# Quantitative Assessment of Contribution of Value of Maintenance Activity using Risk-Based Method in Oil Industry

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***Abstract* - Nowadays the global market becomes more benefit oriented. As increasingly companies and organizations are becoming aware of the maintenance contribution to value generation and its contribution to the reduction in risk as well. Maintenance is an important business process that could contribute to overall profitability. However, it is difficult to quantify contribution of maintenance in value creation and risk reduction by many companies. Therefore companies are not able to plan maintenance management effectively and decide resource allocation for maintenance activity as well. The aim of the study is to find a methodology to quantitatively asses the contribution of maintenance activities in reducing overall risk and ensure the regularity of work. In this work a risk-based methodology is proposed to quantitatively asses the value of maintenance activities. The value of maintenance activities (maintenance value) is expressed as the risk reduction values that could be achieved by performing a particular maintenance activity. In other words maintenance value is defined as the positive contribution of maintenance towards the system.**

***Key words: maintenance value, Risk value, Contribution of maintenance, maintenance cost, maintenance management, fault, failure modes, etc.***

## I. INTRODUCTION

A large number of service companies have established that provide knowledge and technology based services to improve maintenance management effectiveness and efficiency. With the advances in technology, the industry is increasingly becoming dependant on advanced, complex and integrated machinery and equipment. This high complexity increases the interdependencies between different components, and brings more uncertainties to the system. In this case, even a small failure can lead to a catastrophic accident: injury, loss of life and uncountable loss of money.

Besides risk reduction, maintenance can generate value by reducing downtime, increasing equipment life, etc. Some years ago, maintenance was and considered as a “Necessary evil”, and it was believed that “Nothing can be done to improve maintenance costs.” However, the development of modern maintenance techniques such as condition monitoring, computer based maintenance management changed the paradigm. Both the research results and the practical applications show that the successful maintenance programs can greatly improve the value generation by reducing the machine failures, reducing repair time, reducing spare parts costs, and increasing the machine life as well as productivity.

Robert K. Perrons et al.[1] have put forward the view point that the upstream oil and gas industry could potentially make significant improvements in asset maintenance—specifically, with regard to offshore platforms and remote pipelines—by selectively applying some aspects of the maintenance strategies and philosophies that have been learned in the space and satellite sector. J.T. Selvik et al.[2] have suggested an extension of the RCM to reliability and risk centered maintenance (RRCM) by also considering risk as the reference for the analysis in addition to reliability. A broad perspective on risk is adopted where uncertainties are the main component of risk in addition to possible events and associated consequences. Peter Okoh et al.[3] have been presented statistical analysis and interpretation of maintenance-related major accidents’ moving averages as well as data related to the types of facility, hazardous substances, major accidents and causes. This is based on a thorough review of accident investigation reports. Risk based inspection (RBI) methodology has been proposed to evaluate the maintenance strategy in industrial process by Tan Zhaoyang et al.[4] Using classic definition of risk, both the probability and consequence of accident or failure have been investigated respectively under the support of risk-specific code. To arrange the hierarchic structure and evaluation, four main criteria have been defined for pair-wise judgments. Finally, four possible alternative strategies have been proposed for administrators on the site. Elham Sa’idi et.al. [5] have been proposed a model for the risk of the process operations in the oil and gas refineries. The fuzzy logic system (FLS) was proposed for risk modeling. The merit of using fuzzy model is to overcome the uncertainty of the RBM components. Alireza Noroozi et.al. [6] have been provided an analysis of human factors in pre- and post-maintenance operations. For possible failure scenarios, considers the procedures for removing process equipment from service (pre-maintenance) and returning the component to service (post-maintenance). Alireza Noroozi et. Al. [7] have been focused on a human factors analysis in pre and post-pump maintenance operations. The procedures for removing process equipment from service (pre-maintenance) and returning the equipment to service (post-maintenance) are considered for possible failure scenarios. For each scenario ,human error probability is calculated for each activity using the Success Likelihood Index Method (SLIM). Rengarajan Srinivasanet. Al. [8] have been proposed a methodology to assess the benefits offered by condition monitoring systems and the factors that affect the value delivered by such systems. The proposed methodology is based on Partially Observable Markov Decision Process (POMDP) and is illustrated with an industrial case example.

### A. *Maintenance Management*

Management process is a process of planning, leading and controlling the performance or execution of any type of activity through the deployment and manipulation of resources (human, financial, material, intellectual or insubstantial). One can also think of management functionally as the action of measuring a quantity on a regular basis and adjusting an initial plan and the actions taken to reach one's intended goal (Márquez, 2007). Maintenance management can be therefore considered as the process of leading and directing the maintenance organization.

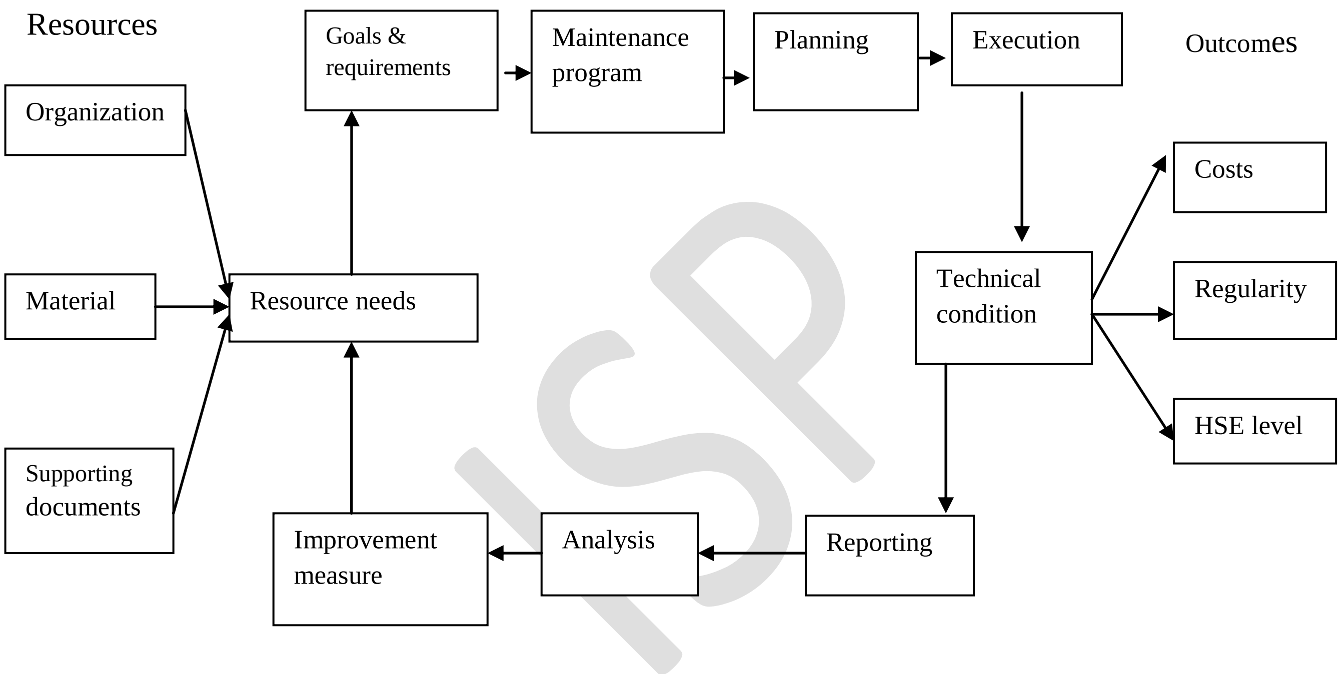


Fig.1 Maintenance Management (NPD, 1998)

## II METHODOLOGY

The value of maintenance activity could be defined as its positive contribution to the system. It expresses the net benefit we can obtain from a maintenance activity.

The purpose we use maintenance activities is to prevent the equipment failures. Once the maintenance activities are not performed, the failures will occur, and correspondingly is the risk to both the production and the safety. Furthermore, the value of risk is a term that we are able to quantitatively assess. Therefore, using the increasing value in risk if the maintenance activity is not done to assess the value of maintenance could be a good option.

Based on this consideration, we can calculate the value of maintenance activity by the following equation:

*Value of maintenance activity= total saved risk value – total costs of maintenance*

In order to facilitate the calculation, in the equation we use the term of *the total saved risk value* instead of the increasing value of risk if a maintenance activity is not performed as the latter one is a negative number. The total saved risk value is positive, and it is equal to the increasing risk value if a maintenance activity is not performed in magnitude. It means all the risk values, no matter economical or HSE related, that can be saved by the maintenance activity. It is the positive contribution of a maintenance activity. On the other hand, the term *total costs of maintenance* represent the negative contribution of the maintenance activity. Therefore, when we use the first term minus the second one, it expresses the benefit we can get from the maintenance activity. That is the value of the maintenance activity.

The process of quantitatively assessing the value of maintenance activity includes 6 steps [9]

*Step 1 - Description of selected equipment*

The assessment process should commence with the description of the selected equipment. This step contains a description

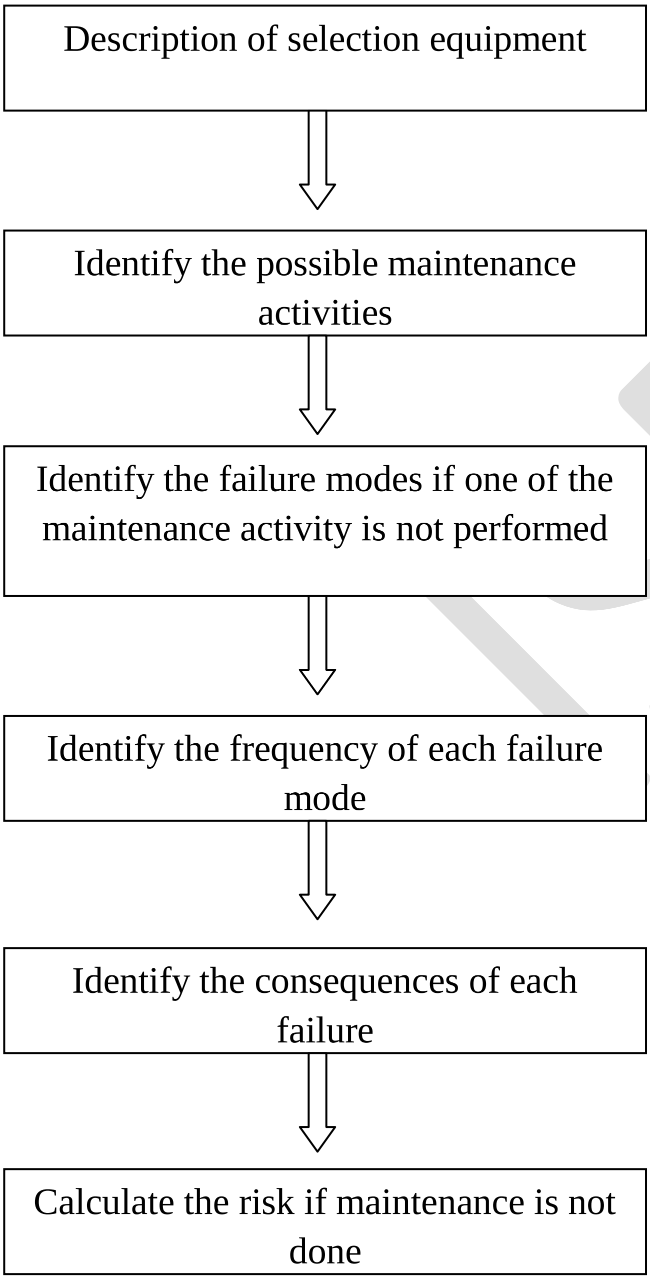


Fig. 2 methodology

of each equipment unit for which data have been collected, e.g., pump, turbine, and etc.. This step includes the description of equipment's function, the situation of the equipment's assignment, as well as some technical data(e.g. capacity, size).

*Step 2 - Identify the possible maintenance activities*

In this step, we should identify the possible maintenance activities that normally be implemented in the equipment, and describe the function, mechanism, and costs of each maintenance activity.

*Step 3 - Identify the failure modes if one of the maintenance activities is not performed*

First, we assume one of these maintenance activities is not performed, and identify what failure modes will occur in the equipment. The analysis of failure causes and failure effects is also necessary.

*Step 4 - Identify the frequency of each failure mode*

The frequency of the failure modes can be identified from many ways, such as historical report from operators, reliability report from authorities (for example OREDA), experts' judgment, OEM's documents, and etc.

*Step 5 - Deduce the consequences of each failure mode*

In this step, we need to identify the consequences of each failure mode. All the risks to personnel, to environment, and to asset should be considered.

*Step 6 - Express the values of the maintenance activities*

The whole assessment process is completed in this step. Till this step, we have got both the total saved risk value and the total costs of maintenance, therefore we can figure out the value of the maintenance activity by the equation:

Value of maintenance activity = total saved risk value – total costs of maintenance

## III. RISK VALUE OF FAILURE MODES

The pumps haves been classified based upon their functions namely oil processing pumps, water processing pumps and fire fighting pumps. Their respective failure modes had been calculated and had been tabulated. The maintenance activities performed upon these pumps also were enlisted and the cost of these maintenance activities has been tabulated. The cost of maintenance activity also has been found out and the values entered.

The expression of risk is shown in the following equation, which is calculated by multiplying probability and numerical value of the consequence for each accident sequence i, and summed over all potential accident sequences:

$$R=\Sigma_i (P_i * C_i)$$

Where: P = probability of accidents
C = consequence of accidents

## IV. TYPES OF PUMPS COMMONLY USED IN OIL INDUSTRY

Generally, two types of pump are usually used in oil industry. They are:

*A) Centrifugal pump.* Centrifugal pumps are the most commonly used pumps in petroleum industry. Among all the installed pumps in a typical petroleum plant, almost 80-90% are centrifugal pumps (Girdhar & Moniz, 2005). Centrifugal pumps have the advantage of design simplicity, high efficiency, wide range of capacity, head, smooth flow rate, and ease of operation and maintenance (Girdhar & Moniz, 2005). They are widely used for fire fighting, injection, oil handling, O&G processing, etc,.

*B) Positive displacement pumps*. Positive displacement pumps, which life a given volume for each cycle of operation, can be divided into two main classes, reciprocating and rotary (Girdhar & Moniz, 2005.). Reciprocating pumps are usually used for chemical injection, gas processing, and gas treatment, while rotary pumps are mainly used for oily water treatment in offshore installation.

## V. APPLICATION OF PUMPS IN OIL INDUSTRY

Pumps are used in every phase of petroleum production, transportation, and refinery (Girdhar & Moniz, 2005). The primary areas that pumps applied in offshore O&G production system include (Karassik & Igor, 2000):

· *Fire pumps*. Normally, the active fire-fighting system centers around a ring main which pressurized by at least two fire pumps as shown on the sketch. (Angus Mather). The fire pumps may be manually activated from strategic locations such as the main control room, helideck and process areas, or automatically by a significant drop in ring. The number of fire pumps required will be determined from the fire and explosion analysis but normally, at least two independently powered fire pumps will be found on an offshore installation. The number of pumps installed should reflect the possibility of the unavailability of equipment due to breakdown or maintenance requirements. Each pump should be capable of supplying adequate water to operate the largest section of deluge equipment in addition to maintaining the pressure.

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· *Production pumps.* Production pumps include reciprocating units for mud circulation during drilling and sucker-rod, hydraulic rod less, and motor driven submersible centrifugal units for lifting crude to the surface. The most common use of centrifugal pumps in production is for water flooding (secondary recovery, subsidence prevention, or pressure maintenance).

*Transportation pumps.* Transportation pumps include units for gathering, for on and offshore production, for pipelining crude and refined products, for loading and unloading tankers, tank cars, barges, or tank trucks, and for servicing airport fueling terminals. The majority of the units are centrifugal. Refining units vary from single stage centrifugal units to horizontal and vertical multistage barrel type pumps handling a variety of products over a full range of temperatures and pressures. Centrifugal pumps are also used for auxiliary services, such as cooling towers and cooling water. Except for some comments about the use of displacement pumps for handling viscous liquids, this section is restricted to centrifugal pumps, the type most frequently used in the petroleum industry. It also includes an overview of the requirements for some of the principal types of centrifugal pumps.

Table I
MAINTENANCE ACTIVITIES OF PUMP

| **Power Transmission** | **Pump** | **Control and Monitoring** | **Lubrication Systems** | **Miscellaneous** |
|---|---|---|---|---|
| Gearbox<br>Bearing<br>Seals<br>Lubricatio<br>n<br>Coupling<br>Instrument<br>s | Support<br>Casing<br>Impeller<br>Shaft<br>Radial bearing<br>Thrust bearing<br>Seal<br>Valve & piping<br>Cylinder lining<br>Piston<br>Diaphragm<br>Instruments | Instrument<br>Cabling and junction boxes<br>Control unit<br>Actuating device<br>Monitoring<br>Internal power supply<br>Valves | Instruments<br>Reservoir<br>Filter<br>Cooler<br>Valve<br>Oil<br>Seals | Purge air<br>Cooling/ heating system<br>Filter<br>Damper |

Table II: RELIABILITY DATA [10]

| Classification of pumps | Failure Modes | Severity Class | Failure Frequency ($10^6$ Hours) | Active Hours | Manhours |
|---|---|---|---|---|---|
| Water Pumps | Breakdown | Critical | 0.93 | 4 | 8 |
| | External Leakage – Process | Critical | 11.47 | 39 | 52 |
| | | Degrade | | | |
| | External Leakage – Utility | Critical | 3.27 | 15.1 | 30.4 |
| | | Degrade | 11.22 | 32.5 | 53.4 |
| | Fail to start | Critical | 13.76 | 57.2 | 63.4 |
| | | Degrade | 37.36 | 17.2 | 25.7 |
| Oil Processing Pumps | Breakdown | Critical | 4.96 | | |
| | External Leakage – Process | Critical | 66.25 | 11.2 | 11.2 |
| | | Degrade | | | |
| | External Leakage – Utility | Critical | | | |
| | | Degrade | 93.14 | 6.2 | 55.8 |
| | Fail to start | Critical | 7.18 | 6 | 6 |
| | | Degrade | | | |
| Fire Fighting Pumps | Breakdown | Critical | | | |
| | External Leakage – Process | Critical | | | |
| | | Degrade | 25.8 | 1 | 2 |
| | External Leakage – Utility | Critical | | | |
| | | Degrade | 372.7 | 7.1 | 14.2 |
| | Fail to start | Critical | 31.38 | 3.6 | 12.8 |
| | | Degrade | 49.37 | 3.3 | 6.5 |

From this data the value of maintenance activity can be formulated and it has been given in Table 3.

## VI. RESULTS & DISCUSSIONS

Value of maintenance Activities

Table III
VALUE OF MAINTENANCE ACTIVITIES

| Classification of Pumps | Maintenance Activity | Saved risk Values (MINR/Yr) | Cost of activity (MINR/Yr) | Contr. Of Maintenance (MINR/Yr) |
|---|---|---|---|---|
| **Water Processing** | Vibration control | 0.17 | 0.01 | 0.16 |
| | Loop test | 25.64 | 2.01 | 23.63 |
| **Oil Processing Pumps** | Vibration control | 2.01 | 0.01 | 2 |
| | Loop test | 0.01 | 26.4 | -26.39 |
| **Fire Fighting** | Vibration control | 0.552 | 0.01 | 0.542 |
| | Loop test | 0.1 | 0.01 | 0.09 |

Result is shown in form of graph below

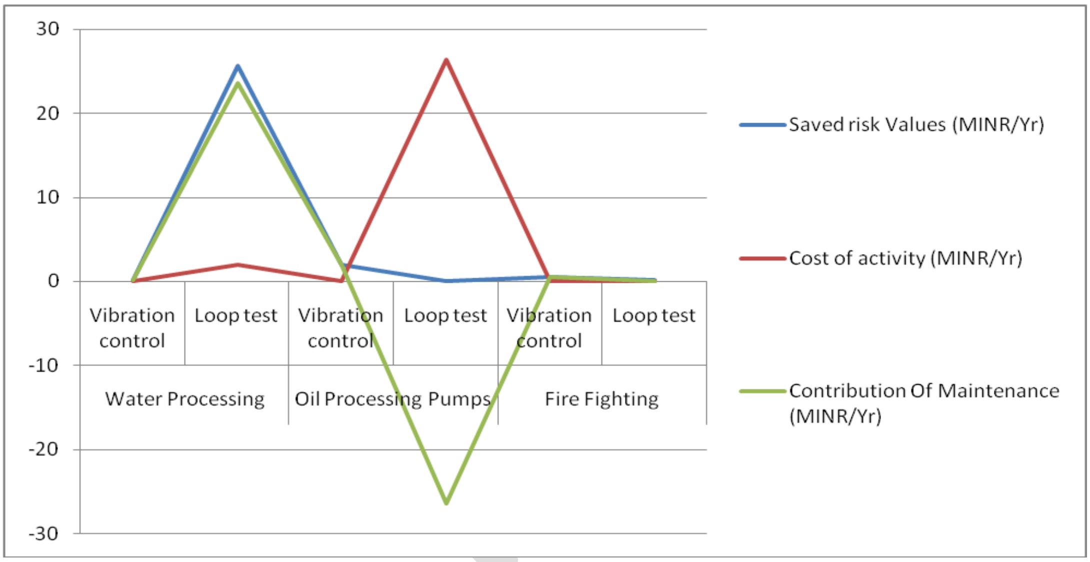


Fig. 4 Value of maintenance activities (result)

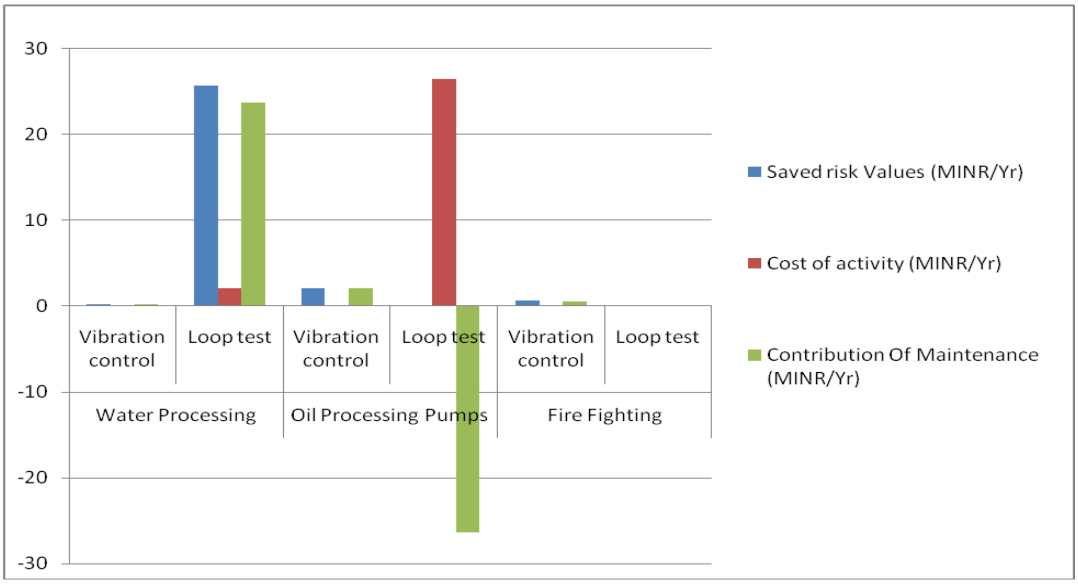


Fig 5 Value of maintenance activities (result)

## VII. DISCUSSIONS

The study finally brings out a very interesting finding to us: saved risk value is the economical value which we saved by applying the maintenance action with the cost of maintenance activity against it. We can see from the graph that in case of water processing pump and fire fighting pump saved risk value is very much high with respect to cost of maintenance activity. But in case of oil processing pump the cost of loop test is very much high i.e. 26.4 MINR/Year with respect to saved risk value due to loop test i.e. 0.01MINR/Year. It means if we apply loop test to the oil processing pump the value of maintenance activity becomes – 26.39 MINR/Year. It means there will be loss of such amount if we do the loop test. Hence loop test is not required in case of oil processing pumps.

The result reveals that the loop test, which is important to water injection pump, is not so suitable for oil processing pump.

From this, we can get such conclusion that the equipment's function, location, and working environment are very important determine matters to the value of maintenance activities. When we make maintenance strategy, these factors should be well considered. The reason why the values of maintenance activities are so different is that the equipment's function, location, and working environment determine what the dominate failure modes are and how serious they are. On the one hand, the equipment's function determines the consequences of failures. Failures represent the loss of the functions.

## CONCLUSION

The study conclude the fact that the value of risk saved in case of water processing and fire fighting pump is greater than the cost of maintenance activity but in case of oil processing pump the risk saved in loop test is less than the cost of maintenance activity. It shows that loop test is not feasible in case of oil processing pump.

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