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New approach for risk based inspection of H_2S based Process Plants

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ABSTRACT

Recent trend in risk informed and risk based approaches in life management issues have certainly put the focus on developing estimation methods for real risk. Idea of employing risk as an optimising measure for in-service inspection, termed as risk based inspection, was accepted in principle from late 80s. While applying risk based inspection, consequence of failure from each component needs to be assessed. Consequence evaluation in a Process Plant is a crucial task. It may be noted that, in general, the number of components to be considered for life management is very large and hence the consequence evaluation resulting from their failures (individually) is a laborious task. Screening of critical components is usually carried out using simplified qualitative approach, which primarily uses influence factors for categorisation. This necessitates logical formulation of influence factors and their ranges with a suitable technical basis for acceptance from regulators. This paper describes application of risk based inspection for H_2S based Process Plant along with the approach devised for handling the influence factor related to the quantity of H_2S released.

1. Introduction

1.1. Background

Deterioration of structures, systems and components in Process Plants has raised the concerns over their ability to with stand operational, environmental and accidental conditions. To protect the public, financial investment and environment from accidents, it is essential to have an ageing management programme for achieving safety in operation. In formulating the life management programme priorities have to be assigned based on operating experience on ageing and premature failures. An effective life management programme depends on the ability to detect degradation and initiate mitigating measures for maintaining functional capability without compromising safety margins as per design. Existing information on deterministic analysis/risk analysis and engineering judgment etc. can aid in prioritization process in life management programme according to safety significance.

Last decade saw a trend where life management programmes are globally moving from prescriptive/time-based towards *risk based decision making*. Risk analysis finds use/application in decision making, for operation, maintenance and regulatory activities. This methodology has been applied in planning maintenance activities such as testing time, repair time, inspection interval etc. When this is applied to inspection planning, it is termed as Risk based inspection. Risk Based Inspection (RBI) is a method for using risk as a basis for prioritizing and managing the efforts in an inspection program. Risk based inspection focuses the utilization of risk quantification in formulating an In-Service Inspection (ISI) plan thereby emphasizing the importance of surveillance and maintenance activities on plant risk. RBI would be able to establish an effective structural integrity management programme, which reduces plant down time, industry and regulatory burdens, and continue to maintain plant safety.

1.2. Objective

Existing in-service inspection programme of H_2S based Process Plant is based on ASME Section XI guidelines. H_2S is highly toxic and inflammable gas. Accidental release of even a small amount of H_2S has enormous consequences on plant personnel and public in the plant vicinity apart from production loss, repair and maintenance costs. With this in view, extensive ISI is carried out on all toxic element-carrying components. This often results in carrying out excessive inspection or ineffective inspection being carried out on some components carrying toxic gas. Risk prioritization of these components enables to determine the optimum level of inspection or inspection effectiveness required to maintain the risk at its present level as the component ages. Various standards have emerged for providing guidelines on applying risk based inspection such as API 581 (1998), ASME (2003), and CWA (2008).

Traditionally API 581 is considered as guideline for applying H_2S based Process Plants. API 581 describes three approaches for risk based inspection: (1) qualitative (for screening), (2) semi-qualitative and (3) quantitative analysis (detailed analysis). Since

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RBI looks into each and every component in a plant for categorisation, qualitative approach is an important step for screening out non-critical components. While applying risk based inspection using qualitative approach of API 581 for H_2S based Process Plant, certain limitations were observed in consequence estimation. This paper describes the experience on applying risk based inspection on H_2S based Process Plant and approach adopted to circumvent the shortcoming.

2. Risk based inspection in H_2S based Process Plant

Risk is defined as "the likelihood of a specified undesirable event occurring within a specified period or in specified circumstances."

$$Risk = \sum_{accident\ scenario} \text{likelihood of undesirable event its consequence}$$

For applying the framework of risk based inspection, it is required to estimate *likelihood of failure* of components in Process Plant and their *consequence,* in terms of damage to the equipment and impact of toxic release to public.

RBI uses the risk to plan, justify and aid in the assessments of results from inspection, testing and monitoring. RBI is the process of identifying and quantifying the consequences and the probability of failures. The method applies both qualitative and quantitative approaches to prioritizing first analysis efforts and then inspection activities. The primary difference between the qualitative and quantitative approach is the level of resolution. The qualitative procedure requires less detailed information about the facility and as a result, its ability to discriminate is much more limited. The qualitative technique would normally be used to screen components for detailed quantitative RBI studies. API 581 provides *influence factors* in quantifying likelihood and consequence in qualitative approach. Typically, expert judgment is used in selecting the values of influence factors for various ranges.

In this study, semi-qualitative approach is followed, wherein likelihood is ranked using the quantitative (assessed using quantified from operating experience data and structural reliability techniques) and consequence is ranked using the qualitative (influence factor approach).

2.1. Estimation of likelihood of failure of components

In this study, estimation of likelihood of failure of components was carried out using two approaches:

(i) Statistical modelling for equipments such as towers, heat exchangers, etc.

Estimation of failure probability of equipment (PoF) is an important step. Eventhough use of generic information is suggested at the design stage, due to the absence of instances of failure in operating period, it is used for estimating failure probability of piping equipment in operating plants. Data bases such as OREDA (2002) are the result of various collaborative efforts taken towards methodical collection of operating experience information, which can be termed as generic data base. Service Data Analysis based on operating experience is one of the popularly employed methods used for this purpose.

When sufficient operating experience is available, these generic estimates can be updated with the plant experience to arrive at plant specific estimates for equipment failure probability. To update the generic information with plant experience, Baye's theorem is used, which facilitates integrating different sources of data. The general form of Baye's theorem is written as (Siu and Kelly, 1998):

$$f(\lambda_i \mid E) = \frac{L(E/\lambda_i)f(\lambda_i)}{\sum_i L(E/\lambda_i)f(\lambda_i)} \tag{1}$$

where $f(\lambda_i|E)$ is the probability of λ_i, given evidence E, (posterior distribution); $f(\lambda_i)$ the probability of λ_i, prior to having evidence E, (prior distribution); $L(E|\lambda_i)$ is the probability of the evidence E, given λ_i, (likelihood function).

Likelihood function denotes the plant operating experience and prior denotes the generic data base. Typically, Log normal distribution is considered for generic data and Poisson distribution is considered for likelihood function. Using these techniques, PoF of equipments were estimated.

(ii) Remaining life model for pipelines.

Corrosion being a predominant degradation mechanism in H_2S based Process Plant, ANSI/ASME B31G model (Caleyo et al., 2000; Santosh et al., 2006), has been used to estimate the remaining strength of pipeline containing corrosion defects. All the failure pressure models are concerned with the estimation of remaining strength but not the failure probability of pipelines containing corrosion defects. For this purpose, reliability analyses were required to assess the remaining life of corroded pipelines with further corrosion growth. First Order Reliability Method (FORM) has been used for reliability analysis of pipelines. The main assumption of the reliability analyses for the corroded pipelines is the randomness of the load and resistance parameters determining the limit state function (LSF). The LSF or performance function is defined for this mode of failure as the difference between the pipeline failure pressure P_{fp} and the pipeline operating pressure P_{op}, i.e.

$$\text{LSF}(P_{fp}, P_{op}) = P_{fp} - P_{op} \tag{2}$$

In this study, the modified B31G model is employed to estimate the pipeline failure pressure.

$$\text{LSF}(P_{fp}, P_{op}) = \frac{2(Y_s + 68.95)t}{D}\left(\frac{1 - \frac{(d_0 + R_d(T - T_0))}{t}}{1 - \frac{(d_0 + R_d(T - T_0))}{(tM)}}\right) - P_{op} \tag{3}$$

The folias factor, M is dependent on defect length, L, pipe diameter, D and pipe wall thickness, t. P_{op} is the operating pressure. R_d is the radial corrosion rate T_0 is the time of last inspection. T_s is the pipeline elapsed time Y_s is the yield strength of the pipe material. Various parameters for failure pressure model were also fixed based on research studies and analysis. These factors were discussed in detail before finalisation. Details of this model can be found from (Caleyo et al., 2000; Santosh et al., 2006).

Categorisation of failure probabilities with respect to level of severity is required for applying RBI. Typical categorisation framed for all type of components is shown in Table 1, based on consensus of expert from regulator, utility and analysts' end.

Table 1
Probability of failure categories.

Probability of failure (PoF) value	Category	
1e−4 to 1.0	5	Very high
1e−5 to 1e−4	4	High
1e−6 to 1e−5	3	Medium
1e−8 to 1e−6	2	Low
<1e−8	1	Very low