & Cap (H) mm		
Tara Weight excluding Cap (Kg)		65
Construction		3 Piece

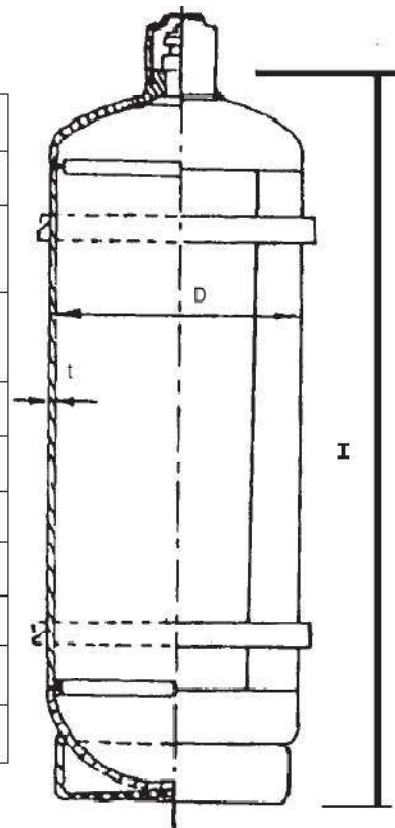


FIG 6.8:DETAILS OF CHLORINE CYLINDER

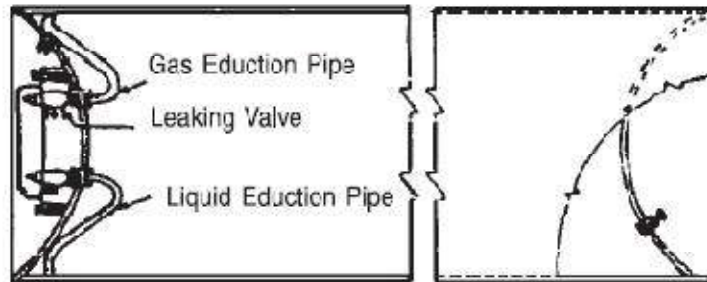
6.10.3 Tonners

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. 900-1000 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 ²	-	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

Tonnners 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 Cl₂ at 20°C are 7 kg/hr and 180 kg/hr for gas and liquid respectively. It depends upon ambient temperature.

6.10.4 Container Valves

Both chlorine cylinder as well as tonners must be fitted with standard valves conforming to IS: 3224 (Fig. 6.10).

6.10.5 Storage and 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_2 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.

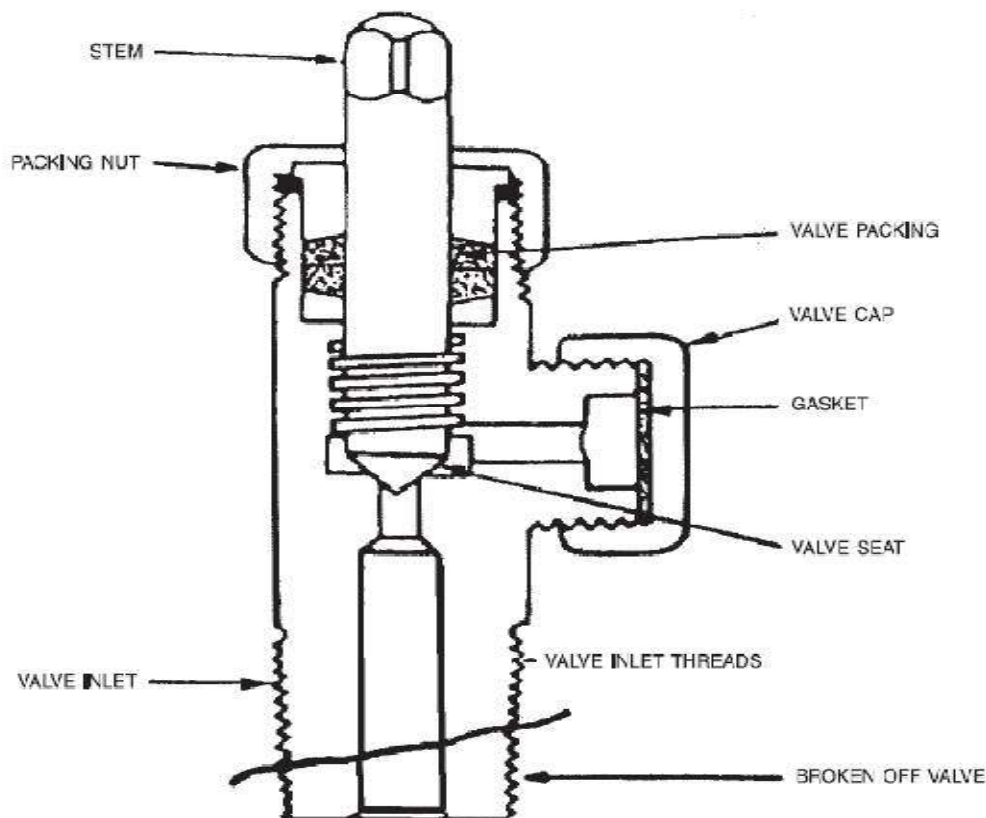


FIG 6.10: STANDARD CHLORINE CONTAINER VALVES

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 251⁰C 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 adapter 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/cm² 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. 6.9 & Fig. 6.10 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. 6.9 & Fig. 6.10 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 fluoro protein 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.

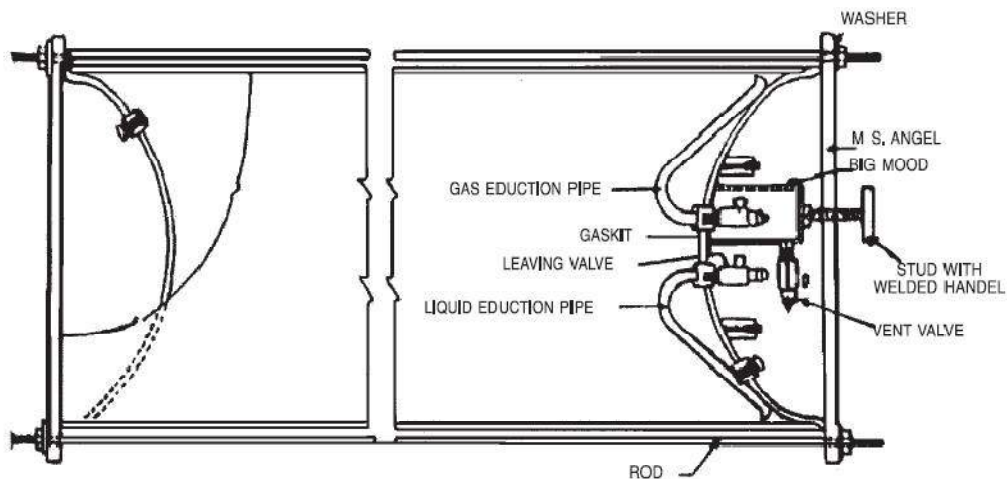


FIG 6.11: APPLICATION OF EMERGENCY KIT

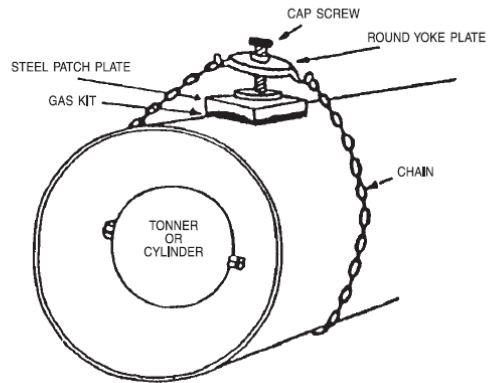


FIG 6.12: USE OF CHAIN AND ROUND YOKE PLATE FOR TONNER CYLINDER WALL LEAK

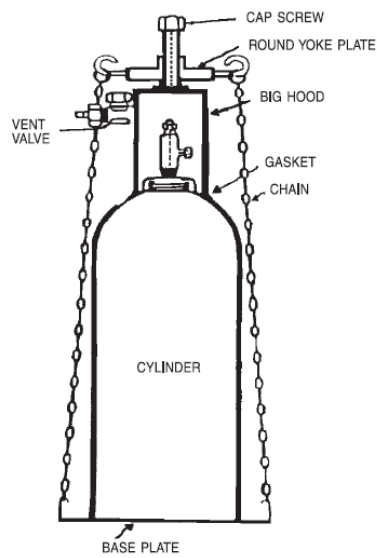


FIG 6.13: CYLINDER VALVE HOOD ASSEMBLY DEVICE

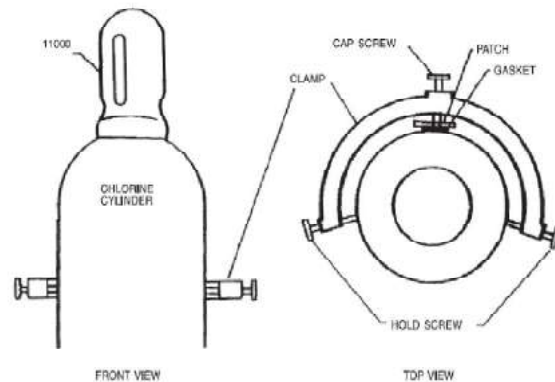


FIG 6.14: CONTAINER WALL LEAK

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% Cl₂

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)

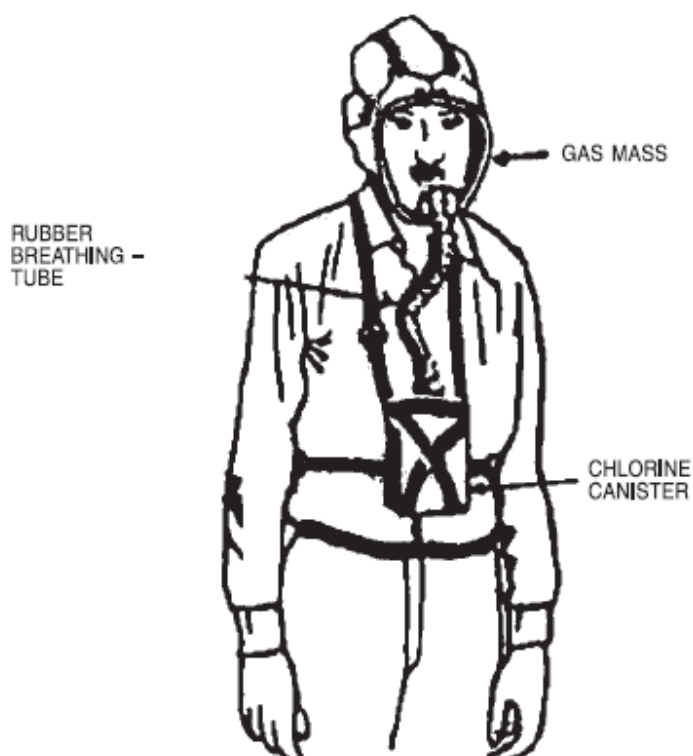


FIG 6.17: USE OF CHLORINE CANISTER GAS MASK

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 Cl₂.

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 Plans

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 onsite 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.

6.11 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.

6.12 Chlorine Dosages

The following illustrate the mathematical methods applied in arriving at the disinfection dosages and rates of dosage using chlorine gas and some of the typical chlorine compounds used by water systems.

Example: Calculation of Dosage

Given:

Water Consumption: 10,000 liters per day (lpd)

Required Residual : 0.3 mg/l

Chlorine Demand: 0.5 mg/l

Required:

Dosage in mg/l,

Dosage rate in gm/day

Using Chlorine gas

Using Bleaching powder

Analysis:

Dosage = Chlorine Demand + Chlorine Residual

Dosage = 0.5 + 0.3 = 0.8 mg/l

Using Chlorine Gas.

Available chlorine = 100%

Dosage rate = $\frac{\text{dosage}}{\text{available}}$ x volume of water to be treated

$$= \frac{0.8 \text{ mg/l}}{100 \%} \times 10,000 \text{ lpd} = 8000 \text{ mg/day} = \mathbf{8 \text{ g/day}}$$

Using Bleaching Powder

Available chlorine = 35%

$$\text{Dosage rate} = \frac{\text{dosage}}{\text{available}} \times \text{volume of water to be treated}$$

$$\frac{0.8 \text{ mg/l}}{35 \%} \times 10,000 \text{ lpd} = 22,857 \text{ mg/day} = \mathbf{22.9 \text{ g/day}}$$

Example: Dosage for Disinfection of well / pipeline after attending leaks or before commissioning.

Given: Well Diameter = 0.3 m

Static Water level = 6 m

Total Well Depth = 50 m

Required: Amount of HTH required

Disinfection Specifications:

Dosage = 50 mg/l

Contact time = 24 hrs

Analysis:

1. Calculate water volume in well

$$\text{Volume} = \pi \times 0.15^2 \times (50-6) = 3.11 \text{ m}^3 = 3,110 \text{ litres}$$

2. Determine amount of chlorine compound using HTH (70% chlorine)

$$\begin{aligned} \text{Amount} &= \frac{\text{Dosage} \times \text{volume}}{\text{Available Chlorine}} \\ &= \frac{50 \text{ mg/l} \times 3,110 \text{ l}}{0.70} = 222,142 \text{ mg} = 222 \text{ g} \end{aligned}$$

Example: Reservoir Disinfection

Given: Diameter = 4 m

Height = 3 m

Required: Amount of Sodium Hypochlorite Needed

Disinfection Specifications:

Contact time = 1 hour

Dosage = 300 mg/l

$$\text{Volume} = \pi \times 2^2 \times 3 = 37.70 \text{ m}^3 = 37,700 \text{ litres}$$

Sodium Hypochlorine availability = 15%

$$\text{Amount} = \frac{300 \text{ mg/l} \times 37,000 \text{ l}}{0.15} = 75,398 \text{ mg} = 75.4 \text{ g}$$

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"> a. Insufficient ejector vacuum caused by insufficient water supply by pressure or excessive back pressure. b. Leakage at vacuum line connection at outlet from flowmeter, rate control valve, differential pressure regulator, and/or inlet to ejector. c. Vacuum line(s) if flexible, crimped. 	<ul style="list-style-type: none"> a. Refer to Trouble at S.no.6. b. Inspect each connection and remake if necessary. c. Replace vacuum tubing and arrange line(s) to eliminate crimping.
2. Required gas flow rate is not achieved on start-up following an extended period of shutdown.	<ul style="list-style-type: none"> a. Insufficient ejector vacuum. b. Leakage at vacuum line connection at outlet of flowmeter, rate control valve, differential pressure regulator, or inlet to ejector. c. Vacuum line(s), if flexible, crimped. d. Leakage around flowmeter gaskets. 	<ul style="list-style-type: none"> a. Refer to Trouble at S.no.6. b. Inspect each connection and remake if necessary. c. Replace vacuum tubing and arrange line(s) to eliminate crimping. d. Inspect and align flowmeter or replace gaskets.
3. Flowmeter float observed bouncing and/or maximum gas flow cannot be achieved during normal operation.	<ul style="list-style-type: none"> a. Gas inlet filter of vacuum regulator dirty. b. Rate valve dirty. c. Flowmeter dirty. d. Ejector water supply pressure fluctuating too wide (float bounce) or insufficient ejector vacuum. 	<ul style="list-style-type: none"> a. Replace gas inlet filter assembly. b. Clean rate valve. c. Clean flowmeter. d. Correct water supply pressure as necessary.
4. Flowmeter fails to indicate gas flow during normal operation but there is no out-of-gas indication.	<ul style="list-style-type: none"> a. Rate valve plugged. b. Gas flowmeter plugged. c. Vacuum lines, if flexible, crimped. 	<ul style="list-style-type: none"> a. Clean rate valve. b. Clean gas flowmeter. c. Replace vacuum tubing and re-arrange lines to eliminate crimping.
5. No gas indication during normal operation.	<ul style="list-style-type: none"> a. Gas supply valve(s) closed. b. Gas supply exhausted. c. Clogging of filter in vacuum regulator. 	<ul style="list-style-type: none"> a. Open gas supply valves. b. Replenish gas supply. c. Replace filter.

6. Insufficient ejector vacuum.	<p>a. Y-strainer in water supply line is dirty reducing available supply pressure.</p> <p>b. Back pressure is greater than value listed for one of the following reasons;</p> <p>i) solution valve, if present, not fully open</p> <p>ii) solution line, if present, partially blocked.</p> <p>iii) back pressure at point of application has increased above its original value.</p> <p>c. Ejector nozzle and/or throat dirty.</p>	<p>a. Clean Y-strainer.</p> <p>b. Open solution valve, clean solution line.</p> <p>c. Clean nozzle and/or throat.</p>
7. Loss of gas feed.	<p>a. Dirty or plugged ejector nozzle.</p> <p>b. Insufficient water pressure to operate ejector.</p> <p>c. No gas supply.</p>	<p>a. Check for vacuum in ejector. Clean nozzle.</p> <p>b. Provide proper water pressure.</p> <p>c. Replenish gas supply.</p>
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

STORAGE OF WATER

(Reservoirs including Service Reservoirs)

The main function of Reservoirs and Service Reservoirs (SR) at habitations is to cater for daily demands and specially peak demands of water. Operator checks the amount of water available 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 Procedures for Operation of Service Reservoir (SR)

Service Reservoirs have to be operated as per the design requirements. Generally, the service reservoirs are constructed at elevated place 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. The command intended area of the service reservoir should be earmarked.

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. Normally, 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.

7.1.1 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.
- In case 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 of SRs.

The operator 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 tackle such situations.

7.1.2 Storage Level & Capacity

Most of the distribution systems establish a pattern of levels for assuring the required supplies at the required pressures. 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. It is also desirable to have an indication of levels of SR in the pump house. Usually water levels are read at the same time each day and the readings recorded. Checking of water levels at other times of the day will enable to determine if any unusual consumption conditions has arisen. If any, significant increase in consumption is anticipated the operations should ensure a corresponding increase in incoming supply into the SR.

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. 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 bypass 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 operation.

7.1.3 Water Quality at SR

Water from all SRs should be periodically sampled to determine the quality of water that enters and leaves the SR. Sampling data can help in setting up periodic cleaning of SR. Common cause of physical water quality problems includes collection of sediment, corrosion and chemical precipitates. Water quality in a SR may also deteriorate due to excessively long periods in stagnant conditions. Whenever seasonal demand rises, residual chlorine has to be maintained properly.

7.2 Plans for O&M of Service Reservoir

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:

- Information of design details for the reservoir such as: capacity in liters, size and depth of storage; size of piping/locations of control valves of inlet, outlet, scour and overflow; 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.
- Key plan 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.
- 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 has to be displayed.
- A record sheet for each valve showing direction for turning, number of turns, inspections, repairs and whether opens 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 mechanized operation of valves, the steps to include starting, running and stopping the operations should be displayed.
- Different inlet pipes/outlet pipes into and out of the service reservoir from different sources and to different command areas, should be marked in paint with different color

7.2.2 Maintenance of Service Reservoirs

- Service Reservoirs (SRs) have to be inspected regularly and the line department 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 leak 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 common. Internal corrosion is prevented by cleaning and painting at regular intervals. Quite Toxic paints should not be used for painting interior surface of SRs. food grade epoxy painted shall only be used for internal 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. Disinfected for a period sufficient to give chlorine residuals of at least 0.2 mg/l. shall be carried before putting into use of the inside coated SR. Manhole covers & vent pipes shall always be properly placed and maintained
- The maintenance procedures shall include step by step procedure for every piece of equipment in SRs such as pipes inside the tank (In-let, out-let, wash-out, over-flow) valves, specials and flow meters following the procedures as per the manufacturers' catalogues.

(a) Pipes (In-let, out-let, wash-out, over-flow) and specials

- All the pipe fittings should be leak proof, any leakage nearby reservoir may affect the safety of reservoir
- Overflow pipe should be connected to the distribution system after the sluice valve installed on delivery side, however it does not hamper the over flow system.
- Concrete platform as protection works may be provided around the service reservoir, for safeguarding the reservoir foundation from any leakages / overflow of water

(b) Valves

All valves should be inspected regularly in defined frequency of inspection and following activities shall be undertaken.

- Required Lubrication has to be done regularly
- Spindles that develop leaks should be repacked
- Rust and sediment in the valve is to be 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 if any
- 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.
- Sluice valve chamber shall not be water logged at any time

7.3 Cleaning of Reservoirs

Routine inspection season wise 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 also be made after draining the tank and then cleaning or washing. Best time in 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.
- Do not empty S.R. and always keep minimum water level at 200-300 mm in the SR.
- Close the outlet valve so that no water will be used while the tank is being cleaned.
- Drain and dispose of 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.
- The higher frequency of cleaning of SR depends on the extent of silting, development of bio films and results from water quality monitoring. Generally cleaning of Service Reservoir should be done periodically.
- Date of last cleaning and the next due date of cleaning may be displayed on the outer surface of the S.Rs.

The reservoir premises has to be maintained clean. The weeds and bushes have to be cleaned in regular interval. The cowls over the reservoirs have to be attended monthly and replace if necessary.

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) should 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, spindle rods, assorted bolts, nuts and washers for the flanges.
- Gaskets for flanged joints for all sizes of sluice valves installed in the SR.
- Spare pulleys.
- Threads, floats for water level indicators.
- Spare manhole covers, spare fly proof mesh for ventilators and
- Consumables like the gland rope, grease and cotton waste etc.,

7.5.2 Tools

The necessary tools to repair and attending 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, axe, spades, iron baskets and
- Housekeeping accessories such as long brooms and coir brushes.

7.5.3 List of available spares and tools

A list of 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

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 cards/certificates of these equipments shall also be kept along with the manufacturer's information. The information of the service personnel to be contacted in case of any breakdown should be available at the SR site

7.7 Records and Reports

7.7.1 Record System

A full proof 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. The following details shall be recorded:

7.7.2 Records of Maintenance

The records on each of the following maintenance/repair works along with the cost of materials and labour shall be maintained along with date

- Water levels in the SRs at hourly intervals
- Time and relevant operation of control valves with time of opening and closure or throttling position of the valves.
- Daily flow meter readings both on the inlets and outlets at fixed time in a day.
- At least once a day Residual chlorine readings of inflow and outflow water.
- Record of Gland ropes of the valves/Spares at the SR changed.
- Record of Manhole covers changed / replaced.
- Record of Water level indicator repaired or replaced.
- Record of Reservoir cleaned.

- Record of Out-fall drain for scour and overflow last cleaned.
- Record of Ladder changed, when the structure of the reservoir last repaired to attend to structural defects or arrest leakage.
- Record of Reservoir and Pipes last painted
- Total cost of repairs and replacements at the SR in previous year along with its breakup of material and labour cost with amount spent on outside agencies for repairs and replacements.

7.7.3 Reports

On capturing of all the essential data, a report can be prepared evaluating the O&M of the system. The report can clearly identifies the deficiencies in the SR and its appurtenances and its plan for future repairs to the structure, valves and other equipment or for replacement of defective valves, 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 half yearly 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.

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.		
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:		
	(a) Spares		
	(b) Consumables		
	(c) Tools		
25	Check for need to paint.		
26	Check for availability of drawings and designs of the SR.		

* To be decided by the respective water utilities.

CHAPTER - 8

WATER METERS, INSTRUMENTATION, TELEMETRY & SCADA

8.1 Water Meters

8.1.1 Introduction

A water meter is a scientific instrument for measurement of quantity of water distributed to the consumers. It also fulfills the need to know accurately the water produced and distributed. It also provides access to the loss of water in distribution system. Water meter is always specified in two accuracies i.e. lower range and upper range accuracies. The upper range and lower range accuracies are 2% and 5% of the actual quantity respectively for the water 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. There are different types of water meters such as mechanical water meter, electro-mechanical, ultra-sonic water meters etc.

8.1.2 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:

- Water meter has to be selected according to the flow to be measured and not necessarily to suit a certain size of water main.
- The maximum flow shall not exceed the maximum flow rating.
- The nominal flow shall not be greater than the nominal flow rating.
- The minimum flow to be measured shall be within the minimum starting flow of the meter.
- Low head loss, long operating flow range, less bulky and robust meter shall be preferred.

CLASSIFICATION OF WATER METER BASED ON

Operating Principle		Inferential or Velocity or Turbine		Metrological Characteristics
		Woltman or Helical Type		
Semi positive or Piston or Volumetric	Inferential or Velocity or Fan Type		Available from 50 mm to 500 mm as per BIS and 50 mm to 800 mm as per ISO Advantages: 1. Suitable for higher flows 2. Less pressure loss 3. Robust construction 4. External and internal regulators Disadvantages: 1. Approach conditioning piping is required 2. Not available in metrological classes in BIS. Limited to higher flows.	Classes Classes A to D A & B as per ISO 4064 779
	Vane Wheel or Fan Type	Multi Jet		
Available in C&D classes as per ISO 4064	Single Jet	Available from 15 mm to 50 mm as per IS 779 and 15 mm to 100 mm as per ISO 4064 Advantages: 1. Simple & less complicated 2. The cheapest 3. Less loss of pressure Disadvantages: 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	Available from 15 mm to 300 mm as per ISO Advantages: 1. Less sensitive to flow disturbances 2. Can sustain hostile flow conditions 3. External regulator facilitates easy calibration 4. Easy maintenance Disadvantages: 1. More costly than that of single jet 2. More pressure loss	<p>Consumer Category</p> <p>Domestic Meter as per IS 779</p> <ul style="list-style-type: none"> Available upto size 50 mm Screwed connection Body with Brass of Bronze or Plastic in Class 'A' & 'B' in IS <p>Bulk Meter as per IS 2373</p> <ul style="list-style-type: none"> Available from size 50 mm and above Flanged connections Body: cast or steel Not available in classes in IS
	Available from 15 mm to 50 mm as per IS 779 and 15 mm to 100 mm as per ISO 4064 Advantages: 1. Simple & less complicated 2. The cheapest 3. Less loss of pressure Disadvantages: 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	Available from 15 mm to 300 mm as per ISO Advantages: 1. Less sensitive to flow disturbances 2. Can sustain hostile flow conditions 3. External regulator facilitates easy calibration 4. Easy maintenance Disadvantages: 1. More costly than that of single jet 2. More pressure loss		
<p>Constructional Features</p> <ol style="list-style-type: none"> Wet dial meter Dry dial meter Mechanically coupled meter Magnetically coupled meter Straight reading cyclometer Multi pointer meter (Analogue type) Combination of Cyclometer & pointer <p>Advantages of mechanical coupled</p> <ol style="list-style-type: none"> Not affected by external magnetic field. <p>Disadvantages:</p> <ol style="list-style-type: none"> Bush leak problems Air escape hole create problem during submergence. Available in class 'A' only <p>Advantages of Magnetically Coupled:</p> <ol style="list-style-type: none"> Available in Class 'A' as well as Class 'B' More sensitive No condensation of water in resister <p>Disadvantages:</p> <ol style="list-style-type: none"> Temperable with external magnetic field. In intermitten supply high temperature of water may damage the properties of the magnet. 		<p>Constructional Features</p> <ol style="list-style-type: none"> Wet dial meter Dry dial meter Mechanically coupled meter Magnetically coupled meter Straight reading cyclometer Multi pointer meter (Analogue type) Combination of Cyclometer & pointer <p>Advantages of mechanical coupled</p> <ol style="list-style-type: none"> Not affected by external magnetic field. <p>Disadvantages:</p> <ol style="list-style-type: none"> Bush leak problems Air escape hole create problem during submergence. Available in class 'A' only <p>Advantages of Magnetically Coupled:</p> <ol style="list-style-type: none"> Available in Class 'A' as well as Class 'B' More sensitive No condensation of water in resister <p>Disadvantages:</p> <ol style="list-style-type: none"> Temperable with external magnetic field. In intermitten supply high temperature of water may damage the properties of the magnet. 		

8.1.3 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. The following guidelines should be borne in mind while installing the meters.

- 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.
- 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(supply) 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
- The meter shall preferably be housed in a chamber with a frame & cover 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 frame and cover. It should not be suspended.
- 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.
- 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.
- Before fitting the meter to the pipeline check the union's 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.
- The protective cover should normally be kept closed and should be opened only for reading the dial.

- 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.
- A meter shall be located where it is not liable to get severe shock of water hammer which might damage the system of the meter.
- 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.
- In case of intermittent water supply to SR and schemes with storage at higher elevation, the bulk water meter may be provided with a suitable air valve before the meter in order to reduce inaccuracy and to protect it from being damaged.

8.1.4 Testing and Calibration of Water Meters

The testing & calibration of a water meter is essential before putting it into use as it is a statutory requirement and may be carried out periodically in order to ascertain its performance. It is likely that its accuracy of measurement may deteriorate beyond acceptable limits in course of its use. 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_n) & 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.
 - a. Lower measurable limit in which +5% accuracy from minimum flow to Transitional flow (exclusive) and

b. Upper measurable limit in which +2% accuracy from transitional flow (inclusive) to maximum flow.

8.1.5 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:

(a) Preventive maintenance:-

- Proper handling, storage and transportation of water meters.
- To clean the dirt box or strainer wherever installed.
- To replace the gaskets, if any
- To clean the chamber in which the meter is installed and keep free from flooding, & seepage.
- To remove the meter for further internal repair/replacement if it does not show correct reading pattern.

(b) Breakdown maintenance:-

Replacement of broken glass, cover 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:

- Disassembling of water meters including strainer, measuring unit, regulator, registering device, etc.
- Clean all disassembled spare parts in detergent solution in warm water.
- Inspect the cleaned parts and replace worn out parts and gaskets, if any.
- Inspect the meter body spur threads and cover threads.
- Inspect the sealing surface on meter body and paint the meter body, if necessary.
- Inspect the vane wheel shaft pinion, bearing & pivot.
- Inspect the vane wheel chamber.

- Reassemble the water meter properly after reconditioning.
- Calibrate & test the repaired water meter for leakage & its accuracy as per IS 678410.
- Make entry in the life register of that water meter for keeping history record

Table 8.2 Trouble Shooting of Water Meters

Sl.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
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

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
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In case of smaller size water meters, it is advisable to check cost benefit ratio before getting them repaired.

8.1.6 Prevention of Tampering of Water Meters

In order to prevent tampering, following precautions (-precautionary measures) should be taken:

- 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.
- The water meters must be sealed properly.
- The water meters shall not allow reversible flow; it should register flow in forward directions only.
- The water meter dials should be easily readable without confusions.
- The lid (cover), glass of water meters must be made up of tough materials as per IS 779 and shall be replaced timely.
- The wiper or dial as far as possible is avoided.
- 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.
- Periodical inspection/checking at site are essential to ensure the proper working of meter.
- Special sealing arrangements may be necessary and provided for bulk meters whereby unauthorized removal of the meter from the connection can be detected. In addition to the 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.
- All repairs etc., should be maintained in a registrar about their status

8.1.7 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-

- The quality of water meter produced by manufacturer and it differs from manufacturer to manufacturer.
- the design of pipeline & fittings in line with meter;
- the workmanship & care when handling and installing the meter;
- the pattern of water passing through the meter;
- the type of supply of water whether it is continuous or intermittent;
- the meter maintenance, testing;
- 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, & especially 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.

8.1.8 Automatic Water Metering Systems

Water meter is a cash register of a water supply agency. 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 recorded by meter readers visiting consumers premises one by one and noting down the consumption reading of 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 through network. In other cases, key entry has been replaced by mark-sense card readers or optical scanners. The environment of meter reading usually is not favorable 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. In some consumers connect their electrical earth terminal to water utility pipe which endangers the safety of meter reader or premises are not accessible the meter reader. The solution to above difficulties is to install automatic system to read meters and process the results by computer.

The data can be captured by the meter readers from the meter in one of the following ways.

- Manual entry into meter books.

- Manual entry into portable hand held entry terminals or recorders.
- Direct electronic entry from meter registers either into portable data terminals or master data facility at remote location either by, Telemetry link or through telephone AMR meters.

8.1.8.1 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 up winds 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.

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 and from the unit to server. The meter readings themselves uploaded if the HDET is programmed in such a way. The meter reader follows the HDET's instructions. The Technology that is adopted is GSM technology. GSM technology is also used to automatic data capture allowing contact less identification using radio frequency.

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 near the meter either inside or outside consumer's premises.

In automatic reading the pulse from the mechanical meter is transmitted on to the dial gauge on the meter which shows the digital reading. This digital pulse will be transmitted to a receptor placed near to the meter either with chord or without chord. From the receptor the pulse is transmitted to a main data base remotely stationed through SIM card. It can be programmed either to transmit the pulse continuously or through a batch process at defined interval. The data can be retrieved and analyzed as required from the dumped data.

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.

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

8.2 Flow Meters

8.2.1 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 range ability 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 characterizes 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.

8.2.2 Types of Flow Meter

In water works, normally, following types of flow meters are used. They can be classified into:

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 (Rota meter)
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 flowmeter 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.

4. 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 solid (cover)s
- 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 160.

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

5. 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.

8.2.3 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 flow meter 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 flow meter 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 flow meter wherever present will get worn out in addition to the effect on overall accuracy of the flow meter 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.

8.2.4 Maintenance of Flow Meter

Modern development in the flow meter measurement is that in most of the equipment a self monitoring facility is provided with which the maintenance staffs monitors the health of the equipment. A number of instruments are enunciating the error conditions. As long as orifice, Pitot tube, Venturi & Annular flow meters 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 flow meter reading may vary upto 20%. Ultrasonic Flow meter and Magnetic flow meters 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 over speeding. Where deposits are to be expected in any flow meter, 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 flow meter, Ultrasonic flow meter 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 flow meter working especially differential pressure type, turbine meters.

8.2.5 Calibration of Flow Meters

Flow calibration is essential to

- i) Confirm performance of flow meter
- 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 cannot 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 flow meters provide laboratory calibration of the flow meters in their works. Some of the Government agencies also provide laboratory calibration is. Fluid Control Research Institute (FCRI), Palghat , Central Water & Power Research Station(CWPRS), Pune and Institute for Design of Electrical Measuring Instruments (IDEMI), Mumbai

8.2.6 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 flow meter to serve the purpose from performance point of view. If the flow meter 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 spiralling 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 – 8.3

Broad areas of applications: Table – 8.4

Performance factors: Table – 8.5

Installation constraints: Table – 8.6

Fluid property constraints: Table – 8.7

Economic factors: Table –8.8

Installation & maintenance: Table – 8.9

Common problems encountered: Table – 8.10

Applicable standards for flow meters : Table – 8.11

Table 8.3 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 8.4 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		
Annular	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; liquids (temp.>2000C) not applicable.

A: General liquid application (< 50 CP)

D: Large water pipes(> 500 mm dia)

B: Low liquid flows (<2 L/min)

C: Large liquid flows(> 1.7 x 10⁴ L/min.)

Table 8.5
PERFORMANCE FACTORS OF FLOW METER

Sr. no	Type of the flowmeter	Linearity %	Repeatability %	Rangeability	Pressure drop	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.	Annular	0.5%R to 1%R	± 0.05% R to ± 0.2% R	4 to 10:1	1/2	V _m
5.	Turbine	± 0.15% R to	± 0.02% R to ± 0.5% R	5 to 10:1		R
6.	Insertion Turbine	± 0.25% R to	± 0.1% R to ± 2% R	10 to 40:1	1-2	V _p
7.	Vortex	± 1% R	± 0.1% R to ± 1% R	4 to 40:1		R
8.	Insertion Vortex	± 2% R	± 0.1% R	15 to 30:1	1	V _p
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	V _p
11.	Doppler	No data	± 0.2% FS	5 to 25:1	1	V _m ,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
 T : Volume flow
 V_m : Mean velocity
 V_p : Point velocity
 % R : Percentage flowrate
 % FS : Percentage full scale
 NS : Not
 1 : Low
 5 : High

**Table 8.8
ECONOMIC FACTORS OF FLOW METERS**

Type	Installation cost	Calibration cost	Operation cost	Maintenance cost	Spares cost
Orifice	2-4	1			1
Venturi	4	1-4	2	3	3
Variable area	1-	2	2	1	1
Annular	2			2	2
Turbine			3	4	4
Insertion Turbine	2			2	3
Vortex	3	3	3	3	3
Insertion Vortex	2			3	3
Electromagnetic	3			3	3
Insertion Ele. Mag.	2			3	2
Doppler	1-	1	1	3	2
Transit time (time of flight)	1-3	3	1	3	2

Legends : 1: Low 5 :High

**Table 8.9
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 conditioning section	Maintenance free	Monitoring with error announcements	Electronic control functions & test simulator

Ultrasonic meter	Flanged connections or welding nipples, electrical installation.	Long conditioning section	Maintenance free	Signals for signal loss	-
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**Table 8.10
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
		Damaged impulse piping	D.P. type	Rectify impulse piping
2.	Unsteady reading : (oscillating)	β 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	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	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 8.11
APPLICABLE STANDARDS FOR FLOW METERS**

BS:7405:1991	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	Measurement of fluid flow by means of orifice plates and –R541 1967(E) 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 Venturimeters: 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 flowing compressible fluids
IS 14615 Part I	Measurement of fluid flow by means of pressure Differential devices– part I : Orifice plates, nozzles and venturi tubes inserted incircula.
IS 9115-1979	Method for estimation of incompressible fluid flow in closed conduits by Bend meters

8.3 Instrumentation

Presently there is a lack of instrumentation in rural water supply sector but in future more instrumentation is expected to be practiced in the following areas:

8.3.1 Level Measurement

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:

- Direct Method
- Inferential Method

A.DIRECT METHOD

Hook Type Level Indicator	Sight Glass	Float Type Indicator
Advantages 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
Disadvantage 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
5ses 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. INFERENCEAL METHOD

Hydrostatic Pressure Gauge Type & Pressure Bulb Type	Displacer Level Type	Electrical Method (Capacitance Type)	Ultrasonic
Advantages 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
Disadvantage 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
Uses 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

8.3.2 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.

- 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 freshwater.
- 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.

8.3.3 Pressure Measurement

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:

- Manometers
- Elastic Pressure Transducer
- 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
Advantages i. Simplest ii. Low cost	i. Zero reference setting is possible ii. Low cost	i. More sensitive ii. Low cost
Disadvantage 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
Uses 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 3kg/cm^2
- 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. Potentiometric pressure transducer
3. Capacitive pressure transducer
4. Variable reluctance pressure transducer
5. Piezoelectric pressure transducer

The advantages & disadvantages of electrical pressure transducers commonly used in water works are as follows.

Potential metric Transducer	Capacitive Pressure Transducer	Variable Reluctance Type
Advantages 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 linearity ii. Good repeatability iii. Low hysteresis iv. High sensitivity
Disadvantage i. Finite resolution ii. Wear out yearly iii. Noise signal is generated	i. Sensitivity changes with temperature	ii. Relatively large size iii. More nos. of components iv. More maintenance
Uses i. Where less accuracy is required	ii. Distribution network iii. In process instrumentation	i. Distribution network ii. In process instrumentation

8.3.3.1 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.

8.3.3.2 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 category

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 kinds of faults, 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' 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

Table 8.12

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
Electrical		Replace electrical/electronic subassemblies and perform calibration

8.3.4 Water Quality Parameter Monitoring

8.3.4.1 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.

8.3.4.2 Turbidity Meter

Online	Laboratory Type
<p>Advantages</p> <ul style="list-style-type: none"> i. Turbidity continuously monitored ii. Can be hooked up for automation iii. Can be set for giving alarm if minimum and maximum limits of turbidity are exceeded. iv. Human error in sampling is eliminated 	<ul style="list-style-type: none"> i. Low cost ii. Simple to use iii. Portable iv. Easy maintenance
<p>Disadvantages</p> <ul style="list-style-type: none"> i. High cost ii. High Maintenance is required iii. Periodical calibration is required iv. It is not portable 	<ul style="list-style-type: none"> i. Does not monitor continuously ii. Human error may encounter iii. Low accuracy
<p>Maintenance</p> <ul style="list-style-type: none"> i. Clean chamber & lens with fresh water ii. Microprocessor based instrument has self calibration facility which is useful for periodical calibration iii. Clean sources of light 	<ul style="list-style-type: none"> i. Clean sampling tube with fresh water ii. Bulb, standard sample tubes and lense should be cleaned with soft cotton iii. Calibrate before carrying out measurement iv. Calibrate with standard samples of 100 NTU, 10 NTU & 1 NTU or calibrate with formazin standard solution

8.3.4.3 pH Meter

Online	Laboratory Type
<p>Advantages</p> <ul style="list-style-type: none"> i. Continuously monitored ii. Can be hooked up for automation iii. Can be set for giving alarm for specified limits iv. Human error in sampling is eliminated 	<ul style="list-style-type: none"> i. Low cost ii. Simple to use iii. Portable iv. Easy maintenance
<p>Disadvantages</p> <ul style="list-style-type: none"> i. High cost ii. Periodical calibration is required iii. High maintenance cost (replacement of electrodes) iv. It is not portable 	<ul style="list-style-type: none"> i. Does not monitor continuously ii. Human error may encounter iii. Low accuracy

Maintenance i. Clean electrode with soap water or clean with 5% concentrated H ₂ SO ₄ and 6% concentrated H ₂ O ₂ ii. Calibrate periodically with standard solution of 4 pH and 7pH iii. Replace electrodes if dried up	i. Clean sampling electrode with distilled water ii. Calibrate the instrument with three standards samples i.e. 4 pH, 7 pH & 9.2pH iii. Prepare standard samples from readily available capsules iv. Calibration may last from 4 days to 7 days
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8.3.4.4 Residual Chlorine meter

Online	Laboratory Type (Lovibond Type)
Advantages i. Continuously monitored ii. Can be hooked up for automation iii. Can be set for giving alarm for specified limits iv. Human error in sampling is eliminated	i. Low cost ii. Simple to use iii. Portable iv. Easy maintenance
Disadvantages i. High cost ii. Periodical calibration is required iii. High maintenance cost (replacement of membrane) iv. It is not portable v. It requires electricity	i. Does not monitor continuously ii. Human error in sampling may encounter iii. Low accuracy
Maintenance i. Clean membrane if it gets clogged ii. If membrane is damaged replace it with new one iii. Fill up electrolyte if necessary iv. Calibrate it using DPD.	i. Clean tubes with distilled water ii. Calibration is not required as it being a comparator

8.3.5 Automation

8.3.5.1 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 advanced ones.

8.4 Telemetry and SCADA Systems

8.4.1 Manual Monitoring

Normally the Managers of O&M of water scheme 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 line department 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.

8.4.2 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 decision. In 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.

8.4.2.1 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.

8.4.2.2 Processing data from telemetry

The meter readings from reservoirs are 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.

8.4.3 SCADA Systems (Supervisory Control and Data Acquisition)

Supervisory Control and Data Acquisition (SCADA) systems provide control functionality and alarms at rural water supply scheme sites which in many cases are very remote. These systems were often used to solve single problems such as reducing power cost, or improving control of a particularly complex operation. The installation of SCADA has subsequently been seen as a means to satisfy a variety of increasing pressures such as consumer demands, regulatory requirements, and to also satisfy the need to reduce operational costs. The deployment of SCADA systems has been extended to cover large rural water supply schemes and has been found very effective.

An important challenge to the commercial success of the organization is to harness the data collection power of the SCADA systems to provide a wealth of operational information to all levels of the organization. Past systems that have been installed in some of the water treatment plants have failed to meet expectations regarding data availability. This has primarily been attributed to difficulties associated with merging traditional engineering and new IT methodology, and a lack of system openness in data interconnectivity and communications.

8.4.3.1 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, analyzed 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 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 threshold values of residual chlorine in the distribution systems.

8.4.3.2 Analysis of Data from SCADA

SCADA systems can be designed to analyze 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 analyzed. 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.

8.4.3.3 Limitation 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.

8.4.3.4 Remote Terminal Units (RTU)

A Remote Terminal Unit (RTU) is a microprocessor-controlled electronic device that interfaces objects in the physical world to a SCADA (supervisory control and data acquisition system) by transmitting telemetry data to the system and/or altering the state of connected objects based on control messages received from the system. Modern RTUs are usually capable of executing simple programs autonomously without involving the host computers of SCADA system to simplify deployment, and to provide redundancy for safety reasons. An RTU in a modern water management system will typically have code to modify its behavior when physical override switches on the RTU are toggled during maintenance by maintenance personnel. This is done for safety reasons; a miscommunication between the system operators and the maintenance personnel could cause system operators to mistakenly enable power to a water pump when it is being replaced, for example.

Further the following preferences relevant national & International Standards on meters are available:

- IS 779-1994: Water meters (Domestic type) - Specification (Sixth revision).
- IS 2373-1981: Specifications for water meters (Bulk type) (Third revision)
- IS: 6784: Testing of Water meter⁴.
- 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.
- 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

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. The Ministry of Drinking water and Sanitation has launched a National Drinking Water Quality monitoring and surveillance programme in 2006. The relevant guidelines and procedures including protocols shall be followed by the states/UTs.

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 diarrheal and other water borne and water related diseases 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 contamination.
- **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 measurements of betterment of water supply.

9.5 Planning and Implementation

Systematic planning, keeping in view the fundamental objectives, is necessary for successful implementation of drinking water quality control program.

9.6 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.

9.7 Legal and Institutional Basis

9.7.1 Legislative Framework

Laws and bylaws prevailing in local bodies should be strictly implemented.

9.7.2 Institutional Framework

Water-quality surveillance requires an institutional framework that reflects its objectives and functions and gives key responsibilities to the relevant agencies. At the center of this framework major responsibility for monitoring and surveillance is shared between two agencies or more whose activities should be mutually exclusive and complementary. Inter sectoral 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.

9.8 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 climatologically conditions.
- Communication and transport facilities available.

9.9 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 also 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 them to 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 delivered 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, village water supply committee (vwsc) etc. Local government should ensure that the agency that supplies drinking water to the area complies with the quality standards.

9.10 Support Structure

Monitoring and surveillance programme requires laboratory network, offices, transport, financial support and adequate qualified manpower.

9.10.1 Community Based Monitoring and Surveillance

Community participation is an essential component of the monitoring and surveillance framework. As the primary beneficiaries community can play a vital 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 hygienic 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 reporting system.

Department or water supply agency should help in providing necessary training to community of water committee or health committee who can supervise the task. The community participation includes:

- Assisting field workers in water sample collection, including sample location points, locating existing damaged net works, causing/likely to cause contamination of drinking water.
- Assisting in data collection.
- Monitoring water quantity and reporting the findings to surveillance staff regularly.
- Ensuring proper use of water supply.
- Setting priorities for sanitation, hygiene and educate community members.
- Undertake 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.

9.10.2 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

9.10.3 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 categorized in two stages; Basic laboratories, State/Regional laboratories. (Annexure 9.3)

9.10.4 Financial Support

Sufficient allocation of fund should be made for maintaining or monitoring water quality and its surveillance, keeping in view, quantum of water supplied, geographic and area covered, etc. Cost of surveillance of quality of water supplied in rural areas in comparison with urban areas will be on higher side. The habitations are in scattered locations and some of them are located in forests, which requires special care.

9.10.5 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.

9.11 Surveillance Action

Surveillance action plan 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.

9.12 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.

9.12.1 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 wellbeing 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 degree of contamination.

9.12.2 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.

9.12.3 Sanitary Inspection Report

The sanitary inspection report shall cover the following:

1. Identify potential sources and sources 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.

9.12.4 Work Chart For Sanitary Survey

For collection of adequate information and follow-up work, proper work chart should be developed 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 required.
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 follow specific guidelines.

8. Water samples should be analyzed immediately for residual chlorine and thermo tolerant coli form, or transported quickly to laboratory in iced boxes.
9. Complete the sanitary report on site, and send it immediately to concerned authority for follow-up remedial action if needed.
10. Undertake appropriate small repairs at the time of survey in remote areas such as changing of washer changing etc, for leakage of taps.
11. For pictorial forms, each risk point should be circled and given to member of water committee to follow-up action.

9.12.5 Time and Frequency

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.

9.13 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 guiding values regarding physical and chemical parameters, kindly refer to Manual on Water Supply and Treatment, III Edition, May 1999.

9.14 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.

9.14.1 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. Quantity Along with quality 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 since in case of inadequate quantity of water supply, community may use alternate source of water, some of which may not be safe and affect the public health.

9.14.1.1 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 stand posts, and by point sources such as wells and hand pumps.

Therefore, it is necessary to undertake wide 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

9.14.1.2 Continuity

In most of the piped water supply system, continuous 24 hrs water supply is not possible 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 in-pipe recontamination due to leakage.

Household storage is necessary for intermittent water supply, which may cause 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.

9.15 Data Interpretation

Assessment of sanitary situation as well as microbiological analysis data together, gives an overall picture of health risk assessment.

9.15.1 Assessment of Sanitary Situation

Sanitary surveillance data generates the information regarding specific areas of risk to the water supply. Such information can be used in various ways to facilitate and to the improve 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 site or at local level.
3. Identify recurrent problems, which require repeated remedial action and define strategies, which provide a permanent solution to the persistent problem, which may need external assistance.
4. Pinpoint the importance of adequate training requirement related to water supply practices in the locality or in the concerned region..

9.15.2 Assessment of water microbial 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 colour 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 not chlorinated. Samples taken at various critical points in the whole system of piped water supply, sometimes may vary 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 also be obtained for supporting 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

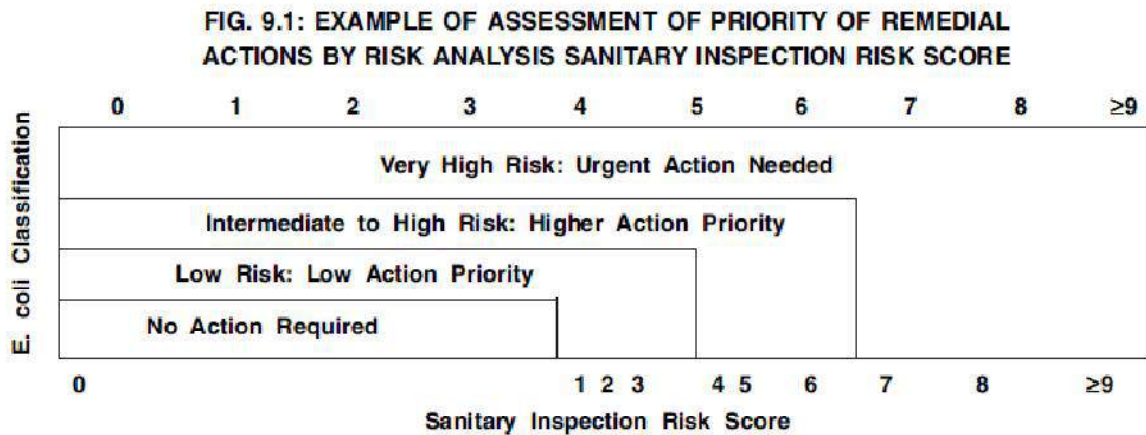
Count per 100 ml	Category and Colour code	Remarks
0	A (blue)	In conformity with WHO guidelines
1-10	B (green)	Low risk
10-100	C (yellow)	Intermediate risk
100-1000	D (orange)	High risk
> 1000	E (red)	Very high risk

9.15.3 Risk Assessment

Microbiological analysis represents the single time moment whenever sanitary inspection considering previous risk score as well as the present assessment. Therefore, the examination of the faecal grading together with the sanitary inspection risk assessment, gives a meaningful risk outcome, to take further suitable action.

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



9.16 Use of Field Water Testing Kit (FTK)

The field water testing kit is a simple device, which can be used for testing some critical water quality parameters in the field as it gives a instant first-hand information on the quality of water. Whenever 100% accuracy is needed, laboratory test shall be carried out. This water testing kit can be used for regular Water Quality Monitoring Programs to be conducted at habitation level. Panchayat level functionaries, NGOS and students of even 7th and 8th standards can easily do the experiments using this kit. The details of water sources and the quality of water in many habitations can be collected and the data computerized at G.P. level. The data will be much useful in planning and formulating various water supply schemes and will be useful for proper maintenance of rural water supply schemes. The kits can be used in Schools to impart

awareness on water quality and help to develop a good practice and scientific culture among the students.

9.16.1 Water Testing Methodology

For testing the water in the field, the following aspects have to be clearly understood.

- Sampling procedures.
- Testing procedures.
- Reporting.

9.16.1.1 Sampling Procedure: (to be included as annexure)

- Before sampling, the source should be flushed adequately.
- For hand pump sources, before collecting the water, the water should be pumped for at least three to five minutes to clear all dirt, turbidity and slime.
- Water from wells should be taken in the middle at mid depth.
- For lakes, rivers and dams, the water should be collected near the off take point.
- The water should be collected after clearing the suspended and floating matter.
- Water for chemical examination should be collected in a clean white 250 ml capacity leak proof polythene container.
- Before collection of sample the container should be washed, rinsed with the water to be sampled for at least two to three times.
- The water should be then filled completely in the container without leaving any air space.
- Place a polythene sheet (10x10cm) over the cap and tie it with a rubber band or twine thread to avoid any leak
- Write the field code number (sample ID) on the container. The field code number and related source details should be separately recorded in a note book.
- The testing of sample should be completed within 12 hrs. from the time of collection.

9.16.1.2 Water Testing Procedure

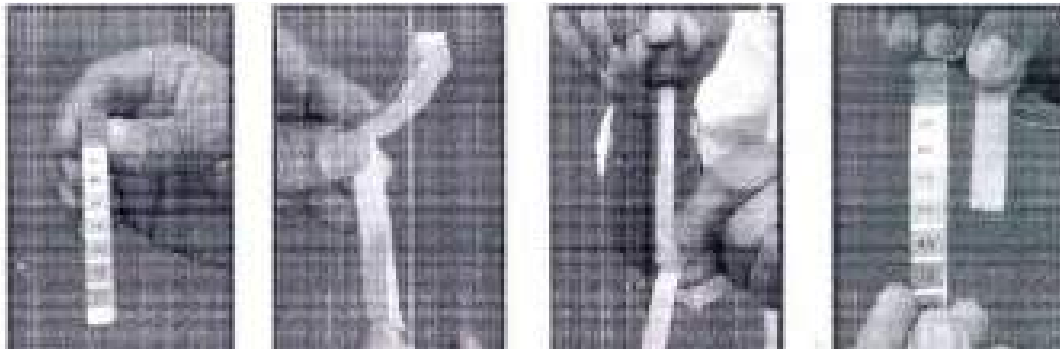
- Pour 10-20 ml. of water into the 100 ml polypropylene / titration cup.
- By observing the water in the cup, record qualitatively the appearance, odor and turbidity.
- Using the pH paper, record the pH also.

1. Appearance: Record appearance as follows: Colorless & clear/ Brownish/ slightly brownish / Greenish/ slightly greenish/ Blackish/ slightly blackish / slightly whitish / Turbid etc.

2. Odor: Record odor as follows: None/ Soil Smell/ Algal Smell/ Objectionable Odor/ Slightly Objectionable Odor/ Rotten Egg Smell etc.

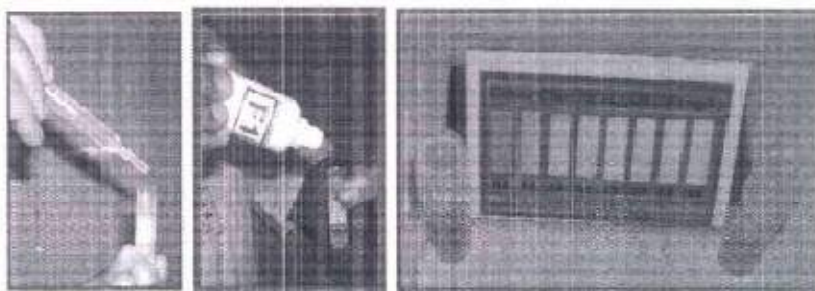
3. Turbidity: Record Turbidity as follows: No turbidity/ slightly turbid/Moderately turbid/Highly turbid

4. PH: Litmus paper are used to measure pH value of water. Tear a portion of the litmus paper and hold it by your fingers. Using the ink filler add one drop of water sample on the paper. Wait for 10 seconds. The color change taking place on the wet portion of the litmus paper is observed and compared with the pH chart provided in the cover page of litmus paper booklet. Record the pH value.



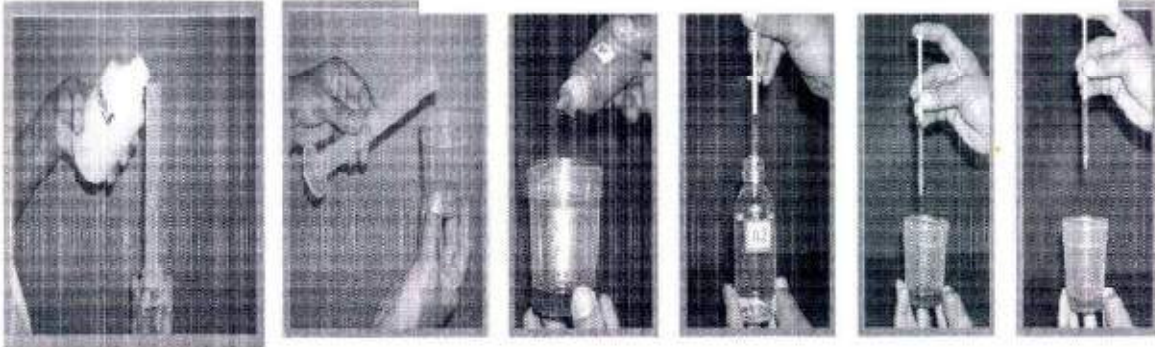
5. Alkalinity: Using the measuring cylinder, measure 20 ml of water sample and pour it into the clean titration jar. Add 5 drops of 'A1 liquid. The water turns bluish green. Using the '1 mL syringe' provided in the kit, add 'A2' liquid. At the end point, the color of water changes into yellow or Orange. Record the number of divisions for which the 'A2' liquid has been consumed to reach the end point. Calculation: Alkalinity mg/L = No. of Divisions of 'A2' added x 10

6. Hardness: Using the measuring cylinder, measure 20 ml of water sample and pour it into the clean titration cup. Add 5 drops of 'H1' and then 5 drops of 'H2' liquids provided in the kit. The water in the titration cup turns Pink in color. Using the '1 mL syringe' add 'H3' liquid in drops. At the end point, the color of water changes into Bluish color. Record the number of divisions for which 'H3' liquid has been consumed to reach the end point.



7. Chloride: Using the measuring cylinder, measure 20 ml of water sample and pour it into the clean titration cup. Add 5 drops of 'C1' liquid. The water turns yellow in color. Using the '1 mL syringe' add 'C2' liquid in drops. At the end point, the color of water changes to slight reddish in

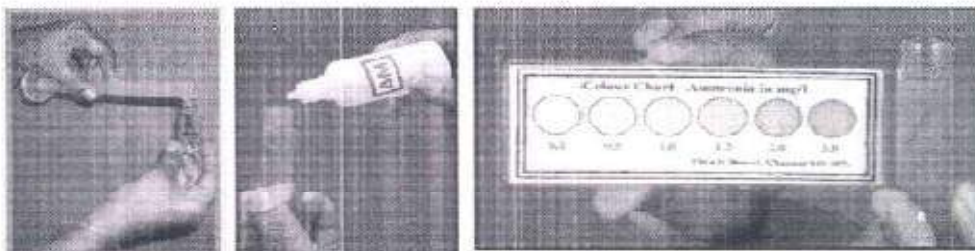
color. Record the number of divisions for which 'C2' liquid has been consumed to reach the end point. Calculation: Chloride mg/L = No. of Divisions of 'C2' liquid x 10



8. Total Dissolved Solids (TDS): The approximate value of TDS can be arrived at by the following calculation: Calculation: TDS mg/L = (Alkalinity + Hardness + Chloride) x 1.2

9. Fluoride: In the 1.5 ml polypropylene tube, add 1.0 mL sample water. Add 5 drops of 'F1' liquid. Mix. Gently. Compare the colour with "fluoride chart" provided and record the fluoride value.

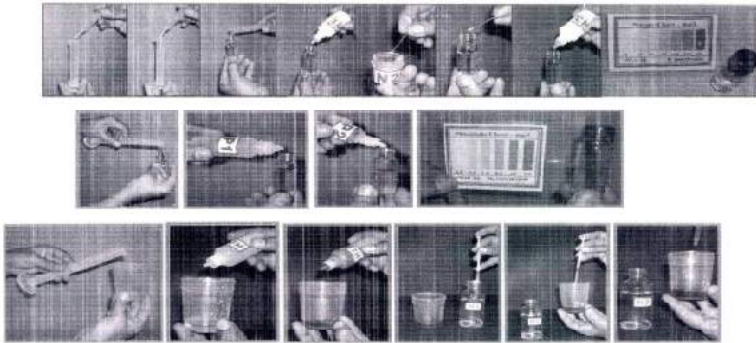
10. Ammonia: In the small glass bottle given, take 10 ml of water sample. Add 5 drops of 'Ammonia' liquid. Gently shake the bottle. If there is no ammonia, the color will not change. If ammonia is present, the water turns yellow, Compare the "yellow colour developed with the 'ammonia chart' provided and record the ammonia value.



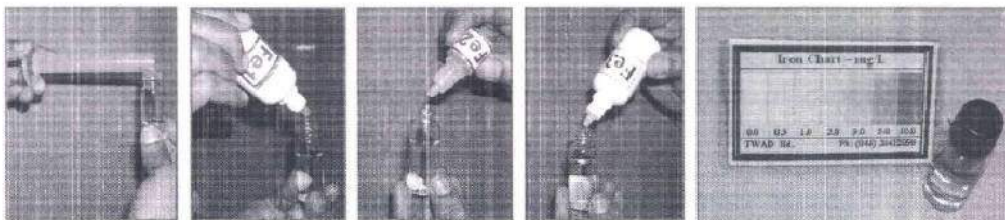
11. Nitrite: In the small glass bottle given, take 10 ml of water sample. Add 5 drops of 'N02' liquid. Gently shake the bottle. If there is no nitrite, the color will not change. If nitrite is present, the color of water will change into pink. Compare the 'pink' color with the 'Nitrite (N02) chart' provided and record the nitrite value

12. Nitrate: In the 10 mL measuring cylinder, take 1 mL of water sample. Add 9 mL distilled/bottled/mineral water and make up to 10 mL. Transfer this to the 10 mL glass bottle.

Add 5 drops of 'N1'. Add a small pinch of 'N2'. Mix. Add 5 drops of 'N3'. Wait for 2 minutes. If there is no nitrate, the color will not change. If nitrate is present, the color of water will change into pink. Compare the 'pink' color with the 'Nitrate chart' provided and record the nitrate value.



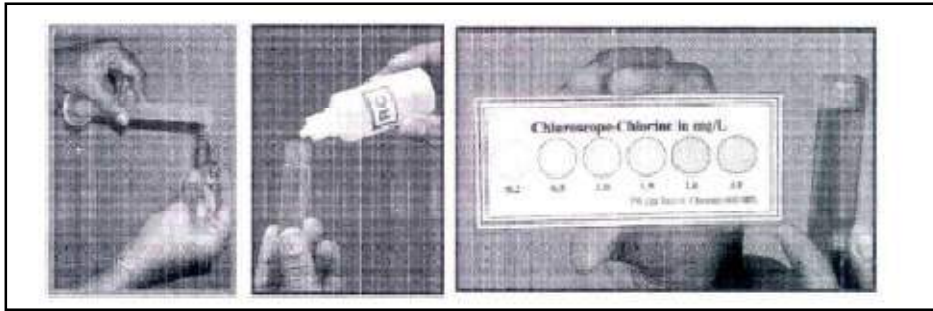
13. Iron: In the 10 mL glass bottle, take 10 ml of water sample. Add 5 drops of 'Fe1' liquid and then 1 drop of 'Fe2' liquid. Mix. Add 5 drops of 'Fe3' liquid. Mix. Wait for 2 minutes. For turbid samples wait for 5-10 minutes till a persistent colour develops. If there is no iron, the colour will not change. If iron is present, the colour of water will change into orange red. Compare the colour with the 'Iron chart' provided and record the value.



14. Phosphate: In the small glass bottle given, take 10 ml of water sample. Add 5 drops of 'P1' liquid. Gently shake the bottle. Then add 1 drop of 'P2' liquid. Again gently shake. If there is no phosphate, the color will not change. If phosphate is present, the color of water will change into blue. Compare the 'blue' color with the

'Phosphate chart' provided and record the phosphate value.

15. Residual Chlorine: In the small glass bottle given, take 10 ml of water sample. Add 5 drops of 'RC' liquid. Slightly shake the bottle. If there is no residual chlorine, the color will not change. If residual chlorine is present, the color of water will change into yellow. Compare the yellow color with the 'chlorine chart' provided and record the residual chlorine value.



16. E.Coli/Fecal Coliform: The test is conducted using H₂S vials (H₂S vials have to be procured separately from the market). The water should be added up to the mark in the H₂S vial. After screwing the cap, keep the vial for 24 hours. After 24 hours observe any of the following changes.

- i) Black color = High level of contamination
- ii) Turbid & brownish = Moderate level of contamination
- iii) No change in the honey brown color = Absence of E.-Coli Fecal Coliform

9.16.1.3 Reporting:

The test results should be compiled in the following report form:

Test Report
Source Details

Location and address of the source Location and address of sampling point Name of Village/Habitation, Name of Panchayat, Name of Block ,Name of District ,Type of source Type of scheme, Open well/ Bore well/ Infiltration well/ Lake/ Dam/ Hand pump/ Power pump Surface, water etc. Collected by (Name, designation & Office)

- 1) Appearance Sample ID:
- 2) Odor
- 3) Turbidity
- 4) Total dissolved solids (maximum)
- 5) pH
- 6) Alkalinity as CaCO₃, (maximum)
- 7) Hardness as CaCO₃ (maximum)
- 8) Chloride as Cl (maximum)
- 9) Fluoride as F (maximum)
- 10) Ammonia * as NH₃
- 11) Nitrite** as NO₂
- 12) Nitrate as NO₃, (maximum)
- 13) Iron as Fe (maximum)
- 14) Phosphate** as PO₄

15) Residual chlorine (minimum)^{***} as Cl_2 0.2 mg/ L

* No guideline value prescribed; however an ammonia level of greater than 1.0 mg/L indicates pollution taking place to the source.

** No guideline value prescribed; traces of nitrite and phosphate indicate pollution.

*** To ensure effective disinfection, minimum residual chlorine of 0.2 mg/L should be present.

Report: The water shall be indicated as bacteriologically and potable/non potable.

ANNEXURE 9.1

WATER RELATED DISEASES AND PREVENTIVE STRATEGIES

Classification	Transmission	Examples	Preventive Strategies
Water-borne (Water-borne diseases can also be washed)	Disease is transmitted by indigestion (Faecal – Oral route)	<ul style="list-style-type: none"> • Diarrhoea • Cholera • Typhoid • Hepatitis (A & E) 	<ul style="list-style-type: none"> - Improve quality of drinking water. - Prevent casual use of other unimproved sources. - Improve sanitation.
Water washed (Water scarce)	<ul style="list-style-type: none"> • Infections of the intestinal track. • Skin or eye infections. • Infections caused by lice or mites. 	<ul style="list-style-type: none"> • Scabies • Trachoma • Conjunctivitis • Amoebiasis • Giardiasis 	<ul style="list-style-type: none"> - Increase water quantity. - Improve accessibility and reliability of domestic water supply. - Improve hygiene. - Improve sanitation.
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"> • Guinea worm • Schistosomiasis 	<ul style="list-style-type: none"> - Decrease need of contact with infected water. - Control vector host populations. - Improve quality of water (for some types) - Improve sanitation (for some types)
Water related Insect-vector	Spread by insects that breed or bite near water.	<ul style="list-style-type: none"> • Malaria • Filariasis • River blindness 	<ul style="list-style-type: none"> - Improve surface water management. - Destroy insect breeding sites. - Use mosquito netting. - Use insecticides

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"> - To ensure that the drinking water is free from health hazards. - To find out what is wrong - Assist in setting things right for both rural and urban systems.
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"> - To provide water in sufficient quantity and potable quality to the population at sufficient pressure.
Pollution Control Board, Central/State	Controlling pollution at water source	<ul style="list-style-type: none"> - To protect the raw water sources from being unduly polluted at Country/State level.

ANNEXURE 9.3

**SUGGESTED WATER QUALITY MONITORING LABORATORY
NETWORK AND THEIR ACTIVITIES**

S.N.	Level	Activities
1.	Basic laboratory 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.	State/Regional level laboratory	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.	Basic Laboratory a. Primary Health Center/Village Level b. Municipal/District Level (Plant capacity >200 mld)	1. Lab. Assistant/Technician 2. Lab. Attendant 1. Chief Analyst 2. Chemist 3. Bacteriologist 4. Assistant Chemist 5. Lab. Assistant/Technician 6. Lab. Attendants 7. Driver 8. Helper	For routine bacteriological and physico-chemical tests, the samples should be sent to municipal/district level laboratory periodically. Wherever Water Treatment Plant Laboratory is existing
2.	State/Regional Level Laboratory	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>Basic Laboratory</p> <p>a. Primary Health Center/Village Level</p> <p>b. Municipal/District Level (Plant capacity >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 (< 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.	State/Regional Level Laboratory	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

ANNEXURE : 9.6c(1)

SUGGESTED MINIMUM SAMPLING FREQUENCY FOR WATER QUALITY CONTROL MONITORING

S.L.	Size and Source	Frequency	PARAMETERS					Heavy Metals & Pesticides	Problem Parameters As, Cr ⁶⁺ , 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				√				
		iii. Quarterly		√	√				√	
	b. Ground Water (Hand Pump)	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							Problem Parameters As, Cr ⁶⁺ , Fe & Mn, Fluoride	Remarks
			Residual Chlorine	Physical	Chemical	Bacteriological	Biological	Heavy Metals & Pesticides			
1	2	3	4	5	6	7	8	9	10	11	
1.	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.	c. Ground Water (Tube Well, Sanitary Well, Bore Well)										From source and distribution system
		i. Weekly	√								
		ii. Quarterly				√					
		iii. Twice a year		√	√				√		In summer & rainy season
	d. Ground Water (Hand Pump)	Annually		√	√	√			√		Preferably in summer
3.	e. Ground Water (Tube Well, Sanitary Well, Bore Well)										From source & distribution system
		i. Weekly	√								
		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 & 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	2	3	4
Open dug wells	Pollution usually expected to occur	<p>a. Clean well if necessary and disinfect with bleaching powder.</p> <p>b. Boiling of drinking water, use of chlorine tablets or bleaching powder and/or filters in the home is recommended.</p>	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	<p>Confirm bacteriological quality analysis and if necessary, recommend use of disinfectant (Bleaching powder) or</p> <p>a. Recommend use of boiling water, chlorine tablets or bleaching powder and/or filters in the home</p> <p>b. Confirm bacterial quality</p> <p>c. Conduct a detailed sanitary inspection to ensure effectiveness of remedial measures against shortcomings found earlier</p>	<p>Eliminate pollution source and/or repair tube wells and/or hand pumps if found necessary in sanitary inspection.</p> <p>a. Promote community education and participation.</p> <p>b. Feedback information on remedial action and sanitary survey results to the water supply agency, to check whether the remedial actions followed are appropriate.</p>
Untreated pipe water supply	Findings of sanitary inspection unsatisfactory	<p>Confirm bacteriological quality and if necessary recommend boiling of water or use of disinfectant or filters</p>	<p>Eliminate pollution sources and/or repair systems if found necessary in sanitary inspections</p>
	Unsatisfactory bacteriological quality of water at source	<p>a. Disinfect (chlorinate) water supply if feasible, recommend boiling or use of chlorine tablets at home</p> <p>b. Conduct a detailed sanitary inspection and correct the shortcomings found</p>	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>a. Ensure 0.5 mg/l free residual chlorine at tail end. Recommend boiling and use of chlorine tablets b. Conduct a detailed sanitary inspection of whole water supply 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. b. Ensure routine sanitary inspections and feedback information to the water supply agencies.</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>a. Eliminate pollution source b. Frequent and improved supervision of the whole system is necessary, careful operations and maintenance is essential, especially for intermittent systems. c. Ensure routine sanitary inspections and feedback information to the water supply agencies.</p>

Chapter – 10

WATER REVENUE (BILLING & COLLECTION)

10.1 Introduction

Revenue management system is an important and back bone of aspect of Water supply System which governs the financial sustainability. Apart from fixing of viable tariff structure, billing and its collection play an important vital role.

10.2 Tariff Fixation

The water consumption charges to be fixed by the water agency / PRIs., taking into account the ability of the system to meet the expenditure on the following heads:

- O&M Cost (Recurring and non- recurring) & Establishment Cost.
- Depreciation.
- Debt Services & Doubtful Charges.
- Asset replacement fund.
- Power charges.

The Tariff structure shall be revised periodically/annually.

10.3 Categories of Consumers

The consumers are generally categories into Domestic, Commercial and industrial. These major categories are again sub categorized. The domestic consumers are the privileged class in terms of supply of water for their healthy existence and major contributor of revenue. The other categories are sub-classified based on their usage and the norms of the supply organization. The tariff will different for three categories. The total revenue shall consumerate for the various factors stated the above paragraph. The revenue tariff shall be prepared based on the above factors and earlier statistical data by a committee.

10.4 Methods of Water Charges

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

1. Metered consumption of water.
2. Non-Metered System:
 - Fixed charge per house per month (depending upon the size of the house) or per connection per month or

- Fixed charge per family per month or per tap per month/per house or
3. Bulk supply charges will be charged at minimum charges even though the consumption is less than minimum quantity.

Note: Charges for APL and BPL family may be determined separately subsequently

10.5 Water Billing Process

The various stages in 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 either metered or unmetered the billing system needs three major entries in 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. are also tagged to the Consumer number.

- Data for each billing cycle - This data will be entered for every consumer and for each billing cycle and will be used for calculating the demand of that billing cycle. Various data items which need to be stored are Consumer number, date 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 bills raised and issued. This data will be entered after the payment is made. 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.

10.5.1 Data Gathering

The Bulk consumer are classified into a number of categories such as Gram Panchayath, Nagara Palikas Municipalities, Municipal corporations, enroute industries and other establishments etc., The prime responsibility of meter reader/meter clerk will be to gather all the data related to the water connections in the assigned area, to collect all the data related to new connections/ disconnection or any change in the category. The billing system can provide very important feed back as far as water/revenue losses concerned including unaccounted for water (UFW).

10.5.2 Distribution of Bills to Consumer

Under Mission Baghiratha the G.P. Ngara Palika, Municipalities, Municipal Corporations, Bulk and other establishments will be served the bills based on their consumption.

In the case of existing system, the Multi Village Water Supply Scheme, the water agency / VWSC / agency charged for O&M will raise the bill every month to each of the Panchayat based on the bulk water meter reading. The Panchayat will pay the water charges to the agency / VWSC and inturn will collect the water charges from the consumers In the case of Single Village water supply scheme, the Panchayat / VWSC will collect water charges from the consumers and utilized the revenue generated for the maintenance of the scheme.

The distribution of bills in rural area can be done by operators specially authorized for this purpose or meter readers and bills can be distributed at the time of meter reading along with the receipt for previous payment if collected in cash by him for the next round.

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

10.5.3 Payment of Bills by Consumer

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

- Counters at G.Ps. / VWSC office.
- At bank / banks authorized for accepting payments.
- Door to door/on the spot recovery by authorized person.
- By cheque through drop boxes.

- Through societies authorised by government, such as cooperative societies.
- On line payments.
- Automatic kiosk.

10.5.4 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.

10.5.5 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 may also be more efficiently carried out by the computerized system.

10.5.6 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/monthly and for the metered system the billing could be bi-monthly/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.

10.5.7 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.

Chapter – 11

WATER AUDIT & LEAKAGE CONTROL

11.1 Introduction

Water Audit of a water supply system can be defined as the assessment of the capacity of total water produced by the Water Supply Agency/village water supply and sanitation committee (VWSC) and the actual quantity of water distributed throughout the area of service by the Agency/VWSC, thus leading to an estimation of the losses otherwise known as non-revenue water/ un-accounted for water (NRW/UFW) and it is the expression used for the difference between the quantity of water produced and the quantity of water billed or accounted for. (Table 11.1)

Table 11.1 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				

1.2 Definition of Water Audit

Water audit in a water supply system is similar to energy audit and determines the amount of water lost from source to a end user through distribution system including losses at users' taps due to leakages and other reasons such as theft, unauthorized or illegal withdrawals from the systems and thus, these loss costs the utility. Complete water audit plan gives a detailed profile of a water supply system including its distribution system and water users, thereby facilitating easier and effective management of the resources with improved reliability. It helps in correct diagnosis of the problems faced and suggests optimum solutions.

It is also an effective tool for realistic understanding and assessment of the system's performance level, efficiency of the service and the adaptability of the system for future expansion & rectification of faults during modernization. Elements of water audit include a record of the amount of water produced, total water supplied, water delivered to metered users, water delivered to unmetered users, water losses and suggested measures to address water loss (through pinpointing & minimizing leakages and other unaccounted for water losses).

Generally, the following are the steps of water audit exercise:

- To conduct a water audit of the system and water accounting practices etc. and its validation
- Preparation of worksheets and sample calculations for each event of the water audit
- To identify, measure and verify all water consumption and loss
- To identify and control apparent losses in metering and billing operations, and recover missed revenues
- To implement a leakage and pressure management program to control real losses, conserve water and contain costs
- Develop plans to assemble the proper resources, information and equipment to launch a reliable sustained accountability and loss-control program
- Prepare action plan for setting short, medium and long-term measures and estimate return on CAPEX cost including over heads.

Leak detection program is a tool, help in minimizing leakages and tackling small problems before they scale-up to major ones. These programs lead to (a) reduced water losses, (b) improved reliability of supply system, (c) enhanced knowledge of the distribution system, (d) efficient use of existing supplies, (e) better safeguard to public health and property, (f) improved public relations, (g) reduced legal liability (h) reduced disruption, thereby improving level of service to consumers, and (i) improved financial performance.

11.3 Application of Water Audit

Application of water audit process may consist of various steps viz. water audit, interventions for water conservation/leakages/ losses control, regulatory framework & community involvement and evaluation of effectiveness of interventions undertaken.

11.3.1 Water Audit Methodology

A reliable water audit methodology was developed jointly by the American Water Works Association (AWWA) and International Water Association (IWA) in year 2000. The water balance of this methodology is given below and shows schematically the various components in which water volumes (typically one year) are tracked.

System Input Volume (corrected for known errors)	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption (including water exported)	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Water (NRW)
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorized Consumption	
			Customer Metering Inaccuracies	
			Data Handling Errors	
		Real Losses	Leakage on Transmission and Distribution Mains	
			Leakage and Over-flows at Utility's Storage Tanks	
			Leakage on Service connections up to point of Customer metering	

The water balance tracks – from left to right – how a water agency supplies water from source to consumer and provides the format for the agency to quantify amounts of billed and lost water. Fundamental to the AWWA/IWA Water Audit Methodology is the distinction that treated drinking water goes to two places: (1) authorized consumption by consumers (its intended use) and (2) a portion to losses (through inefficiencies). The component of losses can be categorized into two broad types:

Apparent Losses are the “paper” losses that occur in utility operations due to consumer meter inaccuracies, billing system data errors and unauthorized consumption. In other words, this is the water that is consumed but is not properly measured, accounted or paid for. These losses cost utilities revenue and distort data on consumer consumption patterns.

Real Losses are the physical losses of water from the distribution system, including leakage and storage overflows. These losses inflate the water utility’s production costs and stress water resources since they represent water that is extracted and treated, yet never reaches beneficial use.

11.4 Planning And Preparation

Planning and preparation shall include collection of the data, element and preparation of suitable plans for the distribution centers and other locations for the installation of the flow meters. Also included within this shall be the confirmation of flow rates at the bulk meter locations which can be carried out by portable flow meters.

(a) Preliminary Data Collection

(b) Pipe Location Survey

11.4.1 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.

11.4.2 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 points (e.g. raw water inlet, clear water outlet, main distribution branch, SRs etc.).
- All tube wells/ sources which supply the system directly.
- Major transfer mains which are expressly required for audit.

At distribution centers, 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 11.1

The size of the meter can be determined by flow of water, size of pipe line and Meter manufacturer's specifications having consideration of the following :

- Number of properties served.
- Per capita consumption (liters/person/day).
- Population density.
- Meter manufacturer's specifications
- Hours of supply-Meter sizes must be decided according to current supply hours or size of the pipe. 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 that 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.

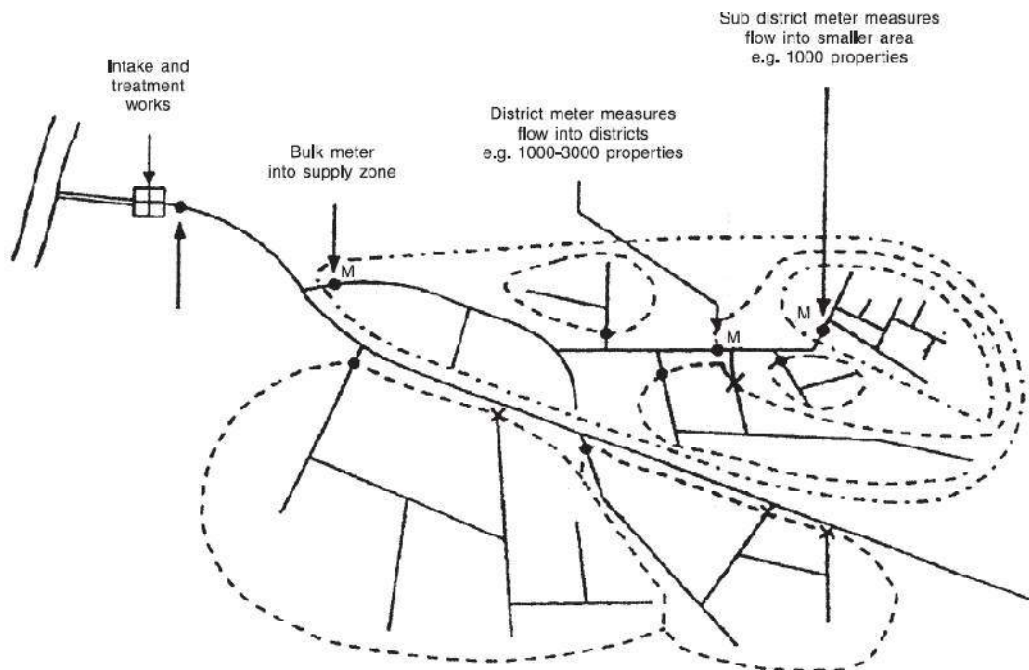


Fig 11.1

11.5 Monitoring of the Production System

The assessment of the leakages through the various features of the water supply system should be undertaken. These will include raw water transmission system, reservoirs, treatment plant, clear-water sump, transmission system, inter-zone transmission system and tube wells/ sources of water supply.

11.5.1 Transmission System

The methodology adopted to make an assessment of the level of losses in the transmission system is to provide bulk meter at both ends of each section of the main being monitored and monitoring both inflow and outflow of the section. 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 tapings. Flow through this meter will indicate the leakage in the main between the two closed valves. It must be ensured that the downstream 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.

11.5.2 Reservoirs

To reduce or avoid any leakage or consequent contamination in reservoirs, the reservoirs should be periodically or as per necessity, 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 manufacturer's instruction)
- Float gauges
- Submersible pressure & level transducers (as per manufacturer's instruction).

11.5.3 Treatment Plant

The losses in treatment plant can be monitored by measuring the inflow into the plant and out flow 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.

11.6 Monitoring of Distribution System

Distribution system comprises of service reservoirs, distribution mains & distribution lines. Metered, unmetered (flat rate), public stand posts, hydrants, illegal connections Water audit of the distribution system consists of:

- Monitoring of flow of water from the distribution point into the distribution system.
- Consumer meter sampling i.e. Water Monitoring Area (WMA) and estimating metered use by consumers, if any.
- Estimating losses in the appurtenances and distribution pipe line network including consumer service lines.

11.6.1 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 (Water Monitoring Area) flows out into another zone a valve or meter is to be installed at this outlet point.

11.6.2 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 viz-a-viz water consumption can be evaluated by:
- 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

11.6.3 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 and illegal connections will also be treated to have same consumption as metered property.

Estimating consumer metered use can also be carried out using the consumer data obtained from the consumer 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).

11.6.4 Losses in Customer Service Lines and Appurtenances

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

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

11.7 Analysis

The information of the results of monitoring 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 present 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 area wise losses and priorities the areas into three categories viz.

- Areas that need immediate leak detection and repair.
- Areas that need levels of losses (UFW) to be closely monitored.
- 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/ villages, it has been reported that the components of UFW may generally be as follows:

- Leakage (physical losses) 35 to 50%
- Meter under-registration 10 to 15%
- Illegal/unmetered connections 3.5 to 6%
- Public use 1.5 to 3.5%

11.8 Problems 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 systems.
- 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 studies.
- By and large, water authorities are not equipped with the necessary equipment.
- Proper budgetary provision is also 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 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.

11.9 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.

11.10 Water Losses

The water losses can be termed into two categories.

- Physical losses (Technical losses)
- Non-physical losses (Non-technical losses/Commercial losses)

11.10.1 Physical Losses (Technical Losses)

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

11.10.2 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 fire hydrants.

11.11 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 Leaks.
- Assessment of leakage.

11.11.1 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 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.

11.11.2 Pipe Location and 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.

11.11.3 Locating the Leaks

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

(a) Walking

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

(b) Sounding

Sounding is the cheapest and an effective method of detecting leaks in a 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 near 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. 11.2) 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.

11.12 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 11.3).
- Turbine water meters with pulse head, pressure point and data loggers.
- Leak Locator.

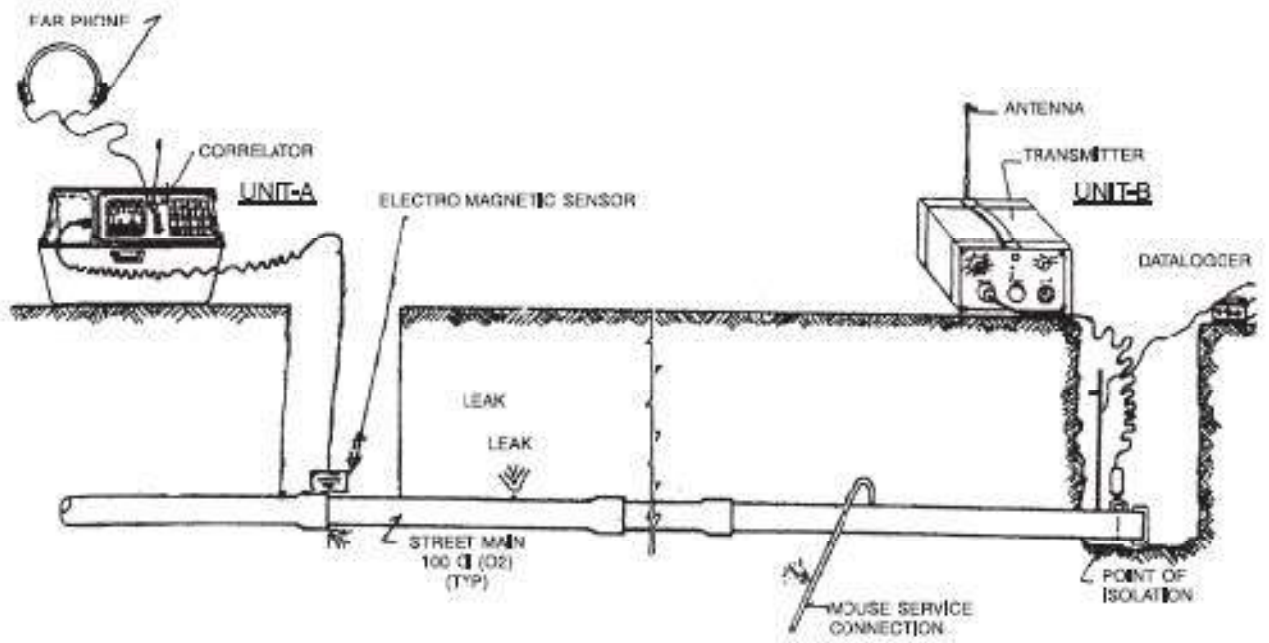


Fig 11.2

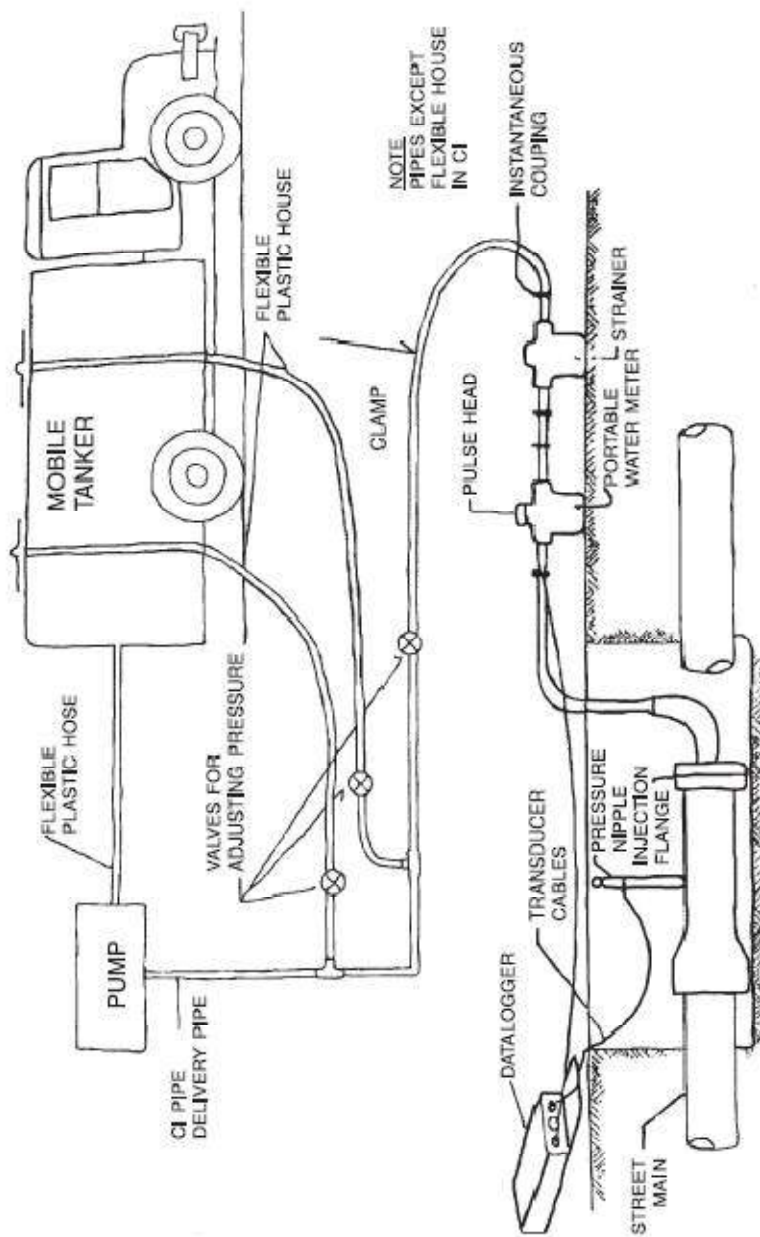


Fig 11.3

11.12.1 Intermittent Water 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, size of mains, valves and consumer connections. If they are not readily available utilise road measurers to measure the 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.

11.12.2 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.

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 11.4 , 11.5)

(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.

11.13 Accepted Norms for Expression of Leakage

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

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

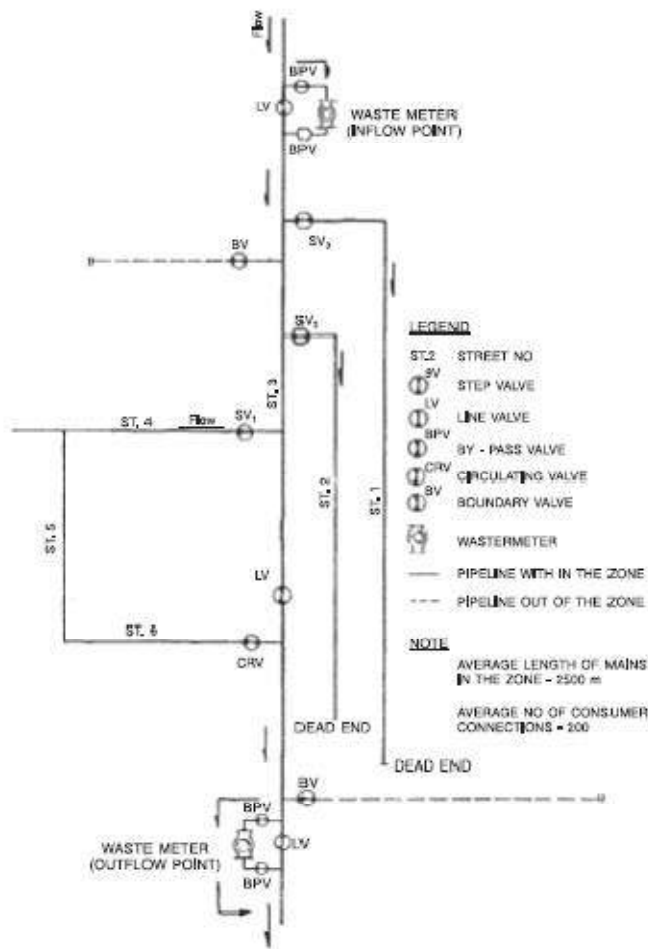
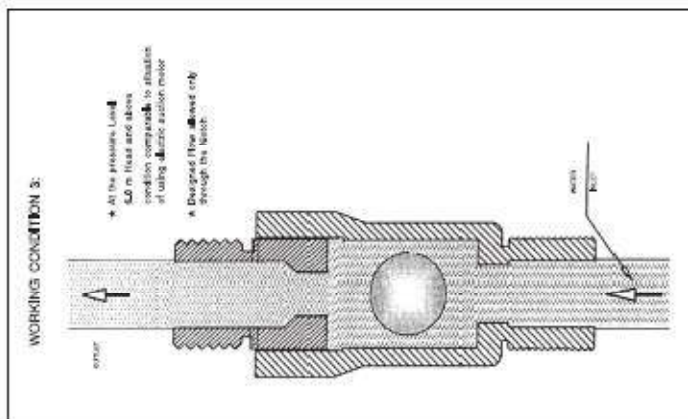
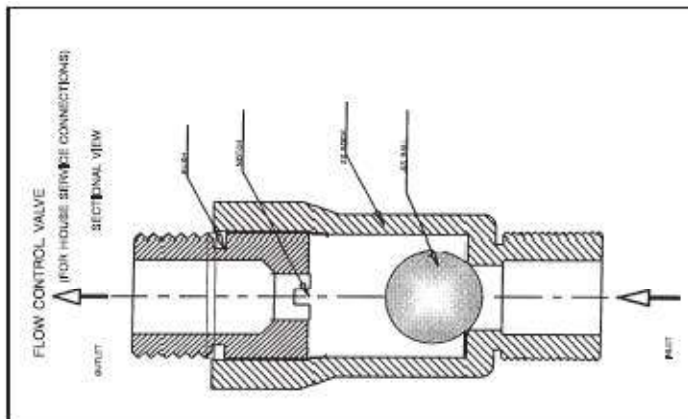
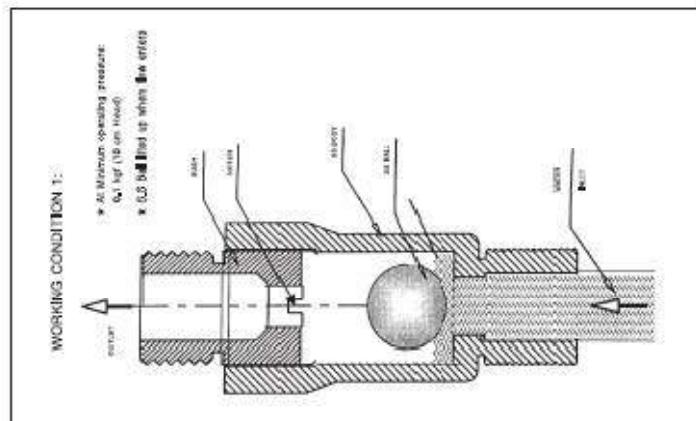
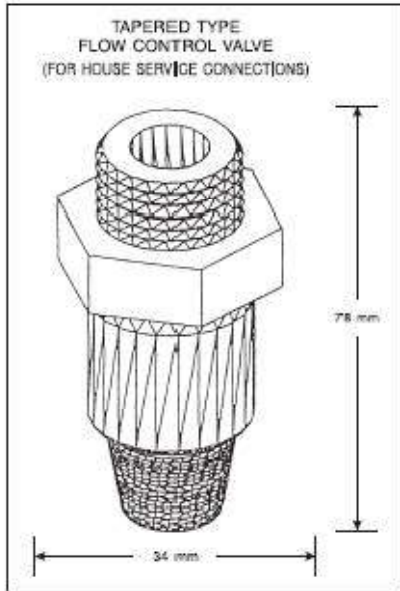


Fig 11.5

11.14 Prevention of UFW in Consumer Connection

For domestic connection MDPE pipes are mainly used. After a period of time these pipes get choked due to tuberculation. For bulk service connection, MDPE /HDPE 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, 10lpm, 15lpm, 20lpm and 25lpm to 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.



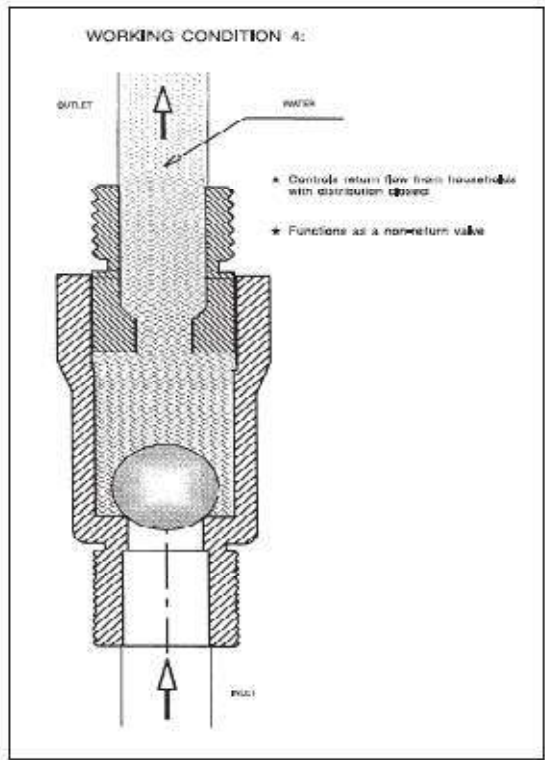
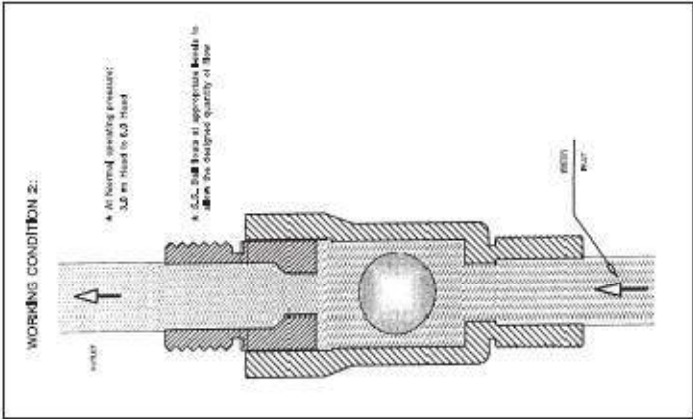


Fig 11.6

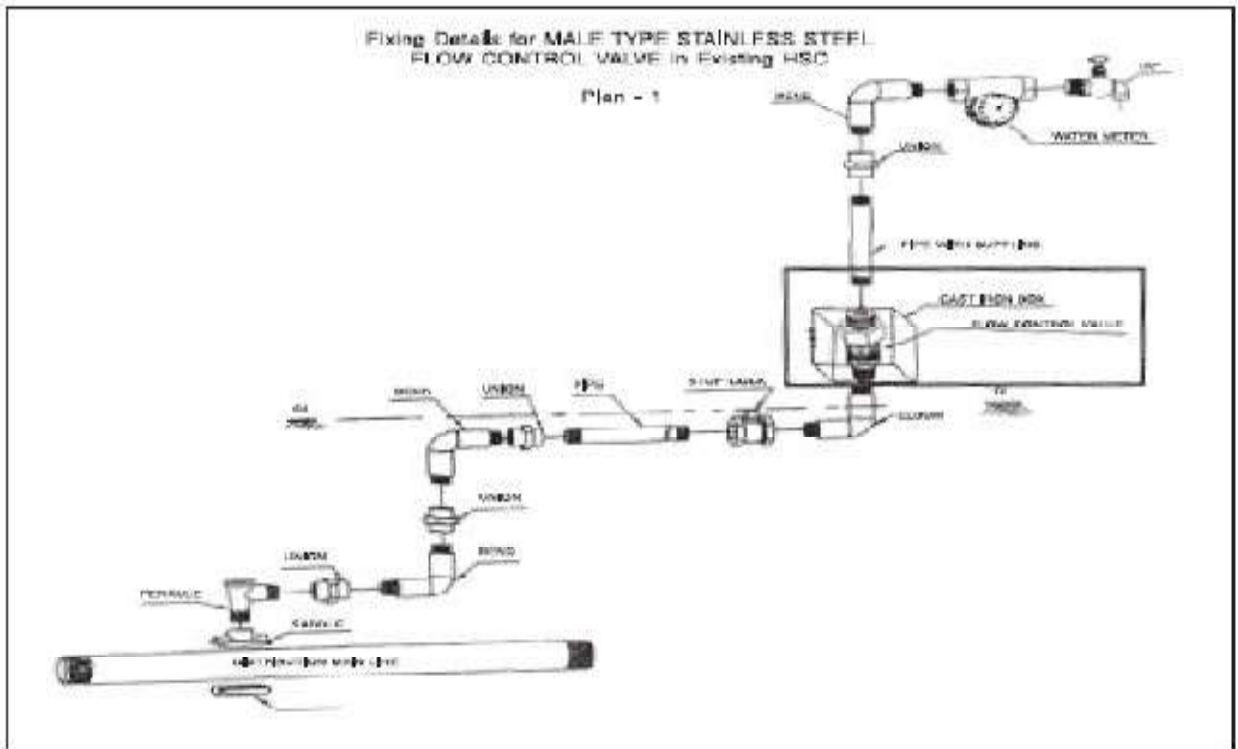


Fig 11.7

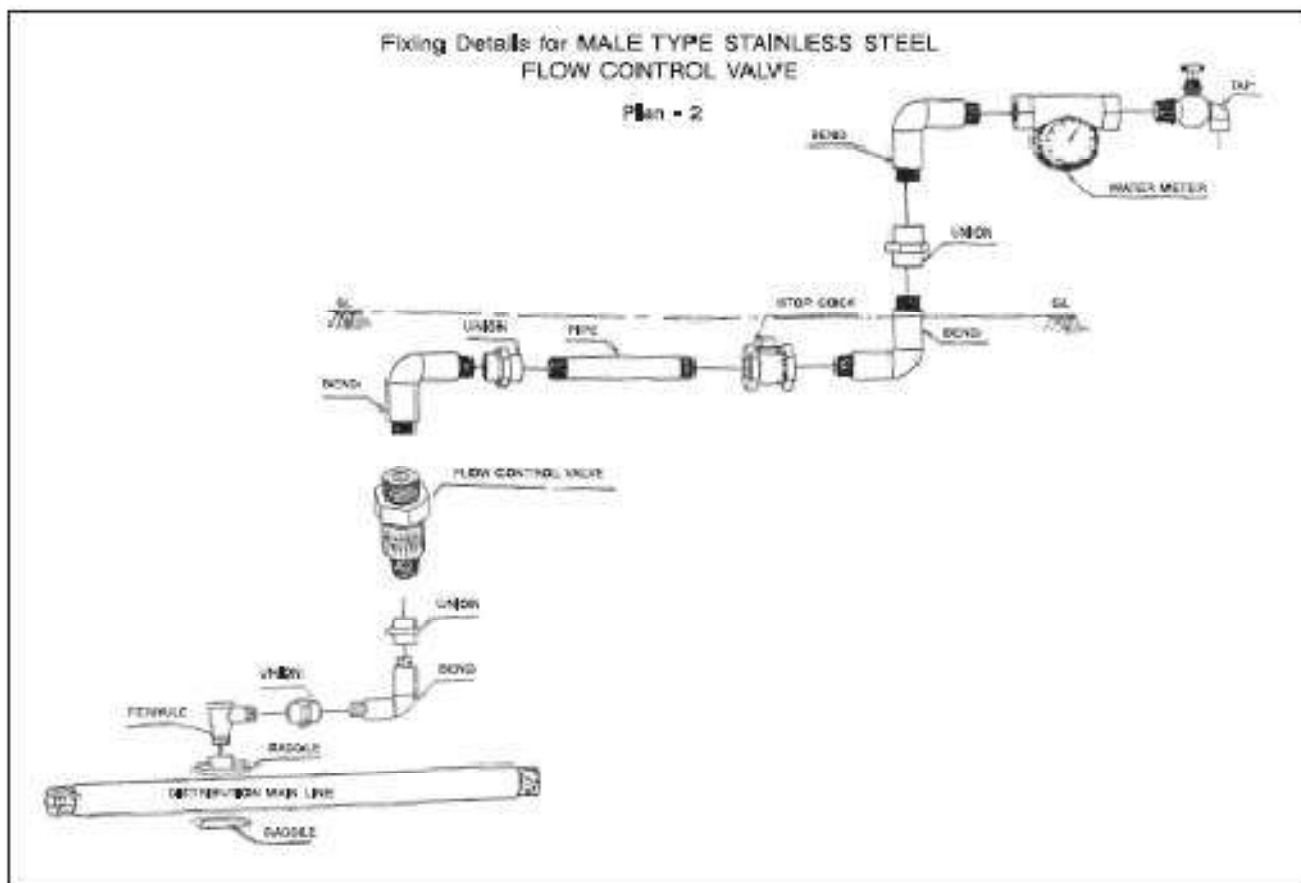


Fig 11.8

11.15 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, amplifier and listening sticks.

Leak detection methods possible under the different condition.

11.16 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 11.2).

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 overall assessment of these figures will give the impact of the UFW exercise.

Table 11.2

Analysis of complaints received In the division before and after the UFW works

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

11.17 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 consumable costs to treat water.

(b) Financial Improvement

A water audit and leak detection programme can increase revenues from consumers who have been undercharged and lower the total cost of supplies including reduction in 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 in reduction 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

11.18 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 part of the pipe length.

11.18.1 Leakage Repair Procedural Overview

The first consideration will be site safety.

Notify the consumer before the commencing the work. Always locate other existing 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.

Chapter – 12

ENERGY AUDIT & CONSERVATION OF ENERGY

12.1 Introduction

Energy is very scarce and short supply commodity particularly in most of the states in the country and its cost 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 supply systems. Need for conservation of energy, therefore cannot be ignored. All possible steps need to be identified and adopted to conserve energy and reduce energy consumption and 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.

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, and 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 equipment's 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 Strategy as follows, therefore need to be adopted in management of energy

- 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.
- 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 the sources like, infiltration wells, open wells, collecting wells, the working head can be decided based upon the suction head, delivery head and frictional loss with reference to the pipe material used and other losses.
- In respect of bore well sources, while submersible pump sets are used, the pump suction depth may be fixed with reference to the final spring achieved during drilling.
- Working of head of pumps shall be made in conservative way.
- If head of pump is excess of actual requirement then pump impeller shall be trimmed as per affinity law.
- In large pumping station pumps with variable frequency shall be used with low power factor loads, the current flowing through electrical system components is higher than necessary to do the required work. In order to achieve power factor greater than 0.9 power capacitors of required capacity shall be installed in all the installation of Pumping machinery.
- Electric motors usually run at a constant speed, but a variable frequency (speed) Drive (VFD) allows the motor's energy output to match the required load. This achieves energy savings depending on how the motor is used. When we use a control valve or regulator, we lose energy because the pumps are always operated at high speed.

12.2 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

12.2.1 Scope of Energy Audit

Energy audit includes following actions, steps and processes:

1. Conducting in depth energy audit by systematic process of accounting and reconciliation between the following:
 - a) Actual energy consumption.
 - b) Calculated energy consumption taking into account rated efficiency and power losses in all energy utilizing equipment and power transmission system i.e.
2. 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.

3. Taking up discharge test at rated head if test at Sr. No. (ii) is not being taken.
4. 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
5. Identifying remedial measures and actions necessary to correct the shortcomings and lacunas in (IV) and evaluating cost of the measures to be taken.
6. Carrying out economic analysis of costs involved in (iv) and (v) above and drawing conclusions whether rectification is economical or otherwise.
7. Checking whether operating point is near best efficiency point and whether any improvement is possible.
8. Verification of penalties if any, levied by power supply authorities e.g. penalty for poor power factor, penalty for exceeding contract demand. 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.

12.2.2 Methodology of Energy Audit

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

12.2.2.1 Study and Verification of Energy Consumption

a) All Pumps Similar (Identical):

- i) 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].
- ii) 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 pump sets 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].
- iii) From (i) and (ii) above, calculate mean system kW drawn per pump set [In the example, mean system power drawn per pump set = $9000 / 49$ i.e. 183.67 kW].
 - iv) 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].
 - v) Depending on efficiency of transformer at load factors corresponding to different cumulative kW, calculate output of transformer for loads of different combinations of pumps. [In the example, if transformer efficiencies are 0.97 and 0.975 for load factor corresponding to 367.34 kW and 551.01 kW respectively, then outputs of transformer for the loads shall be 367.34×0.97 i.e. 356.32 kW and 551.01×0.975 i.e. 537.23 kW respectively.
 - vi) 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.
 - vii) Cumulative input to motors divided by number of pump sets operating in the combination shall give average input to motor (In the example, average input to motor shall be $356.32 \div 2$ i.e. 178.16 kW each for 2 pumps working and $537.23 \div 3$ i.e. 179.09 kW each for 3 pumps working simultaneously).
 - viii) Depending on efficiency of motor at the load factor, calculate average input to pump. [In the example, if motor efficiency is 0.86, average input to pump shall be 178.16×0.86 i.e. 153.22 kW and 179.09×0.86 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
- 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.
- xv) If actual discharge is within 4% - 6% of rated discharge, the results are deemed as satisfactory.
- xvi) Test for efficiency of pumping machinery after each repairing shall be taken. If necessary inefficient machinery should be replaced by energy efficient / star rated machinery.

(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 liters 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.

12.2.2.2 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.

12.2.2.3 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.

12.2.3 Performance Tests of Pumps

12.2.3.1 Parameters to be determined

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

12.2.3.2 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.

12.2.3.3 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

12.2.3.4 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).

12.3 Measures for Conservation of Energy

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

(a) Routine Measures

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

(b) 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.

(c) 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.

(d) Measures for System Improvement

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

12.3.1 Routine Measures

12.3.1.1 Improving Power Factor

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.

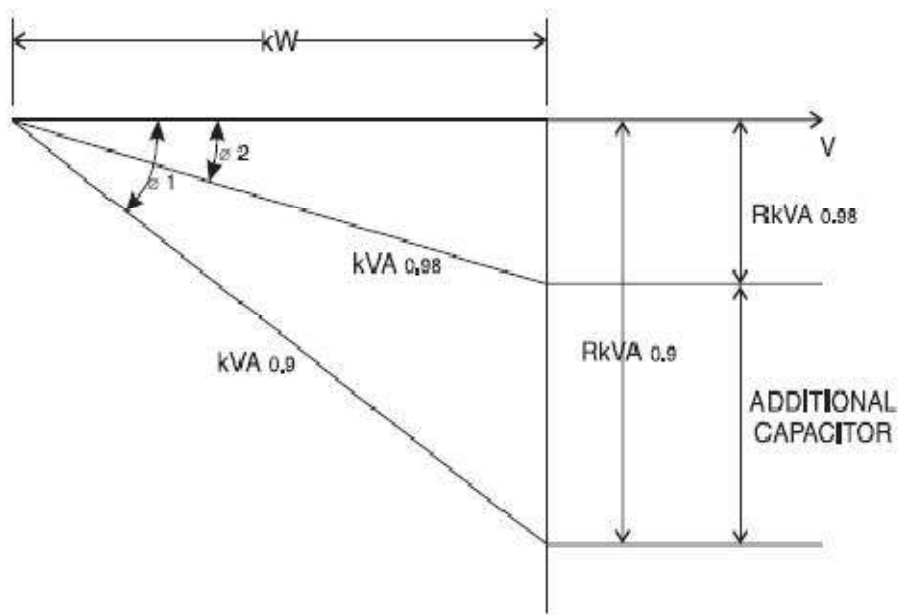


Fig 12.1: CORRECTION OF POWER FACTOR

Initial power factor (Cos ϕ_1) = 0.90

Improved power factor (Cos ϕ_2) = 0.98

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

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

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

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

As copper losses \propto (current)²,

$$RI^2_{0.98} = 30 \times \left[\frac{178.5}{194.4} \right]^2$$
$$= 25.3 \text{ kW}$$

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

$$= (30.0 - 25.3) \times 24 \text{ hours} \times 365 \text{ days} \times \text{Rs. } 4.0$$

$$= \text{Rs. } 1,64,688/-$$

say Rs. 1,64,000/-

The kVA recorded at PF 0.9 and 0.98 are,

$$\text{kVA}_{0.90} = \frac{1000}{0.90} = 1111 \text{ kVA}$$

$$\text{kVA}_{0.98} = \frac{1000}{0.98} = 1020 \text{ kVA}$$

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

$$= (1111 - 1020) \times 12 \text{ months} \times \text{Rs. } 120.0$$

$$= \text{Rs. } 1,31,000/- \text{ per annum}$$

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 be achieved in both sections of the panel.

12.3.1.2 Operation of Working and Standby Transformers

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:

No load losses for 1600 kVA transformer = 1.80 kW

Load losses for 1100 kVA load = 13.50 kW

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)

Load losses at 50% load = $\frac{1}{4}$ of full load losses

$$= \frac{1}{4} \times 13.5 \text{ kW}$$

$$= 3.375 \text{ kW}$$

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

$$= \text{Rs. } 5.99 - \text{Rs. } 3.62$$

$$= \text{Rs. } 2.37 \text{ lakhs per annum}$$

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.

12.3.1.3 Voltage Improvement by Voltage Stabilizer 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.

Low voltage $V_1 = 90\%$

Rated voltage $V_2 = 100\%$

Since $I_1V_1 = I_2V_2$

$$\begin{aligned} I_1/I_2 &= V_2/V_1 \\ &= 1.11 \end{aligned}$$

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

$$\begin{aligned} \text{Therefore } RI^2 \text{ losses at 90\% voltage (} V_1 \text{)} &= 30 \times 1.112 \\ &= 37.0 \text{ kW} \end{aligned}$$

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.

12.3.1.4 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.

1. 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.

2. Other installations
3. Other installations

By operational control

In case multi-pump installation, where inflow is from preceeding 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.

12.3.1.5 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.

12.3.1.6 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 12.2. 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 fulfill 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

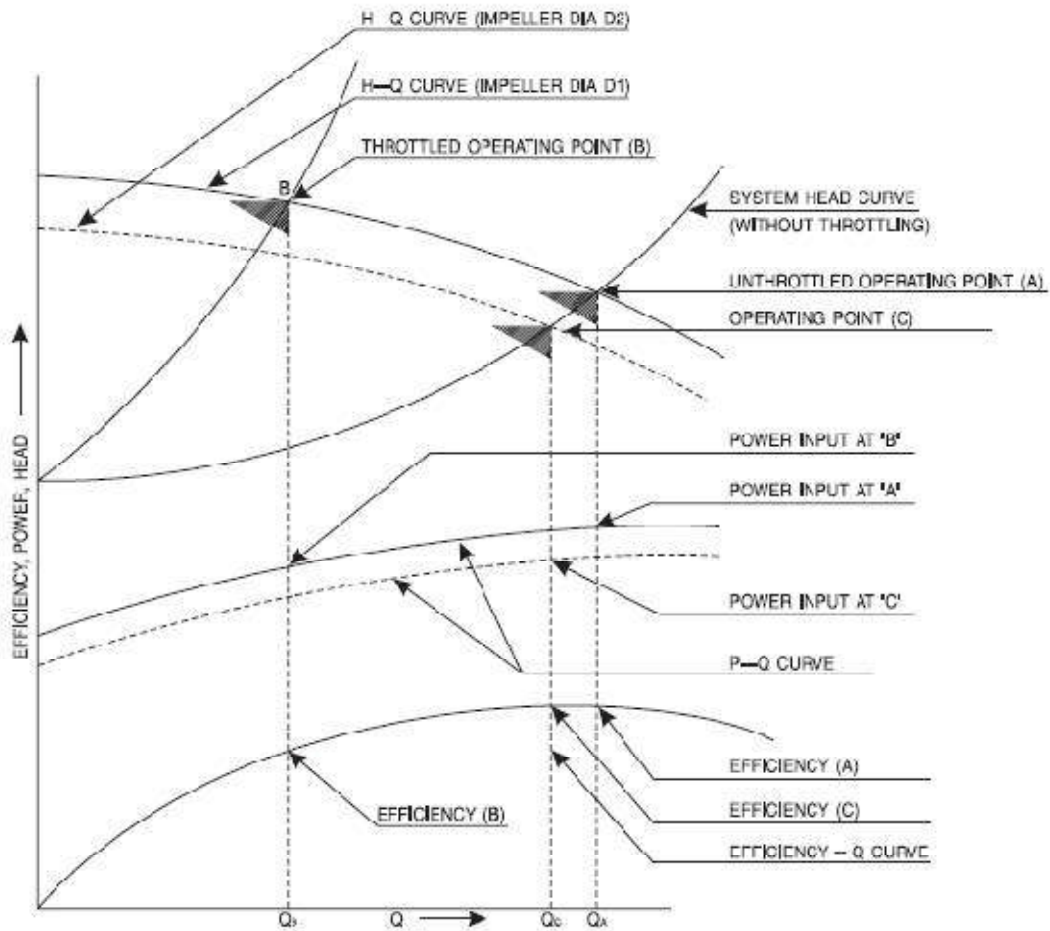


FIG 12.2 EFFECT OF THROTTLING AND TRIMMING IMPELLER

The curves shown in broken lines are characteristic curves for trimmed impeller. The HQ characteristic of trimmed impeller intersects the system head curve at point C. Thus point 'C' is operating point of trimmed impeller. The discharge Q_C is much more than Q_B 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.

12.3.1.7 Replacement of existing Mercury Vapour Lamps & Sodium Vapour Lamps by LED or solar 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 save energy consumption.

12.3.2 Periodical Measures

12.3.2.1 Restoring Wearing Ring Clearance

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

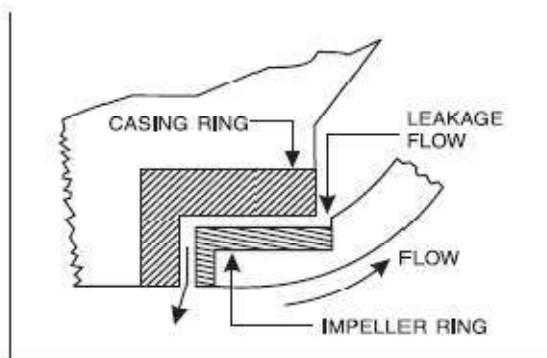


FIG 12.3: A TYPICAL WEARING RING

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 reveals that even though discharge is reduced, power reduction is very marginal and as such the pump operates at lower efficiency. Reduction in discharge up to 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 to the extent of 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.

12.3.2.2 Reducing Disk Friction Losses

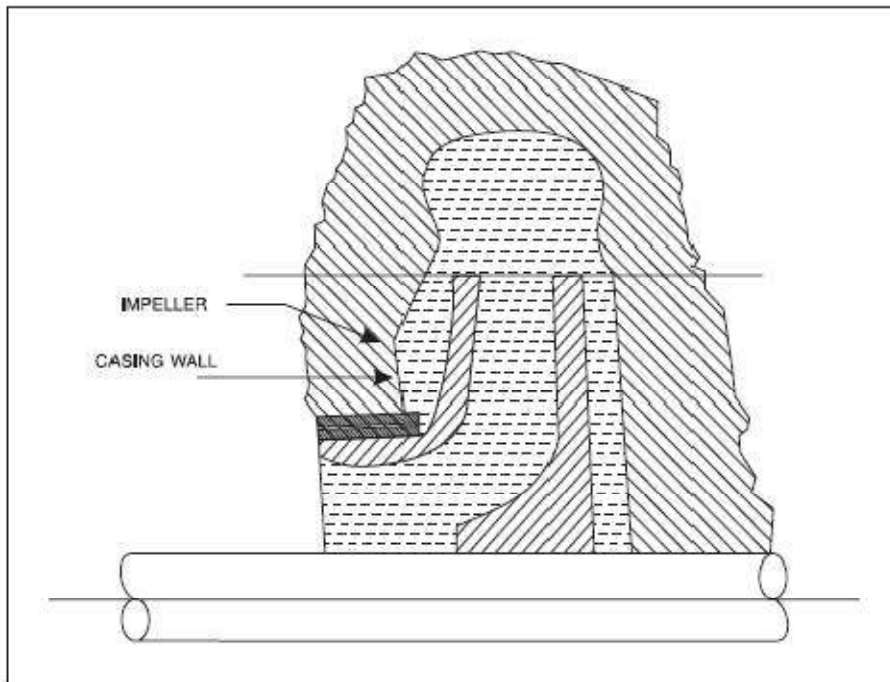


FIG 12.4: IMPELLER AS A DISK

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%.

12.3.2.3 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.

12.3.3 Selection Aspects

12.3.3.1 Selection of star rating motor pump

In recent trends the star rating of three/five star pump sets are available in the market, which can save 10-15 % of power, can be used in place of normal pumping equipment.

12.3.3.2 Optimum Pump Efficiency

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

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

where N = rotative speed, rpm

Q = discharge, m³/s

h = head per stage, m

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

Fig. 12.5 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.

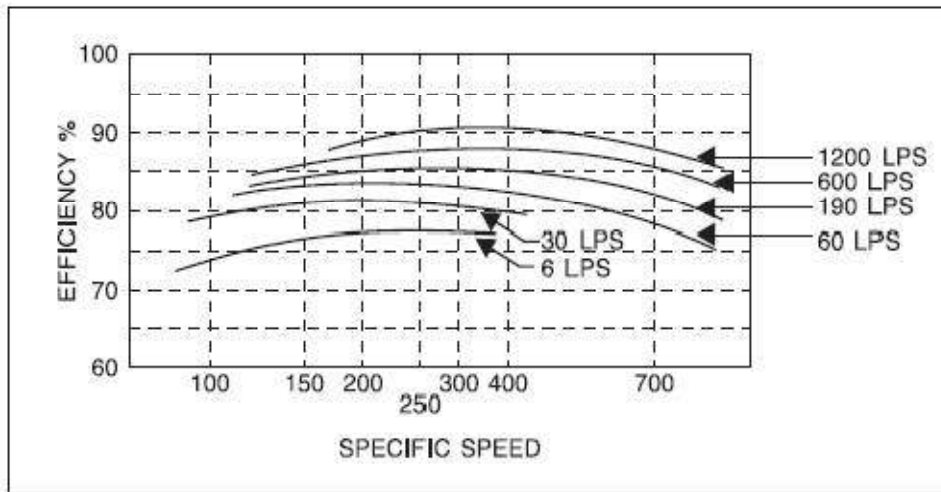


FIG 12.5: PUMP EFFICIENCY VERSUS SPECIFIC SPEED & DISCHARGE

12.3.3.3 Optimisation of Pipe appurtenance

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' valve 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

$$\text{Head loss} = K \frac{V^2}{2g}$$

	$V_1=2\text{m/s}$	$V_2=2.5\text{ m/s}$
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 optimize 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

12.3.3.4 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

12.3.3.5 Delivery Pipe for Submersible Pump

The delivery pipe for submersible pump is comparatively long and therefore, head loss in delivery pipe is considerably high. 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

12.3.4 Measures for System Improvement

12.3.4.1 Replacement of Old and Inefficient Pumps

At times it is observed that the pump efficiency reduces by about 10% - 25% and cannot be improved even though wearing rings are replaced, refurbishment and overhaul carried out to the pump set because of abnormal deterioration in pump. In such a case, it is necessary to replace the old and inefficient pump to save the 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

Therefore increase in HP required due to reduction in pump efficiency

$$= (1 / 0.65 - 1 / 0.75) \times 490$$

$$= 100.5 \text{ HP}$$

Hence, excess energy cost per annum

$$= 100.5 \times 0.746 \times 24 \text{ hours} \times 365 \text{ days} \times \text{Rs. } 4.00$$

$$= \text{Rs. } 26.27 \text{ lakhs}$$

Cost of replacement of pump at Rs. 2500/- per bhp

$$= 670 \times 2500$$

$$= \text{Rs. } 16.75 \text{ lakhs}$$

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 an 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

12.3.4.2 Dispensing With Sump If Inlet Is From Dam

Usual arrangements of intake works as shown in Figure 12.6 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.

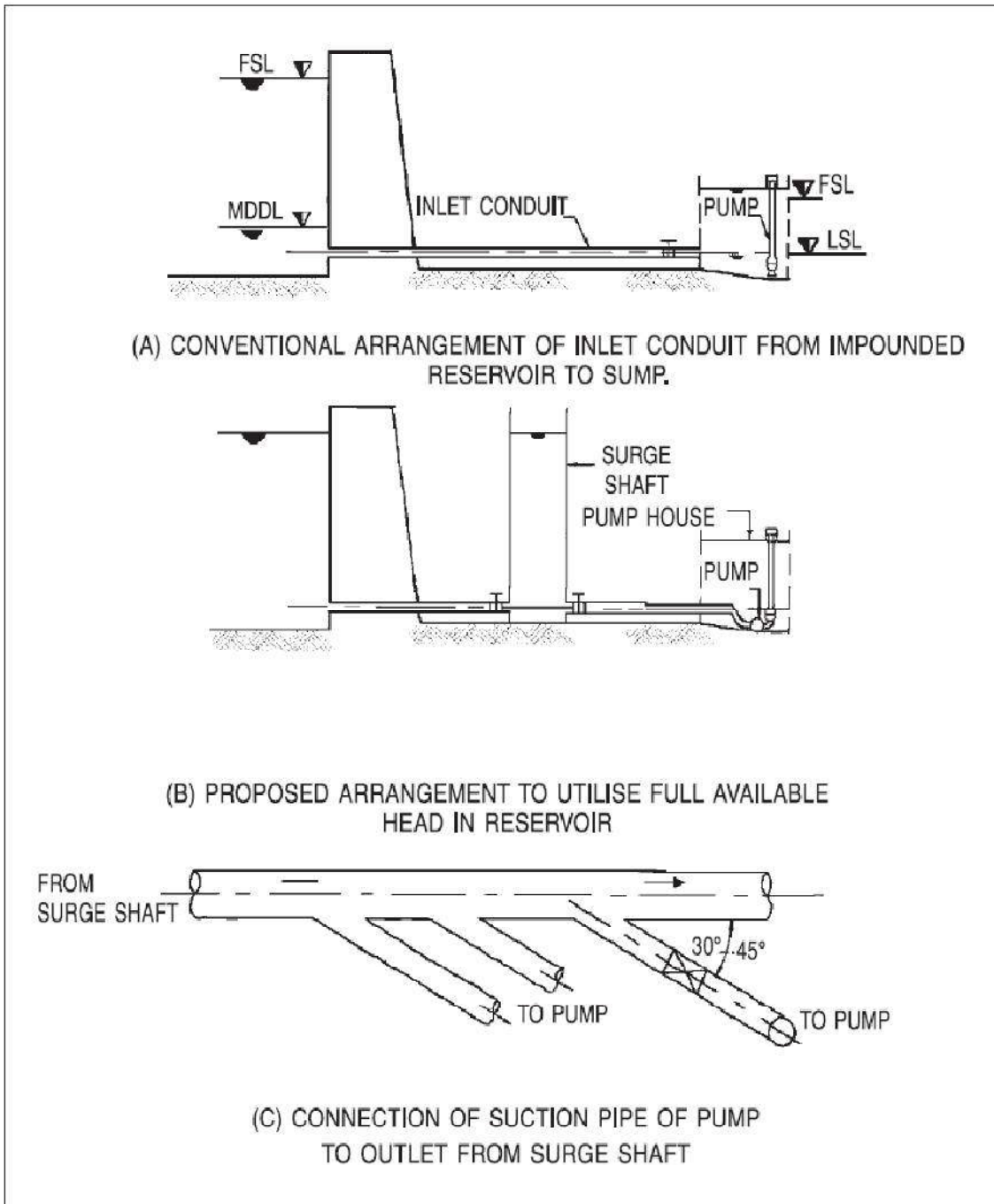


FIG 12.6 INTAKE FROM IMPOUNDED RESERVOIR

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.

12.3.4.3 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 12.7 feasibility of lowering the pipeline at hump and thus reducing head on the pump need to be examined and if feasible, should be implemented.

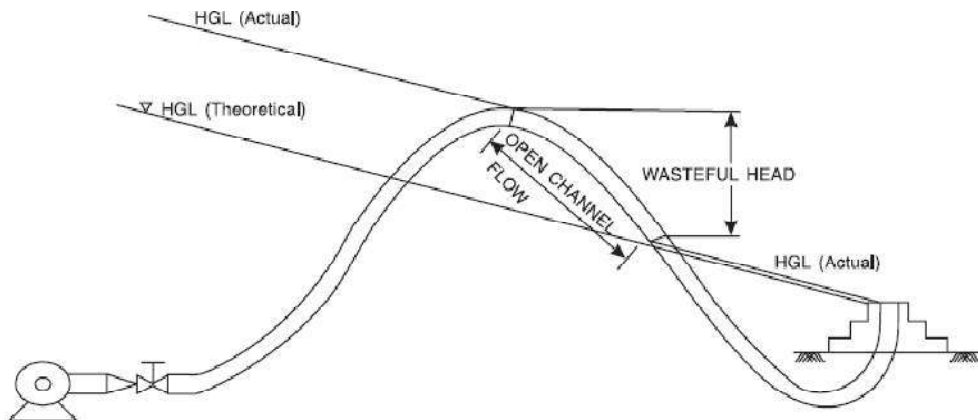


FIG 12.7 HGL CUTTING AT HUMP OPEN CHANNEL FLOW

12.3.4.4 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 12.8, 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.

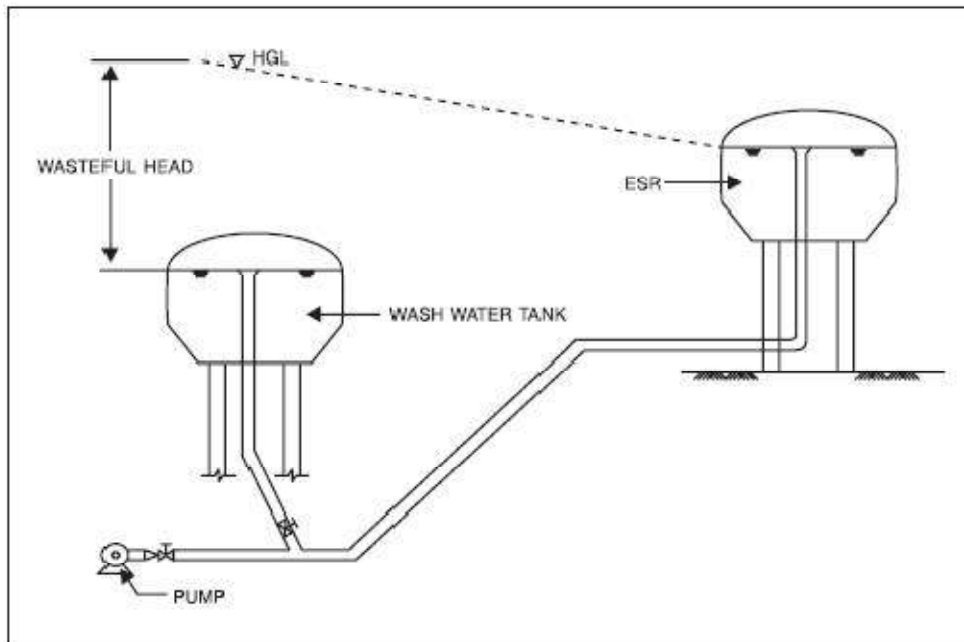


FIG 12.8: FEEDING WASH WATER TANK FROM PURE WATER RISING MAIN

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.

12.3.5 ESCO Concept for Energy Audit

Some State Govt.'s are implementing a new concept of Energy Saving Companies (ESCOS), as pilot project for undertaking Energy auditing. According to this concept these energy Saving Companies who are willing to put in their money will be invited to take up and complete energy saving measures and the at least cost saving will be shared by the local bodies/ Government agencies and ESCO. The local bodies/ Government Agency who follow this model will gain by saving the energy cost without investing in the project.

Energy saving – a scheme specific example.

Energy audit was carried out one of the CWSS in India, with Local planning in Rural areas with a Reservoir as source and the following energy saving measures were suggested.

- Introduction of power capacitors closer to the starters instead of at the panel board. Coro- coating of impellers of the pumps
- Introduction of Variable Frequency Drive (VFD) at the pumping station where trolling of pump discharge is required.
- Introduction of online flow monitoring and accounting system (Telemetry/. SCADA)

The above measures were implemented and the total savings achieved is indicated below:

Location	Activity	Date carried out	Average energy cost / month		Savings/ Month
			Before	After	
A	Shifting of capacitor	Oct.06	26,49,254	25,09,905	1,39,349
A B	Coro-coating of Pump impellers	Oct. 02 to Jan. 03	29,32,505	26,50,300	2,82,205

Chapter – 13

LIFE CYCLE COST & SERVICE DELIVERY APPROACH

13.1. Life Cycle Cost Approach

Life cycle cost (LCC) represents the aggregate costs of ensured delivery adequate, equitable and sustainable drinking **Water Sanitation and Hygiene** services to a population in a determined geographical area. These cost includes not only the cost of constructing system but also what it costs to maintain them in the short and long term, to replace, extend and enhance them as well as the indirect support cost of the enabling environment, viz. capacity building, planning and monitoring at both District and state level, not just for a few years, but at least for project design period or more.

The delivery of sustainable services requires that financial support system are in place to ensure that infrastructure can be renewed and replaced at the end of its useful life, and to deliver timely breakdown repairs, along with the capacity to extend delivery system and improve service delivery in response to changes in demand. Thus the 'life cycle approach is enough flexible to build, sustain, repair and renew a water (sanitation) system through the whole of its cycle of use.

The life cycle cost Approach (LCCA) seeks to raise awareness of the importance of LCC in achieving adequate, equitable and sustainable drinking water services, to make reliable cost information readily available and to mainstream the use of LCC in drinking water governance process at every level.

Life cycle cost approach is a step towards increasing the efficiency and effectiveness of investment in the WASH sector, to find a balance between the allocations of money for new infrastructure to increase coverage, and the allocation for major repair and rehabilitation of drinking water infrastructure to maintain a basic level of service.

The LCCA can be a useful for monitoring and costing sustainable WASAH services by assessing cost and comparing them against levels of service provided, how can we achieve the most by least spending.

13.1.1 Cost Components

The following cost component is generally;

1. Capital expenditure - hardware and software (Cap Ex)-includes the civil structures, Pumps, pipes, filtration units etc. to develop and extend the intended service.
2. Operating and Maintenance Expenditure (Op Ex)-Requirement for recurring regular, ongoing expenditure viz. labor, fuel, chemicals, material and power charges (5% to 20 % of capital investments).
3. Capital Maintenance Expenditure (CapManEx)-Expenditure on asset renewal, replacement and rehabilitation covers the work other than routine maintenance to repair and replacement in order to keep system running.
4. Cost of capital (Co'C) -Cost of Financing a Program or Project i.e. the cost assessing the funds needed to construct a system.
5. Expenditure on direct support (ExpDs)-it includes expenditure on both pre-and post-construction support activities.
6. Expenditure on indirect support (ExpIDS)-include the macro-level support, capacity building, policy, planning and monitoring that contribute to the sector working capacity and regulation but are not particular to any programme or project.
7. Total Expenditure (Tot Ex)-determined using fixed assets accounting to aggregate the cost components described above

13.2 Service Delivery Approach

In a service delivery approach, a water system is maintained through a planned process with occasional capital-intensive intervention to upgrade the service level and to replace the infrastructure before its designed life period.

A service delivery approach aims to provide long term reliable and sustained services towards satisfaction of the consumer. Thus it goes hand in hand with life cycle costing, which accounts for cost over the entire life cycle of a service both the initial engineering, construction of infrastructure and capacity building, institutional support, financial planning and maintenance required to sustain an acceptable level of drinking water service delivery. It requires an approach defining roles and responsibilities of the staff working at different levels and improving coordination and harmonization among their activities

Chapter – 14

COMMUNITY PARTICIPATION AND COMPLIANT REDRESSAL SYSTEM OF O&M OF WATER SUPPLY SCHEME

14.1 Institutional Roles and Responsibilities

It is clear that, local governments/PRIs and communities cannot succeed on their own. They need to be given clear-cut roles and responsibilities. These include Panchayat Raj institutions, line departments, training institutions, and the local private sector and NGOs. The funds allocated under both the sectors Govt of India and States concerned, if needed over and above the revenue generated by this system under support fund. It is also necessary to take up capacity building programmes on redefining roles and responsibilities using these funds. Besides, it is now essential to create separate fund if required to take up capacity building programmes on redefining role and responsibility.

14.1.1 Actions Plan

- States should introduce standard operating procedures for O&M of hand pumps and piped water supply schemes and should identify and assign key functions to the appropriate mechanism for effective O & M through GPs/VWSCs or person such as the hand pump caretaker or operator or civil societies/trusted NGO.
- Timely transfer of O&M, State plan and NITI AYOOG funds is necessary to enable GPs to operate and maintain schemes without service breaks. Wherever it is not yet adopted NRDWP (O&M) and other funds necessary for drinking water supply to GPs should be transferred electronically to GP accounts.
- For hand pumps, the GP or VWSC needs to be provided access to spare parts and trained mechanics by the DWSSMs for regular preventative maintenance of all hand pumps in the GP. Apart from above it is also contemplated by the state through special drive to put into use by conducting crash programmes every year before ensuing summer.
- For piped water supply systems with community stand posts and/or household connections, the DWSSM/MRC and VWSC needs to make sure that community based operators receive training to gain the technical skills to do the job.
- MPP or ZP and Joint Scheme Level Committees consisting of heads of VWSCs/GPs benefited by the scheme are responsible for overall O&M of multi-village schemes.

- In multi-village schemes or large water network, bulk supply should be managed /operated by TDWSCL/RWS&S Dept or ZPs or private operators with tariffs set by the State government/PRIs/ water resources regulatory body.
- Consumer grievance redressal mechanisms should be established such as provision of a toll free number, call centers, mobile SMSs, linking GPs and engineers electronically with Mandal and District IMIS systems, citizen report cards and community score cards.
- Initially all bulk water supply and retail water supply to commercial, industrial establishments and private institutions should be installed with volumetric metering. Gradually all household connections should also be metered.
- Water audits, energy audits and measurement of Unaccounted for Water (UFW) and Non-Revenue Water (NRW) should be introduced & institutionalized for bulk and distribution piped water supplies.
- Automated pumps should be installed, wherever feasible, in piped water supply schemes to ensure reliable water supply and reduce operator workload. If possible supervisory control and data acquisition (SCADA) may be incorporated in the system with modifications of the appurtenances
- Standard operating procedures for coping with natural disasters, including for drought and floods, will be laid down on the lines of SOP published by Ministry of Drinking Water and Sanitation duly disseminated through training and awareness programmes.
- GPs/VWSCs must also prepare and implement service improvement plans (SIP) duly prioritizing repairs, replacement and expansion of source and system components.
- Zilla Panchayats should have a Water Supply O&M Wing to provide continuous technical support to GPs in managing their water supply schemes.
- Federation of VWSCs can also take up major maintenance, renovation and modernization of rural water supply schemes with technical and staff support from RWS & S Dept., /Corporations/Boards thereby reducing in costs by engaging local technicians trained in vocational institutes or industrial training institutes (ITIs) to provide services round the year. This would significantly mitigate deficiencies of technical capacity and manpower availability at mandal and lower levels.

Multi village water supply schemes are formulated to provide water supply to many villages / habitations in many panchayats which in turn will be covered by various panchayats/mandals spreading over a district or districts. In these type of schemes, the source, pumping stations, treatment plant, pumping main and branch pumping main etc. are common components

intended to deliver water to various villages / habitations of various village pancayats covered in the CWSS though the OHSR located in those habitations/ villages.

Wherever necessary urban local bodies like Municipalities/Town, Panchayat who have contributed their proportionate cost involved will also be included in these schemes for maintenance up to the level of OHSR located in these Urban local bodies. For these urban local bodies also, the same source, pumping main, branch pumping main etc. will serve as common components and these schemes are called as combined water supply schemes instead of calling them as multi village schemes since urban local bodies are also included in them.

In many of the schemes, the number of villages / Panchayats covered may cater several numbers and even hundreds in some cases. Therefore operation and maintenance of the scheme including collection of water tariff from all households by one single entity may not be possible. That is why it is considered prudent to entrust the responsibility of operation of maintenance of common components to the RWS & S Dept. who has executed the scheme. The village specify components such as OHSR, Distribution system etc. will be under the custody of the respective village Panchayat / local body for its O&M.

The following may be the operational arrangements.

1. The EE/ Maint.Dn./ TDWSCL/RWS&S Dept. will be in-charge of O & M of the scheme. The TDWSCL/RWS&S will pump water upto the OHSR level in each Panchayat/ local body.
2. The TDWSCL/ RWS&S Dept. will raise the bulk water demand charges to each of the village Panchayat/ local body every month and collect the same from them.
3. The TDWSCL/RWS&S Dept. will initially incur expenditure on power consumption charges, repair and maintenance charges and will be adjusted against the water tariff collected from the Panchayat/local body..
4. The TDWSCL/RWS&S Dept. Field Engineers will prepare Annual Maintenance estimate and obtain necessary sanction.
5. The source of funding for maintenance is by collection of water charges and by utilising the fund earmarked by GOI and states for the purpose of O&M of the scheme out of NRDWP allocation for that year after apportioning the amount between TDWSCL/RWS&S Dept. for maintenance of multi village schemes and PRIs for maintenance of single village scheme. The cost of power consumption charge alone will be about 60 -70%. Therefore any shortfall in meeting out the expenditure for

maintenance by TDWSCL/RWS&S Dept. may have to be compensated by Govt. or by raising the water tariff.

6. The Panchayat will distribute the water equitably to local beneficiaries through the distribution system.
7. The delivery point through house service connection.
8. The Panchayat will collect water charges from the households and also user charges for stand posts / public tap.
9. The Panchayat will remit the water charges to TDWSCL/RWS&S Dept. as per demand raised by EE/Maintenance Dn./TDWSCL./RWS&S Dept.
10. The Panchayat will attend the repair/ replacement of pump set, pipe line for SVS / Intra village network from out of water charges collected and from the fund allocated as grant by the Govt. for each Panchayat.

The TDWSCL./RWS&S Dept. execute intra village/ distribution system (covering habitation wise in Panchayat) should hand over to the Panchayat after execution for operation and maintenance of all infrastructure right from source to Distribution system. The Panchayat will pay electricity charges, attend repair works and collect water charges from the house hold connections as per the tariff fixed by the Govt./G.P. In the case of CWSS covering more than one Panchayat, the common components such as source, pumping main will be under the maintenance of TDWSCL/ RWS&S Dept./ and water will be pumped up to OHSRs whereas the OHSR and Village Distribution system will be handed over to respective Panchayat/local body. The TDWSCL/ RWS&S Dept./PRIs will collect monthly water tariff from the Panchayat/ local body as per the tariff rate fixed by the Govt. (on Kilo liter basis based on water meter reading) The Panchayat/ local bodies will collect water charges from the consumer as decided by the government.

As being followed in some State PHED/Boards/PRIs, the Engineer who is in charge of operation and maintenance of the CWSS along with the maintenance staff may be placed under the control of respective Zilla parshad for effective monitoring of performance of CWSS including collection of water tariff in Panchayat and urban local body and to discuss and sort out the issues of the complaints received. The District collector/DWSM will review maintenance of combined water supply schemes periodically.

14.1.2 Role of State Govt. In Maintenance of Multi Village Water Supply Schemes (MVWSS) and Single Village Water Supply Schemes (SVWSS)

1. To make policy decision like fixing of water tariff, O&M, undertaking major repairs, augmentations etc.
2. Review of operation and maintenance of MVWSS and SVWSS
3. Review of aspects of sustainability of water supply schemes
4. Coordination with various department of state Govt. like Rural development Dept, Electricity Dept. Health Dept. etc.
5. Allocating special funds to execute contingent plan so that the water supply schemes are not affected by inadequate power supply, adverse seasonal conditions like drought period and natural calamities like earthquake, floods, cyclone etc.

14.1.3 Role of Zilla Parshad/DWSM

1. Chairman of Zilla parshad Head of DWSM may review the status of functioning of all water supply schemes periodically.
2. Zilla parshad council may pass resolution for taking up water supply maintenance works for components which are under the maintenance of Panchayat such as extension of distribution main and replacement of damaged pipe line in the existing distribution system of the CWSS /multi village WSS, reallocating the zilla parishad funds to various Mandal Praja Parishat/Panchayat for execution of work, utilizing technical supervisory manpower available with the respective M. P.P.
3. The chairman Zilla parshad/DWSM/ Head of Division/ CEO, Zilla parshad should review the stage of implementation of the works sanctioned by Zilla parshad with their funds.
4. Works such as construction of additional OHSR/ New OHSR or for making any changes in the existing components which are under the maintenance of Panchayat shall also be taken with the concurrence of the TDWSCL / RWS&S Dept.1

14.1.4 Role of Gram Panchayat/(GP)

1. The Gram Panchayat will pass resolution for taking up maintaining works in the distribution system of their intra village which is under their maintenance. The works such as attending leaks and burst, changing gate valve, extension/ pipe replacement of old pipe line etc.
2. The GP may pass necessary resolution for executing the above works utilizing the Panchayat funds. The GP will also maintain their single village water supply schemes including Intra village distribution system and also attend repair works in components

such as pump sets, valves, pipeline etc. and collect water charges as fixed by the state government.

3. The GP may provide house hold connections after passing GP resolution and after obtaining the concurrence of TDWSCL/ RWS&S Dept./PR Engineer institutions.
 - The Panchayat may incur expenditure on water supply maintenance work as per the finance limit prescribe in the government orders shall be followed.
 - The GP will collect water charges from the house holds at the rate fixed by the Govt./DWSM.
 - The Gram Panchayat shall remit the monthly bulk water charges to the TDWSCL/ RWS&S Dept. every month.
4. The gram Panchayat shall consult and discuss with the VWSC before taking any decision/resolution regarding water supply maintenance works
 - The VWSC is fully empowered to supervise and monitor all water supply maintenance works.
 - The VWSC may undertake the following activities
 - Shall assist the Gram Panchayat to appoint a suitable candidate for the post of scheme operator/ plumber etc.
 - Shall ensure equitable distribution of water for all section of village population.
 - Shall assist the Gram Panchayat in collection of water charges.
 - To check whether the water distributed is free from contamination and whether having the adequate residual chlorination using Field test kit or by sending water sample to the nearest labs of TDWSCL/ RWS&S Dept./other institution.
 - To clean and chlorinate the OHSRs periodically
 - To assist the gram Panchayat in hundred percent collection of water charges.
 - To close all illegal connection and pit taps.
5. Cases pertaining to theft of water and damage to assets of water supply scheme shall be treated as public offence.

14.2 Community Participation and Motivation in Maintenance of Wss

The task is to build confidence and general awareness among the community for taking up the management of water facilities for their satisfaction. Water supply protection, sustainability of system; Community mobilization can be taken up through different activities & with different focus groups.

Forming User group with specific representation of community for different activities may be the first step. A sub group with specific responsibility may also necessary in case of monitoring the continuity in practice among users. The details of which may be seen in annexure.

- Monitoring Progress and Performance
- Monitoring, Audit and Reporting

The DWSM should put in place for monitoring and audit system. This should be a combination of annual reports from the Gram Panchayat and field audits. The annual reports would give progress against implementation dates, indicating actions taken where there has been slippage, and provide actual cost returns against budgets. These returns would be reviewed by the DWSM with a view to deciding whether a visit should be organised to carry out a field audit. In addition to field audits to sites where there appear to be problems, it would be desirable to have a few random visits to check on reliability of annual returns. However, the emphasis should be on support to Gram Panchayats other than where falsified returns are suspected.

The DWSM should prepare and publish annual reports on their work for rural water supplies. Some important elements in the report would be:

1. Statements on state policy on expected minimum service standards, subsidies and cost recovery from charges,
2. Lists of Gram Panchayat which have established good baseline data, which have prepared drinking water safety plans and operating plans,
3. Lists of Gram Panchayat which have submitted service improvement plans to the district for funding consideration, and approve.
4. Progress on implementation of each approved improvement programme and its impact on service performance.

14.2.1 Reviews of Tariff Implementation and Cost Recovery

The monitoring and audit role is that of a regulator and the style of regulation should reflect the requirement, which is one of capacity building rather than enforcement. Generally the approach would be to identify difficulties and help Gram Panchayat to find solutions.

14.3 Complaint Communication and Redressal System

The RWS&S Dept. is executing single village water supply schemes and Multi Village Water Supply Schemes (meant for multi village and multi urban local bodies). The single village Water Supply Schemes or multi village water supply schemes may be either maintained by the Panchayats or ZPs. There may be cases in respect complex of multi village water supply

schemes that the common components like sources, transmission mains and pumping up to the OHSRs may be under the maintenance of TDWSCL/ZPs and the distribution of water from OHSR to the consumer is vested with the Panchayat. In case of any shortfall in maintenance and service delivery in water supply scheme components pertaining to the overall scheme/intra village maintained by TDWSCL/ZPs or panchayat, the general public who intend to make a complaint on deficiency in maintenance of the scheme may not be aware who is the concerned authority to set right the deficiency and whom to make the complaint.

Hence the following mechanism for complaint communication and redressal may be setup as follows.

14.3.1 Complaint Communication

1. A centralised complaint cell may be created in the state head quarters O/o EnC RWS&S Dept. equipped with necessary soft & hard skills duly giving adequate publicity about the nature of complaint can be made and also the details such as E. mail address/ fax number/ telephone number/ postal address etc. of the complaint cell.
2. As being done in the case of emergency on par with other service departments, a three digit toll free number may be assigned for lodging urgent complaint through Telephone/ mobile phone.
3. A member of public who instantly come across any leakage/ overflow or any deficiency in maintenance of the schemes may lodge a complaint to three digit number.
4. Immediately after receipt of complaint, a complaint number will be assigned and informed to the complainant, if the complaint is received by phone/ E-mail.

14.3.2 Redressal System

Complaint received may be examined and determined who the maintenance agency/VWSC is within an hour of receipt of complaint. If it pertains to Multi village scheme (up to OHSR), it may be informed by phone/ E. mail to the ZP/TDWSCL and if it is related to Panchayat it will be intimated to the local body/ Panchayat. If the complaint is received through post or any mode of communication also the above system may be adopted.

- The respective maintenance agency should intimate the stage of action taken the next day to District Complaint Cell.
- The District Complaint Cell will create necessary files/ documents in computer and register the name and address of complainant, mode of receipt of complaint, assigning

of complaint number, agency who is attending the complaint, present stage of action taken etc.

- The complaint cell may inform the facts such as who is the agency attending the complaints, their contact number and stage of action taken to the complainant, at the earliest after receipt of complaint.
- The respective maintenance agency should report final stage of action taken at the earliest to the complaint cell.
- The complaint cell may inform the final action taken, to the complainant immediately after receipt of details received from the concerned maintenance agency.
- The status of complaints received and action taken may be reviewed at state head quarters.

14.4 Annexure

14.4.1 Specific IEC and Mobilization Activities

- Display Boards/ Wall Paintings:
- Habitation level meetings:
- Women SHG activities/Youth group/club activities:
- School teacher and Student Programs:
- Competition among user groups on performance:
- Appreciation and Award programs:
- Documentation of all activities:

14.4.2 Community Involvement for Sustainable Water Supply Management

The community may be involved in following aspect:

Assess Water Supply At Distribution Points:

A) street walk

- A group of community members like GP Sarpanch, VWSC members, women SHG members, Community leaders, school teachers and students, etc can be mobilized and taken for a street walk to identify the present condition of various infrastructures like HSCs including condition of platforms, Distribution Pipelines, OHSRs etc.,
- The students, SHGs, VWSCs, can note the conditions of all infrastructures in a notebook.

- In case of any damages, pit taps, unauthorized connections and illegal tapplings in particular, the duration from which the same prevails shall also be recorded. G.P. sarpanch and VWSC shall take immediate action on closing of all pit taps and unauthorized connections.

B) Tap Stand Study

1. The supply condition at water drawl points such as HSCs can be assessed along with the community conducting tap stand study at different locations namely near OHSR, Tail end, higher elevation, etc.. The simple procedure of recording time for filling a standard pot during the start of supply and during the end of supply hours can be recorded.
2. The VWSC and SHG members along with school teachers may be involved in measuring and recording of time and assess the discharge in lpm. Assess the present low-level in discharge and discuss with the community the reasons for such low level of service and the immediate measures the community can undertake to improve the service condition in consultation with departmental engineers.
3. The low cost measures such as introduction of valves to feed higher elevation, zoning and looping for attaining equal distribution, attending leakages, removal of illegal tapplings which can be done through GP or from common community fund can be discussed for service improvement. Any individual who can voluntarily assist can also be explored and motivated.
4. After showing an improvement in the service level, the community can be Triggered to take decision for removal of pit taps in HSCs and also removal / regularize unauthorized connections.
5. Notify at public places including schools, the resolution of community on the actions to be taken, the date and time for undertaking such activities by the community and request other people to join on that day of action.
6. Source Protection Measures:
 - a) The supply of safe water is very essential in the context of acceptability and satisfaction of the community. The first step towards this will be protecting the sources from any contamination.
 - b) The Sources can be inspected with the community members like GP Sarpanch, VWSC members, Community leaders, WSHG animators & members, school students, Teachers, VHN, Pump Operator, etc and the environmental conditions around the sources shall noted and recorded as "Sanitary Survey".

- c) The specific condition of different type of sources which may lead to nonportability / contamination (some items are given below for guidance) can be recorded in “Sanitary Survey”.
 - i) Waste water drain running along or very nearer to the source,
 - ii) Open well not covered with mosquito net / fish net.
 - iii) Damaged and corroded portions in HPs & Open draw wells.
 - iv) Leaky valves and valve pits in case of EPL / CWSS.
 - v) Any other conditions as deemed fit.
- d) The ill effects of sources in the above condition shall be discussed with the community members, necessity to undertake remedial measure to avoid diseases and for safe water supply.
- e) The immediate remedial measures can be taken up along with the NSS Volunteers, students, SHGs and youth club by voluntary labour, individual donations and GP support.
- f) The NSS Volunteers, students, SHGs and youth club members can undertake certain measures as mentioned below for source protection.
 - Leveling the ground around the power pump sources for avoiding water stagnation
 - Diverting the waste water drain running near the source
 - Repairs to Hand Pump platform and providing proper drainage (with soak pits if necessary)
 - Open well shall be covered with mosquito net / fish net to avoid breeding of mosquito and falling of waste materials.
 - Attending leaky valves at tapping points in case of EPL / CWSS.

C) Revival of Traditional Sources:

- A special walk along with the GP President, VWSC members, SHGs, Students, teachers etc., can be undertaken to the areas of the traditional water sources such as pond, tanks, lakes, etc. along with the community.
- The condition of the supply channels and water bodies regarding any encroachments, weeds growth, debris, open defecation, present usage shall be assessed and recorded using the Students, NSS volunteers, SHGs, youth groups, etc.
- The community discussion shall be done on the prevailing conditions and to take up remedial measures with specific responsibilities among the members.

- The NSS volunteers, School students, SHGs and youth club members can be motivated to clean up the ponds, tanks, supply channels, etc by fixing up a date for activity. Any refreshments can be arranged through community common fund or individual donors.
- Specific community decisions to safeguard the traditional water bodies can taken in the following points:
- Banning open defecation particularly around water bodies and supply channels and water supply sources.
- Avoiding direct disposal of waste water in to the supply channels as well as water bodies and to undertake interception and diversion works for the waste water channels / drains. Banning the disposal of debris and garbage in the supply channel and water bodies.
- The community comprising members from SHGs, VWSC and students can form “Water Bodies Protection Team” to monitor the implementation of community decisions

14.5 Operation & Maintenance Aspects

14.5.1 Fixing supply timings:

- A meeting with the community comprising of all sector representatives particularly women shall be organized to regularize the water supply timing which will be advantageous for their day to day work.
- Depending upon the availability of water and their daily requirement the community shall fix the timing & duration of water supply through HSCs.
- This can be monitored by a street user group - ‘Supply monitoring Team by recording the date & time of supply in a notebook. This team may include the SWHG members and school children etc.

14.5.2 Optimizing Pumping Hours:

The major portion of the O&M cost goes towards the Electricity Bill, which directly depends on the hours of Pumping. It is necessary to arrive at an optimum pumping hours in order to economize the O&M cost.

Most of our water supply schemes are having Bore well as source and hence to find out an optimum pumping hours a ‘Pumping Test’ may be conducted as detailed below:

- To conduct this test a community team consists of Pump Operator, VWSC members, WSHG members and school children may be formed.
- During the first day the water may be pumped to the OHSR and the time taken to fill each foot in OHSR can be recorded till the OHSR is filled fully or to the daily pumping level.
- The time taken to fill each foot may vary with respect to yield.
- Note the level where there is an increase in time for filling a particular depth is more than the time taken for previous depth. Then that level as well as pumping hours can be taken as “first optimal stage”.
- During the second day the pumping can be stopped after the first optimal stage and few hours may be given for recuperation of the water in the source. The pumping can be done for the second time up to the depth during which the pump discharge remains almost same including the time taken for that depth again. This can be taken as the “second optimal stage” pumping.
- By repeating the above process for one or two days the optimum hours and stages of pumping can be arrived and accordingly the pumping can be done in future.
- However the above optimum pumping hours may differ depending upon the various seasons and hence such a test has to be conducted at frequent intervals (say once in three / four months) and the pumping hours can be fixed accordingly.
- To make this process sustainable a monitoring mechanism may be made with a user group including some school children besides the Pump operators, VWSC members SHG members etc.
- The pumping time, duration and meter reading on each day may be recorded in a notebook and also can be written on the walls of the pump room for public information

Model Wall tabulation: For cases where there is no intermediate pumping, such records are maintained by the RWS & S Dept. at head works level.

Name of the habitation:						
Names of User team member		1.....		2.....		3.....
Date :	Pumping Hours			Electricity Meter reading		
	Time of start	Time of finish	Total hours of pumping	Reading at start	Reading at finish	Total units consumed
This week: Total pumping hours				Total Units consumed		
Last week: Total pumping hours				Total Units consumed		
Comparison: Excess / less						

14.5.3 Alignment watch

- Generally the major loss of water is due to leakage in the pumping main and Distribution system.
- To identify and attend immediately such leakages, 'Alignment watch Team' with user group (Students, WSHG members Youth groups) and pump operator shall be formed.
- One or Two members in the team can do alignment walk along pumping main preferably during pumping hours and along Distribution system during supply hours.
- If they found any moisture on the soil above alignment or any visible leakages it shall be recorded in a separate note book and reported to the GP / Pump operator to undertake repairs.

- If any burst has identified the team members shall stop the pumping / close the out let of OHSR respectively in case of Pumping main or distribution.
- The team shall ensure repairs and restoration by the GP by intimating the occurrence to the proper person such as Sarpanch/VWSC, pump operator / plumber.
- If sufficient funds are not available for certain repairs, the user team can mobilize the community to spare from common funds or any individual to donate.

14.5.4 HSC maintenance

- The quality of service delivery to the public mainly depends on the condition of PSPs & HSCs. Any damage to the PSP platforms, stagnation of water, garbage around the PSP, taking bath and washing around the PSPs will have different level of contamination to the drinking water collected.
- For maintaining the hygiene at PSPs & HSCs, which in turn will keep the water safe, necessary measures at user level and GP level has to be taken.
- With the community consensus the GP can resolve to ban the other uses at the PSPs apart from collecting water.
- The HSC users shall be motivated for not using the water for non-domestic purpose such as Gardening, cattle washing etc.
- All the HSCs and PSPs shall be ensured with proper taps.
- A street wise PSP user group to monitor the proper water drawl at PSP shall be formed. This group shall mobilize the user not to practice any community banned activities.
- This street wise PSP user group will also conduct 'Tap stand Study' once in a month and record the supply level in a note book. If any undue decrease in supply level noticed, the team will report to the pump operator / GP to set right.

14.5.5 Water Conservation

- The satisfaction of the community can be made permanent only when suitable water conservation measures as a part of general O&M is practiced both at household level and community level. Some conservation measures as mentioned below can be inculcated among the people by IEC and consensus.

14.5.6 At Household level

- The households can collect and store water for daily requirements alone.

- The balance water after usage from the previous day collection in the houses need not be poured as waste and the balance requirement alone shall be collected afresh for the new usage.
- Proper handling and storing of water in the houses shall be practiced to avoid contamination.
- The Water collected for domestic usage should not be used for gardening; the kitchen and bathroom wastewater shall alone be used for gardening.
- Soak pit can be constructed by the households for the disposal of kitchen and bathroom wastewater.

14.5.7 Community level

- At PSPs the tap shall be kept closed when the water is not collected and taps shall also maintained without leakage.
- All taps can be replaced to avoid leakage as well as for a uniform appearance
- Bathing and washing shall not be practiced at PSPs
- Traditional sources shall be maintained as water sources and free from any garbage, debris, and wastewater.
- Rain water collection and recharge shall be practiced and community involvement should be provided.

14.5.8 Water Quality & Disinfections

- Maintaining the quality of water supplied is a major task and the community involvement in practicing and monitoring is important in all aspects. The general measure to maintain the water safe for consumption is detailed below for community level adoption.
- The OHSR shall be cleaned periodically. The user group members such as Youth club and other villagers shall be fixed to do cleaning on voluntary basis and to monitor the regularity. The Last date of cleaning and the due date to clean shall be written on the OHSR wall / Columns.
- The pipeline shall be cleaned and scoured periodically. The pump operator and user group shall be trained to undertake the cleaning and monitoring the regularity.
- Regular chlorination using bleaching powder on daily basis inside the OHSR depending upon the quantity of water to be supplied. The Pump Operator and Women SHGs shall be trained to carry out the disinfection. The user team shall also maintain a separate register on the bleaching powder dosage. In latest trends with the per capita demand of

100 LPCD gas chlorination can be preferred in respect of reliability, sustainability and economics.

- The Open wells and hand pump sources shall be given bleaching powder dosage once in two months using the fitter and WSHGs trained to remove the HP head and refit.
- Testing of residual chlorine at PSPs and HSCs by the Users group and students, recording the results in a note book for improving performance.
- The community shall do water quality analysis using field kit as frequently as possible, duly considering seasonal variation. Students & SHGs shall be trained to carry out test.
- The Water sample analysis for all parameters shall be done by the GP once in year or on need basis at the nearby TDWSCL/RWS&S Dept./Water Boards/Departments District Lab.

14.5.9 Financial Management

The VWSCs and the other user group shall be trained to prepare the monthly or bimonthly O&M Budget based on the actual data available with them. The individual households shall be motivated such that they pay the tariff regularly. The Electricity meter reading card shall be properly entered and maintained by the User group / Pump Operator. The User group shall monitor the O&M budget regularly and shall take measures to reduce O&M costs.

Chapter - 15

SYSTEM MANAGEMENT

15.1 Introduction

15.1.1 Need for Effective Management

Effective management is the single largest factor which causes the greatest positive impact on the performance of water supply systems. Lack of which, 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 manager's in-charge of the O&M of rural 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 shall be to provide to the consumer the best quality service at the lowest cost.

15.2 System Approach to Management

15.2.1 Approach

In a system approach, each water supply organisation is considered as an overall agency within which a range of organizational systems exist. Each organizational system is known by its area of specific action and represents specific functions. These systems can be implementation, 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 performance maintaining etc.

15.2.2 Advantages of System 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 functioning of the agency, relationships between various wings of the agency.

15.2.3 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 collect 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.

15.2.4 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 of 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 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.

15.3 Management Information System (MIS)

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 organization to carry out the specific functions effectively and efficiently in tune with organization's objectives. Organizations have many information systems serving at different levels and functions within the organization. The data fed into 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.

The efficient and effective performance of an agency depends on a clear relationship between management activities such as planning, organization, 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 centers of decision and each of these is supported by an information system.

15.3.1 Organizational 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).

15.3.2 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:

15.3.2.1 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.

15.3.2.2 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.

15.3.2.3 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.

15.3.3 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.

15.3.4 Centers for decision making

Normally an agency has decision centers 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.

15.3.5 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.

15.3.5.1 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 15.1. Each agency has to choose the relevant indicators and then generate the data for MIS required to assess the appropriate indicators.

15.3.5.2 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.

15.4 Computerised MIS

RWS&S department had designed, developed and maintain Online Works Monitoring System for Telangana Drinking Water Supply Project. This serves as a platform for the departmental activities of water supply to the rural regions and bring in better transparency and enhancement in functioning of the department. It serves as a one-stop-shop solution for the works related to Telangana Drinking Water Supply Project.

The Information system had developed on Client/Server architecture using object-oriented approach. It will be menu driven with user friendly GUI, easy to operate, integrate and modular system. These features will make the system flexible and scalable to incorporate any future Computerized MIS has the following characteristics:

- i) Provide Constant feedback on the extent to which the project is achieving its goal
- ii) Evaluate to the extent to which the project is able to achieve its general objectives.
- iii) Manual intervention which increases the errors and data manipulation can be reduced. Hence accuracy in output.
- iv) Dashboard/Widgets provides us reminders like structures which are lagged in reaching the milestones, EOT Requests.
- v) **Spontaneous Remedial Action:** Monitoring provides for great spontaneity. Can identify issues and take immediate remedial action thereby enhancing operating efficiency.
- vi) Minimized Data Inconsistency
- vii) Number of interacting variables.
- viii) Speed is an important factor.
- ix) Operations are repetitive.
- x) Involves large amounts of data.

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

15.4.1 Information System Division

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

15.4.2 The Technology

Technology used for the development of the Online Works Monitoring System :

1. Front end :-
 - a. Java Script, AJAX, (b) Angular JS (c) Boot Strap (d) HTML & CSS
2. Application Layer:-
 - (a) JAVA, (b) Springs (c) Restful Web Services
3. Backend :-
 - (a) My SQL (b) Post GIS

15.4.3 The Environment

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

15.4.4 Various Components in Online Works Monitoring System

- **Asset Management:-** (assets, Pipeline, Household tap connections)

Data Capture:

1. Physical Parameters
 - (a)Capacity, (b) Dimensions (c) Geo-locations
2. Financial Parameters
 - (a)Expenditure (b) Payment Date
3. Progress Parameters
 - (a)Quantity of work done (procured, laid length,% of work,...) (b) Payment Details (amount paid, paid date) (c) As laid Diagrams for the laid Pipeline
4. Agreement Details
 - (a)Agreement Number (b) Agency Name (c) Agreement Date (d) Contract duration (e) Milestone Details

All the structures are inter-linked so that one can have the complete structure from source point to distribution point.

- **Reports**

We can extract all the data with latest progress and images.

- **Graphical Reports**

(a) Pie Charts for Complete project completion (b) Bar Charts for individual asset progress (c) Morris charts for all structure types based on the progress made in the segment selected (d) GIS Report

- **Employee Management**

(a) Employee Management (b) Create User (c) User Management

- **Meeting Manager**

(a) Schedule Meeting (b) Update Schedule (c) Meeting Schedule

- **Vendor capacity assessment**

(a) Daily Production Entry (b) Weekly Production Entry (c) Monthly Production Entry (d) Invoice (e) Day Wise Production Report (f) Week wise Production Report (g) Month Wise Production Report (h) Vendor Details Entry (i) Vendor Details

- **Working Estimation**

(a) Asset Estimation (b) Pipeline Estimation

- **QC Request**

(a) Asset & Pipeline Request (b) Asset & Pipeline Report

- **File Management**

(a) Assign File (b) File Organizer (c) File Explorer

- **GIS Management**

(a) KML Upload (b) GIS Progress

- **Dashboard/Widgets**

(a) a. Alert mechanism to display alerts for the following

I. EOAT requested assets (II) Milestone not achieved assets reports (III) Approval alerts for working Estimates (IV) Approval alerts for QC Requests (V) Calendar view for each asset with the list of milestones and its target dates.

- **Public Report**

(a) Asset Report (b) Pipeline Report

(These reports are available for the public to know the physical progress of the structures under Mission Bhagiratha)

- **Downloads**

Download forms will be accessible to the public and is mainly used for downloading files like GO's, Sanctions etc.

- **Requests**

Any Private organization or Public Sector which needs water from Mission Bhagiratha can raise request for the same through this Request form

Data base related to above is attached as annexure for the reference.

As all the structures are interlinked it will be easy to have a complete glance from source point to distribution point which will be useful for the operation and maintenance works.

Data that need to be captured for the operation and maintenance activities as below:

- Quantity (KL) of water entering into the asset
- Quantity (KL) of water discharging from the asset
- Frequency of water discharging from the asset
- Position and condition of valves
- Availability of water at source
- Quality of water entering into the asset
- Number of house hold connections for which water has to be supplied
- Expenditure spent for the repairing of assets like valves, pipelines, verticals, pumps etc.
- Number of habitations for which water is supplied.

15.5 Various Main/Sub Systems For MIS In Water Supply

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 organization from which the reports for MIS can be generated.

15.5.1 Financial Management Information System

(a) Financial Accounting (b) Payroll (c) Revenue Management (d) General Ledger (e) Accounting (f) Funds

15.5.2 Project Management Information System

(a) Engineering Planning and Design (b) Construction (c) Contracts and Monitoring

15.5.3 Human Resource Management Information System

(a) Manpower planning and Recruitment (b) Personnel Development and Training

15.5.4 Material Management Information System

(a) Purchasing (b) Inventory Control

15.5.5 Operation And Maintenance Management Information System

(a) Operation (b) Maintenance

15.5.6 Marketing Management Information System

(a) Customer Information (b) Demand Forecasting (c) Market planning

15.6 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, analyzing and Prioritizing, 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 organization.

15.7 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.

15.7.1 Financial Information System

Monthly capital budget progress details

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

15.7.2 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.

15.7.3 Human Resource Information System

- Monthly report on staffing and salary.

15.7.4 Project Planning and Contracts Information System

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

15.7.5 Material Information System

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

15.7.6 Marketing Information System

- Monthly demand forecasting and market planning.

15.8 Emergency/Disaster Planning

15.8.1 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.

15.8.2 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:

- (a) Power failure.
- (b) Storms and flooding.
- (c) Epidemics.
- (d) Fire.
- (e) Earthquakes and landslides.
- (f) Explosions.
- (g) Breakdown of water supply system units like pumping burst mains etc.
- (h) Strikes by workmen.
- (i) Sabotage or vandalism.
- (j) Water supply Bioterrorism.

15.8.3 Structure

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 up to 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 co-ordinations 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 organization 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.

15.8.4 Threats 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 defense 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 defense. 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 utilizing DNA analysis for pathogens such as anthrax have been developed. There is need to keep abreast of such developments.

15.9 Database of Rural Water Supply Scheme

To achieve efficient and effective performance of rural water supply scheme following, The Data Base of the scheme is required to be collected and analyze in due course of time. This will help in deciding, life of scheme, time schedule for augmentation of each component, sustainability of source, and the system, and to provide safe drinking water in adequate and desired quantity ,at adequate pressure at convenient location and time and as economical as possible on a sustainable basis.

The Formats of data base are appended as categorized as below :

Sl. No.	Particulars	Annexures
1.	General	2
2.	Surface Source	3-A
3.	Ground Water Source	3-B
4.	Rising Main	4
5.	Storage Tanks	5
6.	Pumping Machinery / Power Filtration	6
7.	Filtration Unit	7
8.	Distribution System	8
9.	Water Revenue	9
10.	Re-Organization / Contingency Works/ Deposit Work	10
11.	Water Quality Assurance Monitoring	11

ANNEXURE 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	
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 dues 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	

Screen Shots of Asset Management Forms:

Asset Entry Form

Urban Rural

Select District *	Select Constituency *	Select Mandal *
Adilabad	Adilabad	ADILABAD
Select Panchayat *	Select Village *	Select Habitation *
ANKOLI	ANKOLI	ANKOLI
Select Segment *	Select Asset Type *	
Yellampally sub segment	OHBR	LandMark

OHBR Asset Information

Capacity(KL)	Ground Level	MWL
LWL	Staging	<input type="radio"/> Circular <input type="radio"/> Shaft

Lead Details (to come)

Land Details (In acres)

Government	Required	Obtained	Survey Number
Private	Required	Obtained	Survey Number
Forest	Required	Obtained	Survey Number

Estimation & Location

Agreement number *	Agent name *	Agreement Date
Target Date	Estimation cost(In lakhs) *	Contract Amount(In lakhs) *
GPS-Coordinates: *	Longitude	Latitude
Estimation Files: *	FILE	Only Zip file allowed

/ata/Sunbinn/Ohrc.html

Estimation Files: *

FILE

Only Zip file allowed

Design Files: *

FILE

Only Zip file allowed

BOQ File (optional):

FILE

Only XLS/XLSX file allowed (Upload in specified format only)

Upload BOQ in specified XLS format only otherwise it will not accept [Download XLS Format here](#) *

Milestones (Enter in chronological order)

Milestone	Target Date *	Target % *
1	Target Date	Target Percentage

ADD NEW MILESTONE

REMOVE LAST MILESTONE

SUBMIT 

GIS Progress Entry

Filter Search

Select Circle: Rangareddy | Select Segment: HMWSSB-Nedchal segment | Transmission Mode: Gravity

SUBMIT

Network	Mode	Length	Location
Transmission	Gravity	247.64	medchal

Stretch List of selected pipeline

select stretch

SEARCH

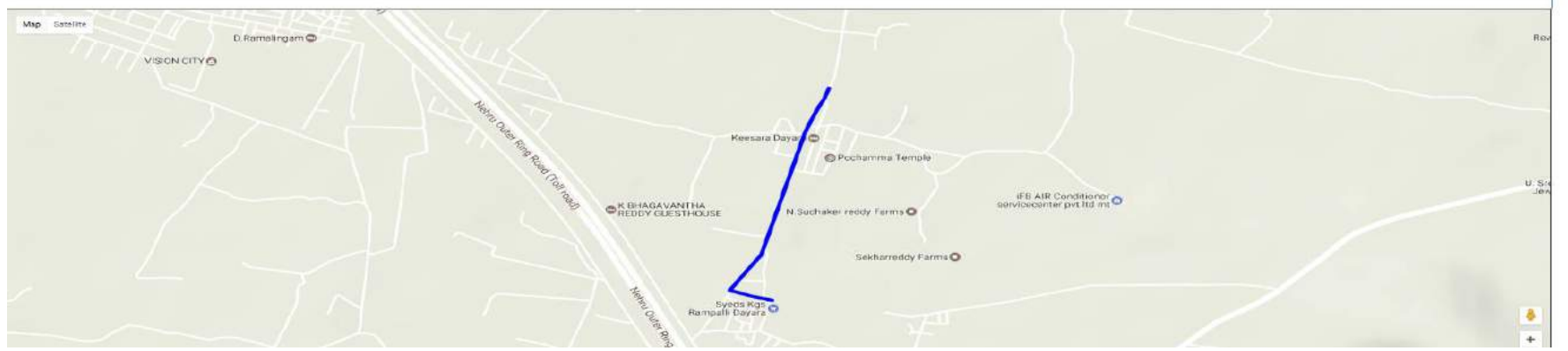
SUBMIT

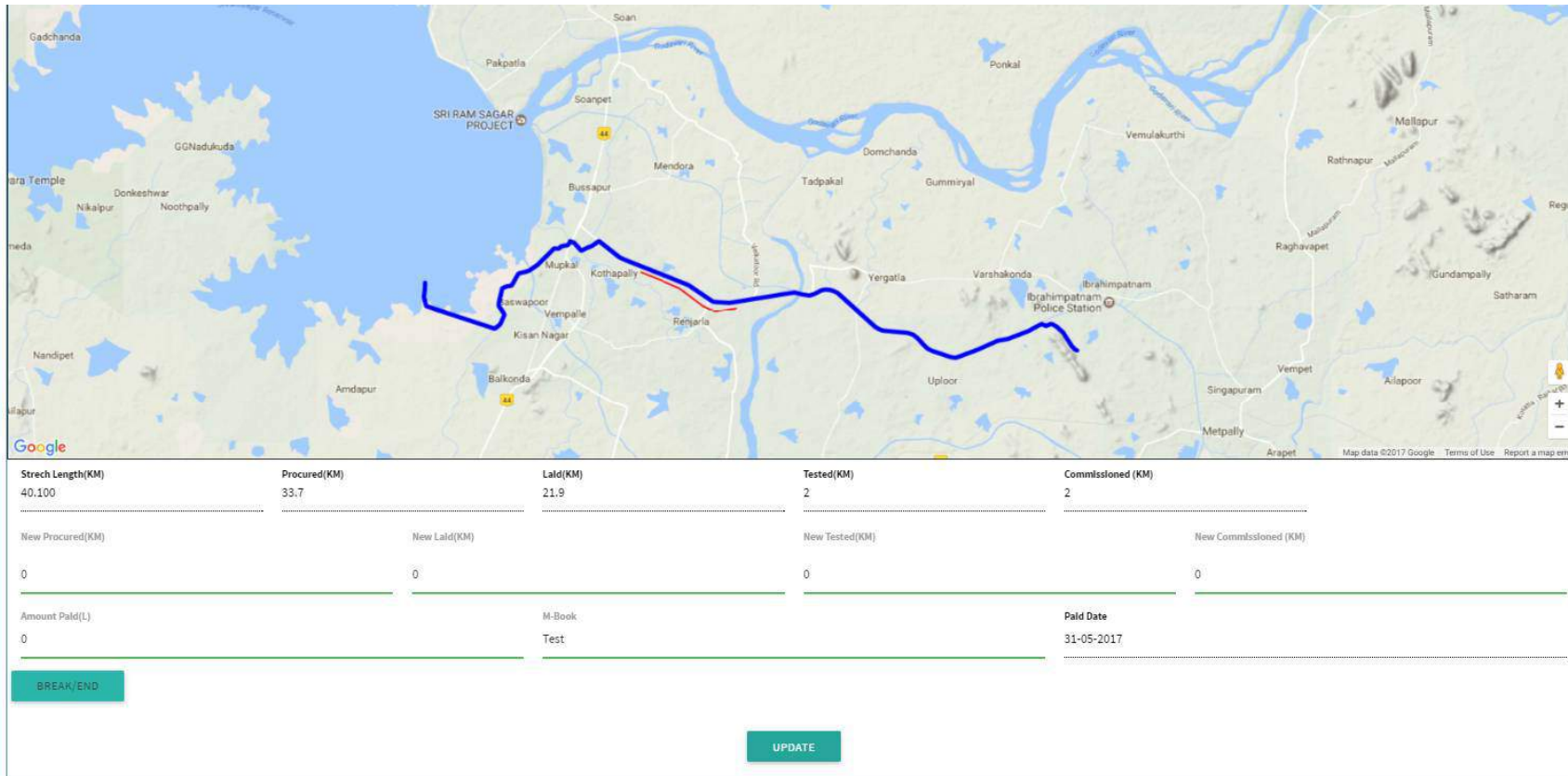
Network	Mode	Length	Location
Transmission	Gravity	247.64	medchal

Stretch List of selected pipeline

0001

SEARCH





House Hold Connection Entry Form:

House Hold Connection Entry Form

Select District *
Choose your District

Select Constituency *
Choose your Constituency

Select Mandal *
Choose your Mandal

Select Panchayat *
Choose your Panchayat

Select Village *
Choose your Village

Select Habitation *
Choose your Habitation

POPULATION				Connections		
SC	ST	PLAIN	Total 0	Households	Existing	Required

Asset Details

Select Segment *
Choose your Segment

Select Asset Type *
Tap Connection

Target Date *

Estimation & Location

Estimation cost (In lakhs) *

Contract Amount (In lakhs) *

Agreement number *

Agent name *

Estimation Files: * FILE Only Zip file allowed

House Hold File: * FILE Only XLS/XLSX file allowed

SUBMIT

Sample Reports:

State Abstract Report:

This report gives the complete details of all the structures , pipeline and valves as below:

State Abstract Report																				
S.no	District	No.of Segments	Amount(L)		constituencies	Mandals	Habs	ULBs	Intake	WTPs	SUMPs	GLBRs	OHBR	BPT	Transmission Pipeline Length KM					
			Estimation Cost	Contract Amount											MS	DI	BWSC	PCCP	HDPE	Total
1	Adilabad	5	3898109.72	3796536.49	10	52	3621	7	5	7	124	23	27	9	13.13	1648.27	9.40	0	3082.44	4754.36
2	Karimnagar	9	45868.28	41278.79	13	57	2248	11	1	8	41	15	19	26	281.35	1973.00	28.77	17.97	3676.13	6022.15
3	Khammam	8	9429580.29	13273516.28	10	41	2724	6	4	6	27	15	42	2	12.86	26287.97	37.77	71.46	106249.61	132954.22
4	Mahabubnagar	2	3033403.60	2487081.66	14	64	3414	11	1	8	62	34	89	23	0	822.34	7.60	0	3269.87	4186.59
5	Medak	5	23061.45	21860.53	10	46	2428	8	2	3	25	3	33	11	11.30	1244.18	25.24	11.36	3499.86	4850.00
6	Nalgonda	8	7825509.07	7824811.34	12	59	3376	7	2	5	49	29	125	3	160.84	2091.83	103.02	16.27	5308.24	8180.98
7	Nizamabad	2	19129.60	17711.66	9	36	1701	3	0	4	51	6	20	22	117.94	617.25	62.79	18.88	2165.99	3064.84
8	Rangareddy	2	8912094.00	7779636.74	9	33	1650	5	0	3	18	0	11	51	0	1281.38	0	0	1471.10	2752.48
9	Warangal	8	90836273.48	125223787.60	10	50	3449	6	4	7	51	14	39	10	124.81	894.88	103.44	5.78	3315.08	4443.99
	Total:	49	124023029.49	160466221.09	97	438	24611	64	19	51	448	139	405	157	722.23	36861.10	378.03	141.72	132038.32	171209.61

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Drill down details of a particular structure for the above report:

Amount(L)											Transmission Pipeline Length KM			
Asset Details														
Sl.No	Asset Code	Asset Type	Location	Segment	Capacity(KL)	Target Date	Estimation Cost(L)	Agreement	Agency	Image	Completed Percentage	Expenditure	Last updated	
1	170374101801120091306001	GLBR	Peerlagutta Hillock	Singur-Narsapur segment	1200	31-01-2017	85	AEE/ /2015-16	M/S.BRC	Image	100	55.16	2017-04-25 02:49:32.0	
2	170382802301170091206001	GLBR	Mirzapur N	Singur-Sangareddy segment	300	18-04-2017	27	AEE/2/2015-16	M/S Pratibha Industries, Mumbai	Image	60	15.71	2017-04-28 04:54:11.0	
3	170422102501260091406001	GLBR	Komatibanda Hillock	HMWSSB-Gajwel Segment	14000	30-04-2016	600	AEE/ /2015-2016	MEIL	Image	100	496.48	2016-12-26 10:24:54.0	

Amount(L)											Transmission Pipeline Length KM									
Asset Details																				
Last updated	Last updated user	Ew Excavation	Pcc stage	Raft stage	Gl stage	Staging Level	Bottom Slab	Side wall Staging	Top Slab Level	Fixing CI Specials	Finishing Stage	Milestone Details	QC Details	Land Details	Asset File Details					
2017-04-25 12:49:32.0	Maaka Suresh:AE	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Progress	Milestones Details	QC Status	-	Asset File Details					
2017-04-28 04:54:11.0	N.Raghuveera:EE	Completed	Completed	Completed	Completed	Completed	completed	completed	Completed	Not Started	Not Started	Milestones Details	QC Status	-	Asset File Details					
2016-12-26 10:24:54.0	Nagarjuna Rao Nayineni:AE	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Completed	Milestones Details	QC Status	-	Asset File Details					
Total:		49	124023029.49	160466221.09	97	438	24611	64	19	51	448	139	405	157	722.23	36861.10	378.03	141.72	132038.32	171209.61

Drill down details of a particular type of pipeline:

Sl.No	Pipeline Code	Netwrk Typ	Tranmission by	Strech code	From JN	To JN	Cum POP	LPM	Type	Dia	Class	Contract Amount(L)	Expenditur
1	159030101002	Transmission	Gravity	0004	OHBR Arch Jn	Girmapur Village Jn	2098	331	HDPE	140	6	7.37	-
2	159030101002	Transmission	Gravity	0005	Balaji nagar OHSR Jn	Gonti guda OHSR	516	81	HDPE	75	6	2.03	0.00
3	159030101002	Transmission	Gravity	0007	BOKKONI GUDA Village Jn	BOKKONI GUDA OHSR	416	66	HDPE	63	10	0.12	-
4	159030101002	Transmission	Gravity	0008	BOKKONI GUDA Village Jn	GHANAPUR OHSR	1545	244	HDPE	125	8	14.54	-

Contract amount(L)	Expenditure(L)	Length(km)	Procured	Laid	Last Updated User	Last Updated Time	HGL start point	HGL end point	GL end point	Fric loss	Resid Head	Length through agl	valves	Pre Qc Status	Post Qc Status
7.37	-	0.99	-	-	Admin:ADMIN	2017-02-07 07:50:19.0	0	644.54	597.59	1.77	0	0	0	QC Status	QC Status
2.03	0.00	0.66	0.688	0.688	Admin:ADMIN	2017-03-22 11:19:46.0	0	521.7	478.996	2.24	0.411663	0	0	QC Status	QC Status
0.12	-	0.039	-	-	Admin:ADMIN	2017-02-07 07:50:19.0	0	523.01	448.494	0.21	0.473334	0	0	QC Status	QC Status
						2017-02-								QC Status	QC Status

GIS Progress Report:

This report will display all the structures and pipeline and valve details.

