

## **CORROSION UNDER INSULATION CONTROL WITH THE PRIMER COATING METHOD**

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### **ABSTRAK**

Tujuan penelitian adalah untuk memberikan gambaran penentuan spesifikasi material primer coating dan metode aplikasinya untuk pengendalian korosi dibawah insulasi sistim perpipaan di industri kilang pengolahan minyak. Target yang ingin dicapai dari penelitian ini adalah tersedianya spesifikasi material primer coating dan kemudahan aplikasinya pada sistim perpipaan dan struktur pipe rack di industri kilang pengolahan minyak. Penelitian ini adalah metode penelitian aplikatif dengan pendekatan studi kasus yaitu dalam rangka mengatasi masalah korosi dibawah insulasi. Diyakini penyebab korosi dibawah insulasi adalah karena didalam spesifikasi proyek kilang tidak terdapat ketentuan aplikasi primer coating dibawah insulasi perpipaan. Hasil penelitian menunjukkan spesifikasi primer coating dengan service temperature  $(-45)^{\circ}\text{C}-(650)^{\circ}\text{C}$  dengan material coating hi-built epoxy, epoxy phenolic, epoxy nonov, inargonic copolimer dan multi polymetric matrix, telah sesuai spesifikasi NACE SP 0198-2010 dan telah diaplikasikan dengan baik dan aman. Hasil penelitian ini juga merekomendasikan bahwa spesifikasi material dan metode aplikasi primer coating yang telah disusun didalam pedoman primer coating dapat dibakukan sebagai standar baku dan metode aplikasi pengendalian korosi dibawah insulasi dengan metode pelapisan primer coating di Pertamina RU V dapat direplikasi untuk mengatasi permasalahan sejenis dilingkungan industri Migas diluar PT. Pertamina.

Key words : *Corrosion Under Insulation, piping system, refinery equipment.*

## 1. INTRODUCTION

### 1.1 Background

One of the important equipment in the operation of an oil refinery is readiness and piping system. The piping system has an important function to drain liquid or gas fluids from one equipment to another and one process to the next. The piping system drains the feed intake from the storage tank, is pumped by a pump and flowed by piping system for further processing in the heating system and fractionation system. The piping system is also tasked with supplying fuel supplies (fuel oil and fuel gas). In addition the piping system also supplies utility needs of refineries such as steam processes, cooling water, boiler raw material water and instrumentation air.

Based on the Data Project Specification X-1 Rev.4 Bechtel International: Pertamina Balikpapan Refinery Expansion Project, 1982 and JGC Data Project Specification: General Specification for Painting, Doc. No. PS-250- 13A1-001-E Rev. R1, Pertamina Balikpapan Refinery I Upgrading Project, 1994, the presence of 65% of the piping system at PT. Pertamina RU V is a pipeline that is covered with heat insulation. The piping system consists of feed intake crude oil pipes, steam pipes, utility oil pipe, diesel product pipes, long residues and short residues.

One of the problems experienced in these piping systems is corrosion under insulation (CUI) which results in thinning corrosion, holes such as fittings (crevice corrosion) and crevice corrosion. The impact experienced was leakage of piping, damage to piping and disruption of refinery operations.

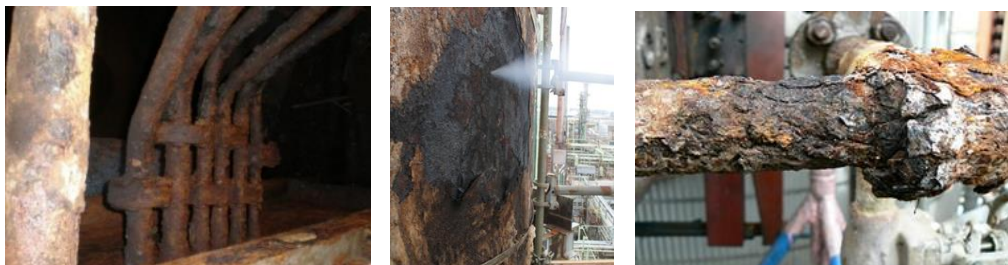


Figure 1. Corrosion under insulation (CUI)

Corrosion is a form of metal surface material degradation due to metal being in humid conditions, free exposure and contaminated with free air (oxidation) environment. The search

results determine that based on Project Specification X-1 Rev.4 Bechtel International: Pertamina Balikpapan Refinery Expansion Project, 1982 and JGC Data Project Specification: General Specification for Painting, Doc. No. PS-250- 13A1-001-E Rev. R1, Pertamina Balikpapan Refinery I Upgrading Project, 1994, heat-insulated piping is not protected by coating so that the pipe surface has direct contact with humid conditions under insulation. Thus it is believed that it is not protected by primer coating.

With regard to these problems, improvements have been made by replacing damaged, leaking and corroding pipes with new pipes. However this does not solve the problem because corrosion problems under insulation still occur and have the potential to disrupt the smooth operation and production of refineries. Based on the data on problem findings in the field and the results of the search for the specification data above, this research is important to find answers to the question of why corrosion occurs under such insulation and how prevention efforts are carried out such as coating the surface of the pipe with primer coating before being covered with heat insulation.

## **1.2 Problem Formulation**

In this study it was developed as the research formula as follows:

- a. Corrosion under insulation (CUI) is the degradation of the surface of a metal material due to the exposed metal surface having a con with no damp conditions under insulation
- b. Corrosion under insulation is caused by oxidation of metal surfaces with moist environments under insulation.

The assumptions that will be developed in this study are:

- a. Corrosion under insulation is a natural legal event that cannot be prevented, but can be suppressed
- b. One effort to suppress the occurrence of corrosion under insulation is to install a barrier layer (barrier effect) in the form of a primer coating
- c. If the promising coating barrier layer works properly then the oxidation of metal surfaces and corrosion under insulation will not occur.

## **1.3 Research Objectives**

The objectives to be achieved through this research activity are to:

- a. Provide an overview of the determination of the specifications of the primary coating material for the piping system at the oil refinery
- b. Provides an overview of the primary coating coating application method under insulation.

## **2. REFERENCE REVIEW**

### **2.1 Corrosion Under Insulation (CUI)**

Corrosion is a damage that results from a chemical reaction between a metal or alloy and in an environment. Corrosion phenomenon is a chemical reaction that results from two half-cell reactions involving electrons to produce an electrochemical reaction. From these two reactions as half cells there is an oxidation reaction at the anode and the reduction reaction at the cathode. Most corrosion processes are electrochemical, where solutions function as electrolytes while the anode and cathode are formed due to inhomogeneity. Some of the factors that influence the corrosion process in aqueous systems include the components of solution ions and their concentration, the acidity of the environment, oxygen levels, temperature and heat transfer and the speed of fluid movement.

Based on the form of damage caused, the cause of corrosion, the environment where corrosion occurs, and the type of material being attacked, corrosion can be divided into several, including (1) General / Uniform corrosion, namely corrosion caused by chemical or electrochemical reactions that occur uniformly on the surface metal. The effect is thinning on the surface and ultimately causing failure due to the inability to hold the load. This corrosion can be prevented or controlled by selecting materials (including coatings), adding corrosion inhibitors to fluids or using cathodic protection (2) Galvanic corrosion, which is corrosion caused by the potential difference between two metals that are in fluid or conductive and corrosive media. As a result, metals with low corrosion resistance will experience a higher corrosion rate compared to metals that have high corrosion resistance. (3) Crevice corrosion, namely corrosion that occurs between gaskets, overlapping joints, screws or rivets formed by sediment impurities or arising from rust products (4) Pitting corrosion, ie corrosion where corrosion occurs in an area on the metal surface which eventually causes a hole in the surface. This corrosion is usually caused by chloride or ion containing chlorine (5) corrosion corrosion, which is corrosion which occurs as a result of the high relative movement of corrosive fluid to the metal surface. This process generally takes place in the presence of chemical or electrochemical decomposition on metal surfaces (6) Stress corrosion, ie

corrosion that occurs due to a combination of load / stress on metals and corrosive media. This corrosion can occur if the load received by the metal exceeds a minimum stress level (7) Crevice corrosion, which is corrosion that occurs between gaskets, overlapping joints, screws or rivets formed by impurities deposited or arising from the product - rust products, and (8) Selective leaching, which is corrosion which is related to removing one element from a metal mixture as in desinification which releases zinc from a copper alloy

Some environmental factors that can affect the corrosion process, including: (1) Temperature, where an increase in temperature will cause increased speed of corrosion reaction. This happens because the higher the temperature, the kinetic energy of the particles that react will increase so that it exceeds the amount of activation energy and consequently the rate of reaction speed (corrosion) will also be faster, and vice versa (2) fluid flow velocity or stirring speed. Corrosion rates tend to increase if the rate or speed of fluid flow increases. This is because the contact between reagents and metals will be greater so that more metal ions will be released so that the metal will experience fragility (3) the concentration of corrosive materials, this is related to pH or acidity and basicity of a solution. Acidic solutions are very corrosive to metals where the metal in the acid solution media will corrode faster because it is an anode reaction. Whereas alkaline solutions can cause corrosion in the cathodic reaction because the cathode reaction is always simultaneous with the anode reaction (4) Oxygen, where the presence of oxygen contained in the air can come into contact with the damp metal surface. So the possibility of corrosion is greater. In water (open environment), the presence of oxygen causes corrosion (5) time of contact between metals and the environment causing corrosion.

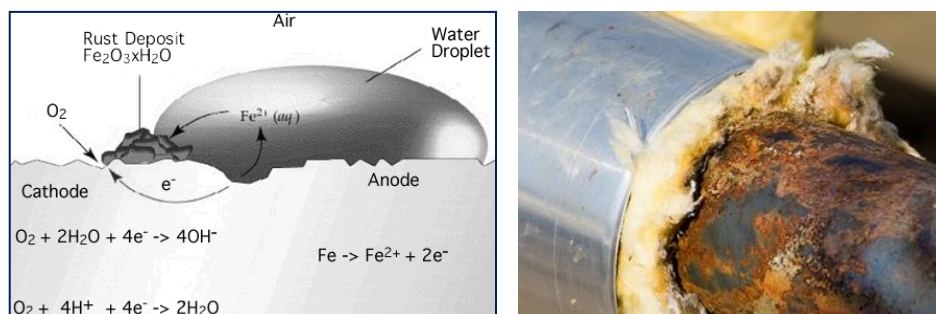


Figure 2. Process of Corrosion and Actual Corrosion Under Insulation (CUI)

Corrosion under insulation occurs because of the presence of fog (moisture) or condensation, can cause corrosion because the air is moist and wet with moisture that stays in place until the

presence of wind pressure or rising temperatures can move it. The corrosion attack under insulation begins with the formation of a thin layer of moisture which does not appear visually at humidity, > 60%. If the humidity is > 80%, the rust formed and the steel will absorb water (hygroscopic) and this is where the corrosion attack under the insulation continues.

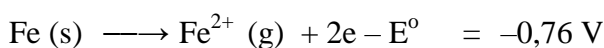
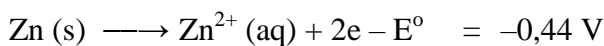
Corrosion rates under insulation under wet soil conditions have a corrosion rate 20 times greater than atmospheric corrosion (ambient). Because it is visually invisible, corrosion under insulation (CUI) seems to occur suddenly and can result in pipe leakage, refinery equipment leakage, danger of fluid bursts, flash and fire especially if piping or equipment is operated at high temperatures and pressures.

Three of factors that cause corrosion under insulation are (1) the factor of water vapor originating during storage of insulation material or during installation of insulation, due to system leakage, due to poor water proofing systems and good insulation system maintenance (service lapses) (2) content chemicals in water. If the pH of the water is <4, corrosion will occur quickly, such as acid corrosion (acidic corrosion) which generally occurs in carbon steel material, so it needs to be maintained (maintenance) so that the pH of the insulation material is in a neutral pH condition, ie at pH. 7.0-11.7 (3) operating temperature or ambient temperature. The increase in temperature has an effect on atmospheric corrosion. At temperature) service (0-100°C) allows water to be in liquid form and at any temperature increase of 10-20°C the corrosion rate will double. Stress corrosion cracking generally occurs in the ambient range <120°C. In addition there are two temperature conditions that accelerate corrosion, namely cyclic temperature and extreme temperatures. Corrosion mechanism under insulation is very closely related to osmosis events, where water vapor trapped in the coating with changes in temperature evaporates, allowing the entry of aggressive ions into the insulation and sticking on the steel material so that electrochemical events occur between steel metals and aggressive ions and the water in the layer. Sometimes it can also occur due to soil stress, namely the gap formed between the coating and the surface of the pipe due to the unevenness of the surface on the seam and the position of the weld girth so that water and microorganisms can enter and cause corrosion cells under insulation. Soil stress or tenting also often occurs on soils with high wet clay.

## **2.2 Corrosion Control Of Corrosion Under Insulation With Primary Coating**

One method that is considered suitable and appropriate for corrosion control is by installing a layer of metal material protection against environmental influences by coating protection methods. This coating is an external coating method. The coating method (external protection) is seen as more feasible and easier to do than the protection method carried out from the inside of the pipe. This is based on the fact that the leakage of the pipe under its dominant insulation is due to damage originating from corrosion on the outside of the pipe. Coatings of paint (coatings) are basically dispersion solutions that can be converted into relatively light solid material after being used as a thin coating on the surface of metal materials. Coating aims to provide a solid and even layer as an insulator or inhibitor of electricity throughout the protected metal surface. The function of the layer is to prevent the metal from having direct contact with the electrolyte and the surrounding environment so that the reaction of the metal and its surrounding environment is inhibited.

Corrosion control by coating coating method is an effort to control corrosion by applying a layer on the surface of iron metal. One of them is by painting or metal plating. Iron plating usually uses metal chrome (Cr) or tin (Pb) as a metal protector. These two protective metals can form an oxide layer that is resistant to rust (passivation) so that the iron can be protected from corrosion. Pasivasi is the formation of a surface film of oxidized metal oxide which is resistant to corrosion so that it can prevent further corrosion. Zinc is used to coat iron (galvanized), but zinc does not form an oxide layer like in chrome or tin, but sacrifices for iron (sacrificial anode). Zinc is a metal that is more reactive than iron, as can be seen from the half potential oxidation reaction as follows.



Therefore, zinc will corrode before iron. If the zinc coating runs out then the iron material will corrode even faster than normal (without zinc). Metal alloys are also a method for controlling corrosion. Stainless steel consists of carbon steel containing a small amount of chrome and nickel. The two metals form an oxide layer which changes the reduction potential of steel to resemble the properties of precious metals so that it does not corrode. One type of coating is a type of epoxy, which is a thermoset type of polier which is generally incorporated in a group of "mer" which are arranged in a repeated manner. A combination of long and branched polymers forms a cross linked polymer containing epoxy or oxirane. Usually this epoxy

consists of two parts and in the first part consists of epoxy resin, pigment and several types of pelatur. The second part of the copolymer, a polymer formed from different monomers as a hardening agent, can be polyamine, amine product and polyanide. Paints with binders undergo chemical drying due to the reaction of two intermediate components and hardeners which are added before the coating is carried out.

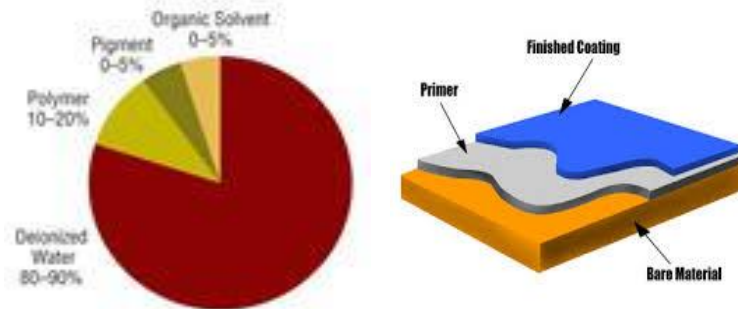


Figure 3. Coating component

Coating is a thin layer on a coating that functions as a separator or breaker between the environment and the metal that it will protect. Coating consists of three components with each function including (1) pigment as coloring agent (2) solvent, as solvent (3) binder as binder and (4) extender and additive as added ingredients. The function of the coating in protecting the protected metal material (coating system) includes (1) the primary shop serves as temporary protection (2) the primary coat functions as a basic coat with good adhesion (3) the intermediate coat, serves to create thickness and water-resistant properties, and (4) top / finish coat functions as a decorative and external protection function. The coating method protects the material being protected is by (1) providing a barrier effect, namely by making the coating layer as a separating layer between the environment and the metal it protects (2) inhibitor effect, namely by forming a passive layer to prevent the entry of corrosion (3) galvanic effect, namely by making coating as the sacrificial anode.

### 3. RESEARCH METHODS

#### 3.1 Approach Method

This research is an application research with a case study approach method, namely a case study of corrosion under insulation in piping systems and operating equipment at PT. Pertamina RU V Balikpapan. For the ease and practicality of the research, in this study the researcher at the same time carried out the professional duties as a Coating Inspection



Engineer and as a Building Maintenance and Maintenance Expert. Handling corrosion problems under insulation (CUI) is an integral part of continuous improvement efforts to innovate maintenance, maintenance methods and maintain the readiness of pipeline systems and refinery operations.

### **3.2 Material**

The specifications of the primer coating material are adjusted to the type of metal material to be coated with primer coating, including carbon steel (CS), alloy steel (US) and stainless steel (SS) materials. The surface temperature (substrate) of the metal to be coated is based on temperature service (1) -45 s/d 60°C (2) -45 s/d 150°C (3)-45 s/d 205°C (4)-45 s/d 595°C (5) -45 s/d 650°C-45 (6) Ambient temperature.

### **3.3 Equipment**

Surface preparation and cleaning equipment that will be coated (grade cleanlines) in coating preparation according to the surface preparation standards and specifications (SSPC) as follows.

- a. SSPC SP-1, is surface preparation equipment in the form of solvent cleaning, namely surface preparation using a solution (water, detergent solution, MEK, and the like) as a surface cleaning media
- b. SSPC SP-2, is a surface preparation equipment in the form of hand tools, namely the process of surface preparation using manual work equipment (light hand tools) such as abrasive paper, glass, wire and the like
- c. SSPC SP-3, is a surface preparation equipment in the form of power tools, namely the surface preparation process using machine tools to clean dirt and form a profile
- d. SSPC SP-10, is surface preparation equipment in the form of abrasive blasting, which is a surface preparation process using abrasive blasting (dry abrasive or wet abrasive) material to remove impurities and rust on metal surfaces and to make profiles on metal surfaces

### **3.4 Primer Coating Application Prosedure**

- a. Coating applications must meet the following environmental conditions:
  - 1) Relative humidity <85%, except for the <90% inorganic zinc silicate specification
  - 2) Surface temperature 3°C above dew point
- b. Surface preparation which will be applied to coating primer is prepared according to the following standard.

- 1) SSPC SP-1, surface preparation in the form of solvent cleaning, which is surface preparation using a solution as a surface cleaning medium
  - 2) SSPC SP-2, using hand tools, namely the process of surface preparation using manual work equipment such as abrasive paper, sheets, tapes and the like so that the surface is ready for coating
  - 3) SSPC SP-3, using power tools, namely the surface preparation process by using machine tools to clean the dirt and form a profile
  - 4) SSPC SP-7, uses an off blast cleaning brush
  - 5) SSPC SP-11, using power cleaning tools to bare metal
  - 6) SSPC SP-6, using commercial blast cleaning
  - 7) SSPC SP-10, cleaning using blasting to near white blast cleaning
  - 8) SSPC SP-5, blasting cleaning to white metal blast cleaning
- c. Material specifications for blasting are angular steel grit, aluminum oxide and dust free mineral abrasives, may not use silica sand material
  - d. The results of surface preparation work are reported written to the owner in the form of an inspection report and to be able to continue the coating application based on the signature of the agreement
  - e. Before the coating application was carried out ambient air temperature measurement, the epoxy coating specification was 10oC and for topping with acryl polyuretahane was 5oC
  - e. Ensuring the condition of the dew point, relative humidity, ambient temperature and substrate temperature, are recorded in the 2x pershift log book
  - f. During the coating application, the implementer must check the thickness of the coating and report to the owner
  - g. Coating thickness tolerance and frequency of coating thickness measurements must refer to standards
  - h. The applicator must ensure that the coating application has no defects in the form of orange peel, pinholes, cracking, run and sags, bubbling and bistering
  - i. The stripe coat must be applied with brushes at all angles, sharp side details, bolts and rivets with the same coating specifications
  - j. If a defect occurs, it must be repaired before the coating application on the next layer and on the edge should be more than 50 mm wide

- k. The applicator must prepare a pre-qualification test / PQT for each coating material on each substrate and the panel material must be with a minimum area of the panel. 225 Cm<sup>2</sup>
- l. In the pre qualification test (PQT) the requirements for environmental conditions, materials and equipment settings, surface profiles, surface cleanliness, visual coating and adhesive tests must be explained.

#### 4. RESULTS AND DISCUSSION

The results of determining the specifications of carbon steel (CS) type metal material piping systems and refinery operating equipment as well as the thickness of the coating based on the type of carbon steel metal that is protected as presented in table.1.

Table 1. Primer coating specification for Carbon steel (CS)

Steel Material Type	Surface Temperature (°C)	Base Type Prime Coat (µm)
Carbon Steel (CS)	-45 s/d 60	Hi-built Epoxy (130)
Carbon Steel (CS)	-45 s/d 150	Epoxy Phenolic (150)
Carbon Steel (CS)	-45 s/d 205	Epoxy Novolac/Silicone Hybrid (100-200)
Carbon Steel (CS)	-45 s/d 595	Thermal Spray Alumunium (TSA) (250-350)
Carbon Steel (CS)	-45 s/d 650	Inorganic Copolymer/ Multi polymeric Matrix (100-150)
Carbon Steel (CS) Galvanized Fire Proofing	Ambeint	Epoxy/ Epoxy Phenolic (100-150)

The results of determining the specifications of stainless (SS) type metals and metal types Alloy steel (AS) p piping systems and refinery operating equipment and the thickness of the coating layer based on the type of metal that is protected as presented in table.2.

Tabel 2. Primer coating specification for Stainless steel (SS) dan Alloy Steel (AS)

Jenis Material Logam	Temperatur Permukaan (°C)	Base Type Prime Coat (µm)
SS/ Alloy Steel	-45 s/d 60	Hi-built Epoxy (125-175)
SS/ Alloy Steel	-45 s/d 150	Epoxy Phenolic (100-150)
SS/ Alloy Steel	-45 s/d 205	Epoxy Novolac (100-200)
SS/ Alloy Steel	-45 s/d 650	Inorganic Copolymer/ Multi polymeric Matrix (100-150)

The primary material specifications vary based on service temperature, ranging from -45°C to 650°C. This temperature service determines the type of coating material used including hi-built epoxy, epoxy phenolic, epoxy novolac and inorganic copolymer / multi polymeric matrix, which is its resistance not to be damaged against the influence of temperature. Variation in thickness of primer coating is 100-200 micron (dry film thickness) DFT, depending on temperature service and prime coat base type used.

The function of the coating layer in protecting the metal material it protects (coating system) includes (1) shop primer coating which functions as temporary protection (2) primer coating which functions as a basic coating or base paint with good adhesion (3) a functioning intermediate coat to create water-resistant thickness and properties, and (4) top or finish coat that will function as a decorative and external protection function.

After being applied, the coating layer will protect the metal material it protects by (1) providing a barrier effect, namely by making the coating layer as a separating layer between the environment and the metal it protects (2) giving an inhibitor effect, namely by forming a passive layer to prevent entry corrosion attack, and (3) give a galvanic effect, namely by making the coating layer a sacrificial anode and sacrificing it for the metal material it protects.

The key to successful coating applications is that good surface preparation is a good surface preparation, namely (1) the surface to be coating has sufficient surface roughness and is suitable for the surface profile, and (2) the surface to be cleaned is clean from rust, dirt, previous paint / existing coatings, dirt & dust (dirt and dust), oil & grease (oil and fat), salt (salt) and remnants of detailed fabrication. Another key concern that should be considered is the environmental aspect parameters that must be tested according to ASTM E 337-15 standard [2] which includes ambient temperature in the form of wet bulb temperature and dry bulb temperature, dew point, relative humidity, surface temperature and wind velocity.

## **5. CONCLUSIONS AND SUGGESTIONS**

### **5.1 Conclusions**

- a. Primary specifications coating with service temperature (-45)°C - (650)°C with hi-built epoxy coating material, epoxy phenolic, epoxy nonov, inargonic copolymer and multi polymeric matrix, are compliant and meet NACE SP 0198-2010 specifications
- b. The method of primary coating application with variations in the thickness of the primer coating is 100-200 micron (dry film thickness) DFT, proven to be suitable and suitable to be used to control corrosion problems under insulation.

## **5.2 Suggestions**

- a. Material specifications and primary application method coatings that have been compiled in the primer guidelines of the coating that are in accordance with NACE SP 0198-2010 specifications can be standardized as standard
- b. The method of application of corrosion control under insulation with the coating coating primer method at Pertamina RU V can be replicated to overcome similar problems in the oil and gas industry environment outside Pertamina.

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