HAZARD: PREVENTION, MANAGEMENT AND CONTROL IN PROCESS INDUSTRY

CASE STUDY: FLUID CATALYTIC CRACKING UNIT OF THE REFINERY SECTION OF KADUNA REFINERY AND PETROCHEMICAL COMPANY KADUNA.

BY

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DEDICATION

This project is dedicated to the loving memory of my late old man **Pa STEPHEN L. AJAYI** who was translated from mortality to immortality on the 19th November, 1999.

CERTIFICATION

This is to certify that this project "Hazard Prevention Management and Control in process Industry" in the original work of Ajayi Sunday Olanrewaju carried out wholly by him under supervision and submitted to the department of Chemical Engineering, Federal University of Technology Minna.

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DECLARATION

I AJAYI SUNDAY OLANREWAJU, 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Information derived from published or unpublished work of others has been acknowledge in the text.

____________________	____________________
Ajayi Sunday Olanrewaju Student	**Date**

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ABSTRACT

This project, Hazard: Prevention, management and control in process industries, critically assessed the production process of the fluid catalytic cracking unit of Kaduna Refinery with the view of assessing the level of safety in the plan and identifying the possible hazards and recommending ways of preventing, controlling and managing the hazard identified the failure rate and common-cause methods were used in the quantification. This methods identified the combination of events that led to an incidents and consequently the root causes of the incident. From the quantification analysis was deduced that the cost of prevention and control in hazard management is cheaper than that of correcting the consequences.

CHAPTER ONE

1.0 INTRODUCTION

Lots of money and valuable lives have being lost and operators maimed or injured due to the accidents that occur in our industries with industrial growth; the need to embark on a hazard review courses to provide a safe environment for workers is therefore paramount to the survival of the industry and the nation at large.

Ensuring efficient plant operation, high safety standards and environmental protection is one of the aims and objectives of Kaduna Refinery and Petrochemical company; thus the need to keep this vision involves the ways of preventing, controlling and managing the occupational hazard involved in the production.

Literatures has shown that the best ways to preventing, managing and controlling of occupational hazard involve the identification, quantification and assessing the hazard (Susan, 1984) and Oyofo (1998). There are various ways of hazard identification. These include the checklist and Hazard and Operability study e.t.c. Hazard prevention strategies include the use of safety wares; training of operator and safety already incorporated in the design. Control with the aid of management policy includes the use of legislation and enforcing the use of provided gadgets.

Failure frequency, failure data and common-cause methods are used in the quantification of failure of component/equipment. Failure rate and common-cause method treats the hazard to the root cause.

1.1 NEED FOR STUDY

The need for the analysis of hazard is to show that a poorly managed, maintained plant is unsafe and a potential hazard to the operators.

Due to the occurrence of accidents over the years, a lot of operators have been maimed and lives lost. Lots of money have been paid as compensation to workers due to impairment deaths or litigation; the financial lost due to increased stoppages of production process increased production cost due to early cost of replacement of damaged machines parts and materials are some of the reasons why accidents should be prevented and controlled.

1.2 AIMS AND OBJECTIVES OF STUDY

The aims and objectives of this study is to obtain or achieve a safe working environment for the concerned plant i.e. upgrading the safety of the plant. To obtain this aims the following steps are taken.

(i) Examine and identify the hazards in the plant, this involves the identification of top events and their most likely root-causes.

(ii) Assessing the effects and consequences of the identified hazard if left unprevented and uncontrolled.

(iii) Quantifying the associated hazard using the failure rate and common-cause methods for the probability of an accident.

(iv) Recommendation ways of reducing, eliminating the root causes of these top events (hazard) and ways of preventing, managing and controlling the uneliminated ones.

1.3 SCOPE/LIMITATION OF STUDY

This study will critically examine, identify and look into ways of preventing, managing and controlling likely hazards or incidents in the fluid catalytic cracking unit of Kaduna Refinery and Petrochemical Company for a period of seven years i.e 1990 to 1997. This project is limited to this unit. Other limitations includes:-

(i) Only general data are obtained in many cases on equipment or component failure

(ii) Data on hours of breakdown of the monitored equipment are on records

(iii) Improper documentation also contribute to the limitation of study

(iv) Response of staff and management to obtain information was not very encouraging

(v) Because of these limitations come of the input information are subjective

CHAPTER TWO

2.0 LITERATURE REVIEW

Industrial development has been gaining ground in Nigeria since independence. The need for the evaluation of occupational hazard, its prevention, control together with management is a part of engineering studies as described by Connell (1998). Before a man (person) can be employed in any industry he/she must be in good health. Odigure (1998) reported that were various hazards generated by industries. Hence the need to keep the workers healthy at all times is the sole responsibility of the management. The task of reducing the occurrence of unexpected and the safe handling f the anticipated hazard becomes a paramount importance to the survival of any industry. Efforts to eliminate hazards begin right from the design stage and it is consolidated through proper training of all categories of personnel throughout the working life of industry (Odigure, 1998).

Dictionary definition of hazard states that is the chance of loss or injury, the degree of probability of loss or danger; However Odigure (1998) defined it as the exposure of life and properties to possible danger or loss, as a result of accident due to leakage of dangerous substances to the environment, high dust and noise level.

From Odigure's definition, it can be deduced that hazard does not take place only in the industry, but also in the environment as a whole. Oyofo (1998) observed that hazards (accident) do not just happen, they are caused; thus the need to know the causes of hazard is important to its prevention, control and management.

Anibuese (1991) listed the causes of hazard under two main categories

(i) human error, and

(ii) machine/equipment failure

Alain (1991) described causes according to failure into different classes i.e sudden, degree and the combination of both suddenness and degree; he further classified this failure into primary, secondary and command failure.

While Anibuese (1991) observed that majority of hazards are caused by human errors. This statement was supported by a case study of Kaduna Refinery accident cases (Samson, 1997). He calculated that 88% of the accidents were due to human errors while the remaining 12% were due to equipment failure.

Odigure also contributed chemical causes to temperature differences that further cause instability in materials leads to the decomposition of most materials, because materials have explosive limit in terms of temperature whenever their temperature were exceeded resulted into fire outbreak, referred to as hazard.

Mechanical causes are due mainly to the moving parts of the machine. This he claimed to have been due human errors. If the operating regulation and procedures are not strictly followed, it could result into mechanical hazards.

Odigure (1998) attributed electrical hazard to largely faults in installation. This could result in electrical shock which varies from tingling sensation to vibration of the heart. This action could lead to death depending on the voltage. Electrical hazards could also occur through various ways like faults as overloading , short-circulating, fault -to-earth and fault contacts.

Environmental hazards are caused by industrial processes i.e. the industrial process which has both desired product and effluent could bring about environmental hazard.

2.1 IDENTIFICATION/ASSESSMENT

Abolarinwa (1998) observed that identification of hazard is a major tool that can be used to prevent, manage and control hazards. A hazard identified is a hazard controlled, prevented and managed. In support of this statement , any industry that hazards will be able to manage, prevent, and control them (Susan, 1984).

There are various ways or techniques of identifying hazards, these are:

(i) Check list

(ii) Hazard operability study (HAZOP)

(iii) Fault tree. Odigure (1998 and Alain 1991)

Alain (1991) defined hazard identification as a process that breaks down the whole process into components (parts or stages) and identifying the potential hazard associated with the process.

Odigure (1998) reported that most of the identification techniques are quantitative in nature which make application simple.

2.1.1 CHECK LIST

Alain (1991) identified checklist to be the oldest from of identification techniques. Odugure (1998), however referred to check list as the simplest techniques for failure analysis. Check list can be used during design and operation as a hazard recognition tool. It involves listing the causes and putting them together in a detached from it could be in a form of "Top down" or "Bottom up" depending on desired event. Odigure (1998) and Alain (1991) observed that omission from checklist could be very dangerous.

2.1.2 HAZARD AND OPERABILITY STUDY (HAZOP)

Alain (1992) observed that it is qualitative in nature and best for safety review at the design stage and in operating plant particularly before modification.

Odigure (1998) defined its application as comprehensive and reliable because it involved a group review this chance of omission or over sight is greatly reduced. He observed that it was time consuming and required the attention of senior safety expert personnel.

2.1.3 FAULT TREE

This is a quantitative hazard analysis technique that analyse the chance of hazardous event occurring Odigure (1998)

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 an selected point forward to the ultimate, the other was capable of tracing element back from the point of primary causes.

Odigure (1998) related this events to components failures, human errors or any other pertinent event that could lead to the top event.

Hence, the fact that human error is the major cause of accident is further established. The new order of uncertainty must be taken into account for hazard assessment to be complete (Susan, 1984).

2.2 PREVENTION

Prevention is the act of stopping an occurrence of a hazard Susan (1984) reported that hazard manifest itself in everything we do or process, but are hardly noticed, thus the act of prevention should be a continuous process. An English adage which says that 'prevention is better than cure" further buttress this point. For any industry to survive, it must first think of its prevention.

Connell (1998) reported that hazard prevention should start from the design stage, while Odigure (1998) included the use of safety measures as a preventive measure from design stage (safety relief valves, automated systems)

Samson (1997) defined hazard prevention as the knowledge of the hazard itself i.e. the identification of hazard is the prevention. Odigure (1998) noted that prevention was the act of defining the problem. This in turn could lead to its identification and eventually its prevention i.e addressing the fundamental causes.

Ezenwa (1995) however reported that prevention involves the use of legislation and safety-gadgets.

Samson (1997) however suggested that the use of safety gadgets in the work permit system.

Oyofo (1998) observed that accidents (event) do not just happen, they are caused. He therefore suggested training of operator on the basic principle of equipment and the safety measures, also the use of sluggard.

Ezenwa (1995) attributed the problem of prevention to inadequate identification and lack of data for strategic planning of preventive measures. For effective prevention of individual hazard, adequate identification measures and necessary data would be made available to the professionals by the management of the industry.

Toney (1998) reported that the best way to prevent hazard was to first recognize and understand the existence of hazards (accidents, incidents and occupational ill health) before applying any preventive measure.

2.3 MANAGEMENT

Lenz (1984) defined hazard management as the identification analysis and elimination of risks (hazard) and selecting the most advantageous methods of treating it. While Munich (1998) described hazard management as a structural programme aimed at coming to term with hazards and dangers that threaten a person.

Thus, hazard management can be said to be the identification, assessment, determination of control system and placing adequate measure to avoid re-occurrence of hazard that threaten people and destructive to assets. Yinka (1998) did not rule out the employment of expert in the identification in process.

The next step after identification is the assessment. Oyofo (1998) suggested that the use of a matrix (hazard assessment techniques) which he asserted was easy to use and simple to understand Odigure (1998) opined that it was qualitative. Oyofo (1998) referred to it to be the simplest and did not require a specialist training to apply he matrix. He however defined assessment as the process of analysing and evaluating in qualifyable terms.

Thus, assessment can be described to be the carrying out of analysis on the identified hazard and its relative impact, if left uncontrolled.

Oyofo (1998) suggested that a good management would not look at the cost of managing hazard, but the health and safety of the staff (workers) should be paramount.

Susan (1984) observed that hazard management involved the ability to differentiate between accident and incident or the act of God, acts of nature or acts of human.

Hazard management imply that hazards and help to decide a course of action to follow, and implement the appropriate control or integration strategies.

Susan (1993) opined that hazard management was a complex process fraught with many unresolved issues such as equity, scientific uncertainty, basic management approaches and the proverbial bottom line of industry; as a result the tools or techniques used in managing these hazards are so highly varies as the hazard themselves.

2.4 CONTROL

Susan (1984) reported that hazard control involves the total elimination, blocking or isolation of the hazard from workers.

Control of hazard occurs when it is not possible to prevent it (hazard) from the design or it sample uneconomical to prevent changed from the design or it is simply uneconomical to prevent or when it is simply unpreventable. Oyofo (1998) referred to control stage as the stage when one begins to figure out what to do to remove the hazard completely, reduce it to a low or bearest minimum. He further described the process of control into two main fold.

(1) software and

(2) hardware

Software includes training, incident report and investigation, enforcement of policies and insurance (which includes workmen's compensations, medical schemes and life assurance policies)

Hardware includes design and engineering practices, audits and inspection, planned maintenance and system management's.

Anibuese (1991) defined control as a set of measure and techniques which aim at the elimination or reduction of hazards in the working environment. He however stressed the recognition of occupation hazard as a major key to hazard control, before any hazard can be effectively controlled identification of such hazard should be carried out. Ezenwa (1995) observed that apart from the identification, the evaluation of hazard which include the determination of the degree and condition of exposures as well as the comparison of such data with standard and accepted standards.

From the foregoing, the use of legislation can also help to put a positive control measures to the acceptable standard in the industry.

2.5 LEGISLATION

In anticipation of the incidence and control of hazard, various infrastructures and machinery have been established by the Federal Government to enhance the safety of the workers. These are laws enforced on the industry. This legislation differs from country to country and state to state.

Ezenwa (1996) described legislation as laws that enforce the welfare of workers on the management. Workers welfares should not be at the total neglect of equipment used in the industry, thus the review or promulgation of most laws has to be affected.

There are various law or legislation's used in Nigeria, these are:

1. Factory Acts of 1990 which replaced the factory's legislation have been made under this factory Acts.

2. The mineral oil (safety) regulation of 1963 was promulgated to ensure safety in the upstream petroleum operation while the petroleum regulation of 1976 and petroleum refining regulation of 1974 provide the guidelines for safety in the down stream operation.

3 The workman compensation Act deals with the care, compensation of the disabled workers.

4. Federal Government" Harmful waste disposal" Decree of No. 42 of 1986 his is related to dumping of harmful waste in any parts of this country (Environmental)

5 Government edits and Decree relating to environmental pollution edits of 1989, this gives direction (standard) for the industrial effluents, gaseous nursing and hazardous waste. The agencies that ensure these laws are enforced includes

   (a) factory inspectorate and factory inspector in Federal Ministry of Labour and Productivity. There is also an inspectorate with inspectors for the petroleum industry.

   (b) Internal (corporate) engineering and medical within the specific industry

   (c) Various agencies and professional association such as the natural industries safety council, Nigeria institute of safety professionals and society of industrial physician of Nigeria

   (d) The Federal Environmental Protection Agency (FEPA). The review of this legislation to include the safety of the equipment to avoid failure due to human errors should be affected since the breakdown of the industry is as hazard too.

In conclusion, the literature review has defined, explained and discussed hazards, what it takes to prevent, control and manage hazards. It talks about ways to the prevention and control and the ways it has been done before, thus given an overview of the ways the quantification of hazard has been done before i.e. the use of accident cases, data on human errors for quantification. This project takes a look at the equipment failure as the hazard and all the quantification are done with respect to it.

CHAPTER THREE

3.0 METHODOLOGY

Failure data of the liquid catalytic cracking unit and other relevant information were obtained from the maintenance department of Kaduna Refinery and Petrochemical company. There are various types of data for the quantification of hazard. These include information on accident data and system malfunction which produces less harmful consequence then the former (e.g. incidents or near misses). Other informations gathered were on performance of components (e.g. electric components and active electromechanical components) and component items or systems; that is reliability data, data on human errors were also considered.

3.1 DATA COLLECTION

The source of data is the maintenance planning and development of the Kaduna Refinery and petrochemical company.

There are two methods of data collections, the reliability test and the operating experience data gathering. The operating experience data gathering was used for this study. This involves the monitoring of the behaviour of some components under operating condition and all the events that might have taken place; Data collected were recorded in the data sheets. They were filled in for each component monitored. Data sheet also contains equipment technical characteristics and important data. The next item was the failure sheets (these were filled in each time an incident affect the components monitored, thus, the equipment history cards were recorded from the data sheets and failure sheets respectively.

Data were recorded by the panel/chief operators in the log book; the Engineering and Technical service department and safety department provided further information for this project.

3.2 ANALYSIS OF DATA

Both the failure rate and common-cause methods were used for the quantification.

(i) Failure rate:

Having known the failure frequency and the total operating time the failure rate can be calculated considering the fact that equipment breakdown is also a hazard to the company; because it could cause accidents to the operators. The use of this method is recommended.

(ii) Common-cause method:

This method is divided into explicit and parametric method. The parametric in particular. Beta method is used in the quantification. It was first used in a nuclear plant in the United State of America. Flaming , the initiator of this device claimed that the method was simple and had a wide range of application. Beta method is the ratio of dependent failure to the total failure ratio.

This method traces the cause of the failure to the root.

3.3 SIGNIFICANCE OF THE VARIOUS METHODS

These methods estimate the number of failures recorded. It also gives an over view of the design of equipment. The frequency of failure allows us to estimate failure rate and asses the availability or reliability of the system knowing the causes of the incident, the methods give an highlight to its. Prevention and control. Common cause provides an insight on how to improve the design of equipment, process and consequently the safety of the equipment.

Since these methods are broadly based, an over sight of a hazardous condition is minimized; these methods are highly efficient for analysis considering the fact that they trace causes to the root. The common-cause can be used for modeling of the failure and it can go for both operation or demand failure.

3.4 FAILURE

Failure is defined as the termination of ability of an entity to perform a required function. An entity is said to have failed when it is no longer able to fulfil its function(s).

Failure can be classified in different ways.

(i) failure as a suddenness

(ii) failure according to degree

(iii) failure as to combination of suddenness and degree

(iv) classification according to the dates of their occurrence in system life time

(v) classification as to effects

(vi) classification as to causes.

3.5 FAILURE RATES

Failure rates gives the limit of the ratio of conditional probability that the instant of time; of a failure of an entity falls within a given time interval, (t,t + Dt) to the length of this interval, Dt, when Dt tends to zero. Given that the entity has not failed over (O,t)

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

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

using the theorem of conditional probabilities

$\lambda(t)$ = lim1/Δt * P{E failed from time t to t+Δt

and E $\Delta t \to 0$ $\frac{\text{not failed over (0,t)}}{\text{P\{E not failed over (0,t)\}}}$

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

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

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

$$\lambda(t) = -\frac{dR/dt^*(t)}{R(t)} = 0$$

The failure rate is referred to as instantaneous failure rate.

3.6 TYPES OF FAILURE RATE

There are various types of failure rate, this includes

(i) operating failure rate

(ii) standby failure rate

(iii) failure rate upon demand

Due to the data obtained, the rate based on operating failure rate was employed.

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:

λ = limit $1/\Delta t$. P(E failed between t and t +Δt)

$\Delta t \rightarrow o$ given that it did not fail over (o,t)

In this case, assuming failure rate is constant, an estimator λ of the failure rate is given by

$\lambda = N_f/T_f$

Where

N_f = Number of failure observed during operation

T_f = cumulative or total operating time

3.6 COMMON - CAUSE FAILURE

This defined the dependability of failure as to originating from the same direct cause. It also define the probability of a failure during operation, there are two types of common-cause methods for computations.

(i) Explicit method:

This is based precisely on the knowledge of the causes of failure

(ii) Parametric method:

Based on the modeling of the failure effects with no identification of the failure causes.

There are various parametric methods

(i) Beta-factor method (used for this study)

(ii) Multiple greek letter method

(iii) Shock method

Beta-factor method:-

This is the most widely used and the easiest to use. It assumes two types of failures

(1) Independent failures (independent primary failures) and it is denoted by λ_I

(2) Dependent failures (of the common causes type) denoted by λ_c

Thus total failure (λ) = $\lambda_1 + \lambda_c$

Parametric β is used to denote the fraction of the total failure rate attribute to dependent failure

$\beta = \lambda_c/\lambda = \lambda_c/\lambda_1 + \lambda_c$

$0 < \beta < 1$

The use of the two methods is significant in that they trace to the root causes of hazard and looks into the ways of modeling the failure (incident) and can be used for both operation and demand failure modeling. It also assesses the availability or readability of a system.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

From the data obtained, losses for each year can be calculated

Loss = Designed throughout - Actual throughout i.e for 1990

The designed though put = 125.63×10^3 kg/hr, while

The actual through put = 64.45×10^3 kg/hr.

Thus, loss = $125.63 \times 10^3 - 64.45 \times 10^3$

= 61180 kg/hr

Thus, table 1 can be gotten

Table 1

YEAR	Design Throughout kg/hr	Actual Throughout kg/hr	Loss kg/hr
1990	125.63×10^3	64.45×10^3	61180
1991	125.63×10^3	45.89×10^3	78740
1992	125.63×10^3	53.92×10^3	71710
1993	125.63×10^3	6.21×10^3	119420
1994	125.63×10^3	17.58×10^3	108050
1995	125.63×10^3	10.45×10^3	115180
1996	125.63×10^3	59.71×10^3	65920
1997	125.63×10^3	33.30×10^3	92330

4.2 Failure rate

There are various ways of quantifying using the failure rate method but due to the data obtained, this calculation is based on operating time

i.e failure rate = frequency of failure/ cumulative operating time

table 4.2 presents the components, the member of failures encountered and the quantification of failure rate over the period of seven years.

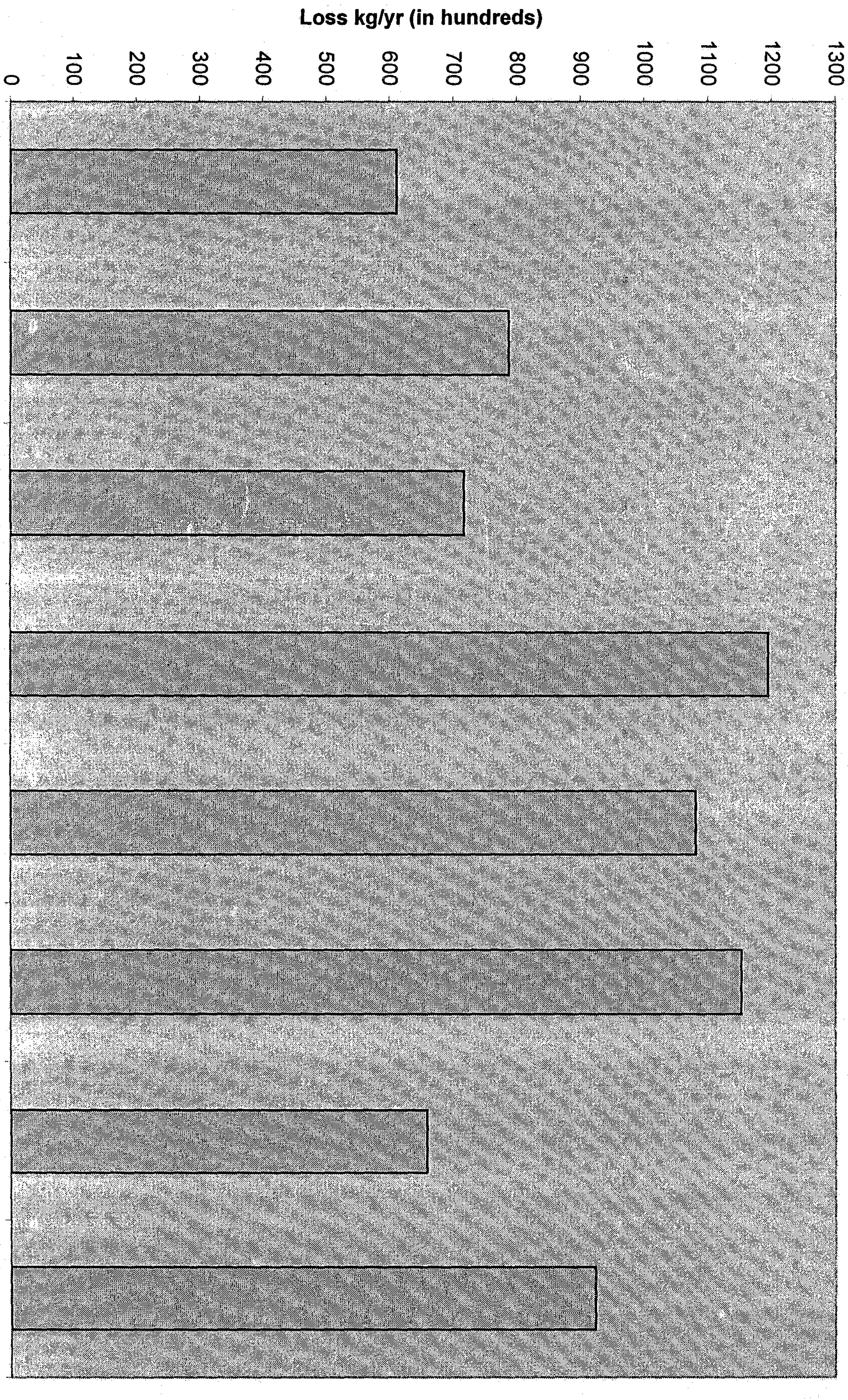
Loss kg/yr (in hundreds)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300

TABLE 2

		90		91		92		93		94		95		96
Component equipment's	Frequency	Failure rate	Frequency	Failure rate	Frequency	Failure rate	Frequency	Failure rate	Frequncy	Failure rate	Frequency	Failure rate	Frequency	Failure rate	Frequ
Hate exchange	15	1.71×10^{-3}	11	1.26×10^{-3}	45	5.1×10^{-3}	40	4.51×10^{-3}	13	1.48×10^{-3}	13	1.43×10^{-3}	32	3.64×10^{-3}	7
Electric motor	80	9.13×10^{-3}	63	7.19×10^{-3}	40	4.55×10^{-3}	23	2.63×10^{-3}	20	2.28×10^{-3}	10	1.14×10^{-3}	7	7.97×10^{-4}	3
Pressure safety value	6	$6.85 \times 10v^{-4}$	3	3.42×10^{-3}	4	4.55×10^{-4}	8	9.13×10^{-3}	6	6.85×10^{-3}	16	1.83×10^{-3}	12	1.37×10^{-3}	11
Pumps	10	1.14×10^{-3}	18	2.05×10^{-3}	15	1.71×10^{-3}	20	2.28×10^{-3}	19	2.17×10^{-3}	21	2.40×10^{-3}	9	1.03×10^{-3}	16
Columns	2	2.28×10^{-4}	3	3.42×10^{-4}	6	6.83×10^{-4}	10	1.14×10^{-3}	11	1.26×10^{-3}	9	$1.03\ 10^{-3}$	7	7.9×10^{-3}	4
Drums	4	4.60×10^{-4}	3	3.42×10^{-4}	6	6.83×10^{-4}	3	3.42×10^{-4}	7	7.99×10^{-4}	8	9.13×10^{-3}	18	2.05×10^{-3}	7
Heaters	2	2.28×10^{-4}	4	4.57×10^{-4}	3	3.42×10^{-4}	2	2.8×10^{-4}	1	1.14×10^{-4}	3	3.43×10^{-4}	7	7.97×10^{-3}	4
Compressors	8	9.13×10^{-3}	2	2.28×10^{-4}	4	4.55×10^{-4}	8	9.13×10^{-4}	7	7.99×10^{-4}	2	2.28×10^{-4}	6	6.8×10^{-3}	3
Air cooler	1	1.14×10^{-4}	2	2.28×10^{-4}	3	3.42×10^{-4}	2	2.28×10^{-4}	1	1.14×10^{-4}	4	4.57×10^{-3}	3	3.42×10^{-3}	2
	128		109		126		116		85		86		101		53

2

90 91 92 93 94

96

iency	Failure rate	Frequency	Failure rate	Frequency	Failure rate	Frequency	Failure rate	Frequncy	Failure rate	Frequency	Failure rate	Frequency	Failure rate	Frequency	Failure rate
	1.71×10^{-3}	11	1.26×10^{-3}	45	5.1×10^{-3}	40	4.51×10^{-3}	13	1.48×10^{-3}	13	1.43×10^{-3}	32	3.64×10^{-3}	7	7.99×10^{-3}
	9.13×10^{-3}	63	7.19×10^{-3}	40	4.55×10^{-3}	23	2.63×10^{-3}	20	2.28×10^{-3}	10	1.14×10^{-3}	7	7.97×10^{-4}	3	3.42×10^{-3}
	$6.85 \times 10v^{-4}$	3	3.42×10^{-3}	4	4.55×10^{-4}	8	9.13×10^{-3}	6	6.85×10^{-3}	16	1.83×10^{-3}	12	1.37×10^{-3}	11	1.26×10^{-3}
	1.14×10^{-3}	18	2.05×10^{-3}	15	1.71×10^{-3}	20	2.28×10^{-3}	19	2.17×10^{-3}	21	2.40×10^{-3}	9	1.03×10^{-3}	16	1.83×10^{-3}
	2.28×10^{-4}	3	3.42×10^{-4}	6	6.83×10^{-4}	10	1.14×10^{-3}	11	1.26×10^{-3}	9	$1.03\ 10^{-3}$	7	7.9×10^{-3}	4	4.57×10^{-4}
	4.60×10^{-4}	3	3.42×10^{-4}	6	6.83×10^{-4}	3	3.42×10^{-4}	7	7.99×10^{-4}	8	9.13×10^{-3}	18	2.05×10^{-3}	7	7.99×10^{-4}
	2.28×10^{-4}	4	4.57×10^{-4}	3	3.42×10^{-4}	2	2.8×10^{-4}	1	1.14×10^{-4}	3	3.43×10^{-4}	7	7.97×10^{-3}	4	4.57×10^{-4}
	9.13×10^{-3}	2	2.28×10^{-4}	4	4.55×10^{-4}	8	9.13×10^{-4}	7	7.99×10^{-4}	2	2.28×10^{-4}	6	6.8×10^{-3}	3	3.43×10^{-4}
	1.14×10^{-4}	2	2.28×10^{-4}	3	3.42×10^{-4}	2	2.28×10^{-4}	1	1.14×10^{-4}	4	4.57×10^{-3}	3	3.42×10^{-3}	2	2.23×10^{-4}
		109		126		116		85		86		101		53	

Finding the average of the failure rate given table 3

Table 3

Year	Average failure rate
1990	2.54×10^3
1991	2.53×10^3
1992	1.59×10^3
1993	1.47×10^3
1994	1.08×10^3
1995	1.09×10^3
1996	2.08×10^3
1997	0.72×10^3

4.3 QUANTITY OF HAZARD

Knowing the average failure rate and the cumulative losses, the hazard for the particular year can be calculated

Hazard = failure rate x loss

i.e.

hazard = Average failure rate x loss, this leads to table 4

Table 4

Year	Hazard
1990	155.40
1991	201.74
1992	114.02
1993	175.55
1994	116.69
1995	125.55
1996	137.10
1997	66.48

4.4 Common-cause failure

This sub-divides the failure causes to either dependent or independent failure, it buttress the quantification to the ratio of dependent failure to the total failure rate

$\beta = \lambda c/\lambda = \lambda c/\lambda_1 + \lambda c$

where:

λ_1 = independent failure

λc = dependent failure

Using the above formular the failure rate can be obtained. Table 5 gives the combination of component and failure rate due to the failures

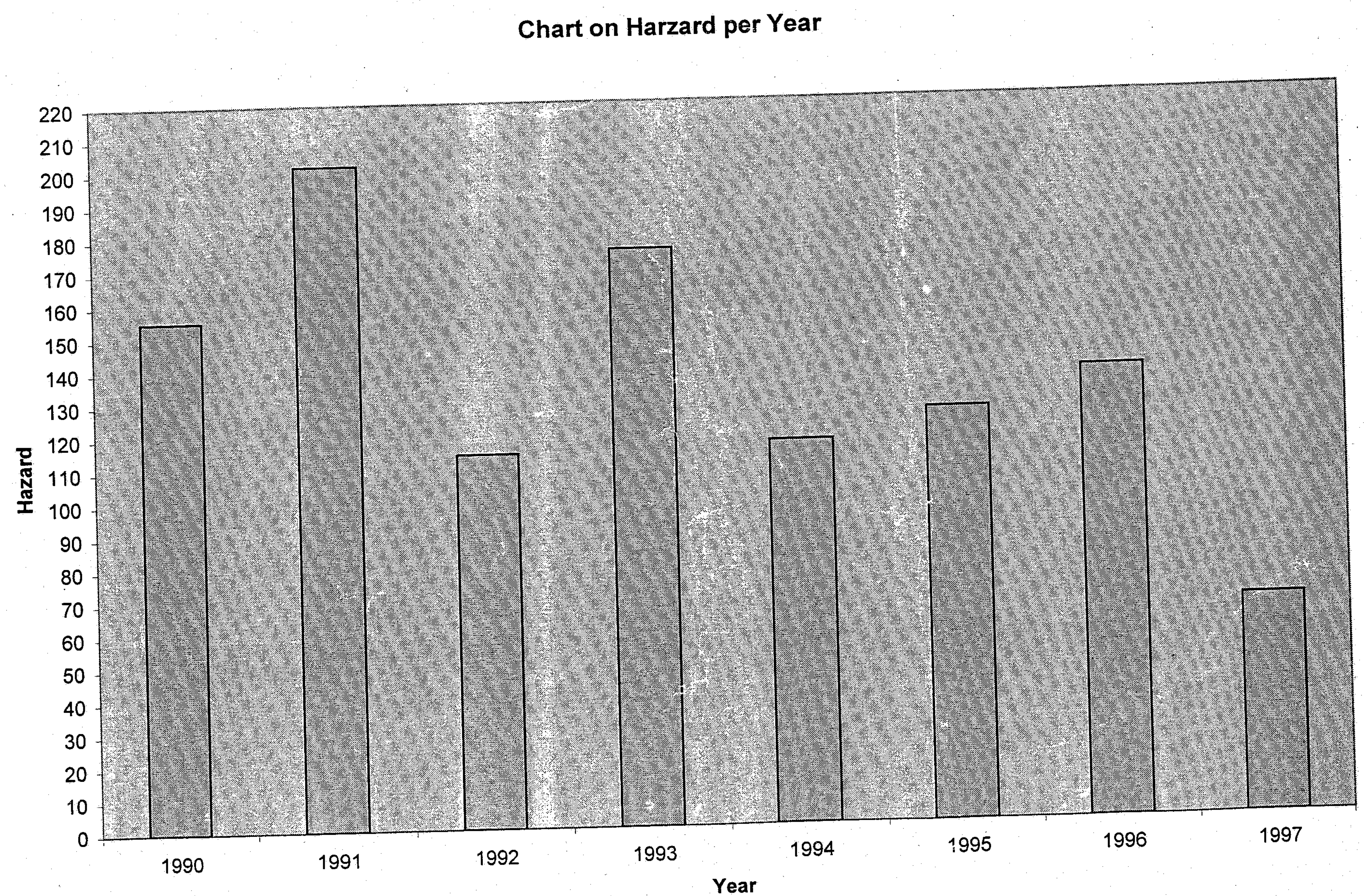
Chart on Harzard per Year
Hazard
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1990
1991
1992
1993
1994
1995
1996
1997
Year

Table 5

Components	Failure rate
Pressure safety value	0.288
Columns	0.365
Drums	0.130
Heaters	0.940
Pumps	0.430
Heat exchangers	0.356
Electric motors	0.190
Compressors	0.152
Air cooler	0.420

This methods restrict the failure rate to individual equipment/component

4.5 DISCUSSION OF RESULT

Hazard quantification highlights the causes of hazard, before a hazard can be quantified, knowledge about the causes must be known, it is also a tool to understanding hazard prevention, control and management.

Hazard analysis address whether high safety standard is necessary or required to maintain a safe operation. This study looks at the likelihood of an undesired incident occurring , if the channels were high or low. It also suggests ways of how to minimize a high incident rate, and looks into prevention, management and control as a measure of reducing the undesired events.

Table 1 shows that 1993 has the highest loss of 119420kg/hr. this is as a result of the political problem of the nation and the fire incident recorded that year. The fire incident rendered the plant unproductive for a long period of time and cost the company about ten million US dollars. 1995 figure of 115180 was also the result of fire incident, the fire incident was attributed to operators error by the management (Samson 1993) it was claimed that they (operators) did not report the breakdown of the air blower on time, while the operators prefer to attribute it to lack of spare parts i.e. human incapabilities (Alani, 1992)

Table 2 show both the frequency of failure and failure rate. High frequency of breakdown which leads to high down time is as a result of constant breakdown of equipment. Heat exchangers and electric motors recorded highest frequency of failure which ranges from 45 to 7 for exchangers and 80 t0 3 for electric motors. This is due to the fact that these equipment are the most used. The sensitive nature of heaters reduces the failure frequency of the equipment. The frequency ranged between 1 to 4 over the years under consideration. The failure rate based on total (cumulative) operating time for 1990 shows the highest average value (table 3). It has a value of 2.54 x 10-3. This is due to a high failure frequency of 128. 1997 showed the lowest failure rate of 0.79 x 10-3 with a total failure frequency of 53. Thus the frequency of breakdown contribute to the failure rate.

Quantification using the common-cause method presented in table 5, showed that the heaters have the highest value of 0.940 perhaps to the sensitive nature of the equipment. This rendered the equipment to be one of the most important in the units. Drums with the convert value of 0.130 shows that most of its failure is more of an independent failure i.e. it is just for storage. The justification of this statement can be obtained from flaming's work where he concluded that the failure rate should not be more than one i.e less than one (Alain 1993).

Hazard quantification (Table 4) showed the important of failure rate and loss. Loss is a function of actual throughput and throughput, this table 4 is a justification of all other quantification of all other quantification.

Abolarinwa (1998) said when all the losses and hazardous condition are quantified in monetary terms it would be better and chapter to place safety devices as a preventive or control measure. The 1993 fire accident which cost the company about ten million US dollars, would have been cheaper and economical if preventive control/safety were installed (i.e. automation of the unit)

The long and frequent breakdown of the plant was attributed to management problem by the operator i.e. due to lack of spare parts to charge the bad ones. While the management prefers to say it's the operators who were at fault due to the fact that when the investigation of accidents were traced, operators are mostly at fault.

Thus as suggested by Anibuere (1991) "finding that faulty designed were responsible would entail enormous shut down and shut down and retrofitting cost; finding that management was responsible preserves the system with some soporific injections about training". While this whole project is not to allocate responsibility and place blames on individual, there is a need to identify possible system improvement in order to avoid future undesirable events (hazards).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This study has shown that the likely hood and consequence of an incident (hazard) can be evaluated or predicted quantitatively. It has also been able to identify the possible or likely hazards in the fluid catalytic cracking unit of Kaduna Refinery using both the failure rate and common-cause methods. Thus, the need for the prevention control and management of hazard has been justified. Both the failure rate and common cause methods have also shown to be very effective due to the fact they quantify hazardous condition to the root. It has also shown that the cost of prevention and control of hazard is much more economical than the cost of correcting the consequences.

5.2 RECOMMENDATION

(i) Efforts should be made to provide proper training for operators, maintenance Engineering and safely personnel, also the provision and usage of safety gear should be made compulsory.

(ii) Because it is inevitable that hazardous material which could be potentially hazardous would be handle by refining workers, proper handling techniques should be incorporated into their training programmes.

(iii) The use of safety control device would be fully implemented and the review of the whole design should be look into to eliminate all errors that could lead to an accident.

(iv) Complete over hauling of the plant should be done on and when due.

(v) Due to the potentially pollutant nature of some substances produced in the plan, proper treatment should be done to avoid environmental pollution

(vi) Reviewing of the start-up or warm up for most of the equipment after a breakdown should be considered.

(vii) Adequate provision of necessary working tools and spare parts should be ensured.

(viii) Since one of the objectives of K.R.P.C is to ensure efficient operation, the management should consider regular review of the process safety management, to ensure that it is kept relevant.

(ix) Awareness safety ands health requirements in the organisation should further be identified with positive action which will encourage more active involvement of the safety and hearth section.

(x) Total quality management should be enforced and placing of the right man on the right job.

(xi)Medical: regular medical check-up on employee should be done and good house keeping with personal hygiene should be preached.

APPENDICES

APPENDIX I

Loss calculation

Loss = Designed throughout - Actual throughput

Thus:

1990	=	125.63×10^3 - 6.445×10^3	= 61180
1991	=	125.63×10^3 - 45.89×10^3	= 78740
1992	=	125.63×10^3 - 53.92×10^3	= 71710
1993	=	125.63×10^3 - 6.21×10^3	= 119420
1994	=	125.63×10^3 - 17.58×10^3	= 108050
1995	=	125.63 x 103 - 10.45×10^3	= 115180
1996	=	125.63 x 103 - 59.71×10^3	= 65920
1997	=	125.63 x 103 - 33.30×10^3	= 92330

APPENDIX II

Failure rate calculation

From the formular

Failure rate = frequency of failure

Cummulative operating time

Failure rate (probability) = Nf/ Tf

Where Nf = number of failures in a year

Tf = cumulative operation time (hours)

1990

heat exchanges (Nf) = 15

cummulative operating time (Tf) = 8760

15/8760

λ = 1.71 x 10-3

electric motors

Nf = 80

Tf = 8760

λ = 80

8760 = 9.13 x 10-3

pressure safety value

Nf = 6

Tf = 8760

λ = 6

8760 = 6.85 x 10-4

pumps:

Nf = 10

Tf = 8760

λ = 10

8760 = 1.14 x 10-3

λ = 2

8760 = 2.28 x 10-4

drums:

Nf = 4

Tf = 8760

λ = 4

8760= 4.6 x 10-4

heater

Nf = 2

T = 8760

λ = 2

8760 = 2.28 x 10-4

compressor:

Nf = 8

Tf = 8760

λ = 8

8760 = 9.13 x 10-3

air coolers:

Nf = 1

Tf = 8760

λ = 1

8760 = 1.14 x10-4

All others follow the same pattern

APPENDIX III

<u>Calculation of Average failure rate</u>

Average failure rate = addition of all the failure rate

Total years under consideration

(average) = addition of failure rates

total years under consideration

1990:

λave = <u>1.7 x 10-3 + 9.13-3 x 10-34+6.85 x 10-3 +1.14 x10-3 +2.28x10-4+4.60 x 10-4</u>

<u>+2.28x 10-4+9.13 x 10-3 +1.14x10-4</u>

8

λ ave = 0.22825 = 2.54 x 10-3

8

1991:

λave = 1.26 x 10-3+7.19 x 10-3+3.42 x 10-4+2.05 x 10+3.42-4 x 10+3.42-4 x 10-1+4.57 x 10-4+2.28 x 10-4+2.28 x 10-4

8

λave = 2.53 x 10-3

1992:

λave = 5.12 x 10-3+4.55 x 10-3+4.55 x 10-3+1.71 x 10-3+6.83 x 10-4+6.83 x 10-4+3.42x 10-4+4.55 x 10-4+3.42 x 10-4

8

λave = 1.59 x 10-3

1993:

λave = 4.51 x 10-3+2.63 x 10-39.13 x 10-4+2.28 x 10-3+1.14 x 10-4+3.42 x 10-4+2.28 x10-3+9.13 x 10-4+2.28 x 10-4

8

λave = 1.47 x 10-3

1994:

λave = 1.48 x 10-3+2.28 x 10-3+6.85 x 10-4+2.17x10-3+1.26 x 10-3+7.99 x 10-3+1.14 x 10-3+7.99x 10-4+1.1.14 x 10-4

8

λave = 1.08 x 10-3

1995:

λave = 1.48 x 10-3+1.14 x 10-3+1.83 x 10-3+2.40 x 10-3+1.03 x 10-3+9.13x

10-4+3.43 x 10-4+2.28 x 10-4+4.57 x 10-4

8

λave = 1.09 x 10-3

1996:

λave = 3.64 x 10-3+7.97 x 10-4+1.37 x 10-3+1.03 x 10-3+7.97 x 10-4+2.05 x 10-3+7.97 x10-3+6.83 x 10-4+3.42 x 10-4

8

λave = 2.08 x 10-3

1997:

λave = 7.99 x 10-4+3.42 x 10-4+1.26 x 10-3+1.83 x 10-3+4.57 x 10-4+7.99 x 10-4+4.57 x 10-4+3.43 x 10-4+2.23 x 10-4

8

λave = 0.72 x 10 -3

APPENDIX IV

Hazard quantification

Hazard = failure rate x loss

i.e

hazard = average failure rate x loss

thus

1990 $= 2.54 \times 10^{-3} \times 61180$

$= 155.40$

1991 $= 2.53 \times 10^{-3} \times 788740$

$= 201.74$

1992 $= 1.59 \times 10^{-3} \times 71710$

$= 114.02$

1993 $= 1.47 \times 10^{-3} \times 119420$

$= 175.55$

1994 $= 1.08 \times 10^{-3} \times 108050$

$= 116.69$

1995 $= 1.09 \times 10^{-3} \times 115180$

$= 125.55$

1996 $= 2.08 \times 10^{-3} \times 65920$

$= 137.10$

1997 $= 0.72 \times 10^{-3} \times 92330$

$= 66.48$

APPENDIX V

Common cause failure calculation

$\beta = \lambda c/\lambda \ = \lambda c/\lambda 1 + \lambda c$

$\lambda \ = \lambda i + \lambda c$

λi = independent failure

λc = dependent failure

thus for

pressure safety value

$\lambda c = 0.002173$

$\lambda = 0.00754$

$\beta = 0.002173/0.00754$

$= 0.288$

columns:

$\lambda c = 0.002165$

$\lambda = 0.005931$

$\beta = 0.002165/\ 0.005937$

$= 0.365.$

drums:

$\lambda c = 0.000802$

$\lambda = 0.006388$

$\beta = 0.000802/\ 0.006388$

$= 0.130$

heaters:

$\lambda c = 0.009569$

$\lambda = 0.010179$

$\beta = 0.009569$

0.010179

= 0.94

pumps:

$\lambda c = 0.00628$

$\lambda = 0.01461$

$\beta = 0.00628/ 0.01461$

= 0.43

heat exchangers:

$\lambda c = 0.00969$

$\lambda = 0.02725$

$\beta = 0.00969/ 0.02725$

= 0.356

electric motors:

$\lambda c = 0.005347$

$\lambda = 0.028059$

$\beta = 0.00534/ 0.028059$

= 0.19

compressor:

$\lambda c = 0.001942$

$\lambda = 0.012784$

$\beta = 0.001942/ 0.012784$

= 0.152

air coolers:

$\lambda c = o.000913$

$\lambda = 0.002053$

$\beta = 0.000913/0.002053$

$\beta = 0.45$

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