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REPLACEMENT ANALYSIS OF AMINE CIRCULATION PUMPS

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ABSTRACT

The paper highlight the study on replacement analysis of amine circulation pumps installed at a gas processing complex. The pumps were commissioned in 1998. Analysis on operation and maintenance costs as well as price of noncompliance (PONC) during the last three years indicated increasing trends for both costs. Since the pumps are more than sixteen years old the increasing trends of both costs are expected. It is then appropriate to consider a replacement for the pumps. The study on replacement was undertaken. Marginal cost (MC) and equivalent uniform annual cost (EUAC) were used to analyse the old pumps (defenders) and the new pumps (challengers) respectively. The MC of the defenders was then compared with the EUAC of the challengers. Results from the analysis indicate the MC of defenders are very much higher than EUAC of the challengers even for the year 2015. Thus it is recommended the defenders to be replaced with the challengers. Sensitivity analysis on the challengers indicates that the energy cost has the greatest influence on the present worth of the challengers.

Keywords: pumps, replacement analysis, defender, challenger, marginal cost, equivalent uniform annual cost.

INTRODUCTION

This study is related to replacement analysis of ten units of amine circulation pumps. The pumps are installed at a gas processing complex and are used to pump amine solution at the plant as shown in Figure-1. The pumps are driven by steam turbines and hydraulic power recovery turbines (HPRT) as shown in Figure-2.

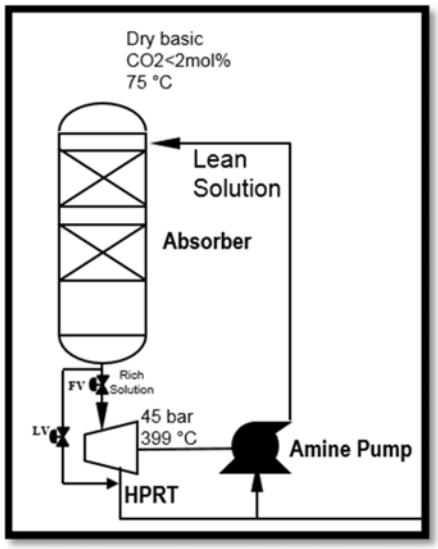

Figure-1. Simplified amine circulation pump process flow.

The pumps were installed in 1996 and commissioned in 1998. Various problems have occurred leading to low reliability and availability of the pumps. Many studies have been carried-out by internal party and consultants during project stage as well as in operations to improve the reliability and availability of the pumps.

There are a numbers of improvements that have been made for the sustainability of the operations of the pumps. Among the significant improvements are:

1. Minimum flow line installation.
2. Pump impellers upgrade.
3. Mechanical seals upgrade.
4. 3rd bearings installation.

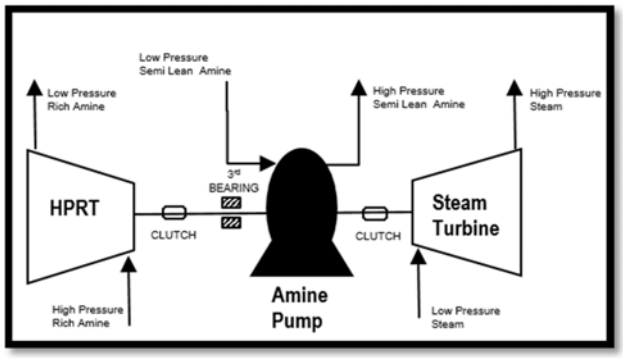

Figure-2. Amine pump train configuration.

Since commissioned, there are several issues associated to the pumps, steam turbines and HPRTs. Among the issues are:

1. Pump impellers 1st stage erosion
2. Mechanical seals failures for both pumps and HPRTs
3. Lube oil leaked through oil seals
4. Check Valve failures (passing) causing reverse rotation of the pumps.
5. Flow Control Valve (FCV) failures to regulate during start-up.
6. No Filling Line after maintenance work.
7. Governor valves failure to control the flow.
8. Piping routing and support for the pumps not meeting the requirements of API-610 (2010).

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The above problems affect the operations of the pumps. Study on the operations and maintenance as well as the price of noncompliance (PONC) during the last three years as shown in Table-1, indicate increasing trends for both of these costs, even though preventive maintenance measures had been undertaken. Since the pumps are more than 16 years old the symptoms are understandable. As such the pumps should be considered for replacement. The study on replacement analysis is then required. This study was undertaken in line with this requirement.

Table-1. The O and M and PONC of the defenders for years 2011, 2012 and 2013.

year	O and M (RM mil)	PONC (RM mil)
2011	1.51	4.42
2012	2.26	3.62
2013	3.30	16.75

REPLACEMENT ANALYSIS

Sullivan *et al*. (2009) underlined three main reasons on requirements for assets replacement. The reasons are: deterioration, altered requirements and technological changes. Based on analysed data for the pumps, it is apparent that the increasing O and M and PONC are due to deterioration. Hence replacement study of the pumps needs to be looked into. Sullivan *et al*. (2009) have identified that engineering studies on replacement are performed involving two or three alternatives. Similar observations are highlighted in other literatures on equipment replacement studies such as Blank *et al.* (2008) and Riggs *et al.* (1998). Life cycle costing (LCC) has also been used for evaluating assets. The approach is explained in details by IEC (2004-07). Other examples on using LCC for evaluating equipments are done by DOE/GO-102001-1190 (2001), Dhillon (2010) and F. W. Hennecke (1999). LCC models are also recommended for selection of pumps by M. Bagg (2013). Study on application of LCC for pumps selection was also undertaken by Freselem M., *et al*. (2014). The study analysed on the effects of reliability on LCC. Results indicate good maintenance strategies could lead to reduction of LCC.

The LCC approach is based on evaluating the net present values of the asset throughout the life cycle of the asset covering from installation to decommissioning. This approach is more applicable if the equipment being compared is new equipment. For comparing the old equipment (defender) with the new equipment (challenger), the present worth (PW) and marginal cost (MC) and equivalent uniform annual cost (EUAC), are more appropriate. In this study all three concepts were used for the analysis as outlined by Sullivan *et al*. (2009). MC was used for the old pumps (defenders). While the EUAC concept was used for the new pumps (challengers). The PW analysis was used for sensitivity analysis of the challengers. Comparison between the MC of the defenders and the EUAC of the challengers was used to determine the option for replacement.

Marginal cost of the defenders

Total Marginal Cost is the sum of the loss in the market value (MV) during the year of service, the opportunity cost of capital invested in the asset at the beginning of year *k*, and the annual expenses incurred in year *k*. The cost is evaluated using equation (1).

$$TC_k\,(i\,\%) = MV_{k-1} - MV_k + i\,MV_{k-1} + E_k \quad (1)$$

Where, TC_k = Total Marginal Cost of year k
MV_k = Market Value of year k
$i\,MV_{k-1}$ = Opportunity cost of capital invested in the asset at the beginning of year k
E_k = Annual expenses incurred in year k

EUAC of the challengers

EUAC was calculated using equation 2. Marginal cost is used as the basis to calculate EUAC.

$$EUAC_k = [\sum_{j=1}^{k} TC_j(P/F, i\%, j)](A/P, i\%, k) \quad (2)$$

Where i is minimum acceptable rate of return, MARR per compounding period, *j* is index for each compounding period (*j* = 1, 2, 3, . . . *n*), *k* is index for each compounding period (*k* = 1, 2, 3, . . . *n*), TC_j is Total (marginal) cost for the year k, and *n* is number of compounding periods in study period.

Sensitivity analysis

Sensitivity analysis was done using the PW equation. The basic PW equation is as per equation (3). The future amounts are discounted to the present by using the interest rate over the appropriate study period:

$$PW = \sum_{k=0}^{N} F_k(1+i)^{-k} \quad (3)$$

Where *i* = MARR per compounding period, *k* is index for each compounding period, F_k is future cash flow at the end of period *k*, and *N* is number of compounding periods in study period

Spreadsheet is used for analysis. The spreadsheet Tables for the MC, EUAC and Sensitivity analysis are included in Table-2, Table-3 and Table-4 respectively. While the data for CAPEX and OPEX are included in Table-5.

RESULTS AND DISCUSSIONS

Marginal cost analysis of defenders

The MV of the defenders are assumed to be RM 4 million due to total overhauled activities are required to make good the units, so that the defenders could be

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operated at their desired functions so as to be competitive in level of service with the challengers. From the analysis, the MC cost of RM11.01 millions is required in order to keep the defenders for year 2015. The MC increases annually due to increase of O and M and energy cost as shown in Table-2.

Table-2. Marginal cost of the defenders.

EOY	Year	(RM million)					
		MV	Loss in MV during year k	Cost of capital = 10% BOY MV	Annual cost	Energy cost	Total marginal cost, TCk
0	2014	4.00	-	-	-	-	-
1	2015	3.20	0.80	0.40	3.96	5.85	11.01
2	2016	2.40	0.80	0.32	4.26	5.85	11.23
3	2017	1.60	0.80	0.24	4.55	5.85	11.45

Table-3. EUAC of the challengers.

EOY	Year	(RM million)							
		MV	Loss in MV during year k	Cost of capital = 10% BOY MV	Annual maintenance cost	Annual operation cost	Energy cost	Total (Marginal) cost, TCk	EUAC
0	2014	13.00	-	-	-	-	-	-	-
1	2015	12.35	0.65	1.30	0.81	0.26	5.93	8.95	8.95
2	2016	11.70	0.65	1.24	0.81	0.26	5.93	8.88	8.92
3	2017	11.05	0.65	1.17	0.81	0.26	5.93	8.82	8.88

Table-4. Sensitivity analysis of the challengers.

Most Likely Values				
Capital Investment		**13**		
Operation and Maintenance		1		
Energy cost		6		
Number of years		5		
MARR		10%		
%Change	Capital Investment	Operation and Maintenance	Energy cost	MARR
-20%	-36.935	-38.724	-35.039	-40.949
-15%	-37.585	-38.927	-36.163	-40.584
-10%	-38.235	-39.129	-37.287	-40.227
-5%	-38.88	-39.33	-38.411	-39.878
0%	-39.535	-39.535	-39.535	-39.535
5%	-40.185	-39.738	-40.659	-39.2
10%	-40.835	-39.941	-41.783	-38.871
15%	-41.48	-40.143	-42.907	-38.549
20%	-42.13	-40.346	-44.031	-38.233

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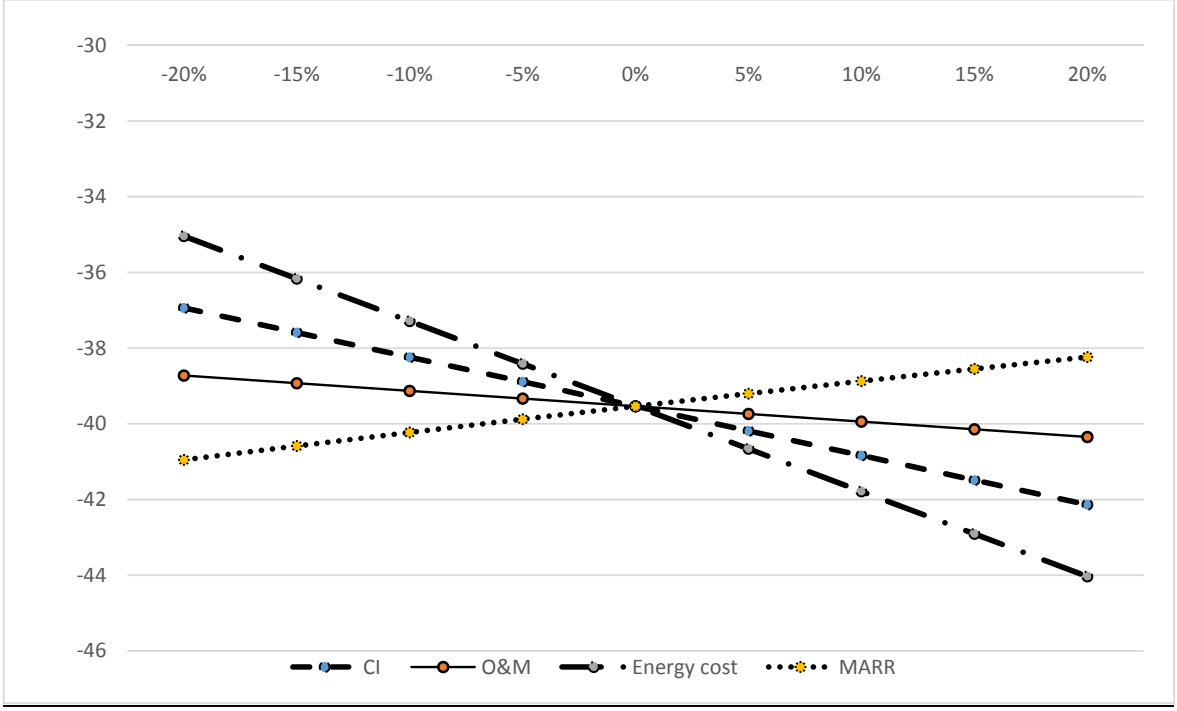

Figure-3. Sensitivity graph for challengers over range ± 20% changes of estimates of CI, O and M and energy cost.

EUAC analysis of challengers

The MV of the challengers are assumed to be depreciated yearly in a straight-line trend for 20 years throughout their expected useful life. The opportunity cost of the capital in year k is 10% of the capital unrecovered at the beginning of each year. From Table-3, the calculated EUAC for year 2015 is RM 8.95 million.

Table-5. CAPEX and OPEX of challengers.

Items	**Cost** (RM, million)
1. Procurement and installation of new 10 units of Amine Pumps	13.00
2. Annual Operating Cost of New Amine Pumps	0.26
3. Annual Maintenance Cost of New Amine Pumps	0.81
4. Annual Energy Cost of New Amine Pumps * with Pump Energy Consumption 2750KW/h (Data given by OEM)	5.93

Replacement decision

Based on the values of MC of the defenders from Table 2 and EUAC of the challengers from Table 3, it is noted that even during year 2015 the MC of the defenders is higher than the EUAC of the challengers. For the year 2015 the MC of the defenders is RM 11.01 millions compared to the EUAC of the challengers which is RM 8.95 millions. Since the MC of defenders is higher than the EUAC of challengers, the defenders should be replaced.

Sensitivity analysis of the challengers

Table-4 shows results of sensitivity analysis. While Figure 3 shows the sensitivity of the PW to per cent deviation changes in each factor best estimates. The per cent deviations used for the study is ± 20%. The other factors are assumed to remain at the most likely values. The PW of the study based on best estimates of the factors is

PW (10%) = -RM13.0 + (-RM1.0 - RM6.0) (P/A, 10%, 5)

= - RM39.535 million

The plot in Figure-3 indicates the PW is most sensitive to energy cost. Hence the energy cost need to be closely monitored in order to ensure minimum operations cost.

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CONCLUSIONS

Based on the MC and EUAC analysis, the MC of the defenders is very much higher than the EUAC of the challengers. Hence the defenders need to be replaced. In terms of the cost for the challengers, sensitivity analysis results indicate PW is very sensitive to energy cost. Hence the energy cost should be closely monitored to ensure minimum operation costs. Future study should take into account the uncertainty elements on the estimates of the cost factors. This is to align to the uncertainty environment, in terms of cost factors faced by the industry.

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