TALK ON CORROSION AND CATHODIC PROTECTION SYSTEM

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INTRODUCTION

The above-mentioned talk was held at the IEM Conference Hall A, Bangunan Ingenieur, at 10.00 a.m. on 17 January 2004.

Ir. Ahmad Nordeen Salleh, Chairman of the IEM Chemical Engineering Technical Division, started the talk with an introductory speech and subsequently passed the floor to the speaker, Ir. Sam Wei Yeow.

The talk was divided into three major parts:

1) Technical Talk and Discussion
2) Snapshots Presentation
3) Question and Answer Session

TECHNICAL TALK AND DISCUSSION

The speaker started by first introducing corrosion concepts, its root causes, and normal prevention and counter-measures.

Corrosion is a deterioration of materials, which occurs as a result of chemical reaction with the environment in the presence of oxygen and water. Corrosion occurs when these are present:

a) anode and cathode within the material
b) electrolyte, e.g. soil and water
c) potential difference which results in current flow (electrical path).

A difference in electrical potential, hence the creation of the anode and cathode, within a metal is mainly due to differences in oxygen and metal ion concentrations. The potential difference causes electron transfer; it is in the transition of these electrons across the steel/electrolyte interface that causes corrosion to occur. In a metal, current flows from the cathode to the anode. For any corroding underground pipe, current flows off the pipe at the anode into the soil while at the cathode, current flows from the soil into the pipe.

Ir. Sam then went into a detailed discussion on the design aspect of a cathodic protection system, for both above and underground pipes within a normal fossil fuel power plant. He started by giving a brief introduction on the general concepts of cathodic protection.

Cathodic protection is a means of converting the whole pipeline into a cathode. In order to achieve this, we must eliminate the differences in potential between the local anodes and cathodes and we tend to drive all the potentials numerically upwards (making them more negative).

For example, when steel reaches a solution potential of –0.85 volts with reference to copper sulphate, the anodic reaction $Fe \rightarrow Fe^{2+} + 2e$ cannot proceed, thus preventing corrosion. The efficiency of –0.85 volts was derived theoretically as the protective potential of steel in near neutral soils or waters. However, for safety reasons, a practical figure of –0.95 volts is often specified.

In designing cathodic protection systems, a reference electrode is necessary. Commonly used are copper/copper sulphate ($Cu\text{-}CuSO_4$) reference electrodes in a soil environment and silver/silver chloride ($Ag\text{-}AgCl_2$) reference electrodes in a seawater environment, *whereas carbon steel is used in neutral soil.*

Cathodic protection can be achieved by using either **sacrificial (galvanic) anodes** or **impressed current.**

The speaker subsequently discussed sacrificial anode and impressed current systems, the stray current effect and galvanic corrosion. To help the audience understand these subjects better, a conceptual sketch for each system was presented.

SACRIFICIAL ANODE

Ir. Sam discussed briefly the design concept and requirements, operation and maintenance considerations, anode selection and functionality of the sacrificial anode system.

Based on their galvanic potentials, some metals are more active than others. The sacrificial anode system employs active metals as anodes, which are connected directly to the object to be protected. The difference in natural potential between the anode and the protected object, as indicated by their relative positions in the electro-chemical series, causes a positive current to flow in the electrolyte, so that the whole of the protected item becomes a cathode.

Metals that are commonly used as sacrificial anodes are magnesium, zinc and aluminium. In the soil, magnesium anodes are commonly 10–20 kg in weight, about 100mm diameter by 750mm long cylinders and provide a current flow of between 10–500 milliamperes, depending largely on soil resistivity.

IMPRESSED CURRENT

The speaker took a similar approach in presenting the impressed current system, highlighting the design concept and requirements.

The impressed current cathodic protection system functions using power from external sources. Besides the presence of voltage, it is also necessary to lower the current in the cathodic protection circuit by using a DC voltage source. AC power is supplied to a transformer rectifier, which will produce a terminal voltage of up to 48 volts.

The negative pole (cathode) of the transformer rectifier is connected via a link box to the structure or pipeline to be protected, while the positive pole of the transformer rectifier will be connected via very well insulated cables to the anodes buried in the soil. Current is impressed between the buried structure and the anode, forcing a reversal of the current, and causes the anode, instead of the pipe, to be consumed. The anode used is normally titanium.

Ir. Sam briefly compared the sacrificial anode and impressed current systems to give the audience a better understanding of these two systems.

STRAY CURRENT EFFECT AND GALVANIC CORROSION

The speaker highlighted the concept of the stray current effect, as well as the requirements to be considered in designing the impressed current system.

The stray current effect arises from cathodic protection system interactions. Foreign structures located in the same electrolyte

a) within the vicinity of the structure or pipeline to be protected, or
b) in direct contact with the structure or pipeline to be protected, or
c) within the vicinity of the anodic location

may pick up some of the current intended for the structure. This current will leave the foreign structures at a location close to the structure to be protected and will then cause corrosion on the foreign structures.

This poses problems when there is a secondary structure or pipeline that passes through or has direct contact with a cathodic protected primary structure or pipeline. Current supplied to protect the main structure or pipeline may be picked up by the secondary ones when the cathodic protection system is energised. Soil potential will change at the crossing point or contact areas between the primary and secondary structures. The change in potential will produce an anodic condition on the contact areas between the primary and secondary structures or pipelines and will further lead to corrosion.

The stray current effect can be overcome either by insulating the foreign structure with insulating materials, or by incorporating the system as part of the cathodic protection system.

The speaker went on to discuss galvanic corrosion, which occurs when two dissimilar materials are in contact with each other in the presence of an electrolyte. As with the sacrificial anode system, the metal with the more negative potential will become the anode and the other the cathode. The potential difference will generate current flow from the cathode to the anode, resulting in increased corrosion.

He gave the example of a stainless steel and a carbon steel flange in direct contact with each other. He highlighted that although connected pipes with painted or coated flanges will not corrode, it is necessary that the flanges must not have any pinholes. Therefore, in practice, it is better to separate the pipes as far as possible.

CATHODIC PROTECTION SNAPSHOTS PRESENTATION

After the technical presentation, the speaker showed the audience various snapshots of main cooling water pipes, extracted from a power plant project undertaken by him in Singapore. The snapshots included the internal cathodic protection system, rubber lining and ceramic coating, which were used to protect the internal surface of the main cooling water pipes against seawater corrosion. The snapshots enabled the audience to obtain a better grasp as to what corrosion and cathodic protection mean.

QUESTION AND ANSWER SECTION

About ten minutes were allowed for the Q & A section. Various topics related to the technical talk were brought up by the audience and further clarified by the speaker.

CONCLUSION

The response to this talk was fairly good; the IEM Conference Hall A was crowded with 47 participants. Before concluding the talk, Ir. Ahmad Nordeen Salleh presented a memento and certificate to Ir. Sam as a token of appreciation. Lastly, the speaker would like to take this opportunity to thank all the attendees for their participation, feedback and comments to make this talk a success.

The Chemical Engineering Technical Division would like to thank Ir. Sam Wei Yeow for the successful and informative talk. ■

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