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Conversion Coating Pretreatment Enhances Pipeline Integrity

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Abstract

It is necessary to coat both the internal and external surfaces of pipelines which transport different types of fluids that are usually contaminated with various percentages of aggressive corrosives. Pipelines pass through various terrains and highly challenging environments hence the need for both internal and external coatings to prevent corrosion and its adverse effects. In order to improve on the longevity of pipelines and the adhesion of the coating system, it is preferable to conversion coat blasted surfaces prior to application of any coating system. Improvements in pipeline coatings applications and the often neglected chromating procedure prior to coating application have been highlighted. This will prolong the lifespan of pipeline networks and secure these strategic assets from being a source of both materials and human resources drain pipes. However, the use of corrosion resistant alloys as internal lining for carbon steel pipes in the petroleum/gas industry is fast gaining recognition.

Keywords

Oil/Gas Industry, Conversion Coating, Pipeline, Corrosion

1. Introduction

From time immemorial conversion coatings based on chromates and phosphates have been of great advantage in improving corrosion resistance and improved paint/coating adhesion on substrates on to which they are applied. Substrates that have enjoyed such special treatments in the past are those employed in the vehicle assembly plants where phosphate was the choice of car manufacturers whereas in the aerospace/aircraft and building industries chromates reign supreme. They are still the first choice of manufacturers in facilities where their adverse environmental effects can be contained. However, to a large extent researchers are searching far and wide for replacements of chromates and phosphates because of the alleged adverse effects they have on the environment as well as on human beings [1]. Other researchers [1, 2] have modified the chromate processing treatment which led to the reduction of its carbon foot print and its application in the field has become less hazardous.

For subsurface and subsea pipelines, there are various excellent coating systems from different manufacturers and suppliers that can withstand various extreme adverse climatic conditions as may be encountered in the oil/gas industries. However, applications of the coatings normally witness unforeseen and unpredictable negative environmental conditions such as changes in humidity, presence of hygroscopic contaminants such as sulphates and chlorides. Such uncontrollable effects may result in inconsistencies in the coating operations. Thus, such flawed coating application procedures will lead to coating failures at short notices.

The best surface preparation in the coating industry is by blasting. However, if a standard surface finish of Sa3 is achieved, true surface cleanliness is not guaranteed and the steel surface also becomes more reactive. In the presence of any of the aforementioned variables, the performance of any coating applied on such surface will be compromised. A worst case scenario is provided when heat is applied on the steel prior to coating application as in the case of fusion bonded epoxy (FBE) or extruded/sintered polyethylene; the effects of these uncontrollable atmospheric contaminants become accelerated.

In order to stabilize the surface of the steel and obtain a stable layer, application of chemical pretreatment becomes important. Thus this paper describes some available pipeline coatings and the surface stabilizing factor, chromate conversion coating.

2. Pipeline Coating Systems

There are typically five main coating systems employed in the pipeline industry, these are: three-layer PE (3LPE), three-layer PP (3LPP) and PP (polypropylene), fusion-bonded epoxy (FBE), asphalt enamel and polyurethane (PUR). The choice of a coating system depends on factors which may include costs, availability of material, control on handling, transportation and some technical factors such as mode of application. Three-layer PE (3LPE), three-layer polypropylene (3LPP) and – up to seven layers – PP as well as FBE are the most commonly used coatings for new pipes, while for repairs, PUR-poly urethane, is the coating of choice.

The 3LPE system consists of an epoxy primer with a high-density (HDPE) top coat designed to operate across a wide temperature range from -45°C to 85°C and also should be able to withstand rough handling and clumsy installation practices.

Three-layer PP coating systems are best used in the temperature ranges of about 0°C to 140°C and for pipes that are subjected to extreme mechanical stress. However, 3LPP system consists of an epoxy primer, a grafted co-polymer PP adhesive that bonds the epoxy primer with a PP topcoat. This coating system has proved desirable in offshore pipeline projects, especially in the deep gas and oil fields far in the bowels of the earth. Polypropylene (PP) systems consist of up to seven PP layers and thermal insulating foams with high compressive strength, to prevent collapse, making them ideal for technically challenging deep-sea projects with high operating temperatures and external pressures.

Fusion-bonded epoxy (FBE) is commonly used in the past however its popularity is declining in favor of 3LPE and PP systems on health, safety and environmental grounds. For pipeline repair projects, asphalt enamel and PUR systems are commonly used, despite health concerns. The polyurethane (PUR) backbone is superior to those of the other coating systems in terms of durability in all environmental conditions. However, it is expensive.

Internal coating lining for gas pipelines was first developed in the 1950s to reduce the impact of rough steel pipe surfaces and the build-up of deposits and corrosion products on pipe capacity, operation and pumping costs.

Pipeline internal corrosion normally occurs due to the presence of CO_2, water, H_2S, chlorides (salt water), bacteria, completion fluids or other substances in the produced hydrocarbon. For example, when CO_2 or H_2S mixes with oxygen or water, the corrosive acids formed will attack and destroy the steel. Also, some types of bacteria, often found in producing formations, can attack and destroy steel as a result of their metabolic activities. Moreover, any of the internal corrosives, separately or in combination, can cause leaks which can result into severe blowouts. Internal protective coating reduces the need for inspections and extends the life of the pipeline. Also, an internally coated pipework dries faster after hydrostatic testing than an uncoated pipe, thereby allowing faster commissioning of the line. The benefits of coatings also extend to reduced energy costs at pumping and compressor stations. It may be possible to achieve further savings by reducing the number of compressor stations, or compressor size and capacity.

However, it has become common practice to employ corrosion resistant alloys (CRAs) in the oil/gas industry. This is as a result of constantly changing chemistries of products during the life of oil fields (LOFs). As with all well-intentioned corrosion mitigation techniques, the use of CRA has its downsides and advantages; the use of CRA as pipe material is very expensive although pipeline operators can go to sleep and may not worry about the negative impacts of corrosion throughout the life of the oil field. However, to reduce this high cost to a minimum, carbon steel pipelines with an inner cladding of 3-6mm thick CRA are very good alternatives that are being employed in the oil/gas industry. Without doubt, the inner lining with CRA is a huge advantage for as long as the wall is not penetrated through erosion caused by process fluids during operation. Galvanic corrosion reactions are usually encountered in such cases with the carbon-steel as anode and CRA lining as cathode. Other disadvantages are the wrinkling of the inner lining of CRA which may occur during pipe lay, and buckling often observed during plastic bending of the pipe during operation at various alternating high pressures and temperatures. These and other occurrences may impact negatively on the life span of CRA liners.

3. Recent Developments in the Coating World

In terms of innovations in the pipeline coating industry, many developments have been achieved in terms of durability of paint/coating systems in varied mild environments and ease of applications. However, in the drive to lay pipes in ever more challenging environments, such as deep offshore or to heat up and pump heavy crude from remote oil fields, this has challenged researchers and boosted the need for ultra-tough external coating that can withstand high temperatures and pressures.

Some newly developed coatings can be flame sprayed or sintered onto non-linear items such as buckle arrestors, bends, fitting and ancillary items. Pipe coatings that can heal themselves and return to their former state after being damaged would prove invaluable in remote, deep or inhospitable environments. Meanwhile, some researchers see the application of nanotechnology and development of self-healing multifunctional pipeline coatings as the next step forward. Other researchers [4-10] are on the path of breakthrough by incorporating nano-containers impregnated with corrosion inhibitors into paints. Such paints have self-healing properties.

4. Surface Preparation

Any surface preparation for steel structures requires the combination of two or all of the following operations: Degreasing or cleansing, physical treatment or abrasion/blasting, chemical treatment and priming. However, of utmost importance for durability and high integrity is the chemical treatment stage which must be combined with cleaning and blasting.

Chemical conversion coating based on chromates stabilizes the active blasted steel surface and modifies the cleaned but slightly oxidised surface as well as converts it to complex, inert mixtures of stable oxides of iron, silicon and chromium. In addition, it forms an integral part of the steel and it is resistant to degradation, oxidation and other unforeseen variables mentioned earlier. Above all when breached to expose the steel surface, leachable inhibitors repair the exposed region disallowing spread of corrosion. This process has been in practical use since the 1980s and was championed by a chemicals company in the UK [3]. The chemical is fast drying and it is often referred to as dry-in-place chromate conversion coating. Once the conversion coating dries almost immediately after application, the steel surface becomes inert and unaffected by the inclement weather prior to any coating system application. With time it is expected that chemical pretreatment will be the norm in the pipeline coating industry for conditioning of blast cleaned pipeline surfaces. Thus it will become realistic for applicators to achieve relative consistency and high quality performance as demanded by clients' specifications.

It is generally known that chromates have been implicated as carcinogens, thus in the past few decades, their applications in metal finishing have been limited to the high technological ends of industries and may be totally banned in the European Union by the 4^{th} quarter of 2019 [11]. Consequently, there is a continuous and wide search for the replacement of chromates in conversion coating formulations by research institutions and military establishments as well as metal finishing industries.

The main chemicals employed in conversion coating formulations are usually inorganic corrosion inhibitors with multiple valences. Thus, researchers have employed Zr compounds [12-14], Cerium chlorides [15], compounds based on Molybdenum [16], Potassium permanganate [17] as alternatives to chromates but with limited successes. These multivalent compounds can be reduced in the conversion process to form the bulk of the conversion coating, contaminated or otherwise with other species in the solution. However, other researchers have employed alternative procedures to the conversion coating processes as well as modification of the chromating formulations to reduce their adverse environmental and human impacts [18, 19]. In the same vein, other workers [20], using Electrochemical Impedance Spectroscopy (EIS) observed synergistic corrosion inhibition of mild steel by silane coating containing extracts of nettle leaves stored in nano-containers.

However, in the interim, researchers [17-20] are still searching far and wide for chromate replacements in conversion coating formulations.

5. Conclusion

For improved performance and good integrity of both internal and external pipeline coatings, chromate chemical pretreatment is a pre-requisite prior to coating application.

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