

CORROSION INHIBITION OF EQUIPMENT UNDER HYDROSTATIC TEST – EXPERIENCE FROM ALGERIA

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ABSTRACT

Hydrostatic test is essential step in integrity management of different pressure equipment, such as vessels, piping, valves etc. In spite of its corrosive characteristics, industries continue to use water for hydrotesting purpose, which then may cause various corrosion rates in relation with time of exposure to hydrostatic test, lay down period, time of retained water after drainage, origin of water, level of chlorides, oxygen content etc. Each case speaks for itself, yet after several projects carried-out in Algeria with selected VCI inhibitor, a database of water corrosivity and optimum dosage rates has been gathered.

Key words: corrosion, hydrostatic test, water corrosivity, inhibitors, dosage rate

INTRODUCTION

Hydrostatic test is universally defined as a means of demonstrating the fitness of a pressurized component for service [1]. These tests are applicable for both; newly manufactured parts or parts that have recently been repaired.

From the standpoint of the operating company, hydrostatic test is to be done to prove integrity and to be given an operating license for the component by the relevant authority.

Hydrostatic test uses water which has to be pressurized to 125% of its Maximum Allowable Operating Pressure (MAOP). Testing period is no longer than 8 hours, where first 4 hours are considered as a strength test, while next 4 hours as a leak test [2]. Water as testing fluid is routine choice, as it is both low cost and available in large volumes. Consequently, water used in testing may cause corrosion of pipe, potentially leading to failure early in its operating life. Moreover, failures have occasionally been reported even before a pipeline enters service [1].

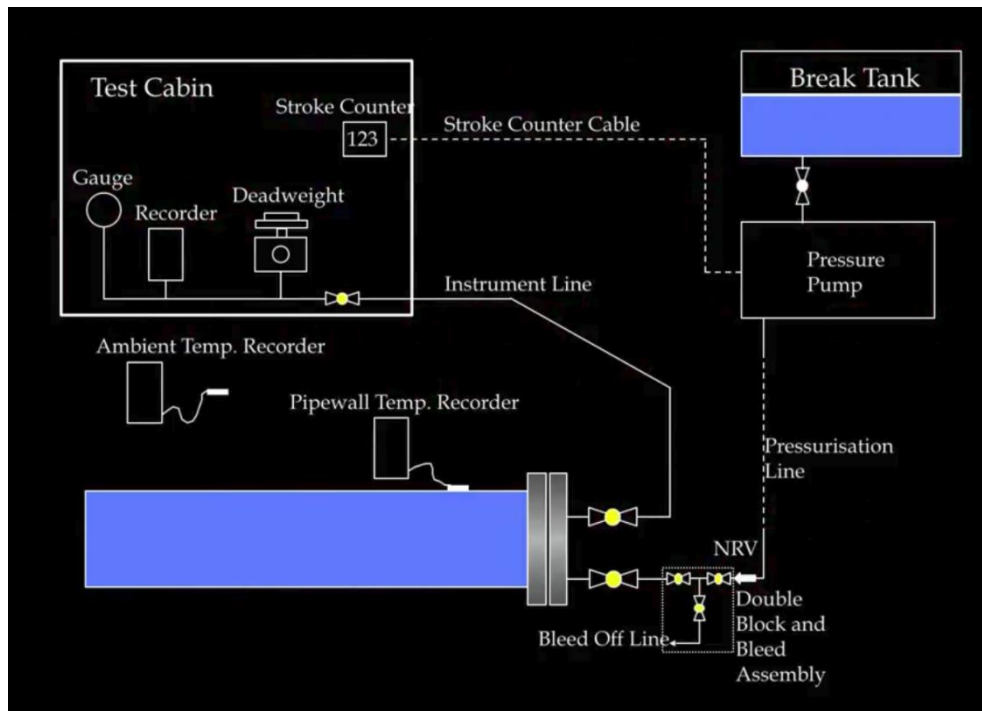


Figure 1. Typical hydrostatic test layout.

A key parameter affecting the extent of corrosion is the amount of time water remains in the pipeline. Obviously, extent of corrosion will be very low over the short period of hydrostatic test, yet, it can be significant during the extended preservation period (lay down period).

The chemical treatment of hydrostatic waters has historically used three types of products;

- oxygen scavengers (to reduce amount of oxygen)
- biocides (kills and prevents bacterial growth)
- corrosion inhibitors (used to inhibit general form of corrosion)

CORROSION MECHANISMS

Microbial corrosion

Bacteria are present in all-natural waters, with estimated concentration ranging from 10^4 to 10^6 cells per ml [1].

Although there is vast number of different species of bacteria in correlation with origin of the water, normally only few of them can cause corrosion issues. Most common trouble making bacteria are;

- sulphate reducing bacteria (SRB)
- acid producing bacteria (APB)

SRB are most common type of bacteria in oilfield systems. In most oilfield systems, dissolved oxygen is at very low level. Since SRB are strictly anaerobic (cannot develop in surrounding where oxygen

concentration is > 0.5 ppm), oilfield system, with oxygen concentration far below 0.5 ppm, seems to be good matching. Even in waters with significant oxygen content, sulphate reducing bacteria can survive by other organisms and deposits which shield bacteria from direct contact with dissolved O₂.

On the other hand, acid producing bacteria (APB) consume hydrocarbons as a food, creating therefore wide spectra of by-products. Their growth and reproduction create biomass beneath which, an under-deposit corrosion may occur.

Oxygen related corrosion

In aerated water systems, corrosion will normally develop through an oxygen concentration cell, figure 2.

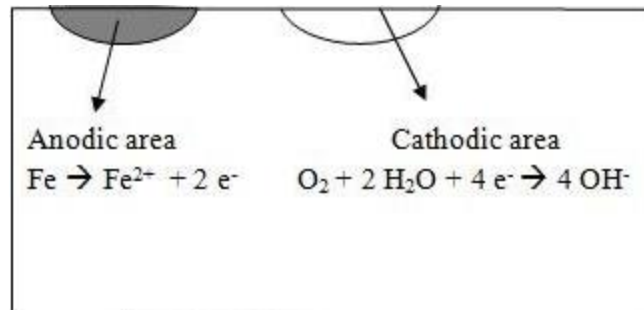


Figure 2. Oxygen corrosion cell.

Galvanic corrosion

When two or more metals with different nobility are brought into mutual connection, most noble one will orientate itself as cathode, leaving less noble metal to be an anode. As a consequence, strong corrosion will occur.

Not only material selection, but welding process as well can leave traces of foreign metal deposit which consequently, can lead to galvanic coupling and corrosion.



Figure 3. Traces of copper left on internal pipeline weld.

FACTORS AFFECTING CORROSION TENDENCY OF HYDROSTATIC TEST WATER

Many factors describe corrosivity level during hydrotesting, such as: water source, presence of solids, exposure temperature, oxygen availability, pipeline/tank material, exposure period, lay down period, internal condition of pipe/tank wall, presence of bacteria etc.

Table 1 sorts water sources considering their desirability for hydrotesting [4].

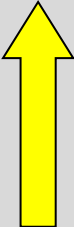
water source	desirability
demineralized water	
high purity steam condensate	
potable water	
sea water	
river water	
lake water	
brackish water	

Table 1. Ranking of water sources.

CORROSION INHIBITOR APPLICATION SCENARIOS

Present literature distinguishes several scenarios of corrosion inhibitor application. Each one is to be considered prior designing corrosion protection solution.

SCENARIO I

The first scenario covers addition of water-soluble corrosion inhibitor to hydrotesting water in amount sufficient to provide protection during both, hydrostatic test and period after water is drained. In such case, concentration of inhibitor is rich, and residual film formed by inhibitor is sufficient enough to protect from corrosion during the storage. Scenario sounds just about right when overall hydrostatic test water volume is relatively small.

SCENARIO II

Alternative is to use relatively small dose of corrosion inhibitor, with aim to prevent corrosion only during the hydrostatic test period (4 + 4 hours). After water being drained, system (e.g. pipeline) can be treated by fogging with appropriate product.

SCENARIO III

The most challenging scenario is treatment of enormously large hydrotesting water volumes (over millions of liters) where at the same time water is contaminated with significant concentration of chlorides and other aggressive species. After draining the water out, residual salts will remain on metal wall. These salts may retain some water and corrosion will occur.

EXPERIMENTAL PROCEDURE

CASE IN ALGERIA

Algeria is significant producer of oil and gas. As a member of OPEC, 2008 Algeria was the top 7th oil products exporter. Less than 11% of world's oil products were exported [3]. Algerian network is managed by big owned companies Sonatrach and Sonelgaz; Sonatrach controls oil & gas production, gathering and exportation through pipelines to Spain & Italy and counts +/- 20000 Km (official declarations). A green filed "GR7" of 344 km 48" pipeline in under construction by Sonatrach (through contractors; Cosider, ENAC). For domestic consumption, Sonatrach sells oil to Sonelgaz to be transported all over Algeria with a total network of more than 20 000 km. For cities distribution, a network of more than 120 000 km is managed by Sonatrach.

Due to its large pipeline network, Algerian companies are often in need of hydrostatic testing routine. Several applicable inhibitors formula by manufacturer were recognized as possible selection for hydrotesting purpose, table 2.

Approximate Dosing for Fresh Water Additive

Product	Metals Protected	During Testing	1-3 Months	6-12 Months*	12-24 Months*
VCI-641	Multimetal	500-750ppm	1000ppm	-	-
VCI-611	Ferrous, aluminium, galvanized steel, brass excluded	2.5-10wt%	5-10 wt%	10-15 wt%	20wt%
VCI-609	Ferrous, aluminium, galvanized steel, brass excluded	0.5-1wt%	1-1.5 wt%	5 wt%	5 -10wt%
VCI-308	Multimetal	0.5-1wt%	1-1.5 wt%	3-5 wt%	5-10wt%
Versions of S-69 and VCI-649	Multimetal	0.3-0.5wt%	0.5-1wt%	0.5-1wt%	0.6-1wt%
VCI-649 Powder and S-69 Powder	Multimetal	0.2-0.35%	0.35-0.7%	0.35-0.7%	0.4-0.7%
VCI-377	Multimetal	0.5-0.75wt%	0.5-1wt%	2-3 wt%	3-5wt%

Approximate Dosing for Cast Iron in Fresh Water

Product	Metals Protected	During Testing	1-3 Months	6-12 Months*	12-24 Months*
VCI-609	Cast Iron	1.5-2.5 wt%	-	-	-
VCI-611	Cast Iron	10-12.5 wt%	10-15wt%	10-20wt%	20wt%
VCI-417P	Cast Iron	0.2 wt%	0.2-0.5wt%	0.5-1wt%	1-2wt%
S-69P	Cast Iron	0.75-2wt%	5wt%	5-7 wt%	7wt%
M-370	Cast Iron	5wt%	10wt%	10wt%	10wt%
M-640L	Cast Iron	2.5wt%	5wt%	5wt%	NE
M-95	Cast Iron	2.5wt%	5wt%	5wt%	NE

Approximate Dosing for Brines Additives TDS <0.5wt%, CL<0.1wt%

Product	Metals Protected	During Testing	1-3 Months	6-12 Months*	12-24 Months*
VCI-644	Multimetal	0.2wt%	-	-	-
VCI-645	Multimetal	0.5wt%	-	-	-
VCI-611	Ferrous, aluminium, galvanized steel, brass excluded	5wt%	5wt%	-	-
VCI-609	Ferrous, aluminium, galvanized steel, brass excluded	1-3wt%	1-3wt%	5- 10 wt%	-
M-645	Multimetal	Dosage based	on area to be	protected	1250 ft2/gal (30.7m2/L)-
Versions of S-69 and VCI-649	Multimetal	0.5-1wt%	0.5-1wt%	-	-

Approximate Dosing for Sea Water Additives

Product	Metals Protected	During Testing	1-3 Months	6-12 Months*	12-24 Months*
VCI-644	Multimetal	0.3-0.5wt%	0.75-1wt%	-	-
VCI-645	Multimetal	0.75-1wt%	0.75-1wt%	-	-
S-69P	Multimetal	5wt%	5wt%	-	-
VCI-611	Ferrous, aluminium, galvanized steel, brass excluded	5wt%	5wt%	-	-
M-645 or Ecoline 3220	Multimetal	Dosage based	on area to be	protected	1250 ft2/gal (30.7m2/L)-

Table 2. Approximate Dosing for Additives by Manufacturer [5].

In order to make selection of wide spectrum, S-69 powder inhibitor was chosen.

Proposed dosage rates in weight % vs. water type for S-69 formula are shown below;



It is obvious that for finding optimal dosage rate relying only on selection table is not sufficient. Given that, more detailed data base of different water types vs. dosage rates was established.

Measurements in lab

A three most common water types were chosen to test inhibitor efficiency. Solution preparation was based on assumption that the most significant impact comes from pH, hardness and Cl⁻ ions. To ensure required chloride and hardness level exact weight of NaCl and CaCl₂ was diluted in 1L container. pH value was adjusted using phosphate buffer solution. The cylindrical samples used in this study as working electrode were made of carbon steel with a diameter of 2,00 cm and exposed area of 3,14 cm². All samples were soldered to insulated copper wire to ensure electrical contact and moulded in epoxy resin. Prior to each measurement, the sample surface was grinded with SiC emery paper up to 600 grit.

Electrochemical measurements were performed in accordance with ASTM G5 and HRN EN ISO 17475 standards using Bio-Logic SP-200 potentiostat/galvanostat and EC-lab software. All measurements were conducted in an electrochemical three-electrode standard corrosion cell with double jacket glass to maintain stable temperature. The reference electrode was saturated calomel electrode (SCE) while two graphite electrodes were used as counter electrode. Prior to each measurements solution was de aerated with nitrogen for 20 minutes in order to maintain oxygen-free environment.

Open circuit potential (OCP) was monitored for 30 minutes and potential dynamic polarizations were performed in the potential range $\pm 0,250$ V vs E_{corr} using a sweep rate of 0,167 mV/s. The values of I_{cor} were obtained using Tafel extrapolation, i.e. intersection of the lines extrapolated from the linear region of cathodic and anodic part of potential dynamic curves. Corrosion rate was calculated according to following equation [6]:

$$\text{Corrosion rate (C.R.)} = \frac{K \cdot I_{cor} \cdot (E.W.)}{d \cdot A} \quad (\text{Eq. 1})$$

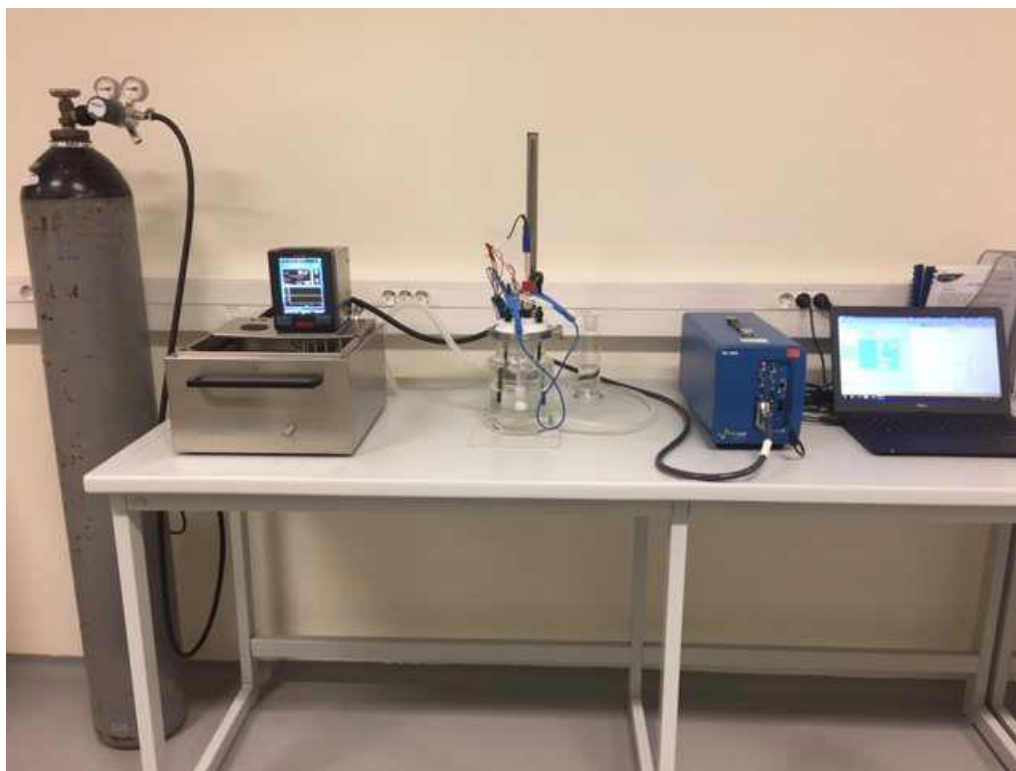


Figure 4. Laboratory setup

RESULTS

Measurement results are given in Table 3 and Figure 5.

Water sample N° 1 (INQ #6)				
pH= 6,90±0,05; Cl ⁻ = 1011,75 mg/L; Ca ²⁺ =392,98 mg/L				
$T=(22\pm 1)^{\circ}\text{C}$	E_{corr} vs SCE, V	I_{cor} $\mu\text{A cm}^{-2}$	Corrosion rate, mmpy	Inhibitor Efficiency, %
WITHOUT INHIBITOR	-0.776	4,804	0.0165	0.00
WITH INHIBITOR (low dosage) - 0.1%	-0.503	1,987	0.0068	58.64
WITH INHIBITOR (recommended)– 0.75%	-0.655	1,805	0.0062	62.43

Water sample N° 2 (INQ #18)				
pH= 6,89±0,05; Cl ⁻ = 111,31 mg/L				
$T=(22\pm 1)^{\circ}\text{C}$	E_{corr} vs SCE, V	I_{cor} $\mu\text{A cm}^{-2}$	Corrosion rate, mmpy	inhibitor efficiency , %
WITHOUT INHIBITOR	-0.741	7,259	0.0249	0.00
WITH INHIBITOR (low dosage) - 0.005%	-0.748	2,811	0.0096	61.27
WITH INHIBITOR (recommended)– 0.75%	-0.441	0,286	0.0009	96.06

Water sample N° 3 (INQ #19)				
pH= 7,11±0,05; Cl ⁻ = 417,70 mg/L; Ca ²⁺ = 135,00 mg/L				
$T=(22\pm 1)^{\circ}\text{C}$	E_{corr} vs SCE, V	I_{cor} $\mu\text{A cm}^{-2}$	Corrosion rate, mmpy	Inhibitor Efficiency %
WITHOUT INHIBITOR	-0.720	2,950	0.0101	0.00
WITH INHIBITOR (low dosage) - 0.01%	-0.688	1,794	0.0061	39.19
WITH INHIBITOR (recommended)– 0.75%	-0.547	0,951	0.0033	67.76

Table 3. Measurement results

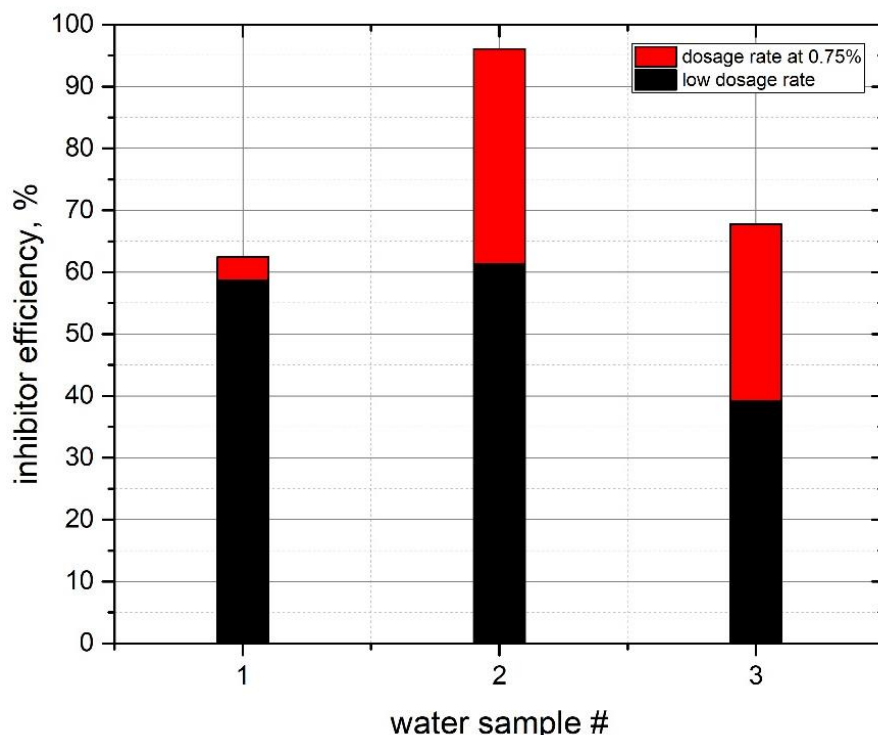


Figure 5. Cumulative result of corrosion inhibitor efficiency for various water samples.

CONCLUSIONS

It is shown that waters used for hydrotesting purposes in Algeria are moderate corrosive and therefore, inhibitor addition is needed. Selected inhibitor S-69 in powder form has demonstrated very good inhibition properties, knowing that added in small amounts it reached significant level of protection (from 40 to 60%).

Adding more inhibitor up to the 0.75% (table data) gives further protection, yet not fully predictable (figure 4). Levels of protection with dosage rate of 0.75% were ranging between 63 and 95%.

Having more of such measurements and results in future will strengthen up database and will tell more on corrosivity level of waters in Algeria and how to deal with them through inhibitor dosage rates.

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