CHAPTER 10

REPAIR OF PIPE LINE

It is one of the most important responsibilities of a Water Undertaking to properly maintain the transmission and distribution mains in order to prevent waste and provide a constant pressurized flow of potable water to the consumers. It is equally important to prevent damage to the public property which could arise for not properly repairing a defective pipe. Proper planning and implementation of remedial measures will avoid leakages and breakdowns.

10.1 CAUSES OF FAILURE IN PIPELINE

For proper planning for the operation of the repair work it is necessary to assess the probable causes of failure. Following guidelines outline some of the factors to be duly considered to ensure protection of pipes from damage/failure.

10.1.1 HANDLING AND STORAGE OF PIPES

1. Damage during transport of the piping material.
2. Defective stacking and storage.
3. Damage to the pipe wall and coating.
4. Cracks in pipe during careless unloading and pipes striking against each other.
5. Weathering effect due to unfavorable environment.
6. Mixing up of different classes of pipes and their jointing materials.

10.1.2 LAYING OF PIPELINE

1. Deviation from proper laying procedures.
2. Improper bedding
3. Loss of support of bedding after laying.
4. Slipping of trench sides.
5. Sinking of soil after laying.
6. Poor quality of backfill material.
7. Improper compaction of trench backfill and its subsequent settling.
8. Excessive overburden on piping trenches, not taken care of during the design of pipeline.
9. Point loads coming on the pipe through the backfill.
10. Excessive vibrations due to traffic during the laying of pipeline.

10.1.3 JOINTING OF PIPES

1. Defective jointing material.
2. Direct strike on the body of the pipe with any sharp edge, while jointing.
3. Slipping of jointing material like rubber ring or lead etc.

10.1.4 CHARACTERISTICS OF SOIL

1. Corrosive nature of soil causing damage to the external surface of the pipe.
2. Extremes of climate: frost heave or clay shrinkage.
3. Loss of support or anchorage (horizontal or vertical), both in case of pipes embedded and those laid above ground level.
4. Movement of soil due to filled soil, mining.
5. Movement of soil while work of laying pipes or other activities like laying of cables etc. is taken up.
6. Changes in soil moisture or water table conditions.

10.1.5 EXCESSIVE TEMPERATURE CHANGES

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

10.1.6 INTERNAL PRESSURE

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

10.1.7 AGGRESSIVE WATER

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

10.1.8 GALVANIC ACTION

10.2 SPECIAL OBSERVATIONS ON FAILURE OF PIPES

10.2.1 PIPE BARREL

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

10.2.1.1 Brittle type fractures

These may be found in rigid and semi-rigid materials such as cast iron, asbestos cement and PVC.

These are characterized by relatively clean, sharp-edged splits or cracks. These may occur as circumferential breaks or longitudinal cracks which may run straight but more often irregularly curved along the pipe barrel.

10.2.1.2 Ductile type failures

These occur in polyethylene and ductile iron. These are usually found as relatively short splits or tears with irregular edges which are often associated with some local swelling around the break.

10.2.1.3 Blow Outs

These are localized failures which only occasionally occur and are usually associated with high pressure, e.g. pumping surges in weakened brittle materials.

10.2.1.4 Pinholes

These may be caused by an impurity or inclusion in the wall of the pipe wall or, more often, by localized chemically or electrically induced corrosion which thins and weakens the pipe wall until a small plug is blown out by internal pressure. Pinholes often enlarge quite quickly due to erosion around the edges of the hole. Pin holes are frequently found within the metallic group of pipes.

10.2.1.5 Generalised Deterioration

More generalized deterioration of pipe barrel may be due to a manufacturing defects but is usually the result of some form of chemical attack. The overall effect is reduction in wall strength depending on the material group. Some of the examples are the graphitization of iron mains, sulphate attacks on AC and concrete, lime leaching from cement lining by soft waters and solvent attacks on the polymeric group of materials leading to softening or delamination of composites such as GRP.

10.2.2 FAILURE AT PIPE JOINTS

Some of the points for consideration are given below:

10.2.2.1 General

1. Failures may occur due to originally careless installation practices causing displacements of the seal and/or eventual separation of the mating surfaces.
2. Stress cracking of pipe material around the joint.
3. Biodegradation of the sealing components.

10.2.2.2 Flanged connections

Stress cracking of the flange can occur due to unequally tightened bolts. Such a situation arises during ground movement or the forceful activation of a valve or hydrant.

10.2.2.3 Crushing of pipe ends

Cracking may occur due to crushing of pipe ends when they touch or bind and are then subjected to high compressional or bending forces.

10.2.2.4 Lead joints

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

10.2.2.5 Sealing rings or gaskets

Many mechanical joint designs rely upon the compression of sealing rings or gaskets which have varying compositions and different resiliences. The physical breakdown (e.g. biodegradation) or change of resilience with time can lead to leaking joints. The loss of compression combined with corrosion of pressure rings or collars or the bolts may aggravate the breakdown.

10.3 REPAIR ACTION PLAN

10.3.1 GENERAL PROCEDURE

Following procedure may be followed:

1. Internal mobilization.
2. Detection of pipe failure: Inspection of site
3. Notification of interruption in water supply and related issues.
4. Location and demarcation
5. Repair planning
6. Repair work: Selection of most appropriate method for repair.
7. Testing of 'dry' repair.
8. Restoration
9. Completion
10. Hygiene
11. Notice of restoration and completion

10.3.2 IMPLEMENTATION OF ACTION PLAN

10.3.2.1 Monitoring of Internal Mobilization

Some of the important activities relating to the mobilization of the internal activities are summarized below;

(a) Senior Level Management

Necessary information to the Senior Level Management may be submitted and their interim approval sought. Details approval can follow in due course of time.

(b) Operation and maintenance staff of the running water supply system

The entire staff must be made fully aware of the likely activities required to be undertaken so as to ensure minimum possible interruption in the system.

(c) Alternative arrangement

Alternative arrangement for water supply may be planned and duties of staff fixed accordingly.

(d) Existing installations

The operation of the water supply system with regard to Intake, Headworks, Pumping machinery, Treatment Plant, Piping system etc. must be co-related with the proposed repair work.

(e) Mobilization of men

Necessary staff may be arranged for the following duties;

1. Location of section;
2. Isolation of section;
3. Scouring of section;
4. Arranging transport, material, machinery, equipment, tools, pipes, fittings etc.
5. Other miscellaneous duties.

(f) Manpower, material, machinery, transport, lighting, safety measures, communication, pipes with fittings and specials etc. for the repairing operation.

These details are variable and depend upon various factors as per the local situation. Some of the factors to be considered are;

i) The importance, utility and function of the affected pipeline with the piping net work.

   This may be the only transmission main of the system. It may be one of the two or many parallel transmission mains. It may be initial portion of the distribution system serving as the only main to supply water to the rest of the area to be served. It may be a distribution pipe serving only a part of the system.

ii) Size and material of the affected pipe.

   These are very important factors which determine the magnitude of the repair to be undertaken.

iii) Depth of the pipeline. Deeper pipes require more labour work for repairing.

iv) Subsoil water table.

   If the pipe is laid much below the local water table, additional work will be required to dewater the trenches excavated for repair.

(v) Other unforeseen factors.

Depending on these factors the requirement of manpower, material, machinery, tools, equipments, pipes, specials, fittings etc. is to be worked out. Given below is a list to meet the requirement of a big transmission main which is a life for the water supply system. This may be considered as a guideline only. Exact requirement may be worked out depending upon the local conditions.

Man power

Desig-nation	Manager	Super-visor	Fitters	Welders	Crane operator	Excavator operator	Truck operator	Jeep operator
Number	1	1	3	3	1	1	1	1

Desig-nation	Emergency Van operator	Electrician	Mechanic	Helper	Semi-skilled	Pump operator
Number	1	1	1	1	8	1

Material

Electrodes, Gaskets, Rubber insertion, Bolts and nuts, Gland rope, Manila rope, Pig lead, Cotton waste, Wooden sleepers, PVC hose pipe, Canvas hose, Engine oil, Wire slings, Grease, M.S. Plates, Diesel, Kerosene, Fire wood, Cement, Sand, Spun yarn, Hard crete, M seal, Sand bags.

Machinery

Machinery	Crane mobile	Excavator	Pumpset (Electric)	Portable Diesel pumpset	Welding generator	25KVA generator	Lighting generator
Number	1	1	2	2	1	1	1

Machinery	Welding set	Mud pump	Gas Cutting set	Pressure Grouting machine	Flexible grinder	Hand drilling
Number	2	2	2	1	1	1

Transport

Vehicle	Truck	Jeep	Emergency breakdown van
Number	1	1	1

Tools

Scour rod with lever, motor driven pipe cutter with extra cutters, H.T.wire cutter, sheet cutter, screw jacks, hammers, spades, buckets, baskets, crow bars, hammers, showels, caulking tools (spun caulking, cement caulking, lead caulking), power wrenches 36 in. to 15 in., adjustable spanner 18 in. to 12 in., chain tong 36 in. long, ring spanner set, DE spanner set, screw drivers, cutting plier, knife, nose plier, knife, chisels, lead pan with sport and bucket, Temporary platforms, files, bench vice and pipe vice.

Pipe Specials

MS gap special, ms barrels, ms split collars (different types available), ms girder, ms angle.

Communication

Wireless set, mobile wireless set, cell phone, pager.

Lighting

Flood lighting, tube light fittings, wire, 3 core cable, insulation tape, main switch, fuse wire, kit kats, welding cable, emergency lights, torch lights, gas lights.

Safety Equipment

First aid box, helmets, headlight, gum shoes, hand gloves (rubber, leather), gas masks, oxygen cylinder.

Amenities

Tents, water cans, jugs and glasses, tarpaulins, electric heaters, rain coats, food (tea and snacks, meals)

10.3.2.2 Detection of Pipe Failure

1. Inspect site and ascertain the nature of the failure.
2. Assess any possible damage or dispute that may arise and take steps to face such situations.
3. Investigate the access to the site so as to plan the arrangement of plant and equipment.
4. Assess urgency of repair, availability of men and equipment, effect on consumers and fix time and day of repair.
5. Locate isolating valves for proper control of requisite activities required for repair work.
6. Depending upon the seriousness of the leakage or burst, the likely effect on the local supplies, decision may be taken on
   i) maintenance of supplies as long as possible
   ii) prevention of possible contamination of the pipeline and
   iii) quick location of the actual position of the pipeline.
7. Establish control and communication network after deciding the time of repair work to be undertaken.
8. Ascertain the sensitivity of the affected area and take steps to avoid undesirable situations.
9. Issue notification and warnings of the likely interruptions.
10. Mobilise men, material and equipment for repairs.

10.3.2.3 Notification

Issue notices to the affected consumers and the departments looking after other affected facilities like telephones, cables, electric lines etc.

Such notifications may be by mobile loud speakers, hand bills, telephones, local media channels etc.

The contents of the notification will be as under:

- Time of closure and affected area;
- A brief and simple reason for interruption;
- An estimated time of restoration of supplies;
- Contact point for any problems;
- Advice on conservation, flushing, boiling, etc.

10.3.2.4 Location and extent of failure

(a) Location of the failure

Make use of local knowledge, plan, experience in locating the failure. Depending on the local conditions, if need be, leak detectors may be used.

(b) Protective signs

Before undertaking any excavation work, all protective measures may be taken including signs, lighting etc. Traffic rules must be complied with. All local utilities must be located and marked and liaison kept with local representatives of these affected utilities.

(c) Excavation

The conventional methods of excavation may be supplemented with more mechanized processes keeping in view the existence and location of the water main.

(d) Shuttering and support

Pay due attention to safety below ground by providing support to trench sides and any exposed pipes and cables.

(e) Extent of failure

The full extent of damage, both to pipe work and any support works, should be assessed.

(f) Work space

Ample workspace should be created to allow for:

i) detailed inspection around the pipe.

ii) provision of sump for continuous operation of a drainage pump

iii) movement of men with jointing material and equipment to be used safely and effectively.

(g) Provide safe dewatering system and discharge points

The discharge of any dewatering apparatus should be checked to ensure free outflow and to avoid any danger or inconvenience caused by flooding.

(h) Control by Valves

Ensure effective operation of repair work by proper control of valves which should be in perfect working condition.

10.3.2.5 Repair planning

(a) Note details of existing pipe

The full details of the failed pipe and/or fitting should be noted including material type, approximate age, class and general condition. Reasons for failure should be established as accurately as possible and recorded. Check actual external dimensions of the pipe and determine any tendency to ovality for effective repair.

(b) Type of repair–wet or dry

A 'wet' repair is defined as a repair which can be achieved while maintaining a nominal pressure in the pipeline. Split collars or identical fittings can be installed in this way if the conditions are favourable.

A 'dry' repair is defined as one in which the main is completely isolated and drained out. 'Cut out 'repairs necessitating the removal of a section of the pipe and/or joints will require 'dry' main on which to work and the pipeline should be drained out.

(c) Extent of repair work and availability of repair fittings and tool

The replacement pipe and/or repair fittings should be selected and their dimensions marked on the pipeline. For a 'dry' repair a final check should be made that all the required fittings and materials are available and are compatible before any attempt to cut the same is made.

(d) Bedding material

Assess and make available the bedding material if required.

(e) Report to Control

When ready to start repair, inform 'control'.

10.3.2.6 Repair work

(a) Repair of small, local defects - 'wet repair'

For small local defects such as pinholes a single split collar or wraparound clamp may be all that is required. The repair can be carried out at as a 'wet' or 'dry' operation. In case of 'wet' repair care should be taken to maintain a steady, gentle flow so as not to dislodge the sealing elements.

(b) Cut out – 'dry repair'

For a more extensive damage e.g. a longitudinal fracture, a section of pipe is cut out and replaced by the use of two appropriate couplers. If full extent of the fracture is not clearly defined cuts should be made at least 300mm beyond each end of the visible crack or defect and in case of any doubt the full length of damaged pipe should be replaced. This necessitates cutting out the joint at both ends of the affected pipe, thus the repair normally requires two replacement pipe sections and three couplers.

(c) Replacement repairs- following observations are important

- Carryout correct measurements and give allowance for expansion;
- All cuts should be made clean and square;
- In A.C. pipes, cuttings should be avoided;
- All cut edges should be prepared (scraped, deburred, chamfered etc.) to the manufacturer's recommendations.
- Both exposed ends of the existing pipe should be similarly treated;
- Couplers should have their sealing rings lubricated if recommended;
- Correct expansion gaps should be allowed;
- Good alignment is essential particularly if narrow couplers are used;
- All couplers and collars should be centralized;
- Tighten all bolts evenly;
- Do not over tighten bolts or compression joints;
- Restore any damaged coatings on the parent pipe;
- Ensure full protection to the bolts and any exposed bare metal before burial.

(d) Record of repair

While the repair is still visible the details of repair should be recorded.

(e) Record of pipe

Record the following items:

- i) any visible damage to the pipe;
- ii) state of protective system or coating;
- iii) depth of cover
- iv) description of the soil/backfill.

10.3.2.7 Testing of 'dry' repairs

(a) Give additional support to repaired pipe portion, if necessary;

All wet slurry should be removed to the extent possible, and the bottom of the excavation should be filled and the exposed pipe work rebedded, with suitable material sufficiently compacted to give adequate support to the invert and lower quadrants of the pipe and any fittings.

(b) Renew bedding and compact

Additional material may be placed to support the repaired pipeline when under test pressure, but it is advisable to leave all joints visible in case of leakage.

(c) Arrange air bleeding and slowly refill isolated section

Refilling the isolated section of the main with water should be done slowly and from one direction only. Arrangements should be made for the expulsion of the air by means of any convenient air valves, hydrants, washouts or taps. The repaired pipe is subjected to a pressure equivalent to the normal working pressure. The repaired pipe should remain under such working pressure until it is adjudged to be satisfactory. Some minor re-tightening of the joints may be necessary due to slight expansive movement of the assembly on being subjected to increase in pressure.

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

10.3.2.8 Restoration

(a) Restore valves and the system in accordance with the original operational plan

The repaired section of main is reintroduced to the system by restoring all valves to their original status.

(b) Checking restoration

The restoration of the supplies to the normal situation supplied at important points should be checked.

(c) Removal of temporary supplies

All standby pipes, temporary supplies and emergency tankers should be removed.

(d) Notification

Notification and acknowledgments should be made wherever necessary.

10.3.2.9 Hygiene

During the execution of the repair work hygienic conditions must be made to prevail at various stages till the completion of work.

(a) Site cleanliness

During the repair work the area should be kept as clean as possible. All debris and contaminants should be removed from the site and the contamination of the trench from plant, equipment or any other potentially hazardous materials must be avoided.

(b) Storage of tools and equipment

All pipes, fittings, tools, equipment and vehicles to be used on site should be regularly maintained and cleaned.

Equipment used for disinfection and sampling should be kept for this purpose and regularly maintained.

(c) Prevention of contamination during repair work

Clean and spray with disinfectant, on all surfaces that come into contact with potable water including the broken main, repair fittings and replacement pipe. Ensure that the contaminants do not enter the main where it is cut for repair.

After completing the repair, flush the main at the nearest hydrant to remove any dirt etc.

(d) Disinfection procedure

For small repairs which do not require the main to be cut, the fracture should be cleaned and this along with the repair collar should be sprayed with disinfectant.

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

10.3.2.10 Completion

(a) Finishing touches

Wherever joints have been left exposed for testing purposes these should be restored to their original position. The bolts, bare metal surfaces etc. should be properly protected prior to side fill.

(b) Side filling work should be suitably accomplished

The dug material should be returned to the trench and placed in layers. The first side fill layer should be placed and compacted under the lower quadrants of the pipe and up to the springing level of the pipe. Successive layers of up to 100 mm thickness may then be placed and compacted to a maximum height above the crown of 250 mm. Light vibrating machinery may be used but not directly above the pipe or the fittings.

(c) Clear site

On completion of the work all materials and protective barriers should be removed from site and the working area left clean and tidy. All records should be completed and submitted.

10.3.2.11 Notice of Completion

Notice of completion or interim or permanent reinstatement must be given within a reasonable period. Location of works and other relevant details should also be given.

10.4 REPAIR METHOD FOR DIFFERENT TYPES OF PIPES

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

TABLE 1

MATERIAL	**CAST IRON**	
Burst	**Action**	**Repair**
Joint failure	Enclose joint Two couplers	Special joint clamp Two couplers and new section
Brittle failure	Remove section/joint Enclose failure	Two couplers and new section Repair collar or clamp
Corrosion	Remove section/joint Rehabilitation technique Enclose failure	Two couplers and new section Sliplining etc. Repair collar or clamp

TABLE 2

MATERIAL	**DUCTILE IRON**	
Burst	**Action**	**Repair**
Joint failure	Enclose joint Remove section/joint	Special joint clamp Two couplers and new section
Extensive pinholing	Rehabilitation technique Remove section/joint	Sliplining etc. Two couplers and new section
Ductile failure	Remove section/joint Enclose burst	Two couplers and new section Repair collar or clamp
Localised pinholing	Enclose burst	Repair collar or clamp

TABLE 3

MATERIAL	**STEEL**	
Burst	**Action**	**Repair**
Extensive pin holing	Rehabilitation Technique Remove section/joint	Slip lining etc. Two couplers and new section
Joint failure	Remove section/joint Enclose joint	Two couplers and new section Special joint clamp
Isolated pin holing	Enclose burst	Patch and weld Repair collar or clamp

TABLE 4

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 calmp

TABLE 5

MATERIAL	PRESTRESSED CONCRETE	
Burst	**Action**	**Repair**
Surface softening	Remove complete length/joint or cracking	Two couplers and new pipe section
Joint failure	Remove complete length/joint Enclose joint	Two couplers and new pipe section Special joint clamp

TABLE 6

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
Joint failure	Cut out joint	Two couplers and new section

TABLE 7

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

10.5 REPAIR PROBLEMS SPECIFIC TO PRESTRESSED CONCRETE PIPES

The most difficult and time consuming repair problems relate to PSC Pipes, particularly the bigger diameter pipes. Some of the cases connected with the damage and leakage of such pipes along with their suggested methods are discussed below:

10.5.1 EXTENSIVE DAMAGE TO A PSC PIPE LENGTH

Sometimes the damage is so extensive that the entire length of a pipe needs replacement. The replacement is done by inserting a steel pipe which shall be fabricated in three pieces. One piece shall consist of a spigotted machine end, another of steel shell and the third a spigotted machine end. The middle portion shall be of steel barrel with an integral manhole. This man hole may be meant for temporary use only so as to be covered and rewelded suitably after the repairing operation has been satisfactorily carried out. The thickness of steel plate used for this purpose shall be equal to the design thickness plus 2 mm extra to take care of corrosion. A minimum of 10 mm may, however, be used. The burst pipe may be broken by taking due precautions and replaced with this set of three pieces. The two machine ends shall be fixed as per normal procedure for laying PSC pipes. The steel barrel shall be introduced in between and duly welded internally and externally.

10.5.2 DAMAGE RESTRICTED TO A SMALL LENGTH ONLY

Sometimes the damage is along a length of 1 m to 1.5 m only and the remaining portion of the pipe remains in a sound condition. To make the damaged portion functional, two plain M.S. Barrels shall be inserted into the pipe, to suit the internal diameter with a gap of 25 mm. on either side of the pipe, 50 mm less than the internal diameter of the pipe, to facilitate jointing with jute and cement mortar. The barrels shall have 2 nos. 12 mm dia. M.S. rings to fix over the shell at the ends. At least 500 mm of overlap on either side of the pipe, length wise, is provided for jointing.

After following the normal procedure (as already discussed at length), break the damaged portion of the pipe to the extent (length wise) of cracks developed in the pipe for more than half of the pipe (diameter wise).

Cut the H.T. wires core reinforcement.

Clean the pipe internally, remove the broken debris and dewater the pipe.

Insert one piece of the M.S. Barrel, duly fabricated with a temporary manhole for entry into the pipe for internal caulking, welding etc.

Shift barrel to one side so as to facilitate the insertion of the second barrel.

Join the two pieces and weld the joint internally and externally.

Keep the barrel in position by covering the damaged portion duly keeping at least 500 mm of overlap for jointing with P.S.C. pipe.

Insert the M.S. ring at the ends and place at 150 mm from the outer ends of the barrels and tag weld the rings to the barrel to caulk the jute firmly.

Caulk both the ends of the barrel with spun yarn for 3 layers and with cement mortar 1:1 duly mixing quick setting cement solution.

Clean the pipe internally and paint with epoxy paint.

Close the manhole made on the M.S. pipe by welding and strengthening the joint with additional plates.

Weld angles on he barrel and support the edges of the PSC pipe.

Caulk the joints with cement mortar and cover the MS barrel with cement mortar.

Embed the damaged portion of the pipe in cement concrete to avoid movement of the M.S. barrel during surge.

(As alternatives to the above procedure, there are other methods in use, depending upon the local conditions and the diameters of the pipes).

Follow other prescribed procedure for completion.

10.5.3 LEAKAGE THROUGH SOCKET/SPIGOT JOINT DUE TO DISPLACEMENT OF RUBBER JOINT

The joint has to be exposed. A medium leakage can be attended without taking the shut down by pushing the rubber gasket to the original position with the help of wooden caulking tools and also inserting lead pieces in the joint. Afterwards, caulking with cement mortar 1:1 will further strengthen the joint. The entire joint has to be caulked with cement mortar.

10.5.4 LEAKAGE THROUGH DAMAGED SOCKET

Such leakage can be attended only by taking shut down and draining the pipe line. The joint shall be exposed by excavating the trench around the joint. The crack and joint shall be filled with lead wool, quick setting cement mortar and the stepped split collar fixed over the joint and filled with cement slurry or cement mortar mixed with quick setting solution.

10.5.5 LEAKAGE THROUGH CIRCUMFERENTIAL CRACK

Such leaks can be attended by providing split collars after arresting the leakage through crack either on running line or by availing shut down.

Materials required for attending the leakage are lead wool, M seal, cement mortar, special adhesives like araldite and plain split collar.

10.5.6 LEAKAGE THROUGH HOLE

The hole can be covered with a plate and bolted to a flat inserted through the hole. The hole shall be covered with a lead washer under the plate and annular gap to be filled with m-seal compound or other suitable sealing material.

If the hole is very close to the joint, a plane cover or a stepped split collar can be fixed and caulked with cement mortar after caulking the joint with lead pieces or lead wool.

10.6 GENERATION OF DATA AND LIFE CYCLE ANALYSIS

Record of repair carried out with costs should be maintained systematically. This will help in assessing the useful life of different materials of pipelines. This data will be useful in carrying out Life Cycle Cost analysis of competing materials and take decision regarding replacements.

***

CHAPTER 11
OPERATION AND MAINTENANCE OF PUMPING MACHINERY

11.1 INTRODUCTION

11.1.1 GENERAL

Pumping machinery and pumping station are very important components in a water supply system. Pumping machinery is subjected to wear, tear, erosion and corrosion due to their nature of functioning and therefore are vulnerable for failures. Generally more number of failures or interruptions in water supply are attributed to pumping machinery than any other component. Therefore, correct operation and timely maintenance and up-keep of pumping stations and pumping machinery are of vital importance to ensure uninterrupted water supply. Sudden failures can be avoided by timely inspection, follow up actions on observations of inspection and planned periodical maintenance. Downtime can be reduced by maintaining inventory of fast moving spare parts. Efficiency of pumping machinery reduces due to normal wear and tear. Timely action for restoration of efficiency can keep energy bill within reasonable optimum limit. Proper record keeping is also very important.

Obviously due attention needs to be paid to all such aspects for efficient and reliable functioning of pumping machinery. This chapter discusses procedures for operation and maintenance and addresses pertinent issues involved in O&M of pumping machinery and associated electrical and mechanical equipment.

11.1.2 COMPONENTS IN PUMPING STATIONS

The components in pumping station can be grouped as follows.

i) *Pumping machinery*

- → Pumps and other mechanical equipment, i.e. valves, pipe work, vacuum pumps
- → Motors, switchgears, cable, transformer and other electrical accessories

ii) *Ancillary Equipment*

- → Lifting equipment
- → Water hammer control device
- → Flowmeter
- → Diesel generating set

iii) *Pumping station*

→ Sump/intake/well/tubewell/borewell

→ Pump house

→ Screen

→ Penstock/gate

11.1.3 TYPE OF PUMPS

Following types of pumps are used in water supply systems.

i) Centrifugal pumps

ii) Vertical turbine pumps

→ Oil lubricated

→ Self water (pumped water) lubricated

→ Clear water lubricated

iii) Submersible pumps

→ Vertical borewell type pump-motor set

→ Monobloc open well type pump-motor set

iv) Jet pumps

v) Reciprocating pumps

11.1.4 COVERAGE IN THE CHAPTER

The chapter covers following aspects regarding operation and maintenance of components of pumping station and pumping machinery.

i) *Pumping Machinery*

→ Operation including starting and stopping of pumps and associated electrical and mechanical equipment

→ Preventive maintenance

→ Trouble shooting

→ Inventory of spares, oil and lubricants

→ Tools and testing equipments

→ Inspection and testing

→ Record keeping

ii) *Ancillary equipment*

→ Operation, maintenance and testing of

* lifting equipment

* water hammer (surge) control device

iii) *Pumping station*

→ Maintenance of following,

* Screen
* Penstock/gate
* Pump house

→ Housekeeping

11.2 OPERATION OF THE PUMPS

11.2.1 IMPORTANT POINTS FOR OPERATION

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

(a) Dry running of the pumps should be avoided.

(b) Centrifugal pumps have to be primed before starting.

(c) Pumps should be operated only within the recommended range on the head-discharge characteristics of the pump.

- If pump is operated at point away from duty point, the pump efficiency normally reduces.
- Operation near the shut off should be avoided, as the operation near the shut off causes substantial recirculation within the pump, resulting in overheating of water in the casing and consequently, in overheating of the pump.

(d) Voltage during operation of pump-motor set should be within $\pm$ 10% of rated voltage. Similarly current should be below the rated current as per name plate on the motor.

(e) Whether the delivery valve should be opened or closed at the time of starting should be decided by examining shape of the power-discharge characteristic of the pump. Pump of low and medium specific speeds draw lesser power at shut off head and power required increases from shut off to normal operating point. Hence in order to reduce starting load on motor, a pump of low or medium specific speed is started against closed delivery valve.

Normally the pumps used in water supply schemes are of low and medium specific speeds. Hence, such pumps need to be started against closed delivery valve.

The pumps of high specific speed draw more power at shut off. Such pumps should be started with the delivery valve open.

(f) The delivery valve should be operated gradually to avoid sudden change in flow velocity which can cause water hammer pressures.

It is also necessary to control opening of delivery valve during pipeline - filling period so that the head on the pump is within its operating range to avoid operation on low head and consequent overloading. This is particularly important during charging of the pumping main initially or after shutdown. As head increases the valve shall be gradually opened.

(g) When the pumps are to be operated in parallel, the pumps should be started and stopped with a time lag between two pumps to restrict change of flow velocity to minimum and to restrict the dip in voltage in incoming feeder. The time lag should be adequate to allow to stabilize the head on the pump, as indicated by a pressure gauge.

(h) When the pumps are to be operated in series, they should be started and stopped sequentially, but with minimum time lag. Any pump, next in sequence should be started immediately after the delivery valve of the previous pump is even partly opened. Due care should be taken to keep the air vent of the pump next in sequence open, before starting that pump.

(i) The stuffing box should let a drip of leakage to ensure that no air is passing into the pump and that the packing is getting adequate water for cooling and lubrication. When the stuffing box is grease sealed, adequate refill of the grease should be maintained.

(j) The running of the duty pumps and the standby should be scheduled so that no pump remains idle for long period and all pumps are in ready-to run condition. Similarly unequal running should be ensured so that all pumps do not wear equally and become due for overhaul simultaneously.

(k) If any undue vibration or noise is noticed, the pump should be stopped immediately and cause for vibration or noise be checked and rectified.

(l) Bypass valves of all reflux valve, sluice valve and butterfly valve shall be kept in closed position during normal operation of the pumps.

(m) Frequent starting and stopping should be avoided as each start causes overloading of motor, starter, contactor and contacts. Though overloading lasts for a few seconds, it reduces life of the equipment.

11.2.2 UNDESIRABLE OPERATIONS

Following undesirable operations should be avoided.

i) *Operation at Higher Head*

The pump should never be operated at head higher than maximum recommended. Such operation results in excessive recirculation in the pump, overheating of the water and the pump. Another problem, which arises if pump is operated at a head higher than the recommended maximum head, is that the radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft which may cause failure of the pump shaft. As a useful guide, appropriate marking on pressure gauge be made.

Such operation is also inefficient as efficiency at higher head is normally low.

ii) *Operation at Lower Head*

If pump is operated at lower head than recommended minimum head, radial reaction on the pump shaft increases causing excessive unbalanced forces on shaft which may cause failure of the pump shaft. As useful guide, appropriate markings on both pressure gauge and ammeter be made.

Such operation is also inefficient as efficiency at lower head is normally low.

iii) *Operation on Higher Suction Lift*

If pump is operated on higher suction lift than permissible value, pressure at the eye of impeller and suction side falls below vapour pressure. This results in flashing of water into vapour. These vapour bubbles during passage collapse resulting in cavitation in the pump, pitting on suction side of impeller and casing and excessive vibrations. In addition to mechanical damage due to pitting, discharge of the pump also reduces drastically.

iv) *Throttled operation*

At times if motor is continuously overloaded, the delivery valve is throttled to increase head on the pump and reduce power drawn from motor. Such operation results in inefficient running as energy is wasted in throttling. In such cases, it is preferable to reduce diameter of impeller which will reduce power drawn from motor. For detailed discussion, refer to para 16.3.16, Chapter 16 on "Energy Audit and Energy Conservation."

v) *Operation with Strainer/Foot Valve Clogged*

If the strainer or foot valve is clogged, the friction loss in strainer increases to high magnitude which may result in pressure at the eye of the impeller falling below water vapour pressure, causing cavitation and pitting similar to operation on higher suction lift.

The strainers and foot valves should be periodically cleaned particularly during monsoon.

vi) *Operation of the Pump with Low Submergence*

Minimum submergence above the bellmouth or foot valve is necessary so as to prevent air entry into the suction of the pump which gives rise to vortex phenomenon causing excessive vibration, overloading of bearings, reduction in discharge and efficiency. As a useful guide the lowest permissible water level be marked on water level indicator.

vii) *Operation with Occurrence of Vortices*

If vibration continues even after taking all precautions, vortex may be the cause. All parameters necessary for vortex-free operation should be checked. Chapter 11 in Manual on Water Supply and Treatment discusses these aspect in details.

11.2.3 STARTING THE PUMPS

11.2.3.1 Checks before starting

Following points should be checked before starting the pump.

- Power is available in all 3 phases.
- Trip circuit for relays is in healthy state
- Check voltage in all 3 phases.

  The voltage in all phases should be almost same and within $\pm$ 10% of rated voltage, as per permissible voltage variation.
- Check functioning of lubrication system specifically for oil lubricated and clear water lubricated VT pumps and oil lubricated bearings.

- Check stuffing box to ensure that it is packed properly.
- Check and ensure that the pump is free to rotate.
- Check overcurrent setting if the pump is not operated for a week or longer period.
- Before starting it shall be ensured that the water level in the sump/intake is above low water level and inflow from the source or preceding pumping station is adequate.

11.2.3.2 Starting and Operation of Pumps

Procedures for starting and operation of different types of pumps are as follows.

(a) ***Centrifugal Pump (of low and medium specific speed)***

i) 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.

ii) Close the delivery valve and then loosen slightly.

iii) 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.

11.2.4 STOPPING THE PUMP

11.2.4.1 Stopping the Pump under Normal Condition

Steps to be followed for stopping a pump of low and medium specific speed are as follows:

i) Close the delivery valve gradually (sudden or fast closing should not be resorted to, which can give rise to water hammer pressures).

ii) Switch off the motor.

iii) Open the air vent in case of V.T. and submersible pump.

iv) Stop lubricating oil or clear water supply in case of oil lubricated or clear water lubricated VT pump as applicable.

11.2.4.2 Stopping after Power Failure/Tripping

If power supply to the pumping station fails or trips, actions stated below should be immediately taken to ensure that the pumps do not restart automatically on resumption of power supply. Though no-volt release or undervolt relay is provided in starter and breaker, possibility of its malfunctioning and failure to open the circuit cannot be ruled out. In such eventuality, if the pumps start automatically on resumption of power supply, there will be sudden increase in flow velocity in the pumping main causing sudden rise in pressure due to water hammer which may prove disastrous to the pumping main. Secondly, due to sudden acceleration of flow in the pumping main from no-flow situation, acceleration head will be very high and the pumps shall operate near shut off region during acceleration period which may last for few minutes for long pumping main and cause overheating of the pump. Restarting of all pumps simultaneously shall also cause overloading of electrical system.

Hence, precautions are necessary to prevent auto-restarting on resumption on power. Following procedure should be followed.

i) Close all delivery valves on delivery piping of pumps if necessary, manually as actuators can not be operated due to non-availability of power.

ii) Check and ensure that all breakers and starters are in open condition i.e. off-position.

iii) All switches and breakers shall be operated to open i.e. off-position.

iv) Open air vent in case of V.T. or submersible pump and close lubricating oil or clear water supply in case of oil lubricated or clear water lubricated V.T. pump.

v) Information about power failure should be given to all concerned, particularly to upstream pumping station to stop pumping so as to prevent overflow.

11.3 PREVENTIVE MAINTENANCE OF PUMPING MACHINERY

Lack of preventive and timely maintenance or poor maintenance can cause undue wear and tear of fast moving parts, and premature failure of the equipment. Such premature failure or breakdown causes immense hardship to the consumers and staff, and avoidable increase in repair cost. The shortcomings in maintenance can also result in increase in hydraulic and power losses and low efficiency. Inefficient running of the pump increases burden of power cost. Importance of preventive maintenance, therefore, need not be overstressed.

Appropriate maintenance schedule and procedure need to be prescribed for all electrical and mechanical equipment based on manufacturers' recommendations, characteristics of the equipment, site and environment conditions i.e. temperature, humidity, dust condition, etc. The maintenance schedule also need to be reviewed and revised in the light of experience and analysis of failures and breakdown at the pumping station. The preventive maintenance schedule shall detail the maintenance to be carried out at regular intervals i.e. daily, monthly, quarterly, half yearly, annually etc. or operation hours. The schedule shall also include inspections and tests to be performed at appropriate interval or periodicity.

General guidelines for maintenance schedules for pumps and associated electrical and mechanical equipment are enlisted below. The guidelines should not be considered as total, full-fledged and comprehensive as characteristics of equipment and site conditions differ from place to place. For example, in dust laden environment or places where occurrence of storms are frequent, blowing of dust in motor, renewal of oil and grease in bearing shall have to be done at lesser intervals than specified in general guideline.

11.3.1 MAINTENANCE OF PUMPS

11.3.1.1 Daily Observations and Maintenance

(a) Daily Maintenance

- Clean the pump, motor and other accessories.
- Check coupling bushes/rubber spider.
- Check stuffing box, gland etc.

(b) Routine observations of irregularities

The pump operator should be watchful and should take appropriate action on any irregularity noticed in the operation of the pumps. Particular attention should be paid to following irregularities.

i) Changes in sound of running pump and motor

ii) Abrupt changes in bearing temperature.

iii) Oil leakage from bearings

iv) Leakage from stuffing box or mechanical seal
v) Changes in voltage
vi) Changes in current
vii) Changes in vacuum gauge and pressure gauge readings
viii) Sparks or leakage current in motor, starter, switch-gears, cable etc.
ix) Overheating of motor, starter, switch gear, cable etc.

(c) Record of operations and observations

A log book should be maintained to record the hourly observations, which should cover the following items.

i) Timings when the pumps are started, operated and stopped during 24 hours.
ii) Voltage in all three phases.
iii) Current drawn by each pump-motor set and total current drawn at the installation.
iv) Frequency.
v) Readings of vacuum and pressure gauges.
vi) Motor winding temperature.
vii) Bearing temperature for pump and motor.
viii) Water level in intake/sump.
ix) Flowmeter reading.
x) Daily PF over 24 hours duration.
xi) Any specific problem or event in the pumping installation or pumping system e.g. burst in pipeline, tripping or fault, power failure.

11.3.1.2 Monthly Maintenance

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

11.3.1.3 Quarterly Maintenance

i) Check alignment of the pump and the drive. The pump and motor shall be decoupled while correcting alignment, and both pump and motor shafts shall be pushed to either side to eliminate effect of end play in bearings.
ii) Clean oil lubricated bearings and replenish with fresh oil. If bearings are grease lubricated, the condition of the grease should be checked and replaced/replenished to the correct quantity. An anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be between one third to half. A fully packed housing will overheat the bearing and will result in reduction of life of the bearing.

iii) Tighten the foundation bolts and holding down bolts of pump and motor mounting on base plate or frame.

iv) Check vibration level with instruments if available; otherwise by observation.

v) Clean flow indicator, other instruments and appurtenances in the pump house.

11.3.1.4 Annual Inspections and Maintenance

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

i) Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. corrosion, wear and scratches. Check end play. Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture.

ii) Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.

iii) Examine shaft sleeves for wear or scour and necessary rectification. If shaft sleeves are not used, shaft at gland packings should be examined for wear.

iv) Check stuffing box, glands, lantern ring, mechanical seal and rectify if necessary.

v) Check clearances in wearing ring.

Clearances at the wearing rings should be within the limits recommended by the manufacturer. Excessive clearance reduces discharge and efficiency of the pump. If the wear is only on one side, it is indicative of misalignment. The misalignment should be set right, and the causes of misalignment should be investigated. When the clearances have to be restored, general guidelines detailed in table 11.1 below shall be followed. Normally, if the clearance in wearing rings increase by about 100% for small pumps and 50-75% for large pumps the rings shall be renewed or replaced to restore to the original clearance.

The tolerances given in the table are to be strictly followed. For example, while machining the internal diameter of the casing wearing ring of basic size, say 175 mm, the limits for machining would be 175.00 minimum and 175.05 maximum. For the corresponding outer diameter at the hub of the impeller or impeller ring, the basic

TABLE 11.1: WEARING RING DIAMETRAL CLEARANCE AND TOLERANCE

Inside diameter of wearing ring (mm)	Diametral clearance (mm)	Machining Tolerance (mm)
Upto 100	0.30	.050
101-150	0.35	
151-200	0.40	
201-300	0.45	0.075
301-500	0.50	
501-750	0.55	
751-1200	0.65	0.100
1201-2000	0.75	0.125

size will be with a clearance of 0.4 mm, i.e. 174.60 mm and the machining limits will be 174.60 mm maximum and 174.55 minimum.

Taking into consideration that part dismantling of the pump is involved in checking wearing ring clearance and as it is not advisable to dismantle vertical turbine pump every year, the frequency for checking wearing ring in case of V.T. pump shall be once in two years or earlier if discharge test indicates discharge reduction beyond limit of 5% - 7%.

vi) Check impeller hubs and vane tips for any pitting or erosion.

vii) Check interior of volute, casing and diffuser for pitting, erosion, and rough surface.

viii) All vital instruments i.e. pressure gauge, vacuum gauge, ammeter, voltmeter, wattmeters, frequency meter, tachometer, flowmeter etc. shall be calibrated.

ix) Conduct performance test of the pump for discharge, head and efficiency.

x) Measures for preventing ingress of flood water shall be examined. Ingress of flood water in sump, well, tubewell or borewell shall be strictly prevented. Seal cap shall be provided above tubewell/borewell.

xi) Check vibration level.

11.3.1.5 Overhaul of Pump

It is difficult to specify the periodicity or interval for overhaul in the form of period of service in months/years or operation hours, as deterioration of pump depends on nature of service, type of installation i.e. wetpit or drypit, quality of water handled, quality of material of construction, maintenance, experience with particular make & type of pump etc.

However generally, following operational hours may be taken as broad guidelines for overhauling.

- Submersible pump – 5000 – 6000 hours
- Vertical turbine pump – 12000 hours
- Centrifugal pump – 15000 hours

11.3.1.6 Problems in Long Column Pipes in VT Pump

Very long column pipes in VT pump at river intake or intake well constructed in impounded reservoir are required to be provided due to large fluctuations in water level from minimum water level in summer to high water level in monsoons. Such long column pipes (if length exceeds about 15 m) usually cause problem of fast wearing of line- shafts bearings in case of water lubricated pumps. Such longer suspended assembly is also more prone to rotation or swinging of column assembly due to vortices.

Precautionary measure as follows may be taken

(a) Prevention of premature wear of water lubricated bearings in column pipes

Water lubricated bearings usually are of rubber or neoprene and wear fast if dry running, occurs during starting of VT pumps. Therefore to avoid dry running water is admitted from external source (usually a tank near the pump provided for the purpose) into the column pipe for about 3-4 minutes so as to wet the bearing before starting the pump.

(b) Preventing rotation or swinging in column assembly

A cone as shown in the figure 11.1 (C) or splitter as shown in figure 11.1 (G) shall be provided underneath bellmouth.

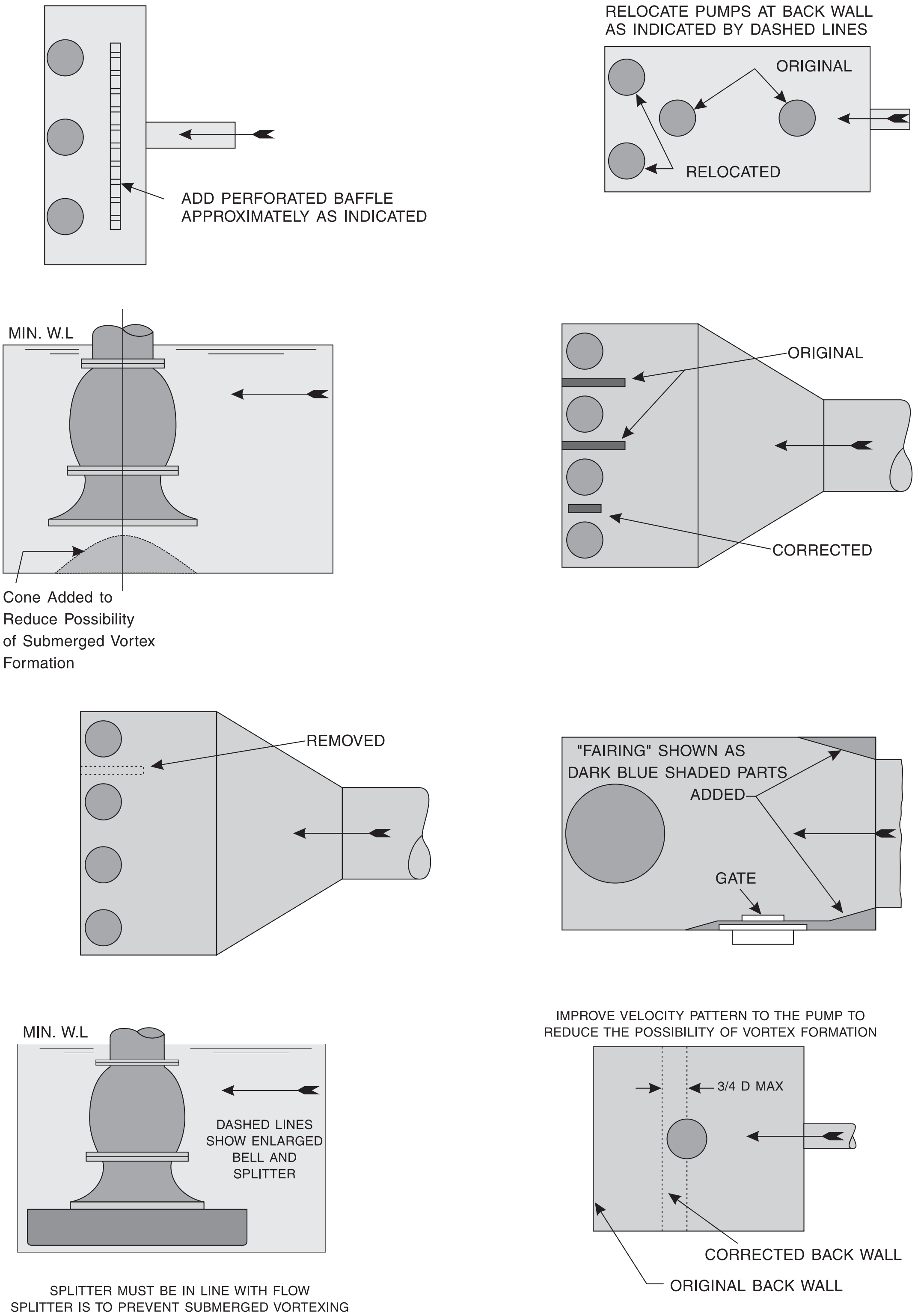


FIG 11.1 REMEDIAL MEASURES FOR VORTEX-FREE OPERATION IN EXISTING SUMPS

Under no circumstances the column assembly be tied or fixed at any point other than discharge head from which it is suspended, as such measure shall result in misalignment.

11.3.1.7 Sludge Water/Filter Wash Recirculation Pump

Due attention should be paid for proper selection of the pump and material of construction, to avoid operation problems and premature wear due to abrasive material in pumped water. The impeller should, preferably, be of stainless steel of grade CF 8 M and wearing ring of CF 8. The pump should preferably be VT type.

11.3.1.8 History Sheet

History sheet of all pumps shall be maintained. The history sheet shall contain all important particulars, records of all maintenance, repairs, inspections and tests etc. It shall generally include the following.

i) Details of the pump, rating, model, characteristic curves, performance test report etc.
ii) Addresses of manufacturer & dealer with phone & fax number and e-mail addresses.
iii) Date of installation and commissioning.
iv) Brief details and observations of monthly, quarterly and annual maintenance and inspections.
v) Details of breakdown, repairs with fault diagnosis, replacement of major components i.e. impeller, shaft, bearings, wearing rings.
vi) Results of annual performance test including discharge and efficiency.
vii) Yearly operation hours of the pumps.
viii) Brief findings of energy audit.

11.3.2 MAINTENANCE SCHEDULE FOR MOTORS

11.3.2.1 Daily Maintenance

i) Clean external surface of motor.
ii) Examine earth connections and motor leads.
iii) Check temperature of motor and check whether overheated. The permissible maximum temperature is above the level which can be comfortably felt by hand. Hence temperature observation should be taken with RTD or thermometer. (Note: In order to avoid opening up motors, a good practice is to observe the stator temperature under normal working conditions. Any increase not accounted for, by seasonal increase in ambient temperature, should be suspected).
iv) In case of oil ring lubricated bearing.
    - Examine bearings to check whether oil rings are working.
    - Note bearing temperature.
    - Add oil if necessary.
v) Check for any abnormal bearing noise.

11.3.2.2 Monthly Maintenance

i) Check belt tension. In case where this is excessive it should immediately be reduced.

ii) Blow dust from the motor.

iii) Examine oil in oil lubricated bearing for contamination by dust, grit, etc. (this can be judged from the colour of the oil).

iv) Check functioning and connections of anti-condensation heater (space heater).

v) Check insulation resistance by meggering.

11.3.2.3 Quarterly Maintenance

i) Clean oil lubricated bearings and replenish fresh oil. If bearings are grease lubricated, the condition of the grease should be checked and replaced/replenished to correct quantity. An anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be between one third to half. A fully packed housing will overheat the bearing and will result in reduction of life of the bearing.

ii) Wipe brush holders and check contact faces of brushes of slip-ring motors. If contact face is not smooth or is irregular, file it for proper and full contact over slip rings.

iii) Check insulation resistance of the motor.

iv) Check tightness of cable gland, lug and connecting bolts.

v) Check and tighten foundation bolts and holding down bolts between motor and frame.

vi) Check vibration level with instrument if available; otherwise by observation.

11.3.2.4 Half Yearly Maintenance

i) Clean winding of motor, bake and varnish if necessary.

ii) In case of slip ring motors, check slip-rings for grooving or unusual wear, and polish with smooth polish paper if necessary.

11.3.2.5 Annual Inspections and Maintenance

i) Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. wear and scratches. Check end-play. Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture.

ii) Clean bearing housing and examine for flaws, e.g. wear, grooving etc. Change oil or grease in bearing housing.

iii) Blow out dust from windings of motors thoroughly with clean dry air. Make sure that the pressure is not so high as to damage the insulation.

iv) Clean and varnish dirty and oily windings.

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

v) Check condition of stator, stamping, insulation, terminal box, fan etc.

vi) Check insulation resistance to earth and between phases of motors windings, control gear and wiring.

vii) Check air gaps.

viii) Check resistance of earth connections.

11.3.2.6 History Sheet

Similar to history sheet of pump, history sheet of motor should be maintained. The history sheet should contain all important particulars, records of periodical maintenance, repairs, inspections and tests. It shall generally include the following:

i) Details of motor, rating, model, class of duty, class of insulation, efficiency curve, type test result and type test certificate etc.

ii) Date of installation and commissioning.

iii) Addresses of manufacturer & dealer with phone & fax number and e-mail addresses.

iv) Brief details of monthly, quarterly, half yearly and annual maintenance and observations of inspections about insulation level, air gap etc.

v) Details of breakdown, repairs with fault diagnosis.

vi) Running hours at the time of major repairs.

11.3.3 VALVES

Following 5 types of valves are generally used in pumping installation

a) Foot valve.

b) Sluice valve.

c) Knife gate valve.

d) Reflux (non-return) valve.

e) Butterfly valve.

Maintenance as follows shall be carried out.

a) *Foot Valve*

- Clean foot valve once in 1-3 months depending on ingress of floating matters.
- Clean flap of the foot valve once in 2 months to ensure leakproof operation.
- Inspect the valve thoroughly once in a year. Check for leakage through foot valve after priming and observing level in volute casing.

b) *Sluice valve and Knife gate valve*

- Check gland packing of the valve at least once in a month. It should be ensured that packings inside the stuffing box are in good trim and impregnated with grease. It may be necessary to change the packing as often as necessary to ensure that the leakage is within limit.
- Grease should be applied to reduction gears and grease lubricated thrust bearing once in three months.

- Check tight closure of the valve once in 3 months.
- A valve normally kept open or closed should be operated once every three months to full travel of gate and any jamming developed due to long disuse shall be freed.
- Inspect the valve thoroughly for flaws in guide channel, guide lugs, spindle, spindle nut, stuffing box etc. once in a year.
- Important DON'T for valve is that it should never be operated with oversize handwheel or cap or spanner as this practice may result in rounding of square top and handwheel or cap or spanner may eventually slip.
- An important DON'T for valve is that it should never be operated under throttled i.e. partially open condition, since such operation may result in undue chatter, wear and failure of valve spindle.

c) *Reflux (non-return) valve*

- Check proper operation of hinged door and tight closure under no-flow condition once in 3 months.
- The valve shall be thoroughly inspected annually. Particular attention should be paid to hinges and pins and soundness of hinged door.
- Condition of dampening arrangement should be thoroughly examined once in year and necessary maintenance and rectification as per manufactures' instructions shall be carried out.
- In case of dampening arrangement, check for oil leakage and replace oil once in a year.

d) *Butterfly valve*

- Check seal ring and tight shut-off once in 3 months.
- Lubricate gearing arrangement and bearing once in 3 months.
- Inspect the valve thoroughly including complete operations once in a year.
- Change oil or grease in gearing arrangement once in a year.

e) *General*

- Operate bypass valve wherever provided once in 3 months.
- Flange adapter/dismantling joint provided with valve shall be loosened and retightened once in 6 months to avoid sticking.

11.3.4 VALVE ACTUATORS

11.3.4.1 Quarterly Maintenance

- Declutch and operate manual handwheel.
- Check oil level and top up if required.
- Regrease the grease lubricated bearing and gear trains as applicable.

- Check insulation resistance of the motor.
- Check for undue noise and vibration and take necessary rectification measures.
- Tighten limit switch cams and check for setting and readjust if necessary.

11.3.4.2 Annual Inspections and Maintenance

- Examine all components and wiring thoroughly and rectify as necessary.
- Change oil or grease in gear box and thrust bearing.
- Check condition of gears & replace gears if teeth are worn out.

11.3.5 L.T. STARTERS, BREAKERS AND PANEL

Note: Circuit diagram of starter/breaker should be pasted on door of switch gear and additional copy should be kept on record.

i) *Daily*

- Clean the external surface.
- Check for any spark or leakage current.
- Check for overheating.

ii) *Monthly*

- Blow the dust and clean internal components in the panel, breaker and starter.
- Check and tighten all connections of cable, wires, jumpers and bus-bars. All carbon deposits shall be cleaned.
- Check relay setting.

iii) *Quarterly*

- Check all connections as per circuit diagram.
- Check fixed and moving contacts and clean with smooth polish paper, if necessary.
- Check oil level and condition of oil in oil tank. Replace the oil if carbon deposit in suspension is observed or colour is black.
- Check insulation resistance.
- Check condition of insulators.

iv) *Yearly*

- Check and carry out servicing of all components, thoroughly clean and reassemble.
- Calibrate voltmeter, ammeter, frequency meter etc.

11.3.6 H.T. BREAKERS, CONTACTORS AND PROTECTION RELAYS

Note: Circuit diagram of breaker/relay circuit should be pasted on door of switch gear and additional copy should be kept on record.

Maintenance schedule specified for L.T. breakers is also applicable to H.T. breakers and contactors. In addition, following important points shall be attended for H.T. breakers and contactors.

i) *Monthly*

- Check spring charging mechanism and manual cranking arrangement for operation.
- Clean all exposed insulators.
- Check trip circuit and alarm circuit.
- Check opening & closing timing of breaker.

ii) *Quarterly*

- Check control circuits including connections in marshalling boxes of breakers and transformer.
- Check oil level in MOCB/LOCB/HT OCB and top up with tested oil.

iii) *Yearly/Two yearly*

- Testing of protection relay with D.C. injection shall be carried out once in a year.
- Servicing of HT breaker and contactor shall be carried out once in 2-3 years.
- Check dielectric strength of oil in breaker and replace if necessary.
- Check male & female contacts for any pitting and measure contact resistance.

11.3.7 CAPACITORS

11.3.7.1 Pre-requisites for Satisfactory Functioning of Capacitors

Ensure following points :

i) A capacitor should be firmly fixed to a base.

ii) Cable lugs of appropriate size should be used.

iii) Two spanners should be used to tighten or loosen capacitor terminals. The lower nut should be held by one spanner and the upper nut should be held by the another spanner to avoid damage to or breakage of terminal bushings and leakage of oil.

iv) To avoid damage to the bushing, a cable gland should always be used and it should be firmly fixed to the cable-entry hole.

v) The capacitor should always be earthed appropriately at the earthing terminal to avoid accidental leakage of the charge.

vi) There should be a clearance of at least 75 mm on all sides for every capacitor unit to enable cooler running and maximum thermal stability. Ensure good ventilation and avoid proximity to any heat source.

vii) While making a bank, the bus bar connecting the capacitors should never be mounted directly on the capacitor terminals. It should be indirectly connected through flexible leads so that the capacitor bushings do not get unduly stressed.

ix) Ensure that the cables, fuses and switchgear are of adequate ratings.

11.3.7.2 Operation and Maintenance of Capacitors

i) The supply voltage at the capacitor bus should always be near about the rated voltage. The fluctuations should not exceed $\pm$ 10% of the rated voltage of the capacitor.

ii) Frequent switching of the capacitor should be avoided. There should always be an interval of about 60 seconds between any two switching operations.

iii) The discharge resistance efficiency should be assessed periodically by sensing, if shorting is required to discharge the capacitor even after one minute of switching off. If the discharge resistance fails to bring down the voltage to 50V in one minute, it needs to be replaced.

iv) Leakage or breakage should be rectified immediately. Care should be taken that no appreciable quantity of impregnant has leaked out.

v) Before physically handling the capacitor, the capacitor terminals shall be shorted one minute after disconnection from the supply to ensure total discharging of the capacitor.

vi) Replace capacitor if bulging is observed.

11.3.8 TRANSFORMER & TRANSFORMER SUBSTATION

Maintenance schedule as follows shall be applicable for transformer and sub-station equipments e.g. lightening arrestor, A.B. switch, D.O. or horn gap fuse, sub-station earthing system etc.

11.3.8.1 Daily Observations and Maintenance

i) Check winding temperature and oil temperature in transformer and record. (For large transformers above 1000 kV, the temperature should be recorded hourly).

ii) Check leakages through CT/PT unit, transformer tank and HT/LT bushings.

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

11.3.8.2 Monthly Maintenance

i) Check oil level in transformer tank and top up if required.

ii) Check relay contacts, cable termination, connections in marshalling box etc.

iii) Check operation of AB switch and DO fuse assembly.

iv) Clean radiators free from dust and scales.

v) Pour 3-4 buckets (6 to 8 buckets in summer) of water in earth pit. *The frequency of watering shall be increased to once in a week in summer season.* The water for earthing shall preferably contain small amount of salt in solution.

vi) Inspect lightning arrestor and HT/LT bushing for cracks and dirt.

11.3.8.3 Quarterly Maintenance

i) Check dielectric strength of transformer oil and change or filter if necessary.

ii) Check insulation resistance of all equipments in sub-station, continuity of earthings and earth leads.

iii) Check operation of tap changing switch.

11.3.8.4 Pre-Monsoon and Post-Monsoon Checks and Maintenance

i) Check insulation resistance of transformer.

ii) Test transformer oil for dielectric strength, sludge etc. If necessary, filtration of oil shall be carried out before monsoon.

iii) Oil shall be tested for dielectric strength after monsoon.

11.3.8.5 Half-Yearly Maintenance

i) Check dielectric strength of transformer oil in CT/PT and filter or change oil if necessary.

ii) Check contact faces of AB switch and DO/HG fuse; apply petroleum jelly or grease to moving components of AB switch.

11.3.8.6 Annual Inspections and Maintenance

i) Measure resistance of earth pit. Resistance shall not exceed 1 ohm.

ii) Check bus bar connections, clean contact faces, change rusted nut bolts.

iii) Calibrate the protection relay for functioning. Check relay setting and correct if necessary.

iv) Ensure that sub-station area is not water-logged. If required necessary earth fillings with metal spreading at top shall be carried out once in a year.

Check drainage arrangement to prevent water logging in substation area and cable trenches.

v) Test transformer oil for acidity test.

11.3.8.7 Special Maintenance

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

ii) The core of transformer and winding shall be checked after 5 years for transformer upto 3000 kVA and after 7–10 years for transformers of higher capacity.

11.3.9 D.C. BATTERY

Maintenance schedule as under shall be applicable for D.C. Batteries.

i) *Daily :* Check voltage and specific gravity of the batteries and battery supply for the tripping circuit.

ii) *Monthly :* Check the battery charging & fuses and clean contact faces.

iii) *Monthly :* Apply petroleum jelly or grease to battery terminals.

iv) *Quarterly :* Check to ensure that battery is not overcharged/under charged.

v) *Yearly :* Check rectifier, diode, rheostat motor thoroughly.

11.3.10 LIFTING EQUIPMENT

Relevant points in the maintenance schedule as follows shall be applicable for lifting equipments, depending on the type of lifting equipment i.e. chain pulley block, monorail (travelling trolley and chain pulley block), manually operated overhead crane and electrically operated travelling crane.

i) *Quarterly :*
  - Check oil level in gear box and top up if required.
  - Check for undue noise and vibration.
  - Lubricate bearings and gear trains as applicable.
  - Check insulation resistance of motors.

ii) *Half yearly :*
  - Clean limit switches.
  - Clean all electrical contacts.

iii) *Yearly :*
  - Change oil in gear box.
  - Conduct load test of crane for rated load or at least for maximum load required to be handled. All fast moving components which are likely to wear should be thoroughly inspected once in a year and if necessary shall be replaced.

11.3.11 WATER HAMMER CONTROL DEVICES

Maintenance requirements of water hammer devices depends on type of water hammer control device, nature of its functioning, water quality etc. Type of water hammer control devices used in water pumping installations are as follows :

- Surge tank
- One-way surge tank
- Air vessel (air chamber)
- Zero velocity valve and air cushion valve.
- Surge anticipation valve (surge suppressor)
- Pressure relief valve.

General guidelines for maintenance of different types of water hammer control devices are as follows:

11.3.11.1 Surge Tank and One-Way Surge Tank

- *Quarterly :* Water level gauge or sight tube provided shall be inspected, any jam rectified, all cocks and sight tube flushed and cleaned.
- *Yearly :* The tank shall be drained and cleaned once in a year or earlier if frequency of ingress of foreign matter is high.

- *Valve maintenance :* Maintenance of butterfly valve, sluice valve and reflux valve shall be attended as specified for valves on pump delivery in para 9.3.3.
- *Painting :* Painting of tanks shall be carried out once in 2 years.

11.3.11.2 Air-Vessel

- *Daily :*
  - Check air-water interface level in sight glass tube.

    The air water level should be within range marked by upper and lower levels and shall be preferably at middle.
  - Check pressure in air receiver at interval of every 2 hours.
- *Quarterly :*
  - Sight glass tube and cock shall be flushed.
  - All wiring connections shall be checked and properly reconnected.
  - Contacts of level control system and pressure switches in air supply system shall be cleaned.
- *Yearly :*
  - The air vessel and air receiver shall be drained, cleaned and dried.
  - Internal surface shall be examined for any corrosion etc. and any such spot cleaned by rough polish paper and spot-painted.
  - Probe heads of level control system shall be thoroughly checked and cleaned.
- *Accessories :*
  - Maintenance of panel, valves and air compressor etc. shall be carried out as specified for respective appurtenances.

11.3.11.3 Zero-Velocity Valves and Air Cushion Valve

Foreign matters entangled in valve shall be removed by opening all handholes and internal components of the valves including ports, disk, stem, springs, passages, seat faces etc. should be thoroughly cleaned and checked once in 6 months for raw water and once in a year for clear water application.

11.3.11.4 Surge Anticipation Valves

Pilot valves and tubes shall be flushed and cleaned every month

11.3.11.5 Pressure Relief Valve

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

11.3.12 AIR COMPRESSOR

i) *Daily :*
  - Clean external surface.
  - Check oil level and top up if necessary.

ii) *Monthly :*

- Clean oil filter
- Clean air filter

iii) *Quarterly :*

- Check condition of oil and change if dirty.
- Check grease in bearing housing and replenish/change if necessary.
- Check condition of oil in air filter and change if dirty.

iv) *Half yearly :*

- Change oil.
- Change oil filter element.
- Thoroughly clean air filter.
- Clean bearing and bearing housing and change grease/oil.

v) *Yearly :*

- Thoroughly check all components, piping valve etc. and rectify if necessary.

11.4 MAINTENANCE OF PUMPING STATION

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

11.4.1 SCREENS

i) Screen should be cleaned at a frequency depending on ingress load of floating matters. The frequency in monsoon season shall be more than that in fair season. However, cleaning frequency should be atleast once in a week, or, if head loss in screen exceeds 0.20 m.

ii) Care should be taken to remove and dump the screening far away from the pump house.

iii) Lubricate wheels and axle of wheel burrows.

iv) The screen, catch tray and screen handling arrangement shall be thoroughly inspected once in six months and any item broken, eroded, corroded shall be rectified.

11.4.2 PENSTOCK / SLUICE GATE

i) *Monthly :*

- The penstock/sluice gate normally remains in open position and closed only when inflow is to be stopped. Since floating matters may adhere to the gate and may accumulate in the seat, it should be operated once in a month. In order to ensure that gate remains free for operation

ii) *Yearly :*

- The gate should be thoroughly inspected once in a year preferably after monsoon and components found worn out shall be replaced. Particular attention shall be paid to the seats of the frame and gate.
- The gate should be closed to check the leakages. For this purpose, the sump/intake shall be partly dewatered so that differential head is created on the gate and leakage test at site can be performed.

11.4.3 SUMP/INTAKEWELL

i) All foreign floating matters in the sump/intake shall be manually removed at least once in a month and shall be disposed off away from pump house.

ii) Desilting of intake/sump shall be carried out once in year preferably after monsoon. Care should be taken to dump the removed silt away from pump house.

iii) It is generally observed that reptiles like snakes, fish, etc. enter intake particularly in monsoon. The intake should be disinfected.

iv) The sump/intake should be fully dewatered and inspected once in a year.

v) It is advisable to undertake leakage test of sump once in a year. For this purpose, the sump shall be filled to FSL and drop in water level for reasonably long duration (2-3 hours) should be observed. If leakage is beyond limit, rectification work shall be taken.

11.4.4 PUMP HOUSE

i) The pump house should be cleaned daily. Good house keeping and cleanliness are necessary for pleasant environment.

ii) Entire pump house, superstructure and sub-structure shall be adequately illuminated and well ventilated. Poor lighting, stale air etc. create unpleasant environment and have an adverse effect on will of the staff to work.

iii) Wooden flooring and M.S. grating wherever damaged should be repaired on priority.

iv) It is observed that at many places, roof leaks badly and at times the leakage water drips on the panel/motor which is dangerous and can cause short circuit and electric accidents. All such leakages should be rectified on priority.

v) All facilities in sub-structure i.e. stair case, floors, walkways etc. should be cleaned daily.

vi) Painting of civil works should be carried out at least once in two years.

11.5 PREDICTIVE MAINTENANCE

Predictive maintenance is the term used to examine and predict likely failure of components. As this requires experience, anticipation, good judgment and expertise and involves costs for repairs for predicted failures, it can be adopted at important, vital and large pumping stations.

11.5.1 PUMPS AND BEARINGS

Some factual evidence i.e. declining of pump performance, excessive noise or bearing temperature, increase of vibration can indicate that the pump probably needs to be overhauled or bearing need to be replaced.

Efforts should be made to rectify noise and vibration level by critical study and adopting measures for rectifications. If noise or vibration still persists, the pump should be dismantled and thoroughly checked.

If significant reduction in discharge is suspected, performance test at site shall be conducted with calibrated instruments and the results of the tests are compared with initial results of new pump. After fully ascertaining that the performance has considerably declined, decision to overhaul may be taken.

In some installations particularly if raw water is corrosive or contains grit or sand, the pump may become prematurely due for overhaul due to deterioration caused by corrosion or erosion. In such cases, the decision for overhaul should be based on circumstantial evidence i.e. previous history. As a long term solution, the manufacturer should be consulted for use of better material of construction for affected components.

11.5.2 ELECTRICAL EQUIPMENT

Weakening of insulation and failure of winding can be predicted by measuring insulation resistance and judging trend of weakening of insulation. The predictive maintenance test is recommended for following components of electrical machinery.

i) Motor winding and insulation … Quarterly

ii) Transformer winding and insulation … Annual

For condition monitoring of motors polerisation index shall be checked. The polarisation index is ratio of meggar value after 10 minutes and meggar value after1 minute. The measurement should be taken with help of motorized meggar. For a healthy motor from insulation resistance point of view, the value of PI shall be more than 1.25.

11.6 FACILITIES FOR MAINTENANCE AND REPAIRS

Facilities as follows should be provided for maintenance, inspection and repairs in the pumping installation.

- Adequate stock of consumables and lubricants
- Adequate stock of spare parts
- Tools and testing instruments
- Lifting equipment
- Ventilated and illuminated adequate space for repairs

11.6.1 CONSUMABLES AND LUBRICANTS

Adequate stock of gland packing, belts, gaskets, lubricating oil, greases, transformer oil, insulation tape, sealing compound, emery paste etc. shall be maintained. The consumables and lubricants shall be of proper quality and grade. Quantity shall be decided depending on consumption and period required to procure and replenish the stock.

11.6.2 SPARE PARTS

Adequate stock of spare parts should be maintained to avoid downtime due to non-availability of spares. Generally spares required for one-two years maintenance as per list below shall be kept in stock. The list should not be considered as full fledged and comprehensive and should be updated and revised in light of manufacturers' recommendations and previous history of repairs undertaken.

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

11.6.3 TOOLS AND TESTING INSTRUMENTS

The pumping installation should be equipped with all necessary tools, testing instruments and special tools required for repairs and testing. Their quantity and special tools depend on size and importance of installation. Generally following tools and testing instruments shall be provided.

a) Tools

- Double ended spanner set and ring spanner set.
- Box spanner set
- Hammers (of various sizes and functions)
- Screw driver set
- Chisel
- Nose plier, cutting plier
- Flies 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
- Crimpling tool
- Heating stove for heating sleeves.

b) Test instruments

- Insulation tester
- Tongue tester
- AVO meter
- Test lamp
- Earth resistance tester
- Wattmeter, CT and PT
- Dial gauge
- Tachometer

11.6.4 LIFTING AND MATERIAL HANDLING AIDS

Following lifting and material handling aids shall be kept in the pump house.

- Chains
- Wire rope
- Manila rope
- Chain pulley block and tripod.
- Other lifting equipment
- Hand cart
- Ladder

11.6.5 SPACE

A well ventilated and illuminated adequate space shall be earmarked for repairs. Minimum facilities such as work table, bench-vice etc. shall be provided.

11.7 TROUBLE SHOOTING OF PUMPS AND ELECTRICALS

Trouble shooting check charts for the following equipments are enlisted below.

- Pumps (Centrifugal, jet, VT, submersible, vacuum, reciprocating).
- Electric motor
- Capacitors
- Starters, breakers and control circuits
- Panels
- Cables
- Transformer
- Batteries
- Air compressor

11.7.1 TROUBLE SHOOTING FOR CENTRIFUGAL / JET / VT / VACUUM / SUBMERSIBLE PUMPS

11.7.1.1 Trouble & Causes

(a) Centrifugal Pump

Trouble	Possible Causes (numbers as per list below)	List of Causes
• Pump does not deliver water. (water not delivered to not completely filled with water).	1, 2, 3, 5, 6, 7, 9, 10, 15, 18, 21, 23, 26, 28, 29, 30, 31, 33, 40, 41, 42.	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).
• Insufficient discharge delivered.	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.	3. Suction lift too high. (Reduce suction lift after calculating permissible suction lift from NPSHA and NPSHR).
• Insufficient pressure developed.	2, 3, 4, 21, 23, 24, 26, 27, 28, 33, 39.	4. Excessive amount of air in liquid.
• Pump loses prime after starting.	4, 5, 6, 7, 10, 16, 17, 18.	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).
• Pump requires excessive power.	22, 25, 28, 33, 37, 38, 49, 53, 54, 55, 56, 58	6. Air leaks into suction line. 7. Air leaks into pump through stuffing boxes or mechanical seal.
• Stuffing box leaks excessively.	34, 36, 44, 45, 46, 47, 48, 50, 51, 52.	8. Net opening area of foot valve less. 9. Foot valve/strainer partially or fully clogged or silted up.
• Gland packing has short life.	11, 12, 34, 36, 44, 45, 46, 47, 48, 49, 50, 51, 52.	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). 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. 11.1).
14. Foot valve leaks.
15. Flap of foot valve jammed.
16. Concentric taper in suction line causing air pocket (Replace with eccentric taper).
17. Occurrence of vortex in intake, sump or well (Check whether all parameters for vortex-free operation are satisfied. Take recommended remedial measures as per Fig. 11.1).
18. Casing not air-tight and therefore breathing in.
19. Short bend/elbow on suction side.
20. Inadequate clearance below suction bell mouth. (Raise bellmouth to achieve recommended bottom clearance for vortex-free operation as per para 11.2 of manual on water supply & treatment).
21. Speed too low for pump driven by diesel engine.
22. Speed too high for pump driven by diesel engine.
23. Wrong direction of rotation.
24. Total head of system higher than design head of pump.
25. Total head of system lower than pump design head.
26. Static head higher than shut off head of pump.
27. Pump characteristics unsuitable for parallel operation of pumps.
28. Burst or leakage in pumping main.
29. Pumping main partially or fully clogged.
30. Air trapped in pumping main.
31. Malfunctioning of line valve causing partial or full closure.

Trouble	Possible Causes	List of Causes
		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
		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)
• 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.
• Insufficient discharge delivered.	1, 3, 4, 5, 6, 7, 8, 10, 11, 14, 15, 16, 17, 18, 19, 25, 26, 27,48.
• Insufficient pressure developed.	1, 2, 8, 10, 12, 13, 14, 15, 19, 25.
• Pump requires excessive power.	9, 12, 15, 19, 23, 24, 35, 40, 41, 42, 44.
• Stuffing box leaks excessively.	20, 22, 30, 31, 32, 33, 34, 36, 37, 38, 48.
• Gland packing has short life.	20, 22, 30, 31, 32, 33, 34, 36, 37, 38.
• 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.
• Pump vibrates or noisy at low flow.	1, 3, 4, 14, 25.
• Pump vibrates or noisy at high flow.	12, 15.

List of Causes

1. Pressure at eye of impeller has fallen below vapour pressure.
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.
5. Circular motion in suspended column-pipes of V.T. pump observed. (The problem indicate occurrence of vortex. Take remedial action as per C or G in Fig. 11.1. If not corrected, the column pipe may crack).
6. Occurrence of vortex in intake, sump or well. (Check whether all parameters for vortex-free operation are satisfied. Take recommended remedial measures as per Fig. 11.1).
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).
8. Speed too low for pump driven by diesel engine.
9. Speed too high for pump driven by diesel engine.
10. Wrong direction of rotation.
11. Total head of system higher than design head of pump.
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, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54.	
• Pump overheats and/or seizes.	1, 5,6, 7, 11, 13, 14, 18, 20, 22, 23, 24, 30, 31, 32, 33, 34, 35, 36, 39, 40, 41, 42, 43, 44.	
• Coupling fails.	20, 22, 24, 29, 46, 53.	
• Pump rotates in reverse direction on shutdown or after power failure or tripping.	55, 56.	

15. Burst or leakage in pumping main.
16. Pumping main partially or fully clogged.
17. Air trapped in pumping main.
18. Malfunctioning of line valve causing partial or full closure.
19. Foreign matter in impeller.
20. Misalignment.
21. Foundations not rigid or broken/loose foundation bolts or supporting structural member (RCC/ structural steel beams) not rigid.
22. Pump (impeller) shaft bent.
23. Rotating part rubbing on 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 stricking 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.11.1).
• 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.

11.7.2 TROUBLE SHOOTING FOR RECIPROCATING PUMP

Symptom	Possible Cause (as per list below)
Liquid end noise	1, 2, 7, 8, 9, 10, 14, 15, 16
Power end noise	17, 18, 19, 20
Overheated power end	10, 19, 21, 22, 23, 24
Water in crankcase	25
Oil leak from crankcase	26, 27
Rapid packing or plunger wear	11, 12, 28, 29
Pitted valve or seats	3, 11, 30
Valve hanging up	31, 32
Leak at cylinder-valve hole plugs	10, 13, 33, 34
Loss of prime	1, 4, 5, 6

11.7.2.1 Suction Troubles

1. Insufficient suction pressure
2. Partial loss of prime
3. Cavitation
4. Lift too high
5. Leaking suction at foot valve
6. Acceleration head requirement too high

11.7.2.2 System Problem

7. System shocks
8. Poorly supported piping, abrupt turns in piping, pipe size too small, piping misaligned.
9. Air in liquid
10. Overpressure or overspeed
11. Dirty liquid
12. Dirty environment
13. Water hammer

11.7.2.3 Mechanical Troubles

14. Broken or badly worn valves
15. Packing worn
16. Obstruction under valve
17. Loose main bearings
18. Worn bearings
19. Low oil level

20. Plunger loose
21. Tight main bearings
22. Inadequate ventilation
23. Belts too tight
24. Driver misaligned
25. Condensation
26. Worn seals
27. Oil level too high
28. Pump not set level and right
29. Loose packing
30. Corrosion
31. Valve binding
32. Broken valve spring
33. Loose cylinder plug
34. Damaged O-ring seal

11.7.3 TROUBLE SHOOTING FOR DELIVERY PIPES, HEADER AND NRV

S.No.	Trouble	Cause	Remedy
1.	Undue thrust on pump foundation and bend in delivery pipe causing shearing or uprooting of foundation bolts of pumps and thrust on common header.	Dismantling joint is not properly designed, to counter thrust at the elbow in the pump.	Provide dismantling joint of proper design. The design should ensure that it has long tie-bolts connecting rigid flanges and thus taking up the pull caused by thrust at pump.
2.	Cracks in welded jointed of individual delivery and common header.	The cracks are caused due to thrust at dead end of common header.	Provide thrust blocks at dead (free) end of common header.
3.	Reflux valve (NRV) closes with slam and high noise in the event of shut-down or power failure or tripping.	• The reflux valve is not designed for non-slam in closure.	• Replace with reflux valve designed for non-slam closure. • Taken up issue of old valve to valve manufacturer.

11.7.4 TROUBLE SHOOTING FOR ELECTRIC MOTOR

S.No.	Trouble	Cause	Remedy
1.	Hot bearings	• Bent or sprung shaft. • Excessive belt pull. • Misalignment • Bent or damaged oil rings. • Oil too heavy or too light.	• 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.
		• Insufficient oil level	• Fill reservoir to proper level when motor is at rest.
		• Badly worn bearings • Bearing loose on shaft or in bearing housing	• Replace bearings. • Remetal shaft/housing or replace shaft or bearing housing.
		• Insufficient grease	• Maintain proper quantity of grease in bearing.
		• Deterioration of grease or lubricant contaminated	• Remove old grease, wash bearings thoroughly with kerosene and replace with new grease.
		• Excessive lubricant	• Reduce quantity of grease. Bearing should not be more than two-third filled.
		• Overloaded bearing	• Check alignment, side thrust and end thrust.
		• Broken ball or rough races.	• Clean housing thoroughly and replace bearing.
2.	Motor dirty	• Ventilation passage blocked. Windings coated with fine dust or lint (dust may be cement, sawdust, rock dust, grain dust and the like).	• Dismantle entire motor and clean all windings and parts by blowing off dust, and if necessary, varnish.
		• Bearing and brackets coated inside.	• Clean and wash with cleaning solvent.
		• Rotor winding coated with fine dust/cement	• Clean and polish slip ring. Clean rotor and varnish
3.	Motor stalls	• Motor overloaded	• Check any excessive rubbing or clogging in pump
		• Low voltage • Open circuit	• Correct voltage to rated value. • Fuses blown, check overload relay, starter and push button.
		• Incorrect control resistance of wound motor • Mechanical locking in bearings or at air gap.	• 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.	• Check voltage in each phase.
		• Motor may be overloaded	• Start on no load by decoupling. Check for cause for overloading.
		• Starter or switch/breaker contacts improper	• 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.
		• Initial starting torque of load too high.	• If of squirrel cage type and with auto-transformer starter, change to a higher tap. If of slip ring type, lower the starting resistance.
		• Rotor defective	• Check for broken rings.
		• Poor stator coil connection	• Remove end shields, check end connections
		• Mechanical locking in bearings or at air gap.	• Dismantle and repair. Clean air gap if choked.
5.	Motor runs and then	• Power supply system faulty. bearings or at air gap.	• Check for loose connections or single phasing in switches, breakers, starter, bus-bars and conductor.
		• Overload replay trips.	• 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.		• Consult manufacturer whether suitable for design duty and load.
		• Voltage too low at motor terminals because of line drop.	• Check voltage, change tapping on transformer.
		• Improper connection.	• Check that all brushes are ridings on rings. Check secondary connections. Leave no lead poorly connected.
		• Broken rotor bars	• Look for cracks near the rings.
7.	Motor takes too long to accelerate.	• Excess loading	• 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)

		• Timer setting of starter not correct.	• Check whether timer setting of star – delta or autotransformer starter is less than acceleration time required for the torque of driven equipment.
		• Defective squirrel cage rotor.	• Replace with new rotor.
		• Applied voltage too low.	• Correct the voltage by changing tap on transformer. It voltage is still low, take up the matter to power supply authority.
8.	Wrong rotation	• Wrong sequence of phases	• Inter change connections of two leads at motor or at switchboard for two phases.
9.	Motor overheats while running	• Check for overload	• 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.
		• End shields may be clogged with dust, preventing proper ventilation of motor.	• Blow off dust from the end shields.
		• Motor may have one phase open.	• Check to make sure that all leads are well connected.
		• Unbalanced terminal voltage	• Check for faulty leads, connections from transformer.
		• Weak insulation	• Check insulation resistance, examine and revarnish or change insulation.
		• High or low voltage	• Check voltage of motor and correct it to the extent possible.
		• Rotor rubs on stator bore	• Replace worn bearings. • Check for true running of shaft and rotor.
10.	Motor vibrates after connections have been made	• Motor misaligned	• Realign
		• Weak foundations or holding down bolts loose	• Strengthen base plate/ foundation; tighten holding down bolts.
		• Coupling out of balance	• Balance coupling
		• Driven equipment unbalanced.	• Balance rotating elements of driven equipment on dynamic balancing machine.
		• Defective ball or roller bearings	• Replace bearing

		• Bearings not in line	• Line up properly
		• Rotor unbalanced	• Rebalance rotor on dynamic balancing machine.
		• Single phasing	• Check for open circuit in all phases.
		• Excessive end play	• Adjust bearing or add washer.
		• Resonance from supporting structure or foundation or vibration of adjoining equipment	• Seek consultation from expert.
11.	Unbalanced line current on polyphase motor during normal operation	• Unbalanced terminal voltage.	• Check leads and connections.
		• Single phase operation.	• Check for open contacts or circuit in all phases.
		• Poor rotor contacts in control wound rotor resistance.	• Check control devices.
		• Brushes not in proper position in wound rotor.	• See that brushes are properly seated.
12.	Scraping noise	• Fan rubbing air shield or striking insulation.	• Check for cause and rectify.
		• Loose on bed plate	• Tighten holding down bolts
13.	Magnetic noise	• Air gap not uniform	• Check and correct bracket fits or bearing.
		• Stator stamping loose	• Retighten stamping.
		• Loose bearings	• Correct or replace bearing.
		• Rotor unbalance	• Rebalance on dynamic balancing machine.
		• Crack in rotor bar	• Replace
14.	Motor sparking at slip rings	• Motor may be overloaded.	• Reduce the load
		• Brushes may not be of correct quality and may not be sticking in the holders.	• Use brushes of the grade recommended and fit properly in the brush holder.
		• Slip ring dirty or rough.	• Clean the slip rings and maintain in smooth glossy appearance and free from oil and dirt.
		• Slip rings may be ridged or out of turness.	• Turn and grind the slip rings in a lathe to a smooth finish.
15.	Leakage of oil or grease on winding	• Thrust bearing oil seal damaged	• Clean the spilled oil on winding. Replace oil seal.
		• Excessive oil, grease in bearing.	• Reduce quantity to correct extent. Grease should be filled upto maximum half space in bearing housing.

11.7.5 TROUBLE SHOOTING FOR CAPACITORS

S.No.	Trouble	Cause	Remedy
1.	Leakage of heclor*	• Leaking welds & solders. • Broken insulators	• Repair by soldering. • Replace insulators.
2.	Overheating of unit	• Poor ventilation	• Arrange for circulation of air either by reinstalling in a cooler and ventilated place or arrange for proper ventilation.
		• Over voltage	• Reduce voltage if possible, otherwise switch off capacitors.
3.	Current below normal value	• Low voltage	• Correct the voltage.
		• Element fuses blown • Loose connections	• Replace capacitor • Tighten carefully
4.	Abnormal bulging	• Gas formation due to internal arcing	• Replace the capacitor
5.	Cracking sound	• Partial internal faults.	• Replace the capacitor
6.	HRC Fuse blowing	• Short, external to the units. • Over-current due to over voltage and harmonics • Short circuited unit. • kVAR rating higher.	• Check and remove the short. • Reduce voltage and eliminate harmonics. • Replace the capacitor. • Replace with bank of appropriate kVAR.
7.	Capacitor not discharging	• Discharge resistance low	• Correct or replace the discharge resistance.
8.	Unbalanced current	• Insulation or dielectric failure.	• 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.

11.7.6 TROUBLE SHOOTING FOR STARTERS, BREAKERS AND CONTROL CIRCUITS

S.No.	Trouble	Cause	Remedy
1.	Starter/breaker not switching on	• Non availability of power supply to the starter/breaker • Overcurrent relay operated • Relay reset not operating • Castle lock is not locked properly	• Check the supply • Reset the relay • Clean and reset relay • Remove lock and lock it properly
2.	Starter/breaker not holding on ON-Position	• Relay contacts are not contacting properly • Latch or cam worn out	• Check and clean the contacts • Readjust latch and cam.
3.	Starter/breaker tripping within short duration due to operation of overcurrent relay	• Overcurrent relay setting incorrect.	• Check and reset to 140-150% of normal load current.

		• Moderate short circuit on outgoing side.	• Check and remove cause for short circuit.
		• No or less oil in dashpot.	• Fill oil upto level mark.
		• Dashpot oil not of proper grade.	• Check and use oil of correct grade.
		• Sustained overload	• Check overcurrent setting. • Check for short circuit or earth fault. • Examine cause of overload and rectify.
		• Loose connection	• Clean and tighten.
4.	Starter/breaker not tripping after overcurrent or short circuit fault occurs	• Lack of lubrication to mechanism	• Lubricate hinge pins and mechanisms.
		• Mechanism out of adjustment	• Adjust all mechanical devices i.e., toggle stops, buffers, springs as per manufacturer's instructions.
		• Failure of latching device	• Examine surface, clean and adjust latch. If worn or corroded, replace it.
		• Mechanical binding.	• Replace overcurrent relay (and heater, if provided)
		• Relay previously damaged by short circuit.	• Replace overcurrent relay and heater.
		• Heater assembled incorrectly.	• Review installation instructions and correctly install the heater assembly.
		• Relay not operating due to:	
		* Blown fuse	* Replace fuse.
		* Loose or broken wire	* Repair faulty wiring; ensure that all screws are tight.
		* Relay contacts damaged or dirty	* Replace damaged contacts.
		* Damaged trip coil	* Replace coil.
		* C.T. damaged	* Check and repair/replace.
5.	Overheating	• Poor condition of contacts.	• Clean and polish contacts.
		• Contacts out of proper alignment	• Align the contacts.
		• Contacts burnt or pitted	• 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.)
		• Loose power connection.	• Tighten the connection.
		• Sustained overcurrent or short circuit/earth fault.	• Check cause and rectify.

		• Poor ventilation at location of starter/breaker.	• Improve ventilation.
6.	Overheating of auto transformer unit	• Winding design improper.	• Rewind.
		• Transformer oil condition poor.	• Replace transformer oil in auto-transformer unit.
7.	Contacts chatter	• Low voltage	• Check voltage condition. Check momentary voltage dip during starting. Low voltage prevents magnet sealing. Check coil voltage rating.
		• Poor contact in control circuit	• 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.
		• Defective or incorrect coil.	• Replace coil. Rating should compatible for system nominal voltage.
8.	Contacts welding	• Abnormal inrush of current	• Check for grounds & shorts in system as well as other components such as circuit breaker.
		• Low voltage preventing magnet from sealing	• Check and correct voltage.
		• Short circuit	• Remove short circuit fault and ensure that fuse or circuit breaker rating is correct.
9.	Short push button and/ or over heating of contacts.	• Filing or dressing.	• Do not file silver tips. Rough spots or discolouration will not harm tips or impair their efficiency.
		• Interrupting excessively high current	• Check for short circuit, earth fault or excessive motor current.
		• Discoloured contacts caused by insufficient contact pressure, loose connections etc.	• Replace contact springs, check contact for deformation or damage. Clean and tighten connections.
		• Dirt or foreign matter on contact surface.	• Clean with carbon tetrachloride.
		• Short circuit.	• Remove fault & check fuse or breaker rating whether correct.
10.	Coil open circuit	• Mechanical damage	• Examine and replace carefully. Do not handle coil by the leads.
		• Burnt out coil due to over voltage or defect.	• Replace coil.

11.	Magnets & other mechanical parts worn out/broken	• Too much cycling. • Dust and dirt or mechanical abuse.	• Replace part and correct the cause of damage.
12.	Noisy magnet (humming)	• Defective coil	• Replace coil
		• Magnet faces not mating correctly.	• Replace magnet assembly. Hum may be reduced by removing magnet armature and rotating through 180°.
		• Dirt oil or foreign matter on magnet faces.	• Clean magnet faces with carbon tetrachloride.
		• Low voltage	• Check system voltage and voltage dips during starting.
13.	Failure to pick-up and/ or seal	• Low voltage	• Check system voltage and voltage dips during starting.
		• Coil open or shorted.	• Replace coil.
		• Wrong coil.	• Check coil voltage rating which must include system nominal voltage and frequency.
		• Mechanical obstruction	• With power off, check for free movement of contact and armature assembly. Remove foreign objects or replace contactor.
		• Poor contact in control circuit.	• Check and correct.
14.	Failure to drop out	• Gummy substances on pole faces or in mechanism.	• Clean with carbon tetrachloride.
		• Voltage not removed from control circuit.	• Check control circuit.
		• Worn or rusted parts causing binding e.g. coil guides, linkages.	• Replace contactor.
		• Residual magnetism due to lack of air gap in magnetic path.	• Replace contactor.
		• Improper mounting of starter.	• Review installation instructions and mount properly.
15.	Failure to reset	• Broken mechanism worn parts, corrosion dirt etc.	• Replace overcurrent relay and heater.
16.	Open or welded control circuit contacts in over current relay.	• Short circuit in control circuit with too large protecting fuses.	• Rectify short circuit in general. Fuses over 10A rating should not be used.
		• Misapplication, handling too heavy currents.	• Check rating and rectify.
17.	Insufficient oil in breaker/ starter (if oil cooled)	• Leakage of oil	• Locate point of leakage and rectify.
18.	Oil dirty	• Carbonisation of moisture from atmosphere	• Clean inside of tank and all internal parts. Fill fresh oil.
19.	Moisture present in oil	• Condensation of moisture from atmosphere	-do-

11.7.7 TROUBLE SHOOTING FOR PANELS

S.No.	Trouble	Cause	Remedy
1.	Overheating	• Bus bar capacity inadequate.	• Check and provide additional bars in combination with existing bus-bars or replace bus-bars.
		• Loose connection • Improper ventilation	• Improper ventilation • Improve ventilation
2.	Insulator cracked	-	• Replace the insulator

11.7.8 TROUBLE SHOOTING FOR CABLES

S.No.	Trouble	Cause	Remedy
1.	Overheating	• Cable size inadequate.	• Provide a cable in parallel to existing cable or higher size cable • Increase clearance between cable.
2.	Insulation burning at	• Improper termination in lug termination	• Check size of lug and whether properly crimpled and correct. • Check whether only few strands of cable are inserted in lug. Insert all strands using a new or higher size lug if necessary.

11.7.9 TROUBLE SHOOTING FOR TRANSFORMER

S. No.	Fault	Trouble shooting Procedure	Cause	Remedy
1.	Abnormal noise	Listen to the noise at various points of the transformer and find out the exact location by means of a solid piece of wood or insulating materials placed on body of transformer tank at various points. This helps in from the inside of determining whether the noise originated from the inside of the transformer or is only an external one.	a) External Noise: A loose fixing bolt/nut of the transformer. a) Noise originating small transformer, the transformer. In the case of old transformer, possibly due to the windings having become slightly slack.	a) Tighten the fixing bolts and nuts and such other loose metallic parts. b) In the case of such facilities are available open the transformer and take up any slackness by placing shim of insulated boards. In case of big transformers it will be necessary to contact the manufacturer or transformer repairer.
2.	High Temperature	• The temperature rise of the transformer during 10-24 hours of operation is	a) Transformer is over loaded. b) Transformer	a) Reduce the load to the rated load. b) Improve the

		observed. The input current, oil temperature are noted down at intervals of half an hour and tabulated.	room is not properly ventilated.	ventilation of the transformer room to achieve effective air cooling.
			c) Dielectric strength of transformer oil low.	c) Filter transformer oil and improve dielectric strength to 40 kV minimum.
			d) Certain turns in the winding 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 short period; transformer oil escapes from the conservator or there is even apperance 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 a 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 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 in consultation with an experienced Electrical Engineer and transformer repairer.

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.
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.

11.7.10 TROUBLE SHOOTING FOR BATTERIES

Battery troubles revealed in service may be due to inadequate maintenance, incorrect operation and incorrect charging. Many battery troubles can be traced to charging source, undercharging or excessive overcharging eventually leads to battery trouble.

S.No.	Trouble	Cause	Remedy
1.	Readings of specific gravity and voltage very erratic even after equalising charge for at least 48 hrs.	• Battery life is over.	• Check the following * 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 80^0F) 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.

11.7.11 TROUBLE SHOOTING FOR AIR COMPRESSOR

S.No.	Trouble	Cause	Remedy
1.	Compressor does not start	• 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	• Loose or misaligned coupling.	• Check alignment & tightness.
		• Insufficient clearance between piston and valve plate.	• Replace worn parts.
		• Motor or compressor bearing worn out.	• Replace bearing.
		• Loose or misaligned belts.	• Check alignment & tension. Belt slack should be at the top.
		• Loose foundation bolts or hold down bolts.	• Tighten bolts.
		• Improper support or isolation of piping.	• Provide sufficient right angle bends in piping to absorb vibration & support firmly with suitable hangers.
3.	Pipe rattle	• Inadequately supported piping or loose pipe connections.	• Support pipes or check pipe connections.
		• No muffler in discharge line or muffler improperly located.	• Install or move muffler closer to compressor.
4.	Compressor will not load.	• Low oil pressure	• See item 5.
		• Capacity control valve struck open.	• Repair or replace.
		• Unloader element struck.	• Repair
5.	Oil pressure lower than normal or no oil pressure.	• Low oil charge	• Add oil
		• Faulty oil gauge	• Check and replace
		• Defective oil pressure regulator.	• Repair or replace.
		• Clogged oil suction strainer.	• Clean
		• Broken or worn oil pump.	• Replace pump assembly.
		• Worn compressor bearings.	• Replace

11.8 SAFETY ASPECTS

11.8.1 GENERAL SAFETY ASPECTS

Following safety precautions should be observed while working in a pump house.

i) No electric live part shall be kept exposed. Particular care should be taken not to keep the motor terminals, starter door, panel door etc. in open condition.

ii) Guard for pump – motor coupling and for extended shaft shall be provided.

iii) Top cover of the VHS (vertical hollow shaft) motor shall not be unnecessarily kept in dismantled condition.

iv) Helmet, gumboots, hand gloves, torch and emergency lamp etc. shall be provided to the workers.

v) Shock proof rubber matting shall be kept in front of panel and starters.

vi) Discharging devices shall also be provided to work safely on HT side of transformer.

vii) Fire fighting equipment suitable for electrical fire shall be provided. The fire extinguisher shall be thoroughly checked and recharged once in a year.

viii) Damaged wooden flooring, damaged grating etc. shall be repaired on priority.

ix) Safety railing shall be provided above all openings, unwalled edges of flooring and all such places vulnerable for falling or slipping of staff.

x) First aid box shall be kept at visible and accessible place. The first aid box shall be checked once in a month and all used items shall be replenished.

xi) Staff shall be trained in the following aspects to enhance safety awareness and skills to handle safety aspects.

- Fire fighting
- Safety procedures and practices in electrical work
- First aid (general)
- First aid for electric shock.

11.8.2 SAFETY PROCEDURES & PRACTICES IN ELECTRICAL WORK

Following Indian Standards (IS) detail comprehensive guidelines for safety in electrical installation.

IS 5216 (Part I)	–	General
IS 5216 (Part II)	–	Life Saving Technique
IS 5216 (Part III)	–	Safety Posters
IS 5216 (Part IV)	–	Special guidance for safety in electrical work in hazardous areas.

General guidelines and precautions as follows should be observed for safe working in electrical installations.

11.8.2.1 Work on Low and Medium Voltage Mains and Apparatus

1. Unless a person is authorized to work on live low and medium voltage mains and apparatus, all mains and apparatus to be worked upon shall be isolated from all sources of supply, before starting the work, proved dead, earthed and short-circuited.
2. For earthing and short-circuiting, only recognized methods should be used. Measures such as removing fuses shall be taken against the inadvertent energizing of the mains and apparatus.
3. Only competent, experienced and authorised persons shall work on live mains and apparatus, and such persons should take all safety measures as required under the Indian Electricity Rules, 1956.
4. Warning boards shall be attached on or adjacent to the live apparatus and at the limits of the zone in which work may be carried out.

5. Immediately before starting work, rubber hand gloves shall be thoroughly examined to see whether they are in sound condition. Under no circumstances shall a person work with unsound hand gloves, mats, stools, platforms or other accessories and safety devices.

11.8.2.2 Work on High Voltage System in Transformer Substation

All high voltage mains and apparatus shall be regarded as alive and a source of danger and treated accordingly unless it is positively known to be dead and earthed.

No person shall work on high voltage mains or apparatus unless covered by a permit-to-work and after proving the mains dead except for the purpose of connecting the testing apparatus, etc. which is specially designed for connecting to the live parts. Incoming high voltage power supply shall be disconnected by opening AB switch/GOD. As additional precaution, the DO fuses or HG fuses shall be disconnected. Breaker on HV side shall be kept in open (off) position.

11.8.2.3 General Precautions in Electrical Installations

It is always necessary to observe the following rules as precautionary measures in electrical installations.

i) Try to avoid work on live mains which should be switched off before working.

ii) If it is not possible to switch off the mains, make sure before working that your hands or feet are not wet and insulated footwear and rubber hand gloves are worn.

iii) Place yourself in a safe and secure position to avoid slipping, stumbling or moving backward against live conductors or apparatus. Do not rely for protection upon the care assumed to be exercised by others.

iv) In the event of near approach of a lightening storm, all outdoor work on electrical system should be stopped.

v) Make a habit of being cautious. Be on the lookout for danger notice plates, danger flags, warning boards and signals etc. Warn others when they seem to be in danger near live conductor or apparatus.

vi) Never speak to any person working upon live mains or apparatus, unless the person doing the work is aware of your presence and that you are working on electrical system.

vii) In order to rescue a person who has got an electric shock, if there is no other insulator available for rescuing, use your feet rather than hands.

viii) When attending electrical work, be sure that the floor is covered with rubber mat. Concrete floors are dangerously conductive.

ix) When working on high voltage try to keep your left hand in the pocket i.e. avoid your left hand to get in contact with any live conductor or metallic casing of an apparatus or metal pole or cross arms.

x) Do not work in such a place where your head is liable to touch the live mains.

11.8.3 FIRST AID FOR ELECTRIC SHOCK

Standard printed instructions for first aid against electric shock shall be framed and displayed at prominently visible and accessible location.

In most of the cases the electric shock due to accidents is momentary and the contact with the live wire is imperfect. In such cases breathing stops momentarily, but due to the shock, the victim becomes unconscious, and heart beats become weak. The most urgent and immediate care for the victim is that he should be given immediate artificial respiration in the manner detailed below, and artificial respiration should be continued till the victims starts breathing normally. It should be borne in mind if the artificial respiration is stopped just after the victims recovers, he is liable to become unconscious again. In some cases the artificial respiration need to be continued for 6 to 8 minutes.

11.8.3.1 Artificial Respiration

At the time of accident due to electric shock, proceed as follows.

i) When any one gets a shock, the first and foremost duty of the observer is to break the contact of the live mains and body either by switching off the main supply, or the body should be rolled away with dry wooden stick. If a stick etc. is not at hand, a dry piece of cloth should be used. Detach the body from the live mains, or if that is also not available, the loose cloth such as coat or shirt of the victim should be pulled without touching his body.

ii) See if the operator's clothes are smoldering; extinguish the spark first.

iii) Check up if the patient is breathing or not. If he is not breathing, immediately start artificial respiration as detained below until medical aid arrives.

iv) Lay the patient so that no pressure on the lungs of the patient is exerted to facilitate artificial respiration.

Method – I

Lay the patient as shown in Fig. 11.2. Kneel over the patient's back, and place both the hands on the patient's thin portion of the back near the lowest rib in such a manner that the fingers

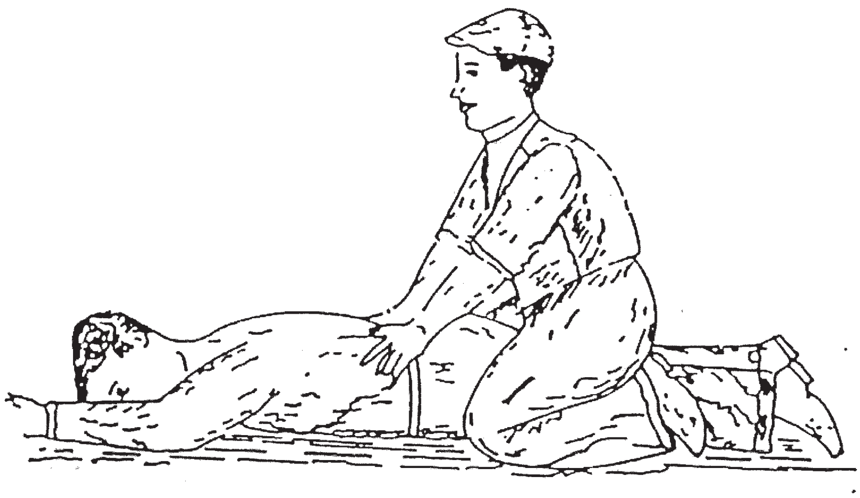


FIG. 11.2 : ARTIFICIAL RESPIRATION

remain spread on the sides and the two thumbs almost touch each other and are parallel to spine. Now press gradually and slowly for about 3 seconds by leaning your hands forward as shown in Fig. 11.3. The patient should be kept warm.

Now relax the pressure slowly and come to the original kneeling position for about 2 seconds as represented in Fig.11.2. Repeat the process for about 12 to 15 times in a minute so as to expand and contract lungs of the patient to initiate breathing. The process should be continued with great patience and in no case undue force should be used.

FIG. 11.3 : ARTIFICIAL RESPIRATION

Method-II

When the patient has got burns etc. on his chest or anywhere on front side, then the patient should not be laid as in Fig.11.3. Appropriate position of laying in such case is on back as shown Fig.11.4 with a pillow or rolled cloth, mat, bedsheet under his shoulders. The clothes of the patient shall be immediately loosened before starting the process of artificial respiration.

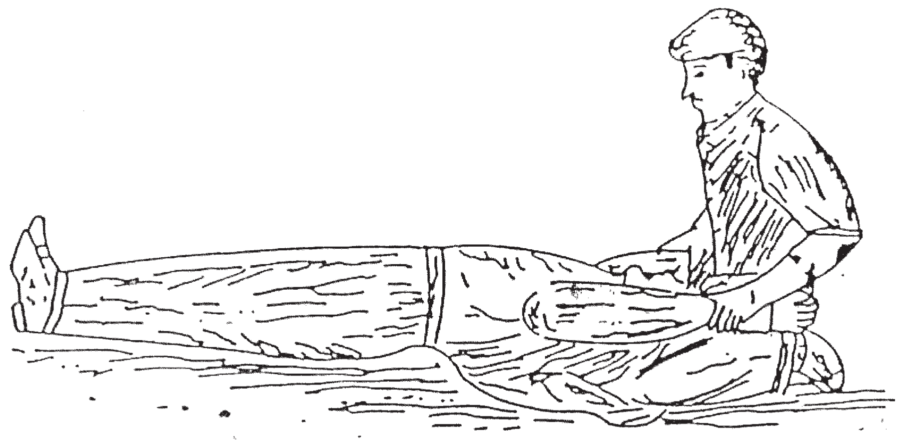


FIG. 11.4 : ARTIFICIAL RESPIRATION

a) Hold the patient just below the elbow and draw his hand over his head until they are horizontal. Keep them in that position for about two seconds. Now bring the patient's hands on to his sides kneeling over the patient's hands so as to compress them down as shown in Fig. 5. After 2 seconds repeat the process again.

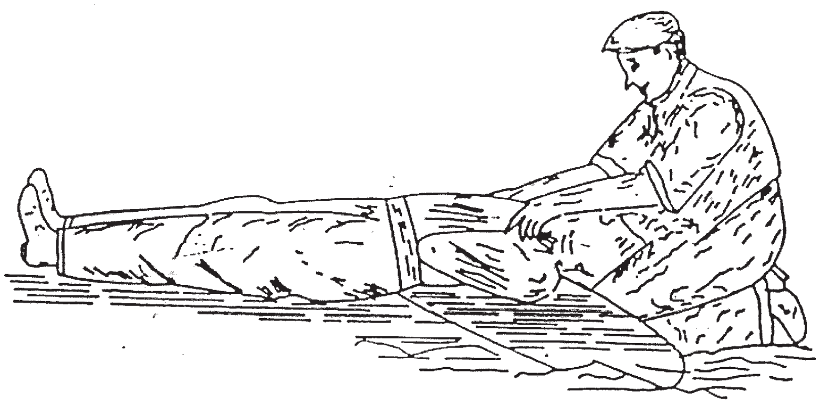


FIG. 11.5 : ARTIFICIAL RESPIRATION

b) If operator has got burns only, the same should be dressed properly. Oil should never be used on the burns. After burns are dressed properly, he may feel better. It is important to note that the one who has received electric shock is liable to get an attack of hyperstatic pneumonia. So it is necessary to keep him warm for at least a day.

11.9 DESIRABLE ENVIRONMENT AND AMENITIES IN INSTALLATION

Environment and cleanliness have tremendous impact on willingness or unwillingness of the workers. In order to maintain working environment following guidelines shall be followed.

- Maintain cleanliness in the installation and surrounding. Cleanliness causes pleasant atmosphere for work.
- Appearance of equipment, furniture and walls etc. should be improved by painting, polishing etc. at about 2 years interval.
- The color selected shall be sober and eye-pleasing.
- Good housekeeping is must for sustaining pleasant environment.
- High noise is major irritant and should be kept within limit, by reducing or isolating the noise emitting sources.

Following amenities shall be provided at installations.

- Dress-changing room and locker facilities.
- Clean toilet and running water supply.
- Drinking water facilities.
- Chairs etc. to rest during work.

* * *

CHAPTER 12

WATER METERS, INSTRUMENTATION, TELEMETRY & SCADA

12.1 WATER METERS

12.1.1 INTRODUCTION

A water meter is a scientific instrument for accurate measurement of quantity of water distributed to the consumers. It also fulfils the need to know accurately the water produced and distributed.

It differs from flow meter in respect of the following points.

1. It is a quantity meter and not a flow rate meter.
2. Water meter is a mechanical device whereas flow meter may be a mechanical or an electronic device.
3. Water meter is always specified in two accuracies i.e. lower range and upper range accuracies whereas a flow meter it is specified in a single range accuracy.
4. The upper range and lower range accuracies are 2% and 5% of the actual quantity respectively for the water meter whereas it is variable for flow meter as per the customer's requirement.
5. Importance is not given for repeatability and linearity in the case of water meter whereas importance is given in the case of flow meter.

Water meters having sizes from 15 mm to 50 mm as per BIS 779 are considered to be domestic water meters and sizes from 50 mm and above as per BIS 2373 are considered to be Bulk Water Meters.

Water meters are classified according to the operating principle, type of end connections, the standard by which the same are covered, constructional features, method of coupling between the counter and primary sensor, the metrological characteristics etc. (Table 12.1)

12.1.2 SIZING OF WATER METERS

Sizing of water meter is done keeping in view the guidelines given in Indian standard IS 2401 and ISO 4064 part-II. In general main considerations are as follows:

1. Water meter has to be selected according to the flow to be measured and not necessarily to suit a certain size of water main.
2. The maximum flow shall not exceed the maximum flow rating.
3. The nominal flow shall not be greater than the nominal flow rating.

CLASSIFICATION OF WATER METER BASED ON

Operating Principle				Constructional Features	Consumer Category		Metrological Characteristics	
Semi positive or Piston or Volumetric	Inferential or Velocity or Turbine				Domestic Meter as per IS 779	Bulk Meter as per IS 2373		
	Vane Wheel or Fan Type		Woltman or Helical Type					
	Single Jet	**Multi Jet**						
Available in C&D classes as per ISO 4064 **Advantages:** 1. Most sensitive 2. Less sensitive to flow disturbances **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 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. Sensitive to flow disturbances 2. Requires specialized calibration as external regulator is not available 3. Not sustained in hostile flow conditions.	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	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.	1. Wet dial meter 2. Dry dial meter 3. Mechanically coupled meter 4. Magnetically coupled meter 5. Straight reading cyclometer 6. Multi pointer meter (Analogue type) 7. Combination of Cyclometer & pointer **Advantages of mechanical coupled** 1. Not affected by external magnetic field. **Disadvantages:** 1. Bush leak problems 2. Air escape hole create problem during submergence. 3. Available in class 'A' only **Advantages of Magnetically Coupled:** 1. Available in Class 'A' as well as Class 'B' 2. More sensitive 3. No condensation of water in resister **Disadvantages:** 1. Temperable with external magnetic field. 2. In intermittent supply high temperature of water may damage the properties of the magnet.	• Available upto size 50 mm • Screwed connection • Body with Brass of Bronze or Plastic • Available in Class 'A' & 'B' in IS	• Available from size 50 mm and above • Flanged connections • Body: cast or steel • Not available in classes in IS	Classes A to D as per ISO 4064	Classes A & B as per BIS 779

4. The minimum flow to be measured shall be within the minimum starting flow of the meter.
5. Low head loss, long operating flow range, less bulky and robust meter shall be preferred.

12.1.3 INSTALLATION OF WATER METERS

In order to ensure proper working of the meters, BIS has given guidelines in IS-2401 of 1973 for their installation as per the drawing given in it. At the same time following guidelines should be borne in mind while installing the meters.

1. The water meter being a delicate instrument shall be handled with great care. Rough handling including jerks or fall is likely to damage it and affects its accuracy.
2. The meter shall be installed at a spot where it is readily accessible.

   To avoid damages and over run of the meter due to intermittent water supply system, it is always advisable to install the meter, so that the top of the meter is below the level of the communication pipes so that meters always contains water, when there is no supply in the line. Also, the minimum straight length condition as per the drawing shall be observed.
3. The meter shall preferably be housed in a chamber with a lid for protection; it should never be buried underground nor installed in the open nor under a water tap so that water may not directly fall on the meter. It should be installed inside inspection pits, built out of bricks or concrete and covered with lid. It should not be suspended.
4. The meter shall be so installed that the longitudinal axis is horizontal and the flow of water should be in the direction shown by the arrow cast on body.
5. Before connecting the meter to the water pipe, it should be thoroughly cleaned by installing in the place of the water meter a pipe of suitable length and diameter and letting the passage of a fair amount of water flow through the pipe work to avoid formation of air pockets. It is advisable that the level of the pipeline where the meter is proposed to be installed should be checked by a spirit level.
6. Before fitting the meter to the pipeline check the unions nuts in the tail pieces and then insert the washers. Thereafter screw the tail pieces on the pipes and install the meter in between the nuts by screwing. In order to avoid its rotation during the operation, the meter should be kept fixed with suitable non metallic clamps. Care should be taken that the washer does not obstruct the inlet and outlet flow of water.
7. The protective lid should normally be kept closed and should be opened only for reading the dial.
8. The meter shall not run with free discharge to atmosphere. Some resistance should be given in the down side of the meter if static pressure on the main exceeds 10 m head.
9. A meter shall be located where it is not liable to get severe shock of water hammer which might break the system of the meter.

10. Owing to the fine clearance in the working parts of the meters they are not suitable for measuring water containing sand or similar foreign matter and in such cases a filter or dirt box of adequate effective area shall be fitted on the upstream side of the meter. It should be noted that the normal strainer fitted inside a meter is not a filter and does not prevent the entry of small particles, such as sand.
11. Where intermittent supply is likely to be encountered the meter may be provided with a suitable air valve before the meter in order to reduce inaccuracy and to protect the meter from being damaged. At higher altitude, if meter is installed as above the problem will be eliminated.

12.1.4 TESTING AND CALIBRATION OF WATER METERS

1. The testing & calibration of a water meter is essential before putting it into use as it is a statutory requirement. It is also essential to test it periodically in order to ascertain its performance as during the course of meter working it is likely that its accuracy of measurement may deteriorate beyond acceptable limits.
2. A meter suspected to be malfunctioning is also tested for it's 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 it's accuracy before installation.

The metering accuracy testing is carried out at Qmin, Qt & Qmax. separately.

Where :

Qmin : 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.

Qt : The flow rate at which the maximum permissible error of the water meter changes in value.

Qn : Half the maximum flow rate Q max.

Qmax : The higher flow rate at which the meter is required to operate in a satisfactory manner for short periods of time without deterioration.

The accuracy of water meter is divided into two zones i.e. (1) Lower measurable limit in which $\pm$5% accuracy from minimum flow to transitional flow (exclusive) and (2) Upper measurable limit in which $\pm$2% accuracy from transitional flow (inclusive) to maximum flow.

3. The procedure for conducting the above test is as follows:

Water meter is fixed on a test bench horizontally or vertically or in any other position for which it is designed and with the direction of flow as indicated by arrow on its body. By adjusting the position of regulating valve on upstream side, the rate of flow is adjusted. At the desired rate of flow, the difference in pressure gauge readings fitted on upstream and downstream side of water meter is noted. The flow is now stopped with regulating valve and measuring chamber is emptied and zero water levels on manometer attached to measuring chamber is correctly adjusted. Initial reading of the water meter from its recording dial is noted. Now the flow at the set rate is passed through the water meter and the discharge is collected in the measuring chamber. After passing the desired quantity of water through the meter, the flow is once again stopped. The discharge as recorded by measuring chamber is noted. The final reading of water meter is noted. The difference between the initial and final readings of water meter gives the discharge figure recorded by water meter. Now the discharge recorded by measuring tank is treated as ideal. The discharge recorded by water meter is compared with this ideal discharge. If the quantity recorded by water meter is more than the ideal, the meter is called running fast or vice versa. The difference in the quantity recorded by meter from ideal quantity is considered as error. This error is expressed in percentage.

If the limits of error for the meter exceed as specified in the IS concerned the meter is readjusted by the regulator if it is available in the meter. A change in position of the regulating screw will displace the error curve (calibration curve) in parallel to former position. With the closing of the regulating orifice the curve will shift upward while opening the same will lower the curve. If the curve does not get into acceptable limit the meter is not used. Some of the organizations are accepting accuracy limit for repaired water meter double the value of new water meters at respective zones i.e. for upper zone accuracy is ±4% & for lower zone accuracy is ±10%.

12.1.5 REPAIRS, MAINTENANCE & TROUBLE SHOOTING OF WATER METERS

The water meters are mechanical devices, which normally deteriorate in performance over time. The fact that a meter does not show outward signs of any damage and has a register that appears to be turning does not mean that the meter is performing in a satisfactory way. It is necessary to ascertain the following preventive cares for water meter after proper installation.

Preventive maintenance:-

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

Breakdown maintenance:-

Replacement of broken glass, lid and fallen wiper wherever provided:-

These are the only basic breakdowns observed during periodical inspection. If a meter found not working, then it shall be removed immediately and sent to meter service workshop. In meter workshops normally following steps are performed to carry out the repairs.

1. Disassembling of water meters including strainer, measuring unit, regulator, registering device, etc.
2. Clean all disassembled spare parts in detergent solution in warm water.
3. Inspect the cleaned parts and replace worn parts and gaskets, if any.
4. Inspect the meter body spur threads and cover threads.

5. Inspect the sealing surface on meter body and paint the meter body, if necessary.
6. Inspect the vane wheel shaft pinion, bearing & pivot.
7. Inspect the vane wheel chamber.
8. Reassemble the water meter properly after reconditioning.
9. Calibrate & test the repaired water meter for leakage & accuracy as per IS 6784.
10. Make entry in the life register of that water meter for keeping history record.

TABLE 12.2 TROUBLE SHOOTING OF WATER METERS

S.No.	Trouble	Cause	Remedy
1.	Meter reads in reverse direction	Might have been installed in reverse direction	Check the arrow on the meter body and install the meter properly, if necessary
2.	Meter not recording	Impeller to register link broken	Remove the meter for servicing and repairs
3.	Continuously moving pointer/digit rotates but no change in indicator	Pointer and drum link missing Drum defect	Remove the meter for servicing and repairs Remove the meter for servicing and repairs
4.	Dial/glass foggy	Climatic condition	Wait for climate change, if it is rainy season
5.	Meter suspected to be slow or fast	Inlet flow disturbance, missing internally defective, deteriorated magnets in case of magnetic meter	Clean the external filter/dirt box where provided and the in-built strainer Ensure full open condition of upstream valve. If doubt persists, remove meter for testing, servicing & repair
6.	Bush/gland leakage	Gland deformity	Remove meter for testing and servicing
7.	Regulator, head, body leakage	Regular washer damaged, loose screw	Remove the meter and repair
8.	Physical damage to meter including broken seal	Improper installation	Remove meter for testing, servicing and repair, physical protection arrangement be made
9.	No water available past the water meter even though inlet side is charged	Semi positive/positive displacement meter with jammed piston	Meter is acting as a stop valve. Remove it for inspection, servicing and repair

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

12.1.6 PREVENTION OF TAMPERING OF WATER METERS

In order to prevent tampering, following precautions should be taken.

1. The water meters, shall be installed properly in the chamber with lock and key or in the C.I. covers with lock and key in order to avoid tampering.
2. The water meters must be sealed properly.
3. The water meters shall not allow reversible flow; it should register flow in forward directions only.
4. The water meter dials should be easily readable without confusions.
5. The lid, glass of water meters must be made up of tough materials as per IS 779 and shall be replaced timely.
6. The wiper or dial as far as possible is avoided.
7. In case of magnetically coupled meters, the proper material to shield magnets must be provided in order to avoid the tampering of such meter by outside magnets in the vicinity of meter.
8. Periodical inspection/checking at site is essential to ensure the proper working of meter.
9. Special sealing arrangements may be necessary and provided for bulk meters whereby unauthorized removal of the meter from the connection can be detected.

Inspite of above, to tackle the problems of tampering suitable penalty provisions/clauses shall be there in the rules or the water supply agreement with the consumer. This will also discourage the consumer tendencies of neglecting water meter safety.

12.1.7 TREND OF REPLACEMENT OF WATER METERS

In general, if a water meter goes out of order due to any physical damage or non operation of registration device and is beyond economical repair it should be replaced with immediate effect. In Indian context, the performance of water meter depends upon -

1. the quality of water meter produced by manufacturer and it differs from manufacturer to manufacturer.
2. the design of pipeline & fittings in line with meter;
3. the workmanship & care when handling and installing the meter;
4. the pattern of water passing through the meter;
5. the type of supply of water whether it is continuous or intermittent;
6. the meter maintenance, testing;
7. the proper selection of meter.

The performance of a water meter is required to be watched continuously with suitable history sheets. Any abnormality noticed needs immediate action. Timely removed faulty meter, & specially mechanical type meter, prevents cascade and cumulative damages.

Looking at the amount of transactions involved, bulk meters shall be given priority in replacements. Based on the experience gained for a specification work, a well planned programme for periodical meter testing, servicing, repairs and replacement wherever necessary shall be designed.

12.1.8 AUTOMATIC WATER METERING SYSTEMS

Water meter is a cash register of a water supply authority. Consumption based water rates require periodic reading of meters except in remote or automated meter reading of meters. Except in remote or automated meter reading these readings are usually done by meter readers visiting consumers premises one by one and noting down the indicator reading by the meter. These readings are recorded manually in books or on cards and later keyed in manually to a customer accounting or billing system. In some cases, meter readers use Hand held Data Entry Terminals to record meter readings. Data from these devices are transferred electronically to a billing system. In other cases, key entry has been replaced by mark-sense card readers or optical scanners.

The environment of meter reading usually is not favourable to the meter reader as most of the water meters are installed in underground chamber; these chambers are filled in many cases with water, reptiles or insects. Often access to these meters is also obstructed when these meters are installed in the consumers' premises. Sometimes manual work is involved for opening the chamber covers. Some consumers connect their electrical earth terminal to water utility pipe which endangers the safety of meter reader. If during the meter reading visit the consumer premises are not accessible the meter reader will have to visit it again which increases the cost of meter reading.

The solution to above difficulties is to install automatic system to read meters and process the results by computer. Because of development in integrated circuit technology and low powered radio trans receivers this system to some extent is simplified.

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

1. Manual entry into meter books.
2. Manual entry into portable hand held entry terminals or recorders.
3. Direct electronic entry from meter registers either into portable data terminals or display units from which readings are transcribed in the field.
4. Telemetry link through radio, telephone.

Remote register meters

This system consists of a coiled spring mechanism wound by the register gears in the meter. A small generator is attached to the spring which trips and upwinds when the meter reaches a certain consumption increment. The spinning of generator sends an electrical pulse to the remote Display unit installed outside. This system is known as electro-mechanical remote registering. The place of this system is being taken by Electronically encoded remote registering. In this type small printed circuit boards are installed between counter wheels of meter register, wiper blades attached to the counter wheels contact discrete positions on the PCBs corresponding to meter reading digits. A small microprocessor determines the positions of the wiper blades on PCB and converts in serially coded output. Similarly non contact type optical-encoded sensing technology is also being used.

In order to collect the data from the site Hand held Data Entry Terminal (HDET) is used. This unit consists of a programmable microprocessor based unit, with memory, key pad, display unit, and battery power supply. It has an interface part so that necessary meter reading route instructions can be down loaded to the unit from a host computer and the meter readings themselves uploaded. The meter reader follows the HDET's instructions.

In a remote electronic meter reading system the output from the encoded register meter is captured through a probe attached to HDET. For reading a meter the probe is connected to a receptacle on the outside of consumer's premises.

Presently there are five different systems of automatic meter reading which are as follows:-

1. Telephone dial outbound:
   In this system a meter interface unit is installed on the phone line in the consumer's premises. The utility begins reading by calling a central office access unit which in turn connected to meter interface unit through telephone line. This access is available through dialing i.e. the meter reading is carried out on demand.

2. Telephone dial in bound:
   In this system meter interface unit dials the utility's computer at predetermined time and transmits the latest reading.

3. Bi directional telephone dial in/out bound.
   It is the combination of two earlier systems. With this system it is possible to read meters at will or to send instructions from the utility control center to meter interface unit as necessary.

4. Cable Television:
   In this system at cable hardware end station on address signal is injected for Meter Interface Units (MIU). All MIUS monitor the signals and the unit corresponds to particular address respond and data is transmitted through the cable.

5. Radio:
   In this system a radio frequency transmitter is installed at the meter and receiver is either located at fixed location or movable through the vehicle. The dialogues between transmitters and receivers are taking place either in predetermined time or on demand.

Some of the accrued advantages of automatic water metering are as follows:-

i) Improvement in efficiency of meter reading.
ii) Reduced operating cost
iii) Skipping of access problems of meter reading.
iv) Estimated billing not necessary
v) Tampering of meter can be detected.
vi) Back up to customer information services.

12.1.9 RELEVANT NATIONAL & INTERNATIONAL STANDARDS

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

4.	BS : 5728	:	Measurement of water flow in close conduits, Part-I : Specifications for meters for cold potable Water
		:	Part – II : Specification for installation requirements for meters
		:	Part – III : Methods for determining principal characteristics of meters
5.	ISO : 4064	:	Measurement of water flow in close conduits, Part-I-Specification for meters for cold potable Water.
		:	Part – II : Installation requirement
		:	Part – III : Test methods and equipment

12.2 FLOW METERS

12.2.1 INTRODUCTION

Various different methods are available for metering flow rate and total flow. Each method has its own specific characteristics, which are directed towards individual installation requirements.

In water industry flow rate meter is termed as flow meter and total flow meter is termed as water meter.

A wide range of standard terms are used to describe the essential performance characteristics of instruments and sensors. Some of these terms are as follows.

1. Accuracy

It is defined as the difference between the reading of an instrument and the true value of the measured variable expressed as a percentage of either full scale or true value of the measured variable i.e. either in terms of full scale or flow rate of the flow meter.

As far as possible the accuracy should be selected in terms of percentage of flow rate as it remains constant within the rangeability irrespective of variation in flow rate.

2. Range

The difference between the maximum and minimum values of the physical output over which an instrument is designed to operate normally.

3. Rangeability/Turndown ratio

Describes the relationship between the range and the minimum quantity that can be measured

4. Linearity

The degree to which the calibration curve of a device matches a straight line.

5. Resolution

The error associated with the ability to resolve output signal to the smallest measurable unit.

6. Repeatability

The quantity which characterises the ability of a measuring instrument to give identical indications or responses for repeated applications of the same value of the quantity measured under stated conditions of use.

12.2.2 TYPES OF FLOW METER

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

A. Differential Pressure/Head Flow Meter

1. Orifice Flow Meter
2. Venturi Meter
3. Pitot Tube
4. Annubar (Average pitot tube)

B. Linear Flow Meter

1. Turbine Wheel Flow Meter
    - Full bore type
    - Insertion type
2. Variable Area Flow Meter (Rotameter)
3. Vortex Flow Meter
    - Full bore type
    - Insertion type
4. Magnetic Flow Meter
    - Full bore or Inline type
    - Insertion type
5. Ultrasonic Flow Meter
    - Doppler type
    - Transit time type

The Advantages and Disadvantages of these Flow Meters are given below.

A. Differential Pressure/Head Flow Meter

1. Orifice Flow Meter

Advantages

i) It can be used for all fluids except some exceptions
ii) No moving parts
iii) Flow rate, indication, integration are easily obtained
iv) It can be fitted in any configuration of pipeline
v) Suitable for any pipe diameter
vi) Signal can be transmitted to long distance
vii) Good accuracy
viii) Suitable for extreme temperature and pressure
ix) Calculation possibilities for unusual situations

Disadvantages

i) Rangeability 4 : 1

ii) Energy cost in terms of head loss

iii) Ideal conditions are required for good accuracy

iv) Suitable for particular range of Reynolds number

v) Accuracy in terms of span

vi) Minimum slope for tapping piping has to be maintained i.e. 1:10

vii) Very long conditioning section required

viii) Intensive maintenance required

ix) Edge sharpness of the orifice must be assured.

x) It requires isolation of pipeline during installation

2. Venturi Meter

Advantages

As mentioned under orifice meter, and less pressure loss and hence less energy cost.

Disadvantages

Same as under Sr. No. i, iii, iv, v, vi & x of orifice flow meter in addition to high capital cost.

3. Pitot Tube

Advantages

As mentioned under orifice flow meter except at Sr. No. 7. It does not require isolation of pipeline for installation and comparatively capital cost of the flow meter is less. Head loss is also less.

Disadvantages

As mentioned under Sr. No. i, iii, v, vi, vii of orifice flow meter in addition to inferiority in accuracy as it being point velocity measurement.

4. Annubar (Average pitot tube)

Advantages

As mentioned under pitot tube in addition to higher accuracy

Disadvantages

As mentioned under pitot tube except inferiority in accuracy i.e. accuracy improves due to averaging of multiported pressures.

B. Linear Flow Meter

1. a. Turbine Wheel Flow Meter (Full bore or Inline)

Advantages

i) Excellent accuracy, linearity and repeatability

ii) Usable at extreme temperature and pressure

Disadvantages

i) Suitable for only for low viscosity

ii) Moving parts and hence wear

iii) Sensitive to contamination
iv) Flow profile sensitive and needs conditioning section
v) Affected by overloading, danger of over speeding
vi) Sensitive to vibration
vii) Isolation of pipeline is required for installation.

b. Turbine wheel flow meter (Insertion type)

Advantages

i) Isolation of pipeline is not required
ii) Low cost

Disadvantages

i) Inferior accuracy because of point velocity measurement
ii) Suspended impurities can clog it. In addition to above the disadvantages mentioned under Turbine wheel flow meter (full bore) are also applicable.

2. Variable Area Flow Meter (Rotameter)

Advantages

i) In expensive
ii) No power supply required for local indication
iii) No conditioning section
iv) Easy maintenance

Disadvantages

i) It requires vertical installation
ii) Affected by density and temperature of the fluid
iii) Affected by vibration and pulsation

3. Vortex Flow Meter

a. Full bore or Inline type

Advantages

i) No moving part
ii) Robust construction
iii) Unaffected by temperature, pressure and density changes

Disadvantages

i) Conditioning of long approached section
ii) Span limitation due to viscosity
iii) Shedding rate is non linear between 2000 and 10000 Reynolds's number
iv) Available upto 400 mm size due to constraints of sensitivity
v) Isolation of pipeline is required for installation

b. Insertion Vortex Flow Meter

Advantages

i) Isolation of pipeline for installation is not required
ii) Less costly than that of full bore

In addition to above the advantages mentioned under full bore vortex flow meter are also applicable.

Disadvantages

i) Inferior accuracy due to point velocity measurement

In addition to above the disadvantages mentioned under full bore vortex meter are applicable except at Sr. No. V.

5. Magnetic Flow Meter

a. Full bore (Inline) Flow Meter

Advantages of full bore magnetic (Inline) flow meter

i) Unobstructed flow passage

ii) No moving parts

iii) No additional pressure drop

iv) Unaffected by changes in temperature, density, viscosity, electrical conductivity

v) Flow range setting can be optimised

vi) Suitable for water containing suspended solids

vii) Short conditioning section is required as it is insensitive to flow profile

viii) Measures flow both the directions

ix) Un- affected by contamination and deposit

x) Minimum maintenance

xi) Good linearity

xii) Smaller diameter flow meter can be used on bigger diameter pipe with the help of reducers having angle not more than 16^0.

Disadvantages

i) Air or gas inclusion causes error

ii) Minimum required conductivity of fluid 0.5 ms/cm.

iii) Isolation of pipeline is required for installation

iv) Vacuum creation may detach inner liner

b. Insertion Magnetic Flow Meter

Advantages

i) Less costly than that of full bore

ii) No isolation of pipe line for installation

iii) Advantages mentioned under Sr. Nos. ii, iv, v, vi, viii, ix, x, xi of full bore magnetic flow meter are applicable.

Disadvantages

i) Inferior accuracy due to point velocity measurement

ii) Long conditioning section is required

iii) Sensitive to vibration

iv) Periodic cleaning of electrode is required

6. **Ultrasonic Flow Meter**

a. **Doppler type Ultrasonic Flow meter**

Advantages

i) Unobstructed flow passage
ii) No moving parts
iii) No pressure drop
iv) Measures flow in both directions
v) Installations of individual elements in existing pipe lines possible
vi) Minimum maintenance
vii) Economical for large diameter pipe
viii) Suitable for turbid water

Disadvantages

i) Not suitable for clear water
ii) Accuracy is inferior
iii) It requires long conditioning section

b. **Transit Time (Time of Flight) Ultrasonic Flow meter**

Advantages

i) Advantages mentioned under Sr. nos. i, ii, iii, iv, v, vi, vii of Doppler type are applicable
ii) Accuracy is improved in multipath
iii) Accuracy is superior in insertion (wetted type) than that of clamp type.

Disadvantages

i) It requires long conditioning section
ii) Not suitable for turbid water or carrying air/gas bubbles.

12.2.3 INSTALLATION OF FLOW METER

Every user expects a problem-free installation of the meter and thereafter only accurate reading. Regular monitoring is desirable in order to avoid failures.

The meter is installed in the pipeline using flanged or threaded connections giving due consideration for conditioning sections. It should be seen that stress-free installation is carried out in pipeline. It is essential to install the flowmeter co-axially to the pipeline without protruding any packing or gasket into the water flow stream. In the case of ultrasonic meter the probes are welded on the pipeline which requires care to see that no projection is protruding in the pipeline. In this case onsite calibration is essential. Wherever converters are used with primary elements it should be observed that the connection between them should be protected against lightning strokes and any other interference signal.

The installation on the existing water supply requires shutting down the water supply. This necessitates shortest installation time. The installations are strictly carried out as per manufacturers' recommendations.

In the case of differential pressure type flowmeter the impulse piping requires special care in respect of slope and protection. Similarly long disturbance free straight sections should be provided for uniformity. Installation should be vibration free as moving parts in the flowmeter wherever present will get worn out in addition to the effect on overall accuracy of the flowmeter.

Installation in 'U' shape is essential for intermittent water supply.

Flow meters should be provided with battery backup in order to retain integrator reading during failure of electric supply.

12.2.4 MAINTENANCE OF FLOW METER

Modern development in the flowmeter measurement is that in most of the equipment a self-monitoring facility is provided with which the maintenance staff monitors the health of the equipment. A number of instruments are enunciating the error conditions.

As long as orifice, Pitot tube, Venturi & Annubar flowmeters are concerned they require regular purging of impulse piping. Similarly the transducers require periodical checking of zero and range setting. For the orifice it is essential to check sharpness of the edge as in the case of its deterioration or damage the flowmeter reading may vary upto 20%.

Ultrasonic Flowmeter and Magnetic flowmeters being self-monitoring, they give information regarding deviation in accuracy or failure of probe or electrode. Whenever cleaning of probes or electrodes is required, those should be cleaned as per manufacturers' recommendation.

Turbine meter should be checked for bearing wear out periodically as presence of air in the liquid may damage the bearing because of overspeeding.

Where deposits are to be expected in any flowmeter, the same should be regularly inspected and cleaned as per the experience gained during the course of time. As these deposits affect the accuracy of the measurement, Vortex meter, Magnetic flowmeter, Ultrasonic flowmeter, may show erroneous reading in the presence of deposits. In an intermittent water supply the corrosion rate of the pipe increases due to chlorine and air. The formation of incrustation & subsequent descaling affect flowmeter working especially differential pressure type, turbine meters.

12.2.5 CALIBRATION OF FLOW METERS

Flow calibration is essential to

i) Confirm performance of flowmeter
ii) Quality control
iii) Comply with statutory or legal requirements
iv) Provide traceability of measurement and confidence in resultant data.

The calibration is normally carried in the flow laboratory with the help of one of the following methods.

i) Gravimetric
ii) Volumetric
iii) Prover
iv) Master or reference meter
v) Tow tank – current meter calibration

There are two philosophies of flow meter calibration. One is that it is better to have a fixed calibration system with all the associated technical back up and with the flow meters being brought to the calibration system, the other favours calibrating in situ leaving the flow meters in their installed condition and using a portable calibrator. The former will generally provide the more accurate calibration but the latter has the advantage that site specific effects such as proximity to hydraulic disturbances can be taken into account. It is necessary to decide carefully to adopt the option.

There is often no choice but to carry out in situ calibration where

i) flow cannot be shut off

ii) site specific conditions have to be accounted for

iii) the meter is so large that removal, transport and testing costs would be prohibitive.

The major constraint with in situ calibration technique is that the high accuracy laboratory calibration can not be matched in the field and accuracies of ± 2% to ± 5% is all that can be achieved and such field tests are called confidence checks rather than absolute calibrations. Such checks are often the precursor to removal of flow meter for laboratory calibration or replacement.

For field test following methods can be used.

i) Clamp on devices

ii) Thermodynamic method

iii) Velocity area methods (insertion meters)

iv) Tracer methods

v) Flow simulators

Normally the manufacturers of the flowmeters provide laboratory calibration of the flow meters in their works. Some of the Government agencies also provide laboratory calibration vis. Fluid Control Research Institute (FCRI), Palghat, Central Water & Power Research Station (CWPRS), Pune and Institute for Design of Electrical Measuring Instruments (IDEMI), Mumbai

12.2.6 CONCLUSION

The present flow meter market is a challenging one to the purchaser. Unless the site problems are known, it is very difficult to select the flowmeter to serve the purpose from performance point of view. If the flowmeter is selected and installed properly, the maintenance will get reduced drastically.

This is an age where 'energy audit' is gaining wide acceptance in view of the spiraling energy cost. Thus, correct and accurate measurement of inputs (electrical power) and outputs (flow measurement in water works) need to be given due weightage and importance in all water works installations for effective and productive utilization of precious potable water resources.

Details of Various Flow Meters in respect of following features are given in respective tables.

Average Accuracies	:	Table – 12.3
Broad areas of applications	:	Table – 12.4
Performance factors	:	Table – 12.5
Installation constraints	:	Table – 12.6
Fluid property constraints	:	Table – 12.7
Economic factors	:	Table –12.8
Installation & maintenance	:	Table – 12.9
Common problems encountered	:	Table – 12.10
Applicable standards for flow meters	:	Table – 12.11

TABLE 12.3

AVERAGE ACCURACIES OF VARIOUS FLOW METERS

Sr. No.	Type of flow meter	Accuracy %
1.	Square edge orifice	±1S
2.	Venturi	±1S
3.	Pitot	±2S
4.	Annubar	±1S
5.	Turbine	±0.5R
6.	Rotameter	±2S
7.	Vortex	±1R
8.	Magnetic	±0.5R
9.	Doppler	±2S
10.	Transit time	±1R

Legends : S : in terms of full scale
R : in terms of flow rate.

TABLE 12.4

BROAD AREAS OF APPLICATION OF FLOW METER FOR LIQUID

	A	B	C	D
Orifice	0	+	0	0
Venturi	0		0	0
Variable Area	0	0		
Anubar	0		0	0
Turbine	0		0	*
Insertion turbine	0		0	0
Vortex	0			
Insertion Vortex	0		0	0
Electro Magnetic	0	0	0	0
Insertion Electro Magnetic	0		0	0
Doppler	0		+	+
Transit time	0	+	0	0

Legends : 0 is suitable, generally applicable
+ is worth considering, sometimes applicable
* is worth considering, limited availability
or tends to be expensive.
A blank indicates unsuitable;

C: Large liquid flows
($> 1.7 \times 10^4$ L/min.)
D: Large water pipes
(> 500 mm dia)

liquids (temp.>200^{0}C)
not applicable.
A: General liquid application
(< 50 CP)
B: Low liquid flows (<2 L/min)

TABLE 12.5

PERFORMANCE FACTORS OF FLOW METER

Sr. No.	Type of the flow meter	Linearity %	Repeatability %	Rangeability	Pressure drop at maximum flow	Flow parameter measured
1.	Orifice	0.25% FS to 1%FS	± 0.2% FS	3 or 4:1	3-4	R
2.	Venturi	0.25% FS to 1% FS	± 0.2% FS	3 or 4:1	2	R
3.	Variable area	± 1% FS to ± 5% FS	± 0.5% FS to ± 1% FS	1% FS	10:1	3R
4.	Anubar	0.5%R to 1%R	± 0.05% R to ± 0.2% R	4 to 10:1	1/2	Vm
5.	Turbine	± 0.15% R to ± 1% R	± 0.02% R to ± 0.5% R	5 to 10:1	3	R
6.	Insertion Turbine	± 0.25% R to ± 5% R	± 0.1% R to ± 2% R	10 to 40:1	1-2	Vp
7.	Vortex	± 1% R	± 0.1% R to ± 1% R	4 to 40:1	3	R
8.	Insertion Vortex	± 2% R	± 0.1% R	15 to 30:1	1	Vp
9.	Electro Magnetic	± 0.2% R to ± 1% R	± 0.1% R to ± 0.2% FS	10 to 100:1	1	R
10.	Insertion Elec. Mag.	± 2.5% R to ± 4% R	± 0.1% R	10:1	1	Vp
11.	Doppler	No data	± 0.2% FS	5 to 25:1	1	Vm,R
12.	Transit time	± 0.2 R to ± 1% R	± 0.2% R to ± 1% FS	10 to 300:1	1	R

Legends: R : Flowrate; T : Volume flow; Vm : Mean velocity; Vp : Point velocity; % R : Percentage flowrate; % FS : Percentage fullscale; NS : Not specified; 1 : Low; 5 : High

TABLE 12.6

INSTALLATION CONSTRAINTS FOR FLOW METER

Type	Orientation	Direction	Quoted range of upstream lengths	Quoted range of minimum downstream	Pipe Diameter mm
Orifice	H, VU,VD,I	U,B	5D/80D	2D/8D	6 to 2600
Venturi	H,VU,VD,I	U	0.5D/29D	4D	>6
Variable area	VU	U	0D	0D	2 to 150
Anubar	H, VU,VD,I	U,B	2D/25D	2D/4D	>25
Turbine	H, VU,VD,I	U,B	5D/20D	3D/10D	5 to 600
Insertion turbine	H, VU,VD,I	U,B	10D/80D	5D/10D	>75
Vortex	H, VU,VD,I	U	1D/40D	5D	12 to 400
Insertion vortex	H, VU,VD,I	U	20D	5D	>200
Electromagnetic	H, VU,VD,I	U,B	0D/10D	0D/5D	2 to 3000
Insertion magnetic	H, VU,VD,I	U,B	25D	5D	>100
Doppler	H, VU,VD,I	U,B	10D	5D	>25
Transit time	H, VU,VD,I	U,B	0D/50D	2D/5D	>4

Legends : H : Horizontal flow
VU : Upward vertical flow
VD : Downward vertical flow
I : Inclined flow.
U : Unidirectional flow
B : Bidirectional flow
D : Inner diameter of the pipe.

TABLE 12.7

FLUID PROPERTY CONSTRAINTS FOR FLOW METER

Sr. No.	Type	Maximum pressure (bar)	Temperature Range (ºC)	Minimum Reynold's number	More than one phase (Gas or liquid).
1.	Orifice	400	<650	3×10^4	P
2.	Venturi	400	<650	10^5	P
3.	Variable area	700	-80 to + 400	No data	N
4.	Anubar	400	<540	10^4	N
5.	Turbine	3500	-260 to +530	10^4	N
6.	Insertion Turbine	70 to 250	-50 to +430	10^4	N
7.	Vortex	260	-200 to +430	2×10^4	P
8.	Insertion Vortex	70	-30 to +150	5×10^3	N
9.	Electromagnetic	300	-60 to +220	No limit	S/P
10.	Elect.Insertion	20	+5 to +25	No data	N
11.	Doppler	Pipe pressure	-20 to +80	5×10^3	S
12.	Transit time	200	-200 to +250	5×10^3	N/P

Legends : S : Suitable P : Possible N : Not suitable

TABLE 12.8

ECONOMIC FACTORS OF FLOW METERS

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

Legends : 1 : Low 5 : High

TABLE 12.9

INSTALLATION & MAINTENANCE OF FLOW METERS

Type	Installation	Pipeline ahead of meter	Maintenance during operation	Self monitoring	Service
Turbine meter	Flanged connections electrical installation	Conditioning section	Maintenance free, monitor, possible foreign lubrication	Not possible	–
Vortex meter	Flanged connections or water installation, electrical	Conditioning section installation	Maintenance free	Error monitoring	Electronic monitor functions and test values
Differential pressure meters	Primary in flanges, impulse piping, convertor power supply	Long conditioning sections	Regular monitoring	Not possible	Direct measurement at primary
Variable area meter	Flanged or threaded connections	No restrictions	Maintenance free	Constant appearance	–
Electromagnetic flow meter	Flanged connections, electrical connections	No 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	–

TABLE 12.10

COMMON PROBLEMS ENCOUNTERED IN FLOW METER PERFORMANCE

Sr. No.	Problems	Causes	Flow Meter	Remedial Action
1.	Erratic reading	Operated below lower range having limited rangeability of flow meter	Differential pressure type	Replace flow meter
		Operated below lower range having limited rangeability of flow meter	Linear flow meter	Change range setting
		Less static pressure	D.P. type	Remove air trap
		Clogged impulse piping	D.P. type	Clear the choke up
		Air trapped in impulse piping	D.P. type	Remove air trap
		Frequent air trap in impulse piping	D.P. type	Change impulse piping slope to minimum 1: 10, If still the problem persists change the flow meter.
		Damaged impulse piping	D.P. type	Rectify impulse piping
2.	Unsteady reading : (oscillating)	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 incrusted	D.P. & Linear type	Clean the internal surface of pipeline
		Scaling is formed at tapping points	D.P. type	Clean the tapping points
		Orifice edge gets blunt	D.P. type	Replace orifice plate
		Flow meter down stream is opened within the range of 50 times dia pipe length	D.P. type	Extend the down stream pipeline beyond 50 dia length
		Unsymmetrical formation of vena contract due to large diameter of throat in relation to static pressure	D.P. (orifice type)	Redesign the orifice
		Mismatch between flow meter & pipeline	D.P. & Linear type	Remove the mismatch
		Absence of sufficient conditioned approach pipeline	D.P. & Linear type	Provide sufficient conditional approach pipeline
		Foreign particles such as pieces of concrete, bricks, debris etc. are gathered at upstream of orifice	D.P. (Orifice)	Remove them
		Flanged coupling used with flow meter leaking	D.P. & Linear type	Rectify the leakage
		Pipeline may not be cylindrical within the range of 0.3% of the diameter of the pipe	D.P. & Linear type	Replace the pipe length of 2 times dia immediate upstream of the flow meter
		Pipeline partially filled	D.P. & Linear type	Install valve down stream of the flow meter for throttling

TABLE 12.11

APPLICABLE STANDARDS FOR FLOW METERS

BS:7405:1991 of	:	Selection and application of flow meters for the measurement fluid flow in enclosed conduits.
BS:1042	:	Methods for the measurement of Fluid flow in pipes – Orifice plates, Nozzles and Venturi Tubes.
BS:5792:1980	:	Specification for Electro Magnetic flow meters.
BS EN ISO :6817-1997	:	Measurement of conductive liquid flow in closed conduits-Method using Electro magnetic flow meters.
ISO Recommendation –R541 1967(E)	:	Measurement of fluid flow by means of orifice plates and nozzles.
ISO 9104-91/BS 7526 : 1991	:	Measurement of fluid flow in closed conduits – Method of evaluating the performance of electro magnetic flow meter for liquid.
BS : 6199 : 1991/ISO9368/1990	:	Measurement of liquid flow in closed conduits using weighing and volumetric methods.
IS : 4477 (Part-2) 1975	:	Methods of measurement of fluid flow by means of Venturi meters: Part-2 Liquids.
IS 2951 : 1965	:	Recommendations for estimation of flow of liquids in closed conduits part I : Head loss in straight pipes due to frictional resistance.
IS 2952 : Part I - 1964	:	Recommendations for methods of measurements of fluid flow incompressible fluids.
IS 14615 Part I	:	Measurement of fluid flow by means of pressure Differential devices – part I : Orifice plates, nozzles and venturi tubes inserted in circula.
IS 9115 – 1979	:	Method for estimation of incompressible fluid flow in closed conduits by Bend meters.

12.3 INSTRUMENTATION

12.3.1 LEVEL MEASUREMENT

12.3.1.1 Introduction

Instrumentation facilitates coordination of various water parameters, which are essential for optimization of water supply & treatment plant. One of the important parameters amongst them is water level measurement, which is carried out at various locations vis. water reservoir, inlet chamber, open channel, alum feeding tank, lime tank, filter beds, air vessel, sump well etc.

This measurement is accomplished in water works by two following ways.

A. Direct Method

B. Inferential Method

Their merits, demerits as well as uses are given below in brief.

A. DIRECT METHOD

Hook Type Level Indicator	Sight Glass	Float Type Indicator
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
Uses 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. INFERENTIAL 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

12.3.1.2 MAINTENANCE OF LEVEL MEASURING INSTRUMENTS.

Sight Glasses

- After closing top and bottom valves remove the glass and clean with soap water using brush. Clean with fresh water. Assemble the parts again in proper order.

Float Operated Instrument

- Guide cable wound round a pulley should be lubricated. Other moving parts should also be lubricated.
- Zero setting should be checked. Float should be checked from corrosion point of view.

Hydrostatic Pressure Instruments (Pressure Gauge Type)

- Check for Zero setting after disconnecting from the system and purging out.
- Check for the leakages from the connection after reconnecting it.

Pressure Bulb Type

- Check for zero setting. Check for air leakages from the bulb by applying soap water.
- Check coupling from corrosion point of view.
- Clean the bulb with fresh water.
- Check for the correctness of the signal by moving the bulb in the water.

Displacer, Electrical or Ultrasonic Instrument

- Clean the instrument and check for zero and range setting.

12.3.2 PRESSURE MEASUREMENT

12.3.2.1 Introduction

In water supply network pressure parameter plays very important role in order to get sufficient water to the consumers. Similarly in flow measurement by differential pressure type flow meter, differential pressure measurement across the primary element is the main physical parameter to inter link with flowing fluid.

This pressure or differential pressure measurement is accomplished with the help of following methods in water works.

A. Manometers

B. Elastic Pressure Transducer

C. Electrical Pressure Transducer

The advantages and disadvantages of the instrument of pressure measurement normally used in waterworks are given below.

A. MANOMETERS

U Tube Manometers	Well Type Manometers	Inclined Manometers
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 3 kg/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. Potentio metric pressure transducer
3. Capactive pressure transducer
4. Variable reluctance pressure transducer
5. Piezo electric pressure transducer

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

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

12.3.2.2 Calibration of Pressure Measuring Instruments

Pressure instrument calibration is the process of adjusting the instruments output signal to match a known range of pressure. All instruments tend to drift from their last setting. This is because springs stretch, electronic components undergo slight changes on the atomic level and other working parts sag, bend or lose their elasticity.

The calibration procedure includes Zero, Span and linearity adjustments. The pressure is varied with the help of pneumatic calibrator so as to give desired pressures to the instrument. The settings are carried out on the instrument for zero and span adjustment on the basis of applied pressures. For carrying out linearity setting various pressures between zero and maximum range of the instruments are applied and adjusted the output of the measuring instrument with the help of controls provided in the instrument.

In the case of pressure gauges the calibration is carried out by means of dead weight tester.

In absence of pneumatic calibrator the air can be supplied to the instrument with proper pressure regulator and pressure is measured with the help of manometer so as to calibrate the instrument.

The calibration should be checked every 3,6 or 12 months depending upon the use and accuracy expected.

Maintenance of pressure instruments is essential for their proper working and accurate reading. It also improves the life and reliability of the instruments.

12.3.2.3 Preventive Maintenance

The manufacturer of the instrument gives the instructions in the manual supplied along with the instruments. These instructions explain how to maintain the instrument. Generally these consist of following categories.

1. Visual Inspection

Any damage to piping or wiring of the instrument observed should be immediately rectified. It avoids entry of foreign bodies into the system and further damage to the instrument.

2. Venting or Blow down

Liquid lines are generally clogged subsequently if those are not vented periodically. Similarly air or gas in the liquid columns gives wrong readings. In order to avoid such incidents it is essential to blow down the instrument piping periodically on the basis of experience gained in the field.

3. Cleaning and Lubrication

Instruments with mechanical linkages undergo wear and misalignment. Dirt may clog the linkages, causing the mechanism to become less flexible. If not attended these kind of faults,

TABLE 12.12

A TYPICAL TROUBLE SHOOTING CHART FOR PRESSURE & LEVEL MEASURING INSTRUMENT (ELECTRONIC TRANSMITTER TYPE)

Fault	Possible Causes	Corrective Action
Low output Or zero output Or High output Or Erratic output	Power Supply	Check output of power supply Check for short and multiple grounds Check polarity of connections Check loop impedance
	Pressure tapping	Check the pressure connection Check for leakage or blockage Check for entrapped air or gas in the line
	Transmitter	Check for shorts in sensor leads Check connector to transmitter Check for amplifier assembly by replacing it with spare one.
	Sensing element	Check sensing element for its working by gently tapping it.
Tapping by hand gently the mechanism sensor does not respond	Mechanical	Check mechanical linkage Check for dirt finding Excessive wear, misalignment For dirt clean and lubricate as per manufactures recommendations Realign Mechanical parts if necessary For wear replace the worn-out components
	Electrical	Replace electrical/electronic subassemblies and perform calibration

the instrument may breakdown subsequently. This clogging can be removed by cleaning and working of the instrument can be improved by lubrication as per manufacturer's recommendations. Dust can be removed from the panels as well as from the instruments with the help of air blower. If auto test facility is provided on the instrument by the manufacturer the same can be used to check the performance of the instrument daily. If any kind of fault occurs, in such instrument, the same is identified and displayed by the instrument itself.

12.3.3 WATER QUALITY PARAMETER MONITORING

12.3.3.1 Introduction

In water works various treatment processes are carried out in order to supply potable water. The parameters of the water which are normally used for monitoring are as follows :

- Turbidity
- pH
- Residual Chlorine

These parameters are monitored either by means of on-line instruments or by analytical laboratory instruments or both. Their relative advantages and disadvantages are as follows.

12.3.3.2 Turbidimeter

Online	Laboratory Type
Advantages 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	i. Low cost ii. Simple to use iii. Portable iv. Easy maintenance
Disadvantages i. High cost ii. High Maintenance is required iii. Periodical calibration is required iv. It is not portable	i. Does not monitor continuously ii. Human error may encounter iii. Low accuracy
Maintenance i. Clean chamber & lense with fresh water ii. Microprocessor based instrument has self calibration facility which is useful for periodical calibration iii. Clean sources of light	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

12.3.3.3 pH METER

Online	Laboratory 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 electrodes) iv. It is not portable	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_2SO_4 and 6% concentrated H_2O_2 ii. Calibrate periodically with standard solution of 4 pH and 7 pH 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 & 9.2 pH iii. Prepare standard samples from readily available capsules iv. Calibration may last from 4 days to 7 days

12.3.3.4 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

12.4 AUTOMATION

12.4.1 INTRODUCTION

In small and medium plants the supervision and coordination of various activities can be carried out by the operator manually. However for large plant it becomes cumbersome to supervise, operate, coordinate, control and protect it. It is preferably to use sophisticated instrumentation and control system. The task of controlling is achieved by programmable logic controller or digital computer.

The process of monitoring the parameter, comparing it with the set values, manipulating the signal and sending the instructions to concerned equipment for taking action is known as automation. Automation entails the replacement or elimination of intermediate components of a system or steps in a process, especially those involving human intervention or decision making, by technologically more advance ones.

12.4.2 AUTOMATION OF TUBE WELLS

12.4.2.1 General

In some of the cases automation is found to be very useful & efficient even when the number of parameters involved in controlling in the system are less. The fine example of it is the automation of tube wells in remote areas. It is being easily achieved without using P.L.C. The functioning of a pumping set automatically as and when required as per the availability of power supply is carried out without the help of pump operator as described in the following paras.

12.4.2.2 How the Automation is Made

For Operation of the tube well electric switch gear is used. In this electric switch gear the starter is a main component. Starter has two buttons visible on the body of it. One button is green and another is Red. Green button is used for starting the pumping set while Red button is used for closing the pumping set. Green button is normally known as 'NO' (Normally Open) and Red button is known as 'NC' (Normally Close). Whenever any pumping set is to be started Green button is pushed to complete the circuit and energize the no volt coil to make the main contactor functional which in turn operates the motor. In manual operation this starting & closing of the tubewells are done by the pump operator when the tubewells are required to run round the clock. This can be achieved by short circuiting the connections of the Green button i.e. NO is converted into NC. This results into all the time complete circuit giving voltage to no volt coil. So long power is available the tubewell remains functioning. Whenever there is any tripping or power shut down, the tubewell remains non-functional. In this case there is no need of any pump operator but for cluster of tubewells an electrician is needed to keep a watch on the smooth functioning of electric switch gear and pumping sets. For automation of tube wells a healthy switch gear is required which should have all protection devices for the pumping set. The details of such switch gear are given below:

a. Automation Switch Gear:

Automation switch gear in the shape of a Panel Board or Feeder Pillar should have the following components:

- Starter of some standard make.
- Volt meter- 0 to 500 volts
- Ammeter of required Capacity
- Circuit breaker of required capacity
- Energy meter
- Capacitor of required capacity.
- Protection device for single phasing & reverse phasing (current sensing or voltage sensing)
- Selector Switch.

Now a days protection devices are available on the market which have an in-built system of prevention of dry run alongwith single phasing and reverse phasing protection. It is recommended that this device should be used along with the automation switch gear. The technical specifications of this device are given below:

Supply Voltage:

1. System : 220 – 240/380 – 415 – 440 V. AC +/ - 10%@50/60 Hz.
2. Auxiliary : 110/240/380/415 – 440 V. AC+/- 10%
3. Output Relay : ICO 5 A at 240 V. AC
4. Trip setting :
   i) Unbalance : 50% of motor current + 5% (fixed)
   ii) Under current : 75% of set current +/ - 5% (fixed)
   iii) Overload : Above 120% of set current (fixed)
5. Trip type delay (seconds)
   i) On phase failure : 4 to 7 (fixed)
   ii) For dry running : Less than 2 seconds
   iii) For overloading : As per inverse time characteristics
6. Resetting : Auto/manual/remote
7. CTS : As per full current load (20/40/….)

b. The Method of Installing the Protection Device in the System

A line diagram of installing the devices in the system is given at Fig. 12.1

In the diagram shown above the main supply 3 phase marked as RYB (colour based) will be controlled through proper rating of main switch or 3 pole circuit breaker. This 3 phase supply will pass through the device with CTS (Current Transformer Sensor) as shown in the diagram. In the diagram it has been indicated that 1st and 3rd phase (R&B) are passing

ANNEXURE - I

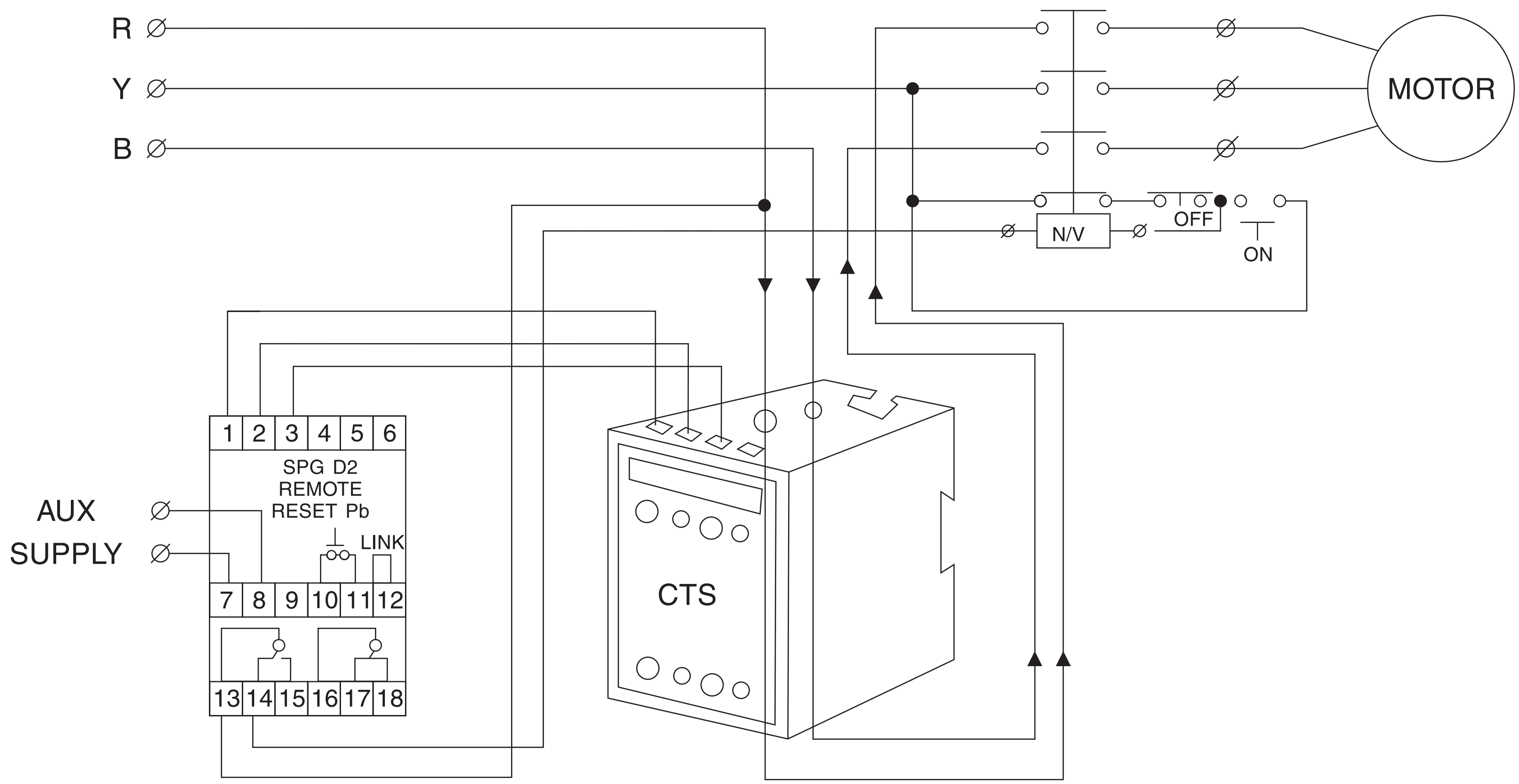


FIG. 12.1: AUTOMATION OF TUBEWELL

through the specified CTS and remaining 2nd phase (Y) is directly connected to no volt coil through relay. A link from phase (R) through the protection device is connected to 2nd point of the no volt coil. Hence after installation this device it will protect the pumping set running with unbalance of motor current, under current i.e. 75% of rated current (dry running condition) and overloading upto 120% of the rated current which may be single phasing also. This device is normally current sensing device.

In case the above mentioned device is not available or is not to be used due to some economic reasons then the conventional single phasing preventor can be used with the automation switch gear. This is normally voltage sensing device. The line diagram is shown at Fig. 12.2.

ANNEXURE - II

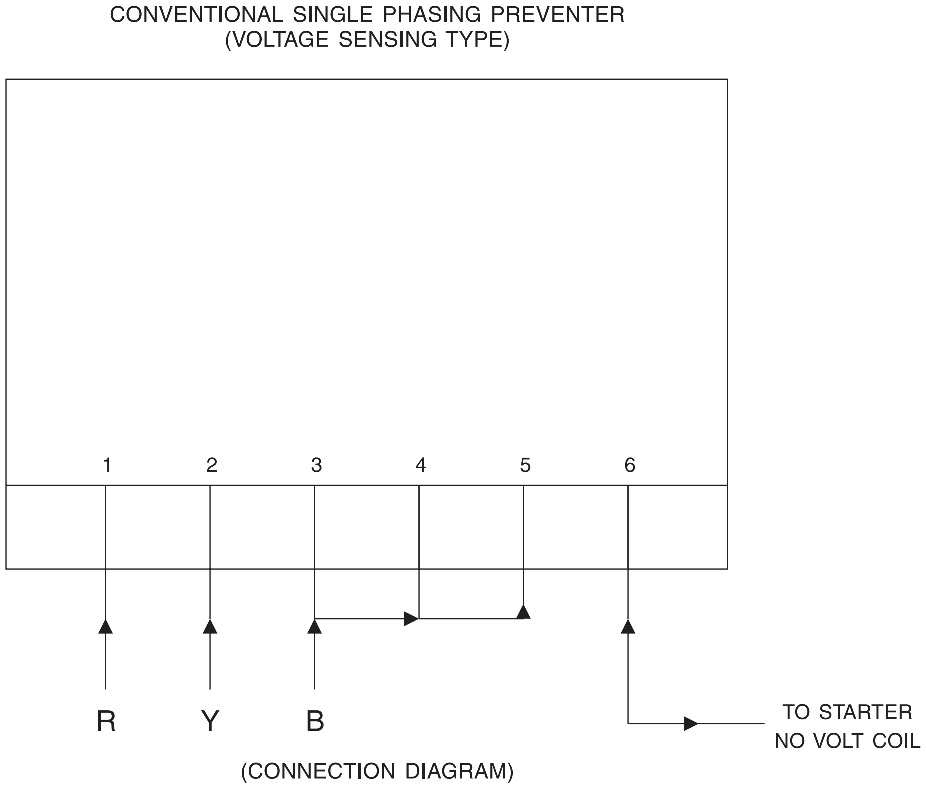
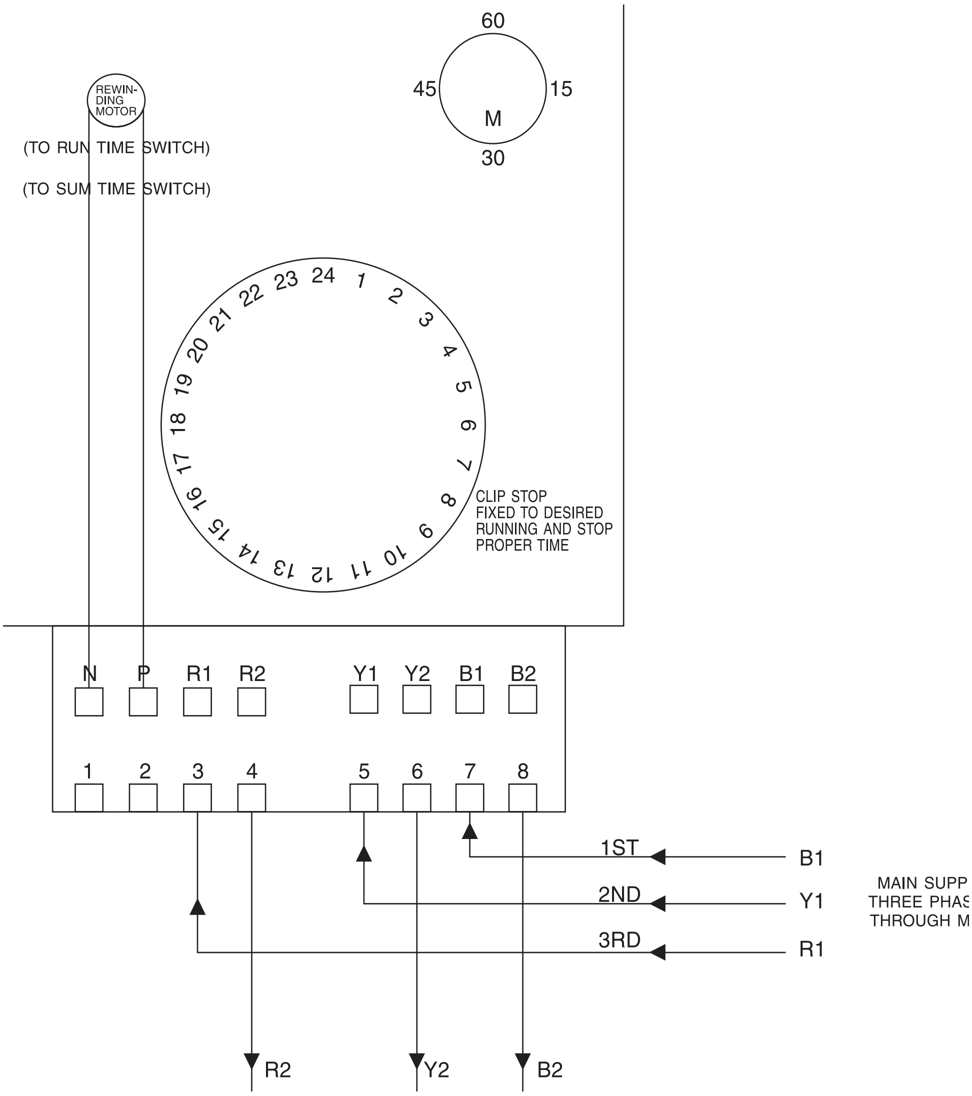


FIG. 12.2: USE OF PROTECTION DEVICE

c. Use of Time Switch with Automation Electric Switchgear

Time switch (timer) is a device to control the operation of the pumping set as and when required. There are certain distribution areas where supply of water is done directly through tubewells. Wherever round the clock water supply is given in the area there is no need of time switch and only conventional electric panel as mentioned in earlier paras will be used. Wherever intermittent water supply for few hours is needed through tubewells then the installation of time switch is required alongwith the electric switch gear to control the operation of tubewell. This time switch will make and break the power supply to starter for a pre-set period of operation of the tubewell. The period between the make and break is the period for operation of tubewell. The make and break period of operation is adjusted with the help of dogs provided on the operating time disc of the time switch. The time disc operated with the help of a energy spring which gets its energy by rewinding the spring. This rewinding system is automatic which is done when the power is available. The circuit diagram of installation of time switch is given at Fig. 12.3.



d. Selection of Type of Relay

It is recommended that whenever there are no or lesser power trippings starters preferably with manual reset relay should be used so that whenever pumping set trips due to single phasing, unbalancing or overloading then it should not start functioning again automatically. It should restart only after the checking by the electrician. He will reset the relay and start the pumping set. If any abnormal condition is there with the pumping set, he will again close the pumping set, put the remark in the log book and will intimate further the concerned supervisor about the probable cause of the abnormal condition of the pumping set.

Although automatic reset relays are available with the starters but for automatic operation of the tubewell manual reset relays are more beneficial. It has been proved practically that automatic reset relays result in more burning of motors in comparison to manual reset relays. However where power trippings are more, there the use of automatic reset relays may be considered to avoid the larger loss of water production.

12.4.3 Problems and Remedial Measures

Sr. No.	Problems	Remedial Measures
1	Whenever there is pumping set shut down due to overloading, single phasing or unbalancing of phases, normally the pumping set remains un-operational (due to manual reset relay) till it is checked and restarted by the electrician. This causes the loss in production of water.	Bulk meters for measuring the inflow at water collection point should be provided. By noticing the inflow rate the operator on duty at collection point must know that from how many tubewells he is getting that rate of flow and accordingly he should intimate the Engineer-Incharge concerned to take corrective measures.
2	Due to reverse phasing the pumping set remains un-operational till it is checked and restarted by the electrician. This causes the loss in production of water.	Bulk meters for measuring the inflow at water collection point should be provided. By noticing the inflow rate the operator on duty at collection point must know that from how many tubewells he is getting that rate of flow and accordingly he should intimate the Engineer, Incharge concerned to take corrective measures.
3	Due to lack of knowledge of the circuits it has been noticed that the electricians by pass the single phasing devices and connect the pumping set directly with the starter. This has resulted frequent burning of motors.	The electricians in charge for checking of tubewells should be given practical training about the circuit diagrams and the functioning of the all components of the automation switchgears. This should be followed by refresher courses after a period of two years.
4	Due to non-availability of spare parts in time, it has been noticed that electricians make direct connections with circuit breakers or ICTP switches thus operating the tubewells directly by circuit breaker/ICTP switches. This has resulted into more burning of motors and electrical accidents also.	Sufficient stock of all moving parts like contact points, no volt coils, contactors blocks, spare parts kits etc. be kept at the levels of Engineer incharge store.
5	Normally preventive maintenance is ignored and dust blowing is not done. This results in failure of automation devices.	There should be regular preventive maintenance as per recommendations of manufacturer. Dust blowing with the help of air blower should be a regular practice and it should be at least once a week. This should be done by the electrician. This will prolong the life of the switch gear.
6	Non-functioning of check valve (non-return valve) in the delivery side of the pump and non-functioning of NRV of pumping set may cause back flow of water of rising main into tubewell when pump set is not functioning. This condition also causes frequent burning of motors.	Both the non-return-valves, one of delivery side & another of pumping set should always be kept functioning & back flow of water into tubewell should not be allowed.

12.5 TELEMETRY AND SCADA SYSTEMS

12.5.1 MANUAL MONITORING

Normally the Managers of O&M of water utilities monitor levels in Service reservoirs, pressures and flows in a distribution system and on operation of pumps such as hours of pumping and failure of pumps and monitor water quality by measuring residual chlorine. The manager usually uses the telephone line or wireless unit to gather the data, uses his discretion gained with experience and takes decisions to ensure that the system is operating with required efficiency. Manual collection of data and analysis may not be helpful in large undertakings if water utilities have to aim at enhanced customer service by improving water quality and service level with reduced costs. This is possible if the management acquires operational data at a very high cost.

12.5.2 TELEMETRY

The inspection, monitoring and control of O&M of a water utility can be automated partially through telemetry. Telemetry enables regular monitoring of the above data on real time basis and the data is provided to anyone in the organization who can review the data and take a decision. In a Telemetry system probes/sensors will be used which will sense and generate signals for the level, pressure and flow in a given unit and transmit the signals by radio/by Telephone. Normally radio link is used and telephone line with modem is used as spare communication. Microwave satellite or fiber- optic transmission systems are also used for data transmission. The water pumping stations may communicate via a cable buried with the pipe. However there may be locations where the main power may not be available and hence solar panels with a battery charger are used to power the remote terminal unit (RTU) and the radio. In urban areas RTU s can communicate on cell phones and or packed radio networks. For remote locations satellite technology is also available.

12.5.2.1 Data for collection by telemetry

The data includes levels in Service reservoirs, pressures and flows in a distribution system, flows/quantity of delivered into a SR and data on operation of pumps such as Voltage, amperes, energy consumed, operating times and down times of pumps and chlorine residuals. In a telemetry system up-to the minute real time information is gathered from remote terminal unit located at the water treatment plant, reservoir, flow meter, pumping station etc. and transmitted to a central control station where the information is updated, displayed and stored manually or automatically.

12.5.2.2 Processing data from telemetry

The meter readings from reservoirs is useful information for managing the distribution system and helps in preventing overflow from reservoirs. However the effectiveness of Telemetry in pumping operations is dependent on reliability of instrumentation for measuring flows, pressures, KWh meters, etc. Standard practice is to calculate pump efficiency and water audit calculations on a monthly basis. Telemetry can also be used to supervise water hammer protection system wherein the pump failures are linked to initiate measures to prevent occurrence of water hammer.

12.5.3 SCADA SYSTEMS

Instead of manual review of data collected by telemetry and initiating action manually, if telemetry is extended to include actions based on the data for remote control of pumps and other equipment then such a system is known as SCADA. Supervisory Control and Data Acquisition (SCADA) is a computer aided system which collects, stores and analyses the data on all aspects of O&M. The operating personnel can retrieve the data and control their operations and sometimes the system itself is programmed to control the operations on the basis of the acquired data. SCADA enhance the efficiency of the O&M personnel who are better informed about the system and hence are in full control of the operations. Whether in a telemetry system or a SCADA system up-to the minute real time information is gathered from remote terminal unit located at the water treatment plant, reservoir, flow meter, pumping station etc. and transmitted to a central control station where the information is updated, displayed and stored manually or automatically. In a SCADA system the information is linked to a supervisory system for local display, alarm annunciation etc. which may be linked to remote control of pumping operations or operation of valves etc.

12.5.3.1 Data collected in SCADA

SCADA systems will have probes/sensors which will sense and generate signals for the level, pressure and flow in a given unit and transmit the signals for storage and analysis in the computer. The signals are transmitted by radio, by Telephone, microwave satellite or fiber-optic transmission systems. The signals transmitted are stored as data, analysed and presented as information. SCADA systems can include the network diagrams of the distribution system of which detailed sketches of a particular area can be viewed by the operator if necessary to observe the current operating data such as flow, pressure, level or residual chlorine. SCADA systems in Water distribution are programmed for collection and processing of following information.

- to monitor levels in Service reservoirs, pressures and flows in a distribution system
- to monitor and store data on levels in SRs, or flows/quantity of delivered into a SR or pressures of distribution system and generate alarms for threshold values of levels, flows and pressures to initiate operation of valves and pumps
- to monitor and store data on operation of pumps such as Voltage, amperes, energy consumed, operating times and down times of pumps
- to measure and record chlorine residuals and generate alarms at thresh hold values of residual chlorine in the distribution systems.

12.5.3.2 Analysis of Data from SCADA

SCADA systems can be designed to analyse the data and provide daily, weekly, monthly and or Annual reports or schedules. It also helps in monitoring the inventories on spare parts and plan requirement of spares. Responses for different scenarios such as seasonal changes or any emergencies can be programmed into SCADA. The information stored in the SCADA can be easily retrieved and analysed. Typical information that could be generated in the system include : Consumption patterns linked to the weather conditions, plots on pressures against flows, electrical energy consumption linked to consumer demands, record on system leaks, record on pump failures, areas with less chlorine residuals etc.

12.5.3.3 Limitations of SCADA

Before installing a SCADA the utility staff should visit facilities with SCADA and discuss with the utility managers and then decide the scope of SCADA to be provided in their utility. The objective of SCADA should be to make the job of operator easier, more efficient and safer to make their facilities performance more reliable and cost effective. There is no doubt that SCADA enables better capacity utilization and help in improved service levels at low operating cost. The following limitations are to be kept in view before embarking on an ambitious program of providing SCADA. SCADA designing calls for careful planning and requires a phased implementation, particularly dependent on appropriate training of utility staff and their willingness to adopt the new technology.

Availability of power supply is very essential to efficient functioning of the system. Wherever possible the RTU for flow meter or pressure sensor is provided power from electricity mains via a battery that acts as a buffer in case of mains failure. There may be metering locations for flow and pressure sensors without any source of power close by. In such cases Solar power may be one alternative. Initially installations at such locations may operate well but they are always subject to poor after sales service by vendors, vandalism and theft.

Ultimate improvement in water supply distribution system cannot be achieved through advanced application of technology like SCADA. The utility staff should have reached a reasonable level of managerial capabilities even with conventional methods of monitoring and control by adopting a holistic approach when the SCADA may further enhance their capabilities; but SCADA by itself is not the answer for poor or inefficient management.

***