

**FAILURE OF NEWLY LAID WATER PIPELINE**

By

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Steel corrodes in most environments, consequently the useful life of the steel is reduced. Thus corrosion prevention is an essential factor in the economic utilization of steel. Steel is coated with appropriate protective coatings which can bring initial savings plus substantial economics in service, due to reduction or elimination of maintenance and lost service time and also by prolonging the time for replacement of structures and equipment.

Galvanizing provides ideal protection for steel due to their versatile applicability under normal conditions of exposures. The service life of galvanized pipes can be challenged when corrosion occurs. This study involves the investigation of the causes of pitting in the galvanized pipes laid about a period of less than two years ago in an Industrial plant situated at 32 K Multan Road Lahore. The study was initiated by the inspection of the site and after obtaining samples from the site. Soil samples were also collected. Since these pipes were installed about two years ago and complaint of leakage started in about July, 2000, therefore it was prudent to include the effect of soil on the pitting of the pipes.

Galvanizing of steel provides dual benefits i.e. aesthetic as well as durability. Hot dip galvanizing protects steel from corrosion by providing a thick, tough metallic zinc envelopes, which completely covers the steel surface and seals from the corrosive action of its environment. The galvanizing coating provides outstanding abrasion resistance, where there is damage or minor discontinuity in the sealing coating of zinc, protection of steel is maintained by the cathodic action of the surrounding galvanized coating. Zinc forms a strongly adherent coating on steel consisting of layers of Zinc-iron inter metallic at the Iron/zinc interface.

Galvanized coatings are highly resistant to attack over a wider pH range, particularly in moderate alkaline conditions. A protective film is formed on the zinc surface in the pH range of 6.9-12.5 and the coating corrodes very slowly. Different types of

compounds are formed when zinc corrodes in different atmospheres for example in saline conditions zinc chloride is formed, while zinc sulphate is formed in the presence of sulphur dioxide fumes and in the presence of moisture zinc hydroxide and zinc oxide is formed. pH of the medium determines the formation and stability of these compounds. Chlorides is the most aggressive anion which causes intense localized pitting of the steel(1). Its aggressiveness depends upon the concentration of inhibitive hydroxyl ions in the environment. In cement the pH of the pore environment is buffered at 12.6 pH due to the formation of calcium hydroxide as the result of hydration reaction of ordinary Portland cement with water. Presence of sodium and potassium in cement further enhances the pH to 13.6. Though zinc can be depassivated and attacked in the presence of chloride ions to form zinc chloride. Zinc hydroxyl chloride has been found to form during the corrosion of zinc in chloride contaminated cementitious materials. It expands causing cracks of overlaid cover even before corrosion of substrate steel has occurred. Later on the steel is attacked.

Thickness of the zinc coating is very vital factor in determining the life

of the galvanized structure. In fact the life of the coating is proportional to the coating weight per unit area. Homogeneity of zinc coating on steel is also extremely important to ensure the durability of the structure. If the coating is mechanically damaged, the risk of corrosion is multiplied. Nature of soil and depth of burial has significant effect on the corrosion of pipes buried in it. Generally, aeration in soils will decrease as the distance below the surface increases and therefore, the corrosivity of the soil should be expected to increase with depth. Severe corrosion has been observed on the pipelines when they are deeper than usual. But in certain instances the corrosion on pipes at increase depth is less as compared to than at narrow depth, this is due to the nature of the soil. In arid regions, the concentration of the alkali may be either near the surface or at a considerable depth, depending on the prevailing direction of the movement of moisture in the soil. Thus it can be seen that, although corrosion in general increases with the depth of burial, other influences, such as drainage and characteristics of soil horizons, may be sufficient to mask completely the effect of depth.

If diameter of the pipe is so large that pipe lies in two soil horizons, or if any part of it is under water, or if there is considerable difference in the distances from the surface of the ground to the top and bottom of the pipe, differential aeration circuits will be set up which will effect the distribution of the corrosion on the surfaces of the pipe and possibly the amount of corrosion also. The deterioration of metal also takes place by corrosion processes that occur directly or indirectly as a result of the activity of living organisms. These organism include microforms such as bacteria and microforms such as algae and barnacles(2). They have been observed to live and reproduce in mediums with pH values between 0 and 11, a temperatures between 30° and 180°F, and under pressure up to 15,000lb/in<sup>2</sup>. Biological activity influences corrosion in a variety of environments including soil, natural water and seawater,

natural petroleum products, and oil emulsion-cutting fluids. Living organisms are sustained by chemical reactions. That is, organisms ingest a reactant or food and eliminate waste products, these processes can affect corrosion behaviour by directly influencing anodic and cathodic reactions or by influencing protective surface film or by creating corrosive conditions and by producing deposits. These effects may occur singly or in combination, depending on the environment and organism involved. Anaerobic bacteria influences the corrosion behaviour of buried steel structures are the sulphate reducing types. These reduce sulphate to sulphide and are most prevalent under anaerobic conditions, as wet clay, boggy soils and marshes. The presence of sulphide ion markedly influences both the cathodic and anodic reactions occurring on iron surfaces. Sulphide tends to retard cathodic reactions, and accelerates anodic dissolution. This acceleration of dissolution is the most pronounced effect, which causes increased corrosion. The corrosion product in the presence of sulphate reducing bacteria is iron sulphide, which precipitates when ferrous and sulphide ions are in contact. Aerobic bacteria are capable of oxidizing sulphur or sulphur bearing compounds to sulphuric acid. These organisms thrive best in environments at low Ph and can produce localized sulphuric acid concentrations up to 5% by weight. Thus sulphur oxidizing bacteria are capable of creating extremely corrosive conditions. These require sulphur in either elemental or combined form for their existence and are therefore found frequently in sulphur fields, in oil fields, in soil rich with sulphates, in sewerage disposal piping that contains sulphur bearing organic wastes. In the case of sewage lines, sulphur -oxidizing bacteria

cause rapid attack of cement piping. Sulphur reducing and sulphur-oxidizing bacteria can operate in a cyclic fashion when soil conditions change. That is, sulphates reducing bacteria grows rapidly during rainy seasons when soil is wet and air is excluded, and sulphur oxidizing bacteria grows rapidly during dry seasons when air permeates the soil. In certain areas, this cyclic effect causes extensive corrosion damage of buried steel pipelines. Also, it is evident that the presence of micro-organisms can accentuate conditions of differential aeration in soils. Certain other bacteria utilize hydrocarbons and can damage asphalted pipeline coatings. Iron bacteria are a group of organisms that assimilates ferrous iron from solutions and precipitate it as ferrous or ferric hydroxide in sheaths surrounding their cell walls. Growth of bacteria frequently results in tubercles on steel surfaces and tends to promote pitting and crevice corrosion. Certain bacteria are capable of oxidizing ammonia to nitric acid. Dilute nitric acid corrodes iron and most other metals. These kind of bacteria may be important where an extensive use of synthetic ammonia fertilizers has been employed on cultivated fields above buried pipelines. Most bacteria also produce carbon dioxide, which can contribute to corrosivity due to the formation of carbonic acid.

## EXPERIMENTAL WORK

Pipe samples of different diameters ranging from ten mm to 75 mm were obtained. Soil samples were also taken from the places where pitting attack was severe. Photographs of the corroded pipe were taken. Cross sections were cut from the pipes at the points where pitting attack was severe, mounted, grounded and polished to 1 micron fine diamond paste. The polished samples were examined microscopically and their micrographs were taken. Chemical analysis of the soil particularly for sulphates, nitrates was carried out by the usual wet analysis methods. Cyclic corrosion testing of the good quality pipes was also carried out. Thickness of the galvanized layer of both the good quality and corroded pipes was determined microscopically

## RESULTS

### Thickness of the galvanized layer

Nature of sample    Pipe diameter in centimeters    Thickness in micron

New pipe	0.1	110 microns inner	85 microns outer
Corroded	0.1	105 microns inner	85 microns outer
New pipe	2.5	85 microns inner	85 microns outer
Corroded	2.5	82 microns inner	80 microns outer
New pipe	5.0	80 microns inner	75 microns outer
Corroded	5.0	80 microns inner	75 microns outer
New pipe	7.5	75 microns inner	

100 microns outer

## CYCLIC CORROSION TEST RESULTS

The new pipes were subjected to CASS test for 100 hours. 5% Sodium chloride solution acidified with acetic acid to pH 4.5 containing 0.5% Copper chloride at the Relative humidity of 98% and 35°C was sprayed on to the new

pipes to check their corrosion resistant.

Corroded Area (pipe diameter 7.5 cm) = 0.001%

Corroded Area (pipe diameter 5.0 cm) = 0.001%

Corroded Area (pipe diameter 2.5 cm) = 0.001%

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Since the corroded area for all the samples was 0.001 %, thus corrosion rating was 10 as per ISO standards.

## Chemical Analysis of Soil

Qualitative analysis indicates the presence of Sulphates, nitrates in the soil.

Quantitative analysis of the soil is as follows:

Sulphate ion 1-7%

Nitrate ion 800ppm

## Discussion and Conclusion

Galvanizing provides ideal protection for steel due to their versatile applicability under normal conditions of exposures. The service life of galvanized pipes reduces considerably when corrosion occurs, zinc then instead of providing protection starts corroding the underlying steel. A potential gradient is developed due the difference in the uniformity of the coatings through out the pipe length. As a result of differences in electrical potential within the cell, negatively charged electron flows from anode to cathode and

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being electrically connected by the underlying steel. Corrosion occurs in the anode areas. As anode areas corrode new material of different composition and structure is exposed. This results in changes in electrical potentials, causing anodes and cathodes to exchange roles, though not all once, and areas previously uncorroded are now attacked. This process continue until the steel is entirely consumed. When zinc and

steel are in contact in an electrolyte, differences in electrical potential develops and an electrolytic cell is formed. Zinc is more electrolytic ally active than steel, it thus becomes anode for all the steel, preventing the formation of small anodic and cathodic areas on the steel surface. Thus negatively charged electrons flow from the zinc anode to the steel cathode and zinc atoms are converted to positively charged zinc ions. At the cathode surface negatively charged electrons react with positively charged hydrogen ions form the electrolyte liberating hydrogen gas. Their is no chemical reaction between the steel cathode and electrolyte. Thus steel is protected as zinc ions at the anode surface react with negatively charged hydroxyl ions from the electrolyte and zinc is slowly consumed. But when the zinc coating is damaged either by chemical means or mechanically corrosion starts and in case of bacterial attack it appears in the form of pits varying in depths. Sulphide ions formation as result of anaerobic bacteria action or the formation of nitric acid due to aerobic bacteria dissolves the zinc coatings and hence pits are formed. Thus it can be concluded that pitting in the pipe lines is due to the bacterial attack.

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## REFERENCES

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