Improvement of the Maintenance Management system in a Petrochemical Complex and Reducing the Costs

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Abstract

This research is a survey and analysis which has been carried on and a variety of data on the maintenance programs such as the comprehensive overhaul of productive units (turnarounds), periodic maintenance and emergency corrective maintenance at an oil and gas processing plant. The information in this project combined results and data to improve the maintenance management system in an oil and gas processing plant and to achieve the goal of reducing expenses and therefore increasing profits. The data collected, and the results of plant survey were, then, thoroughly analysed to reach important recommendations applicable to most petrochemical facilities.

Keywords: maintenance, management, plant, production, petrochemical, costs.

Introduction

This research analyses collected data and the survey carried out at an oil and gas processing complex with the aim of improving the performance of the maintenance management system for oil and gas processing plant. This study and survey were carried out to assess the present situation of the maintenance management system at the Ras Lanuf Company (RASCO) in Libya. The Company was founded in 1982 to manufacture Oil and Gas and it is fully owned and managed by the Libyan National Oil Corporation (NOC). It is a large company with workforce numbering 4,044 employees and 94% of them are national staff according to this latest company annual report issued in 2013. The company has been established for processing of oil its derivatives and the production of related chemicals such as organic plastics and fibre. Now, the complex includes three main plants under capability production size as: Refinery unit with capacity up to ten million tons per year, ethylene plant by capacity of 330,000 tons a year, and a polyethylene plant with production volume of 160,000 tons per year. The complex site was selected based on technical and economic studies where several things taken
into consideration, including: The crude oil production regions, communicating with various cities of Libya, and raw materials supply and export of final petroleum products through the port.

The house keeping of the plant at this petrochemical complex compared to many other places, is at a very good level and people are open minded and have the goodwill to try any new techniques, standards or best practices, which is a key point to start improving the performances (availability and operating costs). Data and history of equipment are available, despite of costs, but they are not used to improve the effectiveness of the maintenance system and the reliability of the equipment. A Risk Assessment Matrix is in place for safety awareness but there is a need to spread risk management tools throughout the whole organisation. The inspection department is thinking for implementation of Risk Based Inspection (RBI), to optimise inspection plans. The responsibilities of different players in the maintenance management are not yet clearly defined through job descriptions, and maintenance resources are spread throughout many departments which result in a lack of use. This is particularly the case for the work force, and for the supervision and maintenance engineering staff. Adjustments in this organisation must be made to promote the culture of multidiscipline team work which sustains any kind of performance improvement.

The work flow is manual because a Computer-Managed Maintenance Systems (CMMS) is not yet in place, which results in a significant amount of administrative and reporting tasks. Therefore, the ratio of all the maintenance staff working in the field that does not have “tools on hands”, i.e., managers, supervisors, planners, etc. to the total staff dedicated to maintenance activities seems a bit high (more than 38%). A priority setting procedure does exist for work requests, but the scheduling process of work orders, which is one of the key points for optimising resources and related costs, is not properly done because of emergency and urgent demands.

**Literature review**

Maintenance is arrangement the activities that required and undertaken to retain or restore technical, administrative and managerial systems in good situation to be able to perform their obligations without failure. The two primary objectives of the maintenance are the high accessibility of production equipment and to lower the cost that come along with maintenance activities (Komonen, 2002). Maintenance currently is recognized as a critical factor that facilitates good performance and the gain of business associations (Arts, Knapp, & Mann, 1998). Therefore, it prompts the maintenance managers to find every way in which to enhance and achieve good performance of the production systems together with saving related cost for the companies (Al-Najjar & Alsyouf, 2004). Thus, when there is poor maintenance management, firms incur a noteworthy monetary expense (Aoudia, Belmokhtar, & Zuringelstein, 2008). Maintenance management is regarded as the primary method that guarantees given techniques are taken into consideration for the successful operation of the equipment (Swedish Institute for Standards; n.d.). Maintenance management was therefore created in the effort to suppress failure disappointments that are associated with the production mainstream (Narayan, 2004).
Carrying out maintenance management can be dispensed into two sections: Mainly, the depiction of the technique and the methodology application (Márquez, De Leon, Fernández, Márquez, & Campos, 2009). In other words, maintenance management is a way of organizing the main assets of a firm to capitalize on the reliability and execution of business firm to some predetermined stage (Gillett, 2001). As stated by Niebel (Niebel, 1994) some of the activities that are undertaken during maintenance are such as mistake confinement, locating and finding deficiency, restore, substitution, updating, adjustment and testing, oiling of segments, rundown control of extra parts, factual investigation of failure and upkeep information, determination of assessment timetables and routines.

Furthermore, Thorsteinsson and Hage (Thorsteinsson & Hage, 1991) together came up with an extensive meaning of maintenance framework that is regarded as a production framework in which the products are maintenance services. The meanings were expressed in twelve primary fields and grouped into three fundamental classifications: The technical section, the human part, and the finance segment. The technical section encompasses the upkeep of items, its quality, and working methods; and maintenance resources, material, and regulating activities. The human part is the inner connections in upkeep capacity. This translates to the connection with outer parties mostly regarding the surrounding and security. More so, it entails contact with local powers, press, work association, client, seller, and with neighbours. Organisation of maintenance capacity. This involves the sketching out of the affiliation, determination of people, and the relationship between gatherings of abilities together with commitment and power. The finance segment is concerned with the finance of maintenance; this entails financial control of upkeep, expense appraisals, spending plans, income, the flow of cash, and Plant venture and financing.

Views from other industries that might have an impact on the improvement of the maintenance systems at the oil and gas industry are mainly from the aircraft industry (Airbus) (Airbus, 2015) and the automotive industry (Toyota) (Toyota, 2015). Aircraft Maintenance Analysis (AIRMAN) is based on examining aircraft upkeep is platform created by Airbus primarily to advance the upkeep of airship. It is asserted that the product always screens the strength of an administrator’s jetliners and instantly exhorts if a flaw or cautioning recorded through its on-board upkeep framework. Furthermore, to directing managers of specialized issues, this platform conveys entry to the fundamental data for determining these circumstances rapidly and productively with a solitary concentrated interface screen. AIRMAN can diminish time taken to investigate because of its propelled capacities. Therefore, it considers essential report of airplane occasions and quick entry to applicable document record while conveying subtle elements on the flying machine's upkeep history and data on past upkeep work done. Despite high reliability on such a software sued for an aircraft at one of the successful large companies like Airbus, but it is not appropriate for Ras Lanuf oil & gas company (RASCO) (Ras Lanuf oil & gas company (RASCO), 2009) because of the massive of complicated input and output parameters in petrochemical industry such as: Raw materials (Crude oil, Natural gas and Utilities), unstable prices in national and international markets, transportation and delivery of spares and final products, and the large number of employees needed. In other word, this maintenance system is impractical to use by RASCO.
The current mining, oil and gas industry views on maintenance workouts are believed to involve different disciplines naturally with an immense number of inputs and yields. Additionally, the execution of upkeep productivities needs require quantified and be totally considered as a consolidated strategy. Because upkeep makes an additional quality to the business procedure, many associations are, therefore, regarding upkeep as a necessary amount for work (Liyanage & Kumar, 2003). Wireman (Wireman, 2007) asserts regarding a lot of asset-intensive commercial enterprises that, the expenses about upkeep are an enormous fragment of the operational costs. He further laments that upkeep expense result to 20-50% of the expense incurred in production especially for the mining enterprise. However, this relies upon the level of machine usage. Accordingly, decreasing upkeep expense by $1 million in bigger organizations results to as much to benefits because sales increase up to $3 million.

There exist a lot of illustrations that point out the calamities brought about by the absence of vital and exact upkeep activities, such as power blackouts in New York and the UK in the middle of 2003. Therefore, the supervisors in charge of resources are liable to be accused by resources administration and changes in the lawful environment due to corporate manslaughter liabilities and changes in the lawful environment for coming activities of the upkeep activities (Mather, 2005). For the same accusation, British Petroleum industry located in United States paid a $21 million as a punishment and more so, used approximately $1 billion for rebuilding for a blast that happened at Texas City refinery. This explosion resulted in the 15 deaths of fifteen people and caused injury to another 500 people. It accounts as the deadliest refinery mishap that ever happened (Bream, 2006). RASCO has had the expert of one of the Ethylene gas spherical tanks was exploded in 2002 due to unclear information contact between operators control supervisor and maintenance team supervisor. That gas explosion caused a totally shutdown for the complex for about 6 months, injured 12 people and cost over $150 million as a production loss. In addition, this accident cost approximately another $100 million to maintain all the affects and back to normal plant operation.

It is not enough to purchase sophisticated equipment because of the advancement in technology, without a proper plan on how this equipment will be maintained. Basically, the effectiveness of any operational system is based largely upon the maintenance of the entire parts of the system, most especially in oil and gas industries. According to Labib (Labib, 2004) the framework referred to as the Computer Managed Maintenance System is of late, a focal part of numerous organizations' upkeep offices. This is because it aids on a different authoritative progressive system. This framework is utilised a method for accomplishing an international upkeep because it provides a stage for choice examination thereby operating as a manual for administration (Kaus, 2009).

The research will analysis the survey carried out based on collected data between 2000 and 2008 with the aim to improve the performance of the Maintenance Management System for RASCO. Results from data analysis with recommendations upon the maintenance management system will be combined with an implementation strategy of the needed system changes. Performance improvements are estimated in terms of cost reduction and availability growth some guidelines in the management of the development of the recommendations and in their implementation.
Computer management maintenance system (CMMS) as a PC-based programming projects is most essential owing to its usability in regulating work exercises and assets in addition to watching and appropriate conveying back information about work performance. Moreover, this program is utilised to investigate money spending plans, downtime, supplies, and screening of candidates among others. These frameworks work by encasing the arranged information on employees’ names, work titles, day by day, week after week or yearly timetables. Accordingly, this information can be kept or recovered much quicker to be utilized in future or even for alterations.

The research will initially evaluate the present situation of maintenance activities at RASCO in terms of cost, structural and policy of maintenance management as well as the new techniques and improving of the manager’s views for maintenance budget. The survey was carried out to aim to compare the existing situation of RASCO Maintenance Management System with worldwide best practices applied in physical assets management, particularly in the oil industry. The most significant benefits of such best practices are: Increase plant availability and the income of the company accordingly; and reduce the expenses of operation and maintenance thus increase company net profits.

Results and Data Analysis

All the data in this research were collected and evaluated by many different groups such as specific task force teams, expert staff and international consultant agencies as per significant required by RASCO during the period from 2000 and 2008 (Ras Lanuf oil & gas company (RASCO), 2009). The results and the analysis of data will concentrate on the main seven areas concerned with maintenance management in petrochemical plants: Reliability and failure management, routine work preparation and control, budget and cost control, maintenance costs versus operating costs, turnaround management, information and database system, and organisation. The data will be studied to provide essential parameters for those areas.

Reliability and failure management

Modern techniques such as Reliability Centred Maintenance (RCM) suggest that the choice between the following two maintenance strategies: “Run to failure” (corrective or breakdown maintenance option), or “prevent failures” (time-based maintenance and/or condition-based maintenance option) depending upon the criticality of the equipment, which is a function of both frequency or probability of the failures. Consequences of these failures, which can be divided into: Health, Safety and Environmental factors (HSE) consequences, financial consequences, e.g., total cost of failures including maintenance costs, and production losses. Criticality assessment, together with risk/benefit analysis, are also useful for many decision-making such as: Priority setting of work requests in day-to-day maintenance, priority setting in extraordinary maintenance items, and justification of turnarounds work requests.

It is important to indicate at this step, that Preventive Maintenance might not be effective to reduce the probability of failures. Most of them have nothing to do with the inherent reliability of the equipment, because there are caused by “external” events which affect the resistance to failure of the equipment (e.g., its useful life). These events are random in nature.
and depend on the operating context. Some of these events are: Incorrect use of the equipment, incorrect assembly of the equipment during maintenance operations or damages made during handling, regular upset of the equipment capabilities, bad quality of spare parts, aggressive environment (steam, sand blasting, etc.).

If such causes can be identified while a failure has occurred, and eliminated by means of appropriate procedures, trainings, modifications, etc., that will obviously be better than doing time-based overhauls. The process is known as “Root Cause Analysis” (RCA). It is effective when all key players (maintenance, operation, and specialists) are involved together as a team to determine causes and find solutions.

**Routine work preparation and control**

The effectiveness of maintenance works depends upon factors such as: The control of the work load, e.g., how work requests are justified and accepted, the application on a daily base and by all players of an agreed procedure to set priorities (“emergency”, “urgent” and “normal” jobs), the coordination between all players and their ability to work as a team, the effectiveness of planning and scheduling, and of course the professional skills of the performers (welders, scaffolders, etc.) (Fig. 1).

![Figure 1: Routine work maintenance flow chart (Ras Lanuf oil & gas company (RASCO), 2007)](image)

The diagram in Fig. 1 illustrates that a good practice in the execution of maintenance works. The inputs of the model are: The initial work load coming out from time-based maintenance (overhauls) programs and inspection programs; work requests are established by each maintenance department in each zone on a year base, and transferred to the central planning section for scheduling purposes on a year basis. The additional work load is coming out from morning daily meetings carried out in each zone between operation and maintenance managers; new work requests are the result of either corrective or breakdown maintenance.
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(failures), condition-based maintenance (on-condition monitoring and on-stream inspection), or other unexpected events.

The purposes of the morning daily meeting are: To justify and analyse each new request (WHAT IS THE PROBLEM? WHAT DO WE HAVE TO DO TO SOLVE IT?), to set priority (EMERGENCY, URGENT, NORMAL) according to a well-established and agreed procedure, to define the latest possible date to start the job (for NORMAL only) which will help the scheduling process, and to identify all other constraints related to the execution of the job for planning needs.

After acceptance, new requests are transferred to the central planning section, except for EMERGENCY requests which require immediate action. The central planning team oversees planning and scheduling, and management of intervention resources in all specialties. The objective is to schedule these resources for the next week, with the aim to optimise their number and their use. To do this, a weekly meeting is carried out between production and maintenance managers together with the scheduler of the planning section.

A daily program for the next day is also issued by the planning section each day, and assigned to the appropriate work supervisors. Supervisors attend another daily meeting in the afternoon with operation to: Prepare work permits for new jobs accordingly, if not already done by the planner, take possible corrective action upon the job already on progress. The meeting must be point out that: Any emergent work order has an impact on the daily work program that was issued the day before, and consequently on the utilisation of the resources dedicated to this program. It will also impact the weekly schedule which will have to be reviewed. This means that a decision must be taken when assigning EMERGENT to a work request, upon which job already scheduled or on progress, must be delayed fulfilling the request. Obviously, this decision must be taken with the agreement of the operation manager or his representative. Any urgent work has no immediate impact on the daily program, but will affect the current weekly schedule as well.

It is then of most importance to keep the proportion of emergent and urgent requests to their minimum to improve the effectiveness of planning and scheduling, and consequently the effectiveness of the whole maintenance execution process. Ideal figures should be: No more than (5%) for emergent requests, and no more than (25%) for urgent requests. Obviously, when doing so, the average number of pending work orders will increase, which will make easier the optimisation of resources. This number can be transformed into number of “working days” of available performers, which is known as the “backlog” of the maintenance execution process.

The model described above does not apply to small jobs (e.g., job cards) because these jobs doesn’t require detailed planning and scheduling. So small jobs are carried out by specific resources dedicated to each zone and not centralised. This is typically the case for most instrumentation jobs and some other mechanical jobs.
Budget and cost control

Maintenance costs are an important proportion of the operating costs in plant industries, about a quarter when considering in these costs, as suggested by the Solomon benchmark: Manpower, including managers and administration that is dedicated to the maintenance activities, whatever their position in the organisation, related expenses and wedges (offices, telephone, computers, etc.), overheads such as procurement, storage facility, etc., contractors, material and spare parts consumption, refurbishment activities even if they are carried out under investment budgets.

In most industries, the maintenance budget and the maintenance expenditures are usually spread into three main sections: Day to day maintenance, e.g. maintenance performed while the plant is running normally; it includes all types of maintenance but is usually divided into preventive maintenance and corrective maintenance; extraordinary maintenance which deals with majors works carried out by the maintenance function (major overhauls or replacement of equipment, refurbishment program, etc.), these items are usually scheduled on a long term five to six years rolling program, and implemented like projects with dedicated resources and budgets (whatever OPEX or CAPEX budgets); and shutdowns and major Turnarounds which are also be managed like projects with specific budgets, and scheduled on the same long term rolling program reviewed each year.

Turnaround management

Turnarounds cost is an important part of overall maintenance costs in the oil industry. As demonstrated by Solomon benchmark they are rating at (6%) of total operating costs and (20%) of maintenance costs, when averaged over the run length. Turnarounds have also a negative impact in the income of the company because the plant is unavailable during turnarounds. Depending in the frequency of turnarounds and in the duration from feed-out to feed-in of turnarounds, downtime used to be in a range of (10 days/year to 15 days/year) in the 80’s in Europe.

This is the reason why oil companies have focused in ways to reduce both turnaround frequencies and duration in the past 20 years. Current figures in Europe are within a range of (5-7 days/year) for refineries and ethylene plants, depending on country regulations, which obviously has a positive impact on the business. These plants are presently running (5 to 6) years between major turnarounds. Such improvements are the results of important reviews made in the field of maintenance and inspection strategies, but also in the field of management of these activities: Implementation of techniques such as RBI to optimise inspection programs, carrying out of techniques such as RCM to optimise preventive maintenance programs, control of the scope of the work using risk/benefit analysis in the requests justification process, and applying project management standards to turnarounds preparation and execution.

Information and data base system

Current situation in Ras Lanuf Equipment history is recorded, but the data are not fully relevant for reviewing the maintenance strategies, because they are not in an appropriate form to be computed easily, and some data such as cost, condition of the equipment, and failure
modes are missing. The acquisition of a (CMMS) is under consideration which will obviously support the standardisation and the monitoring of such data.

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**Organisation**

Actual trends in the organisation of maintenance points out that activities can be divided into three main sections that are different in nature, objectives and skills: equipment management (maintenance strategies), work management (planning and resources scheduling), and maintenance engineering and expertise.

**Potential Savings and Improvements**

The result of analysis of this data will be a set of detailed recommendation to the plant directors. The implementation of the recommendations will lead to savings in maintenance and operating costs together with an increase in plant availability. Savings in other operating costs are also expected. Potential Savings and Improvements will result from improvements in day-to-day maintenance, turnarounds, and production capacity availability. The analysis of this study will provide an example of criticality assessment matrix, an example of consequences classes, an example of probability classes, and how to use criticality assessment matrix in maintenance strategies and in priority setting.

**Day to day maintenance**

The assumptions made for estimating the potential savings are: A reduction by (30% to 40%) of time-based maintenance items which will reduce both the amount of manpower and spare parts accordingly, and an increase of the productivity of the workflow, which lead to a reduction in the number of man-hours by (20 to 30%). All figures detailed in this section are preliminary results from data analysis. Time-based maintenance: Time-based maintenance is about 60% of the total day to day maintenance costs and can be split roughly into (all costs expressed in Real Terms 2007, e.g., RT 2007):

- Man-hours: 432,000 hours/year, rating at 22.5 Libyan Dinar (LD)/hour
- Spare parts consumption: 3.9 MLD RT 2007/year

Applying a reduction of 30-40% to these figures leads to the following savings:
- Man-hours reduction: 129,600 - 172,800 hours/year
- Remaining man-hours after saving: 590,400 - 47,200 hours/year
- Total labour cost savings: 3.92 - 3.89 MLD RT 2007
- Spare part cost savings: 1.17 - 1.56 MLD RT 2007

Total savings: 5.09 - 5.45 MLD RT 2007/year

Productivity

Productivity savings must be applied to the above remaining hours, an amount of savings in terms of man-hours of 109,440 – 177,120 hours/year. Total savings: 2.46 - 3.98 MLD RT 2007/year. Total day-to-day maintenance cost savings: 7.55 - 9.43 MLD RT 2007/year

Turnarounds

Polyethylene plant

The average turnaround costs are 2.86 MLD RT 2007 each 2 years, e.g., 1.43 MLD/year. The extension of turnaround period up to 3-4 years will reduce this cost down to 0.72-0.95 MLD/year. Thus, a saving of: 0.48 - 0.71 MLD RT 2007/year

Refinery

The average turnaround costs are 2.49 MLD RT 2007 each 4 years, e.g., 0.62 MLD/year. The extension of turnaround period up to 5-6 years will reduce this cost down to 0.41-0.50 MLD/year. Thus, a saving of: 0.12 - 0.21 MLD RT 2007/year

Ethylene plant

The average turnaround costs are 7.87 MLD RT 2007 each 3 years, e.g., 2.62 MLD/year. The extension of turnaround period up to 5-6 years will reduce this cost down to 1.31-1.57 MLD/year. Thus, a saving of: 1.05 – 1.31 MLD RT 2007/year. Total turnaround savings: 1.65 – 2.23 MLD RT 2007/year.

Total Estimated Potential Maintenance Cost Savings: 9.2 – 10.8 MLD RT 2007/year. A reduction of (19% - 22 %) against current maintenance costs. The ratio between maintenance costs and total operating costs will be reduced to (22% - 24%) which close to Solomon benchmark average.

Availability

Without any data concerning unscheduled shutdowns we have only calculated the increase of availability achieved after the extension of turnaround periods.

Refinery

- Current average annual downtime: 8-9 days/year
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- Potential average annual downtime: 6-7 days/year
- Potential increase of the running time: 1-3 days/year

**Ethylene plant**
- Current average annual downtime: 15-16 days/year
- Potential average annual downtime: 8-9 days/year
- Potential increase of the running time: 6-8 days/year

**Polyethylene plant**
- Data not available.

The above figures do not consider the possible reduction in turnaround duration which can be achieved by a better control of the work lists as mentioned in chapter (4.4) and which might lead to additional savings in terms of downtime.

**Example of criticality assessment matrix**

Criticality Assessment Matrix is the extension to maintenance of the so-called Risk Assessment Matrix who was developed for Risk Management. A Risk or Criticality level associated with an equipment failure, can be quantified by combining 2 parameters: The consequences of the failure in various areas such as safety, environment, financial, etc., or the probability of the failure. The more the consequences and/or the probability are, the higher is the criticality. This can easily be represented on a 2-dimension matrix known as a Criticality Assessment Matrix. Exact figures of consequences and probabilities doesn’t matter much for assessing criticality. It is only necessary to define specific consequence ranges (known as consequence classes) and probability ranges (known as probability classes) that are suitable in each operating context, to achieve what a criticality assessment should achieve, that is to help to take decision in failure management and in maintenance management: In what way does each failure matter, in other words do we have to do something to reduce the criticality of the failure to an acceptable level? What are the priorities? To which extent do we have to make efforts to reduce the criticality level? Because of different operating contexts and situations, each company must build its own criticality assessment matrix. So, the example developed here must not be used as it is in the Ras Lanuf operating context.

**Example of consequences classes**

The consequences of a failure whether safety failure, environment failure, of finance failure can be divided into different levels of severity (or classes), for example 1 to 5 in different areas such as:

**Safety consequence classes**

- Class 1, low effect: slight injury that doesn’t affect the work performance (first aid).
- Class 2, minor effect: injury that leads to normal work reduction, or that may require few days of rest; reversible health impair.
- Class 3, high effect: accident that require stop of working (Lost Time, Injury), but without any irreversible disability.
Class 4, major effect: accident that leads to permanent disability or serious professional disease.
Class 5, catastrophic effect: fatality.

**Environment consequence classes**

- Class 1, low effect: slight spill within the fences of the plant
- Class 2, minor effect: minor effect to neighbourhood (excess of normal emission level)
- Class 3, high effect: emission of product of known toxicity limited to the neighbourhood of the plant
- Class 4, major effect: serious damage to environment which requires that heavy measures must be taken by the plant to limit the impact (internal crisis)
- Class 5, catastrophic effect: ecological region catastrophe, which will require heavy actions by the authorities (external crisis)

**Finance consequence classes**

- Class 1, low effect: total cost of the failure < 10 K€
- Class 2, minor effect: 10 K€ < total cost of the failure < 100 K€
- Class 3, high effect: 100 K€ < total cost of the failure < 1 M€
- Class 4, major effect: 1 M€ < total cost of the failure < 10 M€
- Class 5, catastrophic effect: total cost of failure > 10 M€

**Example of probability classes**

- Class A, unlikely: failure rate < 1 each 20 year
- Class B, possible: 1 each 20 year < failure rate < 1 each 4 year
- Class C, likely: 1 each 4 year < failure rate < 1 per year
- Class D, frequent: 1 per year < failure rate < 6 per year
- Class E, almost certain: failure rate > 6 per year

Notes: The failure rate is the number of failures per unit of time and is a good estimate of the probability of failure.

**How to use criticality assessment matrix in maintenance strategies**

The upper matrix shows an increase of the criticality from lower left corner to upper right corner. It can be roughly divided into 3 zones, in which decisions are different and might be as (Fig. 2):

- Green zone: the criticality of the failure is Acceptable and might not require any preventive or corrective action; however, in many cases, the best maintenance strategy is “condition-based maintenance” if it is worth doing; if it is not, “run till failure” is most of the time the alternative.
- Yellow zone: the criticality of the failure is medium; condition-based can be applied if it is worth doing; time-based maintenance, if it worth doing (e.g., able to reduce the probability of the failure, the criticality), should be justified according to a risk/benefit analysis process (e.g., should be “cost effective”)
- Red zone: if no preventive maintenance task is effective, then something must be done any way to reduce the probability of the failure and/or to mitigate the consequences of the failure, which might lead to make modifications on the system (process, equipment, etc...).

This is typically kind of decisions which are integrated in the RCM process.

How to use criticality assessment matrix in priority setting

Example of Priority Definitions:
- Priority 1 (Emergency): the criticality is EXTREME Very unsafe situation; integrity of the assets might be affected; unscheduled shutdown… The intervention must start immediately when safety conditions are under control, and work must go on continuously until the problem is solved. The preparation of the intervention is done step by step while it is ongoing, which require continuous supervision. Emergency request affects the daily maintenance program.
- Priority 2 (Urgent): the criticality is MEDIUM Safety awareness are low, but financial losses might be high (slow down, product losses, possible secondary effects of the failure on the equipment, etc.). Planning of the intervention must be done and completed as soon as possible to be able to start the job during the current week. The work is normally performed during normal working hours; otherwise justified against cost effectiveness (risk/benefit analysis). Urgent request affects the weekly schedule.
- Priority 3 (Normal): the criticality is ACCEPTABLE only maintenance costs are affected by the failure. The intervention can be planned and scheduled within the 4/6 coming weeks (backlog).
- Priority 4 (Next Shutdown): The intervention can’t be performed while the plant is running. The request is recorded and will be executed during the next shutdown.

![Criticality assessment matrix](image-url)

*Figure 2: Criticality assessment matrix (Ras Lanuf oil & gas company (RASCO), 2007)*
Decision diagram

Together with the upper definitions, the following diagram (Fig. 3) would help in daily decision making. When a redundant equipment is in place, its condition follow-up is of most importance while the other one is unavailable for repair. Confidence in the reliability of redundancy might increase by: Considerations on the past MTBF (or failure rate) of the equipment, or close follow-up by operation and maintenance while the other one is out for repair such as increase the frequency of vibration monitoring tasks for pumps and motors.

Implementation

The most important highlights coming out from the previous recommendations are:
- Some of them are linked together and can’t be implemented on their own.
- Many of them need to be developed throughout multidiscipline teams.
- Many departments will have to be involved altogether.

Some recommendations need important cultural changes that must be promoted by top managers.

In withstanding such changes, are summarised in the following statements:
- Visible top management commitment who must assess quantitative, achievable but ambitious objectives.
- Managers’ involvement.
- Team building attitude.
- Top down and cross function communication.
- Staff motivation by “quick-wins”.

That the whole recommendations must be integrated into a single project at the plant level, and developed and implemented step by step, using appropriate project management standard, as summarised below.

**Decision to start**

A steering committee composed of relevant top managers (at least operation, technical affair, finance, and chairman or chairman representative) would have to:

- Decide either “TO GO” or “NOT TO GO” with each item of the project; this decision might require a discussion upon resources needed, and possible interactions with other on-going projects in the plant.
- Define main top objectives, e.g., quantitative improvements expected and timing for achievement (examples: reduction of maintenance costs of X% within 3 years, increase of plant availability of Y% in 4 years).
- Nominate a task force composed of relevant managers selected in each department, which will be involved in the detailed planning of the project.
- Nominate a project leader who would have to manage the whole project under the authority of the steering committee; the choice of the project leader is of most importance, because he must be acknowledged by his colleagues as a real leader.
- Communicate upon the project to the relevant staff.
Preliminary development of the project

The task force would have to meet regularly under the facilitation of the project leader, to develop the scope of the project. The development phase would include:

- A feasibility study of recommendations.
- Identification of additional improvement and/or specific pre-studies or surveys.
- To breakdown the project into sub-projects, such as CMMS, RBI, RCM, …
- Preliminary scheduling of the sub-projects all together with possible interactions.
- To nominate a leader for the development of each sub-project.
- Identification of resources needed both from inside and outside, and budget required.
- Identification of appropriate detailed objectives and relevant Key Performance Indicators (KPI’s) to control the project achievements.

During the development phase, the project leader would regularly report to the steering committee who would have to take the necessary decisions to facilitate the implementation of the project. At the end of this phase who should be as shorter as possible (max 6 months), the detailed scope of the project would have to be presented to the management committee to get the final decision.

Detailed engineering and implementation

This phase encompasses the development of detailed action plans related to each sub-project, under the coordination of the project leader, and its implementation. Regular communication upon improvements achieved should be made by the steering committee during the implementation phase, using the above KPI’s and highlighting positive points to maintain the motivation of the staff. During this step it is then of most importance to identify “quick wins items”, improvements that can be easily, quickly and visibly achieved.

Discussion of proposed recommendations

All the recommendations contained in this paper are based on a deep analysis of the information, results and data available, important previous researches on maintenance management which reviewed in the literature chapter and the practical experience of the writer of this research.

Reliability and failure management

A criticality matrix should be developed and used by (RASCO) organisation, especially maintenance, operation and inspection managers. This matrix should integrate the present risk assessment matrix in place for safety issues. The use of such a tool in the area of financial consequences of failures, would be easier when predetermining standard costs and losses:

- Maintenance manpower cost estimated to be (22.5 LD/hour) as an average.
- Typical product loss such as (1000 LD/ton) for ethylene.
- Typical profit loss per day stops such as (10,000 $/day) for polyethylene.

✓ There should be regular meetings between operation, maintenance and experts in each zone, for example each month, dedicated to reliability. The purpose of such meetings is...
to identify “bad actors”, to define a corrective action plan and to review it. The knowledge of multidiscipline team solving problem techniques, such as Root Cause Analysis, should be acquired by all players.

✓ Reliability centred maintenance (RCM) should be implemented in order to review the current preventive maintenance program. This will necessitate to assign an “RCM champion” (reliability engineer) with the necessary skills in reliability and in the utilisation of such technique. Suggest to start usage of this technique with single stage pumps and related motors which will get quick benefits of it.

✓ A similar culture should be developed for the inspection program by implementing the risk-based inspection (RBI) concept. A corrosion specialist should be the leader of the process. Together with (RCM), (RBI) will make easier the reduction of turnarounds frequencies and major overhauls of stationary equipment. Suggest to start the use of the technique in the ethylene plant where turnaround costs are the highest.

✓ As mentioned earlier, all these techniques are participative in nature, and so have to be carried out by multidiscipline teams (operation, maintenance, inspection, experts, vendors), which will require some cultural changes.

✓ Vibration monitoring and related monitoring tasks should be shared with maintenance departments rotating equipment technicians. The activity should be organised as to include:
  
  o First level of diagnosis which has to be close to operation in order to give them more confidence in these techniques.
  o Second level with high expertise in detailed vibration analysis and specific problems which will have to be shared by all zones or outsourced to a contractor specialist.

✓ A review of the program and the frequency of monitoring tasks should also be performed, according to equipment criticality, which any way will come out in the implementation of (RCM). Equipment, data base and software used in these activities might have to be standardised and shared between all technicians and specialists who are involved.

✓ Where time-based overhauls are worth doing, the frequency should not only be governed by vendor’s recommendations, but also by the condition of the components found during previous overhauls or inspections. More relevant data might have to be recorded during these operations in order to use them in the frequency adjustment process.

Routine work preparation and control

✓ Centralise all the working force and the related supervision staff into the central workshops, to the exception of performers who are dedicated to “job cards”, which have to be better stay in their present maintenance departments.

✓ The planning section and the workshops have to work close together for planning and scheduling of these centralised resources.
The proportion of emergent requests should be reduced drastically which to review the current procedure need used to set priorities between maintenance and operation. Objectives in that direction should be defined between operation and maintenance. An example of a procedure for priority setting using the criticality matrix is in chapter (5.4).

Together with the above recommendations, which are the starting point, the whole execution process should move step by step to the model presented, in order to reduce the level of available resources and to use them more effectively by increasing the backlog to an acceptable point in cooperation with operation. The flexibility that is lost during this process would have to be recovered in a second step by contracting out some activities.

The acquisition of a (CMMS) linked to the accounting system and to the warehouse management system will make easier these moves (see further).

The specific situation of the utilities should be considered as a priority. The problem should be assigned to a team composed of maintenance, operation and inspection managers with the objective to identify WHY it is so, and HOW it can be improved. A detailed review of production, maintenance and inspection policies of the units might be the first step.

**Budget and cost control**

**Day to day maintenance:**

- The current accounting system data base have to review in order to split budget and maintenance costs as to make plant production manager and maintenance manager together accountable on operating costs on a monthly base.
- Man-hours and spare parts which are recorded on work orders should be used to determine the cost of relevant requests using standard hourly rate for labour, charged with appropriate overheads (* see Note), hourly or unit rate contracts, spare part costs, etc.
- As already mentioned, the implementation of a (CMMS) will make easier to gather necessary data to make this control with less administrative tasks.

**Extraordinary maintenance:**

- The current refurbishment program should be extended ahead to all equipment and to all zones into a (4/6) years rolling schedule including all items that need important and specific budget such as major overhauls (turbines, furnaces, …), obsolete equipment replacement, etc. This program should be reviewed each year against operation, maintenance an inspection new demand. Priorities in the execution of the program should be assessed by the use of the criticality matrix and risk/benefit analysis. Each
item should be managed like a single project with an assigned project leader and appropriate budget.

A word about production losses:

✓ There is a good practice in the polyethylene plant which is to track and to report all production losses them monthly. We recommend to extend this best practice to all other production zones. These evaluations will be useful to assess equipment criticality and for any decision made in the maintenance strategies of equipment.
✓ This good practice leads to some key issues identified by the production manager in order to improve the availability of the plant.
✓ One of these issues is the number of product quality changes done on a year, which leads to a significant proportion of the plant downtime (6 days each).
✓ Another item impacting the plant availability, is the current interval between turnarounds (2 years). This interval seems to be defined by the test frequency of some safety valves, while in some other place of the world, polyethylene plant is running (3 to 5) years without major turnaround, depending on the type of process.

(*) Note: a rough calculation of the actual hourly rate for Ras Lanuf own personnel can be made from data collected during the survey for the year 2007:

- annual number of hours spent for maintenance jobs: 720,000 hours
- manpower costs (maintenance + services): 16,200,000 LD
- estimated hourly rate: 22.5 LD/hour

Turnaround management

✓ The inspection thinks about implementing (RBI) in order to better assess inspection programs and turnaround frequencies, and we fully support this project.
✓ In order to challenge the frequency of pressure relief valves pre-test should be performed in order to determine the actual condition of this equipment. Recording relevant data on the condition of such equipment during the tests, and using risk-based decision process like (RCM) will make easier to review appropriate inspection frequencies.
✓ Same recommendation should be applied to all other equipment, including rotating equipment.
✓ Apart from these recommendations, a justification procedure based on risk/benefit analysis should be established by the management team and applied by the project leader for work-list management, which is a key point in the control of the duration of a turnaround.
More generally, management techniques used in project management should be applied for the whole duration of the project (e.g., from preparation of the turnaround up to the start-up) of the unit.

Appropriate post-turnaround reviews should be organised in order to identify area for improvement.

All these recommendations will make possible to extend step by step the run length of major units to:

- Refinery: 4 to 5/6 years
- Ethylene plant: 3 to 5/6 years
- Polyethylene plant: 2 to 3/4 years

A starting point might be to do a complete review of the condition of the equipment after the next refinery turnaround with the aim to run for (5) years. This will require to gather all necessary data during the turnaround as explained above.

**Information and data base system**

- Review the data sheets used to record history for each type of equipment. Data sheets should be “standardised” to make easier their use for failure management and maintenance strategies assessment.

- The acquisition of a (CMMS) would help in that way, when building the equipment data base with relevant failure modes. Implementation of such a system will require the mobilisation of many equipment specialists (1 to 2 years), especially in the implementation of the equipment data base, and recommend to consider its development as a top priority project of the plant with a dedicated task force.

- Because of many interactions between (CMMS) and other management systems such as accounting, ware house, procurement, etc., conduct a global reflection concerning the future development of these linked systems before the acquisition, in order to avoid any “regret route” in the project.

**Organisation**

- Transfer the execution work forces presently managed by maintenance department to the central workshops to the exception of the staff that is usually doing “job cards” activities that should stay in their current position. A list of such activities should be determined before doing so.

- Execution and planning & scheduling resources should have to work close together, and it is suggested that they report to the same management line.

- All engineering and technical expertise should be developed into the technical department, as it is at the moment for inspection of stationary equipment, in order to support all other departments, such as:
  - Reliability engineering and related techniques such as RCM, RBI, RCA, …
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- Rotating equipment inspection and condition monitoring tasks, in close relationship with first level monitoring tasks that have to be performed close to maintenance and operation organisations.
- Instruments and all other equipment that require specific expertise.
- Contracting strategies

✓ Again, before doing so, a review of existing and required skills have to be established by concerned managers, which might lead to some changes in the present distribution of responsibilities in the plant.
✓ Process flow charts like the one in place for work requests and work orders, in which WHAT TO DO and WHO MUST DO will make much more comprehensive various maintenance process such as:
  - Maintenance and inspection strategies assessment process.
  - Procurement process.
  - Spare parts stock level definition.
  - Reporting.
  - Budget assessment and cost control.
✓ These flow charts will make also easier the establishment of job descriptions and related responsibilities at least for key players in the process.

Conclusions

The initial objectives of the research project have been successfully achieved and several recommendations has been made in previous section. However, the recommendations proposed in this report cannot be exhaustive because of certain limitation of available data which span from 2000 to 2008. Many other improvement areas would have to be identified by the project team during the preliminary development of the project and further implementation.

On the other hand, some of these recommendations might be found to be unnecessary or are currently been implemented, or incompatible with other present objectives in Ras Lanuf.

Whatever the project scope will be at the end of the development phase of the project, the most important thing is to move up, step by step to the culture of continuous improvement cycle were key points are motivation, communication and team work. The management of such changes require time as well as arrange steps by “The order of priorities, in order of importance”.

As mentioned previously, inevitably, an adequate (CMMS) software must be chosen from the best worldwide practice in order to implement the improvement in the current maintenance management system in Ras Lanuf.

In summary, after careful analysis for the most suitable (CMMS) programs available for the Oil and Gas sector, I strongly recommend to select one or more of these software packages:
- **TabWare** package, “ASSETPOINT” company, USA.
- **MA CMMS** package, “Maintenance Assistant” company, Canada.
- **Siemens CMMS** package, “Siemens” company, Germany.
In fact, many expertise and experience in maintenance management and project management consultancy and training firms would really be enthusiastic in being involved in the development and in the implementation of the whole project. Apart from that, our open mind people in Ras Lanuf Oil and Gas Company are confident in their ability to break through these performance steps.

REFERENCES


Improvement of the Maintenance Management system in a Petrochemical Complex and Reducing the Costs


تحسين نظام إدارة الصيانة في مجمع بترول كيماويات وتخفيف التكاليف

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ملخص البحث

هذا البحث عبارة عن مسح وتحليل تم إجراؤه في مصنع معالجة النفط والغاز. ويشمل ذلك مجموعة متنوعة من البيانات حول برامج الصيانة مثل الإصلاح الشامل للوحدات الإنتاجية (عمليات التحويل) والصيانة الدورية والصيانة التصحيحية الطارئة. وقد دمجت المعلومات الواردة في هذا المشروع النتائج والبيانات من أجل تحسين نظام إدارة الصيانة في مصنع معالجة النفط والغاز. ولتحقيق هدف تقليل النفقات وبالتالي زيادة الأرباح. وتم بعد ذلك تحليل البيانات ونتائج مسح المصنح بنقية للوصول إلى توصيات مهمة تنطبق على معظم منشآت البترول كيماويات.

الكلمات المفتاحية: الإدارة، الإنتاج، المصانع، الصيانة، التكاليف

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