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Cost Reduction in a Brewery Boiler Operation Using Reliability Centered Maintenance: A Case Study.

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ABSTRACT:
Proper machine maintenance is fundamental towards maximizing profit and reducing the cost of production in a brewery boiler operation. In this study, cost reduction in a brewery operation using reliability centred maintenance (RCM) was analysed for a boiler. A planned cost-effective maintenance management structure according to RCM was developed for this study. The reliability method was employed to analyse the data collected from the maintenance log book of a brewery boiler operation located in Oyo, Akwa-Ibom state of Nigeria, for a period of two year. Results obtained indicate that the boiler perform better when RCM was utilized as the maintenance method when compared to corrective maintenance (CM) which is currently used by the brewery is more cost effectives. The cost analysis carried out indicate that the cost of labour decrease from ₦103,320,000/year to ₦77,280,000/year which is approximately 25.2% decrease in the cost of labour. The result also indicates a 23.6% saving in total downtime cost compared to the current maintenance practice carried out on the boiler. The system reliability increases with decreasing labour cost when RCM was applied. Therefore, RCM should be adopted for the maintenance of the boiler in the brewery plant.

KEYWORDS: Reliability Centered Maintenance, Downtime cost, Boiler, Failure rate, Brewery.

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1. INTRODUCTION:

Maintenance is a major tool used in most production industries for asset management. For the brewery industries, optimizing operating and maintenance cost is a major technique towards improving profitability. The type of maintenance adopted by a manufacturing firm is a major factor in determining the reliability of a production process (Muchiri *et al.*, 2011). Most manufacturing sectors in Nigeria such as: cement manufacturing industry, glass manufacturing industries have adopted reliability centered maintenance (RCM) in their production process. Preliminary studies carried out indicate that of the four major brewery industries in Nigeria (Nigerian brewery, International brewery, Guinness PLC and Champion brewery) only two of these brewery industries have adopted this maintenance practice and are making smart results based on measured mechanical conditions of their plant that indicate when maintenance is needed.
The ultimate goal of any maintenance practice is to provide optimal reliability of the equipment to be used during production (Paul, 2004). According to Smith and Mobley (2007), reliability is the probability or duration of failure-free performance under stated conditions. The purpose of maintenance is to extend equipment life or the mean time to the next failure.

The brewery industry is one of the most important sectors in terms of economic growth within the Nigerian Stock Market. And as such, researchers and manufacturers are focusing on ways of applying reliability analysis in the production chain to increase the productivity and the efficiency of the plant for improved competitiveness with other manufacturing sector. Deciding which maintenance practice to adopt has been a major challenge facing maintenance department of most industries (Iselin, 2015). Thus, the need to adopt a maintenance practice that will increase the reliability of the plant (preventive, predictive or corrective maintenance) which will ultimately lead to low maintenance costs. Therefore, the adoption of RCM is geared not just to predict the mean time to failure (MTTF) of the manufacturing system's component, but to reduce cost of production.

The objectives of this study includes: to apply RCM to reduce cost of maintenance for a brewery boiler operation; to study the operations in a brewery boiler operation process and the functional failures that occurs in the production systems, and to examine the effect of the failure of the boilers on the production system and the suitability of the RCM in determining the failure rate.

RCM is the optimum mix of reactive, time or interval-based, condition-based, and proactive maintenance practices (Alan, 2016). These principal maintenance strategies rather than being applied independently are integrated to take advantage of their respective strengths in order to maximize facility and equipment reliability while minimizing life-cycle costs.

Samuel *et al*. (2018) investigated the breakdown trend in an automated section-forming machine. The machine parts and the working mechanisms were analyzed, with specific focus on methods of processes and procedures of improving reliability. Information utilized includes the steps and procedures to identify critical components of the ISM using failure modes and effects analysis (FMEA) as a tool to achieve optimal and efficient maintenance program using the reliability data of the equipment's functional components. Result obtained indicate that that using the recommended PM program demonstrates evidence of an improvement in the machine's availability, safety, and cost-effectiveness and as such result in an increase in the company's profit margin.

Adhikary *et al.* (2010) analyzed the reliability, maintainability and availability of a 210MW coal fired thermal power plant in India. The power plant system is classified into eight subsystems for categorization of the failures. Analysis of each of the subsystems were conducted by considering 13 years of past failure data. Trend test and serial correlation tests were used to validate the assumption of independent and identical distribution of failure/repair data before they are fitted best with theoretical probability distributions. Result obtained indicate that reliability and maintainability analysis is very much effective in deciding preventive maintenance intervals and also planning and organizing the maintenance program

Taj *et al.* (2017) analyzed the reliability of a single machine subsystem of a cable plant for a period of seven years. Six types of maintenance practices were noted for the subsystem: electrical repair, electronic repair, mechanical repair, thermal repair, minor preventive maintenances and major scheduled preventive maintenances. The subsystems were repaired on normal failures and minor preventive maintenance performed at random, whereas the major preventive maintenances were carried out on scheduled basis. Markov process and regenerative point technique were adopted as the research model. Results obtained indicate a gradual decrease in failure rate.

2. MATERIALS AND METHODS:

The boiler in the brewery facility is selected for RCM analysis. The boiler system delivers hot water and steam which are vital and critical requirements for beer production process as shown in figure 1. Failure data was collected from the log book of the boiler in order to analyze its reliability. Firstly, the data were analyzed, and then arranged according to the subsystems. In the layout of the plant, the fire tube boiler has significant impact on beer production capacity, and as such determines the production output of the plant. Figure 1 shows the different processes involved in brewery production according to Roonie (2006).

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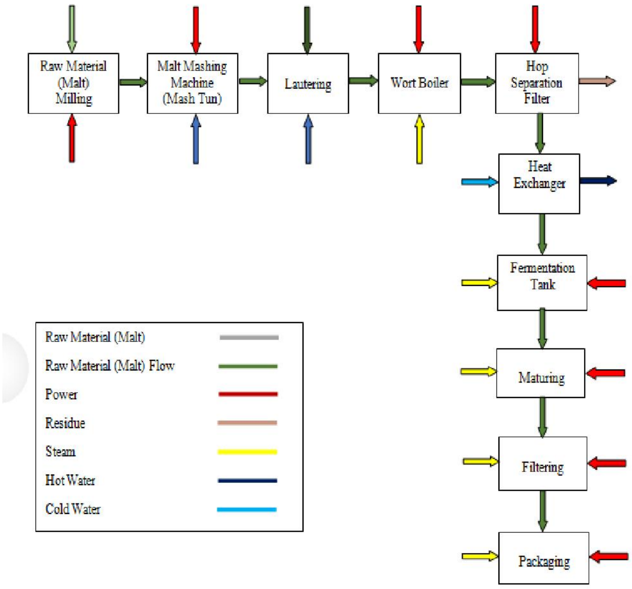

Figure 1: Functional Block Diagram of Brewery System (Roonie, 2006).

The RCM steps adopted for this research are:
Step 1: System selection and data collection.
Step 2: System boundary definition.
Step3: System description and functional block.
Step 4: System function and functional failures.
Step 5: Failure mode effect analysis
Step 6: Logic tree analysis (LTA).
Step 7: Task selection.

These steps describe the systematic approach used to implement and preserve the boiler, identifies failure mode and perform RCM tasks. The boiler failure affects the plant productivity and maintenance cost. Therefore, it is important to identify critical factors that affect selection. These critical factors include:

i. Mean-time between failures (MTBF).
ii. Mean time to repair (MTTR).
iii. Failure Rate
iv. Repair Rate
v. Availability.

The effects of these factors on a plant performance are ascertained using the following relationship:

$$MTBF = \frac{Total\ rnning\ time}{Number\ of\ failures} \quad (1)$$

$$MTTR = \frac{Total\ maintenance\ time}{Number\ of\ repairs} \quad (2)$$

$$Failure\ Rate = \frac{Number\ of\ failures}{Total\ running\ time} \quad (3)$$

$$Repair\ Rate = \frac{Number\ of\ repairs}{Total\ maintenance\ time} \quad (4)$$

$$Availability = \frac{MTBF}{MTBF + MTTR} \quad (5)$$

3. RESULTS AND DISCUSSION:

3.1 The Boiler Failure Data

Table 1 shows the failure modes and their frequencies found from the failure records for 2017 and 2018 for the brewery boiler plant

Table 1: Failure Records of the Boiler Plant

S/N	Failed Component	Number of Failure	Operating Time (hrs)	Down Time (hrs)	Total Available Time (hrs)
1.	Check valve	2	15962	98	16060
2.	Combustion room	7	15632	428	16060
3.	Forced draft fan	2	15998	62	16060
4.	Air Filter	1	16037	23	16060
5.	Furnace	5	15840	220	16060
6.	Fuel system	9	15533	527	16060
7.	Piping system	4	15880	180	16060
8.	Water softener	3	15927	133	16060
9.	Feed water pump	3	15908	152	16060

3.2 Reliability Analysis

For each boiler component,

Total Number of Failures = Total Number of Repairs

Total Available Time in hours

= 365 days/year x 22 hr/day x 2 years
= 16060 hrs

For Check Valve

From equation (1) and using the data presented in Table 1, the MTBF is determined by:

$$MTBF = \frac{Total\ operating\ time\ (hrs)}{Total\ number\ of\ failures}$$

$$MTBF = \frac{15962}{2} = 7981\ \text{hrs/failure}$$

From equation (2) and using the data presented in Table 1, the Mean Time to Repair is determined by:

$$MTTR = \frac{Total\ operating\ time\ (hrs)}{Total\ number\ of\ failures}$$

$$MTTR = \frac{98}{2} = 49\ \text{hrs/repair}$$

From equation (3) and using the data presented in Table 1, the Failure Rate is determined by:

$$\lambda = \frac{1}{MTBF} = \frac{n}{\sum t_1}$$

$$\lambda = \frac{1}{7986} = 0.0001252\ \text{failure/hr.}$$

From equation (4) and using the data presented in Table 1, the Repair Rate is determined by:

$$\lambda = \frac{1}{MTTR} = \frac{1}{49}$$

$$= 0.0204082\ \text{repair/hr.}$$

From equation (5) and using the data presented in Table 1, the Availability is determined by:

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

$$= \frac{7981}{(7981 + 49)} = \frac{7981}{8030}$$

$$= 0.9938979$$

For Combustion Room

From equation (1) and using the data presented in Table 1, The MTBF is determined by:

$$MTBF = \frac{Total\ operating\ time\ (hrs)}{Total\ number\ of\ failures}$$

From equation (2) and using the data presented in Table 1, the MTTR is determined by:

$$MTTR = \frac{Total\ operating\ time\ (hrs)}{Total\ number\ of\ failures}$$

$$MTTR = \frac{428}{7} = 61.14\ \text{hrs/repair}$$

From equation (3) and using the data presented in Table 1, the failure rate is determined by:

$$\lambda = \frac{1}{MTBF} = \frac{n}{\sum t_1}$$

$$\lambda = \frac{1}{2233.14} = 0.000448\ \text{failure/hr.}$$

From equation (4) and using the data presented in Table 1, the repair rate is determined by:

$$\lambda = \frac{1}{MTTR}$$

$$= \frac{1}{61.14} = 0.0163559 repair/hour$$

From equation (5) and using the data presented in Table 1, the availability is determined by:

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

$$A = \frac{2233.14}{2233.14 + 61.14}$$

$$= \frac{2233.14}{2294.28}$$

$$= 0.9733511$$

For Forced Draft Fan

From equation (1) and using the data presented in Table 1, the mean time between failures is determined by:

$$MTBF = \frac{Total\ operating\ time\ (hrs)}{Total\ number\ of\ failures}$$

$$MTBF = \frac{15998}{2}\ hrs/failure$$

From equation (2) and using the data presented in Table 1, the mean time to repair is determined by:

$$MTTR = \frac{Total\ Downtime\ (hrs)}{Total\ number\ of\ Repairs}$$

$$MTTR = \frac{62}{2} = 31\ \text{hrs/repair}$$

From equation (3) and using the data presented in Table 1, the failure rate is determined by:

$$\lambda = \frac{1}{MTBF} = \frac{n}{\sum t_1}$$

$$\lambda = \frac{1}{7999} = 0.0000125\ \text{failure/hr.}$$

From equation (4) and using the data presented in Table 1, the Repair Rate is determined by:

$$\lambda = \frac{1}{MTTR} = \frac{1}{31} = 0.03225\ \text{repair/hr.}$$

From equation (5) and using the data presented in Table 1, the availability is determined by:

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

$$A = \frac{7999}{(7999 + 31)} = \frac{7999}{8030}$$

$$= 0.9961395$$

For Air Filter

From equation (1) and using the data presented in Table 1, the mean time between failures is determined by:

$$MTBF = \frac{Total\ operating\ time\ (hrs)}{Total\ number\ of\ failures}$$

$$MTBF = \frac{16037}{1} = 16037\ \text{hrs/failure}$$

From equation (2) and using the data presented in Table 1, the mean time to repair is determined by:

$$MTTR = \frac{Total\ Downtime\ (hrs)}{Total\ number\ of\ Repairs}$$

$$MTTR = \frac{23}{1} = 23\ \text{hrs/repair}$$

From equation (3) and using the data presented in Table 1, the failure rate is determined by:

$$\lambda = \frac{1}{MTBF} = \frac{n}{\sum t_1}$$

$$\lambda = \frac{1}{16037} = 0.0000624\ \text{failure/hr.}$$

From equation (4) and using the data presented in Table 1, the repair rate is determined by:

$$\lambda = \frac{1}{MTTR} = \frac{1}{23} = 0.0434\ \text{repair/hr.}$$

From equation (5) and using the data presented in Table 1, the availability is determined by:

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

$$A = \frac{16037}{(16037 + 23)} = \frac{16037}{16060}$$

$$= 0.9985679$$

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Similar analysis was carried out for the furnace, fuel system, piping system, water softener, feed water pump and results obtained tabulated in Table 2

Table 2: Reliability Result for the Boiler (2017 - 2018)

S/N	Failed Component	MTBF (hour/failure)	MTTR (hour/repair)	Failure Rate (failure/hour)	Repair Rate (repair/hour)	Availability (%)
1.	Check valve	7981	49	0.000125	0.0204	99.4
2.	Combustion room	2233	61	0.000448	0.0164	97.4
3.	Forced draft fan	7999	31	0.0000125	0.0323	99.6
4.	Air Filter	16037	23	0.0000624	0.0434	99.9
5.	Furnace	3168	44	0.000316	0.0227	98.6
6.	Fuel system	1726	59	0.000579	0.0171	96.7
7.	Piping system	3970	45	0.000252	0.0222	98.9
8.	Water softener	5309	44	0.000188	0.0226	99.2
9.	Feed water pump	5303	51	0.000189	0.0197	99.1

3.2 Maintenance Labour Force

The maintenance labour force is presented in Table 3. This Table shows the size of maintenance labour force calculations for the PM levels (6 months, 1 month and weekly). In addition, the labour saving cost is introduced in Table 4 the cost of labour using RCM ₦103,320,000.00/year decreased with respect to the current values ₦77, 280,000.00/year.

Table 3: The Size of Annual Maintenance Labour Force.

PM Level	Frequency	Duration (Hours)	No. of Workers	Man-hour per PM level
6 months	2	21	4	168
1 month	10	5	2	100
Weekly	50	6.15	1	325

From the cost of labour in Table 4 is observed that if RCM is adopted the cost of labour will reduce by ₦26,040,000 indicating 25.203% reduction of the total amount to be paid to workers for carrying out maintenance on the boiler.

Table 4: Labour Saving Cost.

Item	Labour Type	No. of labourer Per day (current maintenance)	No. of labourers Per day Using RCM
Engineers (₦ 350, 000.00/month)	Mechanical	5	4
	Electrical	5	4
	Control	5	4
Technician (₦ 280, 000.00/month)	Mechanical	6	4
	Electrical	6	4
Total Cost Per year		**103, 320, 000**	**77,280,000**

3.2.2 Downtime Cost

From Table 1 the total downtime from 2017 to 2018 is 1,823hr, therefore the average downtime per year is 911.5hrs/year. Data obtained from the brewery boiler operation shows that the average downtime cost rate ₦399,900/hr.

Therefore, from equation (2)
Total annual cost of maintenance = (Average downtime cost rate) x (Average downtime of the system)

Total annual cost of maintenance = ₦399,900/hr × 911.5 hrs/year

Total maintenance cost = ₦364,508,850/year

Proposed cost saving = (current labour cost + current spare part cost) – (RCM labour cost + RCM spare part cost)

Cost savings using RCM = (₦103,320,000 + ₦23,450,000) – (₦77,280,000 + ₦19,600,000)

Percentage savings in cost = 23.6%

Therefore,

Total savings in maintenance cost using RCM = $\frac{23.6}{100} \, x \, 364{,}508{,}850$

Total savings in maintenance cost using RCM ₦85,944,383/year

4. CONCLUSION:

In this research, the cost reduction in a brewery boiler operation using RCM was evaluated. The MTTF, MTBF, availability, failure rate and repair rate were calculated for the boiler. From the results obtained from the study, it is evident that the use of RCM can reduce the cost of production if properly implemented as it had great impact on the cost of maintaining the boiler. The result obtained show that the cost of labour decreases from ₦103,320,000 per year to ₦77,280,000 per year (approximately 25.203% decrease of the total labour cost of maintenance) using RCM practice. This maintenance practice should be implemented in other manufacturing sectors to improve the maintenance of their equipment. RCM techniques should be adopted in their approach instead of corrective maintenance.

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Cost saved using RCM = ₦29,890, 000

Percentage savings in cost = $\frac{29{,}890{,}000}{126{,}770{,}000} \, x \, 100$

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