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FACTORS INCREASING CORROSION RATES OF OIL FIELD PIPES AND THEIR INHIBITION

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Abstract

Steel pipelines and process equipment used in oil fields are subject to corrosion-erosion effects. Assessing and reducing these degenerative processes have important implications for oil field safety and productivity. This paper presents the results of an investigation of the corrosion rates in the oil well flow lines of an oilfield in the North African desert and factors that inhibit corrosion. The paper presents data gathered from corrosion coupons and ultrasonic measurements over a three-year period (1994-1996) to show that the corrosion rates are significantly influenced by variables such as total production, water cut, and the volume of associated gas. This is followed by a discussion of the factors that inhibit corrosion. The paper concludes with recommendations for the minimization of corrosion.

Key words: Erosion-Corrosion; Oil flow lines; Water-Cut; Total Production.

1. Introduction

Corrosion is a degradation phenomenon that occurs due to chemical or electrochemical action on materials. Corrosion leads to a reduction or loss of the integrity and efficiency of materials subject to it with or without any friction between the corrosive agent and the corrosive medium. The degradation suffered by the metallic container of a chemical substance is an example of the corrosion of a static medium. Erosion, in contrast, results from mechanical wear and tear, for example, gouging or loss of material from solid surface by the impingement or impacting of liquids ,gases or solids. The conjoint action of erosion and corrosion in aqueous environments is known as erosion-corrosion, which is encountered prominently in chemical process industries like oil and gas production. The combined effects of erosion and corrosion can be significantly higher than the sum of the effects of the processes acting separately, technically known as *synergism* [1,2,3].

Extensive research has established that impingement of particles from moving parts and/or constant contact with liquids remove material from the metal surfaces or their protective layers like oxide films, resulting in continuous exposure of fresh metal surface to the corrosive environments, which, in turn will lead to still higher rates of corrosion [1,2,4,5]. Erosion-corrosion is produced by the impingement of gas-oil-water emulsion on the metal at high velocity. Components like valves and propellers in particular are exposed to hydrodynamic conditions that cause the formation of small cavities in the liquid. These cavities deliver multiple sharp blows at the metal surface. Further corrosive effects are induced by chemical factors like high chloride ion concentration in the associated water formation and the low pH due to CO_2.

In other words, erosion-corrosion that produces the maximum impact originates from two sources. The first, viz., the mechanical source results from the high velocity of the corrosive medium (gas-oil-water emulsion) which produces cavitation and impingement. The other, which is electrochemical, results from the chemical reaction between the medium and the exposed parts. Erosion-corrosion produces weight loss as a result of removal of large parts of clear-cut metal portions due to impingement and cavitation. Parts such as manifolds, valves, bends, and inspection omegas are particularly vulnerable to this effect. The synergistic effect here is very high .This effect, according to Barik [5], is the difference between the total effect of erosion-corrosion and the sum of the individual effects erosion and corrosion. But according to the same author [5], the majority of metal loss usually results from mechanical damage as a result of erosion. This agrees with Ramakrishna [1].

Vulnerable pieces of equipment include:

- pipes (bends, elbows, tees),
- valves,
- pumps,
- blower-nozzles,
- flow-measuring orifices, venturies).

Lochman and Howell [6] specifically deals with the effects of erosion- corrosion caused by gases on valves and gas turbine blades.

The present work aims at studying the erosion-corrosion due to the effect of gas-oil-water mixture flowing in the pipelines. The contribution of the volume of this mixture to the erosion-corrosion process is subjected to more specific analysis. The effect of the process on the geometrical features of the exposed parts like the smooth surfaces of the pipe line interior, nipples, and valves as indicated by the corrosion coupons is also analysed. There is also an attempt at quantifying the capacity of conventional inhibitors to reduce the impact of erosion-corrosion.

2. Materials and methods

Measurements using corrosion coupons were conducted in accordance with API RP 45. The coupons were installed in the pipe lines. They were retrieved after three months and subjected to laboratory examination and evaluation. UTS (Ultra Sonic Tests) Measurements were carried out by the inspection teams using Krautkraemer instruments over several years. The annual average of the measurements was considered in our study. Both these measurements were carried out at the regular facility for the company's own corrosion-monitoring purposes.

Production and water cut data were supplied by the field production department.

To investigate the extent of the effect of corrosion inhibitors, the corrosion rate values were collected over a certain period. In this period the inhibitor dosage for those oil wells with higher water cut were raised from 2Qts/th.BbL to 3Qts/th.BbL. Later, for economic reasons, the quantity was reduced to 1.5Qts/th.BbL. This was finally restored to 3Qts.th.BbL. The variations in corrosion rates during these periods provided valuable data on the effect of inhibitors on corrosion.

3. Results and Discussion

Graph 1 indicate increases in corrosion rates against a certain TPR (Total Production Rate) of A-62// 4154 Bbl/Day. The oil wells are classified into 3 groups, each containing 10 wells. The average of 10 wells is calculated and plotted against the related calculated average corrosion rates. Fig.2, and Fig.2B follow the same logic.

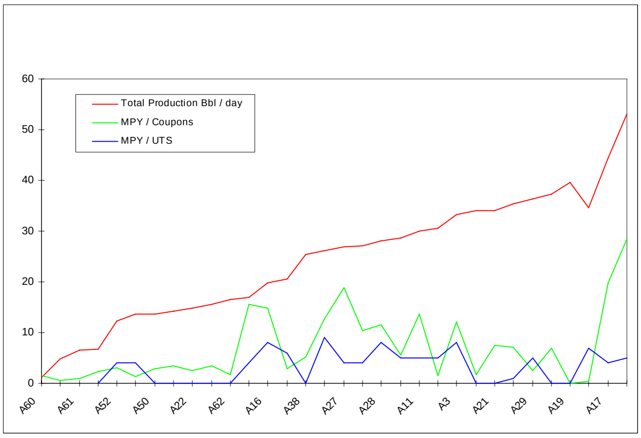

Fig.1 1994 Total Production / Coupons - MPY / UTS – MPY

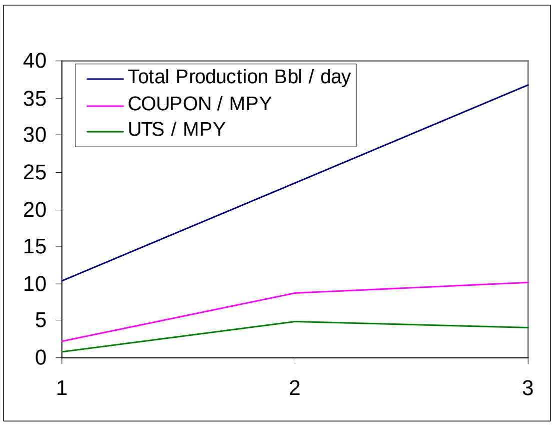

Fig. 1B Total Prod.(calculated average) /Coupon/UTS - MPY (calculated average) /1994

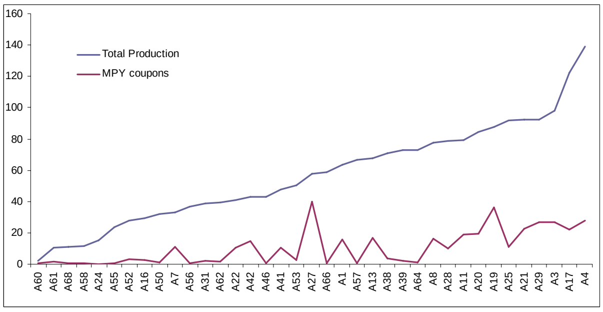

Fig. 2 Total Production 1995-Bbl/day/MPY-coupons

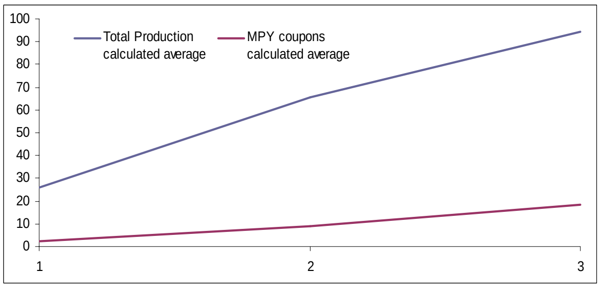

Fig. 2B Average data of the first, second and third group (each group of 10 wells)

The results from corrosion coupon measurements show clear correlation between corrosion rate and TPR, but not between corrosion rate and UTS Values.

Fig.3 show the relation between water cut (W.C.) and corrosion rates. It is clear that if the W.C is very low, i.e., close to zero, the corrosion rates as indicated by the coupons will also be low. Beyond a certain W.C. value (higher than 1% as in the case of the oil well A67), we notice an increase in corrosion rates. But this increase does not continue with any further increase in W.C. This trend is clearer in Fig.3B. In this case, the oil wells are classified into 3 groups of 10 wells each. The average corrosion rate of each group is calculated and plotted against the corresponding corrosion rate value of each well.

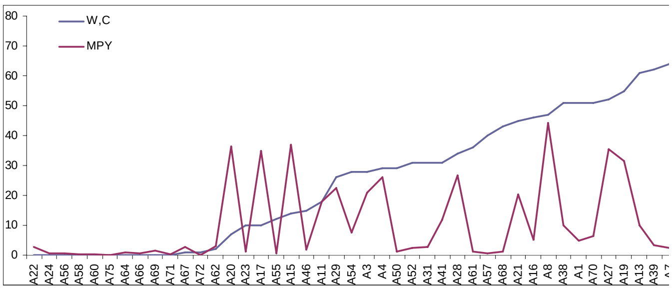

Fig. 3 1996 W.C. % / Corrosion Rate

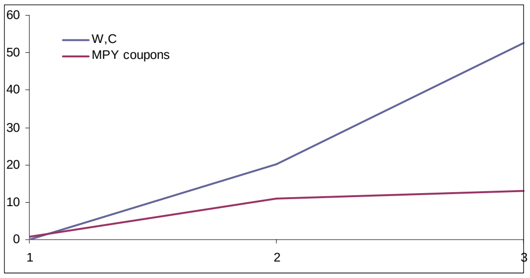

Fig. 3B 1996- calculated average W.C. %/ calculated average corrosion Rate

Fig. 4 shows the relation between the corrosion rates and the volume of the associated gas produced. The erosion impact is more clearly shown in Fig 4B. In this case too, the oil wells are categorized into three groups of ten wells each. The average of each group is calculated and plotted against the average corresponding corrosion rates of each well. There is a clear increase in corrosion rates as the gas volume increases. The effect of volume on erosion rates is also clearly established.

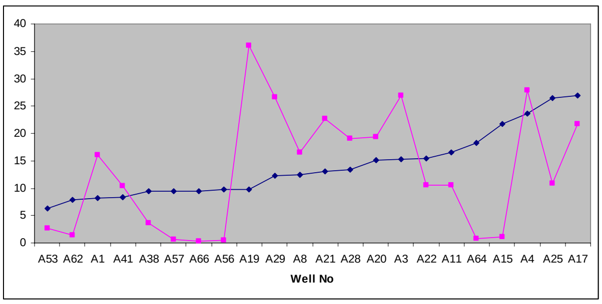

Fig. 4. Relation between corrosion rates and volume of associated gas

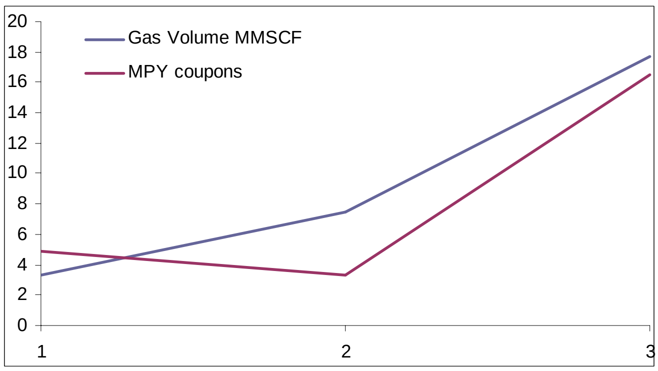

Fig. 4B Gas volume MMSCF/ MPY Coupons / 1995

The above findings prove that corrosion is a logical consequence of the operating conditions in the flow lines. As corrosion is a chemical process, water plays a major role. The gas-water-oil mixture forms an emulsion in the pipelines due to the high velocities and temperatures. It can therefore be assumed that, starting from a low percentage water cut, the water necessary for the reaction is available in sufficient quantities on the metal surface to initiate a corrosion reaction. Any increase in the water cut could influence the corrosion rate, but only up to a certain extent.

TPR will remain the dominant factor in determining erosion-corrosion as flow velocity directly affects erosive action. The increase in water cut will have a greater influence on the corrosion phenomena in cases where there are laminar flow conditions. This will affect the six 'o' clock position of the pipeline but only in case of phase separation.

Comparing the values given by (UTS) Ultrasonic Test instruments with the values given by the test coupons reveals a large discrepancy. This discrepancy does not in fact exist as the UTS values reflect the surface status, and are affected only slightly by the erosive action of the flow. The coupon plates on the other hand are in the mainstream fluid flow, in conditions of high turbulence, and therefore suffer severe erosion. This action on the coupon plates is totally dependent on total production flow, and not on water cut.

The results shown for the coupon plates represent not the status for all parts of the pipeline system, but those in a similar situation to the coupons, such as elbows, valves, restriction fittings and reducers.

4. The Relationship between Inhibitor Dosage and Corrosion Rates

This section examines corrosion rates in relation to the inhibitor dosage rate. In these oil wells, the inhibitor dosage had been increased from 2 Qts/th. Bbl to 3 Qts/th. Bbl, based on water cut higher than 25%. It should be noted that the dosage was reduced to 1.5 Qts/th. Bbl for costs saving purposes, and was subsequently restored again to 3 Qts/th. Bbl.

The above results can be taken as indicative of system behaviour, but not as a definitive representation due to the limited time span over which they were taken. This study shows (Fig. 5) that there is no relationship between corrosion rates and the inhibitor dosage under such conditions even when increasing the dosage by 100% from 1.5 to 3 Qts/th. Bbl.

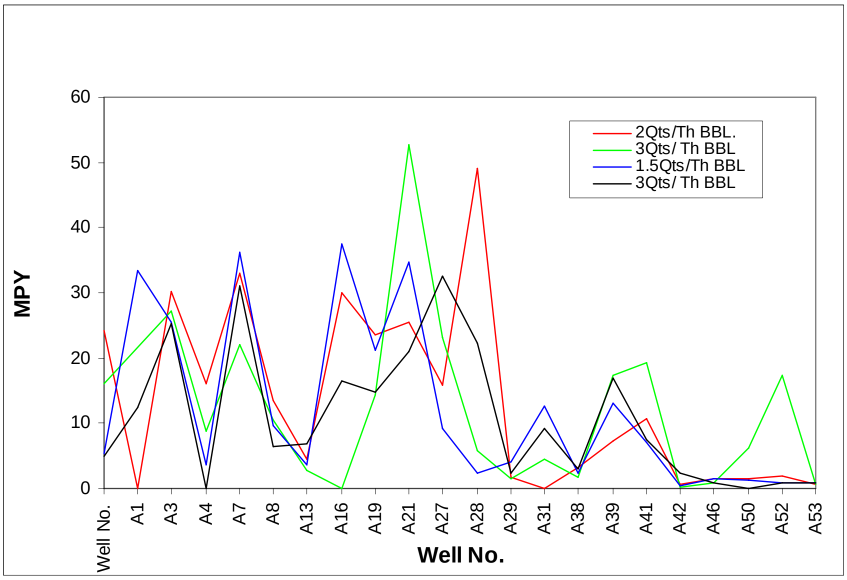

Fig. 5 Inhibitor concentration/corrosion rate

Considering the observations in part 1 of this investigation, these findings are as anticipated. Assuming that, all other conditions being equal, the severity of corrosion is a direct function of the flow conditions, it follows that the effective inhibitor dosage will be related to the severity, or intensity, of the flow conditions generally. This fact has been known for some time, and there exists a critical flow intensity beyond which inhibitors in flowing media lose their effectiveness. At these limits, the corrosion inhibitor is unable to sustain a stable protective film Schmidt [7]. The critical flow intensity varies from inhibitors of one type to another. According to Dereck [8] there exists a laminar regime to a particular flow rate value where corrosion rates are low. At higher flow rates, the laminar flow regime turns to a turbulent flow regime where erosion-corrosion will be very high. Under turbulent conditions, the inhibitors lose there effectiveness. Gueven [9] shows a very clear relation between corrosion rates and flow rates. Proof of a proportional relation between flow rates and erosion-corrosion rates is provided by Derek [8]

It is, however, less well known that critical flow intensity is also a function of inhibitor concentration, Schmidt [7] and that production rates higher than those previously thought possible are quite realistic if the effective inhibitor dosage (concentration) is suitably increased.

Flow-Induced Localised Corrosion (FILC) is amongst the mechanisms most responsible for failure due to corrosion damage suffered by oil and gas equipment. Disturbed flow and the micro turbulence which produces FILC occur in pipeline systems, for example, at steps, grooves and surface imperfections such as corrosion pits and weld beads.

It has been found that grooves as small as 1mm in length and 0.5mm in depth in carbon steel tubing can lead to severe localised attack on the down stream edge in the flow of CO2 gas, at a flow velocity of 3 Mtr/sec and 80 - 100 Deg C at 3 Bar pressure. Under the same conditions, no FILC or pitting occurred at flow velocities up to 10 Mtr/sec in plain tubing with no surface irregularities. The flow velocity at this field is typically 13.5 ft/sec (4.15 Mt/sec) in 6” diameter piping and 21.6 ft/sec (6.65 Mt/sec) at the wellheads.

This makes our results understandable, explaining why the corrosion coupons installed inside the pipe line against the direction of flow of the gas-oil-water emulsion revealed high corrosion values but in the same time the UTS measurements of the pipe line surface are low.

As previously mentioned, the results of monitoring the corrosion on the inner surface of the pipeline by means of the UTS appear to be satisfactory. On the contrary, severe problems are indicated in parts such as elbows, nipples and valves, especially at the oil collection manifold.

5. Conclusions and recommendations

A. The velocities experienced by the flow lines ought to be considered in the evaluation of inhibitor efficiency and consequent computation of the quantum of inhibiting agents to be used for the mitigation of FILC.

B. The data from the corrosion coupons show that inhibitor concentration has no effect beyond a critical level.

C. Flow intensity is a decisive factor influencing corrosion. Therefore, changes in flow, increase in the diameter of pipes and radius of bends, more sophisticated “T” fittings, and more stringent choice of materials should be considered critical at the design stage.

D. The protective action of the inhibitor on the plain metal surface with laminar flow may be higher than on those locations with an erosive turbulent flow.

E. It would be advisable to install by-pass flow loops to enable a proper evaluation of the inhibitor protection efficiency.

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