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Failure Analysis Of Crude Oil Storage Tank Bottom Plate And Remedial Actions For Its Life Enhancement

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ABSTRACT

Corrosion is the degradation of substances to its constituent atom, and it has become a major issue in every industry throughout the world, especially in the petrochemical industry. Crude storage tanks are an important part of the petrochemical process, as they help to keep the process running smoothly. Because of the aqueous environment, there is a high risk of corrosion in storage tanks, resulting in a large financial loss for the petrochemical industry. Water present in the crude carried along with the products, either in suspended or condensed form, is directly linked to corrosion in storage tanks bottom plates of crude oil and refined commodities. Crude oil is extracted from wells and held in a storage tank for 24 to 72 hours normally after processing before being dispatched. Salt particles, sand, carbonates, and chlorides, among other microorganisms, are found in crude extracted from reservoirs. Produced water remains stagnant in the tank's bottom throughout the year because the nozzle for emptying produced water is situated above the bottom plate. Slugs steadily build up in the tank's bottom during the settling process, corroding the bottom plate.

The focus of this study root cause of corrosion in the bottom plate of a crude storage tank, as well as the rate of corrosion in various corrosive mediums such as crude, produced water, and solution (crude 80(%) and produced water 20(%)), were investigated using weight loss method. Also, this study is focused to apply and analyze various corrosion control remedies, such as different types of corrosion inhibitor (oil base, water base) and fiber reinforcement polymer (FRP) coating. The results showed that FRP coating reduced the corrosion rate of the specimen as compared to Corrosion inhibitors. By applying FRP coating 93 (%) reductions in corrosion rate of the bottom plate was observed and the results were compared with the result obtained from other methods.

Keywords: Corrosion, crude, produced water, corrosion inhibitor and FRP coating.

I. INTRODUCTION:

Crude Oil is a naturally occurring, highly inflammable hydrocarbon liquid is refined, to yield various petroleum components through fractional distillation. Before transportation to Refineries, crude Oil is stored in bulk quantities, in large above ground storage tanks, to maintain desired stocks for continuous operation of Pipelines and to maintain crude oil supplies to Refineries for uninterrupted operation. Such storage of highly inflammable crude oil in storage tanks, primarily Steel tanks, brings into focus the primary potential of leakage and consequent probability of fire and explosion due to the combustible nature of crude oil.[[1]]

The failure of bulk storage tanks can be attributed to a number of causes including human error, poor maintenance, vapor ignition, differential settlement, earthquake, lightning strike, hurricane, flood damage and over-pressurization, corrosion and erosion. Such incidents have highlighted the need for the proper assessment of potential risks and the requirement for suitable methods of mitigation. [[2]]

Corrosion is a complex electro-chemical-mechanical process that is a function of the stored product, the external surrounding media and the control measure to mitigate the phenomenon. Thus, the corrosion rate varies from site to site and from tank to tank. Primary corrosion rate determining parameters in AST include temperature, product composition (water content, pH), coating and cathodic protection of the exposed surface. [[3]]

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Storage tanks are used to store fluids such as crude oil, intermediate and refined products, gas, chemicals, waste products, aqueous mixtures, and water. Corrosion is the prime cause of the deterioration of steel storage tanks and accessories; therefore, control and prevention of tank corrosion is of prime importance for efficient plant economics and safety. One of the most efficient methods of tank corrosion prevention is by applying a suitable coating. [[4]]
This paper primary scope is to investigate the root cause of bottom plate corrosion and how to reduce the corrosion by analyzing the plate sample through weight loss method.

II. EXPERIMENTAL WORK

2.1. Sample preparation

Low carbon steel of the specification shown in table 1 is used for bottom plate of crude storage tank. Total of 18 sample of size (L=2cm, W=1.5cm and T= 1cm) were prepared for weight loss method. By using the abrasive paper of 60, 120, 240, 400, 600, 800, 1000 and 1200 grit to finish the surface of the entire 36 samples. Drill a hole of diameter 0.34cm in each of weight loss method sample to hang in a corrosive medium. Weight loss method samples as shown in figure 1.

Table 1 Specimen Specification

Sr.No	Steel plate Grade	Chemical Composition								Tensile Test	
		C%	Si%	Mn%	P%	S%	Ti%	B%	Fe%	Yield Strength N/mm2	Tensile Strength N/mm2
01	Ss400	0.16	0.14	0.29	0.018	0.008	0.031	0.0014	Balance	341	460

Figure 1 Weight Loss Method Sample

2.2. Sand blasting

This process is used for cleaning or etching the surface prior to powder coating, painting or spray galvanization, metals are required to be sand blasted according to their surface conditions. The use of diverse blasting materials creates several types of surface results. [[5]] Before doing fiber reinforcement coating of 03 samples of weight loss method perform the sand blasting of these samples.

2.3. Fiber Reinforcement polymer (FRP)

The FRP of 03 sample of weight loss method have been carried out. The FRP sample as shown in the Figure 2. The properties of resin Malikens AD555-04 and Emulsion Mat used for FRP coating of samples is shown in Table 2 & 3 respectively.

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Figure 2 FRP Coated Samples

Table 2 Resin Malikens AD555-04

Properties	Value	Unit	Test method
Density	1.15	g/ml	DIN 53217
Appearance	Clear	-	-
Acid Value	35-40	mgKOH/g	DIN 53402
Solid Content	60-70	%	-
Viscosity at 25°C (DIN CUP-4)	90-110	Secs	Din cup-4
Styrene Content	30-40	%	-
Gel Time at 30°C (0.33% Co 6 &1%MEKP)	20-30	Min	-
Exothermic Temperature	160-170	°C	-
Time taken from 30°C to Tmax	30-40	Min	

Table 3 Emulsion Mate

Product Name	Emulsion mat
Item Number	EMCL300-1040M
Product garde	A
Glass Type	E-Glass
Filament Diameter	13µm
Density	2.6400g/cm^3-2.6600g/cm^3
Sizing	Silane
Softening point	840°C-875°C
Color	White
Moisture Content (%)	≤0.50
Loss on ignition(%)	4.00±1.50
Mass per unit area (g/m^2)	300±30
Solubility in styrine (s)	≤40
Tensile breaking force (Length wise)(N)	≥60

Tensile breaking force (Side wise)(N)	≥60

2.4. Medium Preparation

There are three main mediums in which the corrosion rate of the specimen is calculated. These are crude, produced water and solution (crude 80% and 20%). The specification of the crude and produced water is listed in the Table 4 and 5 respectively.

Table 4 Crude Analysis

Test Method	**Test Parameters**	**Test Result**
D-1298	Specific Gravity 60/60°F	0.8116
D-1298	Barrel Per M.Ton	7.74
D-1298	API Gravity 60/60°F	42086
D-4294	Total Sulphur Content, wt%	0.032
D-96	BS&W vol%	<0.05
D-95	Water Content by D&S Vol%	<0.05
D-3230	Salt Content, lbs/1000bbl	Nil
D-445	Kinematic Viscosity at 40°C,cSt	2.13
D-97	Pour Point, °C	+18
D-189	Con Carbon Residue (CCR), wt%	0.837
D-323	Reid Vapor Pressure @37.8°C,psi	4.8
D-130	Copper Strip Corrosion @50°C	1a
USB-97	Calorific Value (Gross), Btu/lb	19808
USB-97	Calorific Value (Gross), Btu/lb	18552
D-85	Distillation	
	I.B.P °C	60
	05/10 Vol%, Recovered@ °C	82/110
	20/30 Vol%, Recovered@ °C	136/165
	40/50 Vol%, Recovered@ °C	206/254
	60/70 Vol%, Recovered@ °C	292/338
	Recovery@349° C, Vol%	72

Table 5 Water Analysis

Properties	PH	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Barium	Iron	Strontium	Bicarbonate

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Value	7.5	970 ppm	136 ppm	145 ppm	190 ppm	88380 ppm	2030 ppm	4.18 ppm	2.36 ppm	97.50 ppm	1342 ppm

III. RESULT AND DISCUSSION

Weight loss methods used to investigate the main causes of corrosion and to check the effects of remedies for corrosion control of bottom plate.

3.1. Weight loss method

The prepared 18 Nos sample of weight loss were completely air dried and weight each sample on digital balance up to three decimals. Tie each specimen with thread and hang in bottle of 250ml containing 225ml of crude, produced water and solution (80% crude and 20% produced water). The prepared corrosive medium and different remedies used, and the specimen arrangement as shown in the Table 6.

Table 6 Sample Arrangement

Sr.No	Description	Sample
01	Crude	Sample 1
02	Crude + 5ppm C.I Oil Base	Sample 2
03	Crude +10ppm C.I oil Base	Sample 3
04	Crude + 5ppm C.I Water Base	Sample 4
05	Crude + 10ppm C.I Water Base	Sample 5
06	Crude	Sample 6(FRP Coated)
07	Water	Sample 7
08	Water+ 5ppm C.I Oil Base	Sample 8
09	Water+10ppm C.I oil Base	Sample 9
10	Water+ 5ppm C.I Water Base	Sample 10
11	Water+ 10ppm C.I Water Base	Sample 11
12	Water	Sample 12(FRP Coated)
13	Solution (Crude80% + Water20%)	Sample 13
14	Solution (Crude80% + Water20%)+ 5ppm C.I Oil Base	Sample 14
15	Solution (Crude80% + Water20%)+ 10ppm C.I Oil Base	Sample 15
16	Solution (Crude80% + Water20%)+ 5ppm C.I Water Base	Sample 16
17	Solution (Crude80% + Water20%)+ 10ppm C.I Water Base	Sample 17
18	Solution (Crude80% + Water20%)	Sample 18(FRP Coated)

After 500hr, 1500hr and 4500hr the specimen was removed from the medium and cleaned and then wash with ethanol and dried to remove traces of crude etc. it is also recommended to wash these specimens with distilled water, acetone, and dried in air. Finally, their weights were recorded, and the differences in weights at each interval and the rates of weight losses (corrosion rates) were all determined by using the stated formula.

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$$Corrrosion\ Rate\ (CR) = \frac{weight\ loss(g) * K}{Alloy\ Density\left(\frac{g}{cm3}\right) * Exposed\ Area(A) * Exposure\ Time\ (hr)}$$

The constant can be varied to calculate the corrosion rate in various units

Corrosion Rate Unit	Area (A)	K-Factor
mils/year(myp)	in^2	$5.34x10^5$
mils/year (myp)	cm^2	$3.45x10^6$
millimeter per year (mmy)	cm^2	$8.74x10^4$

The corrosion rate calculated after 500hr, 1500hr and 4500hr of each specimen in different solvent and different remedies added solvent are listed in Table 7

Table 7 Corrosion rate at various time intervals

Sample ID	Medium	Corrosion Rate (mpy) at 500hr	Corrosion Rate (mpy) at 1500hr	Corrosion Rate (mpy) at 4500hr
1	Crude	0.966	1.418	1.852
4	Crude + 5ppm C.I Oil Base	0.802	1.258	1.642
7	Crude +10ppm C.I oil Base	0.555	1.107	1.539
10	Crude + 5ppm C.I Water Base	1.105	1.534	1.963
13	Crude + 10ppm C.I Water Base	1.217	1.671	2.016
16	Crude (FRP Coated)	0.017	0.039	0.069
2	Water	4.239	6.092	9.122
5	Water+ 5ppm C.I Oil Base	2.876	4.289	6.285
8	Water+10ppm C.I oil Base	1.629	2.836	3.922
11	Water+ 5ppm C.I Water Base	1.551	2.312	2.913
14	Water+ 10ppm C.I Water Base	1.041	1.967	2.651
17	Water (FRP Coated)	0.239	0.408	0.628
3	Solution (Crude80% + Water20%)	1.259	2.038	3.237
6	Solution (Crude80% + Water20%)+ 5ppm C.I Oil Base	0.866	1.555	2.820
9	Solution (Crude80% + Water20%)+ 10ppm C.I Oil Base	0.989	1.605	2.979
12	Solution (Crude80% + Water20%)+ 5ppm C.I Water Base	1.314	2.193	3.496
15	Solution (Crude80% + Water20%)+ 10ppm C.I Water Base	0.767	1.325	2.134
18	Solution (Crude80% + Water20%) (FRP Coated)	0.122	0.199	0.285

The corrosion rate is maximum in produced water followed by solution and low in crude as shown in Table 7. Also, the corrosion rate is increasing with time. The Figure 3 shown below depicted the corrosion rate of sample in (a) crude, (b) produced water and (c) solution respectively. From the Table 7 and Figure-3 it is concluded that good remedies for corrosion control in all the corrosive medium is FRP coating.

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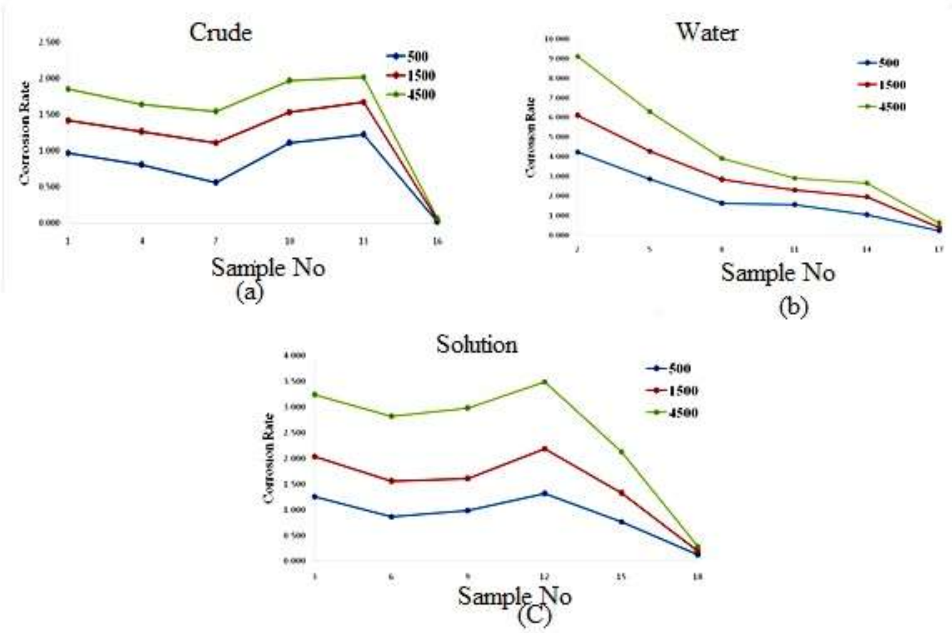

Figure (3) Corrosion rate Comparison

The percentage reduction in corrosion rate by adding different remedies after 4500 hours are listed in Table 8.

Sample ID	Medium	% Reduction Rate
1	Crude	
4	Crude + 5ppm C.I Oil Base	11
7	Crude +10ppm C.I oil Base	17
10	Crude + 5ppm C.I Water Base	-6
13	Crude + 10ppm C.I Water Base	-9
16	Crude (FRP Coated)	96
2	Water	
5	Water+ 5ppm C.I Oil Base	31
8	Water+10ppm C.I oil Base	57
11	Water+ 5ppm C.I Water Base	68
14	Water+ 10ppm C.I Water Base	71
17	Water (FRP Coated)	93
3	Solution (Crude80% + Water20%)	
6	Solution (Crude80% + Water20%)+ 5ppm C.I Oil Base	13
9	Solution (Crude80% + Water20%)+ 10ppm C.I Oil Base	8
12	Solution (Crude80% + Water20%)+ 5ppm C.I Water Base	-8
15	Solution (Crude80% + Water20%)+ 10ppm C.I Water Base	34
18	Solution (Crude80% + Water20%) (FRP Coated)	91

From the Table 7 it is calculted In crude adding 5ppm C.I oil base corrosion rate decrease by 11% which further fall to 17% by adding 10ppm C.I oil base, while corrosion rate increases 6% by adding 5ppm C.I water base while increase to 9% by adding 10ppm C.I water base. The significant reduction observed in FRP coated sample which is 96%.

In produced water by adding 5ppm C.I oil base corrosion rate decrease by 31% which further decrease to 57% by adding 10ppm C.I oil base and by adding 5ppm C.I water base corrosion rate decrease to 68% which further decrease to 71% by adding 10ppm C.I water base. Calculated 93% reduction in FRP coated sample.

In solution (crude 80% and water 20%) by adding 5ppm C.I oil base corrosion rate decrease by 13% while decrease to 8% by adding 10ppm C.I oil base and by adding 5ppm C.I water base corrosion rate increase to 8% while decrease to 34% by adding 10ppm C.I water base. Calculated 91% reduction in FRP coated sample.

IV. CONCLUSION

It is concluded from the current study that among FRP coating and corrosion inhibitor oil base and water base, FRP is the best remedy to reduce corrosion rate in the entire corrosive medium. From the results it is obvious that 93% reduction in corrosion rate is calculated by applying FRP coating. From the results it is also concluded that corrosion inhibitor depends on the medium i.e water base corrosion inhibitor is good for produced water and oil base corrosion inhibitor is good for crude. As in storage tank there is mixture of crude and produced water, so FRP is the best among these remedies. Produced water from storage crude can be minimized but cannot be eliminated by 100%, so produced water remains in the bottom plate though out the year. The quantity and specification may be different depend on the production well nature. The crude and other gases remain above the produced water. So produced water is the main sources of corrosion of the bottom plate. From the results achieved from both method corrosion rate is maximum in produced water.

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