DEDICATION

o the Almighty God through Jesus Christ our Saviour, for his faithfulness towards my life.

.. And also, to my caring parents; Arch. Dosu Adekeye amd Mrs Dayo Adekeye, my brothers; Ir Yemi Adekeye, Mr Dapo Adekeye, and my twin brother, Mr Taiye Adekeye, for their nfailing support ever since I came into this world.

CERTIFICATION

This is to certify that this project "Maintainability of process industry" is the original work of ADEKEYE KEHINDE OLUWADARE, carried out wholly by him under supervision and submitted to the department of Chemical Engineering, Federal University of Technology, Minna.

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Dr. J. O. Odigure
Supervisor

Date

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Date

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External examiner

Date

DECLARATION

I, ADEKEYE KEHINDE OLUWADARE, hereby declare that this project is my original work and that it has not been submitted in any form for another degree or diploma in any University or Institution.

Information derived from published or unpublished work of others has been acknowledged in the text.

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Adekeye Kehinde Oluwadare Date

Student

ABSTRACT

This project, maintainability of process industry, critically assessed the ability of a system to be maintained i.e. retained in or restored to effective usable condition, taking the paste production section of Doyin Industries Limited as a case study. This was done using the failure rate method to assess the effect of system failures on equipment reliability, availability and the productivity of the industry. This reveals that N70, 000 worth of produced goods is being lost per hour due to failure as against N1, 875 being spent per hour on maintenance of the system. This justifies the need for effective maintenance as it reduces the downtime incurred. It also shows that the cost of preventive measures and control of failures is much more economical than the cost of correcting the consequences.

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in the manufacturing industries and evaluate its contributions as a catalyst to the survival, growth and profitability of all manufacturing industries.

1.2 AIMS/OBJECTIVE OF THE STUDY

The aims of this study are to find explanations and solutions to the continous breakdown of equipment in processing industries and analyzing the significance of adequate maintenance as it affect process industries.

The aims can be achieved by the following means:

i. To know the limiting units (factor) in the whole production system
ii. Find means (ways) of eliminating the limiting factor
iii. Increase the productivity of the production system

1.3 SCOPE/LIMITATION OF STUDY

This study will critically examine the impact of good maintenance of equipment in the paste production section of Doyin Industries Limited, for a period of five years i.e. 1995-1999. This project is limited to this production section. Other limitations include:

i. In some cases only general data are available on equipment breakdown rate, maintenance of equipment and cost.
ii. Improper documentation is also a contributing factor
iii. The cost implication of the direct and indirect labour cost of the routine weekly maintenance work are not available.
iv. Because of these limitations, some of the input information is subjective.

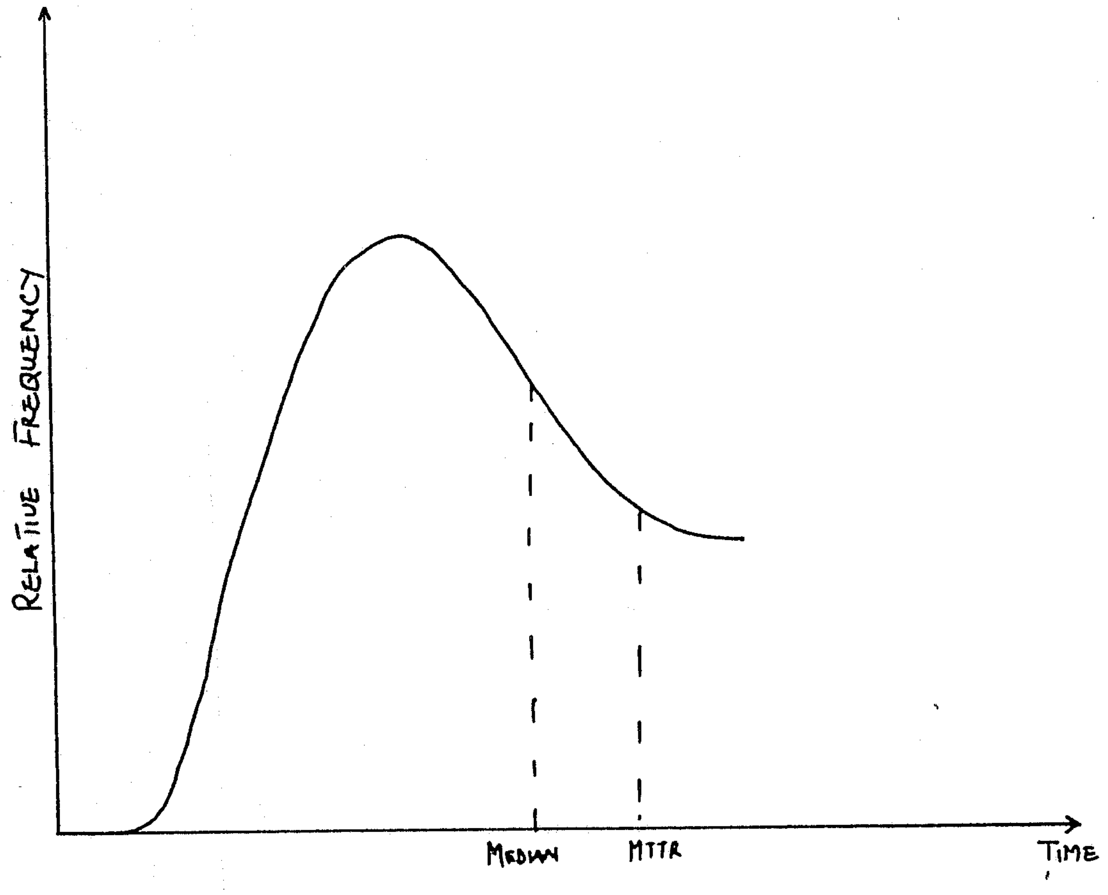
and its equipment in such a manner that production can proceed with the least possible interruption. Maintenance is as much as an art as it is a science.

The problem of cost, downtime and technical knowledge increases with more complicated automation, safety requirement, environmental control and energy conservation. Dowdle and Goedke (1994) reported that maintenance is the largest controllable cost at most chemical process industries plants. It is vital that this expenditure be controlled and directed to maximize onstream time while minimizing cost. This can only be accomplished by a better organisation, management and control of maintenance.

Organisation of maintenance should not start after the first breakdown or catastrophic failure, it must start with the planning of a new facility and the choice of equipment. Maintenance function can be classified as primary or secondary as described by Adediran (2000). Because of the wide and varying scope of maintenance function, the organisation should be tailored to fit the particular, geographical and personnel situations involved. The basic necessity is to maintain the plant at a level consistent with low cost and high productivity. At Quantum Chemical Co., a maintenance management was established to foster use of modern maintenance management techniques through out the company. The MTC consists of groups of persons who have expertise in various maintenance technologies, and this has greatly improved the maintenance of the company. Advanced monitoring equipment has allowed a move from hours-based maintenance to condition-based maintenance. This technique allows for pinpointing of specific problems prior to shutting equipment down for repair. The MTC members developed a list of potential projects, which have a projected savings of about $20million per year (Chemical Engineering progress vol. 90/M010). Odigure (1998) reported that proper organisation of maintenance program ensures introduction of innovative manufacturing practices. It ensures that multiple perspectives are considered in developing the best practice for the company.

2.1.1 MAINTENANCE TIME DISTRIBUTION

Patrick (1992) observed that maintenance time tend to be lognormally distributed. For a task, there are occasion when the work is performed rather quickly, but is relatively unlikely that work will be done in much less time than usual. Whereas, it is relatively more likely that problems will occur which will cause the work to take much longer than usual.



THE LOGNORMAL DISTRIBUTION OF MAINTENANCE TIME

2.2.1 FAILURE MODES AND EFFECT ANALYSIS (FMEA)

Alan (1991) identifies FMEA as an inductive analysis method used to systematically study the causes and effect likely to affect the components of a system. Odigure (1998) listed the aims of FMEA to include

(i) The assessment of the effects of each failure mode component on the overall function of the system.

(ii) Identification of the specific component failure mode responsible for the unavailability or unreliability or otherwise of the system.

2.2.2 HAZARD AND OPERABILITY STUDY

Odigure (1998) described HAZOP as a technique, which is mainly used for safety review at the design stage and in operating plant particularly before modification. Trevor Kletz (1994) observes: The complexity of modern plants makes it difficult or impossible to see what might go wrong unless we go through the design systematically. HAZOP gives the opportunity to go through the design line-byline, deviation-by-deviation to see what was omitted. HAZOP method can be regarded as a specific adaptation of FMEA and also a technique of the causes-consequences type.

2.2.3 FAULT TREE

This is a qualitative hazard analysis, technique, as it analyses the chances of hazardous event occurring. The methodology involves the selection of an undesired top event occurring. Odigure (1998). He related these events to components failure, human errors or any other pertinent event that could lead to the top event. Butter Worths (1980) observed that both hazard and operability study (HAZOP) and fault tree were complimentary in that one considered the development of a fault from a selected print forward to the ultimate, the other was capable of tracing element back from the point of primary causes.

2.2.4 TROUBLE SHOOTING

Troubleshooting is a process of simply gathering enough observations until only one cause explain all the symptoms as described by Bruce (Chemical Engineering progress, 1999). The use of case-based expert system to troubleshoot can provide substantial benefits for process plants in chemical industries.

2.3 RELIABILITY

Henry (1992) defined reliability as the ability of an entity to function without failure. While the last definition given by International electro technical commission (IEC) is the ability of an entity to perform a required function under given conditions for a given time interval. (IEC50 (191), 1991). The entity used here denote any component, subsystem, system or equipment that can be individually considered necessary to provide a given service. Alain (1991) classified reliability into three: operational, predicted and extrapolated reliability.

In the mathematical sense, reliability is measured by the probability that an entity (E) can perform one or several required function(s) under given conditions for a given time interval. i.e.

$$R(t) = P(E \text{ not failed during } [0,t])$$

2.4 MAINTAINABILITY

Alain (1991) defined maintainability as the ability of an entity to be maintained in, or restored to, a state in which it can perform a required function, when maintenance is performed under given conditions and using stated procedures and resources. While Henry (1992) reported that maintainability is the ease with which the product can be retained in its correctly functioning state or, should it fail, be restored to it. Maintainability of equipment is clearly governed by the design which determines features such as accessibility, ease of test and diagnosis and requirement for calibration, lubrication and other preventive maintenance action.

Maintainability is generally measured by the probability that the maintenance of an entity (E) performed under given conditions using stated procedures and resources is completed at time t given that the entity failed at time $t = 0$.

i.e. $M(t) = P$[the maintenance of E is completed by time t]

$\therefore$ $M(t) = P$[E is repaired over $(0,t)$]

2.5 AVAILABILITY

Henry (1992) defined availability as the readiness to function whenever required. Alain (1991) referred to availability as the ability to an entity to be in a state to perform a required function under given conditions at a given instant of time. It is generally measured by the probability that an entity E is in a state to perform a required function under given conditions and at a given instant t;

$A(t) = P$[E not failed at instant t]

An entity's dependability is determined by the reliability, maintainability and availability, Henry (1992). There is thus, a close relationship between reliability and maintainability, one affecting the other and both affecting availability and cost.

2.6 SAFETY

Alain (1991) described safety as the ability of an entity not to cause, under given conditions, critical or catastrophic events. Lindley (1995) defined safety organisation as a systematic method for protecting works and other near by people from injury and from damage to their health as a result of the work they are employed to carry out.

Accident prevention can be achieved by organized and coordinated activity. It should be appreciated at the outset that accidents do not 'just happen', but rather 'accidents are caused'. Since they are caused, they can be prevented by removing the cause. Prevention is thus the function of any safety program.

2.7 COST REPORT

James (1995) observed that maintenance of facilities and equipments can result in reduction of operating cost and increase productivity. Therefore, maintenance-cost information is of considerable value, if the system for classifying accumulating, and reporting all maintenance labour and material costs is well designed. To develop such a cost-accounting system it is necessary to relate the cost of specific type of maintenance work to production cost or to supporting facilities. Such an accounting system can provide sufficient information to determine which piece of equipment requires unduly high maintenance cost.

2.7.1 PROFIT OBJECTIVE

The principal objective of any company engaged in manufacturing of a product is to earn a profit. James (1995) observed that because of the cost involved in engineering work, it is important to establish the returns on investment for engineering time. Therefore, the percentage of time that a production unit operates or that a total system is available for the manufacture of the product will directly affect the amount of profit earned. System availability also results in lower capital investment per unit produced, thereby improving investment returns.

2.8 CONCLUSION (RELEVANCE OF DISCUSSED TOPICS TO PROJECT)

This chapter attempted to discuss all the information necessary for the execution of this project including the definitions of various terminologies used, explain the options available and possibly why such method(s) were used. This is a built up of what it entails in terms of methodologies used for this project.

Section 2.1 – 2.1.2 defines maintenance and explains the meaning of this terminology, the relationship that exists between preventive and corrective maintenance action and the need for maintenance in a process industry.

Section 2.2 –2.6, defines failures, assessment of failure, reliability, maintainability, availability and safety. This explains and relates to increase in production and profitability.

However, this chapter defined, explained and discussed maintenance, reliability, maintainability, availability and cost. This is to enable the reader understand what this study entails and what it is geared towards.

2.9 DESCRIPTION OF SYSTEM (PLANT) GENERAL OPERATING TECHNIQUE

For the purpose of this study, the production procedures of Dentoclean plant of DOYIN INDUSTRIES LIMITED is the case study. The production technique is what is referred to as system which comprises mainly of a boiler fryma (reactor) and nordenmatic system. The general technological scheme is presented in fig 1.

BOILER MECHANISM

This consists mainly of the burner (produces heat required) and the boiler (produces the steam), which is a closed system type. In the burner, black oil is fed into the heater band to heat up the oil slightly and make it light before pumping into the sparking unit. A pre-set timing unit operating at 110V sets on the pumping machine. The sparking (caused by the electrodes) combined with the light black oil, generates the fire, which produces the required heat for the boiler.

The boiler has an innermost layer, which consist of 24 heating spring and an outermost layer, which contains water, pumped in with the aid of a pumping machine. The heat generated from the burner heats up the springs and they become red hot. The red hot heating springs heats up the water in the outermost layer and produces steam required for the paste production in the fryma.

FRYMA MECHANISM

This is a reactor consisting of a mixer, scraper, vacuum pump and a steam jacket. The reactor is heated through the steam jacket, which surrounds the inner layer of the reactor. The outer layer of the reactor is effectively lagged to reduce heat loss from the system. The fryma is operated at a steady increase in temperature and the raw materials are periodically charged into the reactor in the absence of oxygen/air. The airtight condition is achieved through the use of the vacuum pump. Dentoclean product is highly temperature sensitive and raw materials are charged in periodically according to the production procedure during the heating process (which stops at 80 C) and the cooling process (which starts after the heating process). Closing the steam tap and opening the cold-water tap achieve the cooling process.

NORDENMATICS MECHANISM

This is a paste-filling machine, which consist of a filler, sealer, cutter and coder. The tubes (40g, 70g or 175g) are set into the machine, and compressed air is used to blow the tubes and then they are filled with paste. The tubes are passed into the sealer for sealing, then on to the cutter, before the tubes are coded and passed out for packaging.

RELEVANCE OF LITERATURE REVIEW TO CASE STUDY

The literature review has attempted to discussed all the information and methods required for the evaluation and quantification of maintainability in process industries. This method of evaluation will be used in analyzing maintainability as bedrock of productivity in Dentoclean plant of Doyin Industries Limited, which is the case study of this project.

CHAPTER THREE

3.0 METHODOLOGY

This described and explain the procedures employed in the maintainability quantification of the paste production system. The failure dates, the cost of repairs when equipment fails and other relevant information on the paste production department of DOYIN INDUSTRIES Limited. The performance of the component items i.e. its reliability data, was also considered.

3.1 DATA COLLECTION

The source of the failure data and cost of repairs of failed components is from the maintenance department of Doyin Industries Limited. There are two methods of data collection, the operating experience data gathering and the reliability test. The operating experience data gathering was used for this study. This involves the monitoring of the behaviour of components under operating condition and the entire event that might have taken place. Data were recorded by the head of Engineering in the logbook, while other information were provided by the production department.

3.2 ANALYSIS OF DATA

The failure rate method was used for the quantification. The failure frequency and the cumulative operating time is obtained from the failure data, thus, the failure rate can be calculated. Since the breakdown of equipment reduces the system availability and in turn, the plants productivity and profitability, this method is recommended.

3.3 SIGNIFICANCE OF THE METHOD

This method estimates the number of failures recorded and gives an insight to the design of the equipment. The frequency of failure and commulative time allows us to estimate the failure rate and assess the system's repair rate, reliability and its availability. Also, from the cost of repairs And the downtime cost incurred during failures, the productivity and profitability of the system can be improved through adequate maintenance of the plant.

3.4 FAILURE

This is the termination of the ability of an item to perform a required function. An entity is said to have failed when it is no longer able to fulfill its required functions.

Failure can be classified in different ways:

i. Failure according to degree
ii. Failure as a suddenness
iii. Failure as to combination of suddenness and degree
iv. Classification according to the dates of their occurrence in the system life time
v. Classification as to effect
vi. Classification as to causes

3.5 FAILURE RATES

This gives the limit of the ratio of conditional probability that, the instant of time of a failure of an entity fails within a given time interval, $(t,t+\Delta t)$ to the length of this interval, Δt, when Δt tends to zero. Given that the entity has not failed over $(0,t)$

$\lambda(t) = \text{Limit } 1/\Delta t.\ P\{E \text{ failed from time } t \text{ to } t= \Delta t\}$

given $\Delta t \rightarrow 0$ that is did not fail over time period $(0,t)$

Using the theorem of conditional probabilities,

$\lambda(t) = \lim 1/\Delta t^{*}\ P\{E \text{ failed from time } t \text{ to } t + \Delta t\}$

Hence,

$\lambda(t) = \lim 1/\Delta t^{*}\ 1/R(t)^{*}\ P\{E \text{ failed over } (0, t + \Delta t)\}$

$\Delta t \rightarrow 0 - P\{E \text{ failed over } (0, t)\}$

$$\lambda(t) = \lim_{\Delta t \rightarrow 0} \frac{R(t) - R(t + \Delta t)}{R(t)}$$

$$\lambda(t) = \frac{-\,dR/dt^{*}(t)}{R(t)}$$

This failure rate is referred to as instantaneous rate.

3.6 TYPES OF FAILURE RATE

There are three types of failure rates i.e.

i. Operating failure rate

ii. Standby failure rate

iii. Failure rate upon demand

Due to the obtained data, the rate calculated is based on operating failure rate.

3.6.1 OPERATING FAILURE RATE

This parameter gives the probability that an entity E which has been operating over a time t fails during the next time unit. This is expressed mathematically as:

$\lambda = \lim 1/\Delta t.$ $\quad P\{E\text{failed between } t \text{ and } t + \Delta t\}$

$\Delta t \rightarrow 0$ $\quad$ given that it did not fail over $(0, t)$.

Assuming a constant failure rate, an estimator of the failure rate is given by

$$\lambda = \frac{N_f}{T_f}$$

Where N_f = Number of failure observed during operation

T_f = Cumulative operating time.

3.7 RELIABILITY

This is the measure of the capacity of equipment to operate without failure when put to use i.e. the probability that a system will function within specified limit for at least a specified period of time under specified environmental condition. This is quantified using the exponential expression

$$R(t) = e^{-\lambda t}$$

Where t is the operating time of the system

λ is the constant failure rate

In a system, if the possible failures of all the constituents are independent of each other for a successful operation, i.e. non-redundant components, the reliability of the assembly equals the product of the constituents reliabilities. i.e. $R(t) = \prod R_i (t)$

Where $R_i (t)$ = Reliability 9th item

3.8 AVAILABILITY [A(t)]

This is the probability that a unit will perform its required function at a stated instant of time or over a stated period of time. There are many types of availability, which is the proportion of time that a system is available for use when the overall period is of considerable duration.

Availability of repairable system is a function of its failure rate, λ, and of its repair rate, μ.

3.8.1 MEAN TIME BETWEEN FAILURE (MIBF)

This is the mean value of the length of time which elapses between failure. It is applicable to repairable items and at constant failure rates, λ , it can be expressed as

$MTBF = 1/\lambda$

3.8.2 MEAN TIME TO REPAIR [MTTR]

This is defined as the mean of the time required to perform maintenance action or to clear a fault on an equipment i.e. This is the mean value of the length of time taken to carry out repairs. The standard method used is US MIL – HDBK – 472, which contains four methods for predicting MTTR of a system. Method II is the most frequently sued. This is based simply on summing the product of the expected repair time of the individual failure modes and dividing by the sum of the individual failure rate. i.e.

$$MTTR = \frac{\Sigma\,(\lambda tr)}{\Sigma\,\lambda}$$

Where λ= failure rate

t = Repair time.

3.8.3 REPAIR RATE (μ)

This is the number of repairs that can be carried out on a particular unit per hour. Repair rate is the reciprocal of the MTTR i.e.

$$\mu = 1/MTTR$$

Where MTTR = mean time to repair.

3.8.4 STEADY STATE AVAILABILITY

This is the proportion of total time that the item is available. For a simple unit, with a constant failure rate, λ, and a constant repair rate, μ, the steady state availability is

$$A = \frac{\mu}{\lambda + \mu} = \frac{MTB}{MTBF + MTTR}$$

Where MTTR = mean time to repair

MTBF = mean time before failure.

For a non-redundant component in a system, the total availability of the system is given by

$$A_T = \prod A_i$$

Where A_i = availability of i th item.

3.9 EFFECTIVENESS FACTOR (E)

The effectiveness factor is a measure of the probability that the equipment will be ready and capable of performing its function and that it will not experience failure during its mission period. It is determined by the value of the equipment reliability, the value of the availability and indirectly the ability to effect repairs. Effectiveness can be expressed as

$E = R \times A$

Where R = Reliability

A = Availability

3.10 COST ACCOUNTING

This accounting system provides sufficient information to determine which piece of equipment requires unduly high maintenance cost. Also, using the production cost and the minimum profit level of the plant, the down time cost is estimated and the impact of the lost in production time is known.

CHAPTER FOUR

4.0 RESULTS

From the obtained failure data and repair cost, the failure rate for each failure mode and equipment can be calculated as well as the downtime cost

4.1 FAILURE RATE

The failure rate can be calculated based on the operating time and assuming constant failure rate.

I.e. Failure rate $(\lambda) = N_f / Tt$

Where Nf = Number of failure

Tt = cumulative operating time

Table 1 shows the cumulative operating time per year for the whole system.

	OPERATING TIME (HR)				
EQUIPMENTS\YEAR	1995	1996	1997	1998	1999
BOILER	2,406	2,419	2,423	2,421	2,421
FRYMA	2,434	2,442	2,429	2,424	2,429
NORDENMATICS	2,439	2,432	2,438	2,439	2,436
CUMMULATIVE OPERATING TIME	7,279	7,293	7,290	7,284	7,286

* TOTAL OPERATING TIME WITHOUT FAILURE = 2450 Hr/year

Using the failure data obtained and the cumulative operating time, the failure rate (λ) can be calculated.

Table 2 presents the equipment, the mode/member of failure encountered, the frequency of number of failure, repair cost, and the quantification of failure rate over a period of five years.

TABLE 2 Downtime, Failure rate and cost of repairs.

1995

EQUIPMENT	TYPE OF FAILURE	DOWN TIME (Hr)	NUMBER OF FAILURE (N_f)	FAILURE RATE λ ($H^{-1}r$)	COST OF REPAIR (N)
BOILER	Block Nozzle	32	1	$1.37\text{x}10^{-4}$	250.00
	Water pump	12	1	$1.37\text{x}10^{-4}$	195.00
	Total	44	2	$2.747\text{x}10^{-4}$	445.00
FRYMA	Rectifier	5	1	$1.37\text{x}10^{-4}$	650.00
	Vacuum pump	11	1	$1.37\text{x}10^{-4}$	300.00
	Total	16	2	$2.747\text{x}10^{-4}$	950.00
NORDN-MATICS	Filling head value	9	1	$1.37\text{x}10^{-4}$	-
	Photocell	2	1	$1.37\text{x}10^{-4}$	50.00
	Total	11	2	$2.747\text{x}10^{-4}$	50.00

1996

BOILER	Transformer	14	1	$1.37\text{x}10^{-4}$	250.00
	Water pump	17	1	$1.37\text{x}10^{-4}$	195.00
	Total	31	2	$2.747\text{x}10^{-4}$	445.00
FRYMA	Gear box	8	1	$1.371\text{x}10^{-4}$	-
	Total	8	1	$1.371\text{x}10^{-4}$	-
NORDN-MATICS	Control cam	18	1	$1.371\text{x}10^{-4}$	2,500.00
	Total	18	1	$1.371\text{x}10^{-4}$	2,500.00

1997

BOILER	Fuel pump	27	1	1.372x10^{-4}	1,050.00
	Total	27	1	1.372x10^{-4}	1,050.00
FRYMA	Stirrer	12	1	1.372x10^{-4}	13,800.00
	Transfer	9	1	1.372x10^{-4}	
	Total	21	2	2.744x10^{-4}	13,800.00
NORDN-MATICS	Filling Value	12	1	1.372x10^{-4}	800.00
	Total	12	1	1.372x10^{-4}	800.00

1998

BOILER	Heating element	29	1	1.373x10^{-4}	3,200.00
	Total	29	1	1.373x10^{-4}	3,200.00
FRYMA	Vacuum pump	14	1	1.373x10^{-4}	7,000.00
	Gear box	12	1	1.373x10^{-4}	-
	Total	26	2	2.746x10^{-4}	7,000.00
NORDN-MATICS	Air value	11	1	1.373x10^{-4}	650.00
	Total	11	1	1.373x10^{-4}	650.00

1999

BOILER	Water electrode	23	1	1.372x10^{-4}	1,500.00
	Non-Return value	6	1	1.372x10^{-4}	750.00
	Total	29	2	2.745x10^{-4}	2,250.00
FRYMA	Stirrer	21	1	1.372x10^{-4}	9,500.00
	Total	21	1	1.372x10^{-4}	9,500.00
NORDN-MATICS	Filling Value	14	1	1.372x10^{-4}	1,200.00
	Total	14	1	1.372x10^{-4}	1,200.00

From Table 2, the following parameter can be calculated using these formulae. i.e

$$MTTR = \sum (\lambda\, t\, r)/\sum \lambda$$

$$\mu = 1/MTTR$$

$$R(t) = e^{-\lambda t}$$

$$A(t) = \mu/\mu + \lambda$$

where μ =Repair rate.

λ = Failure rate

t_r = Repair time

TABLE 3 Failure (λ), Repair rate (μ), Reliability and Availability

A) 1995

EQUIPMENTS	$\lambda X10^{-3}$ ($H^{-1}r$)	MTTR (Hr)	μ ($H^{-1}r$)	R (t)	A (t)
BOILER	2.747	20.01	0.0455	0.510	0.9939
FRYMA	2.747	8.00	0.1250	0.510	0.9978
NORDENMATICS	2.747	5.50	0.1820	0.510	0.9985

B) 1996

EQUIPMENTS	$\lambda X10^{-3}$ ($H^{-1}r$)	MTTR (Hr)	μ ($H^{-1}r$)	R (t)	A (t)
BOILER	2.747	15.50	0.0645	0.5110	0.9958
FRYMA	1.371	8.00	0.1250	0.7147	0.9989
NORDENMATICS	1.371	18.00	0.0556	0.7147	0.9975

1997

EQUIPMENTS	$\lambda X10^{-3}$ ($H^{-1}r$)	MTTR (Hr)	μ ($H^{-1}r$)	R (t)	A (t)
BOILER	1.372	27.00	0.0390	0.7146	0.9963
FRYMA	2.743	10.50	0.0952	0.5110	0.9971
NORDENMATICS	1.372	12.00	0.0833	0.7146	0.9984

1998

EQUIPMENTS	$\lambda X10^{-3}$ ($H^{-1}r$)	MTTR (Hr)	μ ($H^{-1}r$)	R (t)	A (t)
BOILER	1.373	29.000	0.0345	0.7144	0.9960
FRYMA	2.746	12.997	0.0769	0.5100	0.9964
NORDENMATICS	1.373	11.000	0.0909	0.7144	0.9985

1999

EQUIPMENTS	$\lambda X10^{-3}$ ($H^{-1}r$)	MTTR (Hr)	μ ($H^{-1}r$)	R (t)	A (t)
BOILER	2.745	14.50	0.0690	0.5104	0.9960
FRYMA	1.372	21.00	0.0476	0.7144	0.9971
NORDENMATICS	1.372	14.00	0.0714	0.7144	0.9981

Know the equipment reliability and availability per year, the total system reliability, availability and effectiveness factor for each year can be calculated. ie

$R_T (t) = \Pi R_i (t)$

$A_T (t) = \prod A_i (t)$ Where $R_i (t)$ = Reliability of i th item E =Total effectiveness factor

And $E_T = R_T (f) \times A_T (t)$ $A_i (t)$ =Availability of ii th item

YEAR	TOTAL DOWN TIME (Hr)	R_T (t)	A_T (t)	E
1995	71	0.1326	0.9902	0.1313
1996	57	0.2610	0.9922	0.2590
1997	60	0.2609	0.9918	0.2588
1998	66	0.2603	0.9909	0.2579
1999	64	0.2605	0.9912	0.2582

From table 2, the failure rate (λ) for the period of five years (1995-1999) can be calculated.

The cumulative operating time = 7,279 + 7293 +7290 +7284 +7286 = 36,432 Hr

TABLE 5 {Equipment failure, Total downtime and Repair cost of each Equipment}

1995-1996

EQUIPMENT	TOTAL DOWN TIME (Hr)	NUMBER OF FAILURES (N_F)	FAILURE RATE ($\lambda \times 10^{-4}$) $H^{-1}r$	COST OF REPAIR (N)
BOILER	160	8	2.196	19,625
FRYMA	92	8	2.196	31,250
NORDENMATICS	66	6	1.647	5,200
TOTAL	318	22		56,075

4.2 COST ACCOUNTING

The following information was obtained from the production department and sales department.

i. Two batches of paste were being produced per day

ii. One tube of paste is sold for N90.00

iii. A profit of N20.00 is made per tube on the average.

1 batch of paste yields 70 cartons of 50 (175) tubes per carton.

i.e. 1 batch = 70 X 50 = 3,500 tubes

For 2 batches, 7,000 tubes are produced per day.

4.2.1 FINANCIAL COST OF LOSS OF PRODUCTION

It should be noted that the equipment operates nine hours per day Monday to Friday and four hours on Saturday. Therefore,

7,000 tubes\day costs 7,000 X N90 = N630, 000

∴ Cost of production for 9hr/day = N630, 000

Cost of production per hour/day = N630, 000/9

∴ Cost per hour/day = N70, 000

The monetary value of every hour lost to break down of equipment is N70, 000.

NOTE: This does not include amount spent on repairs, overhaul and replacing damaged part.

From 1995 – 1999, the loss of production can thus be calculated for each equipment i.e.

i. Boiler

Total hours lost (Downtime) = 160hr

Cost = 160 X 70,000 = N11, 200,000.00

ii. FRYMA

Total hours lost (Downtime) = 92hr

Cost = 92 X 70,000 = N6, 440,000

iii. NORDEMATICS

Total hour lost (Downtime) = 66hr

Cost = 66 X 70,000 = N4, 620,000

Total loss of production (1995 – 1999) = N11, 200,000 +N6, 440,000 + N4, 620,000

= N22, 260,000

4.2.2 PROFIT LOSS (DUE TO DOWNTIME)

For a profit of N20 per N90 paste tube,

i.e. % profit per tube = 20/90

= 22.22%

Total profit loss due to production loss (1995 –1999) = 22.22% X22, 260,000

= N4, 946,667

Profit loss/hour of breakdown (Downtime) = Total profit loss/Total downtime

i.e. Profit loss/hour of breakdown = N4,946,667/318

= N15, 556/hour

4.2.3 MAINTENANCE COST INCURED

From table 5, the total cost of repairs (1995 – 1999) was N56, 075 with the Fryma incurring the largest amount of N31, 250, boiler N19, 625 and the nordematics the lowest of N5, 200.

But during this period, the boiler was over hauled three times in 1996, 1998 and 1999 at a cost of N180, 000 per each overhauling.

The total cost of overhauling (1995 – 1999) = 3 X N180, 000
= 540,000
Total cost of maintenance on boiler = N540, 000 + 19,625
= N559, 625
∴ Total cost of maintenance on Fryma = N31, 250
Total cost of maintenance of Nordematics = N5, 200

The total cost of maintenance for the system (1995 – 1999) is N559, 625 + N31, 250 + N5, 200 = N596, 075

The cost of maintenance per each hour of breakdown (1995 – 1999)

$$= \frac{\text{Total maintenance cost}}{\text{Total downtime}}$$

$$= \frac{N596,075}{318}$$

$$= N1874$$

i.e. for every hour of breakdown N1874 was spent on maintaining and restoring the system back to operation.

4.3 DISCUSSION OF RESULT

Failure reporting and data analysis are essential part of reliability management, maintainability and availability of equipment. This analysis is based on the assumption of constant failure rate i.e. exponential failure rate.

Maintainability analysis addresses the ability of a system to be retained in or restored to its effective usable condition. This study looks at the likelihood of an undesired incident occurring in relation to the equipment life, productivity and profitability of the system involved.

Table 2 shows the number of failure and failure rate per year. 1995 has the highest number of failures and thus, highest failure rate, i.e. 6 failures with 2 failures each from the boiler, fryma and nordematics. This high failure rate reflects on the equipment individual reliabilities of 0.510 each (table 3a) and the system reliability of 0.1326 (Table 4) for the year, which was the lowest for the duration of this study. According to Halpen (1961), reliability is acceptable between the range of 0.5 –0.95, and the various equipment reliabilities satisfies this condition for the period of study (table 3). The systems reliability for the year 1996 was 0.2610, 1997 (0.2609); 1998 (0.2603) and 1999(0.2605), which were relatively high compared with that of 1995 (0.1326). These values are approximately equal and were due to a lower failure rate recorded per year for the whole system. The low values of systems reliability can be attributed to the fact that reliability decreases as the number of subunits (equipments) increases [EJUP and Tyler (1992)], i.e. for non – redundant components, only one unit needs to fail for the whole system failure.

Tabble 4 shows the system availability and effectiveness factor per year. A look at the period considered reveals that the availability of the system for each year is very high, all above 0.99 (99% availability). According to EJUP and Tyler (1992), availability is acceptable between the range of 0,998 – 0.9999, while Gavier (1992) availability range is between 0.95 –0.9999. The result obtained shows that 1996 recorded the highest value of availability (0.9922), lowest downtime of 57hrs and, effectiveness factor of 0.2590. While 1995 has the lowest value of availability (0.9902), highest downtime of 71hrs and effectiveness factor of 0.1313. These calculated availabilities falls between Gavier (1992) acceptable availability ranges. From the study, the generally low effectiveness factor was due to the low systems reliability value. This can be improved on by parallel redundancy i.e. stand by systems, in which equal units are allowed to stand idle, ready to take over should the operational unit fails.

Although, the system availability per year is very high, the downtime incurred and the unavailability of the equipment cannot be fully appreciated until the cost accounting of the system is considered. Quinn (1995) reported that to establish potential system availability, it is necessary to know the effects that downtime for repairs or service work have on production, or it is necessary to know what adverse effect downtime of a particular production unit could have on the output of the system. Section 4.2.1 of this chapter reveals that N70, 000 worth of produced goods is being lost per hour due to failure. This amount does not include cost of repairs, overhaul and replacement of damaged parts. Also, section 4.2.2 shows that N15, 556 is lost per hour of failure as profit, which does not include the wages of workers; that must be paid whether or not the equipments are in operation.

Table 5 shows that during the period of the study, (1995 – 1999), the boiler recorded the highest downtime of 160hrs and was responsible for N11.2 million loss of production. While the nordematics has the lowest downtime of 66hrs and a production loss of N4.62million. The Fryma recorded a downtime of 92hrs and a production loss of N6.44million. The total production loss was N22.66million and a total profit of 4.95million was recorded.

Section 4.2.3 deals with the maintenance cost incurred during this period and a total of N559, 625 was spent on the boiler, N31, 250 on the fryma and N5, 200 on the nordematics. The high cost recorded for the boiler was due to the overhauling of the equipment in 1996, 1998 and 1999 at a cost of N180, 000 per each overhaul. The actual amount spent on repairing the boiler when it failed was N19, 625 (table 5).

Spreading the total maintenance cost incurred over the total downtime recorded (318 hrs) for the system revealed that N1, 875 was spent on maintaining and restoring the system back to operation for every hour of failure recorded. Comparing N1, 875 per hour of failure spent on maintenance with a profit of N15, 556 per hour shows that more should be spent on preventive maintenance. This will reduce the downtime recorded, improve reliability and availability, and effectively

ACKNOWLEDGEMENT

First and foremost, all glory and honour to the almighty God who has given me the grace to attain yet another academic height in my life. To my supervisor, Dr. J. O. Odigure, who took his precious time to carefully explain and read every page of this project, his constructive criticism made this work what it is.

Also to my parents, Arch D. Adekeye and Mrs D. Adekeye, for your ever willing support both morally and financially. God who is a just rewarder will continue to bless you. My appreciation also goes to my brothers; Yemi, Dapo and Taiye Adekeye for your unfailing support.

To my friends, Salako Abiodun, Abiodun Olayioye, Alex Mapayi, Kayode Ogunmola, Seyi Oladipo, Yemi Oyetoyan, Francis Ajayi, Iyiola Folayan, Lekan Oduwaye, Anu Agboola and my room mate, Bode Adebayo. Your contributions in one way or the other towards my success are immeasurable and invaluable. To my classmates, most especially Wale, Osi, Deola, Ruth, Oke and the class prof., Benard Abel, thanks for making my time with you a memorable one.

Lastly, to those who cannot be mentioned due to limited space but have also contributed to the success of my academic pursuit, I really appreciate you all and God will surely reward you.

increase productivity and profitability of the system. A careful study of the establishment shows that a larger portion of the downtime recorded was not due to the actual repairs performed but to untimely diagnosis of failure and release of funds from group head office for the necessary repairs.

Thus the ability of a system to be maintained i.e. retained in or restored to effective usable condition, affects equipment reliability and availability. This reduces the operating cost and capital investments per unit produced, and invariably improve investment returns, which is the principal objective of any process industry.

vi. Total maintenance organisation/management should be enforced and placing of the right man on the right job.

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$$(0.0645 + 0.002742)$$

$$\text{Fryme: } A(t) = \frac{0.1250}{(0.1250 + 0.002742)} = 0.9989$$

MAINTAINABILITY OF PROCESS INDUSTRY

CASE STUDY: Tooth Paste Production Section Of Doyin Industries Limited, Coker Lagos.

BY

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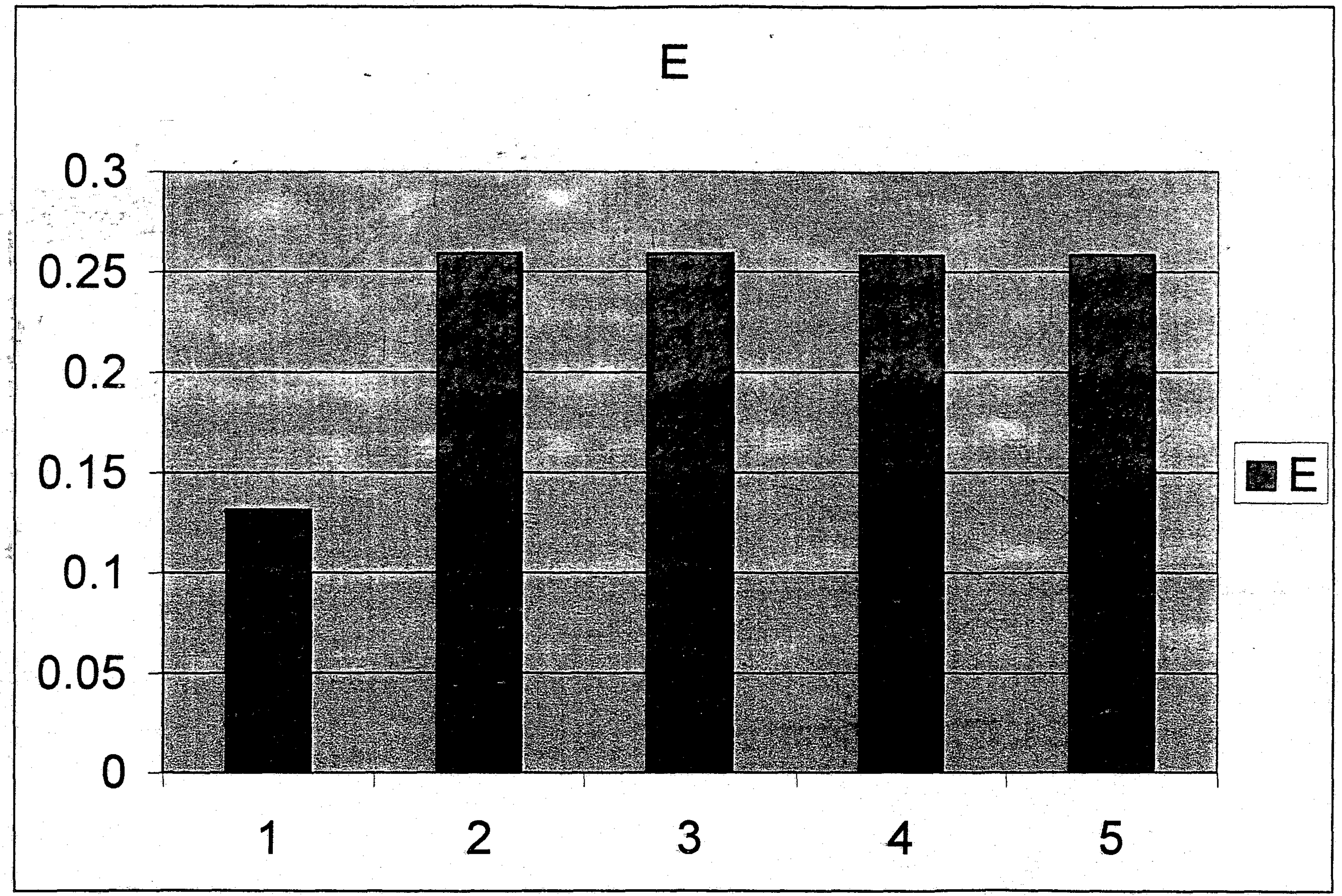
A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) IN CHEMICAL ENGINEERING.

DECEMBER 2000



KEY

1→ 1995
2→ 1996
3→ 1997
4→ 1998
5→ 1998

CHAPTER FIVE

5.0 CONCLUSION

This study addresses the ability of a system to be retained in or restored to its effective usable condition as it affects the equipment life, productivity and profitability of the system involved. The failure method and the financial implication due to failure have been used to identify the limiting factor (Boiler) of the system. It justifies the need for effective maintenance organisation and management as it affects downtime incurred. Since this will reduce the downtime incurred, increase equipment reliability and availability, and eventually increase productivity and profitability. It has also shown that the cost of preventive measures and control of failure is much more economical than the cost of correcting the consequences.

5.1 RECOMMENDATIONS

i. Attempts should be made to provide proper training for operators, maintenance and safety personnel. This will improve the diagnostic time and management of the system.

ii. Efforts should be made to eliminate all single errors that could lead to an undesired incident.

iii. It should be considered whether failed components can be individually replaced to make repair or the failed component can be returned to its useful state. This has an important bearing on the repair list.

iv. Complete overhauling of the plant should be done on and when due.

v. Reviewing of the start up for all of the equipment after a breakdown should be considered.

APPENDIX 1

Failure Rate (λ) Calculation

$\lambda = N_f/T_f$

Where N_f = number of failure

T_f = cumulative operating time.

From Table 1 Tf (1995) = 7,279hrs.

Taking the boiling nozzle, where Nf = 1

$\lambda = 1/7{,}279 = 1.37 \times 10^{-4}\ hr^{-1}$

For water pump ($N_f = 1$)

$\lambda = 1/7{,}279 = 1.37 \times 10^{-4}\ ht^{-1}$

For the Fryma rectifier (Nf = 1)

$\lambda = 1/7{,}279 = 1.37 \times 10^{-4}\ hr^{-1}$

Vacuum pump ($N_f = 1$)

$\lambda = 1/7{,}279 = 1.37 \times 10^{-4}\ hr^{-1}$

For the Nordenmatics head valve (Nf = 1)

$\lambda = 1/7{,}279 = 1.37 \times 10^{-4}$

Photo Cell (Nf = 1)

$\lambda = 1/7{,}279 = 1.37 \times 10^{-4}$

Appendix 2

Reliability calculations

$R(t) = e^{-\lambda t}$ where t = 2450 Hr

For 1995, (Using Table 3A)

Boiler: $R(t) = e^{-2.747}(2450) = 0.510$

Fryma: $= e^{-2.747}(2450) = 0.510$

Nordenmatices: $= e^{-2.747}(2450) = 0.510$

For 1996, (Table 3B)

Boiler: $R(t) = e^{-2.742\,(2450)} = 0.5110$

Fryma: $R(t) = e^{-1.371\,(2450)} = 0.7147$

Nordenmatices: $R(t) = e^{-1.371\,(2450)} = 0.7147$

APPENDIX 3

Availability Calculations

$$A = \frac{\mu}{\mu + \lambda}$$

For 1995 (Table 3A)

Boiler: $A(t) = \frac{0.0455}{0.0455 + 0.00274} = 0.9939$

Fryma: $A(t) = \frac{0.1250}{(0.1250 + 0.00274)} = 0.9985$

Nordenmaties : $A(t) = \frac{0.1820}{(0.1820 + 0.00274)} = 0.9958$

1996 (Table 3B)

Boiler: $A(t) = \underline{0.0645} = 0.9958$