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Risk Based Inspection forAtmospheric Storage Tank

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Abstract. Corrosion is an attack that occurs on a metallic material as a result of environment's reaction.Thus, it causes atmospheric storage tank's leakage, material loss, environmental pollution, equipment failure and affects the age of process equipment then finally financial damage. Corrosion risk measurement becomesa vital part of Asset Management at the plant for operating any aging asset.This paper provides six case studies dealing with high speed diesel atmospheric storage tank parts at a power plant. A summary of the basic principles and procedures of corrosion risk analysis and RBI applicable to the Process Industries were discussed prior to the study. Semi quantitative method based onAPI 581 Base-Resource Document was employed. The risk associated with corrosion on the equipment in terms of its likelihood and its consequences were discussed. The corrosion risk analysis outcome used to formulate Risk Based Inspection (RBI) method that should be a part of the atmospheric storage tank operation at the plant. RBI gives more concern to inspection resources which are mostly on 'High Risk' and 'Medium Risk' criteria and less on 'Low Risk' shell. Risk categories of the evaluated equipment were illustrated through case study analysis outcome.

INTRODUCTION

Corrosion is defined in different ways; however the usual interpretation of the corrosion is an attack on a metallic material by reaction with its environment [4]. Corrosion of metallic materials can be divided into three main groups, they are:

- Wet corrosion where the corrosive environment is water with dissolved species. The liquid is an electrolyte and the process of corrosion is electrochemical.
- Corrosion in other fluids such as fused salts and molten metals.
- Dry corrosion type is a corrosion condition where the corrosive environment is a dry gas. Dry corrosion is also frequently called chemical corrosion and the ideal example is high temperature corrosion.

Materials technology is a very much vital part of modern technology. Technological development is often limited by the properties of materials and the knowledge. Some properties, such as that determining corrosion behavior, are most difficult to map and to control. The cost of corrosion in industrialized countries has been estimated to be about 3–4% of the gross national product. The progressive deterioration, due to corrosion and wear, of metallic surfaces as used in major industrial plants ultimately leads to loss of plants' efficiency and at the worst a shutdown [7].

Corrosionissue is one of the main causes of failure risks in refining and petrochemical equipment. Once the equipmentfailures took place; some common incidents, such as leakage of process media, partial equipment damage,

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and non-scheduled shutdown of units, may occur generally. Thus,to reduce failure risks and economic loss, risk analysis of corrosion failures of equipment would be performed in advance [15]. With the rapid development of petrochemical industry, storage of oil tank plays an increasing role in the storage of oil [3]. Due to the saving steel advantages, saving occupied area and cost-effective construction, large-scale atmospheric storage tanks are widely used [9]. These large-scale oil tanks have high potential risk. Once the leakage of storage of oil tank happens, itcauses not only serious environmental pollution, but also fire and casualties. Storage tanks can become susceptible to a whole variety of threats throughout operational life, which if it is not adequately mitigated against, may eventually compromise storage tanks integrity at the plant.

Inspection of tank is aimed to assess the tank integrity and identify the problem that may lead to future loss of integrity. The inspection is able to provide the information of deterioration state of tank plates and reduce risk uncertainty of oil tank. Currently, time-based inspection is commonly used by Indonesia's power plant for the management of atmospheric storage tanks [14].

The inspection has employed Non-Destructive Testing (NDT) firm as the power plant's partner third party; for atmospheric storage tank inspection, it is generally executed every other years to inspect and control the atmospheric storage tank condition against the external corrosion and the shell thinning. The generated inspection analysis used as one of visibility certification issuance requirement. Due to the high-capacity of oil tank, it consumes lots of time and expensive maintenance in order to inspect and repair tank, which can influence the normal production of oil depot [6]. If the tanks without certain corrosion defects are opened to inspect, it will cause unnecessary inspection cost and business interruption loss. If the tanks with high risk are not timely inspected and repaired, it will bring potential safety hazard, and even in some cases, oil leakage may happen [8].

Risk-based atmospheric storage tank corrosion management strategies which are subsequently developed to the performance of a corrosion risk assessment, deliver benefits in that atmospheric storage tank inspections and corrosion control/mitigation activities. It may be targeted specifically at those atmospheric storage tank assets that are assessed as high risk and medium high risk. High probability of failure and high consequence; corrosion management is essentially a "closed loop" (iterative) process, the corrosion risk assessment is central to the management process [11]. Risk Based Inspection (RBI) is a risk assessment and management cycle which provides a methodology for determining the optimum inspection methods and frequencies. RBI can identify the high-risk and low risk tanks, and focus inspection resource on high-risk tanks [5]. Most of the inspection analyses focus on corrosion rate method [12] and Reliability Analysis for the inspected equipment [16]. RBI is utilized to measure the equipment reliability [3].In this study, semi quantitative method of Risk Based Inspection was used to analyze the Atmospheric Storage Tank's component risk level at one of Power Plants in Indonesia.

METHOD

American Petroleum Institute (API) has issued three standards for RBI: API 580 "Risk-Based Inspection", API 581Risk-Based Inspection Base-Resource Document as the first edition and API 581Risk-Based Inspection Technology as the second edition [1]. The European Committee for Standardization has also developed a new RBI standard named Risk-Based Inspection and Maintenance Procedures for European Industry [10]. There are three methods which widely used in RBI assessment: Qualitative RBI Method, Quantitative RBI Method and Semi-Quantitative Method [2]. The semi-quantitative method employed to assess atmospheric storage tanks.

The RBI methodology provides the basis for managing risk by making an informed decision on inspection frequency, level of detail, and types of NDE. In most plants, a large percent of the total unit risk will be concentrated in a relatively small percent of the equipment items. These potential high-risk components may require greater attention, perhaps through a revised inspection plan. The cost of the increased inspection effort can sometimes be offset by reducing excessive inspection efforts in the areas identified as having lower risk. With a RBI program in place, inspections will continue to be conducted as defined in existing working documents, but priorities and frequencies will be guided by the RBI procedure. The purposes of a (RBI) program are as follows (1) to provide the capabilityto define and measure risk level, create a powerful tool for managing many of the important elements of a process plan; (2) to allow management to review safety, environmental andbusiness-interruption risks in an integrated, cost-effective manner; (3) to systematically reducethe likelihood of failures by making better use of the inspection resources; and (4) to identify areas of high consequence that can be used forplant modifications to reduce risk or known as the risk mitigation [2]. The research followed the following chart shown on Figure1.

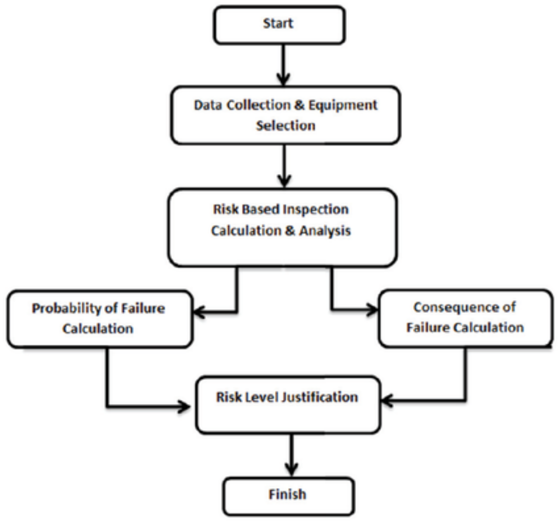

FIGURE 1. Research Flowchart

Risk Based Inspection

The RBI analysis consists of 2 main procedures; they are (1) probability of failure calculation (and (2) consequence of failure calculation. Tank inspection data from the past of 10 years are needed to conduct RBI calculation and analysis. As a matter of fact that the company has problem in providing the complete data, the quantitative was not able to be conducted. Therefore, semi quantitative was the solution to manage the preliminary issue.

In fact, RBI is very unpopular in developed countries like Indonesia.Therefore, semi quantitative method is an ideal solution for the companies which are going to conduct RBI analysis and measurement. However, those companies have limited data and equipment maintenance history. Electrical power industries in Indonesia have not implemented RBI as evaluation method of infrastructure's periodical maintenance program.It is because the number of RBI experts are very limited, and lack ofdata, so that RBI analysis becomes impossible to be done. Moreover RBI software, as a tool to assist RBI analysis,is expensive.

A discussion session with experts was formed in order to establish communication and meetings where the operators provided their knowledge and information regarding the existing processes. The discussion session was made up of 11 participants, and included 3 academics, whose research studies mainly focused on risk based inspection, 2 maintenance operators, 2 reliability & engineering staff, 2 fuel division, 1 health and safety staff and 1 management staff involved in the infrastructure maintenance processes.

Risk-Based Inspection defined as a risk assessment and management process that is focused on loss of containment of equipment in processing industry facilities, due to material deterioration. The potential high-risk components may require greater attention from the management, perhaps through a revised inspection plan.The cost of the increased inspection effort can sometimes be compensated by reducing excessive inspection efforts inthe areas identified as having lower risk [2]. With RBI application programin place, inspections will continue to be conducted as defined existing business and operating documents, but priorities and frequencieswill be guided bythe RBI management procedure.The increased inspection reduces risks through a reduction in future failure frequencies by corrective and preventative approach, in which it is taken after the inspection has identified the problem areas. Inspection does not transform the risk components consequences of the operating unit. Consequences are changed through design changes or other corrective actions. The RBI methodology can recognize areas where consequences of possible failure events can be reduced by system changes or mitigation procedures.

The semi quantitative method is a structured calculation and analysis process which investigates risk level toward the power plant infrastructure due to limited data. It combines numerical calculation and analysis as well as interview data acquisition concerning the factor management system.

This methodology proves to be an appropriate risk based inspection calculation and analysis for this type of research due to data limitation to gain the risk level value.

RESULTS AND DISCUSSIONS

In the semi-quantitative RBI calculation release rate, detection system, detection rating, isolation rating and leak duration on detection should be preceded. The calculation of risk in the Risk-Based Inspection methodology involves the combination of the probability and consequence determination [1].

Atmospheric Storage Tank and Its Comprehensive Values

There are a total of six atmospheric storage tanks at the plant, in which three thanks have being used for High Speed Diesel and the other for Marine Fuel Oil. These tanks were inspected and repaired at different time. However an Atmospheric Storage Tank contained High Speed Diesel has been analyzed and evaluated. Digital ultrasonic thickness gauge were utilized to measure the wall thickness of tank plates and its bottom. As the inspection data of storage tanks are very huge, it is not introducedin this paper.The RBI methodology groups all releases into either of two types: instantaneous or continuous. Instantaneous releases are those that empty the contents of a vessel in a relatively short period of time. Continuous releases are those that occur over long period of time at a relatively constant rate. The operating unit defined as High Speed Diesel Atmospheric Storage Tank with the capacity of 21,000,000 liters. C_9-C_{12} identified as the representative fluid of the evaluated operating unit. Table 1 explains the typical properties of the representative fluid based on the API 581 Risk Based Inspection, Resource Base-Document.

TABLE 1. Properties of the Base Resource Document High Speed Diesel

Fluid	MW	D lb/ft3	NBP F	Ambient State	Cp Gas Constant A	Cp Gas Constant B	Cp Gas Constant C	Cp Gas Constant D	Auto Ignition Temperature F
C9-C12	149	45.823	364	Liquid	-8.5	1.010E+00	-5.560E-04	1.180E-07	406

Where:
MW = Molecular Weight, D= Density, NBP = Normal Boiling Point, AS = Ambient State

According to Table B-1 on API BRD 2000, the inventory category identification for Atmospheric Storage Tank with the aforementioned capacity hasE Category since it is between 1,000,000 – 10,000,000 lbs.

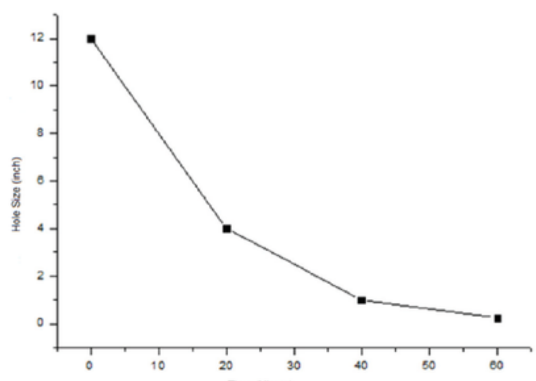

FIGURE 2. Hole size VS Time

Table 3 provides guidance to the user for assigning aqualitative letter rating (A , B, or C) to the unit's detection and isolation systems. These letter ratings are later used in the consequence estimation sections determine the effect of the mitigation systems on final consequences. The Detection and Isolation Classification System defined as C and C.

Detection system finding and isolation system on the tank will automatically simulate leak hole and duration as seen in Fig. 1. It shows that if the hole size is 0,1 – 0,25 inch,the fluid inside the tank will run out for 60 minutes, if the hole size is 0,26 - 1 inch,the fluid inside the tank will run out for 40 minutes, if the hole size is1,1 - 4 inch,the fluid inside the tank will run out for 20 minutes and the tank will be rupturedif there is a 12-inch-diameter hole or more, so that the fluid inside the tank will be catastrophically empty as seen in Figure 2.

Therefore for the evaluated Atmospheric Storage Tank, the leak duration, liquid discharge rate, type and representative fluid phase after release are shown on Table 2.

TABLE 2. Leak Duration, Liquid Discharge Rate and Type

Hole Size Diameter	Leak Duration	Lb/Sec
0.25 Inch	60 Minutes	0.270
1 Inch	40 Minutes	4.320
4 Inch	20 Minutes	69.124
12 Inch	Rupture	622.188

Correlation between hole size diameter, number of fluid release and its release type is shown on Table 3.

TABLE 3. Leak Duration, Liquid Discharge Rate and Type

Hole Size Diameter	Lb/3Sec	Release Type
0.25 Inch	48.603	Continuous
1 Inch	777.648	Continuous
4 Inch	12,442.36	Instantaneous
12 Inch	111,981.244	Instantaneous

The relation between hole size versus Liquid Release Rate is shown on Figure3.

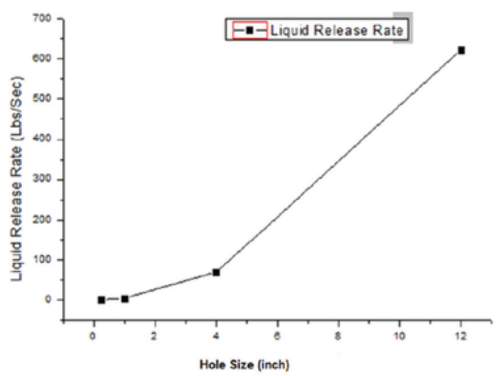

FIGURE 3. Hole size versus liquid release rate

According to API 581, there are 4 kinds of hole size; small, medium, large and rupture. There is a linear change between the hole size and liquid release rate. If the hole size is about 0.1-0.25 inch, it can be categorized as small hole size, if it 1.01-4.0inch, it can be defined as medium hole size, and if the hole size is larger than4 inch, it can be concluded as large hole size. The larger the hole size the more fluid come out from the hole in every second. Thus, tank is categorized as rupture if the hole size reaches 12 inch.

Release type determination at every hole is done based on liquid release rate calculation at every hole size. Initial inventory value becomes the main referencein the rate calculation. Permissible release inventory is a result of inventory value liquid release rate division which occurs during 60 seconds or 1 minute. Release type determination is based on the number of fluid which come out during 3 minutes.

Damage factor thinning calculation that includes minimum wall thickness allowance and corrosion rate are summarized on Table 4.

TABLE 4. Thickness and corrosion rate on each part

Shell Course	Previous Thickness (mm)	Actual Thickness (mm)	Tmin (mm)	Diameter (mm)	Corrosion Rate (mm/year)
Course 1	20.98	20.93	3.14	40.510	0.025
Course 2	16.95	16.94	3.14	40.510	0.005
Course 3	13.37	13.33	2.85	40.510	0.005
Course 4	10.19	10.18	2.85	40.510	0.005
Course 5	8.65	8.64	2.85	40.510	0.005
Course 6	8.64	8.62	2.85	40.510	0.010

To determine Generic Failure Frequency, API 581 table must be entered to RBI Core application. Then GFF component of every holes and the calculation of fraction contribution is found out. Graph 4.43 shows that GFF is unlinearto hole size. The larger the hole size the smaller chance of failure. This is shown from the larger the hole size the smaller GFF value. It is because to reach big value of GFF at large hole, it must pass small size at the first place.Based on the calculation result, small hole of 0,1-0,25 inch is un-identified. Therefore, this supports the condition that failure chance at large hole size is almost rare since it only reaches 0,0000001failure every year.

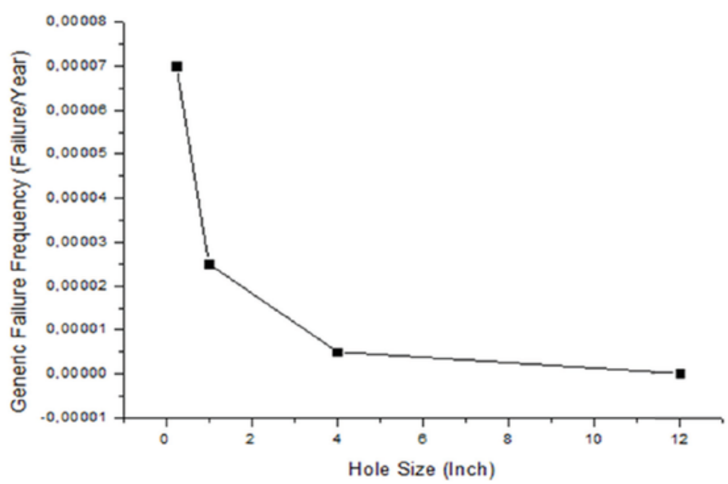

FIGURE 4. Hole size VS generic failure frequency

Based on the calculation above, Fig. 4 justifies the risk of every tank walls as follows; tank wall has 1D category which means Medium Risk.

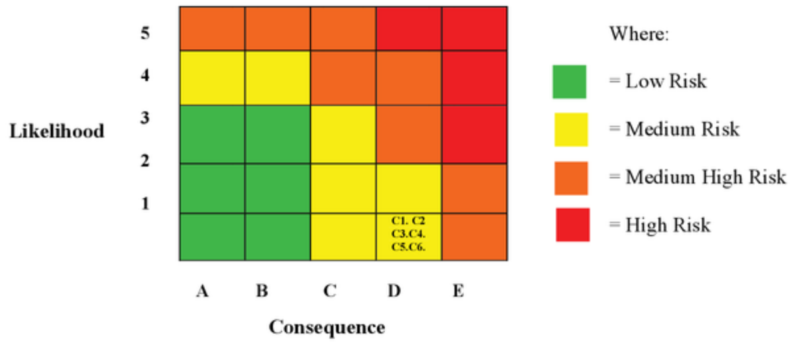

FIGURE 5. Risk ranking distribution

The final risk ranking is summarized in 5 x 5 matrixes that show Likelihood versus Consequence above in which the values are presented as categories. The courses flammable consequence and area on each hole size is shown in Table 5.

TABLE 5. Courses flammable consequence and area

Hole Size	Fraction Contribution	Unit	Area of Equipment Damage	Flammable Area
Small (1/4)	0.699301	ft^2	137.2232594	357.0558312
Medium (1)	0.249750	ft^2	1,911.356572	4,576.426736
Large (4)	0.049950	ft^2	48.14755221	167.436162
Rupture (12)	0.000999	ft^2	154,2846582	548.4540094

SUMMARIES AND CONCLUSIONS

The study has dealt with the Corrosion Risk Analysis and Risk Based Inspection (RBI) as applicable to high speed diesel atmospheric storage thanks equipment parts of the power plant. This was followed by a case study of an application of RBI for external corrosion of tank shells. The importance of the critical analysis within the RBI procedure, and the example of the specific case study has been investigated. Based on the existing inspection method, isolation system, mitigation system as well as the existing implemented management system at the power plant and according RBI analysis result, it is concluded that the evaluated atmospheric storage tank is in a medium risk category. Therefore it is recommended to adjust the existing inspection method, detection, isolation system and the implemented mitigation system at the power plant to reduce the risk which would potentially increase the safety of the equipment and environment.

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