Application of Corrosion Control Techniques in Municipal Water and Waste Water Engineering

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INTRODUCTION

The water and waste water treatment plants as well as the water distribution and sewage collection pipes are subjected to corrosion resulting in reduced efficiencies and even breakdown in extreme cases. The techniques of corrosion control are perhaps better known to the chemical industry and it is possible to adopt them in the field of public health engineering also. It is necessary for public health engineer to adopt proper remedial measures against corrosion in order to avoid major repairs, replacement and the resulting breakdown in the essential public utilities. The purpose of this paper is to acquaint the public health engineer with the various corrosion problems in his field, by indicating the problem areas and the available methods of prevention and cure.

WATER TREATMENT PLANT

A water treatment plant usually consists of chemical dosing, flash mixing, flocculation and sedimentation, sand filtration and chlorination. All these treatment units are subjected to corrosion due to the nature of raw water to be handled, the chemicals used for its treatment and also due to the type of materials used. The basic structural material in water treatment plant is reinforced concrete. Since concrete is relatively inert, it is not subjected to any appreciable corrosion except where acids, alkalies and other corrosive chemicals are handled either in powder form or as solutions.

Intake structure

Screens at the intake are generally coarse screens consisting of flat or round steel bars placed vertically or slightly inclined. In waters of low pH these are subjected to corrosion. In any case it is desirable to have the screens so mounted that they can be replaced easily and proper painting should be done at regular intervals. If screens are made movable in vertical direction, painting them will be an easy job. Finer meshes, wherever provided should be preferably in copper, stainless steel or other material which is cathodic to rest of the frame work.

Chemical Feeding

Chemicals are employed for a variety of purposes in water treatment, namely coagulation, disinfection, taste and odour control, pH correction, etc. The chemicals more commonly used in water and waste water treatment are shown in table I along with their handling requirements. The materials which are in contact with these chemicals must be resistant to their corrosive action.

The feeding of chemical involves its storage, handling, proportioning and conveying. Chemical storage tanks or bins for bulk storage of chemical should be lined with appropiiate material, such as, PVC, glass, stoneware or acid proof bricks. Since some chemicals are non-corrosive only in dry state, it should be ensured that their storage space is kept completely moisture proof. Appropriate type of piping should be used for conveying chemicals, the types available include lead, copper, stoneware, rubber and PVC. While using any pipe, it should be ensured that the pipe joints are made well and are equally resistant to corrosion.

It may be stated that lead pipe is satisfactory for alum, ferrous sulphate and acid solutions in general. Lead lined pipe is more rigid than lead pipe and is equally suitable for carrying ferrous sulphate and acidic solution. Iron and steel are suitable for alkaline chemicals while copper alloys are attacked by alkalies and should not be used. The valves on pipelines carrying alum solution and other corrosive chemicals should not be ordinary gun metal valves but some corrosion resistant material should be used. The PVC and Saunder's valves (glass lined) have given trouble-free service in many installations.

The alum solution tank needs proper protection from alum solution which is strongly acidic (pH of 5 % solution is between 3.2 and 3.5). It is observed that in many water treatment plants, the alum solution tank is of ordinary reinforced concrete without any acid resistant treatment. This has resulted in rapid destruction of concrete giving constant maintenance problem. It is not sufficient to protect the floor and sidewalls of alum solution tank by simple coating with acid resistant paint and it is recommended that the alum solution tanks should be lined with acid resistant bricks, tiles, PVC or fibre-glass.

TABLE 1

Chemicals commonly used in water and waste water treatment

Chemical	Characteristics	Suitable handling materials
1. Filter alum or aluminium sulphate	Acid and corrosive pH of 5% solution is 3.2 — 3.5	In dry form, iron or steel containers. In solution, vessels lined with pvc, fibre glass or acid resisting tile.
2. Hyderabad lime or calcium hydroxide	Alkaline and very encrusting	Cement, rubber, iron and steel vessels.
3. Dolomite lime or calcium oxide	As above	As for hydrated lime.
4. Chlorine	Acid and very corrosive when wet	In dry form black iron, copper, steel wet gas in pvc, stoneware, glass, hard rubber, silver or teflon.
5. Ferric chloride	Hygroscopic and corrosive	Glass, rubber, stoneware, acid resistant bricks.
6. Na-hexameta phosphate	Acidic	Hard rubber, plastic, stainless steel.

Sedimentation basins

In modern water treatment plants the sedimentation basins are usually of circular type. These basins are provided with slow moving scrapers for scraping the bottom sludge and to transport it to one point, from where the sludge can be withdrawn. These scraper blades are constantly under water and should therefore be adequately protected from corrosion by giving few coats of anticorrosive paint and providing a minimum thickness of $\frac{1}{4}$ inch. In order to avoid galvanic corrosion, it is necessary to have the entire scraper arm made of single material. For instance, using aluminium squeegees on a steel scraper arm will be disastrous since aluminium will be anodic to steel and will be eaten away in short time. It is better to use brass squeegees or at least have them of the same material as of the rest of the scraper arm. Since sedimentation is an important step in water treatment, the clarifier should remain trouble free at all times. It is, therefore, necessary to see that the scraper arm is adequately protected from corrosion by proper selection of material and timely painting. Cathodic protection can also be conveniently applied in this case either by sacrificial anode or impressed current.

Rapid sand filters

In the rapid sand gravity filters the units most susceptible to corrosion are the under-drainage system consisting of manifolds, laterals and the nozzles, the compressed air piping and other appurtenant works. The following underdrains are commonly used :

Perforated pipe underdrains : In this system the manifolds are mainly made of cast iron or reinforced concrete. For laterals next to cast iron, copper, asbestos cement and hard plastics are used. Once installed, the underdrains are relatively inaccessible and hence if the water is aggressive, the underdrains should be of corrosion resistant material or adequately protected from corrosion. Erosion due to high velocity can be minimised by lining the holes with brass or bronze bushing. However dezincification of brass at high velocity of flow is a known phenomenon. This may be avoided by adding tin in the alloy.

Pipe and strainer underdrains : In this system strainers are commonly set on top of the laterals while manifold and laterals are embedded in lean, easily removable concrete. The failure of a strainer may result in loss of filtering material into the underdrainage system and thereby clogging the laterals and the manifold. Strainers must therefore be made with corrosion resistant material of sufficient structural strength. Normally brass or plastic is recommended as strainer material.

False bottom and strainer underdrains : False bottoms are commonly made in sections 0.6—1 m^2 of steel, asbestos cement or reinforced concrete, supported by ridges, short columns or even bolts cast into the reinforced concrete bottom of the filter box. Strainers made of plastics are cheap in first cost and also corrosion resistant.

Porous plate underdrains : These are made of sections 0.6—1 m^2 and are supported at a distance of about 0.15—0.3 m above the bottom of the filter box. Porous plates are normally made of vitrified crystalline aluminium oxide granules 6—10 mesh, while in European countries no-fines concrete is used. PVC gasket is fitted round each plate and stainless steel bolts and nuts are used to hold down the plates. This material is not readily available in India. Sometimes it is advocated to construct filter and appurtenances of materials such as hard plastics so that back washing the filter with hydrochloric acid, chlorine solutions, alkalies etc. is possible in order to avoid clogging due to deposit of calcium, magnesium, iron or manganese etc.

Wash water gutters : The filters are sometimes made with steel, wrought and cast iron, aluminium, monel metal, etc., in order to save thickness and to keep the filter box height to a minimum. However, in India, asbestos cement or reinforced concrete gutters may be preferred to the metallic gutters.

The Pipe gallery : Below the operating floor of the filters the piping system is one of the neglected units in filtration plants. Condensation of moisture often poses a difficult problem in the pipe gallery. In painting and by adequate the corrosion of piping is accelerated. Piping should be well protected by prevented. Floor drains ventilation. Accumulation of moisture on the pipe surfaces should be this moist atmosphere with sump and sump pumps for the discharge of collected drainage are essential in this area.

The rate of flow controllers and the piping, valves, gates and metres etc. are all subjected to humid atmosphere which is very conducive to corrosion. It may be desirable to use more cathodic material at the crucial points. It is also observed that electrically operated controls are most affected in the moist atmosphere. Hydraulically operated equipment gives more trouble-free service and may therefore be preferred.

Wash water tanks : The wash water required for washing the filters is usually supplied from an overhead reservoir located near the filter house. In many installations, these reservoirs are of mild steel

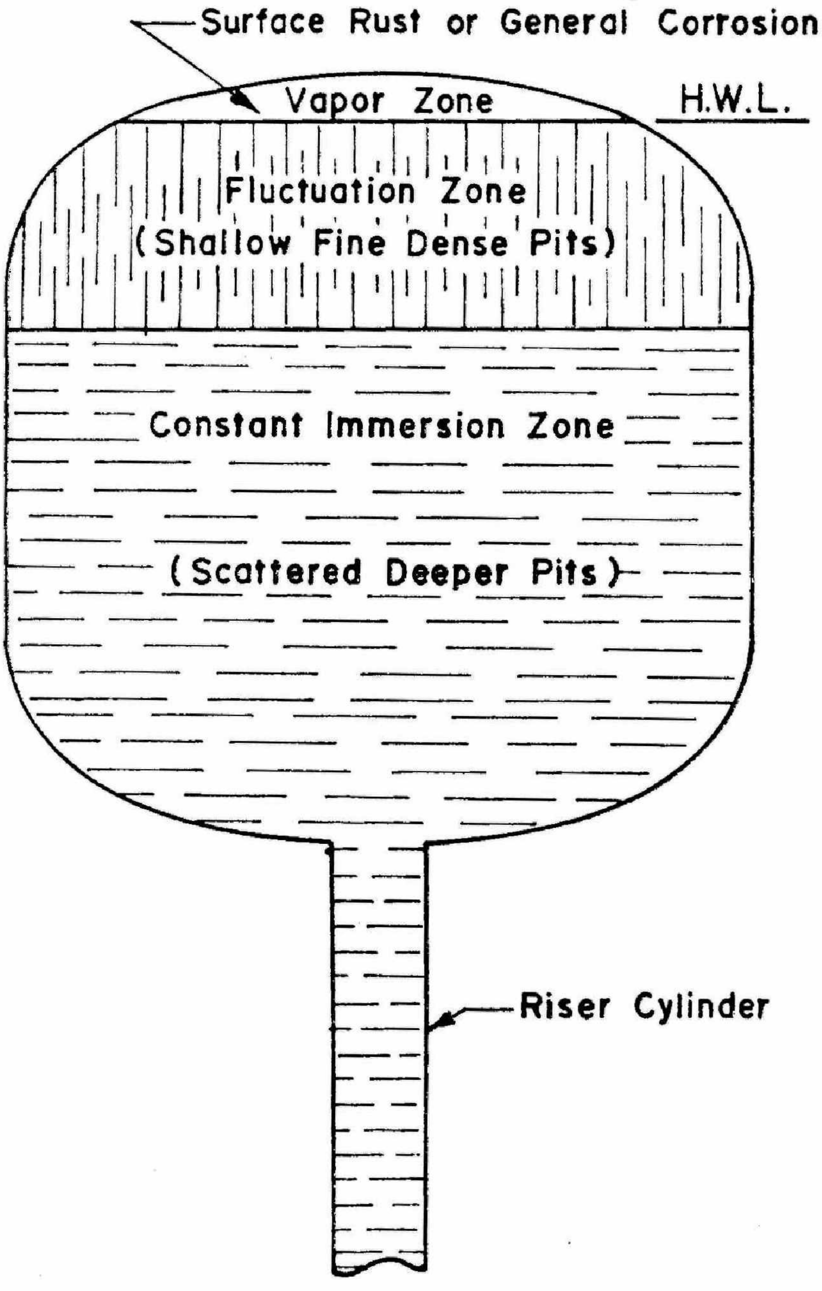

FIG. 1

plates rivetted or welded together. These steel tanks are subject to external as well as internal corrosion. The external corrosion is due to atmospheric conditions while the internal corrosion is due to the water stored in it. Pitting is the most serious type of corrosion in the storage tanks. It is more pronounced when mill scale is not removed from the steel plates. Since it is cathodic to steel, any break in the scale acts as anode and the corrosion reactions are accelerated.

Interior corrosion is generally characterised by the exposure zone, fluctuation zone, and constantly immersed zone (fig. 1). On the tank surfaces above the water line corrosion is not serious except where structural details make protection with paint difficult. In old riveted tanks the roof plates will corrode along the riveted lap joints. In water fluctuation zone also the corrosion is in the form of pitting. In this fluctuation zone a build up of rust scale is often encountered. In the constantly immersed surface, scattered irregular pits will be formed. These pits may form perforations in the metal and give leakage ultimately.

It is possible to give complete protection to steel storage tanks from corrosion by cathodic protection in combination with good quality corrosion resistant paints. The cathodic protection will serve as an adjustable means of corrosion control which would otherwise occur where coating is not perfect due to bad workmanship or tank geometry. Cathodic protection can be in the form of sacrificial anode or impressed current.

In RCC and prestressed concrete tanks also, the cathodic protection can be utilised to prevent corrosion of steel bars, though it is not done usually in India. It is also good practice to give greater cover to reinforcement steel on the water side.

Chlorinator

Chlorination is by far the most widely used method of water disinfection. It is a paradox that the chlorine which is used for corrosion control by preventing algae and other biological growths in water distribution system is itself responsible for corrosion in water treatment plants if handled improperly. Chlorine in dry form is not corrosive, but when in moist air or when it is added to hot water in solution chlorinators, it is extremely corrosive.

It is recommended that vacuum type chlorinators are used so that any chlorine leakage will be inside the dosing system and no chlorine will escape to the atmosphere. Corrosion of the dispensing apparatus is of very common occurrance and it is attributed to very minute leakage of chlorine. In case any slight leakage is suspected, the exterior parts of the chlorine apparatus should be covered with some grease such as petroleum jelly to avoid further damage to chlorine handling equipment. Chlorinators and cylinders of chlorine should be housed separately and not in rooms used for some other purposes. Adequate ventilation should be provided to give frequent air changes and the air outlet should be near the floor.

Clear water storage tanks are normally underground reinforced concrete tanks and are not subject to corrosion. The same remarks apply here for corrosion protection as mentioned under wash water tanks.

INTERNAL CORROSION IN DISTRIBUTION SYSTEM

Internal corrosion in water distribution system merits more attention since the major investment for any water supply system is in its distribution system. The corrosion of the interior surfaces of water mains results in reduced carrying capacity, red water and taste and odour problems. Improper filtration will result in the floc and turbidity passing through the filters and the deposition on the pipe walls, and this can occur in every type of pipe material. In severe cases the deposit may reach such a thickness that the diameter may be reduced considerably. Loss in carrying capacity is also possible due to deposition of organic growth or living organisms in raw water.

The effect of corrosion in reducing the carrying capacity of the pipeline is measured by determining the coefficient of capacity 'C' in the Hazen Williams formula.

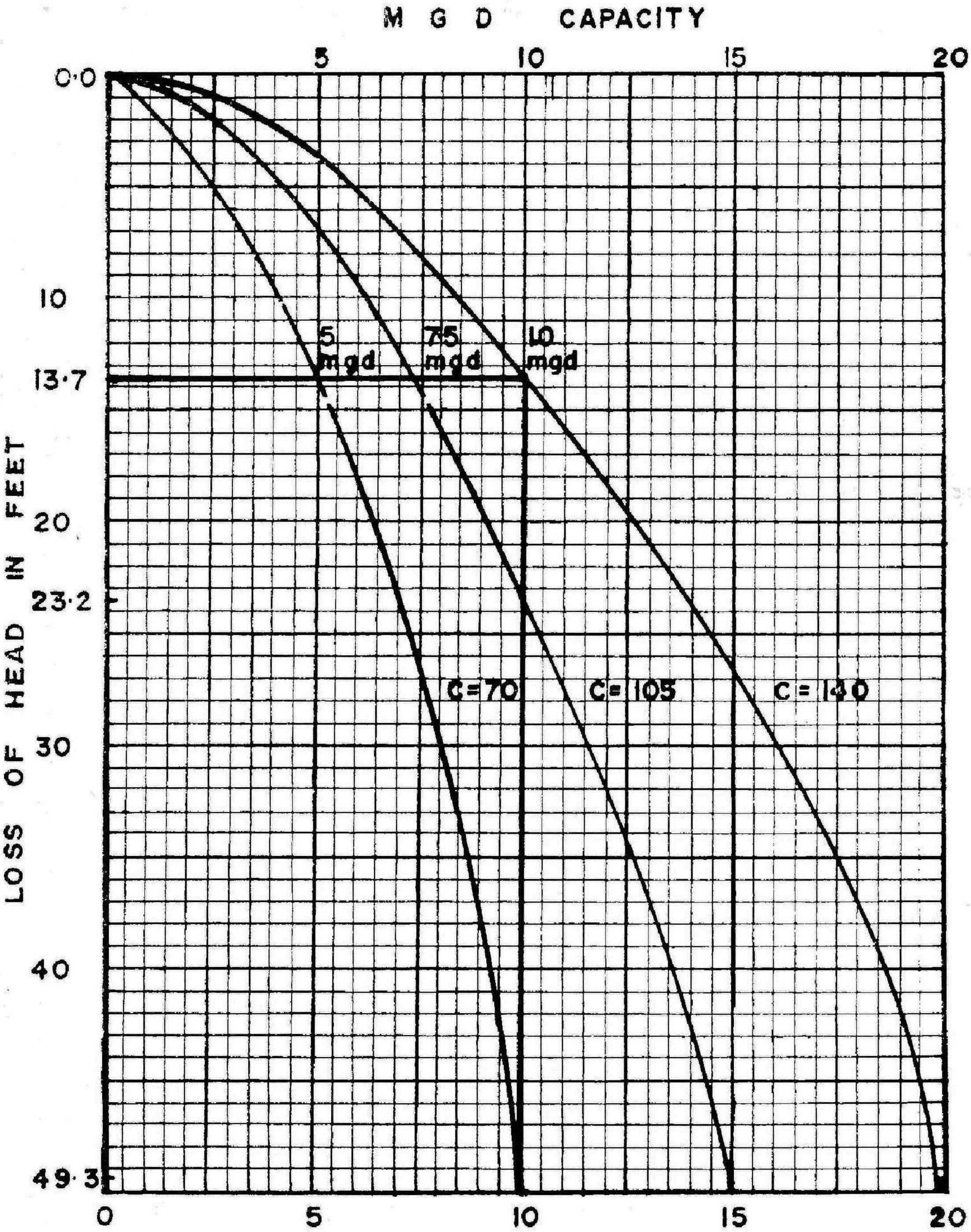

FIG. 2 HEAD CAPACITY CURVE FOR 5000 FT. OF 24 INCH PIPE

Taking case of a cast iron pipeline 5000 ft. in length, 24" in diameter and required to pump up to 10 mgd of water per day, the head loss for 'C' values of 140, 105 and 70 for different age and other physical conditions of pipe, can be calculated and shown graphically (Fig. 2).

It will be seen from the figure that to pump 10 mgd water, the head loss for different 'C' values will be as under :

C = 140,	hf = 13.7 ft.
C = 105,	hf = 23.2 ft.
C = 70,	hf = 49.3 ft.

The seriousness of the problem can be appreciated if we consider the fact that 50% reduction in 'C' value results in 3.61 times the original head loss. The 50% reduction in 'C' value is by no means an extreme case. In U.S.A., it has been shown that reduction in 'C' value for waters of different pH values can be as high as 85% over a period of 30 years.

Observed Reduction in carrying capacity of C.I. mains over a period of 30 years

pH value of water	Loss in carrying capacity
6.0	85%
7.0	45%
8.0	30%

The reduction in C value in the pipelines in India is expected to be appreciable and this has been confirmed by a recent study in Maharashtra which reports values ranging from 30% to over 90% reduction in C value. In Bombay also several pipes have shown 'C' values of only 45-55. The amount of head loss in these existing installations can be very well imagined. The net result is high operating cost of pumping.

Control of internal corrosion of pipelines

The methods of controlling internal corrosion in pipelines due to water include the following :

1. Removal of oxygen
2. Removal of free carbon dioxide
3. Deposition of free protective coating
4. Coating the inside surface with some sort of passive protective coating such as paint
5. Chlorination to prevent biochemical action especially in dead ends of distribution system.

Removal of oxygen : This is achieved either by exposing water to partial vaccum and/or by adding a chemical like sodium sulphite. Both these methods have special application for boiler water supplies on small scale and would not be feasible for municipal supplies.

Removal of free carbondioxide or deposition of calcium carbonate :

This treatment in fact is the one for saturation of water with $CaCO_3$. This is achieved by removing the excess free CO_2 so that $CaCO_3$ is not dissolved but is available for deposition of film on pipe walls. Aeration alone is not enough for removal of CO_2 since this method can remove CO_2 upto 5 ppm only while waters with low alkalinity and 5 ppm free CO_2 can still be corrosive. The calculation of corrosiveness and the correct dose of chemical required can be obtained from the Langelier Index of water. The Langelier index of non-corrosive waters will be positive. In practice lime is used after filtration for corrosion control, and the control of this treatment is usually done by marble test. In addition to lime, soda ash, caustic soda, limestone beds etc. can also be employed. For waters low in mineral content addition of lime alone is not enough and addition of soda ash is also required.

Deposition of free protective coating: 'Calgon' or sodium metaphosphate and 'Nalco' or sodium pyrophosphate are of recent origin for corrosion prevention. It is believed that these phosphate compounds render the metal surface passive or coat them with a thin film. The effectiveness is limited to pH range of 5.2—10 and the chemical dose depends upon the surface area of piping relative to pumping. Therefore the size of system is an important factor in determining the dosage. Initially dosage of 5—10 ppm may be necessary for about 8 weeks after which it can be reduced to 1—2 ppm. During the period of initial application, frequent flushing of the distribution system is advocated. Metaphosphates are available as crystals and are non-corrosive when dry and the typical dry feed equipment can be used. The solutions are corrosive and non-corrodable containers should be used for handling.

Passive protective coatings : These include the following :

1. Paints and thin immersions or sprayed coatings
2. Thicker layers of bituminous base
3. Thicker bituminous layers with reinforcing inlays
4. Cement sheathing or casing
5. Modern plastic sheathings

The methods mentioned above are often adopted at the time of manufacture. It is often necessary to apply corrective measures of corrosion prevention in situ, particularly for replacing or repairing old pipe. The remedial measures include operating procedures such as flushing the lines to remove sediments and slimes. The cleaning of mains by mechanical methods is also effective and is being used in bigger Indian cities. It may be mentioned here that cleaning alone is not sufficient since it does not remove the cause of corrosion, and must therefore be followed by lining with cement mortar. Lining in situ prevents recurrence of corrosion, eliminates red water and also leakages. But it is unfortunately not yet being done in India.

SEWAGE & INDUSTRIAL WASTE TREATMENT PLANTS

The problem of corrosion is more severe in case of waste treatment plants. This is due to the fact that the nature of liquid to be handled in this case is more corrosive (low resistivity and chemically more active). It contains solids which are likely to cause abrasion in pump components thus removing the protective film and accelerating the corrosion process. The sewage as it approaches the plant may be stale or septic in which case it may have a low pH and contain sulphides from reduction of sulphates which will again promote corrosion. If detention periods in settling units are higher this will also result in increased acid conditions. Moreover, the component of mechanical and electrical equipment in case of waste treatment plants, is more than in case of water treatment plants and it is the mechanical and electrical equipment which is more susceptible to corrosion. The cost of mechanical and electrical equipment in a waste treatment plant can be anything between 30% and 45% of the total cost.

A waste treatment plant generally consists of screen and grit removal, primary and final settling tanks, sludge digesters, trickling filters or activated sludge treatment units and the various pumping units for pumping of raw sewage, settled sewage, digested sludge, etc. In case of certain industrial wastes acid or alkali neutralization or preaeration may also be necessary. The more important units from the corrosion point of view are the neutralisation tanks, settling tanks, the digesters and the activated sludge units, in addition to all pumps, and appurtenances. Screens and grit chamber equipment also need same consideration for corrosion prevention.

Neutralisation tanks

Where acidic or alkaline wastes are received they may have to be held first in equalisation tanks to balance out fluctuations in quality and quantity, followed by neutralisation of the resultant acidic or alkaline waste as necessary. In such cases the equalisation as well as neutralisation tanks may have to be provided in RCC with acid resistant lining of tiles or bricks laid in acid resisting stone or cement. The neutralising chemicals would need to be stored in acid or alkali resistant containers as described earlier, and the solutions led to the neutralizing tank by PVC piping.

Sedimentation tanks

The primary sedimentation tanks handle raw waste which is allowed to settle at the bottom. The bottom of the settling tank is scraped by mechanical scrapers in order to divert the sludge to a point from where it is withdrawn either continuously or periodically. The scraper arms and the squeegees are constantly immersed in sewage and are subjected to corrosion as desctibed earlier for water clarifiers. Moreover, sewage and most industrial wastes have much lower resistivity than water, which accounts for rapid corrosion. The specification for the steel used for the underwater mechanisms should be carefully drawn to ensure maximum protection from corrosion. It is normally specified that all the steel below liquid level shall be at least $\frac{1}{4}''$ thick. It is a good practice to keep all chains, bearings or brackets above the liquid surface. All castings in the driving mechanism should be of high grade cast iron.

It is possible to give cathodic protection to the scraper mechanism of the clarifier either by sacrificial anode or by impressed current. The choice of either of the method of cathodic protection will depend upon the comparative costs. In any case, the cost of such a protective measure will not be higher than the cost of good quality acid resistant paint.

Sludge Digestion

In sludge digestion tank, digestion of sludge is carried out under anaerobic conditions for a long period. During the normal functioning of the digester and more so during faulty operations various acids are produced, for a temporary period. The waste may contain appreciable quantity of sulphates due to seepage of sea water in coastal regions or due to industrial wastes. Under anaerobic conditions in digester the sulphate will be converted to hydrogen sulphide. The corrosion due to hydrogen sulphide is in fact due to sulphuric acid formed in presence of moisture. This will attack the digester walls and also the mechanical equipment to such an extent that breakdown may occur ultimately. It is recommended that the cement resistant to attack by H_2S, such as blast furnace slag cement, should be used in the construction of digesters.

It is observed that the draft tubes inside the digester are sometimes provided of mild steel. This is not a good practice since the life of such metallic tubes in the highly corrosive interior will be very limited. Hume or concrete pipes of thicker cross section are therefore recommended for use as draft tubes. Use of guy ropes inside the digesters should also be discouraged. Screw pumps are provided in the digester for proper circulation of the tank contents. The blades of this screw pump should be of corrosion resistant material such as phosphor bronze.

In many installations the sludge gas is collected and burnt or utilised for other purposes. If the gas contains H_2S, this will be very corrosive under moist conditions to the gas engines, gas meters and all the equipment and piping. Instances have been reported of serious corrosion due to H_2S in Bombay also. It is therefore necessary to remove H_2S by scrubbing in such cases.

Activated Sludge

In the activated sludge plant oxygen is provided to the sewage either by compressed air system or by surface aeration system. In the compressed aeration system the clogging of porous filter material is of frequent occurrence. Clogging can be either on the liquid side or on air side or on both the sides. Air side clogging may be due to corrosion inside the compressed air supply lines or dust in air drawn by the compressors. While the latter is controlled by provision of proper air filters, the former can be minimised only by the use of air supply pipelines of noncorrosive material. It is, therefore, important to have the air supply pipelines of non-corrosive material.

In the surface aeration system the simple type of aerators are more widely used in India. The conditions in the aeration tank are more conducive to corrosion since in addition to the corrosiveness of the liquid, oxygen is present to aggravate the situation. Proper material selection and coating are therefore necessary for protection of the exposed parts of the rotor. It may be mentioned here that the protective coating has to be applied at regular intervals since it is found that such coatings have very short life. PVC lining may not be easy to give due to shape of rotor while fibreglass lining can be applied to any irregular shapes.

Floating aerators : With the growing interest of various public health engineering authorities in low cost waste treatment methods, such as mechanically aerated lagoon and oxidation ditches, the use of floating aerators will increase. These floating aerators should be so mounted that they are properly balanced and the rotor is not affected. It is desirable to have corrosion resistant lining, such as of fibreglass, for the floats.

Trickling Filters : In trickling filters the mechanical components include the header, the distribution arm and the distribution nozzles. The header and the distribution arm are normally of mild steel and should be protected from corrosion by proper painting etc. The corrosion and the resulting blockage of distribution nozzles are of common occurrences. This can be avoided by selection of proper corrosion resistant material such as brass or PVC for nozzles.

Sewage & waste water pumps : For pumps and pumping equipment proper material selection is of paramount importance. The pump casing is normally of closed grained cast iron capable of resisting erosion on account abrasive material in the waste. For handling sewage and other corrosive wastes the impeller is generally constructed of high grade phosphor bronze or equivalent material. The wearing rings for impeller should be of good corrosion resistant material such as bronze. The shafts are normally made of high tensile steel and replacable shaft sleeves are recommended.

For pump and pumping equipment, painting is the usual protective measure. Both the interior and exterior surfaces of pumps should be painted after rust scale and deposits are removed by sand blasting, wire brushing or rubbing with sand paper.

Preventive maintenance

It will be seen from the above discussion that anticorrosive paints, coatings, linings have to be used in various equipment to prevent corrosion. The paints, coatings and linings require periodical renewal. Proper maintenance demands that a schedule be drawn up in each paint so that the operator may abide by it and undertake repainting or cleaning at appropriate intervals without waiting for corrosion to become obvious. The accent should be on *preventive* maintenance rather *than just* maintenance in the form of repairs, and replacement of broken down parts.

No doubt, proper design and specifications at the tendering stage would go a long way in ensuring long life. However, once the plant is built it is entirely in the hands of the operator or the supervisor to ensure proper preventive maintenance and carry out judicious replacements of spare parts, piping etc. bearing in mind the requirements described in this paper.