CHAPTER 6

DISINFECTION

6.1 INTRODUCTION

The disinfection of potable water is almost universally accomplished by the use of gaseous chlorine or chlorine compounds, because of the limitations of other procedures, for example ozone, ultraviolet light, chlorine dioxide etc.

Chlorine is easy to apply, measure and control. It persists reasonably well and it is relatively inexpensive.

6.1.1 OBJECTIVE OF CHLORINATION

The primary objectives of the chlorination process are disinfection, taste and odour control in the system, preventing the growth of algae and other micro organisms that might interfere with coagulation and flocculation, keeping filter media free of slime growths and mud balls and preventing possible built up of anaerobic bacteria in the filter media, destroying hydrogen sulphide and controlling sulphurous taste and odour in the finished water, removing iron and manganese, bleaching of organic colour.

It can also be used for flushing pipeline before it is brought into operation after carrying out repairs etc. However in such case chlorinator is adjusted to apply chlorine or hypochlorite solution at the rate of 50 p.p.m. Heavily chlorinated water should be allowed to stand in the pipeline for at least 30 min. and preferably for 12 hours before being replaced with potable water.

For more details please refer to Manual on "Water Supply & Treatment", (1999 Edition).

6.1.2 PRINCIPLES OF CHLORINATION

- Chlorine reacts with water to form hypochlorous acid (HOCl) and Hydrochloric acid (HCl). This hydrolysis reaction is reversible. The hypochlorous acid dissociates into hydrogen ions (H^+) and hypochlorite ions (OCl^-), free available chlorine is hypochlorous acid and hypochlorite ions.
- This free available chlorine can react with compounds such as ammonia, proteins, amino acids and phenol which may be present in the water, forming chloramines and chloro-derivatives which constitute the combined chlorine.
- Chlorination in presence of humic acid and fulvic acid forms Trihalomethane (THM) which is a heath hazard.
- The combined available chlorine has less disinfecting properties as compared to free available chlorine.
- For more details please refer to Manual on "Water Supply and Treatment", (1999 Edition).

6.1.3 CHLORINATION PRACTICES

For details please refer to Manual on "Water Supply and Treatment", (1999 Edition).

6.1.4 METHODS OF APPLICATION OF CHLORINE

Disinfection is carried out by applying chlorine or chlorine compounds. The methods of application are as follows:

1. Preparing weak solution by bleaching powder, HTH etc.
2. Preparing weak solution by electrolysing brine solution.
3. By adding chlorine either in the form of gas or solution prepared from dissolving chlorine gas in small feed of water.

6.2 DISINFECTION BY BLEACHING POWDER

6.2.1 GENERAL

Bleaching powder or calcium hypochlorite is a chlorinated lime, which contains about 25 to 34% of available chlorine by weight. Chlorine being a gas is unstable and as such it is mixed with lime to retain its strength for a longer period, as far as possible. The bleaching powder is hygroscopic in nature. It loses its chlorine strength rapidly due to storage and hence should not be stored for more than three months. The method of chlorination by bleaching powder is known as hypo-chlorination.

The general reaction of ionisation of bleaching powder when mixed with water is as follows:

$$Ca(OCl)_2 \rightarrow Ca^{++} + 2OC1^-$$
$$H_2O \rightarrow H^+ + 2(OH)^-$$
$$H^+ + OC1^- \rightarrow HOCl$$
$$Ca^{++} + 2(OH)^- = Ca(OH)_2 \downarrow$$

The calcium hydroxide settles as precipitate.

The combined action of hypochlorous acid and hypochlorite ion brings about the disinfection of water.

6.2.2 PREPARATION OF SOLUTION

i) The concentrated solution of bleaching powder is prepared in one or two tanks of capacity suitable for 24 hours requirement.

ii) The tank inside should be of glazed tiles or stoneware and should be covered.

iii) The powder is first put on a perforated slab placed longitudinally inside the tank at a higher level, with respect to bed level of tank.

iv) Water is sprinkled on the powder through a perforated pipe above this perforated slab. The solution of bleaching powder & water now enters the tank.

v) The solution is rotated for thorough mixing of powder with water by a hand driven/ motor-reduction gear operated slow speed stirrer.

vi) The precipitates of calcium hydroxide settles at the bottom of the tank. The super-natant water, which contains OCl^-, Cl^- is now ready for use as disinfectant. (See fig. 6.1)

6.2.3 DOSING OF SOLUTION

i) The solution is discharged to a small measuring tank at a lower level through PVC pipe or any other material resistant to chlorine. The level of water in this tank is maintained constant through a float valve. A micrometer orifice valve discharges the solution at any pre-set rate, by adjustment on the scale fitted on it. The solution is dosed to the clear water channel by gravity at the time of entry to clear water reservoir. The waste precipitates at the bottom of tanks are taken out occasionally by scour valve. The system is shown in figure 6.1.

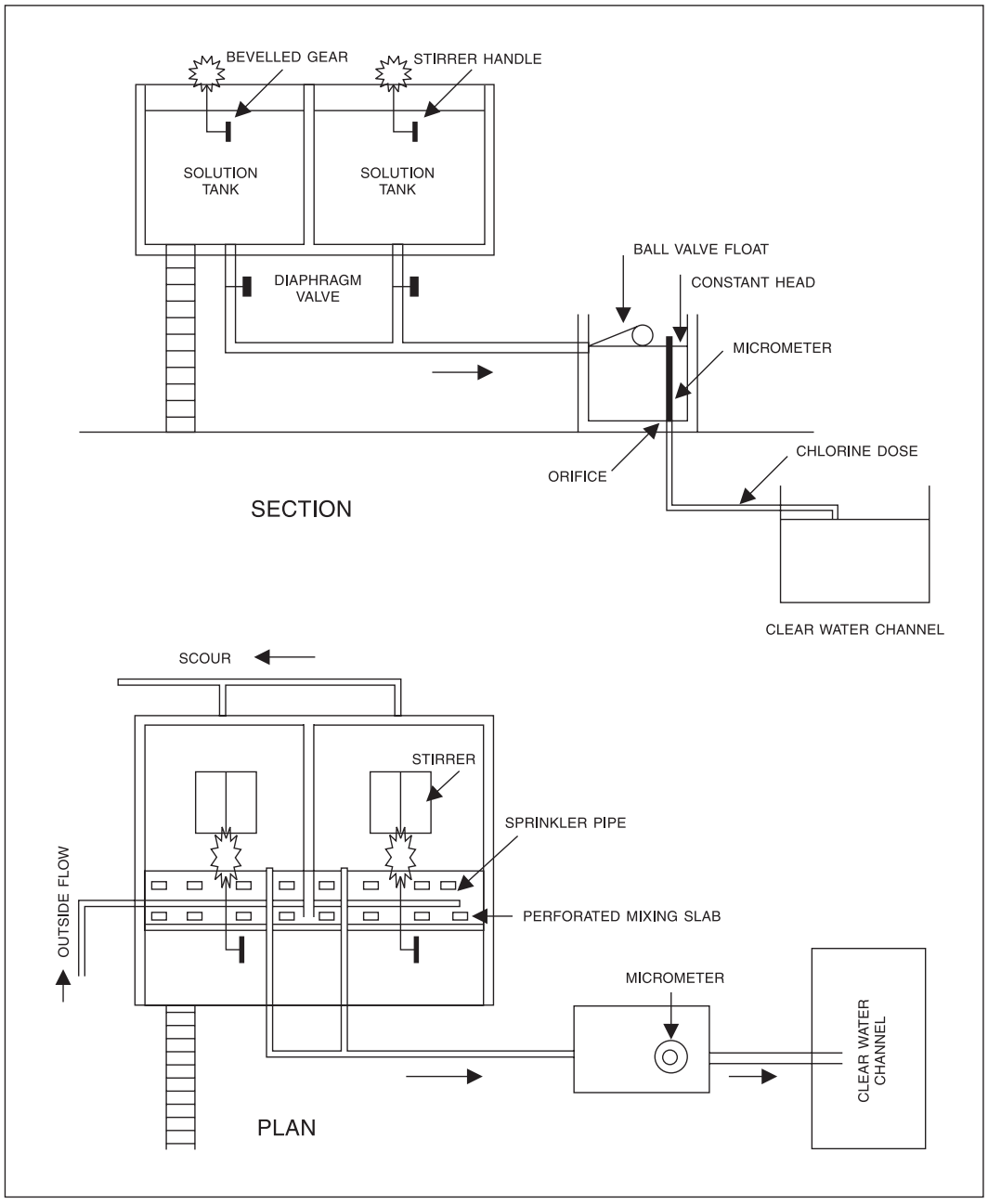


FIG. 6.1 TYPICAL BLEACHING SOLUTION DOSING

ii) The dose has to be monitored properly, depending on the desired residual chlorine required in clear water reservoir.

6.2.4 PRECAUTIONS

i) The operating personnel should use hand gloves, aprons and other protective apparel, while handling and mixing.

ii) The valves, stirrer, tanks, plumbing arrangements require renovation at every 6 months or so.

6.3 ELECTROCHLORINATOR

6.3.1 PRINCIPLE OF OPERATION OF ELECTROCHLORINATOR

Chlorine is instantly produced by electrolysing brine solution. Common salt is mixed with water to prepare brine solution. This solution is passed through an Electrolyser of electrodes comprising of anodes & cathodes, which are energised by D.C. current to produce NaOCl.

Overall reaction is as follows:

$$2\ NaOH + Cl_2 \rightarrow NaCl + NaOCl + H_2O$$

This solution of sodium hypo chlorite is used as disinfectant.

6.3.2 DESCRIPTION OF ELECTROCHLORINATOR

The electrochlorinator set basically comprises of two compartments one comprising of Brine solution tank, electrolyser, cooler, etc. and the other comprising of compact panel board (rectifier). The schematic diagram as well as various parts of electrochlorinator are given in figure-6.2 for a typical electrochlorinator.

Normal life of electrochlorinator is 12 years provided reconditioning of the electrodes at regular interval of four years is carried out. These chlorinators are available at various capacities ranging from 50 gm/hr. to 18 kg/h of active chlorine production. (Refer fig. 6.2) The electolyser consists of a number of electrodes as required. For 500 gm./hr. capacity plant, there are 6 nos. of electrodes comprising of anodes and cathodes. The rectifier is having facilities for auto tripping if there is variation in certain set conditions.

6.3.3 PROCESS DETAILS OF ELECTROCHLORINATOR

1. Make a concentrated brine solution @ 310 gm. of industrial grade salt with 97% purity or more salt in 1 litre of water in a brine solution tank. After pouring salt, the mixture is stirred either manually or through motor driven reduction gear arrangement. In order to reduce the capacity of brine solution tank, a concentrated solution is prepared.
2. Allow brine solution to flow inside the electrolyser at a controlled rate as required for a chlorinator which depends upon active chlorine production. But the quantity of water in brine solution tank is to be replenished, for which fresh water at the same rate is simultaneously sent after controlling the flow, through one of the flow meters (flow meter no. 2) placed in front of brine solution tank.
3. Dilute the concentrated solution with fresh water to attain a strength of 30 gm of salt per litre. Accordingly, fresh water is added to electrolyser, after controlling flow through flow meter No.1 (for 500 gm/h capacity plant, this rate is about 65 l/h) It

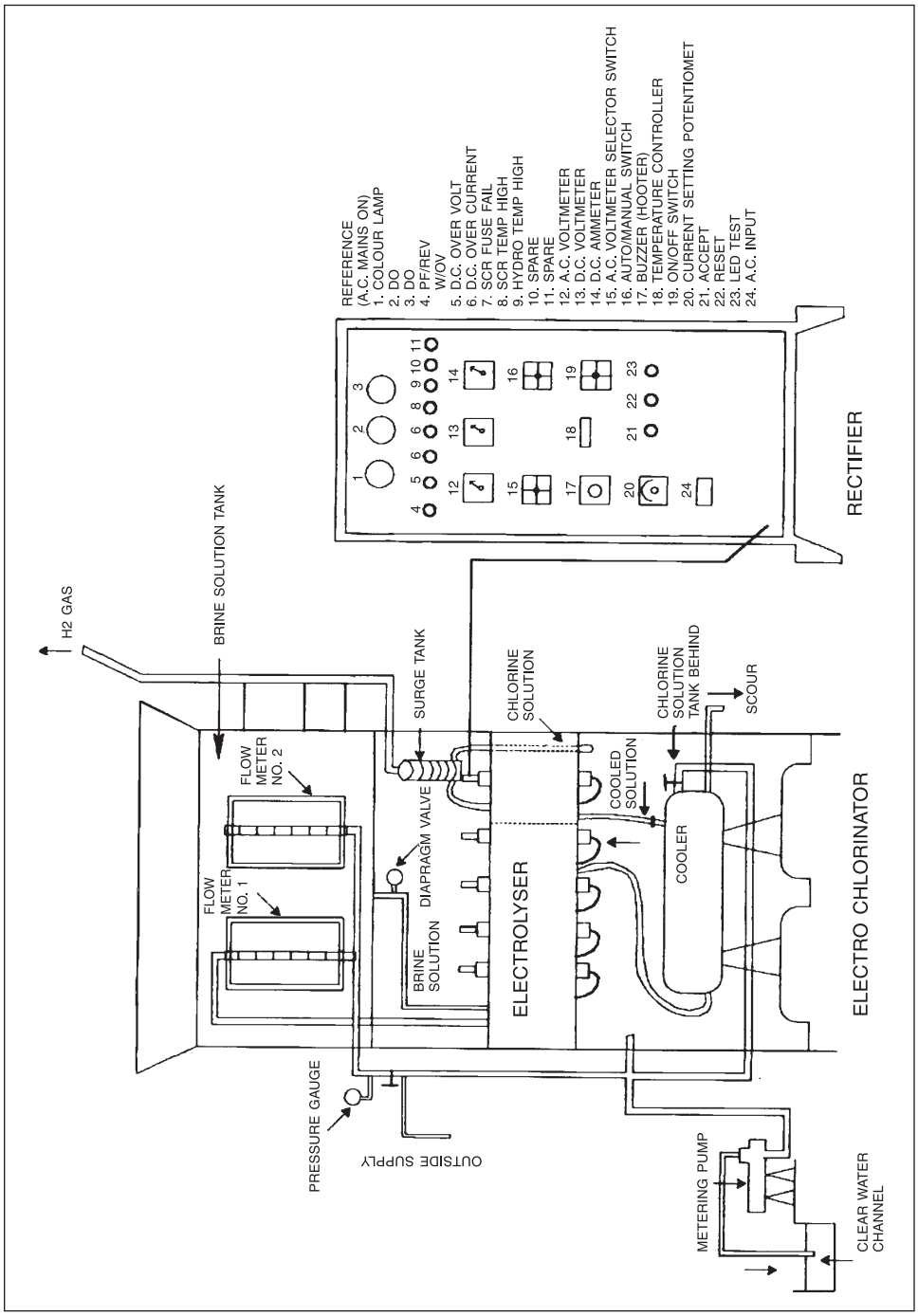


FIG. 6.2 ONSITE PRODUCTION OF HYPO-SOLUTION FROM COMMON SALT

may be mentioned here that for effective functioning of flow meters to control flow, one valve is installed in the common line and pressure through flow meters is controlled at specified pressure rating.

4. After filling the electrolyser with the required solution of salt and water, D.C. power supply through rectifier is put on.

5. The electrolysis process evolves heat. The maximum permissible temperature is of the order of ambient temperature + 12 degree centigrade.

6. In order to control the temperature, the aqueous solution is, required to be cooled through a cooler placed below the electrolyser chamber. The solution is introduced at one end of the cooler and fresh cold water is circulated through coil pipe placed inside the cooler. The cold water used for cooling is continuously discharged to a sump connected with clear water reservoir. The electrolysed solution after cooling is continuously introduced to the 2nd chamber of the electrolyser.
7. After complete electrolysis process, the solution of sodium hypo chlorite (NaOCl), Sodium chloride (NaCl), Water (H_2O), hydrogen gas (H_2) is now passed on to a surge tank which is placed on the rear side of electrolyser i.e. just below the brine solution tank. The hydrogen gas is allowed to escape through a pipe fitted at the top of the surge tank. The solution is now collected through an outlet pipe placed below the surge tank into a solution tank located below.
8. The concentration of active chlorine in the form of sodium hypochlorite solution is, therefore, 7.00 gm per litre.
9. The solution is now taken from the chlorine solution tank and dosed to the clear water reservoir through metering pump installed by the side of the electrochlorinator at the rate at which it is required.

6.3.4 OPERATION OF ELECTROCHLORINATOR

i) For starting the operation, open the brine solution diaphragm valve for a flow to electrolyser. Flow meter No.1, for fresh water is now opened, so that dilution starts inside the electrolyser. The pressure of incoming fresh water should be 1 to 1.1 kg/ cm^2. As soon as the outflow from surge tank starts, electrical operation through rectifier is to be started.

ii) Before starting rectifier, A.C MCB is to be put in 'ON' position. A.C. mains supply in 3 phases is to be checked through indicator lamps. A.C. voltage reading is checked so that requisite voltage of 355 V to 455 V comes to rectifier. By rotating potentiometer clockwise, the D.C. volt and D.C. ampere are set to 23-25 V & 95-100 Amps, respectively. Now electrolysis process is started.

iii) Before closing the operation, brine solution diaphragm valve is to be closed and fresh water is to be allowed inside the electrolyser for cleaning of electrodes for 15-20 mins. Simultaneously, potentiometer is to be operated in anticlockwise direction slowly to set to "zero" position. Now AC main MCB is put to "OFF" position.

iv) If there is any sudden power trip, potentiometer is to be set to 'Zero' position to avoid any sudden shock to the whole system, if power comes back again, immediately. In that case, brine solution diaphragm valve is also to be closed & only fresh water is allowed through flow meter No.1 for 10-15 minutes.

v) If the temperature of hypo solution is increased (i.e. more than ambient temperature + 12^0C), it is sensed through sensor & there will be auto tripping. Potentiometer is then brought zero position. Then brine solution is closed & fresh water is circulated through flow meter No.1 for 20 to 25 minutes, before re-starting. The cooler is checked conveniently to see its effectiveness.

vi) Before closing down of the electrochlorination the flow meter No.1 will be operated for 15 to 20 minutes for cleaning the electrodes.

If the brine solution concentration is reduced, then the D.C volt will rise from 23 to 25 V & there will be corresponding fall of ampere reading from 95 to100 A. At that time, the concentration is to be restored by adding salt & water.

vii) Normally 4.5 kg. of common salt (NaCl) is required to produce 1 Kg. of chlorine with 4.5 kWh power.

6.3.5 MAINTENANCE OF ELECTROCHLORINATOR

1. If there is deposition of chemicals on the body of the electrodes, then D.C. voltmeter will indicate high voltage & concentration of hypochlorite solution will reduce, which can be detected on checking chlorine content. In such a situation electrodes are to be cleared.
2. If there is any fault, at first, all fuses, contact points & their joints are to be checked.
3. D.C. voltage must be kept within the range of 23 volt to 25 volt. The rectifier shall be cleaned and checked occasionally so that all electrical connections remain intact.
4. Plumbing arrangements shall also be cleaned from time to time, if choked with salt deposition.
5. Due to accumulation of positive and negative ions on the anodes and cathodes of the electrolyser, the efficiency of electrolyser process gets reduced and as such the electrodes require cleaning every 25 to 30 days with water jet i.e. without touching them by hands.
6. The staff will require special training for routine maintenance and annual maintenance contract to the specialised agency could be considered for trouble free maintenance of the system.

6.4 CONVENTIONAL CHLORINATION

The conventional chlorination facility i.e. adding chlorine for disinfection of water treatment consists of three essential parts:

1. Chlorine supply system
2. Metering system
3. Diffuser system

In addition to above, there are ancillary equipment, safety equipment, metering & control instrumentation and chlorine residual analysers.

6.4.1 CHLORINE SUPPLY SYSTEM

a) Chlorine Gas Supply System

In gas supply system if the header run passes through an area where ambient temperature may fall below the temperature of the gas leaving the supply containers,

it is necessary to install a pressure reducing valve in the gas supply system. This valve prevents reliquefaction of the gas downstream of it. It is also a good practice to install liquid chemical trap upstream of the valve. The trap will serve to prevent liquid chemical from entering and flashing across the valve seat resulting in poor pressure regulation (Fig.6.3).

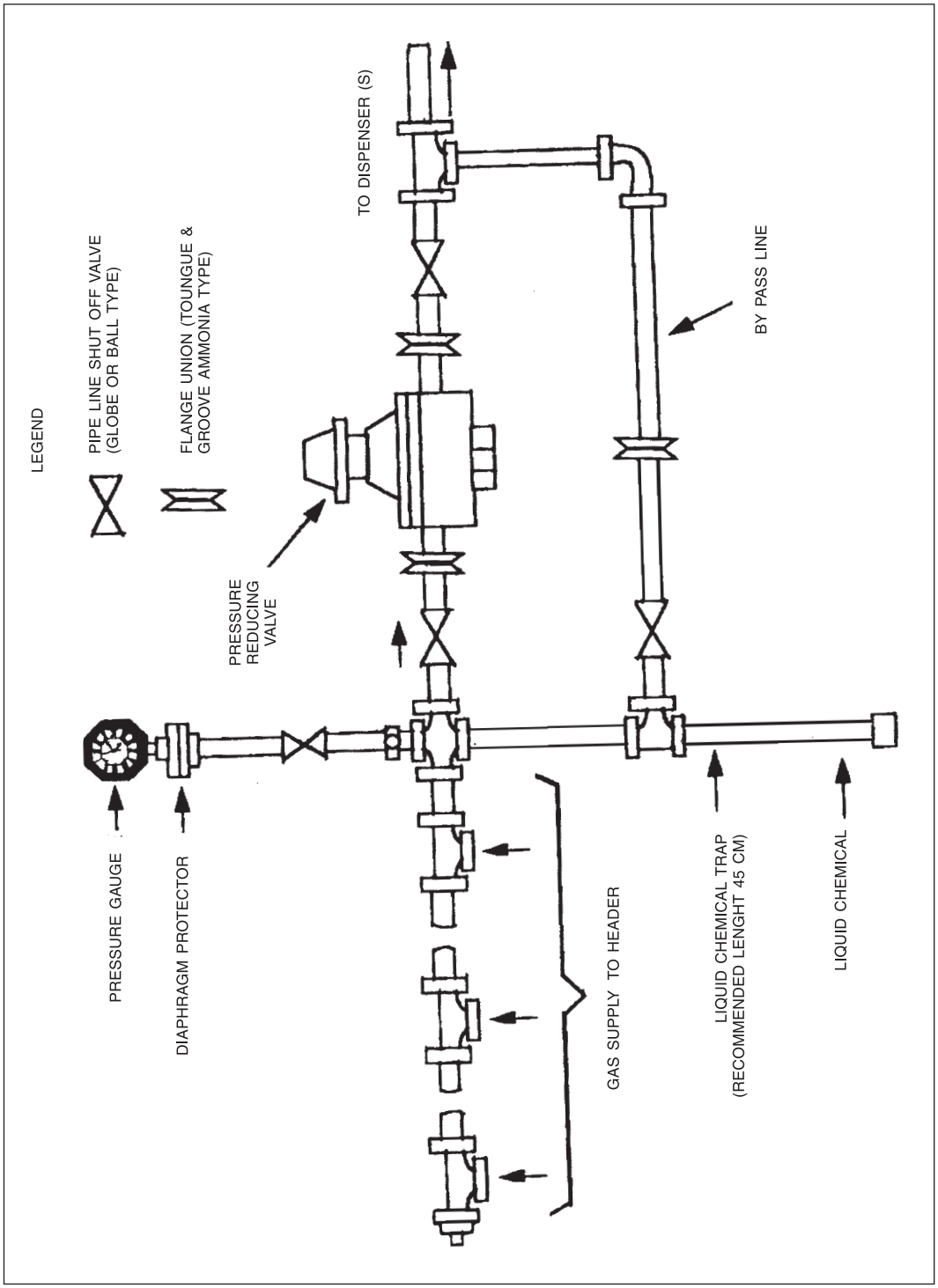


FIG. 6.3 GAS SUPPLY SYSTEM

b) Evaporator Supply System or Liquid Chlorine Supply System

By means of an evaporator, liquid chlorine is converted into gaseous form. The details of Evaporator have been given in Manual on "Water Supply & Treatment" (1999 Edition).

Chlorinator operates the evaporator as per its requirement of chlorine. If requirement of chlorine gets reduced, pressure in the evaporator increases causing liquid chlorine level in it to reduce, thereby reducing its area, which in turn reduces heat transfer. On the contrary, if requirement of chlorine increases, the pressure in the evaporator decreases. As a result of it more liquid is pushed into the evaporator where it is evaporated at higher rate.(Refer Fig.6.4).

c) Chlorine Gas Filter

Small chlorinators usually have same sort of built-in chlorine filter. However, any installation using ton containers (tonners) should have a chlorine gas filter as close as possible to the last cylinder, and always upstream of any external reducing valve. Commonly used material for this purpose is glass wool.

d) External Chlorine Pressure Reducing Valve

Any installation using the variable vacuum system for automatic control requires such a valve to reduce the chlorine supply pressure to 2 to 2.75 kg/cm^2 ahead of the chlorinator to ensure the maximum possible accuracy of the control system. Secondly, this valve also reduces the pressure in the chlorine supply header to prevent re-liquefaction of the gas in the header between the last cylinder connected and the chlorinator (Fig.6.4).

6.4.2 METERING SYSTEM: CHLORINATOR

A chlorinator is a device for feeding chlorine to a water supply. It also serves as gas metering device. Chlorinators are classified into two categories.

- Pressure type
- Vacuum type

6.4.2.1 Pressure Type Chlorinator

It consists of a stop valve, gas filter, pressure reducing valve, regulating valve, an orifice tube with manometer and moisture seal.

The pressure type may be further classified into two groups on the basis of gas or solution feed.

a) Dry Feed Type

These are not used in water treatment presently due to safety reasons.

b) Aqueous Solution Feed Type

It has been established that the only satisfactory method of applying chlorine gas to water is to dissolve the measured feed of gas in a minor flow of water which is then added to the main bulk of the water. For this purpose three distinct types of solutionisers are available. In these systems minimum 1500 litres of water is required per kg of chlorine for making chlorine solution. If the pressure is increased the quantity

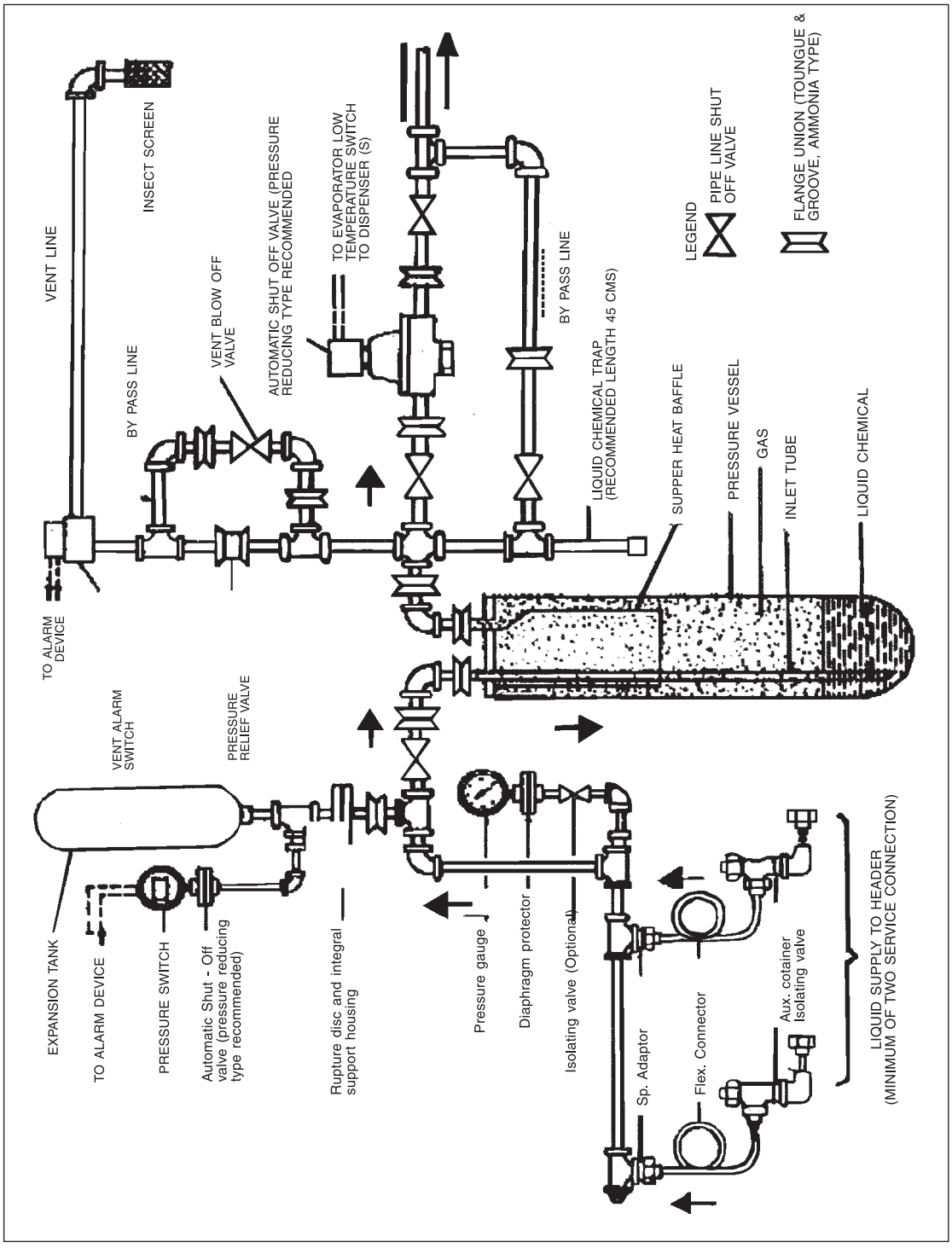


FIG. 6.4 LIQUID WITHDRAWAL SYSTEM

required for making the solution is decreased. The temperature of the water used for preparing the solution must be more than 10ºC. If the temperature of the water is less it must be heated by safe methods before using for solution.

- Gravity feed or Absorption tower feed type.
- Application of the chlorine into a main under pressure i.e. Injector solutioniser.

1. *Gravity Feed*

This can be used where the hydraulic gradient at the point of injection is below the level of the base of the tower. The tower is an ordinary tubular vessel filled with pebbles for percolation of water. A perforated tray is kept at the top of the tower to have an even distribution of water. A perforated PVC or ebonite tube is situated centrally in the tower for efficient and uniform distribution of gas. The water while trickling absorbs the gas and the resulting chlorinated water is delivered through an outlet at the base of the tower. Further it is conveyed to the point of application by a rubber hose. For more details please refer Manual on "Water Supply & Treatment" (1999 Edition).

2. *Injector Solutioniser*

It serves the dual purpose of the conversion of chlorine gas into a chlorine solution and of injecting it into water mains under a hydraulic pressure. The metered gas is introduced to a water-sealed cavity surrounding the injector. The water emerging with high velocity from the jet of injector absorbs chlorine gas due to partial pressure developed around the throat. The resulting solution is passed through a recovery zone to regain the pressure and subsequently injected into water mains (Fig 6.5).

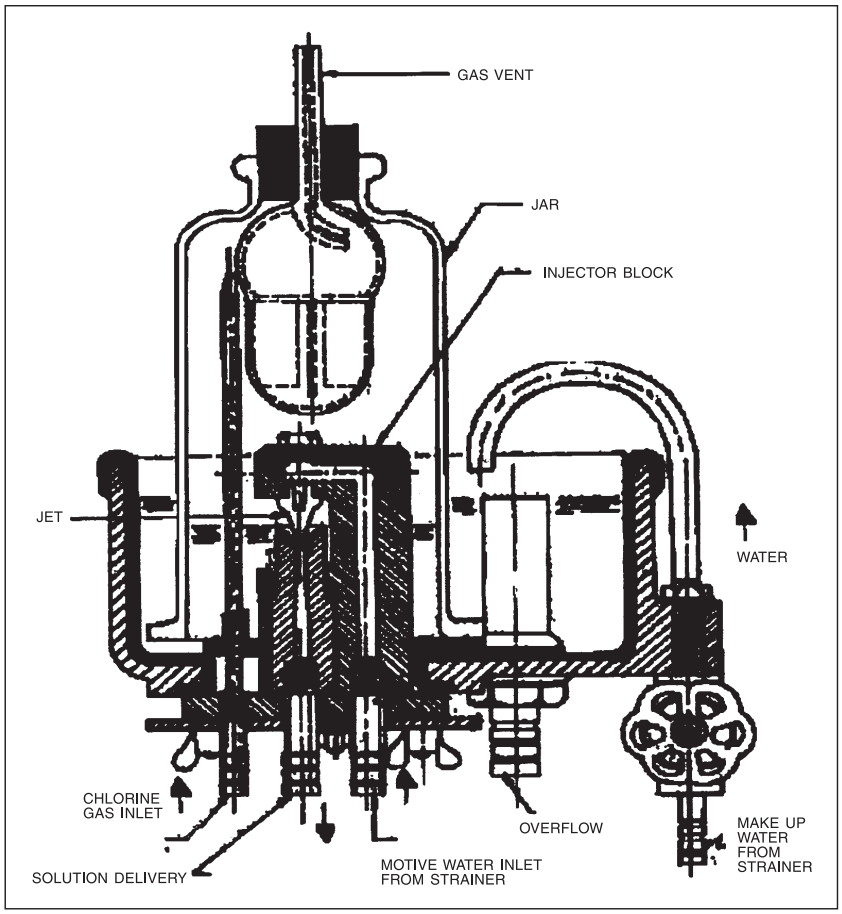


FIG. 6.5 CHLORINE GAS APPARATUS INJECTOR (PRESSURE TYPE) SOLUTIONIZER

It will be seen from the figure that make up water connection maintains the seal of the water across the injector. Hence chlorine does not leak through the jar unless pressure in the jar is increased. For letting the gas outside a gas vent is provided through HCl seal. This arrangement also serves the purpose of vacuum breaking in the system.

6.4.2.2 Operation of Pressure Chlorinator with Aqueous Solution – Gravity Feed Type

(a) Start up of the chlorinator

1. Turn on and adjust the water supply to the solutionizer.
2. With all cylinder connecting valves and regulating valves closed, open one cylinder valve; check the joint for leakage.
3. Slowly open the cylinder connecting valve and stop valve (when fitted). Check for leaks.
4. Open the cylinder connecting valves on any other cylinders that are to be brought into use if connected in parallel. After checking the joints for leakage, open the cylinder valves.
5. Slowly open the regulating valve until the meter indicates the required rate of discharge.

(b) Shutting down

1. Close the cylinder valve and wait until the meter reading returns to zero.
2. Close stop valve when meter shows zero.
3. Shut off the water supply to the tower.

6.4.2.3 Operation of Pressure Chlorinator with Aqueous Solution-Injector Solutionizer Type

(a) Start up of the Chlorinator

Carefully check all connections and make certain that all unions, hose clips are in order.

- Close the stop valve in the operating water supply and open the regulating cock when one is fitted in series with it. A regulating cock is incorporated except when a booster pump or pressure reducing valve is used.
- If the water pressure is to be 'boosted', start the pump.
- Open the water stop valve to the full extent immediately. It is important to open this valve quickly in order to apply full pressure as soon as possible.
- The make up water valve on the side of the tray should next be set so that there is a small surplus of water passing over the overflow tube.
- Close the chlorine regulating valve and stop valve if fitted and also the cylinder connecting valve. Open cylinder valve slowly and check the union joint on the cylinder for leakage.
- In the case of leakage attend to the same and set right the union joint.
- Slowly open the cylinder connecting valve attached to this cylinder and test for leakage at all joints between the cylinder connecting valves and the control panel.

- Open the chlorine stop valve (when fitted) and test for leaks up to the chlorine regulating valve.
- Open the cylinder connecting valves on the remaining cylinders. Test the unions on the cylinders for leakage.
- Open the chlorine regulating valve very slowly until the required rate of flow is indicated by the meter.
- The following conditions should then be noticed in the injector unit.
  (a) The acid in the pressure released bulb should have risen about 6 mm to 12 mm up inside the inner tube.
  (b) The quantity of water passing over the overflow should have increased slightly and there should be further increase if the flow of chlorine is set at a higher rate.
- It may then be possible to reduce the quantity of water by the injector, by reducing the pressure, either by throttling the regulating cock; by lowering the discharge pressure from the water supply pressure reducing valve or, by adjusting the pressure at which the by-pass type pressure relief valve comes into operation, according to the water supply arrangement incorporated. Such an adjustment is indicated when the suction created by the injector is such that it becomes impossible to maintain the seal in the tray. The adjustment should be made with the maximum flow of chlorine and when the pressure against which the injector is operating is also at maximum i.e. when the operating conditions are most exacting. The minimum suitable operating pressure is that which will deal with the chlorine without the acid in the lower part of the pressure release being forced into the upper part. When this condition arises, the acid seal is broken and chlorine is allowed to escape via the vent pipe.
- Following the adjustment of operating water supply, temporarily shut off the chlorine and, if necessary, reset the make up water valve until there is again a small surplus passing over the overflow. This volume is not critical from an operating point of view but it is desirable to avoid undue wastage of water.

(b) Shutting down

1. Close the chlorine stop valve (or other cylinder connecting valve when there is no stop valve) and wait until the meter reading returns to zero.
2. Shut off the water supply to the solutionizer by means of the stop valve, and stop the booster pump when one is used for the supply.

   N.B. For a prolonged stoppage close the cylinder valves and then the cylinder connecting valves before closing the stop valve.

6.4.2.4 Vacuum Type Chlorinator

In this type of chlorinator, chlorine is handled below the atmospheric pressure. The vacuum system has several advantages:

- It is the easiest method of dissolving chlorine in water.
- Chlorine is easily handled when in solution.

- This is the most accurate way of metering chlorine gas since a constant density is maintained under vacuum and it is not affected by ambient temperature changes.
- Operation under vacuum is safer than operating under pressure.
- A metering system can be easily designed to stop automatically if the vacuum should fail.

It consists of a gas filter, pressure regulating valve, variable area flowmeter (Rotameter), vacuum regulating valve, pressure vacuum relief valve, drain valve and injector assembly. (Fig 6.6)

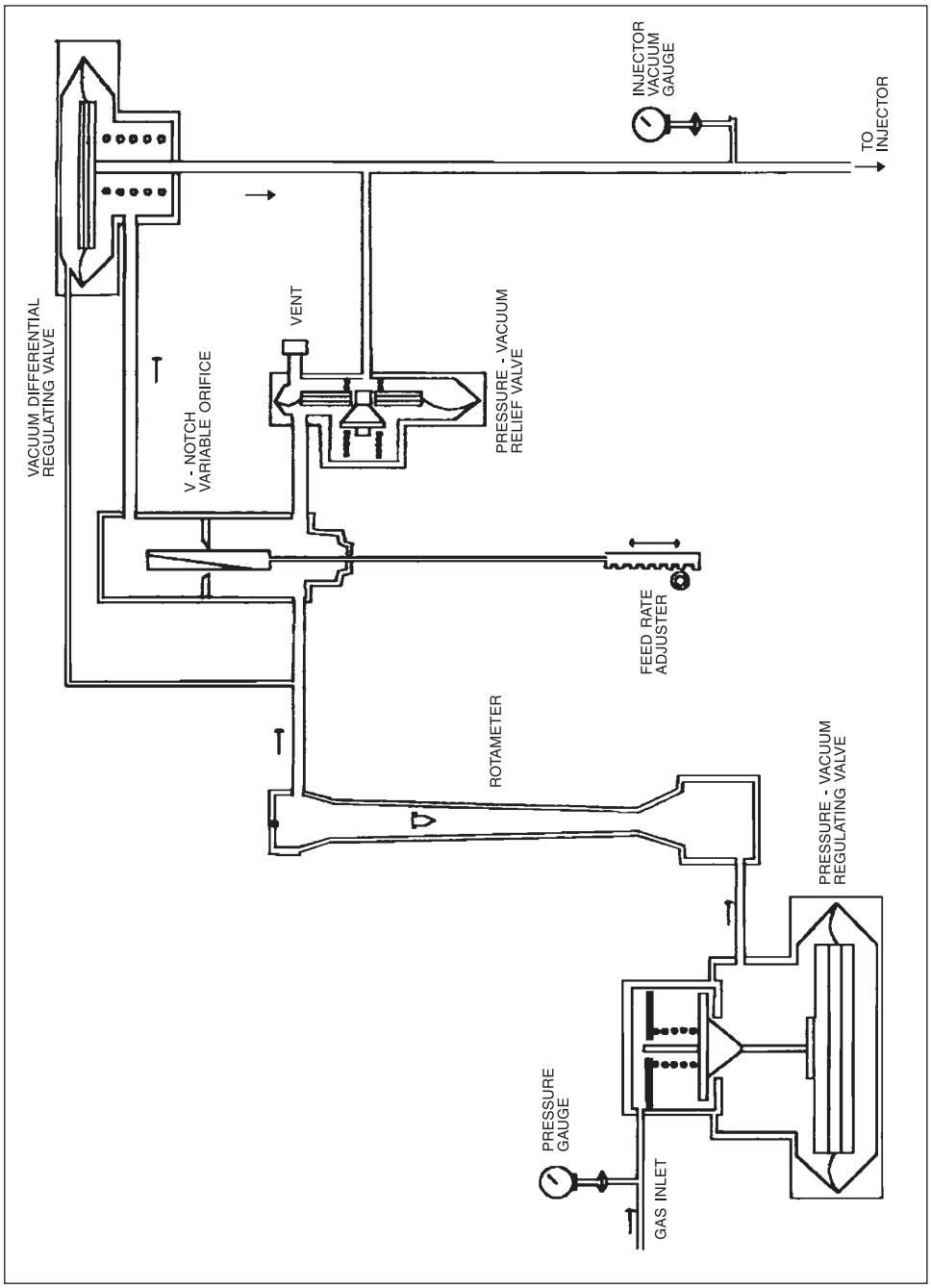


FIG. 6.6 TYPICAL CHLORINATOR

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

6.4.2.5 Start up of Gas Chlorine System

1. First start the booster pumps and make certain that the hydraulic conditions are satisfactory. For that purpose see the delivery water pressure & injector vacuum gauge reading. If the conditions are satisfactory, the vacuum gauge should show reading above 590 mm of Hg. If the chlorinator is not equipped with vacuum gauge, remove the tubing at the injector vacuum inlet and place a hand over the opening. If the injector is performing properly, the suction will be felt instantly on the portion of the hand over the opening. But it is advisable to have a vacuum gauge for proper operation of the plant with safety.
2. Check that all the chlorine valves on the supply line to chlorinators are closed.
3. When the injector system is functioning properly, open the valve of chlorine cylinder partially to allow the gas. Chlorine container should be connected to the system and kept ready before starting the plant.
4. Verify that all of the tubing, manifold and auxiliary valve connections are correct and that all union joints are properly gasketed. Check the leakage with ammonia stick and if there is any leakage, close the cylinder valve immediately and attend to the leaking joint to make it leak proof.
5. Check all the joints between cylinder valve to end.
6. Open the chlorine valve slightly to injector and check all the tubing and components of chlorinators for leakage. Attend if necessary by closing inlet valve. If there is no leak, then the chlorinator is ready for further testing.
7. Open fully the chlorinator gas inlet valve and check the chlorinator for range, automatic control and so on.
8. If at any stage leakage of chlorine is found, close the cylinder valve. Allow the gas in the system to be consumed through injector and then attend for leaking joints.
9. If the leakage is due to missing gaskets etc., close the cylinder valve. Leave the site immediately for safe area. With the help of breathing apparatus carry out the gas evacuation procedure through the chlorinators.
10. After all leaks have been corrected the next step will be to see that the chlorinator will reach its maximum capacity as specified. This is the most important operative criteria of the chlorinator installation.
11. If the chlorinator is not giving specified dose check for injector vacuum and chlorine pressure in the system and attend to the defects. The fault is normally in the hydraulics of the injector system. The next likely place is within chlorinator itself. A malfunction in either place is reflected by a low vacuum reading on the injector vacuum gauge.

    i) The first step in this case is to check the vacuum leak within the chlorinators. If the leak is major, it can be discovered by shutting off the injector water suddenly and using ammonia on all the joints. This sudden removal of vacuum will create

slight pressure and chlorine will be expelled into atmosphere. Very small leak will not show up in this procedure.

ii) Then check for 'O' ring seal in metering tube, vacuum relief valve, for defective spring or seat etc. and attend to it.

12. Vacuum will be affected due to long vacuum line between injector and chlorinator. If this is filled with air, the large amount of air reduces injector vacuum. Moreover if this line is leaking it will also reduce the vacuum.

    Like a long vacuum line, a long chlorine solution line will also affect the injector vacuum. The air in this line, therefore needs to be removed.

13. Defective injector may also affect vacuum.

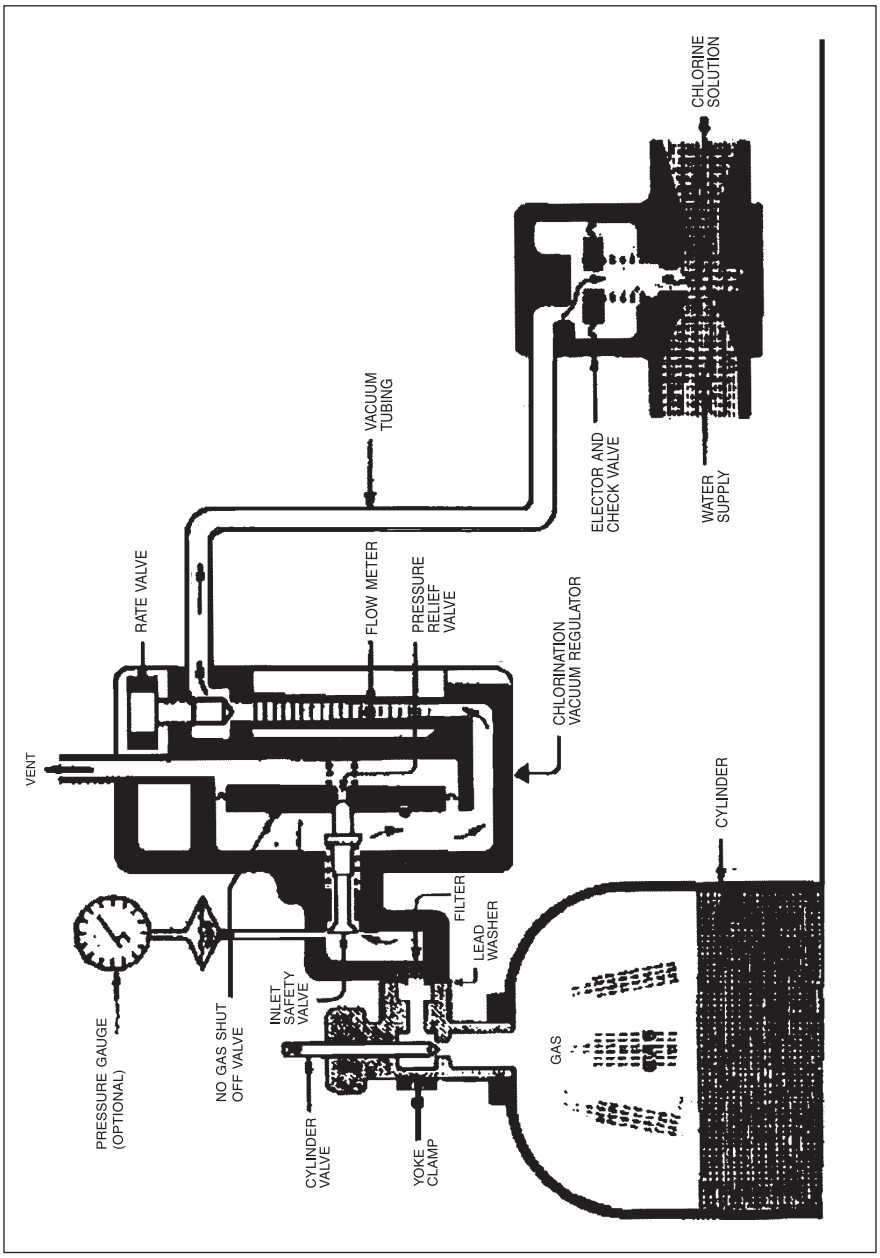


FIG. 6.7: CYLINDER MOUNTED CHLORINATOR

6.4.2.6 Start up of Liquid Chlorine System

If the system is designed for liquid withdrawal, the following procedure should be adopted for starting it up.

The procedure for start up on a liquid system is similar to gas system except for the role of evaporator. The evaporator is an extension of chlorine container system. Whatever happens in the container reflects into the evaporator pressure changes. The danger existing in liquid system is the possibility of trapping liquid chlorine in a pipe line. If this occurs and there is a significant rise in the ambient temperature, the liquid chlorine will expand & rupture the pipe line. For this reason, the liquid line between the evaporator & chlorine supply system should always remain open while the evaporator is operating. From safety point of view, rupture disc system with expansion chamber is provided on this line.

The first step preparatory for starting up a liquid system is to verify that the system is dry, because the moisture after coming in contact with liquid chlorine & metal of container forms ferric chloride which will pass through the chlorine control mechanism with stoppage of chlorine. Whenever this occurs the entire chlorine system must be flushed with water & thoroughly dried. In addition to this, chlorination equipments must be dismantled and cleaned.

When the operator is convinced that the chlorine supply system is clean & dry, the next step is to start up the evaporators. This is done by filling the water bath and adjusting the control devices. When the water bath reaches 65°C temperature, the chlorine pressure reducing valve & shut off valve will open and the system is ready for operation. When water temperature reaches 82°C, start the injector water system and follow the procedure mentioned in gas system.

6.4.2.7 Procedure for stopping the plant

Stopping the chlorination system is also important in order to avoid chlorine leakages as well as for the system safety. The procedure is as follows:

1. Shut off the chlorine supply system.
2. When the chlorine pressure gauge reaches zero remove the cylinder connection & allow the air to evacuate all the residual chlorine gas in the system while the injector is still in operating condition.
3. After the chlorine has been purged to the satisfaction of the operator, the injector system may be shut down.
4. Connect the openings with plastic plugs.
5. For liquid system the chlorine in the evaporator shall be completely consumed.
6. Then close the heater supply to the evaporator.

6.4.2.8 Maintenance of Chlorination Equipment

Chlorine being hazardous chemical, its operating machinery should be maintained properly. In view of this, it is advisable to carry out preventive maintenance of all these equipment keeping in mind the followings for effective maintenance management programme.

(a) 1. Deploy trained personnel

2. Prepare daily schedule i.e.

- Check chlorine leakage by ammonia torch.

- Check exhaust fans working.
- Check rotameter functioning.
- Carry out physical verification of stock and position of tonners.
- Check position of safety equipment.
- Check vacuum of chlorinator.

3. Quantify the work.
4. Use of work permit system. A written work permit system is essentially a document which identifies the plant to be worked on and details precautions to be taken before a work can start. It predetermines the safe procedure and is a clear record of the hazards that have been anticipated defining the appropriate precautions to be taken to avoid them. It is also a statutory requirement.
5. Keep equipment record i.e. history cards.
6. Analyse and plan every job.
7. Forecast yearly & monthly maintenance programme.
8. Prepare check lists for different types of preventive maintenance.
9. Set up a manpower control.
10. Set up a preventive maintenance programme.
11. Use budgetary control – yearly & monthly budget.
12. Provide material control.
13. Always use recommended spares.
14. Plan plant shut downs.
15. Establish major overhaul procedures.
16. Develop standard practices.
17. Improve efficiency of the equipments.
18. Train the supervisors.
19. Train the maintenance staff.
20. Analyse performance and cost.

(b) Since the properties of Chlorine differ in liquid form, gaseous form, and solution form suitable material has to be selected for various components of chlorine equipment. (refer to appendix 6.1 for materials).

(c) Predominantly observed impurities in chlorine are Ferric chloride, Hexachlorethane and Hexachlorbenzene. Normally the chlorine available for disinfection purpose is 99.8% pure (IS 646).

(d) Ferric chloride is formed due to reaction of chlorine with water vapour & metal. This is deposited in the equipment during corrosion from liquid form to gaseous form. While carrying out maintenance of this equipment, warm water is used to clean the equipment. The cleaned equipment is dried thoroughly before putting into the system.

(e) Hexachlorethane & Hexachlorbenzene being volatile impurities, are deposited from the chlorine gas in the equipment wherever pressure changes occur in the system, for example

with pressure reducing valve. These impurities are removed while carrying out maintenance by means of trichloroethane or Isopropyl alcohol, Carbon Tetra Chloride (CTC) should never be used as it is carcinogenic.

(f) Sometimes amongst other impurities, nitrogen trichloride may be present. This impurity is present when the brine solution from which chlorine is manufactured by electrolysis method, contains ammonia or its compound. Because of vapour pressure difference in nitrogen trichloride and chlorine in the evaporator, chlorine is evaporated first leaving more concentration of nitrogen trichloride in evaporator. If under such condition, the evaporator temperature exceeds 94^0C, the evaporator may explode. It is, therefore, always recommended not to exceed evaporator temperature of 90^0C.

(g) Before carrying out any maintenance of the equipment, it should be confirmed that all the chlorine present in equipment is purged out completely. Any chlorine present in the piping will prove hazardous if welding work is carried out on it. Similarly while putting the chlorination system into use all the water vapours should be removed by means of moisture free dry air. The piping carrying chlorine of a length more than 3 mtrs. running from cylinder to the equipment should be provided with a pressure reducing valve just down stream of the cylinder. These two aspects reduce the maintenance problems to a minimum. Whenever cylinders are removed from the system, the disconnected piping should be plugged with Teflon or similar kind of material in order to avoid entry of humid air into it.

TABLE 6.1: SUGGESTED MAINTENANCE OF CHLORINE EQUIPMENT PRESSURE CHLORINATOR – AQUEOUS SOLUTION FEED TYPE

S.No.	Name of item	Period	Action needed
1.	Chlorine leakage	Daily	Inspect & take necessary action
2.	Pebbles in tower	15 days	Clean with water
3.	Calcium chloride	1 month or earlier if shape is changed	Replace
4.	Orifice	1 month	Clean with trichloroethene
5.	Stop valve & regulating valve	3 months	Clean with trichloroethene
6.	Diaphragm	3 months	Clean with trichloroethene
7.	Manometer	3 months	Clean with water
8.	Manometer	3 months	Calibrate
9.	Gasket	3 months	Replace
10.	Sleeves	3 months	Replace
11.	Filter	3 months	Clean or replace
12.	Pressure gauge	3 months	Inspect & calibrate if necessary
13.	Injector	3 months	Clean with water
14.	Tube	6 months	Replace
15.	Nut bolt	12 months	Replace
16.	Sulphuric acid	12 months	Replace
17.	Rubber hose	12 months	Replace

TABLE 6.2: SUGGESTED MAINTENANCE OF CHLORINE EQUIPMENT AND FITTINGS — VACUUM TYPE CHLORINATOR

S.No.	Name of item	Period	Action needed
1.	Chlorine leakage through fittings etc.	Daily	Inspect and take necessary action
2.	Chlorine leak detector & Exhaust fans	Daily	Inspect and take necessary action
3.	Safety equipment & Breathing apparatus	Weekly	Inspect and take necessary action
4.	Chlorine neutralisation system	Weekly	Inspect and take necessary action
5.	Water pump	3 months	Inspect and take necessary action
6.	Chlorine gas filter	6 months	Replace filter element
7.	Sedimentation trap	6 months	clean
8.	Rotameter tube & metering orifice	6 months	clean
9.	Wind cock	6 months	replace
10.	Gas header valve packing	1 year	Replace
11.	Stem & seat of valves	1 year	clean
12.	Injector throat	1 year	clean with mild HCl & then with water
13.	Lifting tackle/crane	1 year	Inspect and take necessary action
14.	Copper tubing between header & cylinder	1 year or screeching sound is heard on bending	Replace
15.	Header system	After every 250 Tons passing of chlorine	Clean with water & dry it
16.	Springs in the valves	2 years	Replace
17.	Pressure gauges & pressure switches	5 years	Replace
18.	Diaphragm in spring loaded valve	5 years	Replace
19.	Joints	Whenever opened	Replace gasket with new one. Wire brush the thread & use teflon tape for lubricant
20.	Evaporator vessel	250 tons of chlorine passage	Clean

TABLE 6.3: COMPARISON OF CHLORINATORS

S.No.	Description	Pressure Type Chlorinator			Vacuum Type Chlorinator	
		Dry feed	Aqueous solution Feed			
			Gravity feed	Injector Solutioniser	With Differential vacuum regulator	Sonic flow type
1.	Rate of feed (max)	230kg/d	230kg/d	230kg/d	4800 kg/d	240 kg/d
2.	Water requirement per Kg of chlorine (min.)	Nil	1500 lit.	Less than 1500 lit. but more than 300 lit.	300 lit.	300 lit.
3.	Accuracy	Low.	Low	Low	High	High
4.	Flow meter	Manometer	Manometer	Manometer	Rotameter	Rotameter
5.	Pressure at point of application	0.7 kg/cm^2 (max)	0.7 kg/cm^2 (max)	More than 0.7 kg/cm^2	More than 0.7 kg/cm^2	More than 0.7 kg/cm^2
6.	Energy requirement	Low	Low	Moderate	Moderate	High
7.	Maintenance	Extensive	Extensive	Extensive	Moderate	Less
8.	Status	Not in production	Not in production	Not in production	In production	In production
9.	Remarks	Not suitable below 10^{0}C water. It is used when quality of water for making solution is not good. It is less safe	Suitable below 10^{0}C provided water for making the solution is beyond 10^{0}C It is used when quality of water for making solution is good. It is less safe	Suitable below 10^{0}C provided water for making the solution is beyond 10^{0}C It is used when quality of water for making solution is good. It is less safe	Suitable below 10^{0}C provided water for making the solution is beyond 10^{0}C It is used when quality of water for making solution is good. It is more safe	Suitable below 10^{0}C provided water for making the solution is beyond 10^0 C. It is used when quality of water for making solution is good. It is more safe

TABLE 6.4: IMPORTANT FACTS ABOUT CHLORINE FROM SAFETY POINT OF VIEW

	Facts	Reasons	Remedy
1.	Chlorine is supplied in liquid form under pressure & it requires heat for converting it into gas.	It occupies less space	Proper ventilation and proper handling.
2.	It is not poisonous but irritant.	It forms corrosive acid with body moisture and hence inhalation can cause respiratory injury ranging from irritation to death depending upon its concentration & duration of inhalation.	Use breathing apparatus.
3.	Dry gas is not corrosive but wet gas is highly corrosive.	It forms acid with water.	Do not use water on leaking container.
4.	It is neither flammable nor explosive but supports combustion of carbon steel at 251^{0}C.	Containers are made up of carbon steel.	Do not carry out welding work on chlorine containers or piping unless purged out.
5.	Gas combines with ammonia & forms white smoke.	White smoke detects chlorine leak.	Use for detecting chlorine leakage through the system.
6.	Liquid chlorine has large coefficient of expansion.	If the container is filled with filling ratio of 1:19, complete container will be occupied by liquid chlorine at 84^{o}C and hydrostatic rupture may take place.	Do not place the container near the fire or source of heat.
7.	Vapour pressure increases with temperature rise.	Container may rupture due to rise in pressure.	Do not place the container near the fire or source of heat.
8.	Gas is 2.5 times heavier than air.	Leaked chlorine settles at the ground level.	Install exhaust fans at ground level & inform the public to take higher level during chlorine leakages.
9.	It is slightly soluble in water but it gets absorbed in caustic soda, soda ash and hydrated lime.	During reaction with caustic soda. Soda ash & hydrated lime heat is evolved.	Use soda ash, caustic soda or hydrated lime for neutralisation of chlorine. Do not use water for neutralisation purpose. Do not push container into solution.
10.	Liquid leaks 15 times more than the gas.	It is because of viscosity difference as well as different laws of gas and liquid.	Turn the leaking container such as to allow leakage in gaseous form.
11.	Chlorine forms hydrate with water at temperature below 9.4^{o}C.	Solid layer is formed.	In the case of liquid leak if chilled water is sprayed on the top a solid layer formation will reduce the rate of evaporation of chlorine.
12.	It is dangerous with ammonia gas, hydrogen, turpentine and hydrocarbon as reactions with these are explosive; powdered metal may cause fire in chlorine.	Fire may start in storage of chlorine.	Avoid storage of these materials in the chlorine storage. Do not lubricate the valves.

6.5 SAFETY ASPECTS OF CHLORINE

6.5.1 GENERAL

Chlorine is potentially dangerous. It is, therefore, important that person engaged in a chlorine plant or in any activity involving handling of chlorine should understand the hazards of chlorine and should know preventive measures needed. These are given below:

6.5.2 CYLINDERS

Cylinders are fabricated as per IS: 7681.

In a vertical position with the valve at the top, chlorine in gaseous form can be drawn from the cylinder. If, however, liquid chlorine is to be drawn, the cylinder can be inverted to bring the valve towards the bottom with the use of an inverting rack which holds the cylinder at 60^0. The withdrawal rates of Cl_2 at 20^0C are 2 kg/hr and 10 kg/hr for gas and liquid chlorine respectively for 100 kg. The withdrawal rate depends upon ambient temperature and it reduces with reduction in temperature. (Fig. 6.8)

SPECIFICATION OF CHLORINE GAS CYLINDER

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

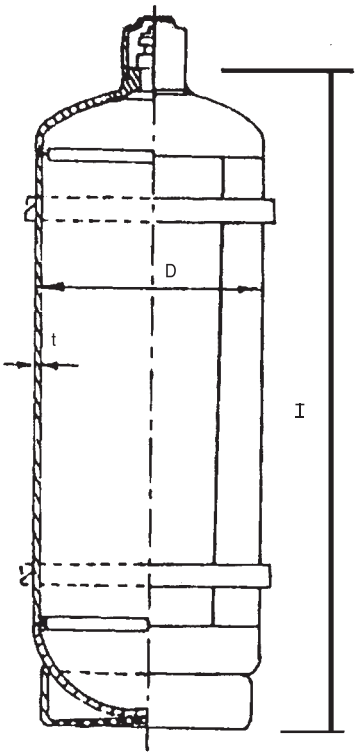


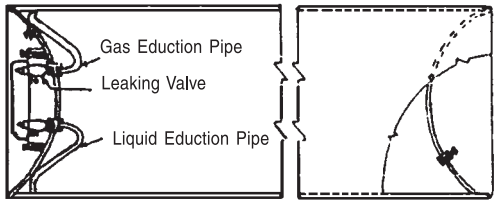
FIG. 6.8: DETAILS OF CHLORINE CYLINDER

6.5.3 TONNERS

Bigger containers are commonly known as 'Tonners" Indian tonners are generally fabricated conforming to the British standards (B.S:1500).

These are kept horizontally so as to bring the two valves in vertical plane. Each has a capacity of approx. 900 kg. It has built-in safety by way of providing concave dished ends.

Both the valves are covered by a protective hood connected to the container by means of lugs. The inside ends of the valves are connected to the eduction pipes. (Fig. 6.9).



GENERAL SPECIFICATION

Water Capacity (approx.) Kg.	-	780
Chlorine Capacity (approx.) Kg.	-	930
Design Pressure, Kg/Cm^2	-	19.9
Inside Diameter (approx.) mm	-	760
Shell Thickness, mm	-	10
Dished Ends Thickness, mm	-	9.6 (Min.)
Overall Length (approx.) mm	-	2085
Tare Weight (approx.) Kg.	-	520

FIG. 6.9: DETAILS OF CHLORINE TONNER

Tonners manufactured in India after 1981 do not have fusible plug as per the Gas Cylinder Rules 1981. However, in imported design where these are provided, they melt between the temperatures of 70°C and 74°C thereby reducing the pressure inside the container in case of fire or high temperature.

The withdrawal rates of Cl_2 at 20°C are 7 kg/hr and 180 kg/hr for gas and liquid respectively. It depends upon ambient temperature.

6.5.4 CONTAINER VALVES

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

6.5.5 STORAGE & HANDLING OF CHLORINE CYLINDERS:

Chlorine is stored in special grade steel containers. As per IS:4379-1967, the colour of Chlorine container should be 'golden yellow'.

(a) Storage Area

1. Obtain storage licence from controller of explosives under Gas Cylinder Rules 1981 if the quantity of Cl_2 containers to be stored is more than 5 Nos.
2. Storage area should be cool, dry, well ventilated, and clean of trash and protected from external heat sources. Please refer to Manual on "Water Supply and Treatment", (1999 Edition), for further details.
3. Ventilation must be sufficient to prevent accumulation of vapour pockets. The exhaust should be located either near the floor or duct be provided extending to the floor. All fan switches should be outside the storage area.
4. Do not store container directly under the sun.

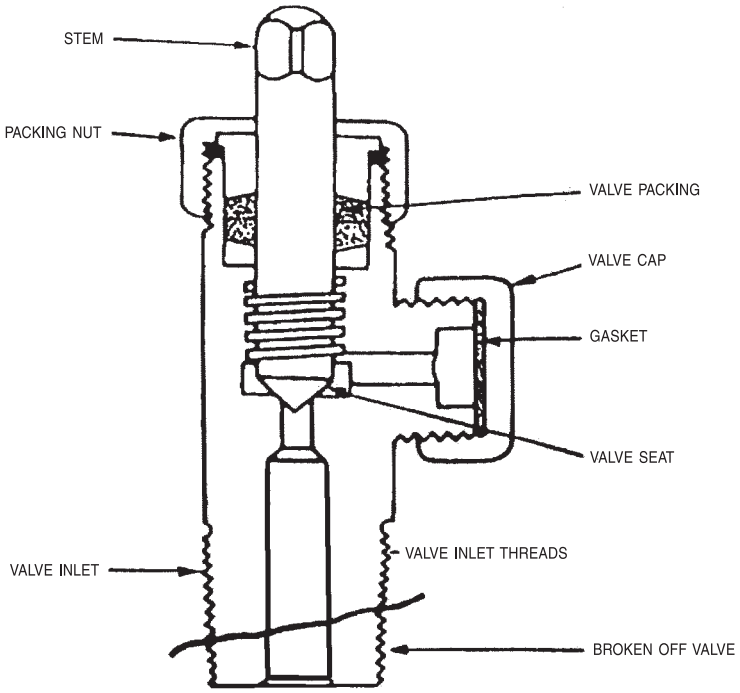


FIG. 6.10: STANDARD CHLORINE CONTAINER VALVE

5. Weather cock should be installed near the storage to determine wind direction.
6. The storage building should be of non-combustible construction with at least two exits opening outside.
7. Neutralization system should be provided.
8. Continuous monitoring of chlorine leak detection equipment with alarm should be installed in the storage area.
9. The area should be free and remote from elevators, gangways or ventilating system to avoid dangerous concentration of Chlorine during leak.
10. Two portable foam type fire extinguishers should be provided in the premises.
11. Corrosive substances shall not be stored nearby which react violently with each other.
12. Unauthorized person should not be allowed to enter into the storage area.
13. The floor level of storage shed should be preferably 30 cms (at least one foot) higher from the ground level to avoid water logging.
14. Ensure that all containers are properly fitted with safety caps or hooks.

(b) Cylinder & Drum Containers

1. Store chlorine cylinders upright and secure them so that they do not fall.
2. Drum containers should be stored on their sides on rails, a few inches above the floor. They should not be stacked one upon the other. They should be stored such that the valves are in vertical plane.

3. Keep enough space between containers so as to have accessibility in case of emergency.
4. Store the containers in a covered shed only. Keep them away from any source of heat as excessive heat may increase the pressure in container which will result into burst.
5. Do not store explosives, acids, turpentine, ether, anhydrous ammonia, finely divided metals or other flammable material in the vicinity of Chlorine.
6. Do not store containers in wet and muddy areas.
7. Store filled and empty containers separately.
8. Protective covers for valves are secured even when the containers are empty, except during use in the system.
9. Never use containers as a roller to move other equipment.
10. Never tamper with fusible plugs of tonners.
11. Check leakages every day by means of ammonia torch. However, it should not be touched to brass components like valves of container for safety.
12. Never carry out any welding work on the chlorine system as combustion of steel takes place at 251^0C in presence of chlorine.
13. The boxes containing emergency kit, safety applications and self contained breathing apparatus should be kept in working order in an easily approachable area.

(c) Use of Cylinders & Drum Containers in Process System

1. Use containers in the order of their receipt, as valve packing can get hardened during prolonged storage and cause gas leaks.
2. Do not use oil or lubricant on any valve of the containers.
3. Badly fitting connections should not be forced and correct tool should always be used for opening and closing valves. They should never be hammered.
4. The area should be well ventilated with frequent air changes.
5. Transport the cylinders to the process area by using crane, hoist or railings etc.
6. The drum containers should be kept in a horizontal position in such a way that the valves are in a vertical plane. The upper valve gives out gas and the lower one gives out liquid chlorine.
7. The cylinder should be kept in upright position in order to release gas from the valve. For liquid chlorine withdrawal, it should be inverted with the help of an inverted rack.
8. Connect the containers to the system by using approved accessories.
9. Use copper flexible tube, with lead washer containing 2 to 4% antimony or bonded asbestos or teflon washer. Use yoke clamp for connecting chlorine container.
10. Never use rubber tubes, PVC tubes etc. for making connections.
11. Use the right spanner for operating the valve. Always keep the spanner on the valve spindle. Never use ill fitting spanner.

12. After making the flexible connection, check for the leakage by means of ammonia torch but it should not come in contact with a valve.
13. Keep minimum distance between the container valve and header valve so that during change-over of the container, minimum amount of gas leaks.
14. The material of construction of the adopter should be same as that of valve outlet threads.
15. The valve should not be used as a regulator for controlling the chlorine. During regulation due to high velocity of Chlorine, the valve gets damaged which in turn can cause difficulty in closing.
16. The tools and other equipment used for operating the container should be clean and free of grease, dust or grit.
17. Wear breathing apparatus while making the change-over of the container from the process header.
18. Do not heat the container to withdraw more gas at faster rate.
19. Use pressure gauge and flow measuring device to control the flow and to know the quantity of gas left in the container.
20. Use an inverted U type barometric leg or vacuum breaking arrangement for connecting the container to the process piping.
21. Withdrawal of the gas should be stopped when the gas pressure inside the container is between 0.1 to 0.5 kg/cm^2 approximately.
22. If withdrawal of the gas from the container connected to the process system has to be suspended for long intervals, it should be disconnected from the system, and the valve cap and hood replaced.
23. Gas containers should be handled by trained persons only.

(d) Disconnecting Containers from Process System

1. Use breathing apparatus before disconnecting the container.
2. First close the container valve fully. After removal of chlorine the process valve should be closed.
3. Remove the flexible connection, plug the flexible connection in order to avoid entry of humid air. Replace the valve cap or hood on the container.
4. Put the tag on the empty container & bring it to storage area marked for empties.
5. Check for the leakage.

(e) Loading and Unloading of Containers

1. The handling of containers should be done under the supervision of trained and competent person.
2. It should be done carefully with a crane, hoist or slanted ramp. Do not use magnet or sharp object for lifting the containers.
3. Small cylinders should not be lifted by means of valve caps as these are not designed to carry the weight.

4. The containers should not be allowed to strike against each other or against any hard object.
5. Vehicles should be braked and isolated against any movement.
6. After loading, the containers should be secured properly with the help of wooden wedges, rope or sling wire so that they do not roll away.
7. The containers should never be dropped directly to the ground or on the tyre from the vehicle.
8. There should be no sharp projection in the vehicle.
9. Containers must have valve caps and plugs fitted properly.
10. Check containers for leakage before loading/unloading.

(f) Transportation of Container

1. The name of the chemical along with diamond pictorial sign denoting the dangerous goods should be marked on the vehicle.
2. The name of the transporter, his address and telephone number should be clearly written on the vehicle.
3. The vehicle should not be used to transport any material other than what is written on it.
4. Only trained drivers and cleaners should transport hazardous chemical
5. The driver should not transport any leaking cylinder.
6. The cylinder should not project outside the vehicle.
7. The transporter must ensure that every vehicle driver must carry "Trem Card" (Transport Emergency Card) and 'Instructions in writing booklet' and follow them.
8. Every driver must carry safety appliances with him, viz; Emergency kit, breathing apparatus etc.
9. The vehicles must be driven carefully, specially in crowded localities and on bumpy roads. Do not apply sudden brakes.
10. Check for the leakage from time to time.
11. In the case of uncontrollable leakage the vehicle should be taken to an open area where there is less population.

(g) Emergency Kit

It consists of various tools and appliances like gaskets, yokes, studs, tie rods hoods, clamps, spanners, mild steel channels, screws, pins, wooden pegs etc. of standard sizes. Separate kits are used for cylinders and tonners. All the gadgets are designed for using in controlling or stopping the leakages from valves, fusible plug and side walls of cylinders and containers used for handling chlorine.

1. Leakage may occur through the valve. There are basically four types of valve leaks.
   i) Valve packing
   ii) Valve seat

iii) Defective inlet thread

iv) Broken valve thread

For controlling the leak please refer Fig. 6.12 & Fig. 6.14 for tonner & cylinder respectively.

2. Leakage may occur through container wall. For controlling such leakages, clamps are used for cylinders and chain and yoke arrangement is used for tonner. Sometimes wooden peg is used by driving into the leaking hole as a temporary arrangement. For controlling leak please refer Fig. 6.12 & Fig. 6.14 for tonner & cylinder respectively.

3. Leakage may occur through fusible plug.

   i) If the leakage is through the threads of fusible plug, yoke, hood and cap nut arrangement is used to control the leak.

   ii) If fusible metal itself in the plug is leaking, yoke and stud arrangement is used to control the leak.

(h) Health Hazards

Wet chlorine being corrosive, it forms corrosive acid with body moisture. Inhalation can cause respiratory injury ranging from irritation to death depending upon its concentration and duration of inhalation.

1. Acute Exposure

The first symptom of exposure to chlorine is irritation to the mucous membranes of eyes, nose and throat. This increases to smarting and burning pain. Irritation spreads to chest. A reflex cough develops which may be intense and often associated with pain behind the breast-bone. The cough may lead to vomiting. Cellular damage may occur with excretion of fluid in the alveoli. This may prove fatal if adequate treatment is not given immediately. Vomit frequently contains blood due to lesions of the mucous membrane caused by the gas. Other common symptoms include headache, retrosternal burning, nausea, painful breathing, sweating, eyes, nose, throat irritation, coughing, vomiting, increase in respiration and pulse rate. Massive inhalation of chlorine produces pulmonary oedema, fall of blood pressure and in a few minutes, cardiac arrest.

2. Chronic Exposures

Persons rapidly lose their ability to detect the odour of chlorine in small concentrations. On account of this, the concentrations beyond threshold limit value may exceed without notice. Prolonged exposure to concentrations of 5 ppm results in disease of bronchitis and predisposition to tuberculosis and concentration of 0.8-1.0 PPM can cause moderate but permanent reduction in pulmonary function. Person exposed for long period of time to low concentrations of chlorine may suffer from acne, tooth enamel damage may also occur.

(i) First Aid - Trained Personnel and Equipment

In the plant trained first aider having the knowledge in the use of aid equipment and rendering artificial respiration should be available. First aid box with necessary contents

should be available. Properly designed showers and eye fountains should be provided in convenient locations and they should be properly maintained. If oxygen is available the same should be administered by authorized person. Such training is imparted by civil defence.

1. General

Remove the affected person immediately to an uncontaminated area. Remove contaminated clothing and wash contaminated parts of the body with soap and plenty of water. Lay down the affected person in cardiac position and keep him warm. Call a physician for medical assistance at the earliest.

Caution: Never attempt to neutralize chlorine with other chemicals.

2. Skin Contact

Remove the contaminated clothes, wash the affected skin with large quantity of water.

Caution: No ointment should be applied unless prescribed by the physician.

3. Eye Contact

If eyes get affected with liquid chlorine or high concentration of chlorine gas, they must be flushed immediately with running water for atleast 15 minutes keeping the eyelids open by hand.

Caution: No ointment should be used unless prescribed by an eye specialist.

4. Inhalation

If the victim is conscious, take him to a quiet place and lay him down on his back, with head and back elevated (cardiac position). Loosen his clothes and keep him warm using blankets. Give him tea, coffee, milk, peppermint etc. for making good effect on breathing system.

If the victim is unconscious, but breathing, lay him down in the position mentioned above and give oxygen at low pressure until the arrival of doctor. If breathing has stopped, quickly stretch him out on the ground or a blanket if available, loosen his collar and belt and start artificial respiration without delay. Neilson arm lift back pressure method is useful. Automatic artificial respiration is preferable if available. Continue the respiration until the arrival of the doctor. Amboo bag can also be used for this purpose.

(j) Fire & Explosion Hazards:

Chlorine may react to cause fires or explosions upon contact with turpentine, ether, ammonia gas, hydrocarbons, hydrogen, powdered metals, sawdust and phosphorus.

Due to fire in the vicinity, the temperature of the containers rises excessively which results in explosion. In order to avoid explosion of the containers, remove all the movable containers from the fire zone immediately by wearing full protective clothing with respiratory protection. In the case of immovable containers, use water for cooling provided there is no leak.

(k) Emergency Measures

In case of leakage or spillage:

1. Take a shallow breath and keep eyes opened to a minimum.
2. Evacuate the area.
3. Investigate the leak with proper gas mask and other appropriate Personal protection.
4. The investigator must be watched by a rescuer to rescue him in emergency.
5. If liquid leak occurs, turn the containers so as to leak only gas.
6. In case of major leakage, all persons including neighbours should be warned.
7. As the escaping gas is carried in the direction of the wind all persons should be moved in a direction opposite to that of the wind. Nose should be covered with wet handkerchief.
8. Under no circumstances should water or other liquid be directed towards leaking containers, because water makes the leak worse due to corrosive effect.
9. The spillage should be controlled for evaporation by spraying chilled water having temperature below 9.4°C. With this water crystalline hydrates are formed which will temporarily avoid evaporation. Then try to neutralize the spillage by caustic soda or soda ash or hydrated lime solution carefully. If fluroprotein foam is available, use for preventing the evaporation of liquid chlorine.
10. Use emergency kit for controlling the leak (Figs. 6.11, 6.12, 6.13 and 6.14).
11. On controlling the leakage, use the container in the system or neutralize the contents in alkali solution such as caustic soda, soda ash or hydrated lime.

    Caution: Keep the supply of caustic soda or soda ash or hydrated lime available. Do not push the leaking container in the alkali tank. Connect the container to the tank by barometric leg.

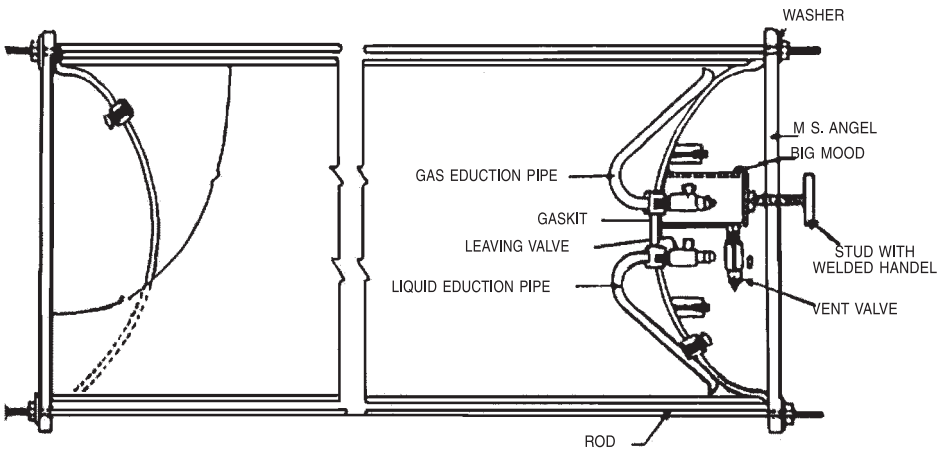


FIG. 6.11: APPLICATION OF EMERGENCY KIT

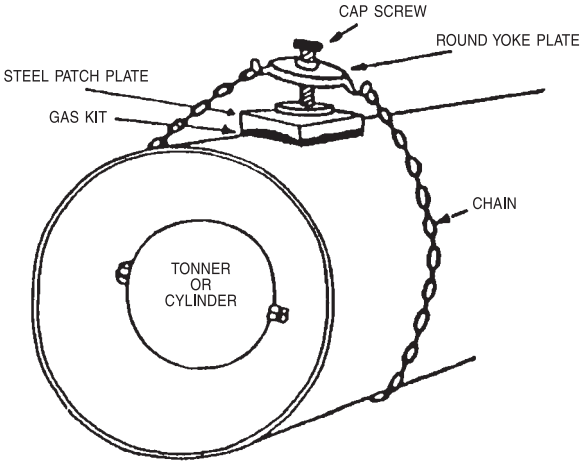


FIG. 6.12: USE OF CHAIN AND ROUND YOKE PLATE FOR TONNER CYLINDER WALL LEAK

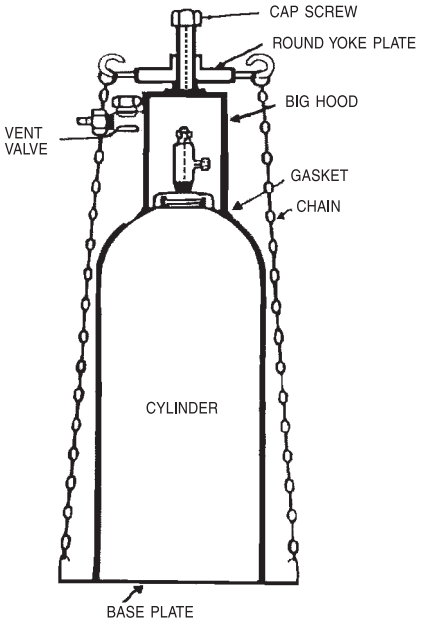


FIG. 6.13: CYLINDER VALVE HOOD ASSEMBLY DEVICE

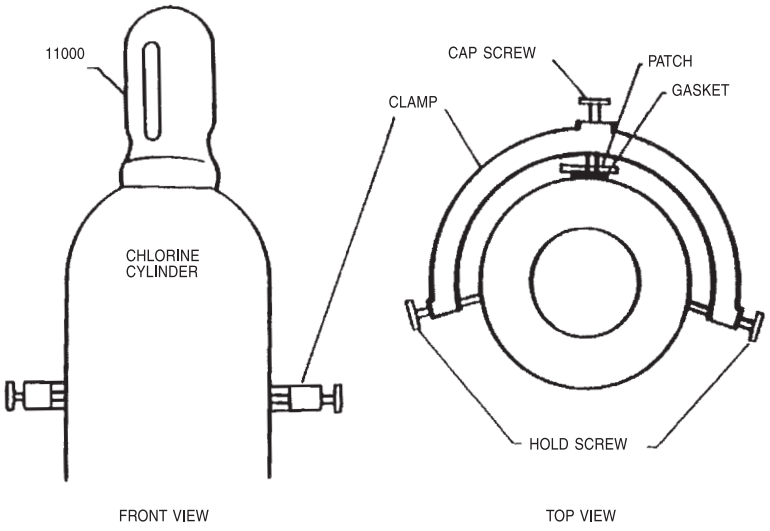


FIG. 6.14: CONTAINER WALL LEAK

12. If container commences leak during transport, it should be carried on to its destination or manufacturer or to remote place where it will be less harmful. Keeping the vehicle moving will prevent accumulation of high concentrations.
13. Only specially trained and equipped workers should deal with emergency arising due to major leakage.
14. If major leak takes place, alert the public nearby by sounding the siren.
15. Any minor leakage must be attended immediately or it will become worse.
16. If the leakage is in the process system, stop the valve on the container at once.

(l) Personal Protective Equipment

1. Breathing Apparatus

Various types of respirators and their suitability are as follows:

i) *Self-contained breathing apparatus*

This apparatus is equipped with a cylinder containing compressed oxygen or air which can be strapped on to the body of the user or with a canister which produces oxygen chemically when the reaction is triggered. This type of equipment is suitable for high concentration of chlorine in an oxygen deficient atmosphere. (Fig. 6.15).

ii) *Air-line respirator:* Air-line length 90 mtrs. (max.)

It is suitable for high concentrations of chlorine provided conditions permit safe escape if air supply fails,. This device is suitable in any atmosphere, regardless of the degree of contamination or oxygen deficiency, provided that clean, breathable air can be reached. (Fig. 6.16).

FIG. 6.15 SELF-CONTAINED BREATHING APPARATUS

FIG. 6.16 AIR LINE RESPIRATOR

iii) *Industrial Canister Type Mask :* Duration: 30 min. for 1% Cl_2

It is suitable for moderate concentration of chlorine provided sufficient oxygen is present. The mask should be used for a relatively short exposure period only. If the actual chlorine concentration exceeds 1% by volume or oxygen is less than 16% by volume, it is not useful. The wearer in such cases must leave the place on detection of chlorine or experiencing dizziness or breathing difficulty. (Fig. 6.17)

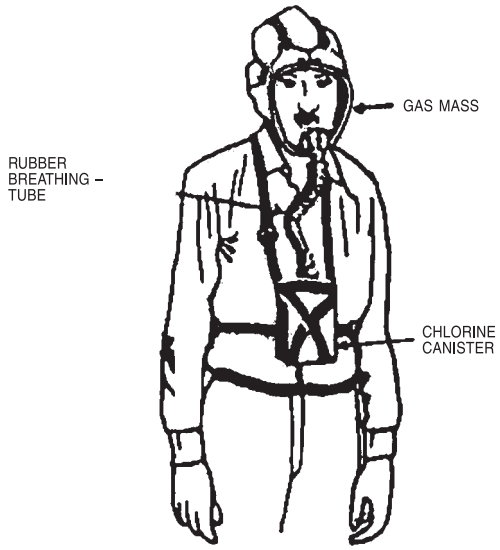


FIG. 6.17 USE OF CHLORINE CANISTER GAS MASK

2. Protective Clothing

Rubber, or PVC clothing is useful in massive exposure which otherwise creates mild skin burns due to formation of acid on the body.

3. Maintenance of Protective Equipment

1. Clean with alkali after every use.
2. Keep in polythene bag at easily accessible place.
3. Check them periodically about their suitability. Many times the seal ring of face mask gets hardened.

(m) Employees Selection

Preplacement medical examination should be carried out of the persons to confirm that they are free from Asthma, Bronchitis and other chronic lung conditions.

Follow up medical examination should be carried out once in a year.

(n) Employees Training

It is essential to impart training to the employees who have to face emergency.

This training should include following:

i) Instructions in the action to be taken in an emergency.
ii) Use of emergency kit.
iii) Handling of containers.
iv) First aid.
v) Use of protective equipment.
vi) Knowledge of Chlorine hazards.
vii) Fire fighting.

viii) Use of safety showers and eye fountains. (Fig. 6.18).

ix) Crash shut down procedure for valves and switches.

x) Communication system.

xi) Study of plant layout with diagram.

xii) Mock drills.

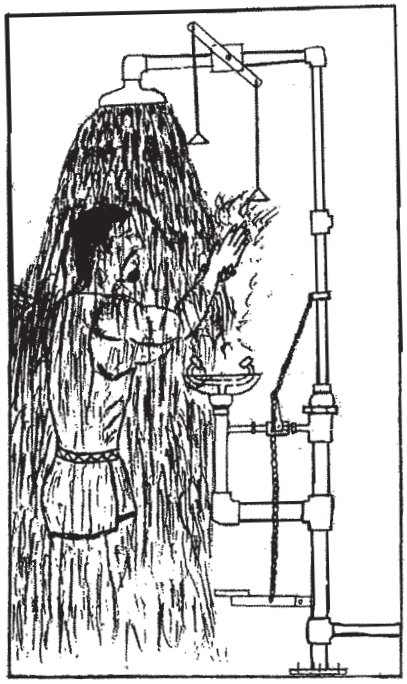


FIG. 6.18: EMERGENCY SHOWER AND EYE WASH FOUNTAIN

(o) Neutralisation of Chlorine

A suitable provision should be available for emergency disposal of chlorine from the leaking container. Chlorine may be absorbed in solution of caustic soda, soda ash and hydrated lime. Caustic soda is recommended as it absorbs chlorine more readily. If hydrated lime is used, the slurry must be continuously agitated and recirculated for chlorine absorption. The neutralization can be carried out by:

- Neutralisation tank holding caustic soda or hydrated lime or sodium carbonate in solution form.
- Scrubber.

i) Neutralisation tank

For the neutralization tank, following proportion of alkali and water is recommended in order to neutralize 900 kg. of Cl_2.

Chlorine	**Caustic soda & water**		**Soda ash & water**		**Hydrated lime & water**	
kg.	Weight (kg.)	Volume (lit.)	Weight (kg.)	Volume (lit.)	Weight (kg.)	Volume (lit.)
900	1160	3680	2720	9050	1160	11350

This system can be used only after controlling the leaking container by emergency kit and connecting it to the tank by inverted U tube of 11 m height.

It is desirable to provide excess quantity of alkali solution over indicated quantities in the table in order to facilitate ready absorption. A suitable tank to hold the solution should be provided in a convenient location.

ii) Scrubber

This system consists of a blower, an alkali (NaOH) tank, an absorption tower packed with rasching rings, alkali circulation pump, piping valves, light weight FRP and PVC duct. In the event of leak which is uncontrollable with emergency kit this system would allow the person to breath easily rather than panic. In this system, the leak is confined by a hood covering the leaking container, sucking the Chlorine by blower and delivering it to absorption tower (Fig.6.19). Chlorine leak absorption capacity of the system is kept 100 kg/h & 200 kg./h for 100 kg. cylinder and 900 kg. tonner respectively.

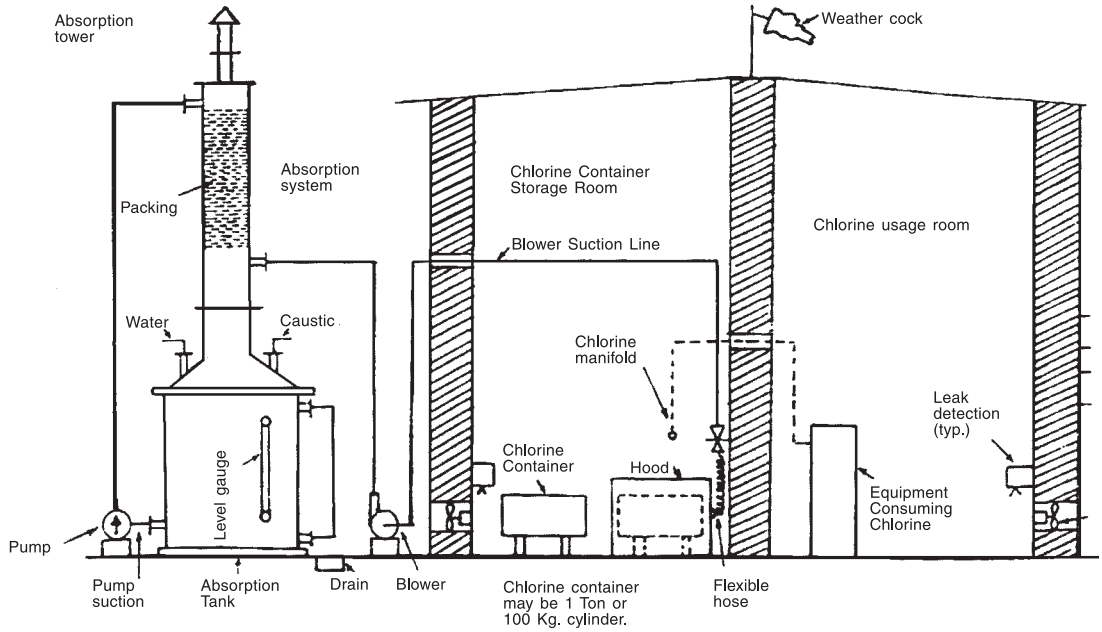


FIG. 6.19 TYPICAL CHLORINE LEAK ABSORPTION SYSTEM

(p) Emergency Response Planning

When a large quantity of chlorine or similar toxic or flammable gases are stored it is essential to have an emergency response planning as leakage of such gases may lead to a major accident such as emission, fire or explosion resulting from uncontrolled developments in the course of an industrial activity, leading to serious danger to man, immediate or delayed, inside or outside the establishment and/or to the environment, and involving one or more dangerous substances. It has, therefore, become obligatory on the part of occupier to take all measures necessary to prevent accidents and to limit their consequences for man and the environment. The hazard control can be achieved by drawing an effective 'onsite emergency plan' for individual organization and if necessary 'offsite emergency plan' by the local authority for that area.

Onsite Emergency Plan

As chlorine is a hazardous chemical, handling and storage of it demand adequate precautions to avoid possible hazards. Leakage of chlorine may develop into a major emergency. Therefore the emergency procedure to cover this eventuality is essential. It is drawn in the form of on-site emergency plan.

The elements of onsite emergency plan are as follows:

1. *Identification of hazard chart*

   In this case the site risk is evaluated by the expert and the extent of the probable damage is calculated on the basis of stored chlorine quantity, nearby population, wind direction, type of equipment failure etc. For this purpose hazard analysis is conducted in which case all the hazardous properties of chlorine are considered. If evacuation is required, the range of it is calculated.

2. *Appointing key persons*

   In order to control the incident like chlorine leakage, it is essential to appoint various persons with their well defined responsibilities. Taking into account the various activities likely to be involved, the following key persons are appointed (i) Site Controller, (ii) Incident controller, (iii) Shift Executive Incharge, (iv) Communication Officer, (v) Safety Officer, (vi) Fire and Security Officer, (vii) Utilities and Services Incharge, (viii) Traffic Controller, (ix) First Aider

3 *Assembly Points*

   These points are set up where persons from the plant would assemble in case of chlorine leakage. At these points the in-charge for counting the heads will be available.

4 *Emergency Control Center*

   The control centre is the focal point in case of an emergency from where the operations to handle the emergency from are directed and coordinated. It contains site plan, telephone lines, public address system, safety equipment, first aid boxes, loud speaker, torches, list of essential telephone numbers, viz. fire brigade, police, hospital, civil defence, collector, factory inspector, organizational authorities, chlorine suppliers, mutual aid group, social workers, list of key persons and their addresses, copy of chemical fact sheet, location plan of fire hydrant, details of dispersion model of chlorine gas, population distribution pattern, location of alarm system.

5. *Procedure to meet Emergency*

   The actions to be taken by the staff and authority are given below;

   Emergency Alarm: An audible emergency alarm system is installed through out the plant. On hearing the alarm the incident controller will activate the public address system to communicate with the staff about the emergency and give specific instructions for evacuations etc. Any one can report the occurrence of chlorine leakage to section in-charge or incident controller through telephone or intercom or in person.

6. *Communication*

   Communication officer shall establish the communication suitable to that incident.

7. *Services*

   For quickness and efficient operation of emergency plan the plant is divided into convenient number of zones and clearly marked on the plan. These are emergency services viz. fire fighting, first aid, rescue, alternative source of power supply, communication with local bodies etc. The incident controller will hand over the charge to the site controller of all these coordinating activities, when the site controller appears on the site. The site controller will coordinate all the activities of the key persons. On hearing the emergency alarm system all the key persons will take their charge. Incase of their absence other alternatives are nominated.

   The person nominated for personnel and administration purposes will be responsible for informing all statutory authorities, keeping account of all persons in the plant including contract labour, casual workers and visitors. He will be responsible for giving information to press or any outside agencies. He is also responsible for organizing canteen facilities and keeping informed the families of affected persons.

   The person nominated as security officer should guide police, fire fighting and control the vehicle entries.

   The site controller or any other nominated person will announce resumption of normalcy after everything is brought under control.

   The on site emergency plan needs to be evaluated by mock drill. Any weaknesses noticed during such drills should be noted and the plan is modified to eliminate the weaknesses.

6.6 STATUTORY REGULATIONS

Applicable Acts and Rules are:

1. The Gas Cylinder Rules 1981.
2. The Factories Act 1948.
3. The Manufacture, Storage and Import of Hazardous – Chemicals Rules, 1989.
4. Public Liability Insurance Act & Rules, 1991.
5. The National Environment Tribunal Act 1995.
6. Chemical Accident Rules 1996.
7. National Environment Appellate Authority Act & Rules 1997.

APPENDIX: 6.1

MATERIALS OF CHLORINE EQUIPMENT & ANCILLARIES

S. No.	Equipment	Material
1.	Piping Rigid	Seamless carbon steel ASTM A 106 grade 'B' schedule 80 or equivalent BIS- 1030-1974
	For gas below atmospheric pressure	Rigid uPVC (for under shed), polyethylene tube, HDPE (outside shed).
2.	Piping (Flexible)	Annealed copper with cadmium plating.
3.	Globe valves	Body : Forged carbon steel Trim : monel or hastelloy 'C' Stuffing box : PTFE or graphite packing.
4.	Ball valves	Body & end piece: Forged carbon steel, ASTM A 105 or equivalent IS Seat : PTFE Ball : Monel
5.	Springs	Tantalum alloy, hastelloy
6.	Gasket	Lead containing 2 to 4% antimony or bonded asbestos.
7.	Chlorinator	Vacuum Regulator body : Carbon Steel Regulator diaphragm : FLUON, FEP, Cabinet: FRP 'O' ring & gaskets : Fluorocarbon lead oxide (litharge cured) viton
8.	Pressure gauge	Diaphragm: silver, tantalum, hastelloy, monel alloy Liquid: fluorocarbon, (silicon oil) fluorolube 'MO'10
9.	Differential Regulator	Body: u PVC, ABS, ebonite, PVDF
10.	Pressure relief valve	Body: uPVC, ABS, ebonite, PVDF Stem: Ag, hastelloy, monel
11.	Injector	Block: ebonite or PVC, ABS
12.	Evaporator	Vessel: boiler quality steel
13.	Rupture disc	Silver: monel, tantalum, hastelloy 'C'
14.	Rotameter	Glass: borosilicate Float: PTFE, tantalum, hastelloy, glass
15.	Filter media	Glass wool
16.	Diffuser & solution line	Rigid uPVC, saran or rubber lined steel, HDPE, natural rubber hose.
17.	Pressure reducing Valve	Body: Ductile cast iron Diaphragm: FPM (Viton), ECTFE/FEP Plugs: silver or tantalum, hastelloy Seats: PTFE
18.	Check valve springs	Tantalloy/hastelloy
19.	Non permanent joints	Mixture of linseed oil and white lead or mixture of linseed oil and graphite or teflon tape
20.	Permanent joints	Glycerine & litharge
21.	Screws	Monel & stainless steel

APPENDIX: 6.2

LIST OF SAFETY SYSTEMS AT CHLORINATION PLANT

1. Breathing apparatus.
2. Emergency kit.
3. Leak detectors.
4. Neutralisation tank.
5. Scrubber system.
6. Siren system.
7. Display of boards in local language for public cautioning, first aid and list of different authorities with phone numbers.
8. Communication system.
9. Tagging system for equipments.
10. First aid including tablets and cough mixtures.
11. Exhaust fans.
12. Testing of pressure vessels, chlorine lines etc. every year as per factory act.
13. Training & mock drill.
14. Safety showers.
15. Eye fountain.
16. Personal protective equipments.
17. Protecting hoods for ton-containers.
18. Fire extinguishers.
19. Wind cock.

APPENDIX: 6.3

TROUBLE SHOOTING CHART FOR VACUUM TYPE CHLORINATOR

Trouble	Cause	Remedy
1. Required gas flow not achieved at start-up.	a. Insufficient ejector vacuum caused by insufficient water supply by pressure or excessive back pressure. b. Leakage at vacuum line connection at outlet from flowmeter, rate control valve, differential from flowmeter, differential pressure regulator, and/or inlet to ejector. c. Vacuum line(s) if flexible, crimped.	a. Refer to Trouble at S.no.6. b. Inspect each connection and remake if necessary. c. Replace vacuum tubing and arrange line(s) to eliminate crimping.
2. Required gas flow rate is not achieved on start-up following an extended period of shutdown.	a. Insufficient ejector vacuum. b. Leakage at vacuum line connection at outlet of flowmeter, rate control valve, differential pressure regulator, or inlet to ejector. c. Vacuum line(s), if flexible, crimped. d. Leakage around flowmeter gaskets.	a. Refer to Trouble at S.no.6. b. Inspect each connection and remake if necessary. c. Replace vacuum tubing and arrange line(s) to eliminate crimping. d. Inspect and align flowmeter or replace gaskets.
3. Flowmeter float observed bouncing and/or maximum gas flow cannot be achieved during normal operation.	a. Gas inlet filter of vacuum regulator dirty. b. Rate valve dirty. c. Flowmeter dirty. d. Ejector water supply pressure fluctuating too wide (float bounce) or insufficient ejector vacuum.	a. Replace gas inlet filter assembly. b. Clean rate valve. c. Clean flowmeter. d. Correct water supply pressure as necessary.
4. Flowmeter fails to indicate gas flow during normal operation but there is no out-of-gas indication.	a. Rate valve plugged. b. Gas flowmeter plugged. c. Vacuum lines, if flexible, crimped.	a. Clean rate valve. b. Clean gas flowmeter. c. Replace vacuum tubing and re-arrange lines to eliminate crimping.
5. No gas indication during normal operation.	a. Gas supply valve(s) closed. b. Gas supply exhausted. c. Clogging of filter in vacuum regulator.	a. Open gas supply valves. b. Replenish gas supply. c. Replace filter.

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

APPENDIX: 6.4

STANDARDS RELATED TO CHLORINATORS

1.	BS: 1500	-	For tonners.
2.	IS: 7681	-	Specification for welded low carbon steel gas cylinders for chlorine gas.
3.	IS: 3224	-	Specification for valve fittings for compressed gas cylinders.
4.	IS: 4263	-	Code of practice for chlorine.
5.	IS: 10553	-	Parts I & II: Requirements for chlorination equipment.
6.	IS: 5844	-	Recommendations for hydrostatic stretch testing of compressed gas cylinders.
7.	IS: 4379	-	Identification of contents of industrial gas cylinders.
8.	IS: 646	-	Specification for liquid chlorine.
9.	IS: 8198 Part 6	-	Code of practice for steel cylinders for liquified chlorine gas.
10.	IS: 5845	-	Code of practice for visual inspection of low pressure welded steel gas cylinders in use.
11.	IS: 8868	-	Periodical inspection interval of gas cylinders in use.
12.	IS: 9200	-	Methods of disposal of unserviceable compressed gas cylinders.
13.	IS: 5903	-	Recommendation for safety devices for gas cylinders.
14.	IS: 3710	-	Filling ratios for low pressure liquifiable gases contained in cylinders.

CHAPTER 7

RESERVOIRS INCLUDING SERVICE RESERVOIRS

7.1 OPERATION OF RESERVOIRS

The main function of Reservoirs and Service Reservoir (SR) is to cater for daily demands and especially peak demands of water. Operators/managers must be concerned with the amount of water in the storage reservoir and the corresponding water levels at particular times of the day. Procedures for operating the Service Reservoir will depend upon the design of its storage capacity and on the water demand.

7.1.1 NORMAL PROCEDURES FOR OPERATION OF SERVICE RESERVOIR (S.R.)

Service Reservoirs have to be operated as per the design requirements. Normally the service reservoirs are constructed to supply water during periods of high water demand and hence the SRs are filled in low water demand period. At times pumps may be used only for filling the SR before the next supply timing or can be used also during supply hours to maintain the levels in the SR.

In some systems reservoirs are allowed to float at the end of distribution system when pumps are used to pump directly into the distribution system and excess water flows into the SR. In such systems multiple pumps are used to cater to varying demand and pressures in the system.

Small changes in the distribution system such as pipeline extensions or the addition of few more connections will not require additional storage requirement. Major system changes such as addition of larger size of main pipelines and increase in large number of connections may require additional storage.

7.1.2 OPERATION OF SRS DURING ABNORMAL CONDITIONS

Abnormal operating conditions arise:

- Whenever demand for water goes up suddenly due to fire demand, or due to excessive demand on one command area/zone of a system.
- Due to failure or breakdown of water supply of another zone of the distribution system.
- Breakdown or out of service pumps or pipelines or power breakdowns or out of service SRs.

The operator/manager must have a thorough knowledge of the distribution system emanating from the SRs. Closure or adjustment of valves at strategic points in the distribution system can focus or divert the flow of water towards the affected areas. Emergency plans must be developed in advance to cope with such situations. Further details for emergency planning may be seen in Chapter 14 – System Management.

7.1.3 STORAGE LEVELS

Most of the distribution systems establish a pattern of levels for assuring the required supplies at the required pressures. A water usage curve over a 24 hour period should be prepared for each SR. It can be seen from the usage curve that the pattern varies not only during the different times of the day but also during different days of the week especially on week-ends, holidays and festivals. Demand pattern also changes during different times of the year depending on the weather conditions such as summer, winter etc. From the usage curve the operator can better anticipate and be ready for the expected high consumption periods. The maximum water levels to be maintained in the SR at each morning should be known to ensure that the system demands are met for the day.

In case of intermittent supply, timings for supply of water in the areas are fixed in advance. In large command areas, the water can be supplied to sub-zones during particular fixed hours by operation of the necessary valves. The operator should work out a programme for compliance.

7.1.4 STORAGE CAPACITY

Capacity of storage reservoir at different levels can be calculated and charts or tables can be prepared and kept at the SR site. Proper functioning of water level indicators is required to read the water level in the SR and assess its capacity. Usually water levels are read at the same time each day and the readings recorded. Checks of water levels at other times of the day will enable to determine if any unusual consumption conditions have occurred. If any significant increase in consumption is anticipated the operations should ensure a corresponding increase in supply into the SR. Automatic valves are used to prevent overflows from SR and maintain a constant level in the SR as long as the pressure in the distribution system is adequate. Often the pumps feeding into a SR are switched off or switched on as per the water levels in the SR. In some SRs advance warning alarms are provided to signal when water levels in SR are either too low or too high. The operator shall ensure that the automatic operations work as and when needed. Some times time clocks are often used to control the water coming into the reservoir. At some places the overflow is connected to the distribution system; in such cases some mechanism must be in place to indicate that the reservoir has started overflowing.

Routine valve operations are normally done at the SRs. Problems in operation of valves in SRs can also be caused by valve seat getting jammed, and hence cannot be opened, or non seating of valves, and hence cannot be closed properly. Sometimes two valves are fixed in series on the outlet and the downstream valve only is usually operated. Whenever the valve under operation is jammed the upstream valve is closed and the jammed valve is repaired. Such an arrangement enables repair of valves without emptying the SR. In some SRs a by pass line is provided direct from the inlet line to the outlet line for drawing water without feeding the SR. Identification of the valves as to their intended purpose such as inlet, outlet, scour, bye-pass etc. and their direction of opening are to be prominently marked. The operator/manager shall ensure that all valves in a SR are in good working condition and are operated as per the schedule for such operations.

7.1.5 STORAGE LEVEL CONTROL

A simple system used to read and control the levels in SRs is a gauge/water level indicator. Whenever the SR reaches the maximum water level, the operator informs the pump house

to stop pumping. In place of the traditional telephones, mobile phones or dedicated wireless units can also be used. Electrodes, ultrasonic signals or solid state electronic sensors are also used to sense the rise and fall in water levels and send signals to the pumps to be stopped or started through cables or wireless or radio frequencies.

It is also desirable to have an indication of levels of SR in the pump house. Automation of level controls at SR s is to be attempted with caution since most of the authorities require only a small amount of instrumentation and control. It is desirable that only simple level control instruments are chosen keeping in view availability of skilled personnel. However, it is desirable that trained and qualified operators only are permitted to repair the instruments.

7.1.6 SAMPLING FOR WATER QUALITY

Water from all SRs should be regularly sampled especially once, before and after monsoon to determine the quality of water that enters and leaves the SR. Sampling data can help in setting up periodic cleaning of SR. Indicators that help to decide when the tank is due for cleaning is turbidity, excessive colour, taste and odour.

Water quality problems may be of microbiological type which could be caused by loss of residual chlorine due to bacterial contamination. Chemical water quality problems may also occur due to leaching from reservoir lining and coating for RCC and masonry tanks and due to corrosion of steel tanks. Common cause of physical water quality problems includes collection of sediment, rust and chemical precipitates. Water quality in a SR may also deteriorate due to excessively long periods of stagnant conditions. Some times poor design, and improperly applied/and or cured coatings and linings may also cause water quality degradation. Proper investigation is required to find the reasons for water quality degradation, determine the source of the problem and address the same. Wherever seasonal demands fall and the residual chlorine levels get depleted, it may be necessary to add additional chlorination facilities.

7.2 PLAN FOR O&M OF SERVICE RESERVOIRS

The plan for O&M of the service reservoirs shall contain operational procedures, maintenance procedures and the manufacturer's information in respect of the instruments/gauges.

7.2.1 PROCEDURES FOR OPERATIONS

The operational procedures inter-alia will contain:

- Design criteria for the reservoir such as: capacity in liters, size and depth of storage; size of piping of inlet, outlet, scour and overflow; sizes and locations of control valves of inlet, outlet and scour; source of feeding the reservoir; hours of pumping or gravity feeding into the reservoir; rate of flow into the reservoir; hours of supply from the reservoir and quantity to be supplied from the reservoir; areas to be served/ supplied; highest and lowest elevations to be commanded from the SR and the water levels to be maintained in the SR for command of the entire area.
- Structural drawing of the SR and the layout drawing showing the alignment of pipe connections, by pass lines, interconnections and location of valves, flow meters, pressure gauges and alignment of out-fall drain to lead off the scour and overflow water from the reservoir.

- Schedule of suppliers' names, addresses and telephone numbers of the equipment installed in the SR such as valves, flow meters, level indicators etc.
- A spot map showing the location of the piping and valves. The map shall also indicate open or closed positions of valves to be operated. This map shall be preserved by a glass cover or laminated to prevent unauthorised meddling.
- Step by step operating instructions indicating how to operate and control various valves located on the inlets and outlets, so as to ensure the required quantity of water is supplied to the command areas at the desired pressures during the period required to be supplied.
- A record sheet for each valve showing direction for turning, number of turns, inspections, repairs and whether open or closed. The direction of operation of valves shall be clearly marked as "open" or "close".
- The name of the valve and piping such as washout, inlet, outlet, by pass, overflow etc shall be painted clearly and repainted regularly.
- In the case of mechanised operation of valves, the steps to include starting, running and stopping the operations.
- Instruction for situations when valves cannot be operated due to some problems regarding authority to be informed and receive further instructions.

7.2.2 MAINTENANCE PROCEDURES

The maintenance procedures shall contain step by step procedure to cover every piece of equipment used in SRs such as valves and flow meters preferably following the procedures indicated in the manufacturers' catalogues.

(a) Valves

- All valves should be inspected and operated regularly.
- The manager shall specify frequency of inspection.
- A small amount of penetrating oil is poured down the spindle to lubricate packing gland and soften the packing.
- Valve spindles that develop leaks on turning should be repacked.
- Rust and sediment in the valve is removed by shutting the disc hard in the seat, then opening about a quarter way and closing tightly several times; the increased velocity usually flushes the obstructions away.
- Valve chambers of the SR also require maintenance to ensure that the interiors of chambers are not silted up and also ensure that the covers are in good condition and are in position.

(b) Service Reservoirs

SRs have to be inspected regularly and the manager can prescribe frequency of inspections. Leakage from structure of SR and through the pipes and valves has to be attended to on priority. It is advisable to resort to pressure grouting to arrest leaks from structures and sometimes an additional coating of cement mortar plastering is also done using water proof compound to arrest leaks from the structure.

Maintenance is concerned with mainly protection against corrosion both externally and internally. Corrosion of roof slab of RCC reservoirs due to the effect of chlorine is also quite common. Internal corrosion is prevented by cleaning and painting at regular intervals. Toxic paints should not be used for painting interior surface of SRs. Anticorrosive painting (epoxy) is also done to the interiors when corrosion due to chlorine is expected.

Painting of steel tanks once in a year and external painting with waterproof cement paint for exteriors of RCC Tanks once in 5 years is usually done. The inside of painted SR shall be disinfected before putting into use for a period sufficient to give chlorine residuals of at least 0.2 mg/l.

7.3 CLEANING OF SERVICE RESERVOIRS

Routine inspection is the best way to determine when a tank requires maintenance and cleaning. A visual inspection can be made from the roof manhole with water level lowered to about half full or less. Alternatively a detailed inspection can be made after draining the tank and then cleaning or washing. Best time of the year to take up cleaning of SRs is during the period of lowest water consumption.

The following activities are normally involved in cleaning of a tank/SR:

- Make alternate arrangement for water supply to consumers served by the SR.
- Close the inlet line before commencing cleaning of SR.
- Draw the water from the SR till 200-300 mm water is left in the SR.
- Close the outlet valve so that no water will be used while the tank is being cleaned.
- Collect sample of water and silt/mud accumulated in the Tank and get the biological analysis and for presence of snails and worms. If snails and worms are found find the source and eliminate it.
- Drain and dispose off the remaining water and silt.
- Wash the interior of tank walls and floor with water hose and brushes.
- Inspect the interior of walls and ceiling of tank for signs of peeling off or deterioration.
- Apply disinfectant (Supernatant of Bleaching powder) to the walls and floor before start of filling the tank/SR.
- Frequency of cleaning of SR depends on the extent of silting, development of bio films and results from water quality monitoring.

7.4 PERSONNEL

Recommended minimum O&M staff for SR s is contained in the Manual on Water Supply and Treatment. The required personnel have to be trained in the maintenance of the valves, flow meters, water level indicators etc; training to include fault location, dismantling and assembling after repairs and replacement of the parts of the valves, flow meters and water level indicators.

The supervisory personnel (managerial staff) have also to be trained in supervision of the maintenance.

7.5 SPARES AND TOOLS

7.5.1 SPARES

The maintenance procedures shall contain a list of spares which are likely to be damaged due to wear and tear and have to be replaced in a SR. This list will also indicate the minimum quantity at which replenishment should be made. The list of probable spares to be kept in stock may include the following:

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

7.5.2 TOOLS

The necessary tools to repair and correct the routine problems and for facilitating repairs and replacements in a SR have to be identified and provided to the maintenance staff.

Some of the tools for the maintenance work in a SR are:

- Key rods for operation of all sluice valves.
- Hooks for lifting manhole covers.
- Pipe wrench of appropriate sizes (200, 300 or 450 mm).
- DE spanner set, Ring spanner set.
- Screw Drivers, Pliers.
- Hammers, Chisels.
- Excavation tools such as crow bars, spades, iron baskets and
- House keeping accessories such as long brooms and coir brushes.

7.5.3 LIST OF AVAILABLE SPARES AND TOOLS

A list consumables such as gland rope and list of spares such as spindle rods or stems, check nuts or wedge nuts and a list of suggested Tools available at each SR site shall be prepared and shown in the premises of each SR.

7.6 MANUFACTURER'S INFORMATION

For each SR compilation shall be made which contains the information about the equipment used in the SR such as sluice valves, Butterfly (BF) valves, air valves, water level indicators, pressure gauges, flow meters, water level indicators etc. The information for the equipment shall include manufacturer's name, address telephone number etc. and also the technical information furnished by the manufacturers. The test certificates, inspection reports and warranty certificates of these equipment shall also be kept along with the manufacturer's information.

7.7 RECORDS AND REPORTS

7.7.1 RECORD SYSTEM

A record system has to be developed which should be realistic and apply to the operating problems involved at the particular SR site. The most efficient way to keep records is to plan what data is essential and then prepare the formats followed by the persons to fill the data, frequency and to whom the record is to be sent for review and report. Sample records to be maintained at a SR site are given below for guidance.

7.7.2 RECORDS TO BE KEPT ON THE OPERATIONS

Note the following:

- Water levels in the SRs (for all compartments) at hourly intervals.
- Time and relevant operation of control valves with time of opening and closure or throttling position of the valves.
- Hourly flow meter readings both on the inlets and outlets.
- Hourly residual chlorine readings of inflow water and outflow water.
- The man-hours spent on routine operations at the SR in previous year and the cost thereof.

7.7.3 MAINTENANCE RECORD

Maintain record on each of the following maintenance/repair works along with the cost of materials and labour.

- When the gland ropes of the valves at the SR were changed.
- When the spares of the valves were changed.
- When the manhole covers were changed/replaced.
- When the water level indicator was repaired or replaced.
- When the reservoir was last cleaned.
- When the out-fall drain for scour and overflow was last cleaned.
- When the ladder was changed.
- When the structure of the reservoir was last repaired to attend to structural defects or arrest leakage.
- When the reservoir was last painted.
- When the piping at the reservoir was last painted.
- Total cost of repairs and replacements at the SR in previous year along with break up of material cost and labour cost with amount spent on outside agencies for repairs and replacements.

7.7.4 REPORTS

With the accumulation of all essential data a report can be prepared evaluating the O&M of the facility. The report can identify the deficiencies in the SR and its appurtenances and

then plan future repairs to the structure or valves and other equipment or for replacement of defective valves or other equipment or additions to the storage capacity where the existing capacity is inadequate.

7.8 CHECKS TO BE CARRIED OUT AT SRS

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

7.9.1 CHECK LISTS FOR CLEAR WATER SUMP AND RESERVOIR

S. No.	Checks required/undertaken	Status	Frequency of reporting*
1.	Proper closure of washout valves; any abrupt stoppage during operation.		
2.	Proper operation of inlet valves; any abrupt stoppage during operation.		
3.	Proper operation of outlet valves; any abrupt stoppage during operation.		
4.	Proper operation of bye pass valves; any abrupt stoppage during operation.		
5.	Does any valve pass water even after closure.		
6.	Leaks through valves; glands and bolts and nuts.		
7.	Leaks through pipes and joints at SR.		
8.	Status of valve chambers and their covers.		
9.	Status of finial ventilators; fly proof mesh intact or is to be replaced.		
10.	Status of manhole covers; are they corroded?		
11.	Functioning of water level indicators.		
12.	Functioning of flow meters.		
13.	Status of ladders and railing; are they corroded?		
14.	Check whether quality of the water in the SR is OK.		
15.	Possibility of SR water getting polluted.		
16.	Check for the need for cleaning and disinfecting the SR.		
17.	Check for the presence of residual chlorine in the water stored in SR.		
18.	Check for signs of corrosion of interior of roof due to chlorine.		

S. No.	Checks required/undertaken	Status	Frequency of reporting*
19 .	Check for structural damages of the SR.		
20.	Check for Leaks through the structure of the SR.		
21.	Status of interconnecting pipe work? Is it corroded?		
22.	Status of lightning arrestor.		
23.	Status of out-fall drains of scour and overflow at SR.		
24.	Availability of:		
	Spares		
	Consumables		
	Tools		
25.	Check for need for painting.		
26.	Check for availability of drawings and designs of the SR.		

* To be decided by the respective water utilities.

CHAPTER 8

DISTRIBUTION SYSTEM

8.1 OBJECTIVE OF A DISTRIBUTION SYSTEM

The overall objective of a distribution system is to deliver wholesome water to the consumer at adequate residual pressure in sufficient quantity at convenient points and achieve continuity and maximum coverage at affordable cost. To attain this objective the organisation has to evolve operating procedures to ensure that the system can be operated satisfactorily, function efficiently and continuously, and as far as possible at lowest cost.

Routine and emergency operating procedures should be in written form and understandable by all operators of the authority to act in emergencies. Further, specific operational procedures are required for inspecting, monitoring, testing, repairing and disinfecting the system as well as for locating the buried pipes and valves. System records and maps should be updated and have sufficient details of the system facilities, their condition, routine maintenance that is needed and done, problems found and corrective actions taken. Analysis of the records will enable the organisation to evaluate how well the installations are functioning and how effective its services are and hence assess their adequacy to meet the needs of the consumers.

8.2 NORMAL OPERATIONS

Normally, the operations are intended to maintain the required supply and pressure through out the distribution system. Critical points are selected in a given distribution system for monitoring of pressures by installation of pressure recorders and gauges. These pressures are either measured manually and transmitted to the control station or automatically measured and transmitted by telemetry to control station. In the direct pumping systems, whenever water pressures in the distribution system or water levels in the Service Reservoir (SR) drop below the minimum required levels, pumps would be manually or automatically started. In an intermittent water supply system, pumps and valves are operated during fixed hours. These pumps will run till the maximum levels in SR and maximum pressures in the distribution system are reached. Operators are required to ensure the accuracy of the measuring instruments for pressures and levels so that the pumps operate or stop at the proper levels. Sometimes, online Booster pumps are introduced to work on line to start whenever the desired pressures fall below the required pressures. Both upstream and downstream pressures are sensed and transmitted to the booster pumping station for automatic starting or stopping of the pumps when the actual pressures are below or above the desired pressures.

8.3 ISSUES CAUSING PROBLEMS IN THE DISTRIBUTION SYSTEM

8.3.1 INTERMITTENT SYSTEM

The distribution system is usually designed as a continuous system but often operated as an intermittent system. Intermittent supply creates doubts in the minds of the consumers about the reliability of water supply. This leads to limited use of the water supplied, which does not promote personal hygiene at times. During the supply period the water is stored in all sorts of vessels for use in non-supply hours, which might contaminate the water. Often, when the supply is resumed, the stored water is wasted and fresh water again stored. During non-supply hours polluted water may enter the supply mains through leaking joints and pollute the supplies. Further, this practice prompts the consumers to always keep open the taps of both public stand posts and house connections leading to wastage of water whenever the supply is resumed. Intermittent systems and systems which require frequent valve operations are likely to affect equitable distribution of water mostly due to operator negligence.

8.3.2 NON-AVAILABILITY OF REQUIRED QUANTITY OF WATER

Failure of source or failure of power supply may cause reduced supplies. Normally, the distribution reservoirs are designed for filling in about 8 hours of pumping and whenever the power supply is affected the pumping hours are reduced and hence the distribution reservoirs are not filled up leading to reduced supply hours and hence reduced quantity of water.

8.3.3 LOW PRESSURE AT SUPPLY POINT

Normally peak demand is considered ranging from 2 to 3, whereas the water supply is given only for a different duration, leading to large peak factors and hence affecting the pressures in the distribution system. This is a common with most water supply systems.

8.3.4 LEAKAGE OF WATER

Large quantity of water is wasted through leaking pipes, joints, valves and fittings of the distribution systems either due to bad quality of materials used, poor workmanship, corrosion, age of the installations or through vandalism. This leads to reduced supply, loss of pressure and deterioration in water quality.

8.3.5 UNAUTHORISED CONNECTIONS

Illegally connected users will contribute to the reduction in service level to authorized users/ consumers and deterioration of quality of water. Sometimes, even legally connected users draw water by sucking through motors causing reduction in pressures.

8.3.6 EXTENSION OF AREA OF DISTRIBUTION SYSTEM

Due to extension of service area without corresponding extension of distribution mains, the length of house connections will be too long leading to reduction in pressures.

8.3.7 AGE OF THE SYSTEM

With age there is considerable reduction in carrying capacity of the pipelines due to incrustation, particularly unlined CI, MS and GI pipes. In most of the places the consumer pipes get corroded and leaks occur resulting in loss of water and reduced pressure and pollution of supplies.

8.3.8 LACK OF RECORDS

System maps, designs of the network and reservoirs and historic records of the equipment installed in the distribution system are often not available, whereas some minimum information is required to operate and maintain the system efficiently.

8.4 OPERATION SCHEDULE

8.4.1 MAPPING AND INVENTORY OF PIPES AND FITTINGS IN THE WATER SUPPLY SYSTEM

Availability of updated distribution system maps with contours, location of valves, flow meters and pressure gauges or taping points is the first requirement for preparation of operation schedule. The agency should set up routine procedures for preparing and updating the maps and inventory of pipes, valves and consumer connections. The maps shall be exchanged with other public utilities to contain information on other utility services like electricity, communications etc.

The activities involved in mapping are:

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

8.4.2 PROCEDURE FOR PREPARATION AND UP-DATING OF MAPS

8.4.2.1 CONTENTS OF MAPS

Comprehensive maps prepared for a scale of 60m/cm to 120 m/cm are used for O&M of distribution system. They provide an overall view of the system with location of reservoirs, pumping stations, valves and hydrants etc. Valve location maps apart from indicating their location also show the direction to open the valve, number of turns to open, make of valve and date of fixing of valve. At times, plan and profile drawings are also available which show the depth of pipe, pipe location vertical and horizontal and distance from reference point. Hydraulic gradient contour maps are also prepared to indicate the pressures in the system in peak demand period. They can be used for identifying high pressure or problem areas with low pressures.

8.4.2.2 FIELD SURVEY

Existing maps are used or conventional survey is employed for preparation and up-dation of maps. As an alternative to traditional survey and map preparation, 'total station method' is gaining popularity. Total station instruments can be used for survey and mapping of towns where data is not readily available.

8.4.2.3 GIS MAPS

Geographic Information System (GIS) is a computer program that combines mapping with detailed information on physical structures with geographic areas. GIS has also compatibility with auto-cad design systems. The remote sensing maps can be used to prepare base maps of the utilities by using GIS. The GIS creates a database within a mapped area such as streets, valve chambers/manholes, pipe networks and pumping stations. The attributes can be address, number of valve chamber/manhole, pipe length, diameter, invert and quadrant (co-ordinates) and can also include engineering information, maintenance information and inspection information. The utility staff will get facility to update the maps and retrieve information geographically. These maps can be used to inform the maintenance crew to locate the place of work. The utility can use a work order system for new/repair works so that after completion of the work like a line is added or a valve is fixed or a new connection is given, the work order can be used by the map unit for up-dation of the map and the attributes also. These maps are used to indicate layers of maps for water lines, sewers, power cables, telecom cables etc.

8.4.3 ROUTINE OPERATIONS OF THE WATER SUPPLY DISTRIBUTION SYSTEM

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

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

8.4.4 OPERATIONS IN OTHER THAN NORMAL CONDITIONS

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

8.4.5 MEASUREMENT OF FLOWS, PRESSURES AND LEVELS

It will be necessary to monitor regularly operational data concerning flows, pressures and levels to assess whether the system is functioning as per requirements. Analysis of data may reveal over drawal of water to some reservoirs and or bulk consumers. At such places appropriate flow control devices may be introduced to limit the supplies to the required quantity. A list of priority points in water supply system have to be identified such as installation of meters to measure flows, pressures and levels. A detailed map showing location for each measuring point has also to be prepared. The degree of sophistication of the devices used at each measuring point with regard to indication, integration, recording, transmission

and reception of data depends mainly on the skills of the O&M personnel available with the agency and affordability of the agency.

8.4.5.1 EVALUATION OF HYDRAULIC CONDITIONS

A continuous evaluation of the hydraulic conditions of the water supply system can be done by the O&M personnel after obtaining the data on water volumes and flows at various points in the system, the water pressures and levels in the reservoirs and comparing with expected performance. This evaluation shall lead to identification of operational problems and or system faults. Depending on the type of problems actions have to be initiated to ensure that the system functions as per the requirement.

8.4.5.2 SYSTEM PRESSURES

Maintenance of a continuous positive pressure at all times (during supply timings) to consumers is the main concern of O&M. Negative pressures can cause contamination of water supplies especially in intermittent supplies. Very high pressures may damage the pipelines and valves, which can be corrected with pressure reducing valves. Complaints from consumers about low pressures have to be promptly investigated if necessary by measuring pressures with pressure gauges. Low pressures may be under the following circumstances:

- Purposefully or accidentally a line valve is left closed or partly closed or blockage due to any material causing loss of pressure.
- Too high velocities in small pipelines.
- Low water levels in SR.
- Failure of pumps/booster pumps (either due to power failure or mechanical failure) feeding the system directly.

8.4.5.3 SIMULATION OF NETWORK

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

8.4.5.4 SAMPLING FOR QUALITY OF WATER

The agency operating the water supply system is charged with the primary responsibility of ensuring that the water supplied to the consumer is of an appropriate quality. To achieve this objective it is necessary that the physical, chemical and bacteriological tests are carried out at frequent intervals. The minimum number of samples to be collected from the distribution system should be as prescribed in the Table 15.1 of Chapter 15 of the Manual on "Water Supply & Treatment". Samples should be taken at different points on each occasion to enable overall assessment. In the event of epidemic or danger of pollution more frequent sampling may be

required, especially for bacteriological quality. For each distribution system a monitoring programme has to be prepared showing the location of sampling points. Based on historic records of a system it will be possible for the manager of the system to decide locations for bacteriological sampling and residual chlorine testing.

Possible water quality problems and causes and remedies are given in Table 8.1.

TABLE 8.1: WATER QUALITY PROBLEMS, CAUSES & REMEDIES

S. No.	Problem	Possible Cause	Suggested remedies
1.	Taste and Odour	High chlorine residual.	Lower chlorine dosage
		Biological growth or microorganisms in dead ends and reservoir.	Chlorinate, flush mains and clean the reservoir
2.	Turbidity	Silt or clay in suspension.	Flushing or proper operation of WTP
		Microorganisms	Same as above
		Floc carryover	Same as above
3.	Colour	Decay of vegetable matter	Chlorination
		Microscopic organisms	Chlorination
4.	Positive coliform results	Contamination in distribution system	Locate and remove source of contamination
		Cross connection	Install backflow prevention such as double reflex valves
		Negative pressure	Maintain positive pressure after disinfection
		Improper disinfection	Improve chlorination process

8.5 MANAGEMENT IN TIMES OF WATER SHORTAGE

The objective of developing a programme for managing in times of shortage of water is to reduce the excessive use of water particularly when the source is limited due to adverse seasonal conditions. Basically it involves that a water conservation policy is developed and implemented among water consumers. The following activities can be considered while formulating such a water management project:

- Installation of accurate water meters and establishment of a realistic tariff structure to encourage water conservation and prevent wastage of water.
- Introduction of restrictions on use of flushing, showers and other household fittings.
- Introduction of devices to limit water consumption in flushing of toilets.
- Enforcement of restrictions on use of treated water for watering lawns, cooling, construction, washing of vehicles etc.
- Encouragement and/or enforcement of the reuse of treated industrial effluents and municipal wastewater.
- Development and implementation of public education programmes to encourage water conservation.

8.6 SYSTEM SURVEILLANCE

Surveillance of distribution system is done to detect and correct.

- Sanitary hazards.
- Deterioration of distribution system facilities, [to detect].
- Encroachment of distribution system facilities by other utilities such as sewer and storm water lines, power cables, telecom cables etc. and
- Damages of the system facilities by vandalism. [detecting and correcting].

In addition, checks are carried out under special circumstances for assessing damage of the system after flooding of streets following a heavy storm. All these checks are done for above ground water facilities such as valves and valve chambers or exposed pipelines. Some less frequent inspection of underground pipelines will also be required, wherein critical areas of the distribution system should be patrolled routinely so that the water utility can watch out for early warning of any adverse conditions of the distribution system. Any activity or situation that might endanger the water facility or water quality shall be investigated and corrective action is to be taken. Surveillance shall also include looking for unauthorised construction activity on or near the utility's pipelines, which may pose a physical threat to the mains. Any digging or excavation or blasting near the mains shall be closely supervised by the utility staff. Surveillance of Valve chambers and valves shall be done as noted in para 6.6 of this chapter.

8.7 MAINTENANCE SCHEDULE

A maintenance schedule is required to be prepared to improve the level of maintenance of water distribution networks and house connections through improved co-ordination and planning of administrative and field work and through the use of adequate techniques, equipment and materials for field maintenance.

- The schedule has to be flexible so that it can achieve team action with the available vehicles and tools.
- Co-ordination of activities is required for spares and fittings, quality control of materials used and services rendered.
- Training of maintenance staff shall include training to achieve better public relations with consumers apart from the technical skills.

8.7.1 ACTIVITIES IN MAINTENANCE SCHEDULE

Following activities are to be included in the schedule:

- Establishment of procedures for setting up maintenance schedules and obtaining and processing the information provided by the public and the maintenance teams.
- Formation of maintenance teams for each type of service with provision for continuous training.
- Establishment of repair procedures for standard services.
- Specification of appropriate tools.
- Allocation of suitable transport, tools and equipment to each team.

- Establishment of time, labour and material requirement and output expected; time required and other standards for each maintenance task, and
- Monitoring the productivity of each team.

8.7.2 PREVENTIVE MAINTENANCE SCHEDULE

A preventive maintenance schedule for Servicing of Valves and Maintenance of Valve Chambers, Maintenance of the pipelines: may include the tasks, set priorities, issue of work orders for tasks to be performed, list of scheduled tasks not completed, record of when the tasks are completed and maintaining a record of tools, materials, labour and costs required to complete each task.

8.7.2.1 SERVICING VALVES

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

8.7.2.2 MANUFACTURERS CATALOGUES

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

8.7.2.3 LIST OF SPARES

A list of spares required for the distribution system shall be prepared and the spares shall be procured and kept for use. The list should indicate the minimum level at which action for replenishments should be initiated. The list of probable spares to be kept in stock may include the following:

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

8.7.2.4 LIST OF TOOLS

The necessary tools to properly repair and correct both the routine problems and for facilitating repairs and replacements in a distribution system have to be identified and provided to the maintenance staff.

Some of the tools for the maintenance work in a distribution system are: Key rods for operation of all sluice valves, hooks for lifting manhole covers, pipe wrench of appropriate sizes (200, 300 or 450 mm), Double ended (DE) spanner set, Ring spanner set, Screw Drivers,

Pliers, Hammers, Chisels, caulking tools for lead and spun yarn, ladles and pans for melting and pouring lead joints, excavation tools such as crow bars, spades, iron baskets, buckets and de-watering pumps.

8.7.2.5 MAINTENANCE OF VALVE CHAMBERS FOR APPURTENANCES

Valve chambers shall be checked to ensure that they are not damaged, nor filled up with earth nor buried in pavement. Covers of valve chambers are stolen or broken up by vandalism or by accident resulting in damage to the valves or may lead to accidental fall of a person into the open valve chamber. Such situations have to be corrected on priority. Road improvement works require constant attention of water utility staff since the valves may be lost or at times the valve chambers in the roads have to be reconstructed to match the renewed road surface.

8.7.3 MAINTENANCE SCHEDULE FOR PIPELINES

8.7.3.1 Main Breaks

Pipeline bursts/main breaks can occur at any time and the utility shall have a plan for attending to such events. This plan must be written down, disseminated to all concerned and the agency must always be in readiness to implement the plan immediately after the pipe break is reported. After a pipe break is located, a decision is to be taken as to which valve is to be closed to isolate the section where the break has occurred. Every consumer (some important consumers may be having an industrial process dependent on water supply which cannot be shut down as fast as the water supply lines are cut off) should be notified about the break and informed about the probable interruption in water supply and also the estimated time of resumption of water supply. After the closure of valve, the dewatering/mud pumps are used to drain the pipe break points. The sides of trenches have to be properly protected before the workers enter the pit. The damaged pipe is removed, and the accumulated silt is removed from inside the pipe and the damaged pipe is replaced and the line is disinfected before bringing into use. After every pipe break a report shall be prepared in regard to the cause of such break, the resources required for rectification and the time and cost required for repairing etc. so that the agency can follow up with measures for avoiding such breaks and also modify their plan to address such breaks in future.

8.7.3.2 Deterioration of Pipes

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

8.7.3.3 Flushing of Pipelines

Flushing is done to clean the distribution lines by removing impurities or sediment that may be present in the pipe. Routine flushing of terminal pipelines is often necessary to avoid taste and odour complaints from consumers. It is advisable that a programme for flushing is prepared and followed so that water mains are flushed before consumers start complaining. The routine for flushing can be prepared by taking into consideration the consumer complaints and type of deposits found while cleaning. Since in distribution system flushing is not the only solution for water quality problems, proper operation of treatment process and cleaning of service reservoirs supplying water to distribution system shall also be planned along with the flushing of distribution system. Flushing is usually done during low water demand, when the weather is favourable. Prior planning and good publicity with public will allow the flushing to proceed quickly and without confusion.

8.7.3.4 Cleaning of Pipelines

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

8.7.3.5 Cement Mortar lining

The present trend is to use Cement Mortar lined Ductile Iron (DI) pipes or Mild Steel (MS) pipes so that they will not lose their carrying capacity with use and age. Still many new pipelines are proposed with unlined metallic pipes and there are several existing pipelines with bare metal surface such as CI or MS. With passage of time these pipelines deteriorate and require rehabilitation. Cement mortar stifles corrosion through its ability to develop high alkalinity. The application of cement mortar lining to pipe in place is done by a lining machine, containing a device that projects cement mortar against the pipe wall. Directly behind this device are mechanically driven rotating trowels, which give the surface smooth finish. In-situ Cement Mortar lining of existing metallic water mains has been beneficial where:

- Pipe carrying capacity may reduce due to tuberculation.
- Water quality is affected due to release of corrosion products from the pipes to the water, and
- Leaks occur through joints and pipe walls.

8.8 LEAKAGE CONTROL

Wastage of water in the system and distribution network occurs by way of leakage from pipes, joints & fittings, reservoirs and overflow from reservoirs & sumps. The objective of leakage control programme is to reduce the wastage to a minimum and minimize the time that elapses between the occurrence of a leak and its repair. The volume of water lost through each leak should be reduced by taking whatever action is technically and economically feasible to ensure that the leak is repaired as quickly as possible. To achieve this, the organisation shall prescribe

procedures for identifying, reporting, repairing and accounting for all visible leaks. It will be beneficial for the agency if the procedures involve the conscious and active participation of the population served by the agency apart from its own staff. For details on detection and leakage control, please refer chapter 13.0. Water Audit and Leakage Control. The Management has to process the data and evaluate the work on detection and location of leaks and for dissemination of the results and initiate actions to control the overall problem of water loss. Interim measures for reduction/control of leakage can be initiated by controlling pressures in the water distribution system where feasible.

8.8.1 LEAKAGE THROUGH HOUSE CONNECTIONS

Leakage can be controlled at the point of house connection and in the consumer pipe by adopting correct plumbing practices and improving the methods used for tapping the main and giving house connection and strict quality control on the pipe material used for house connection. An analysis of leaks in house connections and investigation of reasons for leaks in the house connections shall be carried out to initiate action on reducing the leakage through house connections.

8.8.2 PROCEDURES FOR REPORTING VISIBLE LEAKS

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

8.8.3 PROCEDURES FOR DETECTING INVISIBLE LEAKS

Establishment of procedures for detecting and locating non-visible leaks shall be compatible with the technological, operational and financial capability of the agency. Selection and procurement of equipment for detection and location of leaks must take into account the cost effectiveness and the financial capability of the Organisation.

8.9 CROSS CONNECTIONS

8.9.1 CROSS CONNECTIONS

Contaminated water through cross connections of water supply lines with sewers and drains is a problem prevailing widely. Intermittent supply further aggravates the problem since, during non-supply hours polluted water may reach the supply mains through leaking joints, thus polluting the supplies. In certain instances, when there are extremely high water demands, the pressures in the supply mains are likely to fall below atmospheric pressure, particularly when consumers start use of pumps with direct suction from supply mains. Regular survey has to be undertaken to identify potential areas likely to be affected by cross connections and back-flow. All field personnel should be constantly alert for situations where cross connections are likely to exist. After identifying the cross connections, remedial measures are taken up which include: providing horizontal and vertical separation between the water main and the sewer/drain, (refer to para 10.11.1 of Chapter 10 of Manual on “Water Supply

& Treatment"), providing a sleeve pipe to the consumer pipes crossing a drain, modifying the piping including changing corroded piping with non corrodible piping, providing double check/non return valves at the consumer end etc.

8.9.2 CHLORINE RESIDUAL TESTING

A minimum chlorine residual of about 0.2 mg/l at the selected monitoring point is often maintained to ensure that even a little contamination is destroyed by the chlorine. Hence, absence of residual chlorine could indicate potential presence of heavy contamination. If routine checks at a monitoring point are carried out, required chlorine residuals and any sudden absence of residual chlorine should alert the operating staff to take up prompt investigation. Immediate steps to be taken are:

- Re-testing for residual chlorine.
- Checking chlorination equipment.
- Searching for source of contamination, which has caused the increased chlorine demand.
- Immediate stoppage of supplies from the contaminated pipelines.

8.10 MONITORING SYSTEM PERFORMANCE

Normally the managers of O&M of water utilities monitor levels in service reservoirs, pressures and flows in the distribution system and operation of pumps such as hours of pumping, failure of pumps and monitor water quality by measuring residual chlorine. The manager usually uses telephone line or wireless unit to gather the data, maintain records analyses, uses his discretion gained with experience and takes decisions to ensure that the system is operating with required efficiency. Manual collection of data and analysis may not be helpful in large undertakings if water utilities have to aim at enhanced customer service by improving water quality and service level with reduced costs. In such cases Monitoring system performance can be done with use of Telemetry and SCADA which are discussed in Chapter 11 – Water Meters and Instrumentation including Flow Meters.

8.11 PLUMBING PRACTICES

The internal plumbing system of the consumer shall conform to the National Building Code and also particularly to the bye laws of concerned water utility/local authority.

8.11.1 QUALITY OF PIPE MATERIAL FOR HOUSE CONNECTION

The water utility shall ensure that the connection and communication pipe from the street main up to the consumer premises is laid as per correct plumbing practices and adopt improved methods for tapping the main. Strict quality control is required on the pipe material used for house connection. The bye Laws shall lay down rules for defining the ownership and responsibility for maintaining the point of connection and the communication pipe. In several utilities the communication pipes are leaking since they are corroded; however these are not replaced by the consumer or by the utility particularly where the O&M responsibility for consumer pipe rests with the consumers.

8.11.2 CONTAMINATION THROUGH HOUSE CONNECTION

While laying the consumer connection pipes there is a need to avoid contamination of water supplies. This can be achieved by maintaining horizontal and vertical separation between the water supply communication pipe and the sewer/drain, (refer to para 10.11.1 of Chapter 10 of manual on "Water Supply & Treatment"). In some instances a sleeve pipe may be required to be provided to the consumer pipes crossing a drain. It is always recommended to provide a non-corrodible pipe material for the consumer connection. Contamination by possible back flow can also be prevented by ensuring provision of double check/non-return valves at the consumer end.

8.11.3 RULES FOR CONSUMER CONNECTIONS

The water utility shall formulate rules for sanction of consumer connection, tapping the mains and laying the connection piping. Water utility shall undertake inspection of the consumer premises before releasing the connection to ensure that the internal plumbing system of the consumer conforms to the National Building Code. Water utility shall supervise the process of drilling/tapping of the main for giving connection and laying of the consumer piping. The process of submission of applications for connections by consumers and carrying out the connection work through licensed plumbers is also prevalent in some utilities. In such cases the utility shall formulate procedures for licensing the plumbers including the qualifications to be possessed by the plumber, facilities and tools to be available with the plumber for the work to be undertaken by the plumber. The utility shall closely observe the quality of materials used and works done by him and he should act as per procedures laid down in the bye laws for approval of the connection works, renewal or cancellation of the plumbers' licenses or any other requirement depending on their performance or non performance.

8.12 RECORDS AND REPORTS

8.12.1 RECORD SYSTEM

A record system has to be developed which should be realistic and apply to the operating problems involved in the distribution system. Management must be clear as to why the data/ information is collected, as to who will review the data and who will respond to the results of review. The most efficient way to keep records is to plan what data is essential and then prepare the formats followed by the persons concerned for filling of the data, frequency and to whom the record is to be sent for review and report.

Sample records to be maintained are given below for guidance:

- Updated system map.
- Pressure and flow readings at selected monitoring points.
- Persistent low pressure or negative pressure areas.
- Age of pipes/quality of pipes.
- Pipelines to be replaced.

- Presence of corrosive water in the system.
- Water budget for each zone served by one SR.
- Number of connections given.
- Number of meters out of order.
- Status of fire hydrants and public taps.
- Quantity measured at outlet of reservoir.
- Quantity distributed/measured or billed.
- Source of leaks and persistent leak points.
- Status of bulk meters - function or not.
- Status of consumer meters.
- Facilities for repairs of consumer meters.
- Number of unauthorised connections.
- Residual chlorine levels at the pre-selected monitoring points.
- Bacteriological quality of the water sampling points.
- Persistent areas where residual chlorine is absent/where bacteriological samples are unwholesome.
- Record on carrying out repairs on the following works and its cost:
  - The pipe line leaks or replacement of pipes.
  - Change of gland ropes of the valves in distribution system.
  - Replacement of parts.
  - Replacement of manhole covers.
- Record on man hours spent on routine operations in the distribution system in the previous year and the cost thereof.
- Record on total cost of repairs and replacements in previous year along with break up of material cost and labour cost with amount spent on outside agencies for repairs and replacements.
- Record on when the exposed piping was last painted and the cost of materials and labour cost thereof.
- Record on the unserved areas - extension of pipelines- need for interconnections.

8.12.2 REPORTS

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

8.13 CHECKS TO BE CARRIED OUT IN DISTRIBUTION SYSTEM

8.13.1 PROGRAMME FOR CARRYING OUT CHECKS

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

8.13.2 CHECK LIST

S. No.	Checks required/undertaken	Status	Suggested frequency of reporting
1.	Check whether the Operation of valves is smooth without any abrupt stoppage during closure.		
2.	Check whether closure of a valve results in complete stoppage of flow or if any flow passes the valve (passing valve).		
3.	Check for status of scouring and then proper closure of washout valves.		
4.	Check for leaks through pipes.		
5.	Check for leakage through valves at gland, bolts or any other place.		
6.	Check for leaks at the appurtenances.		
7.	Check for any signs of corrosion of pipelines.		
8.	Check for the status of Manhole covers over the chambers; are they corroded.		
9.	Inspect for any possibilities of pollution of the distribution system water stored.		
10.	Status of out-fall drain for scour and overflow.		
11.	Assess the need for painting of the piping work.		
12.	Check for availability of spares for valves and pipes and jointing materials.		
13.	Review the method of giving consumer connections in the field.		
14.	Preparation of water budget for each zone served by one reservoir.		
15.	Number of connections given.		
16.	Number of meters out of order.		
17.	Status of hydrants and PSPs.		
18.	Status of Distribution System.		

S. No.	Checks required/undertaken	Status	Suggested frequency of reporting
19.	Review of pressures.		
20.	Review of flows.		
21.	Age of pipes/C value of pipes.		
22.	Corrosive water.		
23.	Study of inflows and outflows.		
24.	Identify source of leakage.		
25.	Metering.		
26.	Status of bulk metering and consumer.		
27.	Review facilities for repair of consumer meters.		
28.	Unauthorised connections if any.		
29.	Status of fire hydrants and PSPs.		
30.	Availability of updated system map.		
31.	Need for any interconnections.		

CHAPTER 9

DRINKING WATER QUALITY MONITORING AND SURVEILLANCE

9.1 INTRODUCTION

Drinking water quality monitoring and surveillance is the continuous monitoring of public health along with vigilant assessment and control of safe potable water supply.

9.2 IMPORTANCE OF WATER QUALITY

Safe potable water is the first step to promote good health of the community. Experience has shown that community health and water quality is directly related to each other and an improvement of drinking water quality is followed by an improvement in the community's health. Man made activities; rapid industrialization and agrochemical contamination increasingly affect the quality of water resources. Moreover, infant mortality, mostly from diarrhoeal and other water borne and water related diseases (*Annexure 9.1*) are of great concern in underdeveloped as well as developing countries. Inspite of significance achievements in water supply and sanitation coverage, many factors render good quality water unsafe by the time it reaches the consumer. Poor operation management and unsatisfactory sanitary practices are the major key areas responsible for water contamination. Water quality management and surveillance practices ensure safe water supply to consumers.

9.3 DEFINITION

While describing water quality, certain terms are frequently used, which are to be clearly understood and correctly used. Some of the definitions are given below:

Pollution is the introduction into water of substance in sufficient quantity to affect the original quality of water, make it objectionable to sight, taste, smell or make it less useful.

Contamination is the introduction into water of toxic materials, bacteria or other deleterious agents that make the water hazardous and therefore unfit for human use.

Potable Water that is satisfactory for drinking purposes from the standpoint of its chemical, physical and biological characteristics.

Palatable Water that is appealing to the sense of taste, sight and smell. Palatable water need not always be potable.

Parts per million (ppm) or milligrams per litre (mg/l) these terms are used to express the concentrations of dissolved or suspended matter in water. The parts per million (ppm) is a weight to weight or volume to volume relationship. Except in highly mineralized water, this

quantity would be same as milligram per litre. This is preferable, since it indicates how it is determined in the laboratory.

pH of water an expression of the Hydrogen ion concentration. Alkaline water is with pH of above 7 and acidic water has pH of below 7; whereas water with pH 7 is neutral.

Toxic is harmful, destructive or deadly poisonous.

Physiological effect having effect on the normal functions of the body.

Pathogens disease-producing organisms.

Bacteria a group of universally distributed, essentially unicellular microorganisms lacking chlorophyll.

Virus the smallest form capable of producing infection and diseases in human beings.

Coliform Bacteria group of bacteria predominantly inhabiting the intestine of human beings and animals, but also occasionally found elsewhere. Used to indicate presence of faecal pollution.

Enteric having its normal habitat in the intestinal tract of human beings or animals.

Chlorine Residual chlorine remaining in the water at the end of a specified period.

Chlorine Demand the difference between the amount of chlorine added to water and amount of residual chlorine remaining in the water at the end of a specified period.

9.4 WATER SUPPLY AND SURVEILLANCE AGENCIES

Water supply agency is responsible for safe water supply to consumers. The main objectives of water quality monitoring are:

1. To determine the quality of water in its natural state in view of its present and future needs
2. To assess the suitability of water for required use
3. To find out the pathways for pollution, if any

Monitoring of water quality by water supply agency involves laboratory and field testing of water samples collected from various points in the water supply system, including the source, water purification plants, service reservoirs distribution systems and consumer end, representative of the condition of water at the point and time of collection. Continuous water quality monitoring involves good operating practices and preventive maintenance, as well as the regular routine testing, and monitoring of water quality to ensure compliance with standards.

Surveillance is an investigative activity undertaken by a separate agency, to identify and evaluate factors posing a health risk to drinking water. Surveillance requires a systematic program of surveys that combine water analysis and sanitary inspection of institutional and community aspects, and reporting system. Sanitary inspection of water supply system should cover the whole system including water sources, rising mains, treatment plants, storage reservoirs, and distribution systems; to identify most common risks and shortcomings in the water supply. Moreover, surveillance is concerned with all sources of water used for domestic purpose by the population, whether supplied by a water supply agency or collected from other

individual sources. So it is important to inspect and analyze all sources of water used and intend to be used for human consumption.

Surveillance agency should communicate to the water supply agency and pinpoint the risk areas and give advice for remedial action. It should also maintain good communication and cooperation with water supply agency for detection of risk areas and remedial action for betterment of water supply. *Annexure 9.2* gives functions and responsibilities of agencies for water quality monitoring and surveillance.

9.5 PLANNING AND IMPLEMENTATION

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

9.5.1 GENERAL CONSIDERATION AND STRATEGIES

Quality control activities should be initiated as per the norms of national guidelines for each water supply system on a continuous basis.

Surveillance agency should carry out periodic surveillance of all aspects of water quality safety including sanitary inspection and spot checks and result should be reported to the concerned water supply agency to implement remedial action when and where necessary.

Water supply surveillance can be planned in progressive manner considering the availability of resources. It should start with a basic program, which could generate useful data to plan advanced surveillance as resources, and conditions permit. The initial pilot scale program should cover minimum basic strategies including fewer water quality parameters that provide reasonable degree of public health protection and should be widely applicable. Careful planning of training and resource provision is very essential right from the beginning of the project.

9.5.2 LEGAL AND INSTITUTIONAL BASIS

9.5.2.1 Legislative Framework

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

9.5.2.1 Institutional Framework

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

Intersectoral cooperation is required in all activities related to the promotion and surveillance of water quality, from the planning stage, to the actual supply of water, the monitoring and surveillance of water quality, and the implementation of preventive and remedial measures. In the beginning itself, both the agencies should, in consultation with one another, agree on a program on drinking water quality monitoring and surveillance.

9.6 SURVEILLANCE PROGRAM

Surveillance activities differ from region to region; between urban and rural communities; and according to the types of water supply. They should be adapted to local conditions; availability

of local finances, infrastructure and knowledge. Water supply provider and surveillance agencies, depending on resources available with them, will develop the program for monitoring and surveillance of drinking water quality. Following factors should be taken into consideration while implementation of surveillance activities.

- The type and size of water supply systems.
- The existing and available equipment.
- Local employment practices and the level of training.
- Opportunities for community participation.
- Accessibility of systems keeping in view of geographical and climatological conditions.
- Communication and transport facilities available.

Surveillance program can be phased out in three distinct phases - Initial, Intermediate and Advance.

Initial phase

- Identify agencies and develop collaboration.
- Finalize institutional requirements.
- Prepare inventories of water supply system.
- Preliminary training for staff.
- Assess and identify priority areas for sample collections.
- Develop methodologies for water quality analysis.
- Commence routine surveillance in priority areas.
- Limit water analysis to critical parameters only.
- Establish reporting, filling and communication systems.
- Identify community roles and promote participation.

Intermediate phase

- Establish and expand systematic routine surveillance.
- Expand analytical capability.
- Train staff.
- Use draft standard methods for analysis and field works.
- Establish data based archive.
- Identify common problems and improve activities accordingly.
- Use legal enforcement where possible.
- Involve community.

Advanced phase

- Establish routine surveillance for all health parameters at defined intervals.
- Use guidelines as given in Manual on Water Supply and Treatment.
- Give advance training to staff.

- Use full network of local, regional and central laboratories.
- Improve water services on the basis of local priorities, hygiene awareness and enforcement of standards.
- Involve communities.
- Disseminate data at local, regional and national level.

9.7 INFORMATION MANAGEMENT

The flow of information between and within the water supply and surveillance agencies is necessary to maximize the quality of service to consumer and protection of public health. The report provided by the surveillance agency to water supply provider should include:

1. The summary reports of condition of water supply and water quality analysis.
2. Highlight those aspects, which are considered inadequate and needs action.
3. Recommendation of remedial action in case of emergency.

The report should not be limited to complain about failures but the water supply and surveillance agencies should coordinate their activities to ensure good quality of water to consumers. Such a report should specify actions in order of priorities for intervention based on public health criteria. If consistently, unsatisfactory results are reported in a particular area, the cause for the same should be investigated and remedial measures taken, such as repair of leakage, replacement of corroded and leaking consumer pipes etc.

Local laboratory under surveillance agency should maintain detailed field reports regarding inspections and water analysis of all water supplies available in the area. It should include the results of all inspections and analysis. The local surveillance office should report to the relevant supply agency as soon as possible after field visits. The information should also be passed on to regional authorities to allow follow-up; if recommendations for remedial action are not implemented. However, there must be a rapid means of reporting in case of emergency.

The consumers have the right to know about the quality of water being supplied to them. Therefore, the agencies responsible for monitoring should develop strategies for informing public the health-related results obtained by them along with recommendations for action (e.g. boiling during severe faecal contamination, household water storage education etc.) through publicity, pani-panchayats etc.

Local government should ensure that the agency that supplies drinking water to the area complies with the quality standards.

9.8 SUPPORT STRUCTURE

Monitoring and surveillance programmes require laboratory network, offices, transport, financial support and adequate staffing.

9.8.1 COMMUNITY BASED MONITORING AND SURVEILLANCE

Community participation is an essential component of the monitoring and surveillance framework. As the primary beneficiaries community can play an important role in surveillance activity. They are the people who may first notice the problems in water supply and report it to concern agency or take remedial action if possible. Establishing a genuine partnership

with the community creates a climate of trust and understanding, which generates interest and enthusiasm. It also provides a good foundation for other educational activities such as promotion of good hygiene practices.

The community based monitoring and surveillance can be carried out in two ways:

1. Selection of community volunteers, including women, to undertake surveillance activities after training.
2. Providing encouragement to local worker to carry out certain jobs pertaining to surveillance.

In both the cases, preliminary training is necessary for field workers to identify sanitary hazards associated with the water supply, as well as regarding reporting system. Health department or water supply agency should help in providing necessary training while community water committee or health committee can supervise the work. The community participation includes:

- Assisting field workers in water sample collection, including sample location points, existing damaged net works, causing/likely to cause contamination of drinking water.
- Assisting in data collection.
- Monitoring water quantity, quality, and reporting findings to surveillance staff regularly.
- Ensuring proper use of water supply.
- Setting priorities for sanitation and hygiene and educate community members.
- Under take simple maintenance and repair work.
- Refer problems which require special attention.
- Disseminate results and explain the implications with respect to health with the objective to stimulate involvement in actions to keep water clean, safe and wholesome.

9.8.2 TRANSPORT

The preferred means of transport varies widely depending on climatic condition, distance, and road condition. The main factor to be taken into account in choosing transport is to send samples to the laboratory as quickly as possible in ice, never exceeding 24 hours.

In remote areas motorcycle and in developed areas four-wheelers may be used.

9.8.3 LABORATORY NETWORK

Water quality laboratory is the main backbone of water quality surveillance. A well-located and well-equipped analytical laboratory with competent staff is very essential to evaluate the efficiency of water utility services in terms of water quality. Water samples should be analyzed for priority parameters as per local problems.

In principle, water samples should be analyzed as fast as possible to avoid deterioration of sample quality, especially for microbiological analysis. For more effective coverage laboratory facilities can be categorised in two stages; Basic laboratories, State/Regional laboratories. (*Annexure 9.3*)

9.8.4 FINANCIAL SUPPORT

Sufficient allocation of fund should be made for maintaining/monitoring water quality and its surveillance, keeping in view, size of water works, area covered, etc.

9.8.5 STAFFING

Staff requirements for water supply monitoring and surveillance program vary widely according to the plant size, ecological and economical conditions. *Annexure 9.4 (a) and 9.4(b)* shows the possible suggestions for water quality monitoring and surveillance staff.

9.9 SURVEILLANCE ACTION

Surveillance action comprise of:

1. Investigative action to identify and evaluate all possible factors associated with drinking water, which could pose a risk to human health.
2. Ensure preventive action to be taken to prevent public health problem.
3. Data analysis and evaluation of surveys.
4. Reporting to concerned authorities.

9.10 SANITARY SURVEY

Sanitary survey is periodic audit of all aspects of all water supply system. Systematic program of sanitary survey includes sanitary inspection, water quality analysis, and evaluation of data and reporting.

9.10.1 NATURE AND SCOPE

Sanitary survey is an on-site inspection and evaluation of all conditions, devices and practices used in water supply system, which pose an actual or potential danger to the health and well-being of consumer by trained persons. It is a fact-finding activity, which identifies actual sources of contamination as well as point out inadequacies in the system that could lead to contamination.

The two important activities of sanitary survey are sanitary inspection and water quality analysis; which are complementary to one another. The inspection identifies potential hazards, while analysis indicates actual quality of water and intensity of contamination.

9.10.2 SANITARY INSPECTION

Sanitary inspection covers the inspection of water system, including the source, transmission mains, treatment plants, storage reservoirs and distribution system. Basically it is a fact-finding review to uncover deficiencies and inadequacies, which could lead to contamination of water. Sanitary inspection is indispensable for the adequate interpretation of laboratory results. It provides essential information about the immediate and ongoing possible hazards associated with a community water supply. It is an essential tool to pinpoint target areas for remedial action, required to protect and improve the water supply system.

9.10.3 SANITARY INSPECTION REPORT

The sanitary inspection report shall cover the following:

1. Identify potential sources and points of contamination of the water supply.
2. Quantify the hazards attributed to the source and supply.
3. Provide a clear, graphical means of explaining the hazards to the operator/user.

4. Provide clear recommendations for taking remedial actions, to protect and improve the supply.
5. Provide basic data for use in systematic, strategic planning for improvement.

Moreover inspection report should not be restricted to water quality but should take into account other service condition such as coverage, cost, condition and quantity. Such surveys are important form the point of view of operation and maintenance. *Annexure 9.5* shows suggested inspection forms for different water sources.

9.10.4 WORK CHART FOR SANITARY SURVEY

For collection of adequate information and follow-up work, proper work chart should be prepared considering local requirement. Following should be taken care of:

1. Prior knowledge of source, and type of water supply; and map of distribution system.
2. Notify the visit in advance, where the assistance of community members is needed.
3. Carry prescribed forms and necessary accessories, like sample bottle, sample carry box, analysis kit etc.
4. Verify basic data with community.
5. Interview community members for drinking water supply service.
6. Verify information gathered by observation during survey.
7. Inspection and water sampling should not be haphazard, should follow specific guideline.
8. Water samples should be analyzed immediately for residual chlorine and thermotolerent coliform, or transported quickly to laboratory in iced boxes.
9. Complete the sanitary report on site, and send it immediately to appropriate authority for follow-up remedial action if necessary.
10. Undertake appropriate small repairs at the time of survey in remote areas such as washer changing for leaking taps.
11. For pictorial forms, each risk point should be circled and given to member of water committee for follow-up action.

9.10.5 TIME AND FREQUENCY

No new public water supply should be approved without sanitary inspection', to provide sufficient information to indicate the suitability of the source and the amount of treatment required before the water can be considered suitable for human consumption. Physical, bacteriological, and chemical analysis should be carried out initially. The physical and bacteriological analysis can be followed at regular intervals, while chemical analysis can be carried out after fairly long time, as the substances are unlikely to be changed with time.

Water quality analysis of surface sources should be carried out frequently through out the year as its parameters vary greatly due to rainfall, man made as well as industrial activities, seasonal changes etc.

Sanitary surveys should be undertaken frequently by water supply department. The frequency of inspection and analysis largely depends on community size and local water

quality problems. *Annexure 9.6a, 9.6b, 9.6c(1) and 9.6c(2)* suggests the minimal round of surveys by water supply and surveillance agency.

9.11 WATER SAMPLING AND ANALYSIS

Periodic drinking water analysis is necessary to ensure safe quality water supply. Water samples should be analyzed for various microbiological and physicochemical contaminants. However, the authenticity of water analysis greatly depends on the sampling procedure.

The objective of sampling is to collect a small portion of water which can be easily transported to laboratory, without contamination or deterioration and which should accurately represent the water being supplied. It should cover locations which are most venerable in the supply system.

For recommended sampling procedures and guideline values regarding physical and chemical parameters, kindly refer to Manual on Water Supply and Treatment, III Edition, May 1999, Government of India, Ministry of Urban Development, New Delhi.

9.12 DATA ANALYSIS, INTERPRETATION AND REPORTING

Data analysis and interpretation are fundamental components of surveillance process. It aims at generation of data, which contributes to protect public health by promoting adequate, safe, potable water supply to communities.

9.12.1 DATA ANALYSIS

Evaluation of community water supply requires consideration of number of factors, such as quality, quantity, coverage, continuity of water supply and never the least, its production cost.

9.12.1.1 QUALITY

Quality of water supplied to communities is an important consideration for human health and well being. Remedial and preventive measures also form an important part of water supply quality maintenance. *Annexure 9.7* gives details about the suggested guidelines for the same. Water quality data, generated and summarized by surveillance agencies are useful tools to promote improvement and design action strategies for quality water supplies in compliance with national standards.

9.12.1.2 QUANTITY

Along with quality, quantity of supplied water to the community plays an important role for maintenance and improvement of public health. Personal and domestic hygiene greatly depends on per capita quantity of water supply to the consumers. In case of inadequate quantity of water supply, community may use alternate source of water, some of which may be not be safe and affect the public health.

9.12.1.3 COVERAGE

Coverage, from the point of view of the water supply agency, is expressed as the percentage of the total population served; it may be by domestic connection, by public standposts, and by point sources such as wells, handpumps and springs.

Therefore, it is essential to undertake wider survey of the various water sources, the estimated population served by each source, and relative risk associated with each of source. Such information is a useful guideline for water supply program and funding strategies.

9.12.1.4 COST

Cost plays a vital role for adequate quality water supply. In periurban areas as well as some pockets of urban and metropolitan cities, water is purchased from vendors to cater the shortage of water supply, and in such cases the public health is at risk. As the cost involved in monitoring is very little in comparison to total cost of operation and maintenance, there should not be any financial restraint for this activity.

9.12.1.5 CONTINUITY

In most of the piped water supply system, continuous 24 hrs water supply is not feasible due to constrain of many factors. Generally twice a day water supply at full pressure to consumers is adequate; keeping the main line charged for 24 hrs to take care of in pipe-recontamination, which may be potentially hazardous to the consumers. Surveillance data regarding bacteriological analysis at non-peak hours is a good indicator of the in-pipe recontamination due to leakage.

Household storage is necessary for intermittent water supply, which may lead to an increase risk of contamination during such storage and associated handling. In such cases surveillance data on hygiene and subsequently hygiene education is important.

Information collected during surveillance will be of greater use for planning of hygiene awareness program.

9.13 DATA INTERPRETATION

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

9.13.1 ASSESSMENT OF SANITARY SITUATION

Sanitary surveillance data generates the information regarding specific points of risk to the water supply. Such information can be used in various ways to facilitate the improvement of community water supplies.

Sanitary inspection data interpretation can be used to:

1. Identify most important source(s) of pollution amongst the number of noted potential sources.
2. Identify simple remedial measures that can be undertaken on the sight or at local level.
3. Identify recurrent problems, which require repeated remedial action and define strategies, which provide permanent solution to the problem, which may need external assistance.
4. Pinpoint the importance of adequate training requirement related to water supply practices in the locality or region concerned.

9.13.2 ASSESSMENT OF MICROBIOLOGICAL WATER QUALITY

Microbiological quality data can be divided into number of categories depending on the level

of contamination associated. *Table 9.1* below shows the suggested classification scheme based on increasing order of magnitude of faecal contamination. Suggested color scheme will be useful for pictorial inspection forms.

The level of faecal contamination may vary widely between successive samples due to seasonal influence such as rainfall where water supplies are unchlorinated. In piped water supply, the samples taken at various points in the whole system sometimes may defer in water quality. The point showing, higher faecal coliform count (>100/100ml) is a sure indication of a sewer water contamination, which may be due to cross contamination or caused by leak in the pipe line. Sanitary inspection data may support the suspicion. Remedial action should be taken immediately.

TABLE 9.1: EXAMPLE OF CLASSIFICATION AND COLOUR-CODE SCHEME FOR THERMO-TOLERANT COLIFORM OR E. COLI IN WATER

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

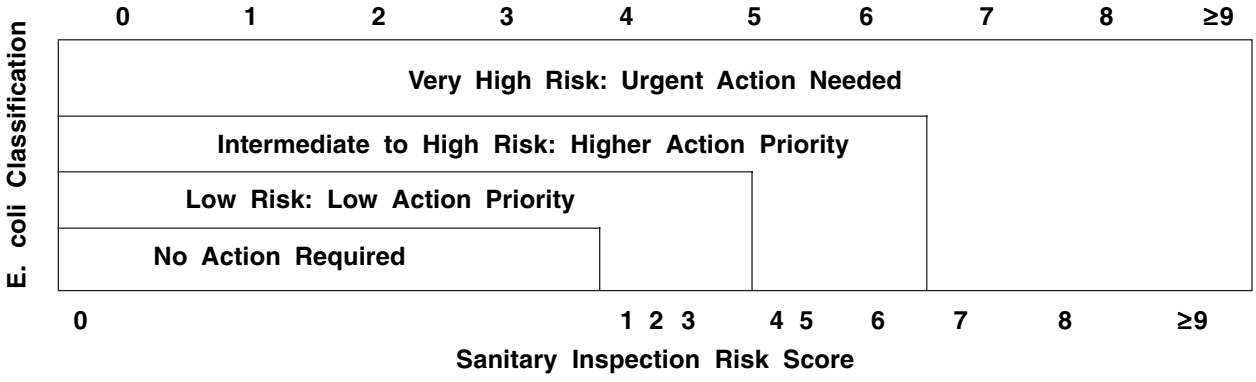
9.13.3 RISK ASSESSMENT

Microbiological analysis represents the single time moment whenever sanitary inspection takes account of the previous history as well as the present situation. Therefore, the examination of the faecal grading together with the sanitary inspection risk score gives a meaningful risk assessment.

Fig. 9.1 illustrates risk analysis keeping in view combined faecal coliform grading and sanitary inspection risk score.

It is expected that greater risk of contamination is likely to be associated with higher grade of contamination. However, a high sanitary risk score associated with low level of faecal contamination still requires urgent action, as it indicates the outburst of contamination any time and preventive action is needed immediately.

FIG. 9.1: EXAMPLE OF ASSESSMENT OF PRIORITY OF REMEDIAL ACTIONS BY RISK ANALYSIS SANITARY INSPECTION RISK SCORE



ANNEXURE 9.1

WATER RELATED DISEASES AND PREVENTIVE STRATEGIES

Classification	Transmission	Examples	Preventive Strategies
Water-borne (Water-borne diseases can also be washed)	Disease is transmitted by indigestion (Faecal – Oral route)	• Diarrhoea • Cholera • Typhoid • Hepatitis (A & E)	- Improve quality of drinking water. - Prevent casual use of other unimproved sources. - Improve sanitation.
Water washed (Water scarce)	• Infections of the intestinal track. • Skin or eye infections. • Infections caused by lice or mites.	• Scabies • Trachoma • Conjunctivitis • Amoebiasis • Giardiasis	- Increase water quantity. - Improve accessibility and reliability of domestic water supply. - Improve hygiene. - Improve sanitation.
Water based	The pathogen spends part of its life cycle in an animal, which is water based. The pathogen is transmitted by indigestion or by penetration of the skin.	• Guinea worm • Schistosomiasis	- Decrease need of contact with infected water. - Control vector host populations. - Improve quality of water (for some types) - Improve sanitation (for some types)
Water related Insect-vector	Spread by insects that breed or bite near water.	• Malaria • Filariasis • River blindness	- Improve surface water management. - Destroy insect breeding sites. - Use mosquito netting. - Use insecticides

Source: 'Water – Quality or Quantity?', "Running Water", International Technology Publication 1999, Page 77.

ANNEXURE 9.2

FUNCTIONS AND RESPONSIBILITIES OF AGENCIES FOR WATER QUALITY MONITORING AND SURVEILLANCE

Agency	Function	Responsibilities
Surveillance Agency 1. Ministry of Health/Rural Development 2. State PHED/Rural Development 3. Local Health Authority, CMO/Health Officer 4. Pollution Control Board	Surveillance of drinking water quality	- To ensure that the drinking water is free from heath hazards. - To find out what is wrong. - Assist in setting things right for both rural and urban systems.
Water Supplying Agency 1. State PHED/Water Boards/Urban Development 2. Urban Local Bodies/Authority 3. Autonomous Agencies	Supply of potable water	- To provide water in sufficient quantity and potable quality to the population at sufficient pressure.
Pollution Control Board, Central/State	Controlling pollution at water source	- To protect the raw water sources from being unduly polluted at Country/ State level.

ANNEXURE 9.3

SUGGESTED WATER QUALITY MONITORING LABORATORY NETWORK AND THEIR ACTIVITIES

S.N.	Level	Activities
1.	**Basic laboratory** a. Primary health centre/Village level	1. Residual chlorine 2. Turbidity 3. Priority parameters as per local water quality problems, preferably through field kits.
	b. Municipal/District level (Plant capacity > 200 mld)	1. Bacteriological tests (Routine) 2. Physico-Chemical tests (Routine) 3. Biological tests (Routine) 4. Other laboratory testing works
2.	**State/Regional level laboratory**	1. Bacteriological tests (Advanced) 2. Physico-Chemical tests (Advanced) 3. Biological tests (Advanced) 4. Other laboratory testing works

Note: For the capacity less than 200mld, Refer to Manual on Water Supply and Treatment, III Edition (Revised and up dated), 1999.

ANNEXURE 9.4a

SUGGESTED LABORATORY SERVICE INFRASTRUCTURE FOR MONITORING WATER QUALITY

S.No.	Level	Minimum Recommended Staff	Remarks
1.	**Basic Laboratory** a. Primary Health Center/Village Level	1. Lab. Assistant/Technician 2. Lab. Attendant	For routine bacteriological and physico-chemical tests, the samples should be sent to municipal/district level laboratory periodically.
	b. Municipal/District Level (Plant capacity >200 mld)	1. Chief Analyst 2. Chemist 3. Bacteriologist 4. Assistant Chemist 5. Lab. Assistant/Technician 6. Lab. Attendants 7. Driver 8. Helper	Wherever Water Treatment Plant Laboratory is existing
2.	**State/Regional Level Laboratory**	1. Chief Analyst (Higher Scale) 2. Chemist 3. Bacteriologist 4. Biologist 5. Assistant Bacteriologist 6. Assistant Biologist 7. Lab. Assistant/Technician 8. Lab. Attendants 9. Driver 10. Helper	

Note: 1. Kindly refer to Manual on Water Supply and Treatment, III Edition, May 1999.
2. The level and the no. of the personnel shall be decided by the respective agencies depending on magnitude of problems and resources available.

ANNEXURE 9.4b

SUGGESTED WATER QUALITY SURVEILLANCE TEAM

S.No.	Level	Minimum Recommended Staff	Remarks
1.	**Basic Laboratory** a. Primary Health Center/Village Level	3. Health/Sanitary Inspector 4. Laboratory Assistant/Technician 5. Lab. Attendant	For periodical testing, samples shall be sent to District or State Health Laboratory
	b. Municipal/District Level (Plant capacity >200 mld)	A – Class (5-10 lakhs or greater) 1. Senior Health Officer 2. Zonal Health Officer 3. Chief Health/Sanitary Inspector 4. Health/Sanitary Inspector 5. Chemist 6. Bacteriologist 7. Lab Assistant 8. Lab Attendant	
		B – Class (1-5 lakhs) 1. Health Officer 2. Health/Sanitary Inspector 3. Chemist 4. Lab. Assistant/technician 5. Lab. Attendant	
		C – Class (< 1 lakhs) 1. Chief Health/Sanitary Inspector 2. Health/Sanitary Inspector 3. Lab. Assistant/technician 4. Lab. Attendant	For periodical testing, samples shall be sent to District or State Health Laboratory
2.	**State/Regional Level Laboratory**	Staff as per existing State Medical and Health Deptt. norms	

Note: 3. The level and the no. of the personnel shall be decided by the respective agencies depending on magnitude of problems and resources available.

ANNEXURE 9.5a

CHECK POINTS

Type of facility **Protected Spring Source**

1. General information: Health Center .....

   Village .....

2. Address .....

3. Water authority/community representative signature .....

4. Date of visit .....

5. Water sample taken ..... Sample no. ..... Total Coliform/faecal Coliform .....

S.N.	Particulars for Assessment	Risks
1.	Is the spring source unprotected and therefore open to surface contamination?	Y/N
2.	Is the masonry protecting the spring source faulty?	Y/N
3.	If there is a spring box, is there an unsanitary inspection cover in the masonry?	Y/N
4.	Does the spring box contain contaminating silt or animals?	Y/N
5.	If there is an air vent in the masonry, is it unsanitary?	Y/N
6.	If there is an overflow pipe, is it unsanitary?	Y/N
7.	Is the area around the spring unfenced?	Y/N
8.	Can animals have access to within 10 m of the spring source?	Y/N
9.	Does the spring lack a surface water diversion ditch above it or if present, is it nonfunctional?	Y/N
10.	Are there any latrines uphill of the spring?	Y/N

Total score of risks……../10

Contamination Risk Score: 9-10 = Very High, 6-8 = High, 3-5 = Intermediate, 0-2 = Low

Results and Recommendations

The following important points of risks were noted: ..... (list no. 1-10)
And the authority advised on remedial action

Name and Signature of Inspector: .....

ANNEXURE : 9.6a

SUGGESTED MINIMUM SAMPLING FREQUENCY AND NUMBER FROM DISTRIBUTION SYSTEM

Population Served	Maximum interval between successive sampling	Minimum no. of samples to be taken from entire distribution system
Upto 20,000	One month	One sample per 5,000 of population per month
20,000-50,000	Two weeks	
50,000-1,00,000	Four days	
More than 1,00,000	One day	One sample per 10,000 of population per month

ANNEXURE : 9.6b

SUGGESTED MINIMUM ANNUAL FREQUENCY OF SANITARY INSPECTIONS

Source and mode of supply	Community	Water supply agency	Surveillance agency
Dug well (without windlass)	6	–	1
Dug well (with windlass)	6	–	1
Dug well (with hand pump)	4	–	1
Shallow and deep tube well with hand pump	4	–	1
Rainwater catchment	4	–	1
Gravity spring	4	–	1
Piped supply: ground water sources (springs and wells) with or without chlorination	–	1	1
Treated surface source of piped supply, with chlorination			
< 5,000 population	12	1	1
5,000-20,000 population	–	2	1
20,000-50,000 population	–	12	1
50,000-1,00,000 population	–	24	2
>1,00,000 population	–	48	2

ANNEXURE : 9.6c(1)

SUGGESTED MINIMUM SAMPLING FREQUENCY FOR WATER QUALITY CONTROL MONITORING

S.L.	Size and Source	Frequency	PARAMETERS					Heavy Metals & Pesticides	Problem Parameters As, Cr^{+6}, Fe & Mn, Fluoride	Remarks
			Residual Chlorine	Physical	Chemical	Bacteriol-ogical	Biological			
1	2	3	4	5	6	7	8	9	10	11
1.	< 50,000 Population	i. Daily	√							From source & distribution system
	a. Ground Water (Tube Well, Sanitary Well, Bore Well)	ii. Quarterly		√	√	√			√	
	b. Ground Water (Hand Pump)	Twice a year		√	√	√			√	In summer & rainy season
2.	>50,000 upto 1,00,000 Population	i. Daily	√							From source and distri-bution system
	a. Ground Water (Tube Well, Sanitary Well, Bore Well)	ii. Monthly				√				
		iii. Quarterly		√	√				√	
	b. Ground Water (Hand Pump)	Twice a year		√	√	√			√	In summer & rainy season
3.	>1,00,000 Population a. Ground Water (Tube Well, Sanitary Well, Bore Well)	i. Daily	√							From source & distribution system
		ii. Monthly				√				

1	2	3	4	5	6	7	8	9	10	11
		iii. Quarterly		√	√				√	
		iv. Annually						√		
	b. Ground Water (Hand Pump)	i. Twice a year		√	√	√			√	In summer & rainy season
		ii. Annually						√		
4.	Surface water a. Raw water, source and intake point	i. Daily		√	√					
		ii. Weekly				√				
		iii. Annually						√	√	
		iv. Occasi-onal (As & when required)					√			
	b. Sedimentation tank after clarifier	i. Daily		Turbidity only						
		ii. Weekly				√				
		iii. Occasi-onal (As & when required)					√			
	c. Filtered water	i. Daily		Turbidity only						
		ii. Weekly				√				
	d. Clear water storage reservoirs	i. Daily	√	√	√					
		ii. Weekly				√				
	e. Distribution system	i. Daily	√							
		ii. Weekly				√				
		iii. Monthly		√	√					

Note: 1. Refer to the Manual on Water Supply and Treatment, III Edition, Ministry of Urban Development, New Delhi, May 1999, Appendix 15.9, for minimum tests to be performed.

2. Parameters and frequency are general in nature and in case of special situations, they can be altered according to the local conditions by the local authority.

ANNEXURE : 9.6c(2)

SUGGESTED MINIMUM SAMPLING FREQUENCY FOR WATER QUALITY CONTROL SURVEILLANCE

S.L.	Size and Source	Frequency	PARAMETERS					Heavy Metals & Pesticides	Problem Parameters As, Cr^{+6}, Fe & Mn, Fluoride	Remarks
			Residual Chlorine	Physical	Chemical	Bacteriol-ogical	Biological			
1	2	3	4	5	6	7	8	9	10	11
1.	< 50,000 Population									From source & distribution system
	a. Ground Water (Tube Well, Sanitary Well, Bore Well)	i. Weekly	√							
		ii. Twice a year		√	√	√			√	In summer & rainy season
	b. Ground Water (Hand Pump)	Twice a year		√	√	√			√	Preferably in summer
2.	>50,000 upto 1,00,000 Population									From source and distri-bution system
	c. Ground Water (Tube Well, Sanitary Well, Bore Well)	i. Weekly	√							
		ii. Quarterly				√				
		iii. Twice a year		√	√				√	In summer & rainy season
	d. Ground Water (Hand Pump)	Annually		√	√	√			√	Preferably in summer
3.	>1,00,000 Population									From source & distribution system
	e. Ground Water (Tube Well, Sanitary Well, Bore Well)	i. Weekly	√							
		ii. Quarterly				√				

1	2	3	4	5	6	7	8	9	10	11
		iii. Twice a year		√	√				√	In summer & rainy season
		iv. Annually						√		
	f. Ground Water (Hand Pump)	Twice a year		√	√	√		√	√	In summer & rainy season
4.	Surface water g. Raw water, source and intake point	i. Fortnig-htly				√				
		ii. Quarterly		√	√					
		iii. Annually						√	√	
		iv. Occasi-onal (As & when required)					√			
	h. Filter	i. Monthly		Turbidity only		√				
	i. Clear water storage reservoirs	ii. Fortni-ghtly	√			√				
		iii. Monthly		√	√					
	j. Distribution system	i. Weekly	√							
		ii. Monthly iii. Quarterly		√	√	√				

Note: Refer to the Manual on Water Supply and Treatment, III Edition, Ministry of Urban Development, New Delhi, May 1999, Appendix 15.9, for minimum tests to be performed.
Parameters and frequency are general in nature and in case of special situations; they can be altered according to the local conditions by the local authority.

ANNEXURE 9.7

REMEDIAL AND PREVENTIVE MEASURES FOR PROTECTION OF WATER SUPPLIES

Source and Mode of Supply	Evidence or Information available	Immediate remedial measures available	Preventive action
1	2	3	4
Open dug wells	Pollution usually expected to occur	a. Clean well if necessary and disinfect with bleaching powder. b. Boiling of drinking water, use of chlorine tablets or bleaching powder and/or filters in the home is recommended.	Well is protected by raising a pucca wall all around and cover. It is preferable to provide hand pumps and promote community education and participation.
Unpipped supplies from tube well or hand pumps	Findings of sanitary inspection, unsatisfactory localized epidemic of enteric infection	Confirm bacteriological quality analysis and if necessary, recommend use of disinfectant (Bleaching powder) or a. Recommend use of boiling water, chlorine tablets or bleaching powder and/or filters in the home b. Confirm bacterial quality c. Conduct a detailed sanitary inspection to ensure effectiveness of remedial measures against shortcomings found earlier	Eliminate pollution source and/or repair tube wells and/or hand pumps if found necessary in sanitary inspection. a. Promote community education and participation. b. Feedback information on remedial action and sanitary survey results to the water supply agency, to check whether the remedial actions followed are appropriate.
Untreated pipe water supply	Findings of sanitary inspection unsatisfactory	Confirm bacteriological quality and if necessary recommend boiling of water or use of disinfectant or filters	Eliminate pollution sources and/or repair systems if found necessary in sanitary inspections
	Unsatisfactory bacteriological quality of water at source	a. Disinfect (chlorinate) water supply if feasible, recommend boiling or use of chlorine tablets at home b. Conduct a detailed sanitary inspection and correct the shortcomings found	Protect the source and its catchment area

1	2	3	4
	Unsatisfactory bacteriological quality of water in the distribution system	a. Disinfect (chlorinate) water supply or recommend boiling or use of chlorine tablets at home b. Conduct a detailed sanitary inspection of distribution system and rectify the shortcomings	Frequent and improved supervision of the distribution system and prompt repair and good maintenance are essential, especially for intermittently operated system.
	Localized epidemic of enteric infection	a. Take samples for bacteriological analysis. Without waiting for its result, immediately chlorinate water supply so that the tail end has minimum 0.5 mg/l of free residual chlorine. Recommend boiling and use of chlorine tablets at home b. Conduct a detailed sanitary inspection of source and distribution system and rectify the shortcomings found.	
Treated pipe water supply	Findings of sanitary inspection of source, treatment plant, distribution systems is unsatisfactory	Confirm bacteriological quality and if necessary, recommend boiling or use of disinfectant (Bleaching powder) home	a. Frequent and improved supervision of the whole system is necessary, careful operations and maintenance is essential, especially for intermittent systems. b. Ensure routine sanitary inspections and feedback information to the water supply agencies.

1	2	3	4
	Unsatisfactory bacteriological quality of water after treatment or in the distribution system	a. Ensure 0.5 mg/l free residual chlorine at tail end. Recommend boiling and use of chlorine tablets b. Conduct a detailed sanitary inspection of whole water supply system and rectify the shortcomings found	a. Frequent and improved supervision of the whole system is necessary, careful operations and maintenance is essential, especially for intermittent systems. b. Ensure routine sanitary inspections and feedback information to the water supply agencies.
	Localized epidemic of enteric infection	a. Take samples for bacteriological analysis. Without waiting for its result, immediately chlorinate water supply so that the tail end has minimum 0.5 mg/l of free residual chlorine. Recommend boiling and use of chlorine tablets at home b. Conduct a detailed sanitary inspection of source and distribution system and rectify the shortcomings found.	a. Eliminate pollution source b. Frequent and improved supervision of the whole system is necessary, careful operations and maintenance is essential, especially for intermittent systems. c. Ensure routine sanitary inspections and feedback information to the water supply agencies.