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Investigation of the Factors which Affect the Performance of VpCI-608 for Protection of Tank Underbodies

VpCI-608 has been installed into interstitial space as a supplement to the operating sacrificial anode system. Corrosion protection was evaluated in two ways: by the weight loss of the installed coupons and monitoring the corrosion rate with corrosion probes connected to a corrosometer. The results of this trial are contradictory. At the same time, a study carried out at Cortec confirms good performance of VpCI-608/609 (see report # 07-084-1225)

Several hypotheses were made to explain the difference in the effectiveness in corrosion protection of VpCI in the Valero facility vs. Cortec testing:

1. Influence of CP on the performance of VpCI-608 and effect on the corrosion reading by probes with a Stainless Steel body;
2. Pressure of the tank on the sand;
3. Contaminates of the sand;
4. Amount of water used for the preparation of the slurry.

Below are several tests which were set up to clarify this matter.

1. Study of the influence of CP.

1a. Bench corrosion protection

1. Test was performed in a plastic container with a lid.
2. Two panels of carbon steel were placed on the surface of the sand treated with VpCI-608 and just moisturized with water.
3. Zinc panel was placed on the top of these panels.
4. Container was sealed with the lid and appearance of the panels was visually evaluated at the regular bases.

Table 1. Corrosion of Carbon Steel/Zinc coupled with VpCI-608 and without it (control)

Container	Time before corrosion of Carbon Steel panel	Zinc Cathode
Control	After 1 week	After 2 days
Treated VpCI-608	More then 4 months	More then 4 months

The data presented in Table 1 show that VpCI-608 provided more durable protection for Carbon Steel than the electrical connection with Zinc. At the same time cathodic polarization by Zinc did not negatively affect VpCI-608 performance.

1b. Electrochemical potential of the following sets of electrically connected panels vs. Calomel Saturated Electrode was measured during immersion in tap water and in a 0.5% solution of VpCI-608 in tap water.
a) Carbon Steel, Zinc and Stainless
b) Carbon Steel and Zinc

Figure 1. Diagram of the electrical circuit used for the measurement of the electrochemical potential of the couple Carbon Steel/Stainless Steel - Zinc cathode and Carbon Steel - Zinc cathode.

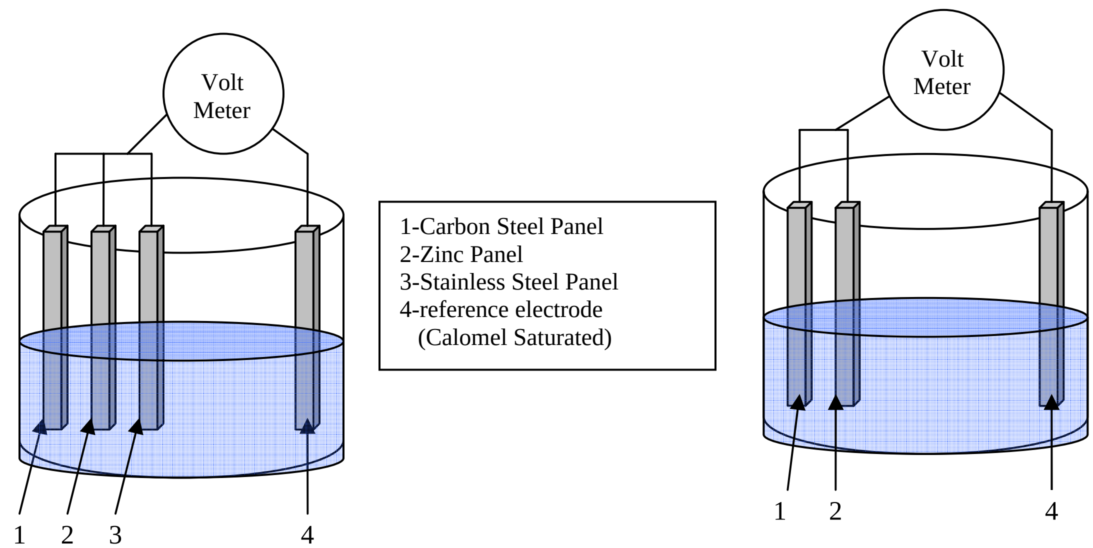


Table 2. Electrochemical potential of Carbon Steel/Zinc and Carbon Steel/Stainless Steel/Zinc vs. Saturated Calomel Electrode.

Solution	Carbon Steel / Zinc			Carbon Steel / Stainless Steel / Zinc		
Tap Water	24 hours	48 hours	72 hours	24 hours	48 hours	72 hours
	-867	-	-	-720	-	-
0.5%VpCI-608	-556	-561	-580	-530	-558	-578

Table 3. Weight loss of Carbon Steel and Carbon Steel connected with Stainless Steel.*

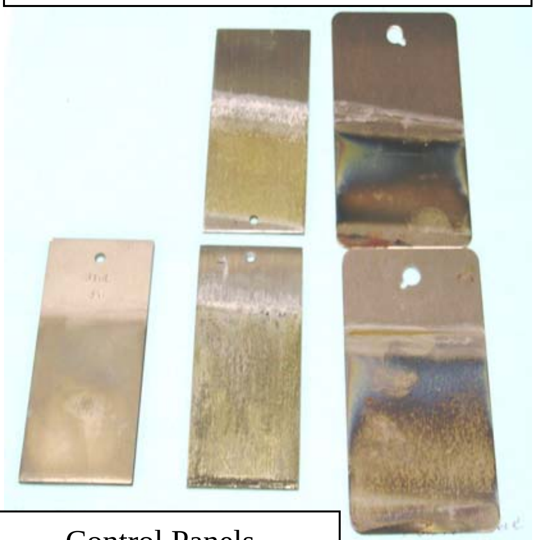
Solution	Carbon Steel/Stainless Steel, weight loss, g	Carbon Steel, weight loss ,g
Tap water	0.0399	0.0199
0.5% VpCI -608	0.0041	0.0071

Test was performed at room temperature for 48 hours.

The results presented in Table 2 and Table 3 show that the half cell potential and weight loss can be different when carbon steel is electrically connected with stainless steel versus without this connection. Based on this data, it is possible that a stainless steel bodied corrosion probe can promote corrosion at the carbon steel end of the corrosion probe.

Figure 2. The photos show that the panels immersed into tap water corrode even under CP (connection with Zinc panel). At the same time all panels (Stainless Steel, Carbon Steel and Zinc) immersed into 0.5% VpCI-608 solution show much less corrosion.

Stainless Steel. Zinc. Carbon Steel



Control Panels

Stainless Steel, Zinc, Carbon Steel

Panels in 0.5 wt% VpCI-608

2. ***The effect of the weight of the tank*** (load on the bottom) on the performance of VpCI-608 was evaluated. For this purpose the panels were pressed against the sand through the plastic pad in a vice, which produced a pressure of ~ 40psi on the panels. The conditions of the panels were visually evaluated in 2 days. (See Figure 3).

Figure 3.

This test showed that an applied load did not adversely affect the corrosion protection of VpCI-608.

3. ***To evaluate how contaminants*** in the sand can affect the corrosion protection of VpCI-608, sodium chloride was added to sand in plastic pools and plastic containers at the concentration of 1500 ppm. The corrosion rate in the pools was monitored with corrosion probes and evaluated by the weight loss of the installed coupons. Also, the condition of the panels in the plastic containers was visually evaluated.

Table 4. Data from Corrosion Probes

Probe ID	Pool Details	Probe Reading Before salt was added	Corrosion rate before NaCl was added, mpy	Probe Readings after NaCl was Applied			Corrosion rate after NaCl was applied, mpy
				after 15 days	after 39 days	after 64 days	
R481	Large pool (17% VpCI-609 in slurry)	105	0.10	114	133	146	1.169
R482	Large pool (17% VpCI-608 in slurry)	123	0.17	133	165	188	1.853
R483	Small pool (5% VpCI-609 in solution)	105	0.14	130	189	275	4.845
R484	Small Pool (Control)	136	0.31	187	269	334	5.643

Corr. Rate = (Difference in probe reading): (time, days) x 0.365 x span.

Table 5. Weight Loss Data (Coupons e installed in 'pool' test)

Large Pool (1.5lb VpCI-609 : 9lb water)

Coupon ID	Start Weight	End Weight	Difference	Cor. Rate, mpy
1	11.6740g	11.6589g	15.1mg	
2	11.6495g	11.6160g	33.5mg	
3	11.7375g	11.5740g	163.5mg	
4	11.6776g	11.4897g	187.9mg	
5	11.5750g	11.2271g	347.9mg	
6	11.6902g	11.3871g	303.1mg	
7	11.4510g	not found	n.a.	2.29

Large Pool (1.5lb VpCI-608 : 9lb water)

Coupon ID	Start Weight	End Weight	Difference	
8	11.7034g	11.5683g	135.1mg	
9	11.7434g	11.2310g	512.4mg	
10	11.6707g	11.5402g	130.5mg	
11	11.7024g	11.5402g	162.2mg	
12	11.7578g	11.5553g	202.5mg	
13	11.7112g	11.5237g	187.5mg	
14	11.7412g	not found	n.a.	2.89

Small Pool (1lb VpCI-609 : 19lb water)

Coupon ID	Start Weight	End Weight	Difference	
15	11.6592g	11.5264g	132.8mg	
16	11.7378g	11.5663g	171.5mg	
17	11.6947g	11.3977g	297.0mg	
18	11.7444g	11.4643g	280.1mg	2.90

Small Pool (Control)

Coupon ID	Start Weight	End Weight	Difference	
19	11.6683g	11.4161g	251.9mg	
20	11.7419g	11.3997g	342.2mg	
21	11.6368g	11.4988g	138.0mg	
22	11.7540g	11.2495g	504.5mg	4.05

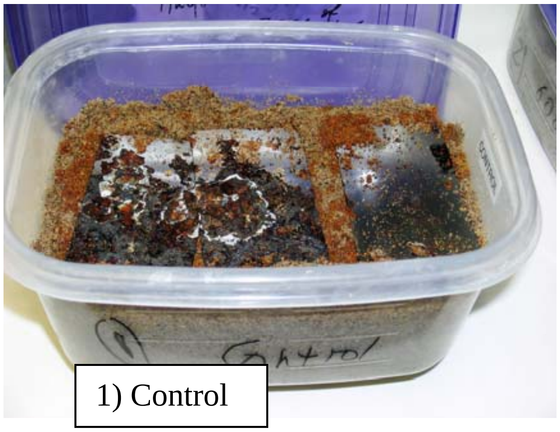
Corrosion Rate=(KxW): (AxTxD), where K= 3.45×10^6; (per ASTM G 1 -90)
W –weight loss, g; A-surface area, cm^2
T – time, hours; D – density, g/cm^3

The data presented in the tables 4 and 5 show that the addition of sodium chloride to the sand causes a significant increase of the corrosion rate when evaluated by both corrosion probes and weight loss of installed coupons. However, the data also shows that the rate of corrosion in the pools/containers where the sand was treated with VpCI-608/609 is much lower than that in the 'Control' pool/container.

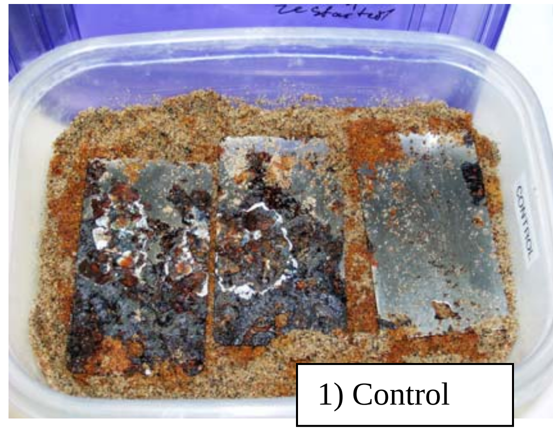
It needs to be mentioned that the corrosion rate in the large pool treated with VpCI-609 varies by ~ 30 times from one coupon to another, which is most likely due to the different concentration of VpCI-609/Chloride in different places.

The bench test in the plastic containers (Figure 4) also shows that VpCI-608 protects Carbon Steel even in the presence of Chlorides. Please note that there is less corrosion in the #2 (Figure 4) container treated with VpCI-608, where inhibitor was initially mixed with the sand versus more corrosion in the container where the slurry was poured into the container and than the sand was placed on top of it.(See Figure 4)

Figure 4. Set up of plastic containers during bench test.

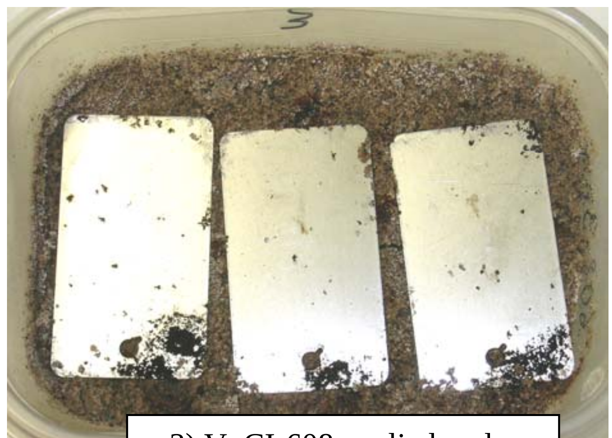


1) Control



1) Control

2) VpCI-608 uniformly mixed with sand



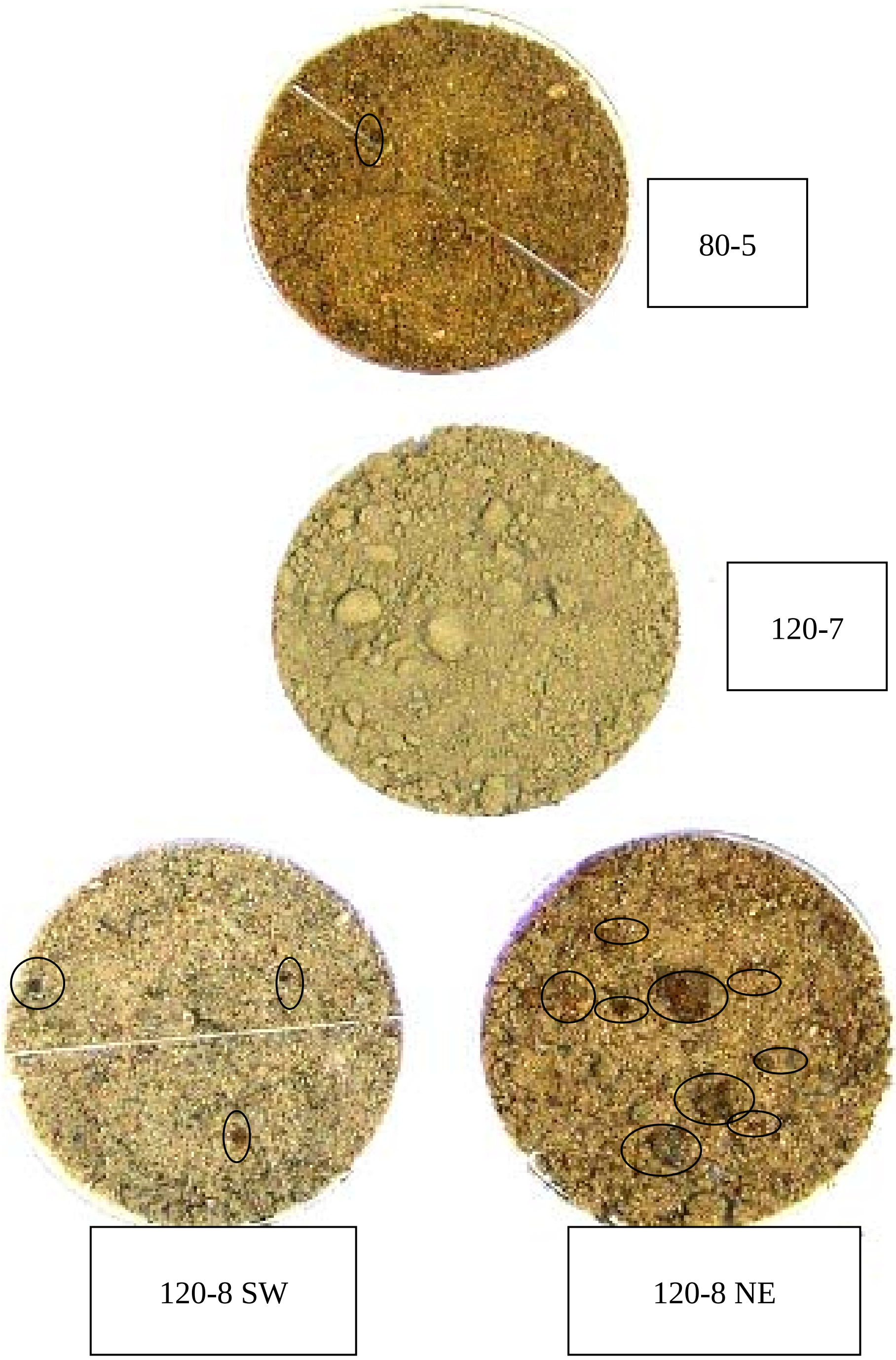
3) VpCI-608 applied under the sand

Study of Four Samples of Sand Sent by Joe D./Scott Paul

The list of the samples:
1) 80-5 sand from Praxair tank treated with 500lbs of VpCI-608.
2) 120-7 ‘Control’ sand contains no VpCI.
3). 120-8 NE sample from Valero tank treated with 300lbs of VpCI-608.
4) 120-8 SW sample from Valero tank treated with 300lbs of VpCI-608.

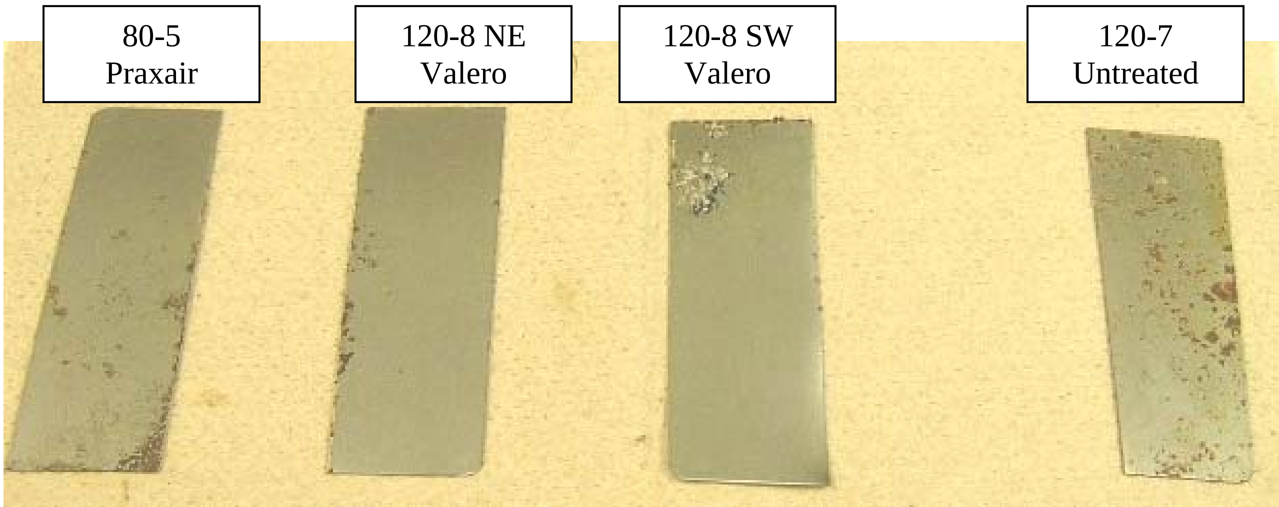
By running a magnet over the surface of the sand, it was noticed that samples 1, 3 and 4 have pieces of iron/iron oxide in the sand. Sample labeled 120-8 NE had the most and largest pieces of iron/iron oxide, while 80-5 had a few pieces and 120-7 had none. (See Figure 5)

Figure 5. Sand Samples



On November 28, 2006 metal coupons were placed inside the bags with the sand samples sent to Cortec. Photos below show coupons 23 days later, on December 21. Coupons 120-7 (not treated) show the most corrosion. (see Figure 6)

Figure 6. Metal Coupons after 23 days in sand



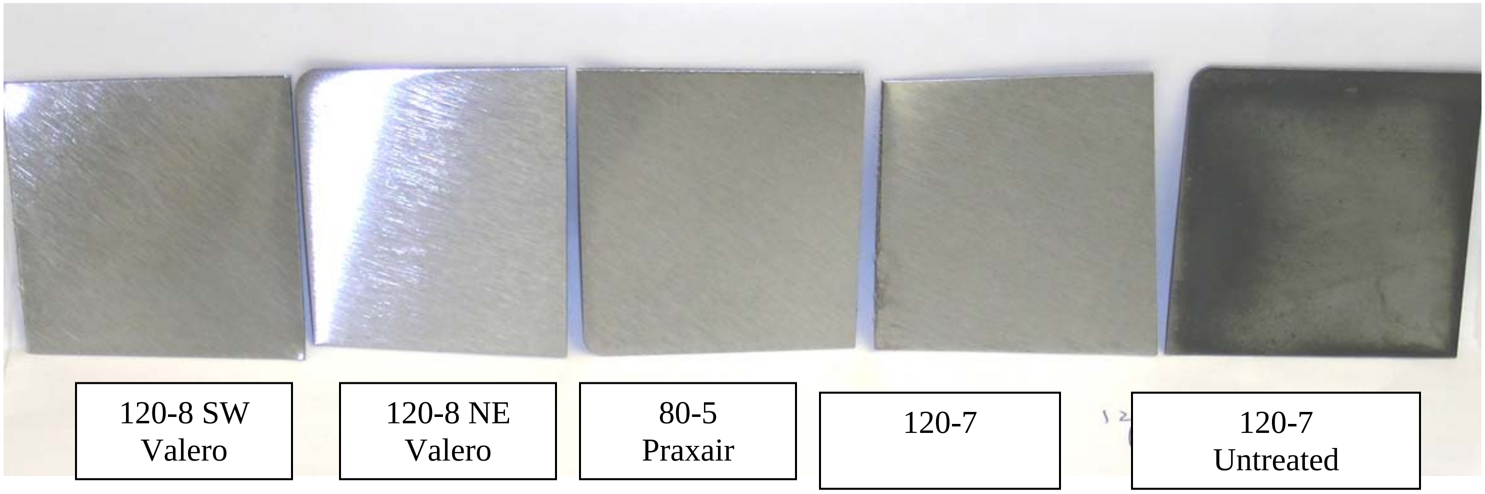
Solution of 2% VpCI-608 in DI water was prepared. Corrosion test was performed in the mixtures 1:1 sand: 2%VpCI-608 solution. The results after 2 days of testing presented in Table 6.

Figure 7. Corrosion test in the mixture of sand and 2% VpCI-608 solution.

Table 6. Corrosion test data in the mixture of sand and 2% VpCI-608 solution.

Material	Initial Weight, g	Final Weight, g	Weight loss, g
120-8 SW	20.6128	20.6128	0.0000
120-8 NE	20.0370	20.0366	0.0004
80-5	21.6038	21.6038	0.0000
120-7 with 2%VpCI 608 solution	20.8282	20.8282	0.0000
120-7 with the DI water (Control)	22.6631	22.6478	0.0153

Figure 8. Coupons after testing.



Conclusions:

1. VpCI-608/609 provide excellent corrosion protection, when incorporated in sand in the recommended quantity. Even (1000ppm of Cl ions) didn't prevent corrosion protection.
2. According to the data presented in Tables 1 and 2, CP does not negatively affect the performance of VpCI-608.
3. It was found that in the presence of CP, additional electrical contact with Stainless Steel may affect corrosion rate results.(see Tables 2 and 3)
4. According to the test results, in Tables 4 and 5 the main factor which can cause high corrosion rates in sand treated with VpCI-608 is irregular contamination of this sand, such as the presence of particulates of metals (for example, after welding).
5. In case the sand under the tank is heavily contaminated it is recommended to use more inhibitor, not 2-4, but 5-7 pounds per 100 square feet.
6. Based on the data presented in report # 07-084-1225, overdiluted slurry/solution of VpCI-608/609 negatively affects corrosion rate. If during the application an extra amount of water is desired, the amount of corrosion inhibitor has to be increased correspondingly.
7. While installing the inhibitor, it is necessary to make all possible efforts to spread it evenly under the bottom of the tank.