Algerian Journal of Environmental Science and Technology
December edition. Vol.9. N°4. (2023)
ISSN : 2437-1114
www.aljest.org

Monitoring and inspection to combat corrosion of pipeline lines in an oil field

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ARTICLE INFO

Article History :

Received : ***08/09/2022***
Accepted : ***30/01/2023***

Key Words:

Inspection;
Monitoring;
Corrosion;
Inhibitors; Pipelines.

ABSTRACT/RESUME

Abstract: *Corrosion control for oil and gas industry equipment and pipelines is paramount. In order to ensure increased reliability in its production, the oil industry must develop and optimize corrosion monitoring, control and management methods.In this context, our study is carried out at an oil field located in the South of Algeria (field Hassi Berkine (HBNS)) and in order to treat the problem of corrosion occurred on the steels API 5L of grade X60 of pipeline lines transporting petroleum products to the processing center (CPF).The detection of failures caused by corrosion is done by inspection of pipeline lines by non-destructive ultrasonic testing, while corrosion monitoring allows the evaluation of corrosion rate as a function of time. This will allow us to follow the behavior of the steel as well as the evaluation of the performance of the corrosion inhibitors. Ultrasonic techniques have allowed us to perform a complete examination of the pipelines due to the ability to inspect inaccessible areas. The inhibitors used led to the formation of an impermeable organic film preventing metal-water contact and thus reducing the corrosion rate.*

We note that the lifespan of the pipes depends on a good continuous monitoring and a rigorous inspection of all the integrity of the pipes and the implementation of safety and protection measures against corrosion such as: corrosion inhibitors, coatings and cathodic protection.

I. Introduction

In the oil industry, pipelines are essential tools for transporting large flows of hydrocarbons over long distances. They are the safest and most economical mode of transport [1,2]. In Algeria, the network is estimated at more than 18,000 km for all diameters combined [3]. The investment in the construction of a pipeline consists of agreeing to an immediate expense with, in addition, the lowest operating and repair charges. It is therefore necessary to ensure their longevity and to avoid unplanned stops as much as possible [4]. Today, the technical and economic objectives of manufacturers in all sectors are moving in the direction of reducing costs, improving performance and productivity. Pipelines or equipment must withstand numerous stresses [5]:

- external stresses: mechanical stresses, fatigue,
- internal stresses: friction, abrasion, temperature, erosion,....

- environmental stresses: corrosion, oxidation, chemical attack, heat....

However, the multiplication of more or less serious accidents, due in particular to corrosion, as well as their incidence on the economy and their impact on the environment, make this type of transport increasingly worrying.
Statistical data indicates that the losses caused by failures produced by corrosion oscillate between 25 and 30% of all losses [6].
In order to ensure increased reliability of its equipment, the oil industry has developed and optimized methods for monitoring, controlling and managing corrosion. For example, to control the thousands of kilometers of pipelines in the gas, oil or refined product transport networks, scrapers equipped with several control technologies have been developed [7,8].
Indeed, the protection of pipes against corrosion by soil or water could simply be achieved by insulating them. However, the coatings used for this purpose do not practically ensure the complete and lasting preservation of the steel tubes. It is therefore necessary to use another method of protection, called active or protection by the use of inhibitors [9].

II. Experimental methods

II.1.Corrosion monitoring and inspection methods

A pipeline is a buried or aerial pipeline carrying goods, whether in liquid or gaseous form.
Pipelines are most often constructed from butt-welded steel tubes, coated on the outside or even on the inside and usually buried in the ground [10]. These pipelines are expensive and sometimes difficult to implement depending on the characteristics of the land crossed, in seismic risk or politically unstable areas. Unlike their initial investment; they are relatively inexpensive to use compared to other competing forms of transport, at least over short and medium distances [11].
The material used in the pipelines studied is carbon steel of grade X 60: API 5L X60 with the following chemical composition (Table1).

Table 1. *Chemical composition in % of steel X 60[6]*

Chemical composition of grade X60	**Fe**	**C**	**Mn**	**Si**
Composition in %	97.14 à 97.66	0.19 à 0.24	1.15 à 1.35	0.20 à 0.40
Chemical composition of grade X60	**P**	**S**	**Al**	**Cr**
Composition in %	$\leq$ 0.025	$\leq$ 0.025	0.02 à 0.04	$\leq$ 0.02
Chemical composition of grade X60	**Mo**	**Ti**	**V**	
Composition in %	$\leq$ 0.05	0.03 à 0.04	0.11 à 0.15	

The monitoring techniques used in our work are: corrosion coupons, electrical resistance probe (ER), biological analysis and chemical analysis.
These corrosion monitoring techniques have been successfully applied and are used in an increasing number of applications because [12]:
•The techniques are easy to understand and implement.
•The reliability of the equipment has been proven in the field for many years.

II.1.1. Corrosion Coupon

The coupon is a sample of the same grade of steel as the pipeline, weighed beforehand, and introduced into the pipeline [13]. After a reasonable interval of time, the coupon is then cleaned of all corrosion products and weighed again. The weight loss is converted into a corrosion rate.
The most common types of coupons are shown in the figures 1 and 2:

Figure 1. *Image of a strip coupon*

Figure 2. *Image of a corroded Coupon Disc*

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www.aljest.org

II.1.2. Electrical resistance thermometer (ER)

Electrical resistance probes , shown in the figure 3 , measure the change in electrical resistance of a component and provide information on metal loss. These probes can operate in all environments for long periods of time. Additionally, they are able to provide periodic (eg: daily, weekly, monthly) or continuous (eg: hourly) corrosion rate data.[14]

Figure 3. *Electrical resistance probe (ER)*

II.2. Biological analysis

Biological analysis measures the presence of bacteria that consume sulphate and generate sulfuric acid (H_2SO_4). This last is known to be extremely corrosive to metal equipment.[15]

II.3. Chemical analysis

The samples of water from discharges and spring wells taken on site were transported by road and received at the Laboratory, they are the subject of a chemical analysis according to standardized methods [16,17]. These analyzes include: measurement of PH by electrometry, salinity and iron content.

Pipeline inspection techniques make it possible to find defects in the integrity of pipelines without degrading them using various methods ranging from visual inspection to the most sophisticated methods[18].

In our work, we have used non-destructive testing (NDT) methods such as: visual inspection and inspection by ultrasound tests: inspection by guided waves (GWT), inspection by Phased Array Ultrasonic Technique (PAUT) and inspection by conventional ultrasound.

III. Results and discussion

The results of the corrosion tests of the coupons immersed in the pipes in the presence of the inhibitor and biocide were obtained by the weight loss method on three different wells.

The corrosion rate(v (mpy)) is calculated, using the following conversion equation[19]:

$$v = \frac{3650\times \text{ loss of mass (g)}}{\text{metal density}\left(\frac{g}{cm^3}\right)\times \text{ coupon area } (cm^2)\times \text{ time(days)}}$$

mpy :miles per year

The corrosion rate variation as function of time, in the three wells was shown in figure 4 :

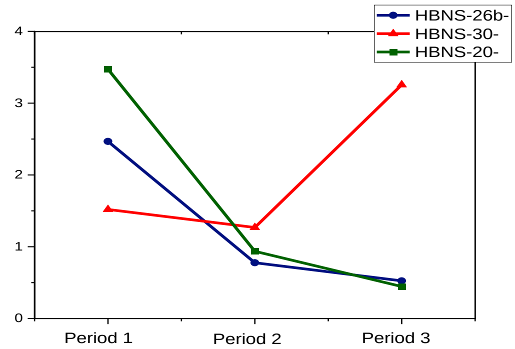

Figure 4. *Variation of corrosion rate as a function of Time (from coupon)*

In Figure 4 we represent the evolution of the corrosion rate in mpy (ordinate axis) for three different oil wells as a function of time (periods: 3 x 90 days) with bath (shock) and continuous injection of inhibitors corrosion (irregularity of the injection pumps in their operation).

We find that the continuous treatment (well HBNS-26b-) is more effective compared to the bath treatment (well: HBNS-30-, HBNS-20-). The corrosion inhibitor forms an organic film impermeable to metal/electrolyte interface by reducing the rate of corrosion.

The results of the corrosion rate measurement by the ER corrosion probe for the HBNS-26b well as a function of inhibitor injection are shown in Figure5

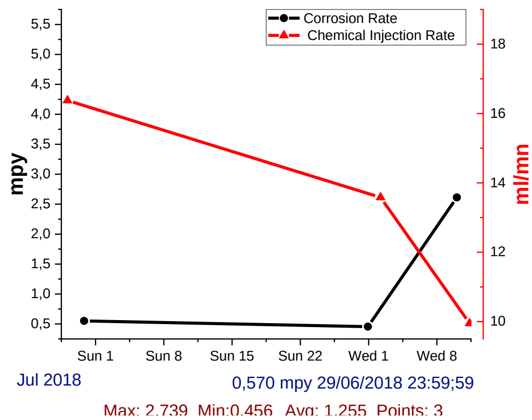

Figure 5. *Variation of corrosion rate as a function of injected inhibitor*

This method is based on the electrical resistance of a filament[20]. The corrosion rate remains stable as long as we inject the inhibitor, as soon as we decrease the injection, this rate increases. This increase in corrosion rate is explained by the detachment of the protective surface film which is not very resistant.

Biological analysis reveals very low bacterial corrosion.

The chemical analysis and the measurements carried out concern dissolved iron, salinity and pH give the following results:

Table 2. *Chemical analysis*

	Measurements			
Name of The wells	pH at 20 ˚C	Iron 2^{+}(mg/l)	Cl^{-} (mg/l)	Salinity (NaCl/Kg)
HBNS-26b-	6.27	39	26197.55	43226.00
HBNS-30-	6.33	43.50	25665.80	42349.00
HBNS-20-	6.35	37.00	22936.15	37845.00
HBN-23-	6.28	54.00	28076.40	46327.00

According to the PH values obtained, we find that the water produced with the crude is acidic, this is due to the presence of chloride and the salinity which is high, which promotes corrosion in the pipelines.

From the chemical analyzes of the gas from the four oil-producing wells (viscosity and density), we find that the crude from the Berkine group is a light crude, and therefore of good quality.

Ultrasonic inspection was performed on pipeline lines from three crude-producing wells. Its purpose was to monitor the integrity and general condition of the pipeline in service to detect any loss of metal due to corrosion or erosion.

III. Conclusion

The Berkine group, like any oil industry, is confronted with corrosion problems of external origin, linked to the ground or internally linked to the presence of acid gases dissolved in the oil such as hydrogen sulphide (H_2S) or carbon dioxide. (CO_2), and many bacteria that attack the internal walls of pipelines [21]. To counteract this, surveillance and inspection methods are put in place for detection and the appropriate choice of a protection method. In the HBNS field, the fight against corrosion has been designed by the addition of chemical additives (corrosion inhibitors, biocide), injected continuously or discontinuously. The study of corrosion in the Berkine group revealed the existence of a rigorous follow-up of the anti-corrosion program, a dynamic program, which can be changed frequently according to the supervision (monitoring) and the circumstances gave its fruits, and then preventing the installations against damage due to corrosion so as to increase their service life. The phenomenon of corrosion at the Berkine group is under control.

The policy adopted by the group for the fight against corrosion required the desired results. Monitoring will be improved to better protect the facilities and thus ensure their integrity for as long as possible.

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Please cite this Article as:
Bourenane K.,Haddar ABD.,Haddar A.,Zerouki I.,Abdessemed D., Monitoring and inspection to combat corrosion of pipeline lines in an oil field., ***Algerian J. Env. Sc. Technology***, **9:4 (2023) 3414-3418**