Capítulo 86

Study of surface treatment techniques for industrial painting in near shore environments

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ABSTRACT
Corrosion is one of the main factors responsible for losses in companies subject to aggressive atmospheric environments, as is the case with industries in the oil and gas area, close to coastal regions. This work carried out a comparison between two surface treatment techniques for industrial painting in order to find the most resistant technique to the environment in which the equipment was inserted. An experiment, using the techniques of mechanical treatment with needle gun and wet abrasive blasting, was carried out in an industrial oil refining unit. The study was developed through the application of the two techniques in industrial valves that were in operational conditions and available in a treatment cabin. The results showed, right after treatment and before paint application, that the surface worked with wet abrasive blasting was cleaner and free of encrusted oxides than the surface treated with a needle gun. The results were also analyzed during the exposure of the valves, over time, after the application of the paint. It was noticed, in a period of sixteen months, that there was greater durability, in relation to the appearance of corrosion points, on the surface treated with wet abrasive blasting.

Keywords: Surface Preparation, Abrasive Blasting, Needle Gun, Corrosion Protection.

1 INTRODUCTION

Since ancient times, man has been suffering from changes in materials, generally metallic, determined by corrosive processes. Corrosion losses reach high sums worldwide and include material losses, maintenance, prevention and unscheduled stops of the production system [1]. It is estimated, according to Justina and Bastos [2], that about 20% of iron and steel production in the world is lost due to the effects of corrosion and that this represents between 1% and 5% of the wealth generated by countries. In Brazil, the same data also show that the number is 4% of the Gross Domestic Product (GDP), equivalent to R$ 236 billion spent in 2015.

In the process of extracting, transporting and refining oil, equipment and pipes used for this purpose are constantly exposed internally and externally to the deleterious action of the environment where these processes occur [3]. In the case of oil refineries close to the seafront, the wear and tear of materials and equipment due to the harmful effects of corrosion is common. Therefore, finding solutions for anticorrosive protection in these unhealthy industrial areas has been a constant challenge for companies involved in this sector.

Corrosion is one of the main causes of failures in land pipelines and can cause ruptures and leaks in the installations. The degradation of this equipment is the result of the persistent attack from the external environment on the pipeline materials (pipes, welds, coatings, etc.) and on the characteristics of the fluids that pass through it [4]. In external corrosion, wear occurs through an electrochemical process in an interaction between the pipeline and the environment in which it is mounted, that is, in these cases, there is the formation of the electrochemical pile that will cause losses due to corrosion.

The atmospheric environment in which the pipeline is installed will cause material wear according to the aggressiveness of the corrosion present in the atmosphere in which the equipment was inserted. In this way, it can be said that atmospheric corrosion is the result of the interaction between a material, an object made of metal with a paint coating, and its surrounding atmospheric environment [5,6].

For Jambo and Fófano [7] atmospheric corrosion is defined as an electrochemical process that occurs in local batteries, thus requiring the presence of an electrolyte. Such electrolyte is formed by the condensation of water on the metallic surface and this water film will depend, mainly, on the relative humidity of the air. Figure 1 shows an example of atmospheric corrosion in an industrial environment located on the shores of a seafront:

Figure 1: Atmospheric Corrosion in Piping.

Characterized by high humidity and salinity, the marine atmosphere is an extremely hostile environment from the point of view of corrosion [8]. It is notable that the corrosion of metals is more severe when placed in the marine atmosphere environment. As the moisture content in the marine atmosphere is very high and the air humidity can reach 70%-80%, rich in water vapor and oxygen, the conditions are favorable and sufficient for electrochemical corrosion [9,10].

Coatings are one of the most cost-effective methods of preventing external corrosion of equipment and piping in a hostile environment [11]. Of the various methods used for anticorrosive protection, the use of coatings is the most popular and economical for protecting carbon steel or other materials, as it provides both the choice of a substrate with the desired physical and mechanical properties, and the use of a resistant coating. to the environment in which the material will be exposed [12].

Industrial paint coating and, more specifically, the surface preparation steps appear as opportunities to reduce corrosion damage and provide good results for the protection of materials and equipment inserted in these more aggressive environments.

Thus, the need to use technologies that provide greater efficiency in this stage of industrial painting application is perceived, generating greater resistance of materials to corrosion. The performance and durability of any coating system are significantly affected by the type and quality of surface preparation performed [13,14]. Therefore, the surface preparation for painting on industrial equipment and structures, carried out before applying the paint, must be evaluated very carefully, since the durability and useful life of the entire painting system will depend on the correct application of the treatment on the substrate. of the material to be worked on. Another important point should be a bibliometric evaluation in relation to the international literature aiming at the selection in relation to the inks used in the most diverse industrial segments [15].

The need for knowledge and use of surface treatment techniques that provide the best results for anticorrosive protection of structures and equipment in industries close to the seafront was the main justification for choosing the subject. In industries, corrosion causes problems related to the costs of maintenance and replacement of equipment, loss of products and environmental impacts resulting from leaks in tanks and corroded pipes, not to mention the human lives put at risk in accidents and explosions. [16].

In this way, the work addresses the application of wet abrasive blasting and treatment with a needle gun in pipe sections in the field (industrial area) and in a treatment cabin. It is also evaluated the state of the surface of the pipes after the treatment, before the application of the paint, of the two surface treatment techniques studied. Finally, the appearance of the surface of the pipes after painting is compared, verifying the progress of corrosion over time between the two applied techniques and between field and cabin activities.

2 METALLIC SURFACES PREPARATION TECHNIQUES FOR FIELD APPLICATION

Surface preparation is the step that precedes paint coating and ensures that the paint adheres to the material being protected. According to Chen et al. [17], in order to avoid corrosion of steel surfaces, it is important to have a good surface preparation before applying the coating and that the pre-painting steps, associated with the paint application process, play important roles in preventing corrosion. from corrosion.

2.1 SURFACE TREATMENT WITH NEEDLE GUN

The use of a needle gun in the surface treatment of materials is a relatively simple activity that consists of manually operating a tool, usually pneumatically powered, whose tips oscillate rapidly when making contact with the contaminated surface [18]. The vibration of the rods or needles, usually made of steel or beryllium, in contact with the surface, provides the removal of paints and surface oxides in order to generate the necessary finishing degree for the painting to be applied, as shown in figure 2.

Figure 2. Action of the needle gun in the preparation of the metallic surface.

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Stango et al. [18] state that during the contact of the needles with the substrate, that is, when the bundle of rods parallel to the surface of the workpiece is attrition, there will be a rapid oscillation in the axial direction of the tool, providing a repeated movement between the tips. of the rods and the target surface. This frequent contact allows the removal of surface debris and simultaneously generates the desired surface texture.

The use of mechanical treatment with a needle gun is quite common in industry in general. Islam et al. [19] present several applications for this technique, from use in automotive repairs to the preservation of structures on board ships. In the oil and gas industry, there is a great use of the needle gun as it allows easy access to places that would become unfeasible with the use of medium or large machines. Manual service performed with this technique requires only a source of service air that is connected, through a hose, to the tool handled by the worker.

Disadvantages in the use of mechanical treatment with a needle gun can also be observed when compared to other surface treatment techniques. The degree of surface finishing stands out, which has been shown to be inferior to other applications.

Therefore, the application of surface treatment with a needle gun has proven to be advantageous in specific situations, but each application situation must be analyzed, since it is a tool widely used in industrial areas.

2.2 SURFACE TREATMENT WITH ABRASIVE BLAST

Abrasive blasting is a system of blowing abrasive particles through a blasting machine, using compressed air to impel it over a surface. Three main components make up a blasting process setup: air compressor, blast machine, and abrasive. The air pressure and volume required for the service must be provided by the compressor to transport the abrasive from the blast machine to the surface to be treated [20].

In industrial environments, two types of blasting are normally used during services: dry abrasive blasting and wet abrasive blasting. The latter, in addition to using compressed air and abrasives, blows using water in the mixture that will be propelled onto the work surface. An example of wet blasting used in this research is shown in figure 3.

Figura 3: Aplicação de jateamento úmido com abrasivos**.**

Windyandari [20] states that the most common surface preparation technique observed in the shipbuilding and repair industry is abrasive blasting in preparation for painting hulls, parts and components in general. With regard to the use of abrasives, the constant use, in the oil and gas industry, of copper slag or steel grit is observed for dry abrasive blasting, and the use of glass granules when wet abrasive blasting is used.

Other abrasives are being introduced more gradually, such as flexible media blasting. This type of blasting, according to Zakaria et al. [21] uses an abrasive that is released from the machine at high speed, generating a flattening, and consequently, an anchoring profile, due to the impact energy on the surface that will receive the treatment.

The abrasive blasting technique also has some disadvantages, such as the generation of dust, in the case of dry blasting, which can cause illness in the equipment operator. However, the characteristics of the quality of the treated surface and the speed with which the services are carried out have provided for the continued use of this technique in various branches of industry when compared to treatment using a needle gun.

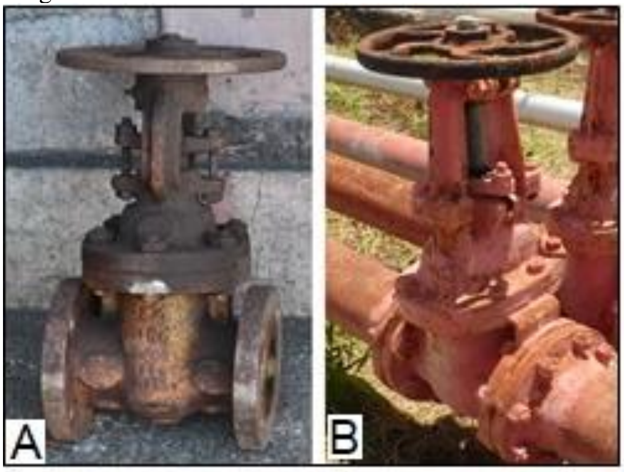
3 MATERIALS AND METHODS

3.1 TEST SPECIMENS (BLOCK VALVES)

The choice of materials used in the experiment of this work was made through the definition of piping components that are used in the daily activities of treatment of metallic surfaces and painting, in construction sites, in industrial units in the oil and gas sector. Therefore, block valves were defined, which are constantly used in pipe sections in the analyzed industrial environment.

Initially, two valves were separated to be worked on in a surface treatment cabin environment, seeking controlled working conditions, similar to a real situation of services in a blasting cabin carried out at a construction site. At the same time, a valve that belonged to a section of piping assembled in an industrial area was also chosen, so that it represented the real conditions of an activity carried out in the field. Figure 4 addresses the valves in the two study conditions before treatment.

Figure 4: Valves available for in-cab and field treatment.



The valve that received the surface treatment in the field was mounted and operated for more than ten years in a fire network piping. This section of pipe was chosen because it is located in an open area, at ground level and easily accessible for carrying out and monitoring the experiment.

Another determining factor for defining the field valve was the limited use of this valve in the industrial unit's operating area. The constant use of the operational valve could cause bumps and damage to the painting that would be carried out in the experiment. As it is a fire water pipe, the use of this valve for opening or closing happens only in an annual test of the system or in an eventual accident that could happen. Separate valves for surface treatment in the cab were disconnected from pipes and had geometries similar to the pipe-mounted valve for field service. This choice also sought to ensure that the results were not impacted by constructive differences.

3.2 EQUIPMENT USED IN SURFACE PREPARATION

3.2.1 Needle Gun

In this work, the needle gun was chosen because it is the tool used in almost all surface treatment services carried out in the industrial area of study, mainly services carried out in an open environment, outside the blasting booth.

As shown in Figure 2, the compressed air, when reaching the equipment through a hose, activates a piston that pushes the rods (or needles) fixed in the needle holder. The frequent displacement and return of this set, through the springs, provides the necessary vibration on the outside of the needles, thus making contact with the surface of the material to be treated.

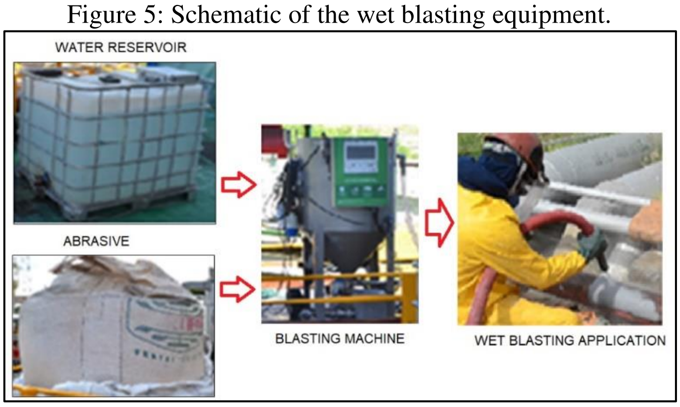
3.2.2 Wet abrasive blasting machine

The experiment in this work also allowed the use of equipment and tools from the abrasive blasting treatment technique. During the application of this technique, wet abrasive blasting equipment was used in which an abrasive mixture composed of glass granules and water was used. During the experiment, an abrasive blasting machine was used, which can be used in open areas, without harming the environment, the health of the operator and people around the services performed. Machine adjustments and configurations were defined for working pressure of 8 bar (0.8Mpa), operating temperature around 30°C, air consumption between 80 and 135 ft3/min, abrasive consumption around 2 kg /min, water consumption around 100 liters/hour and the 8mm blasting nozzle.

The blasting machine receives the water and abrasive inputs, as seen in the diagram in figure 5, and sends the necessary mixture to the blasting nozzle to carry out the treatment on the surface to be worked on. The mixture is carried out in the blasting machine that works from an electric power source and a compressor that supplies the compressed air.

It is important to point out that the wet abrasive blasting machine was initially configured in the blasting function, where effective treatment of the surface of the valves was allowed. Following the treatment, the surface was washed to remove oxides and loose paints resulting from the treatment and finally the surface was dried with dry air.

Figure 5: Schematic of the wet blasting equipment.



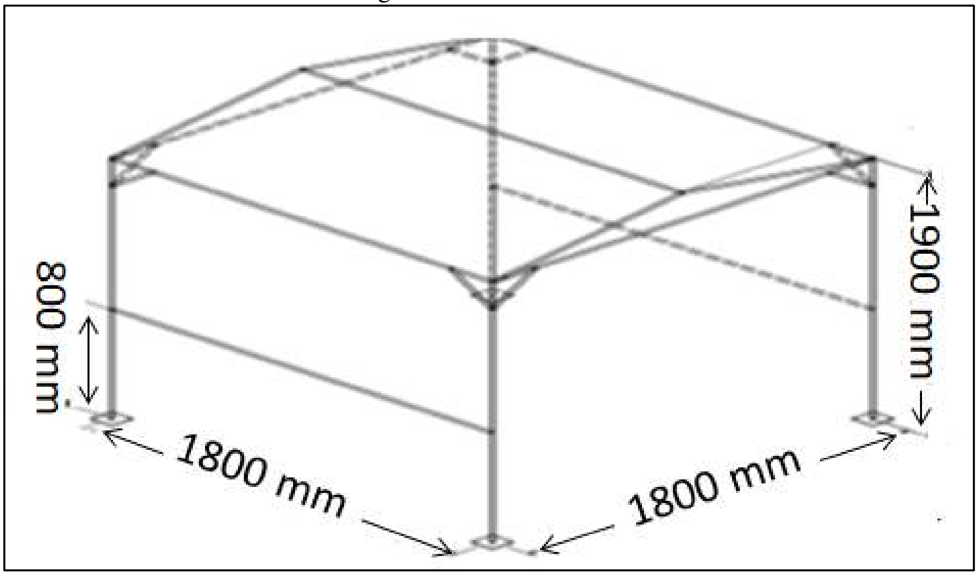
4 METHODOLOGY

The research focused on carrying out an experiment that represented the same conditions of daily activities carried out on the service fronts of the study environment. In this way, surface treatment and painting were carried out on a piping valve operational in the field and on disassembled valves in a treatment booth. In the case of in-cab services, normally the treatment is carried out so that later the parts can be made available for assembly and operation.

4.1 EXPERIMENT LOCATION

The experiment was carried out within the industrial area of an oil refining company close to a coastal region. The data were collected in an area where there are routine piping maintenance services in an industrial environment. The pipes in operation received the treatment in the place where they are assembled, naturally, while the disassembled piping components received the treatment in a paint booth in order to represent a blasting/painting workshop and to seek the least possible interference from the environment as shown in the diagram. of figure 6. The steel structure was covered entirely with a tarpaulin.

Figure 6: Cabin structure



The location defined for the cabin used, temporarily, a structure to carry out mechanical treatments with a needle gun and treatment with wet abrasive blasting on the two disassembled valves defined for this activity. In relation to the location of the valves assembled and in operation, a section without any protection or enclosure of the piping within the industrial area was defined and that represented working conditions similar to those normally found in these construction sites.

During the experiment of this work, the environmental conditions of wind speed present in the place, the ambient temperature, the temperature on the surface of the valves and the relative humidity of the air were verified. The data collection allowed knowing the differences between the two environments in which the experiment was carried out, taking the temperature at 11 am (AM).

Inside the cabin, the ambient temperature measured was 32.9°C, with a temperature on the surface of the valves of 32.4°C. As it is a sheltered environment from the sun, it was observed that the local temperature and the surface of the piece were very close. The air humidity was 52% and using an anemometer there was no incidence of wind.

During the survey of data carried out in the field, a condition different from the data found inside the cabin was verified. The local temperature measured in the industrial area was 35.8 °C, the surface temperature of the valves was 41 °C and the relative humidity was 46%. The anemometer registered the wind speed at 11.1 m/s, while in the cabin there was no wind incidence.

4.2 EXPERIMENT DEVELOPMENT

4.2.1 Initial Surface Condition

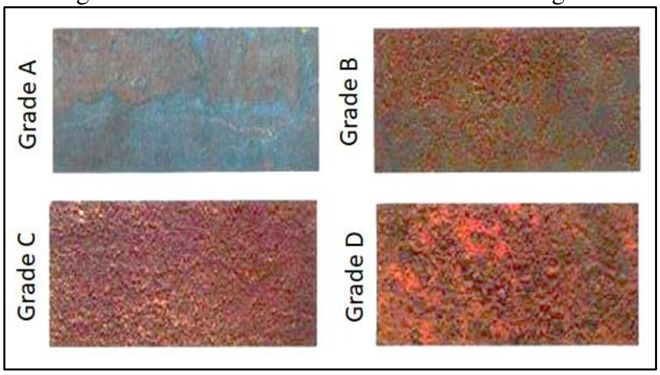
The amount of corrosion products and paint wear found on the surface of the pipes that were separated for this work was classified based on an analysis of the guidelines contained in Petrobras N-9 [22] and ABNT NBR 7348 [23] standards that describe and guide surface treatment and paint application procedures.

According to the Petrobras N-9 standard [22] it is important to highlight the differences in concepts inherent to the conditions found on a surface. Therefore, the degree of weathering of a steel surface refers to the conditions in which the surface is found before the execution of the cleaning process. The degree of surface preparation corresponds to the standard of final cleaning of the surface before the application of paint or other coatings.

Knowledge of the degree of weathering is of great importance for the correct choice of paint scheme and, consequently, the type of treatment required for the material to be worked on. Depending on the state of degradation found on the surface of the valves, the surface treatment method expected to provide the best performance would be defined.

According to ABNT NBR 7348 [23] the degrees of weathering of unpainted hot-rolled steel surfaces must be evaluated and classified before surface preparation, according to the visual standard of ISO 8501-1[24].

Figure 7 Visual Patterns of Steel Oxidation Degree.



Source: Standard ISO 8501-1[24].

Figure 7 shows the ISO 8501-1[24] visual standards for a comparative assessment of the degree of weathering of the surface available to be worked on. Based on the evaluation of the surface found on the valves in this experiment, it was understood that the study surfaces had a severe degree of corrosion. To make this decision, a comparison was made between what was found on the surface and the photographs in figure 7, in addition to the description verified in the Petrobras N-9 standard [22].

The state of corrosion observed on the valves was very close to grade D classifications (steel surface from which the mill scale has been removed by atmospheric corrosion and which shows severe pitting corrosion) and grade 2 (completely "burned" paint, blistered or with oxidation stains, and up to 33% of its surface may have corrosion, bubbles, loose paint and a small incidence of pitting described in ISO 8501-1[24]. Corrosion on valves resulting from local atmospheric corrosion.

Other sections identified, such as the flanges and screws region, had loose paint and the presence of pitting, in addition to spots that already had no paint, showing characteristics of crevice corrosion (crevice). In this way, we also sought to use two surface treatment techniques in the experiment that could eliminate the corrosion found and that, subsequently, the most appropriate technique for this type of corrosion that is normally found on the surfaces of valves in the study region would be evidenced.

4.2.2 Application of Treatment Techniques

The first technique applied was inside the cabin with the needle gun. The entire surface area of the valve received the treatment. In this step, the preparation of the paint was carried out and the paint was applied to the entire valve body still within the same environment. The expected interval for removing the valve from inside the cabin was the time required for the paint to become dry to the touch. This was important as it prevented damage to the paint during shipping.

After removing the valve treated with a needle gun, the wet abrasive blasting equipment was set up to carry out the treatment on a second valve also in the cabin. The time between the application of the two techniques was the shortest possible, seeking to reduce the possibility of alteration in the results due to changes in climatic conditions.

After completing the services in the cabin, the equipment was disassembled and transported for assembly in the section of piping defined in the field. Carrying out the experiment in the field required a little more attention, since the treatment would be carried out in a pipeline that was in operation.

It is worth mentioning the extra requirements and care related to activities in the industrial area of oil refineries. It is necessary to constantly assess the risk conditions present in the various services carried out in these places. It is also important to highlight that the risks of accidents are inherent to the treatment and painting activity itself or due to different situations close to the workplace, such as leaks of flammable gases, generation of sparks from welding services that can reach the paint being used.

After analyzing these extra precautions, the surface treatment in the field was carried out in a similar way to the activity in the cabin, but with all the real circumstances of interference from the prevailing temperature and wind conditions in the region.

The treatment was performed on the entire surface of the valves available for both techniques. Then paint was applied to them. Shortly after the end of the services, the valves worked in the cabin were transported and positioned on top of a support next to the valves that were assembled in the field.

The exposure of the valves worked on in the cabin next to the pipeline of the valve worked on in the field allowed to minimize differences in terms of the atmospheric conditions that the two environments would be subject to during the time and waiting for the results. Thus, both the valves worked in the booth and in the field were exposed in the same place to monitor the results during the evaluation period of the experiment.

4.2.3 Application of Painting Systems

After completing the treatment of the surface of the valves, the experiment proceeded with the application of paints. It was decided to apply the same painting system to all the valves, whether they were worked on in the cabin or the valve that received treatment in the field.

The painting system applied followed the guidelines provided for in Petrobras N-442 [25] standard, so that all test specimens received the same system and did not have their evaluation results influenced by the paint, but only by the type of surface treatment that was applied. was performed. The paint system applied is described below:

a) Application of a base coat with two coats of solvent-free epoxy paint tolerant to wet surfaces, as specified in Petrobras N-2680 [26] standard, with a dry film thickness of 150 μm per coat.

b) Application of finishing paint with a coat of acrylic polyurethane paint, as specified in Petrobras N-2677 [27] standard, with a dry film thickness of 70 μm.

The application of the finishing paint on the experiment's valves resulted in the finalization of the painting system that was implemented. In all, the valves in the experiment received 370 μm of paint film, 300 μm of the paint that followed the Petrobras N-2680 standard [26], and 70 μm of the paint characterized by the Petrobras N-2677 standard [27].

After a period of 24 hours, the valves that received the painting inside the cabin were transported to the pipeline area, so that the valve worked in the field was exposed side by side during the period of 16 months.

5 RESULTS AND DISCUSSION

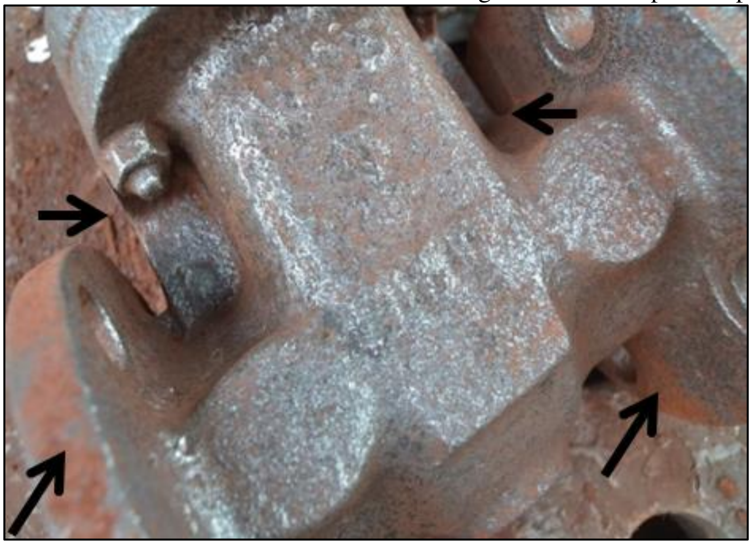
5.1 SURFACE EVALUATION AFTER TREATMENT

The evaluation of the surface condition of the valves was carried out after the completion of the mechanical treatment with each applied technique and immediately before the application of the chosen paint.

5.1.1 Visual Aspects of Surface Treated with Needle Gun

The surface treated mechanically with the needle gun tool presented, from a visual inspection, an apparently clean condition, without the presence of contaminants and loose paints, as observed in figure 7. However, reddish patches on the surface indicated that small paint particles or probable encrusted oxides had not been removed using the needle gun used.

Figure 7: Treatment with Needle Gun still showing corrosion and paint deposits.



In view of the treatment condition verified in Figure 7, the surface cleaning standards present in the ISO 8501:1[24] standard were used to identify the degree of surface treatment that was found. It is important to point out that the photographic standards used as a comparison in this work are constantly used in construction and assembly work sites in the oil and gas industry, being a reference in the evaluation of the quality of a surface treatment with the purpose of applying paint.

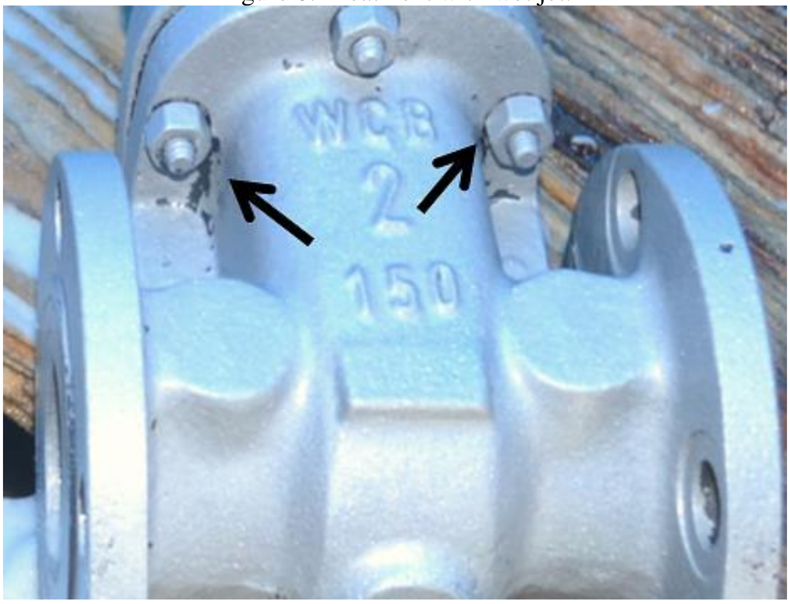
Therefore, after the treatment, it was noticed that small incrustations of oxides in pits identified on the surface (small concave cavities) were still present even though the treatment with the needle gun had been performed more than once at these same points. This has been one of the points identified as a disadvantage in using this technique.

According to Amorim [28] soluble salts tend to be retained inside the formed alveoli and are difficult to remove with this treatment, which still leaves oxides on the surface. Therefore, the service performed with a needle gun generated a clean surface of oils, but still showed some incrusted oxide points observed in darker regions.

5.1.2 Visual Aspects of the Surface Treated with a Wet Abrasive Jet

The appearance of the surface treated with wet abrasive blasting visually showed an apparent quality superior to the mechanical treatment that was carried out with a needle gun, as shown in Figure 8. Cleaning characteristics were observed in which the steel had a lighter color than the metal, tending to gray-white when compared to the surface treated with a spray gun. However, dark deposits that were not completely removed are also noted, although no ink deposits were observed.

Figure 8: Treatment with wet jet.



Another aspect identified was the absence of virtually no trace of remaining ink. The wet blasting, when compared to the treatment with a needle gun, showed a surface where there were no spots of adhered paint not removed from the surface, in addition to corrosion products or any other foreign matter that could be present on the surface at the moment before the treatment.

In view of the verified characteristics, it can be seen that the surface treated with wet abrasive blasting is classified as CSa3 based on the ISO 8501:1[24] standard, which characterizes the white metal blast cleaning classification.

High-quality blasting, such as treatments similar to standard blast cleaning of white or off-white metal, provide very effective removal of the oxide layer from the metal surface, and are widely used in high-performance paint schemes, particularly on the inside. equipment for storage of fluids, internal painting of pipes, submerged or buried structures, special coatings of high thickness, high temperature, etc.

5.1.3 Results of Soluble Salts Assessment

The measurement of soluble salts was carried out in the treated area of the valves immediately before applying the paint. In order to verify the amount of salts present on the surface, the bresle test kit equipment was used, a model produced by the company WS Equipamentos, consisting of a digital meter, adhesive, syringe and distilled water, as shown in Figure 9.

The bresle test kit is one of the tools widely used in painting inspection in works in the oil and gas industry, mainly in order to determine soluble salts. sodium chloride from the sea breeze. The equipment makes it possible to assess the condition of the surface that will receive the painting based on the measurement of the amount of salt mass per unit area. During the experiment, the Bresle test kit presented as operating parameters the measurement range of 0.01 to 2000 μg/cm², resolution of 0.01 μg/cm², precision of 1%, temperature range of 0 to 50 ° C, automatic calibration of 84 μS/cm and patch area of 12.5 cm².

The measurement was initially performed with the fixation of the adhesive on the surface that received the treatment. Using a syringe, distilled water was introduced into the area delimited by the adhesive. After waiting for one minute, the water was removed and inserted into the equipment, which recorded the amount of salts present on its display. Figure 9 records the photographs of the moments of distilled water collection and measurements recorded on the equipment display.

Figure 9: Measurement of soluble salts.

The value found in the measurement performed on surfaces treated with a needle gun was 4.67 μg/cm². In the measurement performed on the surface that received abrasive blasting, the value was 4.48 μg/cm². These values measured within the measurement range of the equipment represent the amount of impurities (salts) found in each technique for comparison between them. This difference is not representative considering concentrations of the order μg/cm². The Petrobras N-9 standard [22] cites the concentration of soluble salts in water at a maximum value of 5 μg/cm² as acceptable for use in wet blasting. Thus, the results found are not significant for the evolution of the corrosive process.

5.2 RESULTS OF THE TESTS AFTER PAINTING

The evaluation and monitoring of the progress of corrosion on the surface of the valves were carried out periodically every four months through the visual photographic record made of each valve. It was decided to analyze this period of time because it was understood that it was only possible to identify the differences in the surface conditions of the valves when they had a visually clear degree of corrosion (without the aid of microscopic instruments) and that allowed a more detailed evaluation, since the analysis was carried out in the field in a routine operational service at a construction site.

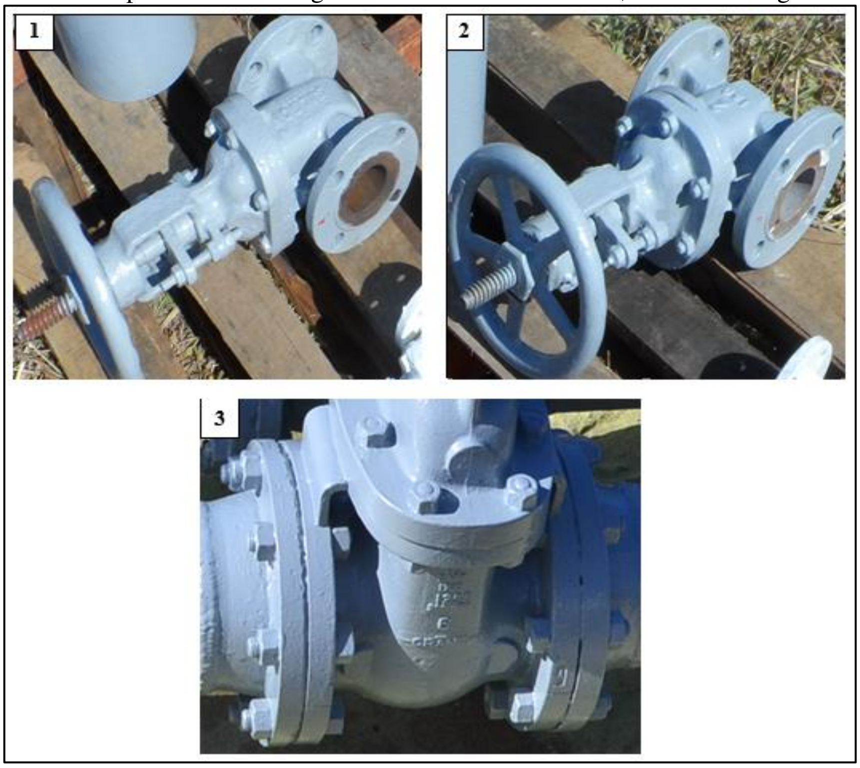
At the end of a year and four months, it was possible to visually clearly perceive the differences in the advance of corrosion points on the surface of the valves. Photographic records were taken in order to identify the gradual advance of corrosion points in each four-month period evaluated.

The photographs in figures 10 to 15 shows the surface condition of the valves in each evaluation period, so that the appearance of corrosion points was recorded from the moment the painting was completed until the final period of sixteen months.

5.2.1 Results Immediately After Ink Application

The first set of photographs was taken shortly after the completion of the paint application, as shown in Figure 10.

Figure 10: Photographs After Completion of Painting: 10.1-Needle Gun in Cabin; 10.2 - Blasting in Cabin; 10.3-Field blasting.



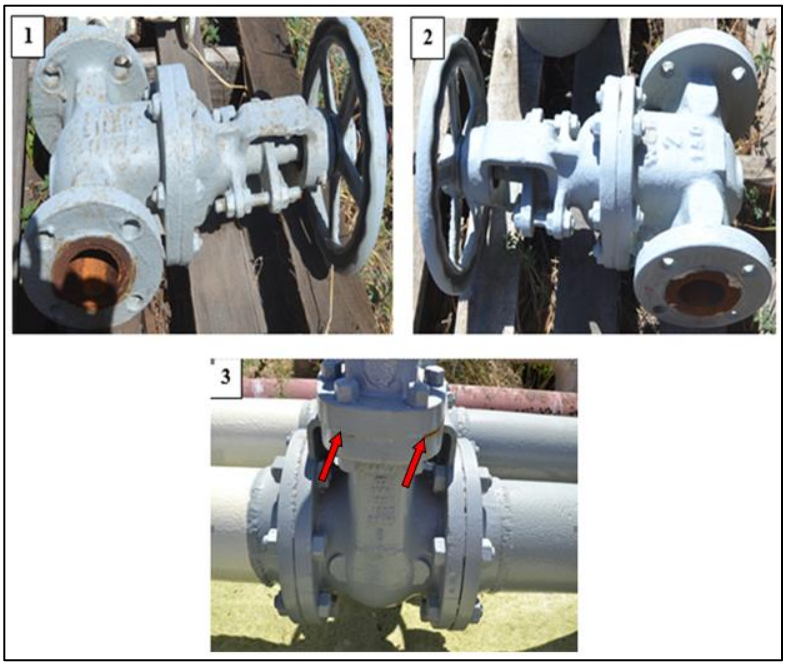
As seen in all the photographs in figure 10, the condition of integrity of the valves after application of the finishing paint was identified. None of the valves or parts of them were not covered with paint after finishing the surface treatment services.

It was noticed that in the three valves there was no appearance of corrosion points in this first moment, since the paint application had been carried out moments before the photographic record. The images shown in Figure 10 serve as a standardization and starting point for viewing the appearance and evolution of corrosion points in the evaluations that are carried out over subsequent periods.

5.2.2 Results After Four Months

The surface condition of the valves, four months after the end of the paint application, was recorded in Figure 11.

Figure 11: Situation four months after completion of painting: 11.1-Needle Gun in Cabin; 11.2 - Blasting in Cabin; 11.3-Field blasting.



The results observed when performing a visual comparison between photographs 11.1 and 11.2 show that the valve treated in a cabin with wet abrasive blasting was more resistant to weathering during this period than the valve treated with a needle gun also in a cabin. The first corrosion spots appeared on the valve body treated with a needle gun, as seen in photograph 11.1, while on the valve treated with wet abrasive blasting, seen in photograph 11.2, the paint remained free of these spots.

The result of the painting carried out both in the cabin and in the field using wet abrasive blasting remained in good condition during this four-month period, however the valve installed in the field showed a small beginning of corrosion in the crevice of the upper flange of the valve, as indicated by the arrow in photograph 11.3.

5.2.3 Results After Eight Months

The results shown in figure 12 allow the comparison of the evolution after eight months of exposure of the specimens.

Figure 12: Situation Eight Months After Completion of Painting: 12.1-Needle Gun in Cabin; 12.2 - Blasting in Cabin; 12.3-Field blasting.

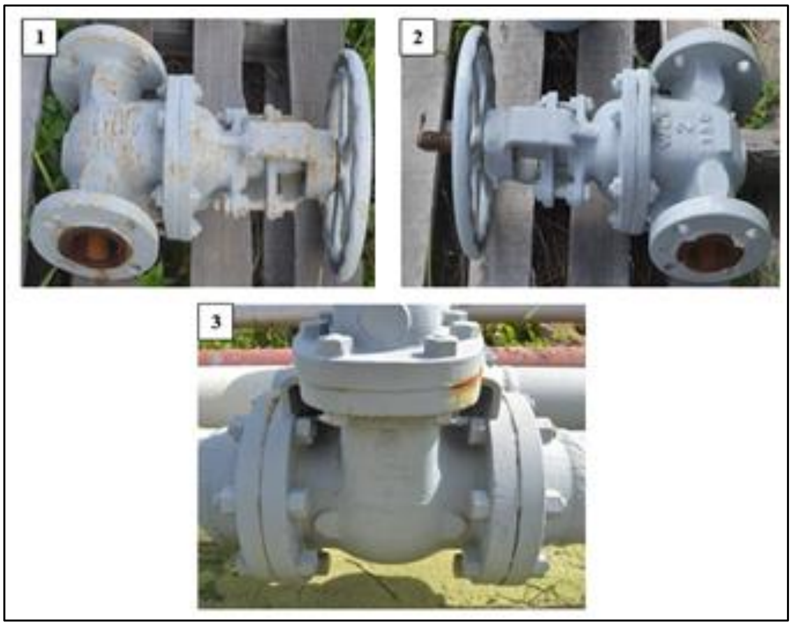


Photo 12 records the evolution of the corrosion points on the surface of the valve treated in a cabin with a needle gun. The process took place continuously and was more intense in this evaluation period. It is clear from photograph 12.1 that there is a generalization of the appearance of yellowish spots when compared to photograph 12.2. In different places of the entire surface of the valve treated in the field with a needle gun, the presence of localized corrosion was identified.

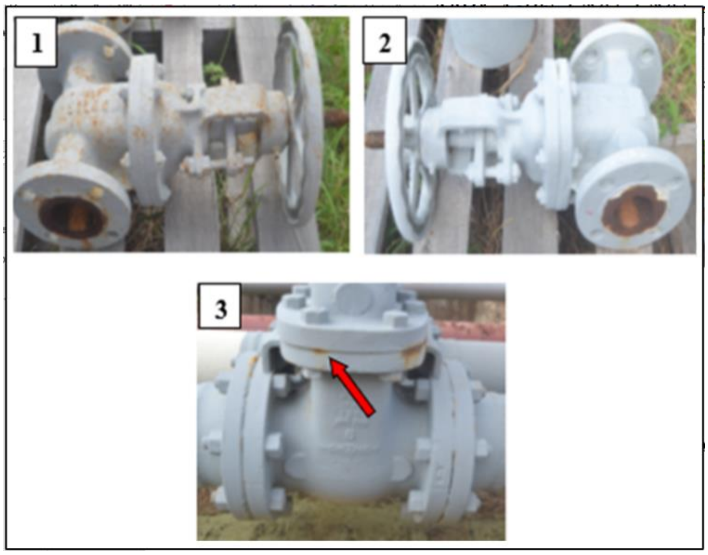
Photo 12.2, identified by the valve that received treatment in a booth with wet abrasive blasting, still looked similar to the four-month period, that is, no clear signs of corrosion on its surface were seen during this period.

In photograph 12.3, it is possible to observe that the first point of corrosion in the crevice of the upper flange of the valve intensified more in this period. Crevice corrosion, which was minimal before, has increased considerably.

5.2.4 Results After Twelve Months

A new evaluation was carried out based on the results of the photographs shown in Figure 13, which allow a comparison of the evolution of corrosion after twelve months of exposure of the specimens.

Figure 13: Situation Twelve Months After Completion of Painting: 13.1-Needle Gun in Cabin; 13.2 - Blasting in Cabin; 13.3-Field blasting.



The visual comparison made between photographs 13.1 and 13.2 of figure 13 identifies the continuity of the evolution of the corrosion points on the surface of the valve treated in a cabin with a needle gun. The generalization of the corrosion points was accentuated when the same valve was also observed in the evaluation four months ago, that is, an intensification of corrosion was observed from the comparison between figures 12.1 and 13.1.

In Figure 13.2, which shows the blasted valve in the cabin, it was observed once again that the appearance of corrosion, perceptible for a visual evaluation, practically did not exist. However, it was noticed that there was a slight loss in the brightness of the paint that was applied. Therefore, it was possible to infer which corrosion points could appear in later months.

It was observed that the corrosion points on the valve bonnet flange already identified earlier in Figure 13.3 of the figures presented in previous exposure periods intensified even more. Another notable point observed was the corrosion identified by the red arrow in the same photograph, showing the evolution of almost imperceptible corrosion points on the valve bonnet in previously evaluated periods.

5.2.5 Results After Sixteen Months

The last verification of the results was carried out after one year and four months of applying the paint to the valves, that is, the surface condition found on the valves clearly allowed us to perceive the differences between them in terms of exposure time and corrosion progression. Figure 14 addresses the three photographs that represent the surface state found for each valve in this period.

Figure 14: Situation Sixteen Months After Completion of Painting: 14.1-Needle Gun in Cabin; 14.2 - Blasting in Cabin; 14.3-Field blasting.

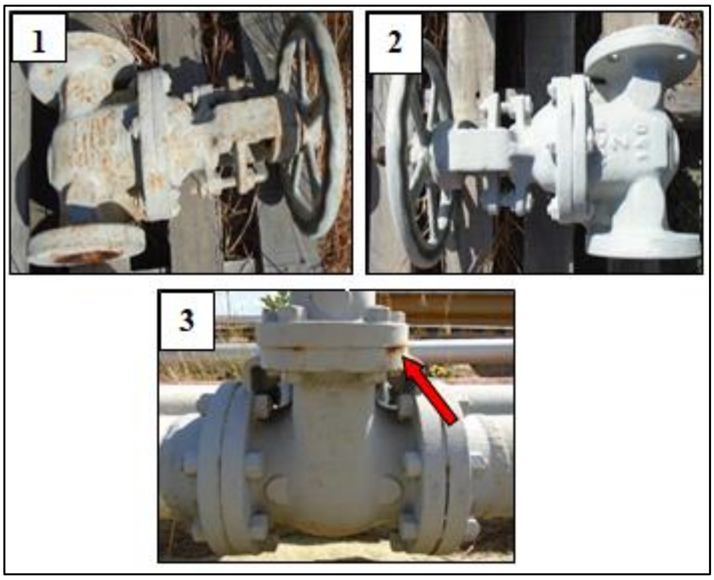


Photo 14.1 recorded a corrosion condition far superior to the other periods, demonstrating that the valve that received treatment with a needle gun in the cabin did not withstand the environmental condition of weathering like the other valves. The valve worked in a blasting booth, as shown in photograph 14.2, presented itself with an increasingly opaque appearance, however, throughout this period, spots of corrosion on the surface were not noticeable.

Finally, Figure 14.3 showed the continued increase of small pits of corrosion on the field blasted valve body. During this period, it began to be noticed that there was localized corrosion in the crevices, but in the other areas of the valve when small yellowish spots appeared as indicated by the arrow.

5 CONCLUSION

The work carried out in this research allowed comparing two surface treatment techniques for painting industrial valves and presenting the results of their anticorrosive protection effectiveness in an industrial setting located on the shores of a seafront. The comparison between the techniques and the verification of the results found in this work led to the conclusion that:

- • The visual aspects of the surface of the valves analyzed right after the application of the surface treatment showed that the material treated with wet abrasive blasting presented a cleaner surface and freer of contaminants than the surface that received the treatment with the needle gun. Therefore, this aspect of cleanliness perceived with abrasive blasting was decisive for the good corrosion resistance of the valve during the exposure period.
- The presence of soluble salts verified on the surfaces that received the two types of treatment studied were found in very similar amounts. The measured value of salts on the surface worked with the needle gun technique was slightly higher than the surface that received blasting, but there is no relevant quantitative value for this difference to have

influenced the durability of the paint system applied. Therefore, regarding the measurement of salts, it can be said that the results did not influence the definition of a more advantageous treatment technique.

- The results evaluated after applying the paint for a period of sixteen months of exposure of the valves showed that, when compared to the valves that received wet abrasive blasting, there was a better durability performance of the paint applied to the valve that received blasting in the cabin. The experiment showed that, despite the application of the same technique with the same professional, the abrasive blasting applied indoors provided greater durability of the painting system.
- The results evaluated during exposure after paint application also showed that, when compared to valves that received surface treatment in the cabin area, there was a better paint durability performance in the valve that received treatment with wet abrasive blasting. It was noticed that even performing the treatment with a needle gun in a confined place, the valve blasted in this same place and under the same conditions presented greater resistance to corrosion.

Given this scenario, it can be said that the activities carried out in a closed environment and with the wet abrasive blasting technique were more effective in protecting against corrosion in the conditions studied in this work.

REFERENCES

[1] OLIVEIRA, C. B.; MIRANDA, L. M.. Revestimento anticorrosivo à base de Nb_2O_5 como alternativa para combater os problemas de corrosão na indústria de zinco metálico. Revista de Engenharia da Universidade Católica de Petrópolis, Petrópolis, v. 14, n. 1, p. 82-93, 20 jul. 2020.

[2] JUSTINA, E. D. D.; BASTOS, T. E. revestimento epóxi novolac de alto desempenho à corrosão para aplicação em superfícies ferrosas preparadas por meio de ferramentas mecânicas, nos serviços de manutenção industrial. Revista Abraco Corrosão & Proteção, Rio de Janeiro, Ano 17, n. 71, p.43-51, 2020.

[3]MARIANO, C. Obtenção de revestimentos de nióbio depositados por aspersão térmica para proteção à corrosão marinha. Dissertação (Mestrado em Engenharia) - Programa de Pós-graduação em Engenharia e Ciência dos Materiais, Universidade Federal do Paraná, Curitiba, 2008.

[4]AHMAD, I.; ELSHAWESH, F.; SASSI, O. and ABURIAH, H. A. Case study of pipeline integrity management in Green stream natural gas export pipeline through corrosion mitigation and inspection strategy. In: Offshore Mediterranean Conference. One Petro, 2019.

[5]LEYGRAF, C.; WALLINDER, I. O.; TIDBLAD, J. and GRAEDEL, T. Atmospheric Corrosion. 2. ed. New Jersey: John Wiley & Sons, 2016.

[6]MAINIER, F. B., MONTEIRO, L. P. C., MERÇON, F., GUIMARÃES, P. I. C., MAINIER, R. J., Teaching of corrosion based on critical evaluation of urban furniture of a public square, IOSR Journal of Research & Method in Education, 3, 3 (Sep.-Oct.), p. 13-19, 2013.

[7]JAMBO, H. C. M.; FÓFANO, S. Corrosão: Fundamentos, Monitoração e Controle. 1. ed Rio de Janeiro: Editora Ciência Moderna Ltda., 2008.

[8]LI, C.; CHEN, Y.; WANG, P.; WANG, G.; CHENG, Q.; OU, J. and ZHANG, D. Dynamic self-propelling condensed microdroplets over super-hydrophobic surface: An exceptional atmospheric corrosion inhibition strategy. Colloids and Surfaces A: Physicochemical and Engineering Aspects, v. 613, p. 126055, 2021. https://doi.org/10.1016/j.colsurfa.2020.126055.

[9]ZHANG, S.; ZHENGA, X.; WANGB, P. and ZHANG, D. Fabrication of super-hydrophobic micro-needle ZnO surface as corrosion barrier against corrosion in simulated condensation environment. Colloids and Surfaces A: Physicochemical and Engineering Aspects, v. 585, p. 124087, 2020. https://doi.org/10.1016/j.colsurfa.2019.124087.

[10]FELICIANO, F. F., LETA, F. R. and MAINIER, F. B., Texture digital analysis for corrosion monitoring, Corrosion Science, volume 93, April, 138-147, 2015. https://doi.org/10.1016/j.corsci.2015.01.017.

[11]MIYASHITA, J.; TSUDA, T. and HORIKIRI, K. Evaluation of Protective Coating Performance in a Cyclic-Temperature Environment. In: NACE International Corrosion Conference Proceedings. NACE International, 2016.

[12]VERGÉS, G. R. Estudo do desempenho de sistemas de pintura para materiais das redes de distribuição de energia elétrica situadas em regiões litorâneas. Dissertação (Mestrado em Engenharia) - Programa de Pós-graduação em Engenharia e Ciências dos Materiais, Universidade Federal do Paraná, Curitiba, 2005.

[13]MAINIER, F. B., SILVA, O. P. and SILVA, G. O., Alternative System of Industrial Paint Applied to Spherical Mount for Liquefied Petroleum Gas, Journal of Materials Science and Chemical Engineering, 2, May, p.7-14, 2014. https://doi.org/10.4236/msce.2014.25002.

[14]MORTON, D.; PRIETO, A.; ALHAMBRA, T.; MORALES, R. and JUNI, C. The importance of surface preparation method on the corrosion resistance and mechanical properties of zinc rich primers. In: CORROSION 2021. One Petro, 2021.

[15]ALENCAR JUNIOR, A. A. M., DELESPOSTE, J. E., MAINIER, F. B., & MATTOS, L. V. Industrial sustainability in architectural paints: a bibliometric research. International Journal of Innovation and Technology Management, July, 23p. 2022. https://doi.org/10.1142/S0219877023500037.

[16]MERÇON, F.; GUIMARÃES, P. I. C. and MAINIER, F. B. Sistemas Experimentais para o Estudo da Corrosão em Metais. Química Nova na Escola, São Paulo, v. 33, n. 1, p.57-60, 2011.

[17] CHEN, G.X.; KWEE, T. J.; TAN, K. P.; CHOO, Y. S. and HONG, M. H. High-power fiber laser cleaning for green shipbuilding. Journal of Laser Micro/Nanoengineering, Singapore, v. 7, n. 3, p. 249-253, 2012.

[18] STANGO, R. J.; FOURNELLE, R. A. and MARTINEZ, J. A. Bristle blast surface treatment of welded joints fabricated from commercial ship construction steel. In: CORROSION 2011. One Petro, 2011.

[19]ISLAM, M. S.; TONG, L. and FALZON, P. J. Influence of metal surface preparation on its surface profile, contact angle, surface energy and adhesion with glass fiber prepreg, International Journal of Adhesion and Adhesives, v. 51, p. 32-41, 2014. https://doi.org/10.1016/j.ijadhadh.2014.02.006.

[20]WINDYANDARI, A.; HUBOYO, H. S. and ZAKKI, A. F. Investigation of structural response of floor panel unit on the portable blast room using finite element method. Journal of Engineering and Applied Sciences. vol. 15, n. 3, 2020.

[21]ZAKARIA, J. H.; ZAID, M. H. H. M.; BATCHA, M. F. M. and ASMUIN, N. Feasibility study on pliant media drying using fluidized bed dryer. In IOP Conference Series: Materials Science and Engineering. September, 2015. https://doi.org/10.1088/1757-899X/88/1/012071.

[22]Norma PETROBRAS N-9: Tratamento de superfícies de aço com jato abrasivo e hidrojateamento. Rio de Janeiro: Comissão de Normalização Técnica, Petrobras, 2011. https://abraco.org.br/src/uploads/2020/07/N-9-REV.-F.pdf.

[23]ABNT NBR 7348: Preparação de superfície de aço com jateamento abrasivo ou hidrojateamento (Industrial painting - Steel surface preparation by abrasive blasting or water jetting). 3 ed. Rio de Janeiro: ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, 2017. https://www.normas.com.br/visualizar/abnt-nbr-nm/5684/nbr7348-pintura-industrial-preparacao-de-superficie-de-aco-com-jateamento-abrasivo-ou-hidrojateamento.

[24]ISO 8501-1. Preparation of steel substrates before application of paints and related products - visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings. 2007. https://www.iso.org/obp/ui/#iso:std:iso:8501:-1:ed-2:v1:en.

[25] Norma PETROBRAS N-442. Revestimento externo de tubulação em instalações terrestres. Rio de Janeiro: Comissão de Normalização Técnica, Petrobras, 2011. https://abraco.org.br/src/uploads/2020/05/N-442-REV.-P.pdf.

[26] Norma PETROBRAS N-2680: Tinta epóxi, sem solventes, tolerante a superfícies molhadas. Rio de Janeiro: Comissão de Normalização Técnica, Petrobras, 2011. https://abraco.org.br/src/uploads/2020/07/N-2680.pdf.

[27] Norma PETROBRAS N-2677: Tinta de poliuretano acrílico. Rev.A. Rio de Janeiro: Comissão de Normalização Técnica, Petrobras, 2007. https://abraco.org.br/src/uploads/2020/07/N-2677-REV.-A.pdf.

[28]AMORIM, C. C. Efeito da preparação de superfície de aço carbono na formação de produtos de corrosão sob tinta epóxi. In: INTERCORR, 2016, Búzios-RJ. ABRACO, 2016.