R#sk analysis for pressure vessel with external corrosion using RBI method based on API 581

by Gunawan Dwi H

Rısk Analysis for Pressure Vessel with External Corrosion using RBI Method Based on API 581

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Abstract. Internal corrosion and external are the one major cause of accidents in liquid and natural gas in a pressure vessel. To lessen the vessel risk level, many companies have adopted and applied risk based inspection (RBI) methodology to risk reduction equipment, This study applied RBI methodology to optimize the inspection planing of the pressure vessel in power plant unit Jawa-Bali.In API 581, the risk situation for each type of equipment was classified into four levels: low risk level, medium-risk level, medium-high-risk level, and high level. This is expressed as a risk matrix. In this paper, semi-quantitative analysis method of risk-based inspection (RBI) was carried out for reducing the failure level of risk and optimized inspection plans, risk analysis of equipment failures resulting from corrosion need to be implemented. The result RBI analysis showed that pressure vessel has a medium high risk level and medium level. Failure mechanisms that occur in the pressure vessel is general thinning.

INTRODUCTION

The pressure vessel unit is the core equipment system in power plant that was used for this study. The hazards posed by the pressure system are a function of its available energy, pressure, volume, pressurized media characteristic, and system characteristics [1]. Based on jurisdictional requirements all pressure containing equipment must be inspected according to appropriate inspection code for ensuring its mechanical integrity for service [2]. With the need to periodically verify equipment integrity, organizations first resorted to time-based or calendar based intervals /due dates. Within inspection approaches, and understanding of the type and rate of deterioration, inspection intervals/due dates became more dependent on the equipment condition [3].As a pressure vessel ages, it can be affected by a range of corrosion mechanisms, which may lead to a reduction in its structural integrity and eventual failure. Clearly, Preventive maintenance is one method used to prevent it. However, with conventional preventive maintenance is carried out in which the inspection was based on the condition monitoring, they are static and not dynamic it will be a lot to pay for things that may not necessarily be any inspection or replacement [4].

The purpose of this unit is to store hydrogen gas. Hydrogen gas (H_2) is used as a cooling medium generator because it is much more effective than using air to cool generators, because H_2 has a thermal conductivity and heat transfer coefficient which is higher than the air. H_2 weakness explosive when mixed with air [5].This unit had been in service for 16 years.

Risk-based inspection method is an integrated methodology to prioritizing and managing the efforts of inspection activities on the basis of the actual risk [6-7]. The purpose of a RBI analysis is to focus inspection activities on those pieces of equipment where failure risks associated with an active damage mechanism are highest. In accordance with the API 581, the hazards were identified, and the magnitudes of hazards release were estimated for the pressure vessel unit. The main failure modes were determined, and the Likelihood of Failure (LOF) and the Consequence Of

The 3rd International Conference on Advanced Materials Science and Technology (ICAMST 2015)
AIP Conf. Proc. 1725, 020052-1–020052-6; doi: 10.1063/1.4945506
Published by AIP Publishing. 978-0-7354-1372-6/$30.00

Failure (COF) were calculated for each vessel. Finally, risk, value for each pressure vessel, item was defined by the risk matrix, and the inspection plan was developed [8]. In this study, Risk Analysis based on RBI Base-Resource Document used to analyze the external corrosion in pressure vessel in one power plant units in Indonesia.

METODOLOGY

Risk Based Inspection Method

A product of the likelihood of a failure and consequences is defined as the risk [9]. RBI is the process of identifying and quantifying the consequences and the likelihood of failures. The method applies both qualitative, quantitative and semi-quantitative. for prioritizing analysis and inspection activities [10]. An overview of RBI methodology is shown in Fig. 1.

Qualitative analysis can be implemented by using a simple workbook to audit the likelihood of failure as well as the consequence of failure. Quantitative risk analysis uses logical model to describe the combination of events that leads to serious accident, the process of the accident and the dangerous material in the propagation of the environment. Quantitative RBI program divides these consequences into four aspects: flammable or explosive events, toxic medium leaking, environmental risk and business interruption [11].

Semi-quantitative analysis takes account of the inspection results, such as corrosion rate, historical records, and maintenance information, and so on. Under certain circumstance, the method can alleviate the discrepancies in risk assessmentinduced by a person with subjective judgments.Semi-quantitative approach is a combination of the two previous approaches. Advantages of this approach is the speed of analysis, which is an excess of qualitative approach and thoroughness of analysis which is the excess of the quantitative approach.

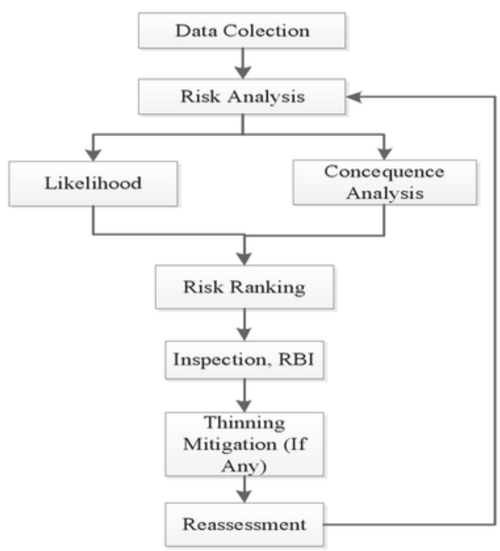

FIGURE1. Research structure of risk-based inspection

Risk Assesment

RBI method uses risk to assess the results of inspection, testing, and monitoring of a pressure vessel. Risk is defined as the product of the likelihood of a failure and consequence. So, based on this risk definition, the risk value of each pressure vessel in the RBI assessments can be calculated by the following equation:

$$Risk = LOF \times COF \quad (1)$$

In which LOF and COF are likelihood of failure and consequence of failure.

Data Colection and Identify Failure Mode

A semi-quantitative RBI analysis requires a complete description of the design of equipment, data material, records of inspection, repair and replacement, composition of the process fluid, inventory fluid, operating conditions, safety systems, detection system, the mechanism of the damage, level of damage, data coating, cladding and insulation.In this study, the failure modes of interest are those which develop over a period of time, gradually weakening the pressure boundary integrity of components until failure is predicted. According to the information obtained from the plant used for this study, standard industry process knowledge, and API581 [10], these failure modes include external corrosion and for the failure modes is general thinning.

Likelihood of Failure

The likelihood analysis is based on a generic database of failure frequencies by equipment types, These generic frequencies are then modified by two terns, the equipment modification factor (FE) and the management systems evaluation factor (FM), to yield an adjusted failure frequency, as follows:

$$F_{adjusted} = F_{generic} \times FE \times FM \quad (2)$$

The database of generic failure frequencies is based on a compilation of available records of equipment failure history. A detailed generic database is presented in API 581,see Table 1. Which is listed by different equipment types such as filters, pressure vessels, reactor, heat exchangers, piping, and so on. The equipment modification factor, or FE, is developed for each type of equipment, based on the specific environment in which the equipment operates. The FE is composed of four subfactors: the technical module subfactor, the universal subfactor, the mechanicalsubfactor, and the process subfactor. Among them the technical subfactor is the main factor.subfactor is the main factor [10].

TABLE 1. Generic failure frequensi for pressure vessel

	Small (0.25 in)	Medium (1 in)	Large (4 in)	Repture (16 in)
Pressure Vessel	4x10-5	1x10-4	1x10-5	6x10-6

To determine the damage factor (DF) from equipment using the limit state function, the DF is thinning. For demage factor thinning can be determined by A_{rt}, which is a function of time observed the use of equipment, corrosion rate, thickness actual, minimum thickness, corossion rate, service time, and corossion allowace.

$$A_{rt} = \max\left[\left(1 - \frac{t_{rd} - C_{r,bm} .age}{t_{min} + CA}\right), 0.0\right] \quad (3)$$

In which t_{rd} is thickness, $C_{r,bm}$ is corossion rate, t_{min} is minimum thickness, and CA is corossion allowace.

The management systems evaluation factor, or FM, adjusts for the influence of the facility's management system on the mechanical integrity of the plant. It consists of 101 questions with a maximum possible score of 1000. For the power plant industry considered for this study, the factual score is 900. From Fig. 8-5 of API581 [8]. The relationship between management system evaluation score and FM, FM can be determined.

Consequence of Failure

For calculating the consequence has to take into account the nature and amount of fluid released. The amount and rate of fluid released depend on factors such as the size of the hole, the fluid viscosity, and density and operating pressure seefigure 2. The rupture of a large diameter pressure vessel obviously has a different consequence than a hole look at a small diameter pressure vessel. API 581 assumes each equipment item the standard has four hole sizes: a hole type leak 1/4 in., a medium size hole 1 in, a large hole 4 in, and a rupture 16 in. The consequence of each type of failure is calculated and combined with the probability for that failure to calculate the overall risk associated with each equipment item.

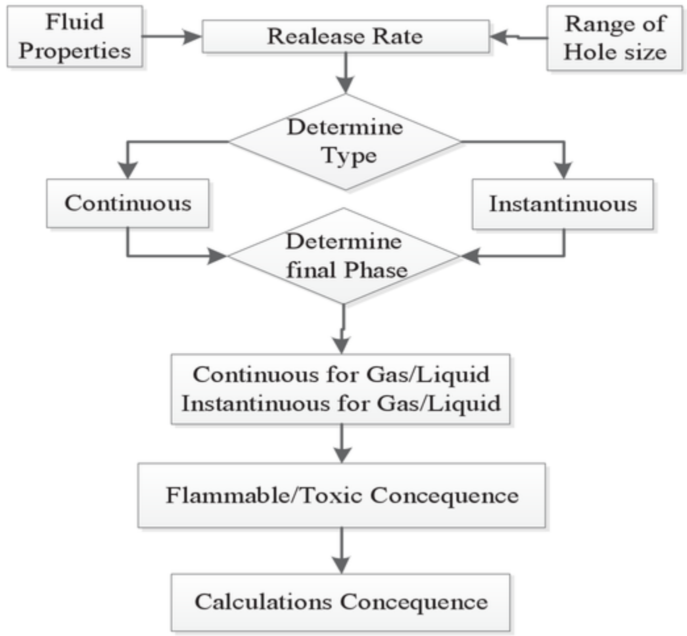

FIGURE 2. Consequence calculation

Risk Calculation

In this research API RBI methodology based on API 581 Semi-quantitative was used for risk assessment of pressure vessel equipment. The 5 x 5 matrix is used for presenting the risk. The location of each piece of equipment on the risk matrix can be determined based on the calculated LoF and CoF. A different area of the matrix is shaded to illustrate High level, Medium High level, Medium level, and Low level categories of Risk. [10]. The likelihood and Consequence categories can be determined using the guideline given in Table 2.

TABLE 2. Consequence category and likelihood category

Consequence Category		Likelihood Category	
COF	Range	LOF	Range
A	< 10 ft2	1	< 1
B	10 – 100 ft2	2	1 – 10
C	100 – 1,000 ft2	3	10 – 100
D	1,000 – 10,000 ft2	4	100 – 1,000
E	> 10,000 ft2	5	> 1,000

RESULTS AND DISCUSION

The calculation of risk in the Risk-Based Inspection methodology involves the determination of a likelihood of failure combined with the consequence of failure.In the semi-quantitative RBI calculation release rate, detection system, detection rating, isolation rating and leak duration on detection should be preceded.

Realease Rate Calculation

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 see Table 3.

TABLE 3. Leak duration, Liquid Discharge Rate and Type

Pressure vessel	Hole size	Leak Duration	Release Rate	Release Type	Phase Type
Head and Shell	0.25	0.0490625	0.050665132	9.119723714	Continuous
	1	0.785	0.810642108	145.9155794	Continuous
	4	12,56	12.97027373	2334.649271	Continuous
	16	200.96	207.5243796	37354.38833	Instantaneous

LikelihoodAnalysis

TABLE 4. Thinning damage factor

Pressure vessel	T_{rd} (in)	C_{rbm} (in)	Age (y)	T_{min} (in)	CA(in)	Art	LOF
Head	1,0157	0,0118	16	0,7414	0,2500	0,17	3
Shell	0,9291	0,0118	16	0,7650	0,2500	0,27	4

Consequence Analysis

TABLE 5. Result of consequence calculation

Hole size	Mitigation system (15%)		Flammable consequence area	
	Damagearea of head and shell	Fatalities area of head and shell	Flammable area of head and shell	Consequence area of head and shell
0,25	41.94	112.45	112.45	29.39
1	789.64	2116.74	2116.74	1383.49
4	12634.34	33867.97	33867.97	2213.59
16	32862.73	97913.75	97913.75	1919.36

Risk Calculation

The result of calculating LoF and CoF by the location of equipment can be determined on the risk matrix. A different area of the matrix is shaded to illustrate Medium High level is head of vessel with a likelihood factor greater than 100 Category 4 and Medium level is shell of vessel with a likelihood factor greater than 10 Category 3, consequence factor for head and shell greater than 1000 category D see Fig. 3.

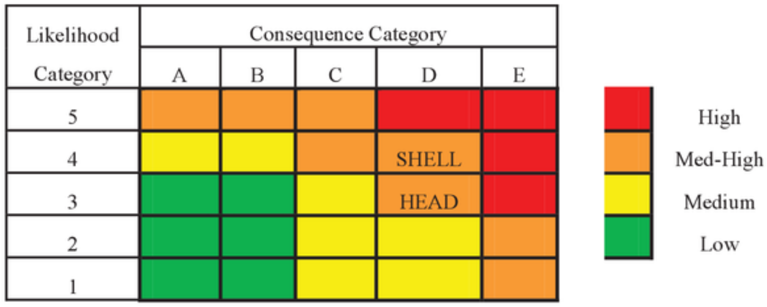

FIGURE 3. Risk matrix

SUMMARY

Based on the results of this study, concepts and application of RBI for pressure vessel in power plant clearly shows that for the pressure vessel has the prevailing modes of equipment failure is general thinning, This study also shows that the risk in head of vessel is medium high risk and shell of vessel is medium risk.RBI is a very effective method to assess the risk on critical items when the procedure is correctly implemented. The RBI method is a powerful method to increase the safety and reduce the inspection and maintenance costs of operating unit at the power plant.

ACKNOWLEDGMENT

The authors gratefully wish to acknowledge the great support provided by Indonesia Power, Reactor Unit in Semarang. The authors extend their sincere thanks to Reliability Evaluation Laboratory Management at Center of Research and Services, Diponegoro University, Republic of Indonesia and Strength of Material And Reliability Evaluation Laboratory, Pukyong National University, Busan, South Korea for the facilities all those who have supported and provided constructive feedback on the work.

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