Risk-Based Maintenance (RBM) Approach for Identifying the Optimum Time of Whole Shutdown (SD) for Gas Liquid Recovery Unit; Processing Columns as a Case Study

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ABSTRACT

Pieces of equipment for any a processing unit, which run continuously under severe conditions usually exposed to undesirable failures such as a corrosion, leakage and other reasons due to over pressure and fluctuated temperatures. These failures could be resulted in huge risk of the unit. Therefore, these pieces of equipment should be subjected to risk-based maintenance approach in order to conduct planned shutdown event without taking the recommended periods of the original equipment manufacturers into account, which may not be represented the optimum solution of planned shutdown scheduling in the long-term due to operating conditions that differ from a unit to another. The purpose of this work is to determine optimum interval of planned shutdown for unit based on processing columns to avoid an unplanned estimation of shutdown, mitigate risk, extend critical equipment life, maximise uptime, decrease maintenance cost, reduce production losses and improve reliability of system. The results of risk-based maintenance application in gas liquid recovery unit demonstrated that interval of planned shutdown could be increased based on the risk assessment related to processing columns.

Keywords: Planned Shutdown (SD), Risk-Based Maintenance (RBM), Failure Analysis, and processing columns.

1 Introduction

Static equipment pieces in Gas Liquid Recovery Unit (GLRU) consider a complex in terms of process, operation and maintenance, especially which run continuously under severe operating conditions. Processing columns is a part of equipment that can be tended to deteriorate over time due to aging, corrosion, fatigue and fluctuating temperatures and pressures. Therefore, unit these pieces cannot be maintained or inspected during the normal operation of a unit unless facilities of unit are total shutdown to execute Planned Shutdown (SD) activities: inspections, modifications, installations, replacements and repairs [1]. Duffuaa and Ben Daya [2] defined also SD as an entire shutdown of the unit during a certain time period to carry out SD activities associated with inspection, repair, overhaul, modification, and replacement in accordance with Scope of Work (CWo).

Ghosh and Rao [3] proposed optimisation of the maintenance intervals using the reliability based on cost/benefit ratio. Megow et al. [4] stated that the SD interval of a large unit can be repeated more than one year. Rusin and Wojaczek [5] presented optimizing maintenance intervals of power machines by taking the risk into account. Obiajunwa [6] reported that interval of SD for petrochemical and refinery plant conducted every two years and power plant executed every four years. Hameed and Khan [7] also presented a framework to estimate the risk-based shutdown interval to extend intervals between shutdowns for a processing unit. Swart [8] reported that historically, intervals of SD identified without any real strategy associated with operating process. Swart [8] stated that the estimation of the SD interval is either indiscriminate or has become as a redundant.

The constant identification of SD interval means that SD activity was not based on the residual life of the equipment that can increase risk due to fixed-interval. Consequently, this study is designed to estimate SD interval of a processing unit based on the processing columns, while ensuring that the overall cost is kept to a minimum. RBM provides an efficient way to select the most critical processing columns based on the RBM approach to manage assets in comparison to the individual equipment strategy and achieve better results with less operating expenses.

2 Risk-Based Maintenance (RBM) of Processing Columns

Processing columns comprise seven columns that can be classified into C-701 to C-707. These columns are spread across many units of gas plant (Gas Liquid Recovery Unit, Gas Treating Unit, Gas Drying Unit, Cryogenic Column and Fractionation Unit).

The GLRU experts demonstrated that most of inspected columns that were exposed corrosion due to fluctuating feed temperatures resulting from errors in the operating process and sometimes specification of natural gas.

According to the failures records of seven columns in the GLRU, it was found many trays and caps in these columns, which were prone to corrosion due to the presence of water vapour in natural gas resulting from fluctuated temperatures as shown in Figure.1. These can be resulted to a lot of consequences:

- Reduce the ability of gas to flow in the flowlines and process systems.
- Water vapour causes corrosion in trays parts.
- At low temperature, water vapour forms hydrates - complicated molecules of hydrocarbon liquid and water, causing blockage of lines.

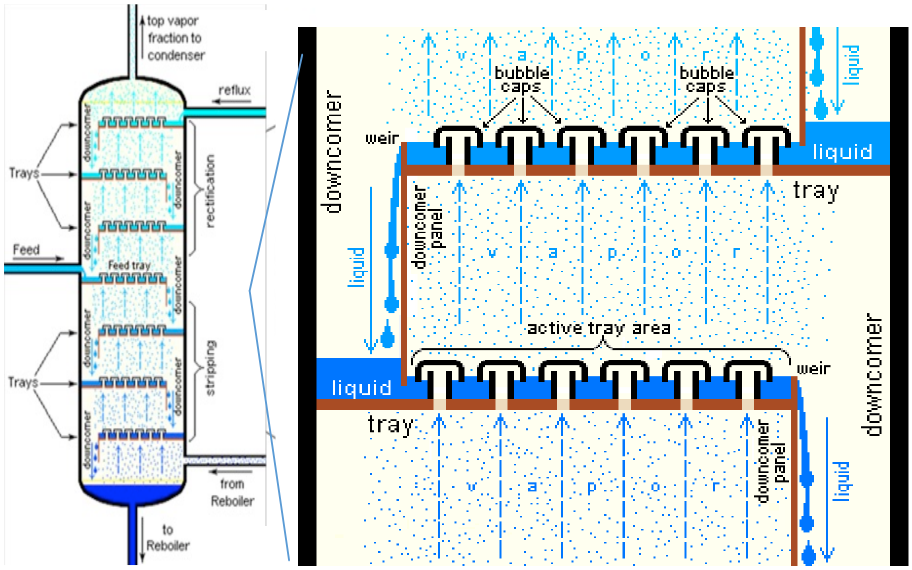


Figure 1: The prone trays to failure in GLRU columns

These parts are one of the outstanding challenging problems in the natural gas industries caused by complex operating conditions that constitute the highest risk. Therefore, it is necessary to highlight the RBM approach to mitigate consequences on the functional performance of the unit resulting from over pressure and fluctuating temperatures. RBM approach has played an important role in the decision-making process due to complex processes that required a higher reliability of their facilities [9].

The proposed risk analysis matrix is applied according to RBM approach to identify the most critical pieces of processing columns that represent the highest risk on the unit facilities. These critical pieces of processing columns of a unit can be distributed the risks' matrix (5 x 5) according to Probability of Failure (PoF) and Consequences of Failure (CoF) on GLRU in terms of Environment Damage (ED), Production Losses (PL) and Asset Damage (AD). The estimated risk of system can be identified by using Equations (1) and (2), below:

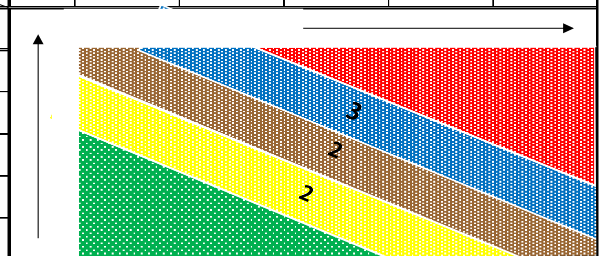
$$\text{Estimated Risk} = \text{Probability of Failure} \times \sum \text{Economic Consequence of Failure} \tag{1}$$

$$ER = \left[\, 1 - \prod_{i=1}^{n} Ri(t) \,\right] \times \left[\, \sum CoF_{\,ED+} CoF_{\,PL+} CoF_{\,AD} \,\right] \tag{2}$$

This paper focuses on seven pieces of columns located in GLRU. Those columns distribute on the risk matrix (5x5) to estimate risk ranking as shown in Figure 2. Two of seven columns are rated in the low risk zone, two pieces of columns are classified in the moderate risk zone and three columns (C-706 and C-707A/B) are rated in the high risk zone.

Consequnces / Likelihood	ED	No effect	Minor	Moderate	Major	Massive
	PL	Less 20 %	20 – 40 %	40 - 60 %	60 - 80 %	More 80 %
	AD	Very Low	Low	Moderate	High	Very High
	COF	**1**	**2**	**3**	**4**	**5**

Failure Level	**Range / Mth**	**P(t)**	**POF**
Frequent	t > 160 (Mths)	1	**5**
Likely	120 < t ≤ 160	0.7	**4**
Possible	80 < t ≤ 120	0.5	**3**
Unlikely	40< t ≤ 80	0.2	**2**
Rare	≤ 40	0.1	**1**



Key for Ranking						
	Risk Ranking	R ≤ 3	3 < R ≤ 6	6 < R ≤ 9	9 < R ≤12	R > 12
	Risk Catogery	V. Low	Low	Moderate	High	V. High
	Risk Level					

Figure 2: Risk matrix for seven processing columns

As a result, four pieces were rated in the low and moderate risk zone respectively, two pieces of columns are classified in the moderate risk zone. These columns are not required SD and must be excluded from the current SD. However, these pieces should be taken into account in the next cycle of SD according to priorities. Three of seven columns were classified in the high risk zone. These items must be involved to a scheduled SD to be determined the reliability and unreliability function using the appropriate probability distributions.

3 Failure Analysis

This case is designed to focus on the outcome of risk matrix (the located in the high risk zone – blue area). Three of seven pieces of columns that were classified in the high risk zone. Based on the shape parameter (β) for each one, it was found that the Weibull model was the most appropriate in the estimate of Probability of Failure F(t) due to its inherent flexibility of modelling the behaviour for other distributions.

3.1 The Weibull Distribution

The Weibull distribution can mimic the behaviour of other distributions, such as normal for ($\beta = 3.5$) and exponential for ($\beta = 1$) distributions. A decreasing failure rate ($\beta < 1$) corresponds to an early life failure or infant mortality.

A constant failure rate ($\beta = 1$) suggests that units are failing from random events. An increasing failure rate ($\beta > 1$) suggests that wear out is occurring and that parts are more likely to fail over time [3]. The shape parameter β estimated by the failure data provides an insight into the failure processes of unit. This includes reliable operation for certain durations and when the device enters into the wear out zone. All SD activities are based on this assumption so that action can be taken before any failures occur. It is necessary to express the probability of failure for unit as a function of time for RBM interval estimation. In this work, the Weibull model with the parameters β and η is used to model the time dependent reliability of the static equipment involved in the unit. Ebeling [10] stated that the reliability of unit following the Weibull distribution is defined as:

$$Ri(t) = \left[e^{-\left(\frac{t}{\eta}\right)^{\beta_1}}\right] \times \left[e^{-\left(\frac{t}{\eta}\right)^{\beta_2}}\right] \times \left[e^{-\left(\frac{t}{\eta}\right)^{\beta_3}}\right] \tag{3}$$

$$F(t) = 1 - \prod_{i=1}^{n} Ri(t) \tag{4}$$

3.2 The Reliability Block Diagram (RBD)

The RBD of three pieces C-706 and C-707A/B of GLRU are connected with each other as series configuration as shown in Figure 3.

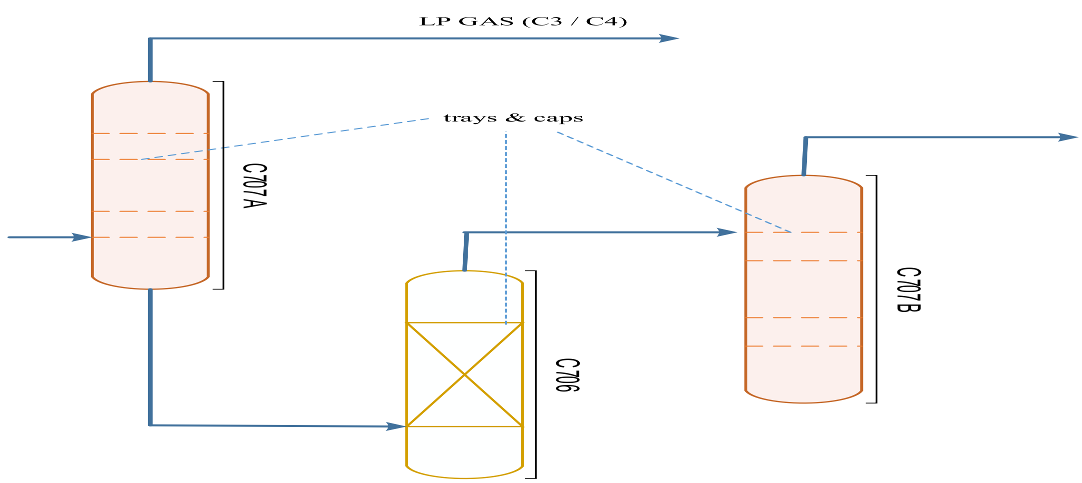


Figure 3: *RBD for selected columns of Gas Liquid Recovery Unit (GLRU)*

The Weibull distribution is used for modelling the SD scheduling of Splitter Column C-706A/B and two Debutanizer Column C-707 A/B columns based on shape and scale parameters as shown in Table 1.

Table 1:. *Shape and scale parameters of C-706 and C-707 A/B*

Equipment Code	C-706	C-707A	C-707B
Shape Parameter β	5.80	5.6	5.5
Scale Parameter η (hr)	83430	95880	97335

4 Results and Discussions

Based on a tolerable risk that is adopted based on expert judgment of safety criteria of GLRU, the estimated risk of C-706 and C-707 A/B associated with melting trays and caps, and disappearing bolts due to overpressure and increase feed temperatures (fluctuating temperatures). Table 2 shows that an estimated risk is consistent with a tolerable risk at 81000 operational hour and 47.4% of F(t) according to the following constraint as shown in Figure 4:

Estimated Risk (ER) ≤ Tolerable Risk (TR) (5)

$250\$/h \leq ER \leq 500\$/h$

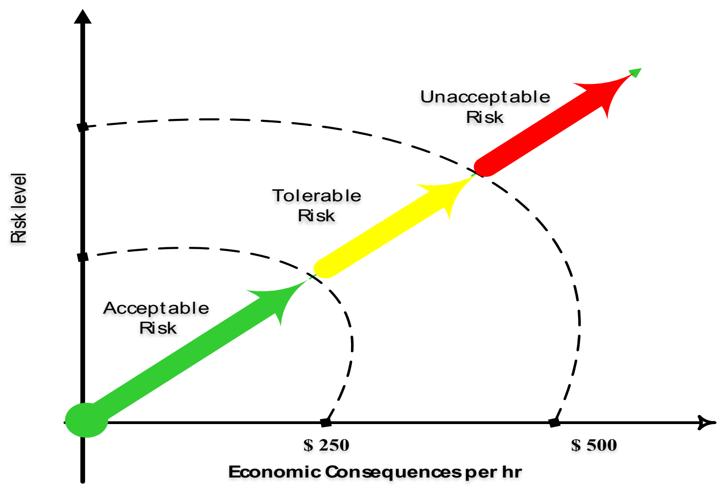


Figure 4. *Tolerable risk of GLRU*

$$ER = F(t) \times \sum [PL(\$) + AD(\$) + ED(\$)] \quad (6)$$

ER = [0.474)] x [$85,420,000] = 500%/hr

Table 2: *Scenario of R(t), F(t), and ER results of C-706 and C-707A/B*

SD (hr)	50000	60000	70000	75000	81000	85000	90000	95000	100000
R(t)	0.795	0.713	0.625	0.565	0.526	0.438	0.371	0.250	0.185
F(t)	0.205	0.287	0.375	0.435	0.474	0.562	0.629	0.750	0.815
ER	350.25	408.6	457.6	495.5	500	564.77	597	674.3	696

Based on processing columns for GLRU, the ER is achieved 500 $/hr at 81000hrs. This means that ER can be acceptable with comparing to the assumed TR. Therefore, 81000 hours has become an indicator to start whole SD of plant and to execute maintenance events representing an inspection, repairs, modifications and improvement for critical equipment pieces that cannot be maintained during the normal operation of plant and to avoid an unexpected risk, which may be occurred in the plant assets, environment damage and production losses resulting from melting trays and caps, and disappearing bolts due to overpressure and increase feed temperatures. However, implementation of SD event is a feasible means to avoid these consequences, which justifies the widespread adoption of SD in real maintenance of processing columns. This means that, it is prudent to make total shutdown of the plant every nine years and three months based on the most critical processing columns.

5 Conclusions

The purpose of the work was to identify the optimum time of SD (operational period) at GLRU that worked under fluctuated temperatures and pressures. The goal was increased interval between SDs periods to increase reliability, availability and reduce production losses and maintenance cost. To address this concern RBM approach was applied as a new techniques to identify the most critical equipment in GLRU.

All of approximately sixteen pieces of processing columns were identified and distributed on the risk (5x5) matrix. Two out of seven pieces were selected as the most critical columns in the GLRU based on PoF and CoF.

The proposed RBM was generated well-maintained and well-regulated for critical equipment pieces at less hazardous agents. Therefore, this approach could be implemented in any an industrial environment run continuously under severe operational conditions, however, proper attention must be identified according to the most critical pieces of equipment which cannot be inspected or maintained during the normal operation of a plant.

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