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Effect of Water Vapour Permeability on Cathodic Disbondment of Pipeline Coating Materials

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Abstract

Cathodic Protection (CP) widely used internationally as a major corrosion mitigation techniques in pipeline integrity. The use of protective coatings in conjunction with cathodic protection has been an extensive record of proven performance in the protection structures including underground pipelines, ships, underground storage tanks, pipings, and tank bottoms. The use of both a protective coating and a cathodic protection system presents unique design, installation and maintenance consideration. However, if the coating is not properly chosen there will be premature failure of adhesion between a coating and the material substrate which directly attributed to cathodic protection conditions. This paper will discuss about the correlation of vapour permeability with the extent of cathodic disbondment of different coating materials under accelerated conditions.

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Introduction :

A combination of cathodic protection (CP) and protective coatings has historically provided the best type of protection for immersed and buried pipelines. Cathodic protection is the application of an external source of current used to counteract the electrochemical potential of natural corrosion in the service environment. Protective coatings provide a physical barrier that limits the transport of corroding species to the substrate.

To understand the practical analysis of Cathodic Disbondment Test (CDT), one must first understand the chemistry and mechanisms involved. Applied potentials results in the following dominant cathodic reactions at the defect or holiday :

$H_2O + ½O_2 + 2e^- \rightarrow 2OH^-$ ……. (i)

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ …….. (ii)

Both reactions produce a highly alkaline environment in addition to other side reactions depending on the ionic species present.

Cathodic disbonding is defined as failure of adhesion between a coating and metallic substrate that is directly attributed to cathodic protection conditions. This action is often initiated by a defect in the system caused by accidental damage during handling & installation or imperfect application resulting in excessive permeability of a coating.

Cathodic Disbondment Testing (CDT) introduces a controlled defect and stimulates the effects of CP under service condition thus providing a powerful tool for developing and qualify coating systems.

Although electrical resistance is important, but if a coating does not possess sufficient resistance to water vapour transfer, the life of the coating system is abbreviated because of blistering and pitting of the substrate, regardless of its high electrical resistance properties. Cathodic protection can have very significant influence on the water absorption of a coating through the process of electroendosmosis.

Electroendosmosis can cause failure of a coating system that are not resistant. In general, the less permeable coatings are more resistance to electroendosmosis than more permeable coatings. If moisture penetration occurs at the cathodic area, blister will form due to liberation of hydrogen during cathodic reaction resulting in loss in adhesion and subsequent corrosion.

So, to successfully design relevant test parameters & interpret CDT data, it is important to understand the effect of test parameters on the rate of disbondment. This paper is intended to establish a correlation of the synergic effect of the permeability of coating & its resistant to cathodic protection.

This paper is intended to establish the effect of cathodic disbondment test on accelerated coating material & to select them for specific use to rank them in order of economics & environmental guidelines.

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Method of testing :

1. Sample Preparation :

For salt spray test followed by cathodic disbondment and water vapour permeability test, MS plates of SME 8" X 4" are shot blasted over while different coating materials are applied.

Coal Tar Enamel is applied by flushing technique at a temp. of 230°C – 240°C. Coal Tar Tape is applied by torching method. Cold Applied PE Tape is applied by pressure technique while 3LPE coatings are applied by cross-head extrusion process on a shot blasted pipe heated to a temp. of 160°C – 180°C over which three layers of PE are applied (melted at a temp. of 140°C – 150°C) from while the samples of requisite sizes are taken out.

For others such as Coal Tar Epoxies, High Build Epoxies & Polyurethanes, films are drawn by airless spray techniques by mixing the base and the hardener in the desired ratio.

In each case, eight numbers of samples were prepared and subjected to salt spray test for 500 hrs, 1000 hrs, 1500 hrs & 2000 hrs followed by cathodic disbondment test & water vapour permeability test respectively.

2. Method followed for Salt Spray Test (Fog Test)

- The salt solution has been prepared by dissolving 5±1 parts by mass of wall in 95 parts of water conforming to type (IV) reagent water as per ASTM D 1193.
- The plot of the salt solution shall be such that when atomized at 35°C the collected solution will be in the pH range from 6.5 to 7.2.
- The compressed air supply to the Air Saturated Tower is free of grease, oil & dirt which is done by passing through well-maintained filters.
- All the samples were placed at an angle of 15° to 30° and exposed for the requisite period as desired.
- The exposure zone of the salt spray chamber was maintained at 35±1°C throughout the period of exposure. The salt solution had been replaced at every alternative day.
- After complete exposure of the requisite time span the panels were gently washed with clean running water to remove salt deposits from their surface, immediately dried and then subjected to cathodic disbondment test.

3. Method followed for Cathodic Disbondment Test of accelerated coating materials :

- The instrument shall have a d.c. power unit, having a controlled voltage output between 0 to 10V and a current capacity sufficient to supply 20mA simultaneously to each site in circuit.

  The potential is measured with the help of reference electrode of saturated calomel type.

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– The test samples of different coating materials after exposure in salt spray test for 500 hrs, 1000 hrs, 1500 hrs & 2000 hrs respectively were withdrawn and subjected to cathodic disbondment test for 28 days at -1.5 potential at 30±5°C.

– For cathodic disbondment test method followed as per ASTM G 8 two individual calls were made having electrolyte concentration of 3% NaCl solution.

  A 6mm hole was drilled out at the centre of each cell to remove the coating material upto the base metal substrate as a predamaged area which acted as a cathode. Here platinum electrode is used as an anode and reference calomel electrode was immersed in each test cell to measure the continuous potential for 28 days and were noted in a log sheet.

4. Method followed for Water Vapour Permeability for the accelerated coating material :

– The water vapour transmission rate WVT, is the steady water vapour flow in unit time area of a body, between two specific parallel surfaces under specific conditions of temperature and humidity.
– After exposure in salt spray (fog) test for 500 hrs, 1000 hrs, 1500 hrs, & 2000 hrs respectively sample of different coating material are removed and washed at first, air dried at 50±5% RH and then kept for 24 hrs in a desiccator for further removed of any moisture present within the coating films.

– The respective coating films of uniform thickness were then cut according to the size (dia) of the perm cup and sealed with wax after adding small amount of distilled water inside the cup.

  The perm cup or dish consists of a container made of a non-corroding material impermeable to water or water vapour. Three (3) nos. perm cup are used for measuring water vapour permeability.

– The loaded cups were weighed upto 1 mg & then place in a desiccator for 24 hrs for reweigh. The cups were returned to the desiccator immediately after weighing it and was continued for at least 7 days to get the average weight loss.

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Test Results

Table 1					
Summary of CD Test Results of Different Pipe Coating Materials after Salt Spray					
SL. No.	**Product**	**500 hrs. in mm**	**1000 hrs. in mm**	**1500 hrs. in mm**	**2000 hrs. in mm**
1.	Coal Tar Enamel	2.50	3.25	3.75	4.25
2.	Coal Tar Tape	3.25	3.75	4.25	4.75
3.	Cold Applied Tape	14.00	23.25	32.50	33.25
4.	Polyurethane	6.50	10.25	13.00	14.25
5.	Coal Tar Epoxy	3.75	4.50	4.50	4.75
6.	High Build Epoxy	6.00	9.25	10.50	13.25
7.	3 Layer PE	2.25	2.50	3.25	3.50

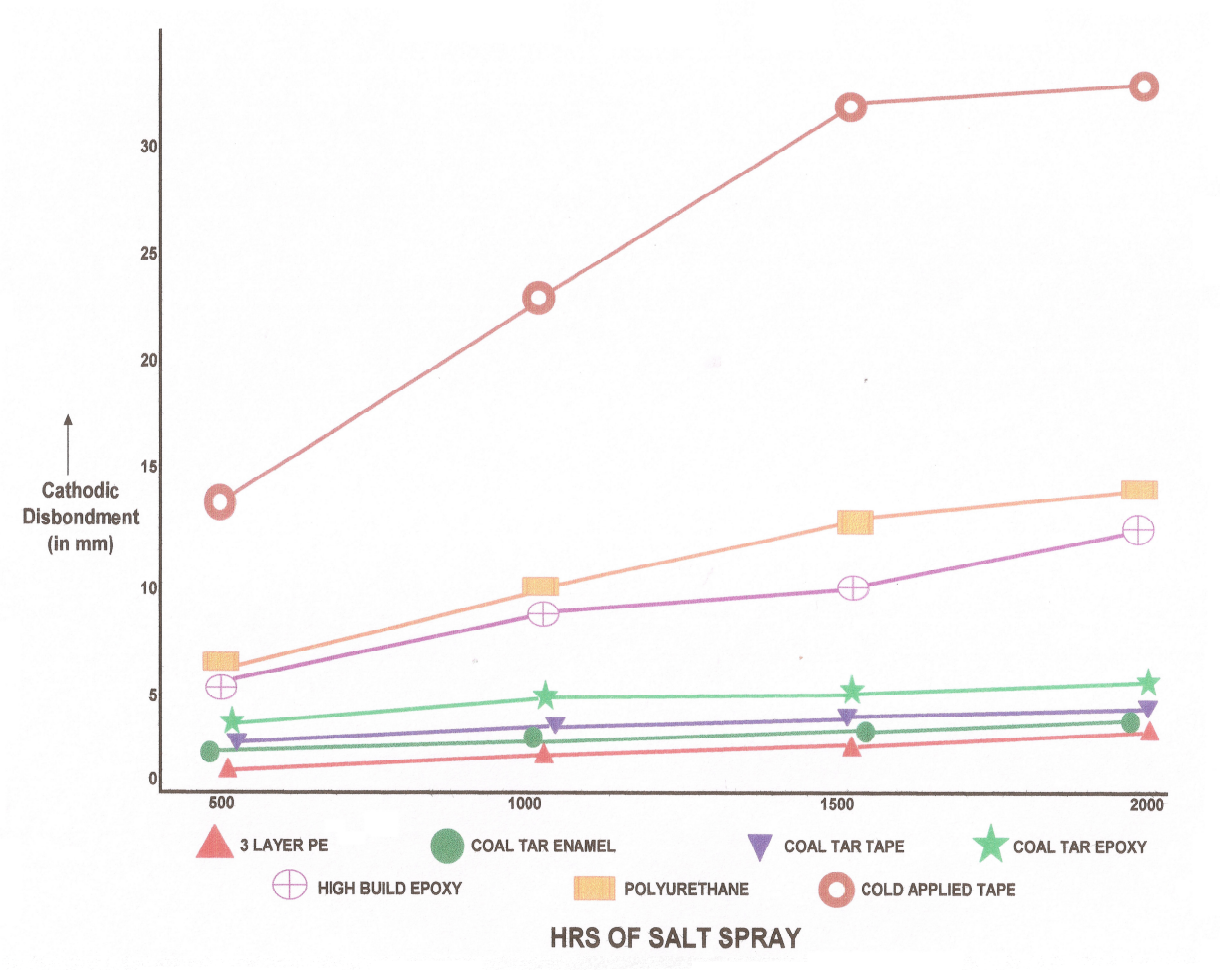

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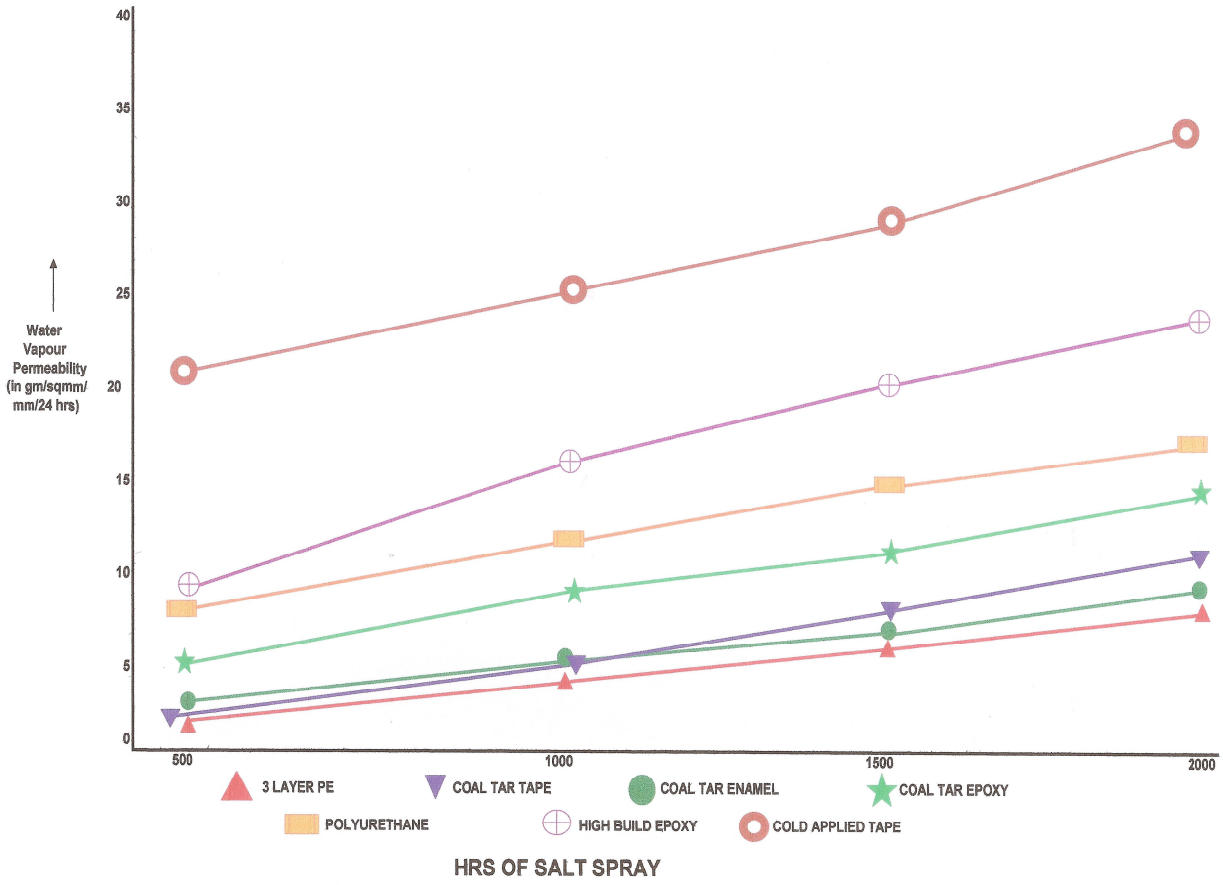
Table 2					
Water Vapour Permeability in 10^{-5} gm/Sqmm/mm/24 hrs.					
SL. No.	**Product**	**After 500 hrs. Salt Spray**	**After 1000 hrs. Salt Spray**	**After 1500 hrs. Salt Spray**	**After 2000 hrs. Salt Spray**
1.	Coal Tar Epoxy	5.84	9.08	11.72	14.60
2.	Polyurethane	8.77	12.00	15.00	17.45
3.	High Build Epoxy	9.08	16.24	20.96	24.00
4.	Coal Tar Tape	2.96	5.89	8.38	11.28
5.	Coal Tar Enamel	3.02	5.29	7.21	9.90
6.	Cold Applied Tape	21.33	25.51	29.18	34.49
7.	3 Layer PE	2.90	4.83	6.71	8.49



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Observations :

1. Analysis of the effect of Salt Spray (Fog)Test & Cathodic Disbondment Test

i) After 500 hrs exposure in Salt Spray by CD for 28 days

From the results it has been observed that cathodic disbondment is minimum in case of 3LPE, Coal Tar Enamel & Coal Tar Tapes and maximum in case of Cold Applied Tapes (14mm). Coal Tar Epoxy also have disbondment of only 3.75mm whereas polyurethanes & High Build Epoxies have moderate disbondment of around 7mm.

ii) After 1000 hrs exposure in Salt Spray followed by CD for 28 days

From the results it has been observed that cathodic disbondment in case of 3LPE remains almost same. A steady increment in disbondment is also observed in case of Coal Tar Enamel & Coal Tar Tape. Coal Tar Epoxy shows moderate increase in disbondment. Whereas others such as Polyurethanes & High Build Epoxies show moderately high increase in disbondment & a very high disbondment is observed in case of Cold Applied PE which is about 23mm.

iii) After 1500 hrs & 2000 hrs exposure in Salt Spray followed by CD for 28 days

The trend of disbondment remain same after 1500 hrs. & 2000 hrs.

2. Analysis of the effect of Salt Spray (Fog)Test & Water Vapour Permeability

PE tapes being thermoplastic material is a straight chain molecule whereas any two component system is a cross-linked molecule. From the structure it is clear that any cross-linked molecule must have better water permeability than any straight chain structure. Hence water permeability in PE Tapes is more than any two component system. However, due to molecular stability of PE chain the increase in water vapour permeability has not increased substantially / proportionately with the increase in duration of salt spray.

Moreover, Coal Tar Tape, Coal Tar Enamel have complex structure for which it shows very loss water permeability.

Conclusion to establish correlation of the effect of cathodic disbondment test with water vapour permeability of accelerated coating materials

From the results of cathodic disbondment test it is evident that best result is obtained in case of 3LPE which is mainly due to its very less moisture vapour permeability. Coal Tar Enamel, Coal Tar Tape & Coal Tar Epoxy also shows less moisture permeability which is reflected from the extent of disbondment of only 4.25mm, 4.75mm & 4.75mm after 2000 hrs exposure followed by cathodic test. High Build Epoxy & Polyurethanes films have moderate permeability to water vapour, hence the extent of cathodic disbondment is higher in these cases. Cold Applied PE film are very susceptible to moisture penetration due to its straight chain molecular structure thereby shows very poor results in cathodic disbondment test showing disbondment of about 33.25mm after 2000 hrs exposure in salt spray.