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Impact of Total Quality Maintenance Parts on The Operation of Electric Motor in Thermal Desorption Unit

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Abstract

Thermal desorption Unit been a vital equipment with complex applications in the sections of waste and minerals treatments, suffers intensively in the managerial section as a whole. This paves a way towards the aim of this research work which covers the type of the impact of Total Quality maintenance electric motor parts on the Operation of the Thermal Desorption Unit [TDUs] using that of the Halden Nigeria Limited, located within Port Harcourt zones of Nigeria as a case study. In this research work Microsoft Excel version 2019 was used as the data analyses tool, and the descriptive plots are mainly bar charts for easier presentation and interpretation of results. Various methods used in this work are mainly mathematical evaluations and quality models developed as management evaluation models satisfactory to the achievements of the various determinable variables for the evaluation of the impact of Total Quality Maintenance of electric motor parts on the Operation of the Thermal Desorption Unit [TDUs]. The calculated values of the system Mean Time to Failure (MTTF) and Mean Time between Failures (MTBF) have a significant impact on the reliability of the systems under study (TDUs), Failure Rate (δ), Repair Rate (φ), Availability (A), Mean Time to Repair (MTTR), Cost Implementation, Reliability of Equipment [ROE] determined respectively as the total evaluations of the 3-4-3 sub-units of the TDU, correlatively to other none calculative factors which are independent to the calculative variables but still control the reliability of the system as a driving force of the calculative variables. Via the results and graphical descriptions it was noticed that the Electric Motor [EM] over the studied period of six years [2016-2021] with a total running time in operation of 52560 *hours and mean time between failures of 4043.0769 hours, has the highest MTBF which shows a better reliability index, when compared to the Air lock system [AL] and Solenoid Motor [SM] units of the TDUs, stands so clearly defined that the unit has higher life expanses and so cannot be easily malfunctioned or get spoiled when utilized as compared to the AL and SM units also in the case of mean repair rate[φ], Electric Motor [EM] within same studied period has the mean repair rate[φ] of 336 failure/hours, which is the highest [φ] when compared, this still makes it a better quality unit of the TDUs that has less tendency of getting damaged during used.*

Key words: Electric motor, impact, maintenance parts, operation, thermal desorption unit, total quality.

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INTRODUCTION

Total Quality Management (TQM) is a term that originated in the 1950s and has become a worldwide topic in the twenty-first century which has its roots partly in the USA and partly in Japan. TQM is an improvement of the traditional way of doing business which is a proven technique to guarantee survival in world competition [1-5]. The goal of Total Quality Management (TQM) is long-term success via quality and employee participation. "Total" refers to quality management involving the entire organization [6]. By satisfying the standards that customers desire, the term "quality" is linked to their level of satisfaction [7]. According to its definition, Total Quality Management (TQM) is a management strategy that aims to attain and maintain long-term organizational performance by valuing and encouraging employee input and participation, meeting customer demands and expectations, adhering to legal requirements and regulations, and honoring society views and values [8–9].

The foundation of an organization that never stops improving is both a philosophy and a set of driving justifications [10–11]. In order to increase customer happiness and organizational performance, this management concept seeks to continuously improve a product, service, and process improvement by concentrating on the requirements and expectations of the customer [12]. It aims to achieve system effectiveness in terms of production, design, planning, quality tools, techniques, and customer satisfaction because it can boost firm effectiveness and increase customer satisfaction in addition to bolstering competitiveness [13–14].

Complete quality management is a representation of the mindset, personality, and organization of a business that aims to offer goods and services that satisfy consumers. Quality in the organization's operations is necessary for total quality management, as is the avoidance of operational waste and the execution of activities correctly the first time [15].

Defect identification and prevention are aspects of TQM. Under TQM, quality control is a continuous process as opposed to the typical practice of focusing on fault discovery through inspection after the product is completed, which leads to waste and rework. TQM concentrates on comprehending the root causes of issues and looks for the most cost-effective way to lessen or eradicate their effects [16–17]. Waste can be seen as an inefficiency or flaw in a process that causes a business to perform poorly in terms of the environment.

Waste Management works toward the reduction and reuse of all resources [18]. By encouraging the reduction of energy consumption, water conservation, the purchase of reused products, reduce its environmental impact and operating costs. The oil and gas business manages waste streams produced during drilling operations in accordance with the most recent laws and globally recognized standards. The emphasis on waste minimization as a means of preventing trash creation is a significant advancement in waste management [19–20]. To maintain high standards of quality in the oil business, waste management techniques must be taken into account. Reduction, reuse, and efficient waste management are the goals of waste management utilizing Thermal Desorption Units (TDU) in the oil and gas waste management system [21].

A reclamation technique called a Thermal Desorption Unit (TDU) is used to extract hydrocarbons from different kinds of materials. It recovers oil and other materials by using high heat and non-contact, non-incineration technology. By heating the contaminated material, TDU is frequently used to treat organic compounds like oil-bearing material from refineries. Low boiling point contamination forces the substance to evaporate, creating a vapor that can be collected and processed in an off-gas treatment unit [22–26]. Contaminated material can be reused without risk of contamination if the waste is removed.

TQM is used in the oil and gas waste management industry to improve environmental performance by eliminating waste or reducing its impact [27-30]. This research is being carried out to analyze the impact of TQM on the operation of the TDU in the oil and gas waste management industry [31-34].

MATERIALS AND METHODS

Materials

Due to the great relevancy of the research focus, which is majorly on the management scale of a Thermal Desorption Unit [TDU], case study of the Halden Nigeria Limited, whose vitally points towards large economic importance in sections of waste treatments, multiple materials were applied in this section of research aiming at determining the various means which could be applied on evaluating the impact of the total management scale on the operations of the Thermal Desorption Unit [TDU], the materials used include: Data from the Thermal Desorption Unit of Halden Nigeria Limited and Data Analyses Tool.

Data from the thermal desorption units of halden nigeria limited

Halden Nigeria Limited is an oil and gas exploration service company located at plot 229 Trans Amadi industrial layout, phase two behind Sasun hotel, port Harcourt, the company cultured on providing qualitative services to their clients through the use of cutting-edge technology and highly skilled professionals. The engineering design branch of Halden Nigeria Limited is responsible for conceptual and detailed design in the following areas: plumbing, civil/structural, process, electrical, and instrumentation. It also carries a variety of as-built documentations related to flow stations, manifolds, and NAG gas collection systems. Another important and crucial division of the Halden corporation is Waste Management. As a waste management company, they have set up a procedure for cleaning equipment, such as tanks, boats, skips, etc., that uses recycling, reusing, and reducing techniques to get the work done efficiently while little altering the initial amount of garbage.

Within the period of six years [2016 - 2021], their round up data was recorded and seek for, under grants and conditions of the company aiming at helping the successfulness of this research work having seen its importance towards the company and technological growth / development in sections of the desorption units.

From the Halden Nigeria Limited, the following data were obtained and tabulated as follows.

Table 1. Description of Thermal Desorption Unit of Halden Nigeria Limited for a period of 6 years [2016 - 2021]

S/n	Description	Cost ($)	Date of installation	Date of failure	Year of Failure						No of failure	
					2016	*2017*	*2018*	*2019*	*2020*	*2021*		
	Electric Motor TS BABE	253 400 480	17/06/2016 13/08/2018 04/04/2020	31/08/2018 04/04/2020 03/11/2021							532	2s 4s 3s

Where, TS =Toshima, BA =Baldor Reliance R and BE =Berkeley

The above data were obtained with a high level of reliability factor based on their percentile accuracy which was classified 100% by the Manager of Waste Manager of Halden Nigeria Limited.

This data was used to ascertain the Failure Stands Probability [FSPs] of the Halden Nigeria Limited correlatively to other relative factors placed on great considerations due to their supportive or auxiliary control of the system as a determinant and in dependable factor to the management of the Thermal desorption Unit of Halden Nigeria Limited.

Data analyses tool

Data analyses tools are computerized tools used to evaluate or describe the performance of a system placed under study via plots, charts and pictograms, with respect to the quarry data queued into the computer as the operative controllable domains representing the studied system.

In this research work the data analyses tool used is Microsoft Excel version 2019, and the descriptive plots are mainly bar charts for easier presentation and interpretation of results.

Methods

The various methods used in this work are mainly mathematical evaluations and quality models developed as management evaluation models satisfactory to the achievements of the various determinable variables for the evaluation of the impact of Total Quality Maintenance electric parts on the Operation of the Thermal Desorption Unit [TDU] using Halden Nigeria Limited TDUs utility as a case study referenced to their data.

The fundamental methods applied in this research aiming at attaining to the satisfactory bases of the research objectives and aims are Development of Management Evaluation Models, Data grouping and Management Evaluation Models.

Management evaluation models are reliability models designed or developed to be used in ascertaining the reliability of the TDU in this research work.

The reliability of the studied system such as that of the Halden Nigeria Limited units TDU, greatly depends on the calculative value of the system Mean Time to Failure (MTTF), Mean Time between Failures (MTBF), Failure Rate (δ), Repair Rate (φ), Availability (A), Mean Time to Repair (MTTR), Cost Implementation, Reliability of Equipment [ROE] (Meeker & Escobar, 2008), correlatively to other none calculative factors which are independent to the calculative variables but still control the reliability of the system as a driving force of the calculative variables. Owing to the data collected from the Halden Nigeria Limited described in Table 1, the models will go a long way in evaluating the impact of the Total Quality Maintenance of electric parts on the Operation of the Thermal Desorption Unit TDU using Halden Nigeria Limited TDU.

Mean time to failure (MTTF)

The mean time of failure of a system can be simply referred to as the time required for a system or operational unit of equipment to fail in its act of operation due to one or more inappropriate factor of the system. MTTF can be used in studying the impact of the quality management of any system, in TDU, it is the measure of the total time in operation of the TDUs such as that used by the Halden Nigeria Limited to the total number of failures or breakdowns recorded within a specific studied period of time.

$$\mathrm{MTTF} = \frac{\sum t_1}{n} \quad (1)$$

Where, $\sum t_1$ = the total running time in operation of the TDU during an investigation period for both failed and non-failed items, n = number of failures breakdowns of TDU or its parts taking place during a certain investigation period and MTTF is used for non-reparable parts or subsystems in the TDU.

Mean time between failures (MTBF)

This refers to the average time between a proper operation scale of a system or unit to the abnormal operation time, which is commonly known as the unit failure time, and is estimated by the total time in operation of the TDU and its subsystems used by the Halden Nigeria Limited divided by the total number of failures or breakdowns recorded with a specific investigation period.

$$\mathrm{MTBF} = \frac{\sum t_1}{n} \quad (2)$$

Where, $\sum t_1$ = the total running time in operation of the TDUs during an investigation period for both failed and non-failed items. n = number of failures (breakdowns) of TDU or its parts occurring during a certain investigation period and MTBF is used for non-reparable parts or subsystems in the vehicles.

Failure rate (δ)

This refers to the breakdown or degradation level over time of an operating system or unit of equipment. It is the reciprocal of the Mean Time Between Failure [MTBF] as a function of an industrial operating unit, mathematically it is defined as:

$$\delta = \frac{1}{\mathrm{MTBF}} = \frac{n}{\sum t_1} \quad (3)$$

Where, $\sum t_1$ = the total running time in operation of the TDU during an investigation period for both failed and non-failed items, n = number of failures (breakdowns) of TDU or its parts occurring during a certain investigation period.

Mean time to repair (MTTR)

Mean time to repair (MTTR) refers to the time taken to put back to place spoiled or malfunctioning equipment aiming at improving the performance of the tool utility section. Mean time to repair can also be referred to as an equipment maintenance time which is the time between when the malfunctioning or spoiled equipment is placed under repairs to when the repair is been done and equipment returns to its functionality bases. In this one must consider that the longer it takes or the higher the value of the MTTR the reduction in the functionality or activeness of the industry using the tool over production scale.

Mathematically, mean time to repair can be referred to as the ratio of the total accumulative time of TDU or parts to repair or maintain in statistical time to the number of repair or maintenance actions in the TDU during the allotted investigation time period.

$$MTTR = \frac{\text{total maintenance time}}{\text{number of repairs}}$$

$$MTTR = \frac{\sum t_1}{N} \quad (4)$$

Where, t_1 = total accumulative time of TDU or its parts to repair or maintain in statistical timen = number of repair actions in the population of TDU during the specified investigation time period

Availability

Availability as implied in this research is the degree of activeness and proper functionality of an operating unit. It is not just for the equipment or unit to be there but for it to function when used for a given set of production. The availability measure is used for TDUs when failure consequences only lead to economic losses. (Han & Yamei, 2007). The “availability” of a device is, mathematically stated as:

$$A = \frac{MTBF}{(MTBF+MTTR)}$$

$$A = \frac{T_o}{T_o+T_1} \quad (5)$$

Where, T_o, = Time that TDU works and T_1 = time that TDU do not work, include repair and maintenance time.

Repair rate (φ)

This is the reciprocal of the mean time to repair, and it demonstrates the time taking to re-install a malfunction tool or equipment stated mathematically as:

$$\varphi = \frac{1}{MTTR} \quad (3.5)$$

Where, MTTR = Mean time to repair

RESULTS AND DISCUSSION

Results

This section of the research focus on the evaluation of the gathered data discussed in materials and methods of same research work relatively to the narrated mathematical models displayed as equations 1, 2, 3, 4 and 5 referenced to Meeker & Escobar, 2008, for the determination of the quality management of the operation of the thermal desorption units of Halden Nigeria Limited, based on three TDUs put into service in the period [2016-2021], the Electric Motor [EM] which has been in service without exceeds of its useful life forecast with 3 components respectively.

Also, the section discussed and present the plots outlined from the data analyses tool used i.e, Microsoft excel, numbered as figures, as a validation towards the aim and objectives of the research work as large.

The total studied period of six (6) years was placed or considered for the study, hence;

$$\sum t_f = 6\, years \times 365 days \times 24\, hours = 52560\, hours$$

$\sum t_f =$ can be referred to as the total up time of study which as well can be referred to as the total running time in operation of the TDUs during an investigation period for both failed and non-failed items.

N = n = the total number of failures of each component within the studied period of time, And MT = the total maintenance time of three units as 2 weeks

$$= 2 \times 14 \times 24 = 3360\, hours$$

Table 2. below shows the summarized and arranged form of Table 1, to be used for easier evaluations and determinations of the active parameters that to be used in assessing the impact of total quality maintenance of electric parts on the operation of the thermal desorption units.

Table 2. TDU' Operational Parameters.

TDUs	Total operating time[n] in hr	Total maintenance time [MT] in hr	Total number of failures/repairs
Electric Motor [EM]	52560	3360	10

Determination of the TDUs' mean time between failures (MTBF):

Considering the model at equation 3.1

$$\text{MTBF} = \frac{\sum t_f}{n}$$

Where: $\sum t_f =$ the total running time in operation of the TDUs during an investigation period for both failed and non-failed items/total up time, n = number of failures (breakdowns) of TDU or its parts occurring during a certain investigation period.

Substituting the values obtained from the operational parameters in Table 2, we have respective for each component of the three units as follows:

For Electric Motor [EM]

Electric Motor [EM] for the year 2016

- $(MTBF)_{TS}^1$ =No failure, $(MTBF)_{BA}^1$ =No failure and $(MTBF)_{BE}^1$ =No failure

Electric Motor [EM] for the year 2017

- $(MTBF)_{TS}^2$ =No failure, $(MTBF)_{BA}^2$=No failure and $(MTBF)_{BE}^2$ =No failure

Electric Motor [EM] for the year 2018

- TS component MTBF (2018) = $\frac{\sum t_f}{n} = \frac{52560\text{hours}}{5\text{ failures/breakdowns}}$ =10512 hours/failure (breakdown)
- $(MTBF)_{BA}^3$=No failure, $(MTBF)_{BE}^3$ =No failure

Electric Motor [EM] for the year 2019

- $(MTBF)_{TS}^4$ =No failure, $(MTBF)_{BA}^4$=No failure and $(MTBF)_{BE}^4$ =No failure

Electric Motor [EM] for the year 2020

- $(MTBF)_{TS}{}^{5}$ =No failure
- BA component MTBF (2020) = $\frac{\sum t_f}{n} = \frac{52560\text{hours}}{3\text{ failures/breakdowns}}$ =17520 hours/failure (breakdown)
- $(MTBF)_{BE}{}^{5}$ =No failure

Electric Motor [EM] for the year 2021

- $(MTBF)_{TS}{}^{6}$ =No failure and $(MTBF)_{BA}{}^{6}$=No failure
- BE component MTBF (2021) = $\frac{\sum t_f}{n} = \frac{52560\text{hours}}{2\text{ failures/breakdowns}}$ =26280 hours/failure (breakdown)

MTBF For Electric Motor [EM]

- TS component MTBF (2018) = $\frac{\sum t_f}{n} = \frac{52560\text{hours}}{5\text{ failures/breakdowns}}$ =10512 hours/failure (breakdown)
- BA component MTBF (2020) = $\frac{\sum t_f}{n} = \frac{52560\text{hours}}{3\text{ failures/breakdowns}}$ =17520 hours/failure (breakdown)
- BE component MTBF (2021) = $\frac{\sum t_f}{n} = \frac{52560\text{hours}}{2\text{ failures/breakdowns}}$ =26280 hours/failure (breakdown)
- Total MTBF = $\frac{\sum t_f}{n} = \frac{52560\text{hours}}{10\text{ failures/breakdowns}}$ =5256 hours/failure (breakdown)

Determination of The Tdus' Mena Time To Repair (MTTR):

- For the determination of the Mean time to repair (MTTR) we use equation (2),
- MTTR = $\frac{\sum t_I}{MT}$
- Where, $\sum t_f$ = the total running time in operation of the TDUs during an investigation period for both failed and non-failed items/total up time.
- MT = the total maintenance time of three units as 2 weeks
- $= 2 \times 14 \times 24 = 3360\ hours$

Substituting the values obtained from the operational parameters in Table 2, we have respective for each component of the three units as follows:

For Electric Motor [EM]

- TS component MTTR = $\frac{\sum t_f}{MT} = \frac{3360\text{hours}}{5\text{ failures/breakdowns}}$ =10512 hours/failure (breakdown)
- BA component MTTR = $\frac{\sum t_f}{MT} = \frac{3360\text{hours}}{3\text{ failures/breakdowns}}$ =17520 hours/failure (breakdown)
- BE component MTTR = $\frac{\sum t_f}{MT} = \frac{3360\text{hours}}{2\text{ failures/breakdowns}}$ =26280 hours/failure (breakdown)
- Total MTTR = $\frac{\sum t_f}{MT} = \frac{3360\text{ hours}}{10\text{ repairs/ma int enance}}$ = 336 hours/repair (maintenance).

Determination of the TDUs' Mean failure rate (δ):

For the determination of Mean failure rate (δ) equation (3.3) is applied as follows,

$$\delta = \frac{1}{MTBF} = \frac{n}{\sum t_f}\ \text{failure/hour}$$

Where, $\sum t_f$ = the total running time in operation of the TDUs during an investigation period for both failed and non-failed items/total up time.

n = number of failures (breakdowns) of TDU or its parts occurring during a certain investigation period.

Substituting the values obtained from the operational parameters in Table 2, we have respective for each component of the three units as follows:

For Electric Motor [EM]

- TS component $\delta = \frac{1}{\text{TS component MTBF}} = \frac{1}{10512} = 9.5129 \times 10^{-5}$ failure/hour
- BA component $\delta = \frac{1}{\text{BA component MTBF}} = \frac{1}{17520} = 5.7078 \times 10^{-5}$ failure/hour
- BE component $\delta = \frac{1}{\text{BE component MTBF}} = \frac{1}{26280} = 3.8052 \times 10^{-5}$ failure/hour
- Total component δ of EM $= \frac{1}{\text{Total component MTBF of EM}} = \frac{1}{5256} = 0.0001903$ failure/hour

Determination of the TDUs Mean repair rate (φ):

For determination of the Mean Repair rate (φ) equation (3) has been used as follows,

$$\varphi = \frac{1}{\text{MTTR}}$$

where: MTTR = Mean time to repair

Substituting the values obtained from the operational parameters in Table 2, we have respective for each component of the three units as follows:

For Electric Motor [EM]

- TS component $\varphi = \frac{1}{\text{TS component MTTR}} = \frac{1}{10512} = 9.5129 \times 10^{-5}$ failure/hour
- BA component $\varphi = \frac{1}{\text{BA component MTTR}} = \frac{1}{17520} = 5.7078 \times 10^{-5}$ failure/hour
- BE component $\varphi = \frac{1}{\text{BE component MTTR}} = \frac{1}{26280} = 3.8052 \times 10^{-5}$ failure/hour
- Total component φ of EM $= \frac{1}{\text{Total component MTTR of EM}} = \frac{1}{336} = 0.002976$ repaire/hour

Determination of the TDUs Availability (A):

For the determination of the unit availability equation (5) needs to be carefully applied as follows.

$$A = \frac{\text{MTBF}}{(\text{MTBF+MTTR})}$$

Substituting the values of the mean time between failures (MTBF) Mena time to repair (MTTR) obtained from the previously evaluated variables, we have:

For Electric Motor [EM]

$$A = \frac{5256}{5256+336}$$

$$A = 0.9399$$

Plots and Discussion

Using the data in Table 3 which are the Total mean time between failures (MTBF) Mena time to repair (MTTR), for ALs SMs and Ems over the six years studying of the Halden Nigeria Limited operations of their Thermal Desorption Units [TDUs], plots and discussions with respect to the plots were developed as correspondent to the nature of the evaluated values which initially calculated using multiple models stated with reference at chapter three of this research work, using Microsoft excel as the simulation analytic tool for accurate plots

Table 3. Operational Reliability Indices for the TDUs in Halden Nigeria Limited.

TDUs	MTBF [h/failure]	MTTR [h/repair]	δ x10^{-3}[failure.h	φ x 10^{-3}[failure.h	A
Electric Motor [EM]	5256	336	0. 1903	0.02976	0.9399

Plot of mean time between failure (MTBF) against TDUs units

Figure 1 plot shows the comparison of Electric Motor [EM] over the studied period of six years [2016-2021] with a total running time in operation of the TDUs as 52560 hours and mean time between failures of 4043.0769 hours, has the highest MTBF which shows a better reliability index when compared to the AL and SM units of the TDUs.

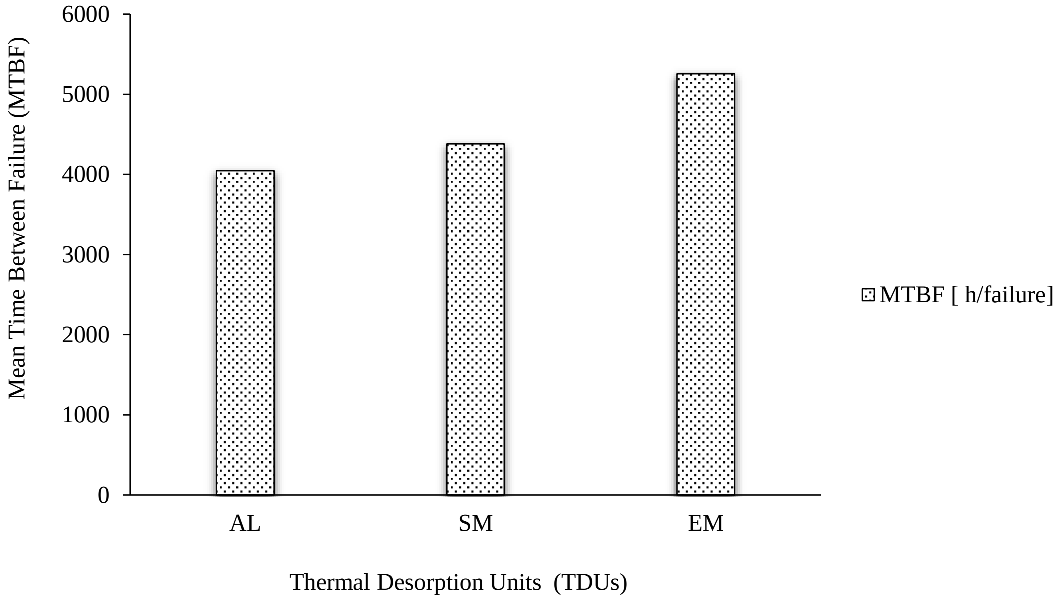

Figure 1. Comparison of TDUs of electric motor against mean time between failure (MTBF).

Plot of mean time to repair (MTTR) against TDUs units

Figure 2 plot shows the Electric Motor [EM] over the studied period of six years [2016-2021] with a total running time in operation of the TDUs as 52560 hours and Mean Time to Repair (MTTR) of 336 h/repair, has the highest [MTTR] which shows a better reliability index when compared to the AL and SM units of the TDUs in the stands of ease to repair when malfunctioned.

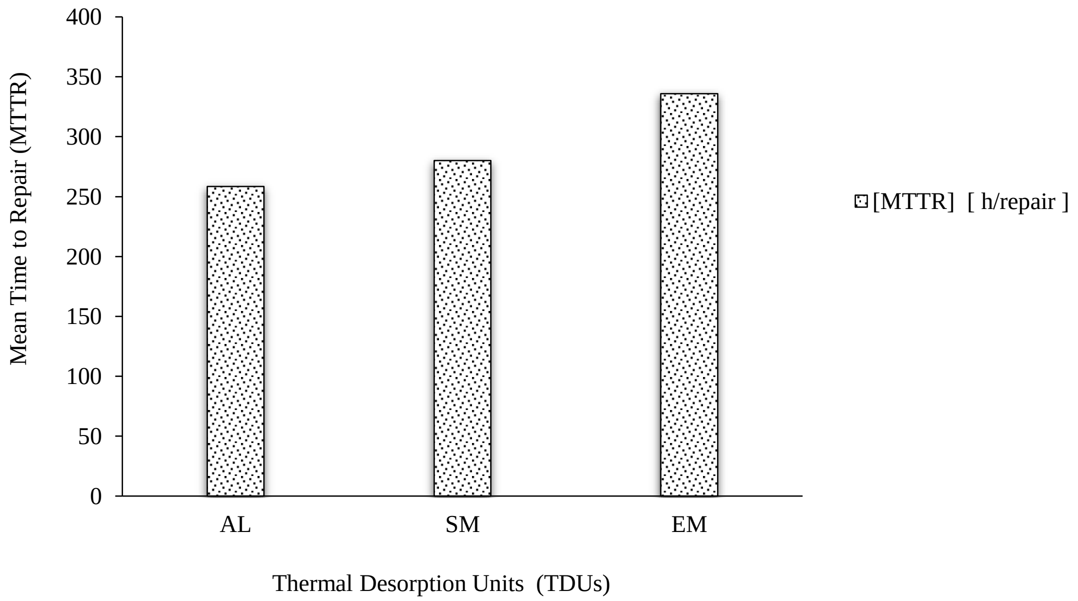

Figure 2. Comparison of TDUs’ of electric motor against mean time to repair (MTTR).

Plot of mean time between failure (MTBF) against TDUs units

Figure 3 plot shows that the Air Lock System [AL] over the studied period of six years [2016-2021] with a total running time in operation of the TDUs as 52560 hours and the highest failure rate of 0.4273 failure/hours, has the highest Failure count per year which shows a that is not reliable under reliability index when compared to the SM and EM units of the TDUs.

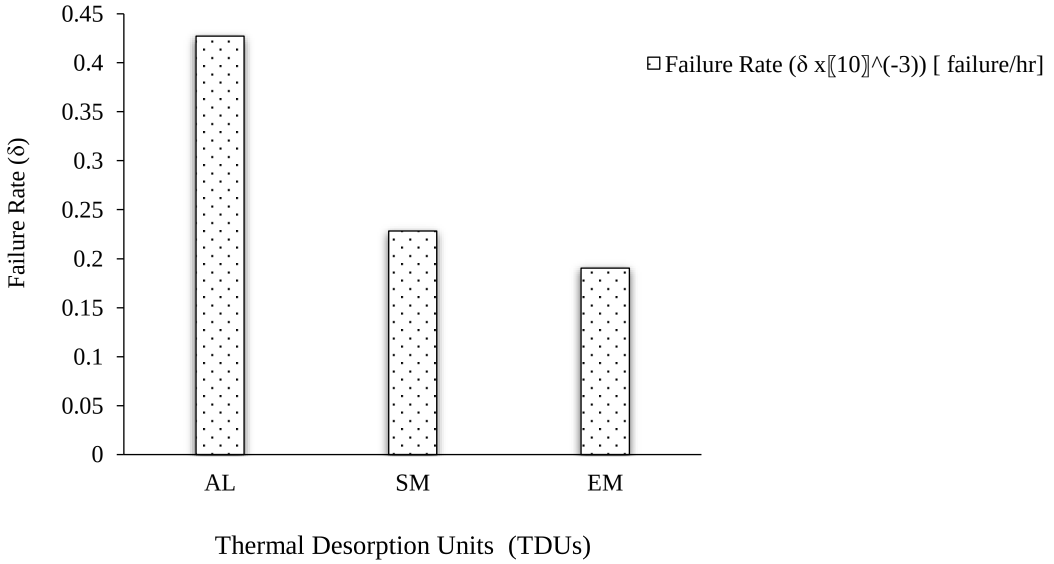

Figure 3. TDUs' failure rate.

Plot of mean repair rate (φ) against TDUs units

Figure 4 plot shows that the Electric Motor [EM] over the studied period of six years [2016-2021] with a total running time in operation of the TDUs as 52560 hours and mean repair rate [φ] of 0.02976 failure/hours, has the lowest φ which shows that it will not easily gets spoiled when used , hence will require the lest repair rate as compared making it a better reliability index when compared to the AL and SM units of the TDUs in the stands of ease to repair when malfunctioned.

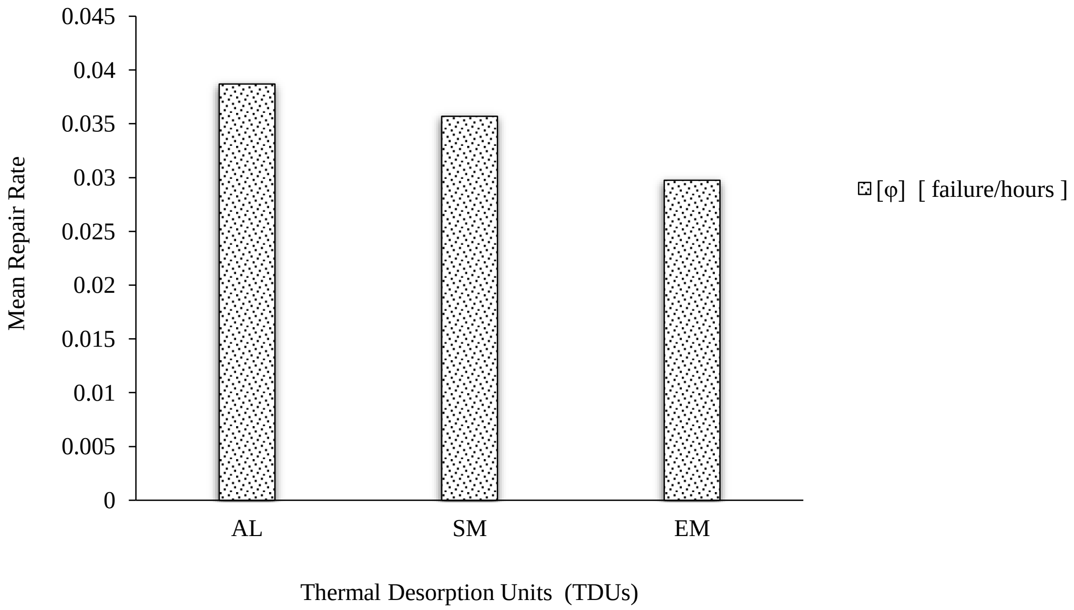

Figure 4. TDUs' mean repair rate (φ).

CONCLUSION

In totality of the entire research work with cooperativeness to the data evaluations and plots, it can be concluded that the Electric Motor (EM) although the three been listed are the active controllers or units of the Thermal Desorption Unit [TDU], appears to be of deferent Mean time between failures (MTBF), Mean time between to repair (MTTR), Mean failure rate of repair (ɉ), Mean rate of repair (μ) and the Proper functioning probability (availability) (A) values which can be describes as follows;

In stands of the MTBF, the Electric Motor [EM] over the studied period of six years [2016-2021] with a total running time in operation of the TDUs as 52560 hours and mean time between failures of 4043.0769 hours, has the highest MTBF which shows a better reliability index when compared to the AL and SM units of the TDUs making it so cleared to be said that the unit has higher life expanses and so cannot be easily malfunction or get spoiled when utilized as compared to the AL and SM units also in the case of mean repair rate[φ], Electric Motor [EM] withen same studied period has the mean repair rate[φ] of 336 failure/hours, which is the highest [φ] when compared, this still makes it a better quality unit of the TDUs that has less tendency of getting damaged during used .

So, in all, from the research, the AL requires more concentration in management to avoid failure of use of the thermal desorption unit as a whole due to unit failure as explained in Figure 3.

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