CHAPTER 1

INTRODUCTION

1.1 Background of Study

Refineries, petrochemical and gas processing plants deal with hazardous chemicals, which are highly flammable and toxic, and these chemicals are typically operating at extreme conditions of temperature and pressure. Leakages of hydrocarbons from these chemicals in those plants can lead to a serious risk of fire and explosion and a loss of plant availability. It has been found that one of the causes of the leakage is due to corrosion that contributes about 15% to 20% of the leakage occurrences (HSE UK, 2002).

Exxon Mobil Chemical reported that the highest incidence of leaks in the refining and chemical industries is due to corrosion under insulation (CUI), not due to process corrosion, which contributes approximately 40% to 60% of the maintenance costs (Corrosion under insulation, n.d.). Every year, there are failure cases due to CUI on pipes and vessels around the world. However, only a few failures are reported in the literature. "Mostly they remain hidden and are not discussed publicly, but the implications for safety are significant (Hills, 2005)". CUI has become a major problem for insulated systems since the corrosion takes place beneath the insulation which makes it hard to detect and to predict. The corrosion progresses in an insidious manner which unfortunately results in serious consequences in many occasions.

Therefore, predicting how likely CUI is to take place is necessary so that mitigating action can be planned before any failure occurs. Once CUI can be predicted, then a proper inspection and maintenance program can be developed, which is seen to be the key for maintaining a safe and continuous operation of those plants. Currently, CUI inspection and maintenance strategy adopt the risk-based inspection (RBI) approach where the strategy uses risk as a criterion to prioritize inspection tasks for the insulated systems. Risk is defined as the probability of failure and its consequences.

At present, the assessment of the probability of failure for CUI based on API 581 follows either the qualitative and semi-quantitative methods. Both approaches are subject to many uncertainties (i.e. uncertainties can be related to the definition of qualitative terms by experts in the qualitative method such as very low, low, high, very high) and the results for inspection planning based on risk may not be optimized. Predicting the probability of failure using these approaches is not objective and typically produces inaccurate results. Therefore, the quantitative method is required in order to produce a more objective result in determining the probability of failure.

1.2 Problem Statement

Even though the common practice in estimating the failure probability due to CUI follows the standard API 581, it is also recognized that this method to assess the probability of failure due to CUI is rather subjective (i.e. very low, low, high, and very high). This approach does not provide a means for quantitatively establishing the future reliability levels for the equipment/system which can be employed as a basis for optimizing inspection intervals. Therefore, there is a need to develop a model that can predict quantitatively the reliability over time for equipment/systems subject to CUI. Using the developed model, corrosion and inspection engineers can estimate when the systems will fail after going through the deterioration process.

The main requirement in developing either statistical or mathematical models is the availability of data where the failure data or inspection data is required to estimate the parameters of the models being used. In the case of corrosion, typically the failure data is insufficient and this presents an obstacle in the way of using the quantitative models to design practical maintenance/inspection programs. Another way is using the inspection data, typically measurable wall thickness data, to estimate the model parameters. The wall thickness data are collected during each inspection period to estimate the corrosion rate with the objective to predict the remaining life of the equipment or systems.

However, for CUI, neither the failure data nor the wall thickness data are usually available. Even though there are available techniques to measure the wall thickness data, the techniques are not commonly applied during each inspection period due to high cost. Measuring each thickness measurement location during each inspection period to assess the wall loss due to CUI is quite costly. Typically what available in the inspection report is the visual inspection results which can be interpreted as CUI is found or CUI is not found.

At present, there is no model, either mathematical or statistical or Markovian, available to estimate the failure probability subject to CUI. The models available in the literature are meant for other types of corrosion, mainly for internal corrosion, i.e., flow accelerated corrosion and erosion corrosion. Therefore, there is a need to develop a model that can predict quantitatively the probability of failure over time for piping systems subject to CUI. A question rise is: Can one still predict the probability of failure quantitatively with lack of failure data and inspection data? Looking at the various scenarios related to the type of data available for CUI, this motivates the explorations of quantitative methods for assessing the probability of failure in equipment/systems subject to CUI degradation mechanism.

Hence, this study aims to find the alternative methods which can be used to assess the probability of failure quantitatively for optimizing the inspection interval based on types of data available.

1.3 Objectives

The objective of this study is to assess quantitatively the probability of failure for piping systems subject to CUI for RBI. The followings are the main activities to be performed in order to achieve the objective of the study:

- To analyze CUI data that is available in practice and to collect those data, i.e., failure data, inspection and maintenance data, technical details of the selected system under study such as design and operating pressure and temperature.
- To identify several proposed quantitative models to assess the probability of failure for systems subject to CUI based on the type of data available for CUI.
- To evaluate these models and make recommendations based on the findings from the developed models.

1.4 Scope of Study

- Piping systems are chosen in this study because it is found that one of the most important structural elements in refineries and petrochemical plants is piping systems. According to the statistics, the highest percentage of structural elements in those plants is piping systems when compared to other equipment (Chang et al., 2005). Moreover, it is also found that, unfortunately, the regulatory requirements on piping safety and inspection interval is lacking when compared to pressure vessels where the inspection interval requirement is clearly documented. American Petroleum Institute does provide a guideline on the inspection interval of three categories of piping systems based on fluid content in piping or the half remaining life (API, 2001). However, this is generally insufficient as the actual conditions of the piping are not considered and thus, the possible failure of the piping is usually not quantified. Pressure vessel will not be in the scope of the study.
- This study will focus only on insulated piping systems, both small-bore (nominal pipe size less than 2 inch) and big-bore (nominal pipe size more than 2 inch) pipes.

- This study will focus only on insulated pipes that are made of carbon steels. Austenitic stainless steel piping systems will not be in the scope of study.
- The scope of work will only be in estimating the probability of failure for RBI analysis. Estimating the consequence of failure and thus, the risks are not included in the scope of work.

1.5 Organization of the thesis

The thesis is divided into six chapters, including the first introductory chapter. Followings are the details for each chapter.

- Chapter 2 discusses an overview of CUI including the factors that affect CUI and estimation of corrosion rate , RBI strategy and the standard technique used (based on API 581) in assessing the probability of failure and also the mathematical/statistical methods used to predict the failure probability for system subject to corrosion including CUI.
- Chapter 3 explores the theories of four quantitative models. The first model is the logistic regression model to estimate the probability of CUI occurrence. The model takes the advantage of the visual inspection data which are considered as binary data. Another model that focuses on estimating the failure probability is the structural reliability analysis that is based on the design and operating data. The third model is degradation analysis that typically being used when the failure data are not available and the time-to-failure data extrapolated from the estimated corrosion rate. The fourth model is Markov-modeling technique that models the actual progression of corrosion defects under the insulation that will undergo into several states before the actual failure occur.
- Chapter 4 outlines the research project framework. The methodology used for each model is described in details.
- Chapter 5 deals with the results and discussions where all the results generated from the four models being explored will be compared.
- Finally, Chapter 6 describes conclusions of the thesis and highlights other interesting topics for future research.