realistically assess plant and rotating equipment conditions when combined with cost, repair time and statistical events. Monte Carlo model is very helpful for considering approximate operating conditions in a plant including cost effectiveness and sizing to provide protection for short duration failures.

The study was carried out in Eleme petrochemical refinery, Rivers State Nigeria. In carrying out this research secondary data was used in this study, because secondary data involves using already existing data. Existing data collected was summarized and collated to increase the overall efficiency.

Data for the replacement and reliability analysis of the rotating equipment was obtained from failure history of the compressor system of a refinery plant in Eleme petrochemical company utilizing the reliability models established. Failure data was collected from Eleme petrochemical company for reliability analysis in the compressor system of their rotating equipment. First, secondary data were collected from the operational logs, maintenance records and historical data.

To satisfy this point, the components failure rates was extracted from a refinery plant in Eleme petrochemical plant in equipment availability.

Some of the components have high reliability and failure rarely happens. These data include the number of tested units, number of failures and duration for a number of items such as bearing, cylinder, piston, rings, and crank shaft.

2.1 Analytical Methods and Tools.

Mathematical Language of Reliability: The following approaches were used in resolving the analysis of compressor components using reliability tools and techniques

i. Start reliability improvement program with simple arithmetic and spreadsheets to quantify important cost and failure numbers.
ii. Gaining momentum with good maintenance practices will improve team work using total productive maintenance program such as root cause analysis to efficiently solve problems.
iii. The application on improvement of program by using statistics to quantify the results.
iv. Application of Monte Carlo model to simulate generator engine components availability, reliability, maintainability, capability and life cycle costing for deciding reliability strategies.

2.2 Analytical Methods.

The mathematical model for this research was established by considering five years study interval (SI) as well as the number of failures (NF) and the corrective time per failure (CTPE) (Pedregal *et al.*, 2004)

$$\lambda = \frac{number\ \ of\ failures}{number\ \ of\ unittested\ \ x\ durati\ on\ of\ test} \quad (3.1)$$

$$\text{MTTF} = \frac{1}{\lambda} \quad (3.2)$$

$$(MTBF) = \frac{SI}{NF} \quad (3.3)$$

TMTBF = $\frac{Annual\ \ hours\ per\ year}{Total\ failures\ \ per\ year}\frac{AHPy}{TFPy}$ (3.4)

FR = $\frac{1}{MTBF} = \frac{1}{SI/_{NF}} = \frac{NF}{SI}$ (3.5)

$(FR)_A = (\frac{1}{MTBF})_A = (\frac{NF}{SI})_A$ (3.6)

TFR = $[(FR)_A + (FR)_B + (FR)_C + (FR)_D + (FR)_E]$ (3.7)

FPY = (FR) (AHPy) (3.8)

FPy = $(\frac{NF}{SI})$ (AHPy) (3.9) FPY = $(\frac{1}{MTBF})\ |AHPy|$ (3.10)

TFPy=$\sum(FPy)A+\sum(FPy)B + \sum(FPy)C + \sum(FPy)D + \sum(FPY)E$ (3.11)

2.3 Reliability, Unreliability and Availability Model.

Reliability Model.

To determine the Compressor component's reliability (CCR) the equation used is expressed mathematically as (Pedregal *et al.*, 2004):

$CCR = e^{-}(\frac{1}{MTBF})\ xt$ (3.12)

$BR = e^{-}(\frac{1}{MTBF})_A + (\frac{1}{MTBF})_B + (\frac{1}{MTBF})_C + (\frac{1}{MTBF})_D + (\frac{1}{MTBF})_E\ xt$ (3.13)

$BU = 1 - e^{-\left(\frac{1}{MTBF}\right)T\ xt}$ (3.14)

2.4 Availability Model.

To determine the compressor components availability (CCA) we have (Yang & Hong, 2013):

$CCAV\ \frac{MeanTimeBetweenFailure\ \ -lostti\ \mathrm{m}eperyear}{MeanTimeBetweenFailure}$ (3.15)

2.5 Model for Production Time and Capacity of Refinery Plant.

$Q = PCxPT$ (3.16)

3. `RESULTS AND DISCUSSION.

3.1 Results.

This result shows the calculations involved in the reliability analysis of the compressor components performance in the refinery plant. It also includes the outcome of the calculated operating time of the study equipment, the outcome of calculated mean time between failure (MTBF) of the component of the compressor, the summary of the calculated failure rate of different compressor components, the presented calculated total failure for five years, the calculated down time of the different components. Also, the summary of the calculated, reliability, unreliability, availability and unavailability is presented and discussed.

3.2 Computational Data and Reliability Analysis for Bearing Component.

The bearing component of a rotatory equipment (compressor) of the refinery plant was found to be one of the equipment with normal breakdown. Appendix 1 shows the data amassed for the bearing for a length of five-years (study length) which blanketed the failure rate per year, operating time per week and restore time to restore every breakdown per year. Appendix 2 indicates the calculation for the reliability parameters as proven in Figure 4.1

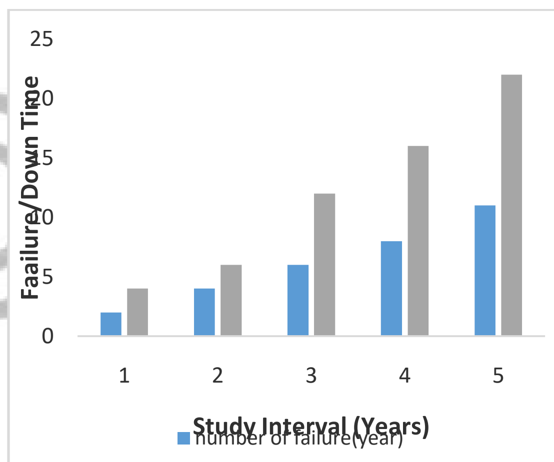

Figure 1: Number of Failure/Year and Downtime (DT) against the year.

The evaluation of the study in Figure 4.1 indicates that in production because the year will increase, the number of failures for the bearing component was found to be gradually increasing from the first year (2015) till fifth year (2020). Figure 4.1shows that the down time was additionally increasing with the failure rate from the first year after which gradually increasing till the fifth year. The break down because of this equal component additionally affected the production potential for those five years.

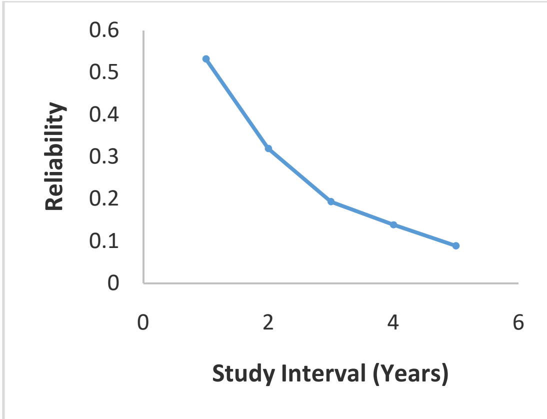

Figure 2: Reliability against the Study Interval (5 years).

The research of the reliability from Figure 4.2 of the bearing component within the compressor within the refinery plant as graphically represented indicates that the reliability was reducing sharply. This was found as from between the first year and second year, there was a pointy drop within the reliability curve, from 0.5325 to 0.3197 after which it persisted at some stage in the five-year length.

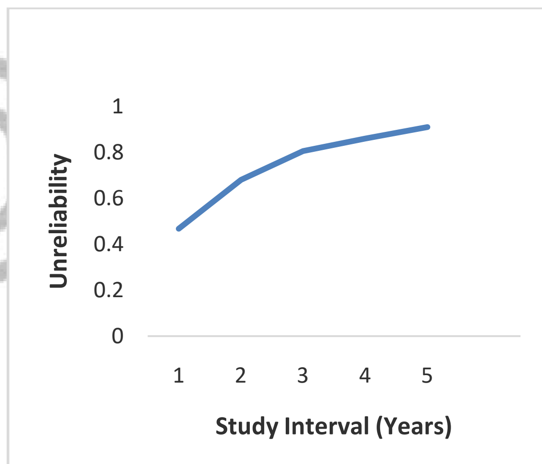

Figure 3: Unreliability against the Study Interval (5 years).

The unreliability graph indicates an opposite impact from the reliability graph as visible on Figure 4.3. This indicates that because the year will increase, the bearing component within the compressor have become much less dependable because of normal breakdown and maintenance.

3.3 Computational Data and Reliability Analysis for Cylinder Component.

The compressor cylinder upon research confirmed that for the five-year length, there had been a general upward push within the downtime and failure rate every year as may be observed on Figure 4.4. The computational values for the reliability evaluation had been received with the use of Monte Carlo approach for the cylinder component as calculated in Appendix 2.

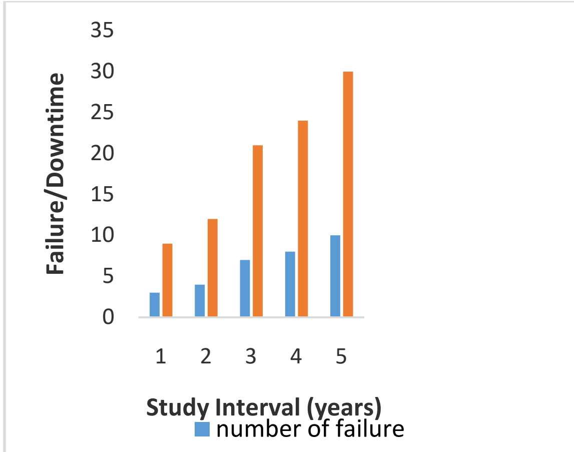

Figure 4: Number of Failure/Downtime against Study Intervals (years).

From Figure 4.4, it was found that there was an increase within the failure rate and downtime over the length of five years equal as was found within the bearing component. The cylinder had greater downtime than the bearing as it takes as a minimum 24 hours to restore a damaged cylinder; for this reason, the downtime time steadily will increase for the whole five-year length.

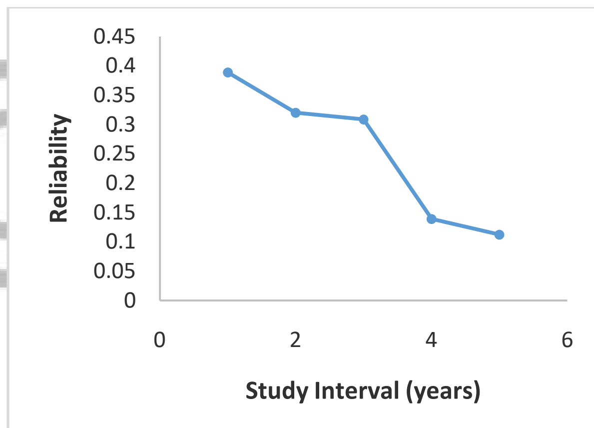

Figure 5: Reliability Analysis of the compressor cylinder for a 5 Year Period.

There was a pointy reduction in reliability in Figure 4.5 and an increase in Figure 4.6 (unreliability) as in case of the bearing component. The reliability was reducing from 0.3886 to 0.1513 because the failure rate was increasing, whilst the unreliability was increasing. This indicates that the compressor cylinder was becoming much less dependable every year because of normal breakdown and restores, and occasional reliability from the primary year to the fifth year means that there was low maintenance exercise within the company.

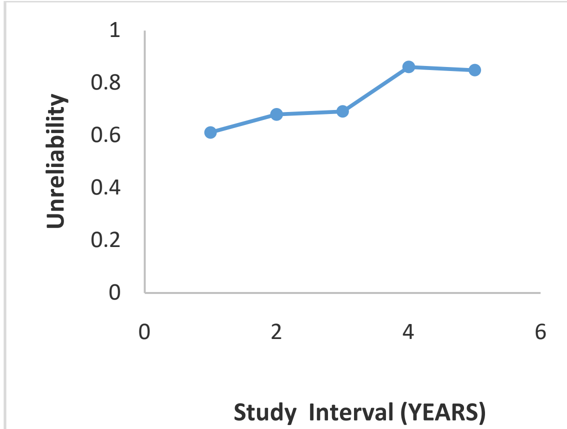

Figure 6: Unreliability Analysis of the Compressor cylinder for a 5 Year Period.

Looking on Appendix 2 from the computational cylinder values, it was found that there was a reduction within the uptime (operating time) from the first to the fifth year. Also reducing every year is the mean time between failure, whilst the down time (DT) will increase from the first to the fifth year. There was additionally an increase within the failure rate shape from the first to the fifth year. Subsequently, from the study a bar chart was used to expose the connection between the variety of years against the variety of failure and downtime received.

3.4 Computational Data and Reliability Analysis for compressor piston Component.

The compressor piston upon research confirmed that for the five-year length, there had been a general upward push within the downtime and failure rate every year as may be observed on Figure 4.7. The computational values for the reliability evaluation had been received with the use of Monte Carlo approach for the piston component as calculated in Appendix 2.

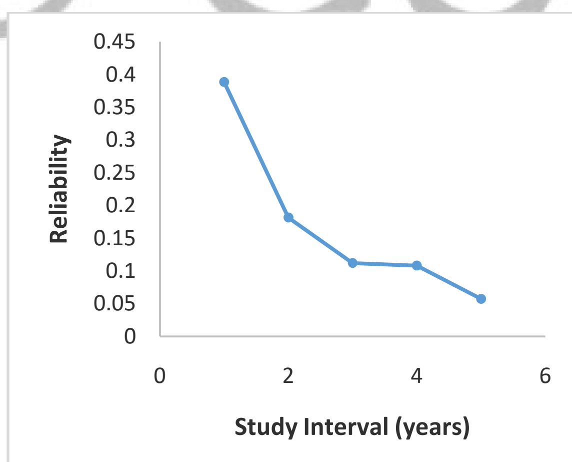

Figure 7: Reliability Analysis of the Compressor Piston for a 5 Year Period.

There was a pointy reduction in reliability in Figure 4.7 and an increase in Figure 4.8 (unreliability) as in case of the bearing and cylinder component. The reliability was reducing from 38.86% to 5.72% because the failure rate was increasing, whilst the unreliability was increasing. This indicates that the compressor piston was becoming much less dependable every year because of normal breakdown and restores. Also, the low reliability shows that there may be low maintenance exercise within the corporation as time progresses.

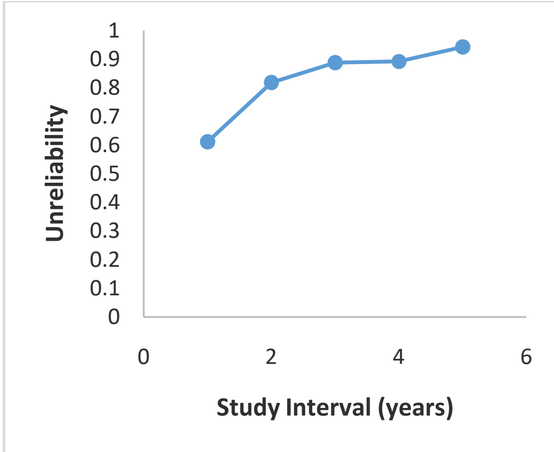

Figure 8: Unreliability Analysis of the compressor piston for a 5 Year Period.

Looking at Appendix 2 from the computational compressor piston values, it was found that there may be a reduction within the uptime (operating time) from the first to the fifth year. Also reducing every year is the mean time between failure, whilst the down time (DT) will increase from the first to the fifth year. There was additionally an increase within the failure rate shape from the first to the fifth year. Also, it was found that there was an increase within the failure rate and downtime over the length of five years equal as was found within the bearing component and compressor cylinder. This piston had greater downtime than the bearing as it takes as a minimum 24 hours to restore a damaged piston; for this reason, the downtime time steadily will increase for the whole five-year length.

3.5 Computational Data and Reliability Analysis for compressor Rings Component.

The compressor rings upon research confirmed that for the five-year length, there had been a general upward push within the downtime and failure rate every year as may be observed in Figure 4.9. The computational values for the reliability evaluation had been received with the use of Monte Carlo approach for the rings component as calculated in Appendix 2.

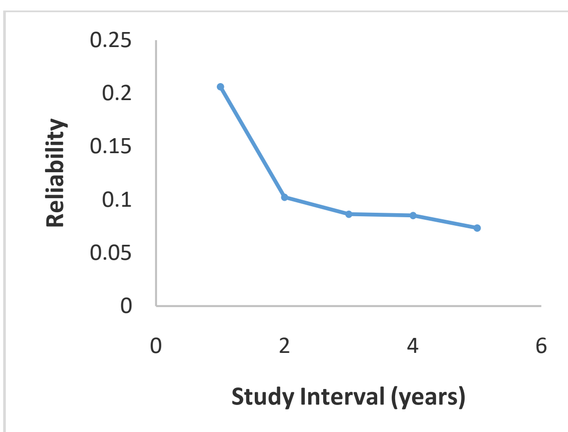

Figure 9: Reliability Analysis of the Compressor Rings for a 5 Year Period.

There is a pointy reduction in reliability in Figure 4.9 and an increase in Figure 4.10 (unreliability) as in case of the bearing and piston component. The reliability was reducing from 20.63% to 7.34% because the failure rate was increasing, whilst the unreliability was increasing. This indicates that the compressor rings had been much less dependable every year because of normal breakdown and restores. The reliability of the rings reduces notably from the primary year as evaluate to the compressor bearing and cylinder, this indicates that there were bad maintenance practices in the company.

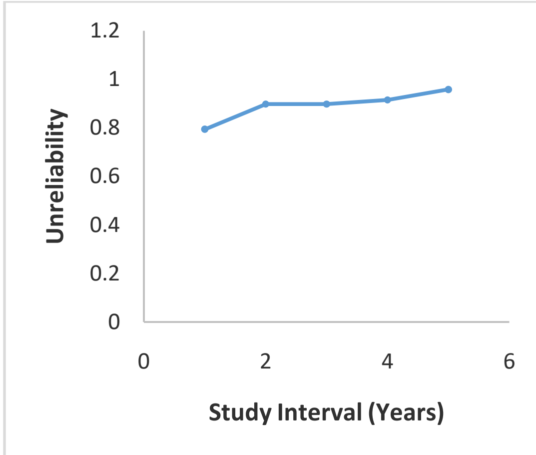

Figure 10: Unreliability Analysis of the compressor Rings for a 5 Year Period.

Looking at Appendix 2 from the computational compressor rings values, it was found that there may be a reduction within the uptime (operating time) from the first to the fifth year. Also reducing every year is the mean time between failures, whilst the down time (DT) will increase from the first to the fifth year. There was additionally an increase within the failure rate shape from the first to the fifth year. Also, it was found that there was an increase within the failure rate and downtime over the length of five years equal as was found within the bearing, cylinder and compressor piston component. These rings have greater downtime than the piston as it takes as a minimum 24 hours to restore a damaged ring; for this reason, the downtime time steadily will increase for the whole five-year length.

3.6 Computational Data and Reliability Analysis for Crank shaft Component.

The compressor crank shaft upon research confirmed that for the five-year length, there had been a general upward push within the downtime and failure rate every year as may be observed on Figure 4.11. The computational values for the reliability evaluation had been received with the use of Monte Carlo approach for the rings component as calculated in Appendix 2.

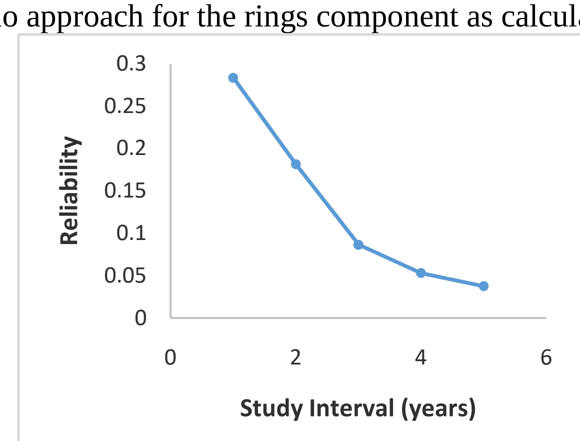

Figure 11: reliability Analysis of the compressor Crank Shaft for a 5 Year Period.

There was an excessive reduction in reliability in Figure 4.11 and an increase in Figure 4.12 (unreliability) as in case of the compressor rings and piston component. The reliability was reducing from 28.36% to 3.75% because the failure rate was increasing, whilst the unreliability was increasing. This indicates that the compressor crank shaft was becoming much less dependable every year because of normal breakdown and restores. Also, there may be a bad indication of bad maintenance exercise due to the reducing of reliability from the primary year to the fifth year. This was a clear indication for the corporation to alternate their maintenance approach.

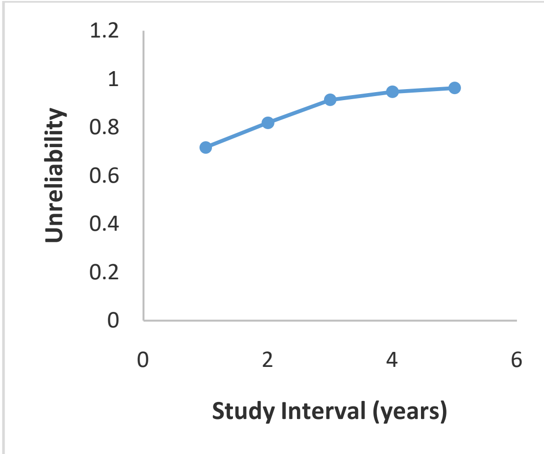

Figure 12: unreliability Analysis of the compressor Crank Shaft for a 5 Year Period.

Looking on Appendix 2 from the computational compressor crank shaft values, it was found that there was a reduction within the uptime (operating time) from the first to the fifth year. Also, reducing every year is the mean time between failure, whilst the down time (DT) will increase from the first to the fifth year. There was additionally an increase within the failure rate from the first to the fifth year. Also, it was found that there was an increase within the failure rate and downtime over the length of five-years equal as was found within the bearing, cylinder compressor piston and rings component. Conversely, the mean time between failure was found to be reducing because the operating time (uptime) was reduced every year as observed on Appendix 2. The Crank Shaft had greater downtime than the piston as it takes as a minimum 24 hours to restore a damaged crank shaft; for this reason, the downtime time steadily will increase for the whole five-year length.

3.7 Production Capacity of Refinery Plant for five-year Period.

The production capacity from the company records are shown in the figure 4.13. The production capacity, quantity of petroleum produced and the production time for a 5-year period.

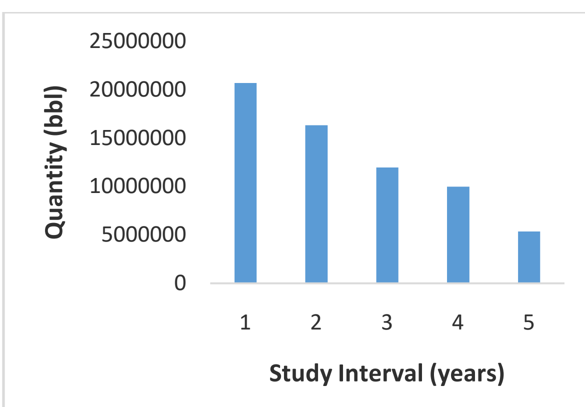

Figure 13: Production Capacity of Petroleum Produce.

From the figure 4.13 it observed that the steady downtime obtained by these various compressor components over the years has affected the production rate of the plant. From the first year, the production capacity has its maximum operating time which produced about 20,730,000bbl of fuel. The decrease started to occur as a result of the downtime experienced by the compressor which led to 5,356,800bbl of fuel produced in the 5th year as shown in Appendix 1. Also, from Figure 4.13 the consequences of the frequent breakdown of bearing. Cylinder, piston, rings and crank shaft has caused the refinery plant to drop to less than 50% production capacity within a 5-year period from 2015 to 2020.

4. CONCLUSIONS

This research was carried out principally on rotating equipment of refinery plant, which the compressor system failure component of bearing, cylinder, piston, rings and crank shaft during operation for a 5-year period. This investigation shows that these failures of the components either breakdown or fails during production after operating for several hours over a period of time running into years, if components of bearing cylinder, piston, rings and crank shaft are not properly maintained or reformed, the propensity of influencing the production capacity destructively can occur.

These components include bearing, cylinder, piston, rings and crank shaft as considered in this study. The Monte Carlo method was used for the successful evaluation of the reliability analysis of the compressor components. The method was effectively used to evaluate the reliability of the compressor failure components during operation and production. The Monte Carlo analysis was used to evaluate parameters such as the mean time between failure, failure rate, reliability, unreliability, availability and unavailability for each component as shown in Appendix 1 and Appendix 2 respectively.

From the research work, it was also observed that the failure and break down of these components affected the operation capacity over these 5-year period at which the capacity decreases as the year increases and the components become less reliable. In all these, we can conclude that the reliability of compressor component was carried out successfully and that the failure components are factors to operation capacity which must be critically looked into to enhance productivity. In evaluating the reliability of compressor components such as the bearing, cylinder, piston, rings and crank shaft, some functional parameters such as the uptime, study interval, downtime, meantime between failures, reliability and unreliability were determined. It shows that the reliability of these components was decreasing as the year increases giving rise to decrease in production of fuel for the 5-year study interval.

The study recommends that;

The compressor components should be readily available for replacement in the storeroom to reduce the downtime in a year as well as to enhance productivity

Management of refineries has to invest in time, money and resources for a successful implementation of good maintenance strategies.

Marching maintenance strategies with the world best is a continuous process and it takes years to realize the benefits, the firms should therefore not lose hope but to find the maintenance practices that are beneficial to their firms. There should continuous review and improve the maintenance strategies to help the firms compete in the market.

Personnel should be assigned and be made responsible for setting up this procedure. The various sub-processes of the MREMS procedure should be handled by different individuals or departments for better performance.

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