Investigation into Corrosion Under Insulation

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Introduction

With more than one million miles of pipe laid in the United States alone, upkeep is a major cost faced across the country. Overall, it is said that the cost to keep up with corrosion in all sectors around the country is a measurable percentage of the United States' Gross Domestic Product; 3.4% according to a 2013 study done by the US Federal Highway Administration [1]. There are several types of corrosion, each with separate issues. Over time, the technology available to fight corrosion in piping becomes more advanced and more specific. This is a study specifically regarding technology and practices related to mitigating corrosion under insulation, or CUI. CUI is of interest because it is the most expensive type of corrosion, and maintenance issues to deal with, costing process plants about 10% of their overall maintenance budgets [1]. Ideally, there would be a solution to both monitor and protect insulated piping segments without incurring too much extra cost; however, lacking the ability to actually observe the surface of a pipe makes this extremely difficult and expensive.

Issue

CUI is one of the most expensive issues when it comes to corrosion as it is difficult to monitor and conditions under insulation can be very conducive to corrosion. Since insulation blocks any sort of visual on the outside of a pipe, CUI is very difficult to monitor. There are constantly new technologies and methods being defined to monitor CUI, however none of them are perfect and they tend to be quite expensive. As for protection, there is not any single recognized method that is near perfect, and there are many methods and products on the market. This paper is a review of the different technologies that exist for both monitoring and protection of insulated piping.

Detection

Detection of corrosion on insulated pipes is one of the more expensive and recurring maintenance costs that are necessary in a process facility. There are several methods of detection that have pros and cons. Each of those methods is detailed in the table below and analyzed.

Detection Method	Effectiveness	Limitations	Cost
Visual Inspection	Very effective if done timely	May involve system shutdown	High
Ultrasonic Thickness	Accurate	Feasible for small scale only	Low if done well
X-ray Tomography	Very accurate	Possible health issues from radiation	Likely high

Table 1. Methods of detection for pipe corrosion.

The first method in Table 1 is visual inspection. For an insulated pipe, visual inspection involves a lot of man power and a lot of material. To complete such an inspection insulation has to be physically removed from the pipe segment of interest and then reinstalled later. Depending on the contents of the pipe and the duty of the insulation, the entire process may need to be stopped for such an inspection to take place. All of this makes this method of visual inspection very expensive. However, since many insulated pipes do not have any more intricate monitoring systems installed, this method is still used widely. The American Petroleum Institute (API) actually has detailed inspection practices regarding the frequency at which insulated pipes should be visually inspected [2]. These practices can be found in API RP 574.

The next method of detection listed in Table 1 is a bit more complex than the first. The remainder of the detection practices no longer involve actually measuring corrosion, but rather measure a signal that is representative of detecting corrosion. These methods are also generally nonintrusive, so the beforementioned significant limitation does not exist here. The second detection method is that of Ultrasonic Detection [3]. This method involves cutting out very small pieces of insulation to allow contact between the pipe and a sound wave generator and sensor. The generator produces sound waves and the sensor listens for them to bounce back. The time that it takes for the sound waves to be recovered can be very accurately correlated to wall thickness. Positives of this method are that it is very accurate and very lightly intrusive. However, the integrity of the insulation can be compromised if the small holes cut for the sensor are not properly filled in. Also, this method can only be used for somewhat localized segments of pipe. It would be impossible to go through with this method on a large scale.

The final method detailed in Table 1 is X-ray computed tomography; x-rays are taken from different angles along a pipe, and the produced images are fit together to create a three-dimensional image [4]. This method of imaging is very common in medical professions; the same concept is used in CT scans. Although X-ray computed tomography is not used on an industrial scale for this application as of yet, it is very promising as it does not require the removal of any insulation. The three-dimensional image produced via this method does detail both internal and external corrosion, so it is useful for more than just CUI detection. Before this detection method finds its way to wide spread industry, an analysis of the radiation exposure that will undoubtedly result needs to be assessed for human health implications.

Protection

As supposed to detection, the idea of protection against CUI is to reduce the necessary number periodic inspections of piping for signs of corrosion. The focus of this section will be protective coatings; coatings have a lot to offer and there is quite a range of options when it comes to selecting a coating. Each of the specific types of coatings are listed in the table below and will be discussed in this section.

Coating	Effectiveness	Limitations	Per Application Cost
Thermal Spray Aluminum	Very effective if done timely	May involve system shutdown, but often not	More
Organic Coatings	Relatively effective if applied well	Needs replacement often	Less

Table 2. Methods of protection for pipe corrosion.

The first protective coating displayed in Table 2 is Thermal Spray Aluminum (TSA). TSA is really just a melted metal that is passed through a nozzle and sprayed onto the surface of another metal. The metal in the spray (in many cases Aluminum) is supposed to have a better tolerance for the environment around the pipe than the pipe does itself. TSA can be used in applications where CUI is a risk. TSA is a well-developed technology as it has been used to protect Navy vessels for many years, however it is still very expensive for use on pipes [5]. TSA works by cathodic protection, the pipe itself becomes the cathode and the coating becomes the sacrificial anode [6]. As expected, the sacrificial anode will slowly disintegrate, thus reducing the layer that serves as protection for the actual pipe. That being said, the metal coating will have to be periodically reapplied to the system. However, given the expected life of a single coating, up to 25 years, this cost is not a concern.

The second entry in the table above is not as a much of a specific coating but a broad category. Rather than using some thermally sprayed metal, there are many organic coatings available on the market that will theoretically protect piping from corrosion, including beneath insulation. By far the most common type of organic coating is epoxy resin; polymers that contain an epoxide group. In general, the higher the temperature of service, the higher the functionality of the epoxy resin is required, which is controlled by molecular weight. Functionality is a measure of the number of reactive sites within the copolymer during formation. With a higher functionality, more cross-linking will occur and a higher number of aromatic rings will form, making it more thermally resistant [7]. A highly thermally resistant epoxy resin does make it more advantageous at high temperature service, however it is not any less functional at low temperature service; therefore, the selection of an epoxy resin for a given service is based solely on its upper temperature bond. The thickness of the application of each epoxy is generally between 100 and 200 micrometers; recommendation by the product manufacturer will vary. As compared to the conditions of the service of the pipe, the environmental conditions have much less of an effect on protection selection. In general, coatings will perform best in dry environments, but this isn't always possible. Coatings are designed to keep water out. One limitation of organic coatings in general is the application conditions; organic coatings must be applied to the pipe at relatively low temperatures (usually below 60° C) [8]. With this limitation, it is likely that the process will have to be shut down for application. Application is usually done by brush.

Comparing the organic and thermally sprayed coatings further, it should be noted that thermally sprayed coatings are generally more expensive to apply. On average, this difference in price is around 20% per application [5]. However, the lifespan of thermally sprayed metal is almost twice as long as the average organic coating, so in the long run the thermally sprayed metal is more cost efficient. As far as service, both TSA and organic coatings are able to protect from corrosion over a very wide range of service temperatures, neither one is limited in this area.

Conclusion

Between both the detection of CUI and protection from CUI there are many options on the market. With all of these options there is likely not a single best choice that will meet every application's needs, but many that are viable. Depending on the length of time that a pipe is going to be in service, the process conditions, and its environment, there are multiple options for both detection and protection.

References

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