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Reliability Analysis of Air-Condition Failure Modes in Ministry of Works and Housing Borno State, Nigeria.

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ABSTRACT

The Work Involves the Examination of the Possible Failure Modes/Causes that occur in a Air-condition for safety of operation, time and routine maintenance. The failure modes/causes constitute the total failure of a Air-condition which if identified and eliminated will ensure high level of reliability, availability and efficiency of the system. The methodology employed the identification of significant few and insignificant many Air-condition failures using Pareto analysis in capturing the failure modes, which help in determining which of these modes/causes, have an overriding importance in terms of frequency of occurrence and extent of possible damage, it is also crucial in reliability assessment. Field failure data were collected from Ministry of Works and Housing Borno State Maintenance Handbook in 198 a period at which full maintenance documentation was up to date. The Pareto chart was then plotted using line-column in two axis Microsoft Excel spreadsheet. The result indicates that attending to Compressor, Gasket leakage, Thermostat, Motor and blower, Condenser, Evaporator coil, Capacitor, Blown fuse and burn contact ***failures will lead to reliability increase. Hazard and probability plots were made which shows the mean time before failure MTBF of*** $\mu = 48.554$ ***hours. They indicate the distribution of failure time to be exponential with a failure rate of*** $\lambda = 0.0202[hr]^{-1}$.

INTRODUCTION

The probability that a component part, equipment, or system will satisfactorily perform its intended function under given circumstances, such as environmental conditions, limitations as to operating time, and frequency and thoroughness of maintenance for a specified period of time is known as reliability (http://www.Answer.com.). Reliability being an inherent characteristic of a product has to be designed into the product in the first place. However, complete information to achieve optimal designed reliability may not be available until the component or system has been put into field use. The performance in the field can be fed back into the design stage and the cycle goes on. The condition of use and maintenance also has a bearing on the performance of the item. Air-condition units were installed at various locations within the Ministry of works and Housing in Borno State to aid in providing a condusive working environment within the Ministry are prone to probabilistic failures at any time.

This work, reliability analysis of Air-conditions, constitutes a partial survey of some of the common and more elementary methods in reliability engineering analysis. A Pareto chart is created using frequency of failure modes and cumulative percentage arranged in descending order. 80% of the failure modes to the left of the Pareto chart are the significant few failure modes. The factors that lead to failures do not impact on the process at the same degree. It is therefore necessary to determine the factors that impact most on reliability and determine control measures to be adopted in order to reduce their effect.

METHOD

The work involves collection of failure data of Air-conditions by going through the Ministry of Works and Housing Borno State Maintenance Handbook for 1987 to identify the most common types of failure. As a first step in reliability data analysis we use the Pareto principle of' significant few' and the 'insignificant many' to analyze and also calculate the reliability of the Air-condition (O'Connor, 2002). The significant few account for about 70% to 90% of the failures. Pareto analysis uses the principle that problem solvers should focus on 20% of factor causing 80% of the problem instead of the 80% factors causing 20% of the problems. It is also called the 80/20 rule (Leavengood and Reebs, 2002). In other words, it can also be stated that by doing 20% of work you can generate 80% of the advantage of doing the entire research (Mindtools Ltd, 2007). This principle was named after Vilfredo Pareto, an Italian sociologist and economist in the 19th century who observed that 80% of Italy's wealth was owned by 20% of the population (Strickland, 2006). This methodology has been employed in the design and optimization of industrial processes (Haaland, 1989).

From the failure frequencies the reliability of the Air-condition is evaluated. We then use the failure time to determine failure distribution using Hazard probability plots which helped in arriving at the mean time before failure MTBF μ and the failure rate λ.

The hazard is calculated as follows: (O'Connor, P. D. T, 2002)

a. Sort and rank the N failure times from shortest to longest failure time. Note that the hazard can accommodate data where the time may be a censoring time rather than a failure time (i.e., the unit was taken out of service before it failed).

b. Calculate a hazard value at each of the failure times. Note that the hazard is only calculated at failure times, not censoring times. The hazard is 100.0* 1/(K) (O'Connor, P. D. T, 2002), where K is the reversed ranking of the failure time. This expresses the hazard as a percentage. You can express the hazard as a proportion by omitting the multiplication by 100.

c. The cumulative hazard is the cumulative sum of the hazard. That is, the cumulative hazards at the failure time with reverse rank K. See Table 1.

Theory of hazard plotting

By definition reliability is the probability of a component or system to perform its designated function under specific condition of maintenance and time satisfactorily.

$R(t)=l-F(t)$ or $F(t)=l-R(t)$ 1

Now the hazard function $\lambda(t) = f(t) / F(t)$ 2

Inserting the value of F(t) from equation 1 into equation 2

$\lambda(t)=f(t)/[l-R(t)]$ 3

$\lambda(t) = \{1/[1- R(t)]\}.\frac{dR(t).R(0)}{dt(t)} = 1$ 4

and

$R(t) = 1 - F(t) = \exp\{-\int_0^1 \lambda(t)dt\}$ 5

$H(t) = \int_0^1 \lambda(t)dt$ 6

Therefore,

$H(t) = -\ln[1-F(t)]$ 7

The relationship in equation 7 is utilized to derive a special paper with the graph of "t" versus H(t) plot as a straight line on a given hazard paper of the distribution.

Exponential distribution

The exponential distribution of time to failure is given by:

$F(t) = 1 - e^t$ it follows that

$H(t) = \lambda t$ and $t(H) = l/\lambda t$ 8

Therefore, time to failure is a linear function of the cumulative hazard. The line passes through the origin and its slope is $1/\lambda$ which is the mean to failure. The advantage of hazard function theory is that when special hazard paper are not availably we can use any linear , log linear, or log - log graph paper to plot sample data; and also the theoretical relationships to estimate the parameter of the distribution.

ANALYSIS

From the real life failure data that has been collected which relate to only about Nine Hundred and Seventy Seven (977) cases where failure has caused damage to the Air-condition were selected. The principle of Pareto analysis is employed to determine which of these failure modes and causes have the overriding importance in terms of frequency of occurrence and extent of possible damage. Frequency distribution is used to determine the frequencies of failure for each of the failure modes.

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Table 1 (data collected) gives the summary of the failure modes/faults and cases collected as field data. In order to apply the Pareto principle, the data was arranged in descending order of occurrence. The relative and cumulative frequencies of each of the failure modes were calculated. It is observed that the significant few cases of the Pareto analysis principle contribute almost 80% i.e. the first eight (8) components of the total failure of the Air-condition. A sample calculation of relative frequency of Compressor failure is given as:
Total number failures of 977.

Frequency of Compressor failure = 140
Relative frequency of Compressor failure
$= (^{140}/_{977})x100 = 14.33\%$

The cumulative frequency was used to show the combined effect of the significant few failures leading to the failure of the Air-condition. This was carried out by adding the relative frequency of each type of failure to the sum of all preceding relative frequencies.

Table 1: Failures of Air-Condition Arranged in Descending Order With Relative and Cumulative Frequencies.

S/NO	Faults/Failures	FREQ. OF FAULTS	R.FEQ	R. FREQ (%)	CUMUL.FREQ(%)	R(I)
1	Compressor	140	0.14	14.33	14.33	0.86
2	Gas leakage	120	0.12	12.28	26.61	0.88
3	Thermostat	104	0.11	10.64	37.26	0.89
4	Motor and blower	90	0.09	9.21	46.47	0.91
5	Condenser	85	0.09	8.70	55.17	0.91
6	Evaporator coil	80	0.08	8.19	63.36	0.92
7	Capacitor	72	0.07	7.37	70.73	0.93
8	Blown fise and burned contact	65	0.07	6.65	77.38	0.93
9	Compression and expansison valve	55	0.06	5.63	83.01	0.94
10	Thermal overload and over change	45	0.05	4.61	87.62	0.95
11	Circuit breaker	38	0.04	3.89	91.50	0.96
12	Damper and grilles	32	0.03	3.28	94.78	0.97
13	Control circuit	28	0.03	2.87	97.65	0.97
14	Switch and start relay	15	0.02	1.54	99.18	0.98
15	Capillary tube	8	0.01	0.82	100.00	0.99
		977	1	100		0.35

Using line-column in two-axis of Microsoft Excel spreadsheet, the Pareto chart Figure 1 below was plotted based on the data of Table 1. The line plot and bar graph represent the cumulative failure frequency curve and frequency of failures respectively. In Figure 1 the 80% line was traced to intercept the cumulative frequency curve. Compressor, Gasket leakage, Thermostat, Motor and blower, Condenser, Evaporator coil, Capacitor, Blown fuse and burn contact are the significant few failures that need to be attended to. Solving these failure events, will lead to the following failure reduction in the Air-condition system,

Percentage of failure events that require attention

$$\left(\frac{\text{Few failure that required attention}}{\text{Total failures}}\right) \text{ x } 100$$

$$\frac{756}{977} \text{ x } 100 = 77.\ 0\%$$

A total of 977 failure case were recorded, hence relative frequency of compressor failure is 140/977 = 0.143 and reliability R_1 is 1-0.14 = 0.856.

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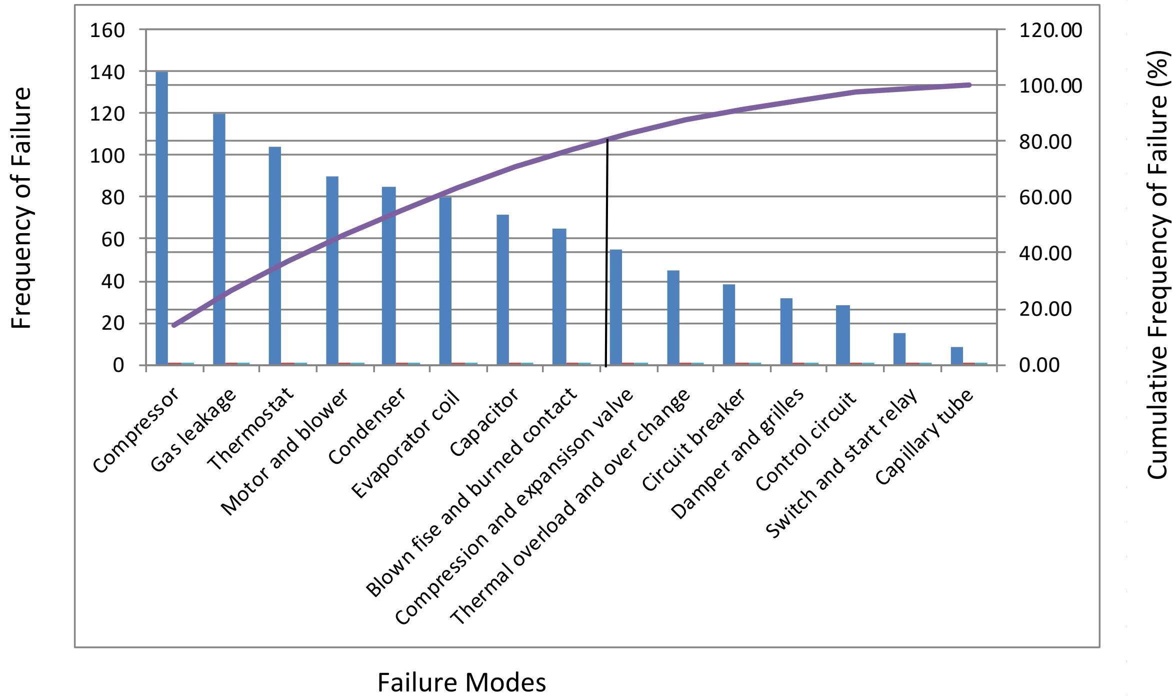

Figure 1: Pareto Chart of Air-Condition Failure Data

The reliability of the system is
$R_s(t) = R_1 \times R_2 \times R_3 \ldots\ldots\ldots R_{15} = 0.35$

From Table 1 the reliability of the Air-condition system is 0.35.
Therefore,

Unreliability = 1 - 0.35 = 0.65

The improvement due to the application of the Pareto analysis is the product of the percentage of failures that require attention and unreliability, this is given as:

0.77X0.65 = 0.50

Thus, attending to Compressor, Gasket leakage, Thermostat, Motor and blower, Condenser, Evaporator coil, Capacitor, Blown fuse and burn contact, in the Air-condition failure will lead to unreliability reduction of 0.52. This fraction reduction of unreliability will lead to the same fraction increase in reliability, thus the Air-condition reliability becomes:

0.35+0.50=0.85

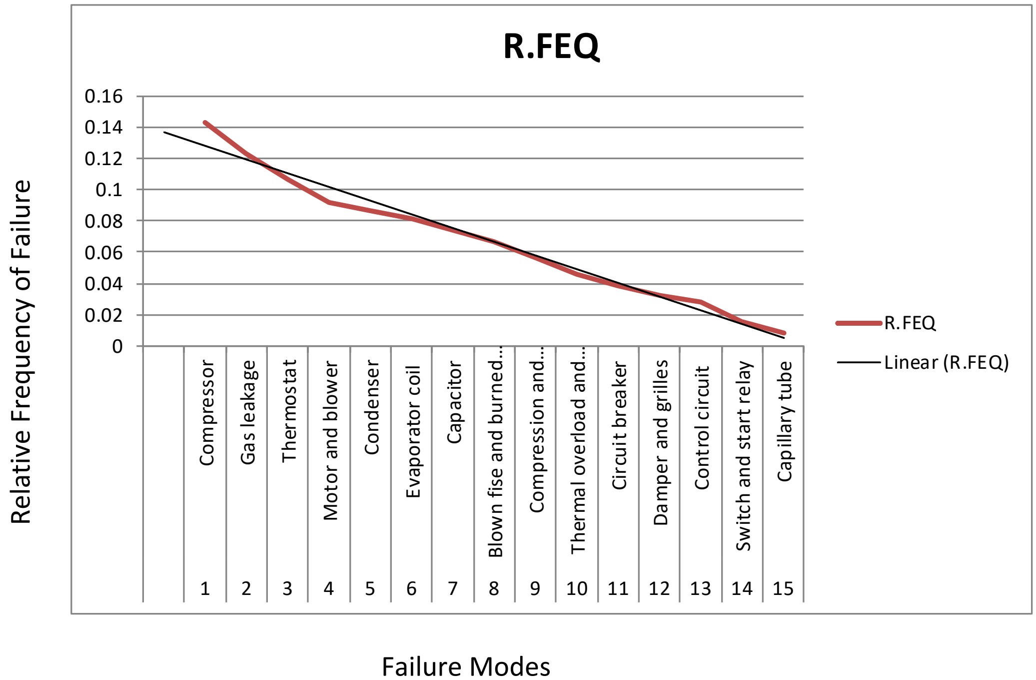

Figure 2: Relative Frequencies of Air-condition Failure Mode

Table 2: Hazard Calculation for Failure Time

Hours (T)	Reversed (K)	Hazard (100/K)	Cumulative Hazard (H)
128	91	1.1	1.1
184	86	1.2	2.3
217	82	1.2	3.5
283	78	1.3	4.8
443	69	1.4	6.2
581	66	1.5	7.7
800	56	1.8	9.4
919	53	1.9	11.3
1067	47	2.1	13.5
9972	42	2.4	15.8
1403	34	2.9	18.8
1585	31	3.2	22.0
1968	22	4.5	26.6

Figure 3 below shows the plot on a linear graph paper of the Cumulative Hazard Function (H) with failure time in hours (T). The straight line approximates the hazard function indicating that the distribution of the failure data is exponential.

This result is also shown in figure 2 above. The slope is 48.07 hours which implies that:-

a. The mean time before failure (MTBF) is given by:
MTBF = $\mu = \frac{1}{\lambda} = 49.554$ hence λ the failure rate is 1/49.554 = 0.0202/hour.

b. The intercept 48.07 hours the failure free life (life of intrinsic reliability).

Thus $R_{(t)} = e^{-0.0202t}$
The regression equation shows that:
Intercept is 48.07 and the slope is 49.554, r is 0.992 while r^2 is 0.98

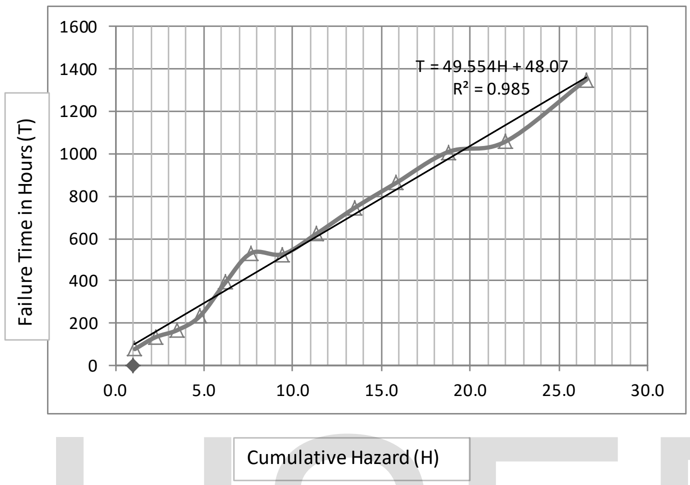

Figure 3: Plot of Cumulative Hazard Function with Time to Failure

RESULTS AND DISCUSION

The Pareto analysis indicates which failure modes / causes occur most frequently and at which location and the likely affected part or component. The hazard and or probability plotting techniques assist in determining the underlying failure distribution (exponential) and the failure rate. The results of such analysis help in arriving at the design modification and or maintenance strategy that would be employed for the component of the Air-condition particularly the significant few. It also assists in deciding the maintenance culture that would be adopted, thus the maintenance team become well equipped with the information necessary to determine optimal maintenance strategy.

The reliability of the Air-condition system at its present operating condition was calculated to be 0.35 and elimination of the identified significant failures will result in reliability increase to 0.87. The failure distribution turned out to be exponential with a constant failure rate λ of 0.0202/hour which is often referred to as memory less. This indicates that the remaining life of the Air-condition system is independent of its current age. Hence for the Air-condition to maintain such a high level of reliability, the maintenance term must strictly adhere to preventive maintenance strategy.

CONCLUSION

A Pareto analysis has been successfully applied to failures that lead to Air-conditions system failure in Ministry of Works and Housing. The Pareto analysis generated from the frequency and cumulative frequency of failures, focuses attention on the significant few failures that when solved result in remarkable increase in Air-condition reliability. The analysis shows that the elimination of failure of Compressor, Gasket leakage, Thermostat, Motor and blower, Condenser, Evaporator coil, Capacitor, Blown fuse and burn contact will lead to having reliability increase from 0.35 to 0.87. Thus maintaining such a high level of reliability requires a consistent application of preventive maintenance plan.
The following details of the Air-condition make/type/rating and location of service could not be provided in this paper because the Ministry considers them as information that should not be made public.

REFERENCES

Haaland, P. D., 1989. Experimental Design in Biotechnology. Marcel Decker Inc., New York and Basel

http://www.Answer.com

John Moubray., 2000. The Case against Streamlined RCM http://vvww.rcliabilirywcb.com.

Borno State Ministry of Works and Housing Air conditioning and refrigeration section job card record 1987.

Leavengood, S. and Reebs, 2006 Pareto Analysis and Check Sheets, Oregon State University United State of America. http://www.wood.oest.edu

Mindtools Ltd, 2007. Pareto Analysis, http://www.mindtools.com.

O'Connor, P. D. T., 2002. Practical Reliability Engineering (4th Edition) John Wiley and Sons Ltd, England, http://www.amazon.com pp: 336., *medwelljournals.com*

Strickland, J., 2006. Pareto Analysis in Seven steps. Sevcnrings Limited. United Kingdom, hltp://w wvv.se venrings.co.uk