Risk Analysis of Central Java Gas Transmission Pipeline by Risk-Based Inspection Method

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Abstract. During the operational period of gas transmission pipeline was found a potential hazard that could result in pipeline failure. As a consequence, the problem of the pipeline failure happening more and more. Economic and environmental factors, as well as human life, be considered to involve the current challenges as structural integrity and safety standards. Therefore, the reliability of structural integrity and security of gas pipelines under various conditions, including the existence of defects should be carefully evaluated. The results of this study were the steps for setting a Risk Level on any instrument using the Risk-Based Inspection API 581 standard and the subsequent results are recommended as an effective inspection planning by Risk Level and Remaining Life Time.

Keywords: Pipe, risk, risk level, risk-based inspection, remaining life time.

1. Introduction

Oil and gas sector is an activity that has the potential hazards of high risks, capital-intensive, high-tech, as well as requiring human resources with competence and specific qualifications. The activities in this sector should constantly be monitored so as not to cause significant harm, either to workers, the public, property or the environment [1].

Natural gas is a clean fuel that has been used by many countries as fuel for power generation. This trend makes the supply of natural gas will be increasingly in demand. One crucial thing is the distribution of natural gas transportation system. Duct piping is one method that is most practical and affordable that has been applied in oil and gas transportation system since 1950. The pipe has been used as one method that is most practical and needs the lowest cost for oil and gas transportation. Installations of pipes for oil and gas transmissions increased dramatically in the past three decades [2].

Pipe is a technology that is used to drain fluid such as oil, gas or water in large amounts and long distances by sea and specific regions. The pipeline is a silent mean of transport that serves to distribute the fluid in the form of liquid or gas [3] that is widely used to transmit fluids in oil and gas industry. Its use is quite diverse, among others, used to channel the fluid from the wells to the treatment plant or offshore building (offshore facility) or of offshore platforms built directly on the land (onshore facility) [4].
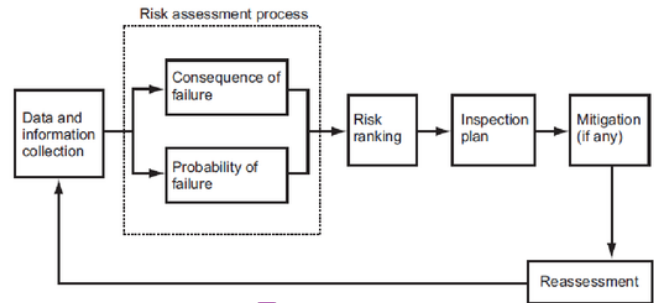
Figure 1. Risk-based inspection [5]

The Risk Based Inspection (RBI) is a practical way to assess the possible application of the inspection process and the impact that can occur on an instrument failure, evaluate the level of risk and recommend the type of action taken for the development of preventive measures and risk management. Risk Based Inspection (RBI) using a risk to plan and assist in the assessment of the results of the inspection, testing and monitoring [3]. The advantages of such RBI method are the increasing operational time and the work of a processing facility, which at the same time there is an increase or absence of treatment at the same risk level. The Concept of Risk Based Inspection can be seen in figure 1.

The results of this study are expected to be useful for damage prevention measures, especially in terms of materials and the development of material sciences in addition to the complete simulation data checks based on risk known as Risk Based Inspection (RBI).

2. Experimental Method

2.1 Corrosion

The piping system is a part of the most sensitive structural element of the power plant. Therefore, this system analysis and quantification of their vulnerability regarding failure probability are essential [4]. Corrosion is defined as damage to the material that results from their chemical reaction with the surrounding environment of the material. In the event of corrosion, metal would undergo oxidation, while the oxygen (air) is reduced. Metal rust is usually in the form of oxides or carbonates. The chemical formula of iron rust is $Fe_2O_3.nH_2O$, a brown-colored solid red. Corrosion is an electrochemical process. In the iron corrosion, certain sections of the metal act as the anode, where the metal undergoes oxidation.

$$Fe_{(s)} <=> Fe^{2+}_{(aq)} + 2e \qquad (1)$$

Electrons are released in the anode flow to other parts of the iron which act as the cathode, where oxygen is reduced [6].

$$O_{2(g)} + 4H^+_{(aq)} + 4e <=> 2H_2O_{(l)} \qquad (2)$$
$$O_{2(g)} + 2H_2O_{(l)} + 4e <=> 4OH^-_{(aq)} \qquad (3)$$

The corrosion rate is the propagation velocity or speed of decline in the quality of materials on time.

$$CR = \frac{d - d_0}{T - T_0} \qquad (4)$$

where CR, T, d_0, d, and T_0 respectively represent corrosion rate, year of first examination, initial thickness, examination thickness, and recent year of examination.

Table 1. The numerical values of probability and consequence categories

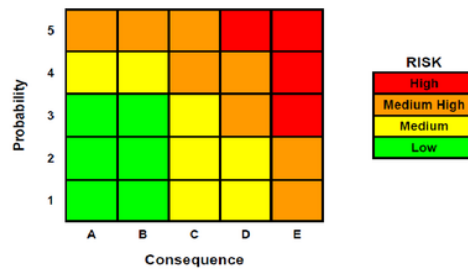| Category of probability		Category of consequence	
Categories	*Range*	Categories	*Range* (ft^2)
1	$Pf(t) \leq 2$	A	$CA \leq 100$
2	$2 < Pf(t) \leq 20$	B	$100 < CA \leq 1000$
3	$20 < Pf(t) \leq 100$	C	$1000 < CA \leq 3000$
4	$100 < Pf(t) \leq 1000$	D	$3000 < CA \leq 10000$
5	$Pf(t) > 1000$	E	$CA > 10000$

Figure 2. Risk matrix [5]

2.2 Risk

Risk is a possibility of an unwanted event that will affect an activity or object [7]. Mathematically, the definition of risk is as follows:

$$Risk = Probability \times Consequence \tag{5}$$

The reference in figure 2 can be used for determining the risk level. While the numerical values of probability and consequence categories can be shown in table 1.

2.3 Probability of failure

The probability of failure is a possibility of equipment or component to fail (API, 2008). Analysis of the occurrence of a failure in the component can be performed if they are currently in working conditions. The equation of the probability of failure in API RBI is given by the following equation [8]

$$P_f(t) = g_{ff} \times D_f(t) \tag{6}$$

where $P_f(t)$, g_{ff}, and $D_f(t)$ respectively represent probability of failure, generic failure frequency, and damaging factor.

2.4 Consequences of failure

The consequences of failure are the impacts that can be caused by an equipment failure. The semi-quantitative RBI API calculation involves only consequences of flammability and toxicity [9].

2.5. Remaining lifetime

Remaining lifetime can be defined as equipment tolerance to the type of damage. Remaining lifetime will determine the next inspection interval of time [10].
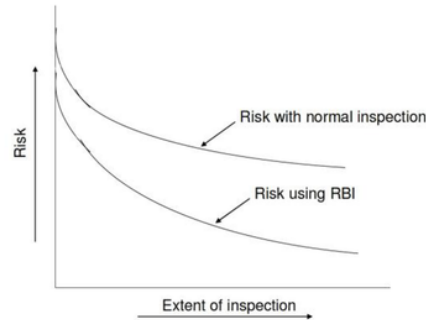
Figure 3. Management of *Risk Based Inspection* [*10*]

$$Remaining\ Life\ Time = \frac{d_0 - d_R}{CR} \tag{7}$$

where d_0, CR, and d_R respectively represent current actual thickness, corrosion rate, and required thickness.

2.6 Risk-Based Inspection
Risk Based Inspection (RBI) is a relatively new method of conducting an inspection. This method is based on a risk analysis which includes the analysis of the magnitude of the possibility of a failure and the magnitude of the effects of emerging risks [5]. In general, the RBI management can be seen in figure 3.

3. Results and Discussion

3.1 Data
The data of inspected equipment are shown in Table 2.

Table 2. Data of equipment

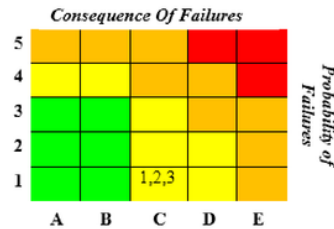| Component	Process Data			
	P. Design (psig)	P. Operation (psig)	T. Design (°F)	T.operation (°F)
Line pipe (inlet KP.20 Ø20")	900	450	650	250
Tee (inlet KP.20 Ø20")	900	450	650	250
Line pipe (outlet KP.20 Ø20")	900	450	650	250

Figure 4. Matrix risk

Note: (1) *Inlet Automatic Shutdown valve KP-20 Ø20"*, (2) *Tee KP-20 Ø20"*, and (3) *Outlet Automatic Shutdown Valve KP-20 Ø20"*.

3.2 Risk level

The risk level in three components can be seen in the Risk Matrix as presented in figure 4. From the risk matrix, we can know that the level of risk of all the three components is medium with the overall value of 1819.654 ft^2. The consequences of failure and the value of the probability of failure were 1.

3.3 Remaining lifetime

The data of the remaining lifetime of each component can be seen on the graph to make it easier to set priorities for the next inspection as illustrated in Figures 5, 6, and 7. From the graph of Remaining LifeTime Gas Pipe Straight (Automatic Shutdown Valve Inlet KP-20 Ø20"), we can know that the pipeline would fail in the years between 2025 to 2026 which was marked by an actual pipe with thickness values that approached the minimum thickness of the pipeline design.
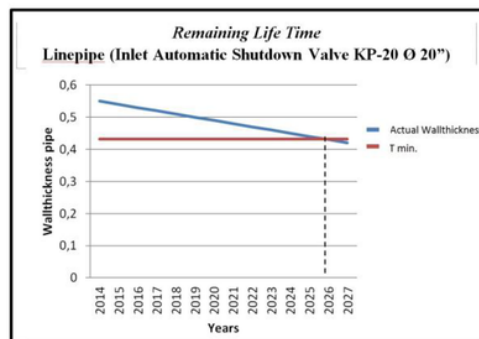

Figure 5. Graph of Remaining LifeTime in pipeline (Inlet Automatic Shutdown Valve type KP-20 Ø20")
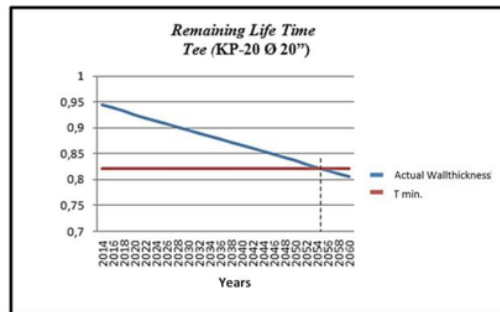

Figure 6. Graph of Remaining LifeTime in Tee (KP-20 Ø20")

From the graph of remaining lifetime connection Tee (KP-20 Ø20"), we can find that the pipeline would fail in the years between 2054 and 2055 was, which was marked by actual pipe thickness values that approached the minimum thickness of the pipeline design.

In the graph of Remaining LifeTime Gas Pipe Straight (Outlet Automatic Shutdown Valve) KP-20 Ø20", we can know that the pipeline would fail in the years between 2030 and 2031, which were marked by the actual pipe thickness values that approached the minimum thickness of the pipeline design.
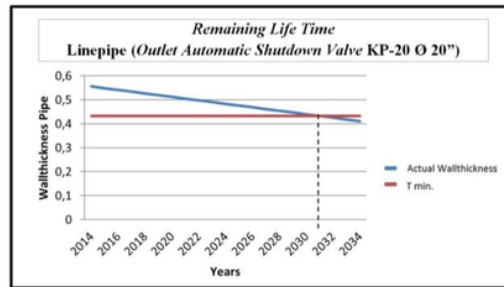
Figure 7. Graph Remaining LifeTime in pipeline (Outlet Automatic Shutdown Valve) KP-20 Ø20."

3.4 Risk-Based Inspection

Inspection planning recommendations for each component based on Table 3 and Table 4, namely:

Table 3. Static Equipment Integrity Inspection of RBI

Risk Level	Type of Inspection
High	Internal Entry
	External NDT
Medium	Internal Entry
	External NDT
	Limited Internal Inspections
Low	Internal Entry
	External NDT
	Limited Internal Inspections

Table 4. Test Results for the Type of Failure in Critical Levels

Probability of Failure	Consequences of Failure	Inspection Method	Inspection Frequency (Month)	Wide Inspection Area
High	High	Ultrasonic Testing	12	Full
High	Medium	Ultrasonic Testing	12	Partial
High	Low	Ultrasonic Testing	12	Small
Medium	High	Ultrasonic Testing	12	Full
Medium	Medium	Ultrasonic Testing	12	Partial
Medium	Low	Ultrasonic Testing	12	Small
Low	High	Ultrasonic Testing	12	Full
Low	Medium	Ultrasonic Testing	12	Partial
Low	Low	Ultrasonic Testing	12	Small

From Tables 3 and 4, it can be recommended:

	Pipeline (Inlet SDV KP-20 Ø20")	Tee (KP-20 Ø20")	Pipeline (Outlet SDV KP-20 Ø20")
Frequency	every 36 months	every 36 months	every 36 months
Inspection Method	External NDT	External NDT	External NDT
Next Inspection	before the year 2020	before the year 2035	before the year 2023

4. Conclusion

Based on the Level Risk analysis, it can be seen that all components have a medium risk level (1C) with an overall value of 1819.654 ft^2. The consequences of failure and the value of the probability of failure was 1. The most critical component is the Straight Gas Pipeline (Automatic Shutdown Valve Inlet KP-20 Ø20") with the Remaining LifeTime of 9.8 years, as a result of the magnitude of corrosion rate on these components. The prioritizations of API 581 Risk-Based Inspection are the Gas Pipe Straight (Inlet Automatic Shutdown Valve KP-20 Ø20") that will be inspected in 2020 by the NDT inspection method, Gas Pipe Straight (Outlet Automatic Shutdown Valve KP-20 Ø20") that will be inspected in 2023 by NDT inspection methods and lastly Connection Tee (KP-20 Ø20") that will be inspected in 2035 via NDT inspection methods. It is concluded that RBI is an efficient method to assess risk and target inspection resources on critical items. When correctly implemented, the RBI approach is a powerful mean for increasing the safety and reducing the inspection and maintenance costs of process plant equipment.

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