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Reliability of Valve Failures in Niger Delta Refinery Ltd Plant

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ABSTRACT

Reliability on values were investigated with the effect of fluid flow on the rate of failures in Niger Delta Refinery plant. The obtained results demonstrates the ageing factors on constant failures of the values as well as the flow characteristics. Ageing factors reveals high cost of unreliability in terms of maintainability of the value especially when the failure is related to corrosion influence. However, extensive investigation was conducted to examine the parallel connection of the values and how they affect the flow characteristics as well as induce the service time of the values in an operational plant that contains substances that are carries of agent of corrosive materials. This research work was able to address the significance of reliability engineering as a good tool in engineering management for optimum performance and productivity and safety of life and equipment by provide strategy for maintenance. The research on performance evaluation of the feed line components may not have been previously carried out by ND Refineries however; this research will contribute in improving the overall production capacity of distillation column plant through preventive and regular maintenance checks on the valves.

Key words: Valve, reliability, unreliability, ageing, failures, flow, fluid

1. INTRODUCTION

The performance evaluation of a viable speed direct current (DC) compressor was investigated [1]. The research experiment based on the use of a direct current compressor with a viable speed operation of four different speed operations upon compressor temperature, pressure, and power input parameters was carried out for an interval of 30 seconds [2]. Exergy and energy data were analyzed based on their frequencies. The results obtained reveal that the variable speed operation using a direct current compressor is more reliable and more efficient than the constant speed compressor [3]. Though a compressor can be categorized based on the dynamics and the positive displacement, the positive displacement can be subdivided into reciprocal and rotatory based on the quantity of fluid displaced. Whereas the dynamics type has centrifugal, axial, and thermal jet due to the quantity of gas displaced [4].

The phenomenon of given to birth and the occurrence of death is even that must take place in life. This eventuality is also applied to all manmade equipment, it is a universal concept that anything that has life must dead a consequence decay, this concept is also applied to plants and equipment, they are

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bound to fail due to the laws of nature, either by aging, wearing or tearing due to weathering or friction, corrosion, etc [5]

The phenomenon of given to birth and the occurrence of death is even that must take place in life. This eventuality is also applied to all manmade equipment, it is a universal concept that anything that has life must dead a consequence decay, this concept is also applied to plants and equipment, they are bound to fail due to the laws of nature, either by aging, wearing or tearing due to weathering or friction, corrosion, etc [6]. Hence in reliability engineering, these eventualities cannot be overruled. Natural death or failure of equipment cannot be seen as an undesired event in the study of reliability, but termination of a process during mission time is an undesired event, this undesired event is known as failure in reliability [7]. The major role of a reliability engineer is to prevent this undesired even called failure during the mission time.

Failure is expected to occur on every operating equipment, therefore, it is impossible to eliminate failure, but through the techniques of reliability engineering, it can be curtailed to some certain degree by altering or influencing the equipment (plant) functionality [8].Total reliability is achieved when a system under no circumstances fails, no matter what the mission time for a plant is, reliability can certainly not be 100% accept in an ideal state, when there no operation going on that is the equipment is not in used, at zero mission time. It only tends toward unity but can never be unity; there must be a slight failure or death of one of the functional parameters [9].

The moment of failure of equipment cannot be predicted by an operator, since there is no correlation or mathematical equation or model to determine the failure of equipment when is in operation [10], the instance of failure is neither here nor there, is just an occurrence that happens with chance, therefore it is imperative to note that study of reliability cannot state or predict the moment or the instance equipment will give up or fail. The certainty of failure to occur is an event of chance and can occur at any time [11].

2. MATERIALS AND METHODS

Study Area

Niger Delta (ND) Refinery Limited Company is located at Ogbele, Ahoada East Local Government Area of Rivers State Southern Nigeria. The facility was built initially to refine 1000bpd of crude oil to extract diesel (AGO) as shown in Figure 1.

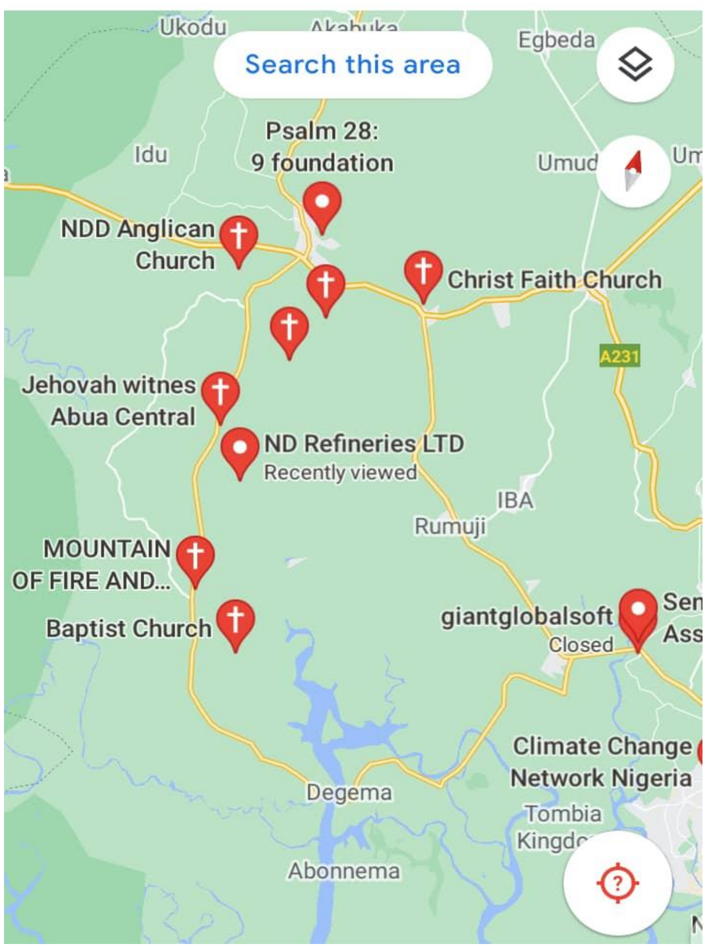

Figure 1: Study Area

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The crude oil to be distilled or refine is sourced from her Ogebele and Otari oil field. Recently the plant has undergone expansion and upgrade which has increased production capacity to 11000bpd. Also the ND modular refinery has been expanded to produce 600,000 litres of gasoline per day. Consistent delivery of the 600000lpd of gasoline produce by ND refinery optimally will account for about 30% of the total gasoline produce by the State NNPC. According to an investigation carried out by Nigeria oil and gas industry Annual report of 2018, find out that NNPC produce 2043070L of gasoline per day.

Tests for Reliability

Reliability engineering is study of the durability and dependability of any engineering components, products and system. It is more of controlling and preventing of risk. Reliability engineering make use of various analytical techniques designed to enable engineers understand the failure mode and pattern of a system. Reliability is a measure of performance or dependence of a facility or a product within a specify time. This measure is a binary function (success or failure), in practice it is imperative to evaluate the period which the product is subjected to use such evaluation is called lifetime or failure time evaluation. Also reliability is seen as an attribute of a product that evaluates the performance of the product in line with the user [7]. Reliability hence, is refers to whether a test that is recurring on or about a study would give the same results or not [7-8].

Methods of Data Collection

Data collection is the process of gathering useful information or material to enable a researcher carried out a research successful. The source of these data could be primary or secondary. The primary sources of data collection consist of first-hand information or raw data obtained by the researcher himself through the records and data collected from the company. Also the secondary data are most data obtained from literatures. For the purpose of this research the data used are primary data. That is information obtained by the research from Niger Delta Refinery (NDR) and also the failure are categories in the three stages such as failure due to infant mortality failure (IMF), constant failure rate (CFR) and wear out failures (WOF).

Material Components

The following components are to be analysed in this study of valves.

Reliability Tools and Techniques

There are reliability tools and techniques methodologies available for failure of plant components. We have the Monte Carlo reliability model which can realistically assess plant condition when combined with cost, repair times and statistical events.

Mathematical Model Formulation and Development

The mathematical model for this research was evaluated using running time of five years (5) year (T) as well as the number of failures (N_F) ,N_S as the number of components still running at the stipulated time duration and N_0 as the total number of components.

Failure rate and mean time to fail or before to fail (MTTF AND MTBF)

The aim of quantitatively reliability is to ascertain the rate of failure compared or relative to time and the model of the failure rate using mathematical and probability density for the sole purpose of understanding the quantitatively aspect of failure . The basic fundamental approach is to establish the failure rate

$$N_0 = N_S + N_F \quad (1)$$

Where, N_0 is number of components, N_s is number of components still operating and N_F is number of failed components

The ratio of failure components per sample sized is a measure of the unreliability of the components within a given time frame.

$$\varphi = \frac{NF}{N_0} \quad (2)$$

The reliability of the components is given as

$$\Gamma = \frac{NS}{N_0} \quad (3)$$

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where: $N_S = N_0 - N_F$ (4)

$\Gamma = \frac{N_0 - N_F}{N_0}$ (5)

$\Gamma = 1 - \frac{NF}{N_0}$ (6)

Γ=1-φ (7)

The probability density function is given as

$$\text{Pdf} = \frac{dN_F}{dtN_0} \quad (8)$$

Where, Pdf is the probability density function, dN_F is the change in the number of failure and dtN_0 is the number of components changing with time

Substituting equation (2) into equation (8) gives

Pfd $= \frac{d\varphi}{dt}$ (9)

Let pfd = f(t) (10)

F(t) $= \frac{dN_F}{dtN_0}$ (11)

Equation can be express as

f(t) dt $= \frac{dN_F}{N_0}$ (12)

upon integrating equation (13) gives the relationship for the unreliability in terms of probability density function Pdf(f (t)

$$\varphi(t) = \frac{N_{F(t)}}{N_0} = \int_0^t f(\tau)d\tau \quad (13)$$

where the integral is the probability that a product will fail in the time interval

$0 \leq \tau < t$ (14)

$\Gamma(t) = \int_0^\infty f(t)d\tau$ (15)

Assuming that the probability of the failure tends to 1

$$\int_0^t f(\tau)d\tau = 1 \quad (16)$$

Hazard Rate

The failure of a component or equipment in a plant can be attributed from inherent design faults or weakness, production and quality assurance related issues, other may be cause by operator usage, the maintenance polices as well as improper use of the equipment. Therefore the hazard rate (H(t)) is the number of failure per unit time per number of non-failed components still running at time (t)

H(t) $= \frac{N_F}{dt} \cdot \frac{1}{N_S}$ (17)

Recall that :

$\Gamma(t) = \frac{N_{S(t)}}{N}$

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$F(t) = 1- \Gamma(t) = \frac{N_{S-}N_F}{N_S}$ (18)

Dividing both sides by dt

$\frac{F(t)}{dt} = \frac{d(N_0 - N_S)}{dtN_0}$ (19)

$\frac{dF(t)}{dt} = -\frac{1}{N_S}\frac{dN_S}{dt}$ (20)

Therefore the hazard rate or the instantaneous failure rate

$h(t) = \frac{f(t)}{\Gamma(t)}$ (21)

$h(t) = \frac{N_0 - N_S}{N_0 dt}$ (22)

Hazard rate is therefore a relative rate of failure but is in depended of the initial size of the components.

$h(t) = -1\frac{d\Gamma(t)}{\Gamma(t)dt}$ (23)

$f(t) = \frac{-d\Gamma(t)}{dt}$ (24)

Integrating equation (24) from 0 to t

$\int_0^t h(\tau) = -\int_0^t \frac{d\Gamma(\tau)}{\Gamma(\tau)dt}$ (25)

$\int_0^t h(\tau) = -\ln \Gamma(t)$ (26)

$\Gamma(t) = e^{-\int h(\tau)d\tau}$ (27)

Total hazard rate THR

$H(t) = \int_0^t h(\tau)$ (28)

$\Gamma(t) = e^{-\tau t}$ (29)

Where τ is hazard constant rate, the (3.27) is an exponential distribution the most use prediction formula.

$\tau = \frac{N_F}{T}$ (30)

Where $\tau$is hazard rate or failure rate, N_F number of failed components, T is total time.

Mean Time between Failures (MTBF)

Another useful concept in reliability study is the mean time between /to failure (MTBF/MTTF). The only distinction between MTBF and MTTF is MTBF is use when referring to components that are repairable while MTTF is used when the components is not repairable. That is any faulty component is thrown away and replaced. The estimate of mean time between failure (MTBF) and mean time to failure (MTTF) are both measures of central tendency. It can be evaluated by taking the inverse of the hazard rate function.

Taking the inverse of equation (28), we have

$$\frac{1}{\tau} = \frac{T}{N_F} \quad (30a)$$

$$\frac{1}{\tau} = \delta \quad (30b)$$

Where δ is mean time between to failure (MTBF)

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Total Mean Time between Failure (TMTBF)

To determine the total mean time between failures for pumps and valves for each year for five year period, we must first establish total failure per year (TFPy).

Thus,

$$(TFPy) = \left[(\frac{T}{NF})_{y1} + (\frac{T}{NF})_{y2} + (\frac{T}{NF})_{y3} + (\frac{T}{NF})_{y4} + (\frac{T}{NF})_{y5}\right] xannualhr/\ yr \quad (31)$$

$$(TFPy)= \left[(\frac{1}{MTBF})_{y1} + (\frac{1}{MTBF})_{y2} + (\frac{1}{MTBF})_{y3} + (\frac{1}{MTBF})_{y4} + (\frac{1}{MTBF})_{y5}\right] xannualhr/\ yr \quad (32)$$

where:

$$TMTBF = \frac{annualhoursperyear}{Totalfailureperyear} = \frac{AHPY}{TFPY} \quad (33)$$

Failure Rate (FR)

To determine the failure rate for each component, the mathematical expression stated in Equation (31) can be applied.

$$\tau = \frac{N_F}{T}$$

$$FR = \tau \quad (34)$$

Total Failure Rate (TFR)

The total rate (TFR) of each component is the sum of the failure rate in each year and is expressed mathematically in Equation (38).

$$TFR = [(TFR)_1 + (TFR)_2 + (TFR)_3 + (TFR)_4 + (TFR)_5] \quad (35)$$

Failure Rate Per Year (FRPY)

To estimate the failure rate per year (FRPY) for each component to be investigated, the mathematical expression for FRPY is expressed in Equations (39), (40) and (41).

FRPY = (failure rate for each component) x (annual hour per year)

$$= (FR)\ (AHPY_1) \quad (36)$$

$$=\left(\frac{NF}{operational\ time}\right)(AHPY) \quad (37)$$

$$FRPY= \left[\frac{1}{MTBF}\right] (AHPY) \quad (38)$$

Total Failure Rate Per Year (TFRPY)

Therefore, the total failure rate per year (TFRPY) is gotten by summing the failure rate of each component per year Equation (38).

$$TFRPY = (FRPY_1) + (FRPY_2) + (FRPY_3) + (FRPY_4) + (PRPY_5) \quad (39)$$

Reliability Model

To determine the reliability of each component, the mathematically expression is given as in Equation (30).

$$\Gamma(t) = e^{-\tau t}$$

$$R = e^{-}(\frac{1}{MTBF})^{t} = e^{-\tau t}$$

where: $\tau = \frac{N_F}{T}$ and $\tau = \frac{1}{MTBF}$

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When as the reliability for each component for five year study is given as in Equation (13).

$$\Gamma = e^{-}\left[(\frac{1}{MTBF})_1 + (\frac{1}{MTBF})_2 + (\frac{1}{MTBF})_3 + (\frac{1}{MTBF})_4 + (\frac{1}{MTBF})_5\right]^{t} \quad (40)$$

Unreliability Model

To determine unreliability for each asphalt plant component, the mathematical expression is from equation (6)

Γ=1- φ

$$\varphi = 1 - \Gamma = e^{-}(\frac{1}{MTBF})_t \quad = 1 - e^{-\tau t} \quad (41)$$

Reliability Evaluation or Analysis of Standby –Line for ND Refinery Pumps and Valve System. Since the ND refinery plant is built to run for several years it is necessary to evaluate the reliability parameter of the ND refinery pumps and valves system aim to ascertain the risk of continue to operate the pumps and valves in these conditions. The ND refineries pumps and valves are arranges in parallel manner, with a stand -by system with one unit of pump and vales operating and the other is waiting in a stand-by-mode for failure of either a pump or a valve in the first line or line A. Specific system is configured in such a way that, as soon as s failure occurs the operator switch to the stand-by unit is shown in Figure 2..

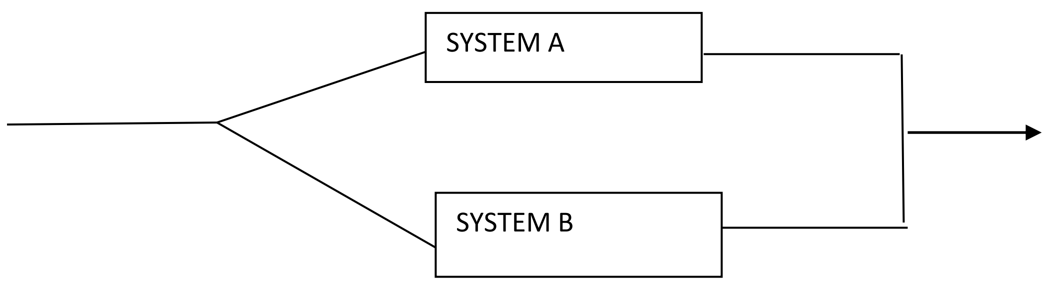

Figure 2: Parallel Arrangement of the Pump and Valve

$$r_{sb=e^{-t\tau_a}} + \left(\frac{\tau_a}{\tau_b - \tau_a}\right)(e^{-t\tau_a} - e^{-t\tau_b}) \quad (42)$$

Where, Rsb = reliability of stand-by line, τ_b = failure rate of line B and t = Operation *time*

Availability Model

To determine availability (A) of each pumps and valves component per year, the expression is given as in Equation (43).

$$A = \frac{uptime}{uptime + down\ time} \quad (43)$$

Unavailability

The unavailability (UA) for each component is determined by Equation (42).

$$UA = 1 - A = 1 - \left[\frac{uptime}{uptime + down\ time}\right] \quad (44)$$

Cost Evaluation

Cost analysis is one of the important aspect reliability analysis or evaluation. The main purpose of the analysis is to the reliability into money. This is the money that will be used for plant maintenance management to justify improvements and avoid loss of the gross margin of the company. Though it is the duty of an engineer define the equipment failure rate and the risk pose by failure on the life of the equipment.

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$$cou = cost_{spareparts} + cost_{labour} + cost_{loss\ of\ prduction\ time} \qquad (45)$$

Table 1: Data for Failure and Repair Time for Valve A

Years	Failure/year	Repair Time (T) hours	Operating Time (Hour/Week)
1	15	2	161
2	30	2	154
3	45	2	133
4	60	2	126
5	70	2	105

Table 2: Data for Failure and Repair Time for Valve B

Years	Failure/year	Repair Time (T) hours	Operating Time (Hour/Week)
1	20	2.5	161
2	28	2.5	154
3	47	3	133
4	80	3	126
5	90	3	105

Table 1 and Table 2 illustrates the failure and the repairs time for valves A and B

Evaluation Analysis of Parallel Valve A

Table 3: Data Collected from ND Refineries Distillation Column Feed line Valves A

Years	Failure/year	Repair Time (T) hours	Operating Time (Hour/Week)
1	15	2	161 (7728)
2	30	2	154 (6384)
3	45	2	133 (6384)
4	60	2	126 (6048)
5	70	2	105 (5040)

Table 3 shows the data collected for the valve line A for a period of 5 years which comprises of the failure rate per year, operating time per week and time to repair each breakdown per year.

To Evaluate the Operating Time Per Year for ND Refineries Distillation Column Feed line Valve A

Operating Time Per Year = Operating Time per Week x 4 Weeks x 12 Months

For 1st year = 161 x 4 x 12 = 7728 hrs/y,

for 2nd year = 154 x 4 x 12 =7392 hrs/y,

for 3rd year = 133 x 4 x 12 = 6384 hrs/y,

for 4th year =126 x 4 x 12 = 6048 hrs/y and

for 5th year = 105 x 4 x 12 = 5040 hrs/y

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Total operating times = 7728 + 7392 + 6384 + 6048+ 5040 = 32592 hrs/y

Mean Time between Failure (MTBF) for the pump on line A

M MTBF = $\frac{Operating\ times}{no\ of\ failure}$

For 1st year = $\frac{7728}{15}$ = 515.2hrs,

for 2nd year = $\frac{7392}{30}$ = 246.4 hrs,

for 3rd year = $\frac{6384}{45}$ =141.866 hrs,

for 4th year = $\frac{6048}{60}$ = 100.8 hrs and

for 5th year = $\frac{5040}{70}$ = 72 hrs

Total mean time between failure for the for (pump) on line B for 5 year

= TMTBF = $\frac{Annual\ hours\ per\ year}{Total\ failure\ per\ year} = \frac{(Y1+Y2+Y3+Y4+Y5)}{15+30+45+60+70}$

= $\frac{515.2+246.4+141.866+100.8+72}{15+30+45+60+70}$

TMTBF = $\frac{1076.266}{220} = 4.892\ hrs/failure$

Failure Rate for the Valve on line A per Year

Failure rate = $\frac{Number\ of\ failure\ per\ year}{operational\ time\ \ (hours)}$

Study interval = 1 year x 24 hours =365 x 24 = 8760 hours/year

For 1st year = $\frac{15}{7728}$ = 0.0019,

for 2nd year = $\frac{30}{7392}$ = 0.0041,

for 3rd year = $\frac{45}{6384}$ = 0.0070,

for 4th year = $\frac{60}{6048}$ = 0.0099 and or

5th year = $\frac{70}{5040}$ = 0.0139

Total failure rate for 5 years = ∑ failure rate/year

= 0.0019 + 0.0041 + 0.0070 + 0.0099 + 0.0139

= 0. 0341/year

Lost Time Per Year for the valve in line A (down time)

Lost time per years = failure of each component per year x Repair Time

For 1st year = $15 \times 2 = 30,$

for 2nd year = $30 \times 2 = 60,$

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for 3rd year = $45 \times 2 = 90$,

for 4th year = $60 \times 2 = 120$ and or

5th year = $70 \times 2 = 140$

Reliability Analysis (R) for Valve on line A

Reliability®, $\Gamma = e^{-\lambda t}$

where τ = failure rate/year and t = operating time/year

For 1st year = $e^{-0.0019\times1}$ = 0.9981,

for 2nd year = $e^{-0.00041\times2}$ = 0.9918,

for 3rd year = $e^{-0.0070\times3}$ = 0.9790,

for 4th year = $e^{-0.0099\times4}$ = 0.9612 and

for 5th year = $e^{-0.0139\times5}$ = 0.9329

Unreliability (UR) for valve for line A

Unreliability(φ) : $\varphi = 1 - \Gamma = e^{-}(\frac{1}{MTBF})_t$ $= 1 - e^{-\tau t}$

Where, R = Reliability

For 1st year = 1 – 0.9981 = 0.0019,

for 2nd year = 1– 0.9918 = 0.0082,

for 3rd year = 1 – 0.9790 = 0.0219,

for 4th year = 1 – 0.9612 = 0.0388 and

for 5th year = 1 – 0.9329 = 0.0671

Availability (A) valve on line A

Availability (A) = $\frac{uptime}{uptime + downtime}$

For 1st year = $\frac{7728}{7728+30}$ = 0.9981,

for 2nd year = $\frac{7392}{7392+60}$ = 0.9955,

for 3rd year = $\frac{6384}{6384+90}$ = 0.9930,

for 4th year = $\frac{6048}{6048+120}$ = 0.9902 and

for 5th year = $\frac{5040}{5040+140}$ = 0.9863

Unavailability (UA) for Valve on line A

Unavailability = 1 – A

where , A = Availability

For 1st year = 1- 0.9981 = 0.0019,

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for 2nd year = 1- 0.9955 = 0.0055,

for 3rd year = 1- 0.9930 = 0.0070,

for 4th year = 1- 0.9902 = 0.0098 and

for 5th year = 1- 0.9863 = 0.0137

Table 4.5 shows the summary data evaluated from the valve component on line A for 5 year period of reliability analysis. This table was evaluated from the raw data obtained from ND Refineries distillation feed line as shown in Table 4.5.

Table 4: Summary Results of Reliability Parameters for Valve on Line A

Parameters	Period (Year)				
	1	**2**	**3**	**4**	**5**
Uptime(UT) (hrs)	7728	7392	6384	6048	5040
Study Interval (SI) (hrs/year)	8760	8760	8760	8760	8760
MTBF	515.2	246.4	141.866	100.8	72
Failure Rate (FR)	0.0019	0.0041	0.0070	0.0099	0.0139
Downtime (DT) (hrs)	30	60	90	120	140
Reliability (R)	0.9981	0.9918	0.9790	0.9612	0.9329
Unreliability (UR)	0.0019	0.0082	0.0219	0.0388	0.0671
Availability (A)	0.9981	0.9955	0.9930	0.9902	0.9863
Unavailability (UA)	0.0019	0.0045	0.0070	0.0098	0.0137

Table 4 illustrates the summary of the functional parameters of the valve on line A, from the evaluated valve values, it is observed that there is a decline in the uptime (operating time) as the year increase from the 1st year to the 5th year. Also, the mean time between failures shows a decrease this could be attributed to the decrease in operating time. Likewise the down time (DT) increases as down the years as the component ages with years. There was also an increase in the failure rate form their 1st year to the 5th year.

Evaluation Analysis of parallel Valve B

Table 5: Data Collected from ND Refineries Distillation Column Feed line Valves B

Years	Failure/year	Repair Time (T) hours	Operating Time (Hour/Week)
1	20	2.5	161 (7728)
2	28	2.5	154 (7392)
3	47	3	133 (6384)
4	80	3	126 (6048)
5	90	3	105 (5040)

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Table 5 shows the data collected for the valve line b for a period of 5 years which comprises of the failure rate per year, operating time per week and time to repair each breakdown per year.

To Evaluate the Operating Time Per Year for ND Refineries Distillation Column Feed line valve B

Operating Time Per Year = Operating Time per Week x 4 Weeks x 12 Months

For 1st year = 161 x 4 x 12 = 7728 hrs/y,

for 2nd year =154 x 4 x 12 =7392 hrs/y,

for 3rd year = 133 x 4 x 12 = 6384 hrs/y,

for 4th year = 126 x 4 x 12 = 6048 hrs/y and

for 5th year = 105 x 4 x 12 = 5040 hrs/y

Total operating times = 7728 + 7392 + 6384 + 6048+ 5040 = 32592 hrs/y

Mean Time between Failure (MTBF) for the Pump on Line B

M MTBF = $\frac{Operating\ times}{no\ of\ failure}$

For 1st year = $\frac{7728}{20}$ = 386.4hrs,

for 2nd year = $\frac{7392}{28}$ = 264 hrs,

for 3rd year = $\frac{6384}{47}$ = 135.83 hrs,

for 4th year = $\frac{6048}{80}$ = 75.6 hrs and

for 5th year = $\frac{5040}{90}$ = 56 hrs

Total mean time between failure for the for (pump) on line B for 5 year

= TMTBF = $\frac{Annual\ hours\ per\ year}{Total\ failure\ per\ year} = \frac{(Y1+Y2+Y3+Y4+Y5)}{20+28+47+80+90}$

= $\frac{386.4+264+135.83+75.6+56}{20+28+47+80+90}$

TMTBF = $\frac{899.43}{265} = 3.39\ \ hrs/failure$

Failure Rate for the Valve Per Year

Failure rate = $\frac{Number\ of\ failure\ per\ year}{operational\ time\ \ (hours)}$

Study interval = 1 year x 24 hours =365 x 24 = 8760 hours/year

For 1st year = $\frac{20}{7728}$ = 0.0026,

for 2nd year = $\frac{28}{7392}$ = 0.0038,

for 3rd year = $\frac{47}{6384}$ = 0.0074,

for 4th year = $\frac{80}{6048}$ = 0.0132 and

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for 5^{th} year = $\frac{90}{5040}$ = 0.0179

Total failure rate for 5 years = $\sum$ failure rate/year

= 0.0026 + 0.0038 + 0.0074 + 0.0132 + 0.0179 = 0. 0449/year

Lost Time Per Year for the valve in line B (down time)

Lost time per year = failure of each component per year x Repair Time

For 1^{st} year = $20 \times 2.5 = 50,$

for 2^{nd} year = $28 \times 2.5 = 70,$

for 3^{rd} year = $47 \times 3 = 141,$

for 4^{th} year = $80 \times 3 = 240$ and

for 5^{th} year = $90 \times 3 = 270$

Reliability Analysis (R) for pump

Reliability®, $\Gamma = e^{-\lambda t}$

where τ = failure rate/year, t = operating time/year

For 1^{st} year = $e^{-0.0026 \times 1}$ = 0.9974,

for 2^{nd} year = $e^{-0.0038 \times 2}$ = 0.9925,

for 3^{rd} year = $e^{-0.0074 \times 3}$ = 0.9781,

for 4^{th} year = $e^{-0.0132 \times 4}$ = 0.9486 and

for 5^{th} year = $e^{-0.0179 \times 5}$ = 0.9146

Unreliability (UR) for valve for line A

Unreliability(φ) : $\varphi = 1 - \Gamma = e^{-}(\frac{1}{MTBF})_t \quad = 1 - e^{-\tau t}$

where R = Reliability

For 1^{st} year = 1 – 0.9974 = 0.0026,

for 2^{nd} year = 1– 0.9925 = 0.0075,

for 3^{rd} year = 1 – 0.9781 = 0.0219,

for 4^{th} year = 1 – 0.9486 = 0.0514 and or

5^{th} year = 1 – 0.9146 = 0.0854

Availability (A) valve on line B

Availability (A) = $\frac{uptime}{uptime + downtime}$

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For 1st year = $\frac{7728}{7728+50}$ = 0.9974,

for 2nd year = $\frac{7392}{7392+70}$ = 0.9962,

for 3rd year = $\frac{6384}{6384+141}$ = 0.9927,

for 4th year = $\frac{6048}{6048+240}$ = 0.9869 and

for 5th year = $\frac{5040}{5040+270}$ = 0.9825

Unavailability (UA) for valve on line B

Unavailability = 1 – A

where A = Availability

For 1st year = 1- 0.9974 = 0.0026,

for 2nd year = 1- 0.9962 = 0.0038,

for 3rd year = 1- 0.9927 = 0.0073,

for 4th year = 1- 0.9969 = 0.00131 and

for 5th year = 1- 0.9825 = 0.0175

Table 6 shows the summary data evaluated from the valve component on line B for 5 year period of reliability analysis. This table was evaluated from the raw data obtained from ND Refineries distillation feed line as shown in Table 6.

Table 6: Summary Results of Reliability Parameters for Valve on Line B

Parameters	**Period (Year)**				
	1	**2**	**3**	**4**	**5**
Uptime(UT) (hrs)	7728	7392	6384	6048	5040
Study Interval (SI) (hrs/year)	8760	8760	8760	8760	8760
MTBF	386.4	264	135.83	75.6	56
Failure Rate (FR)	0.0026	0.0038	0.0074	0.0132	0.0179
Downtime (DT) (hrs)	50	70	141	240	270
Reliability (R)	0.9974	0.9925	0.9781	0.9486	0.9146
Unreliability (UR)	0.0026	0.0075	0.0219	0.0514	0.0854
Availability (A)	0.9974	0.9962	0.9927	0.9869	0.9825
Unavailability (UA)	0.0026	0.0038	0.0073	0.0131	0.0175

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Table 6 illustrates the summary of the functional parameters of the valve on line B, from the evaluated valve values; it is observed that there is a decline in the uptime (operating time) as the year increase from the 1st year to the 5th year. Also, the mean time between failures shows a decrease this could be attributed to the decrease in operating time. Likewise the down time (DT) increases as down the years as the component ages with years. There was 7also an increase in the failure rate form their 1st year to the 5th year.

3. RESULTS

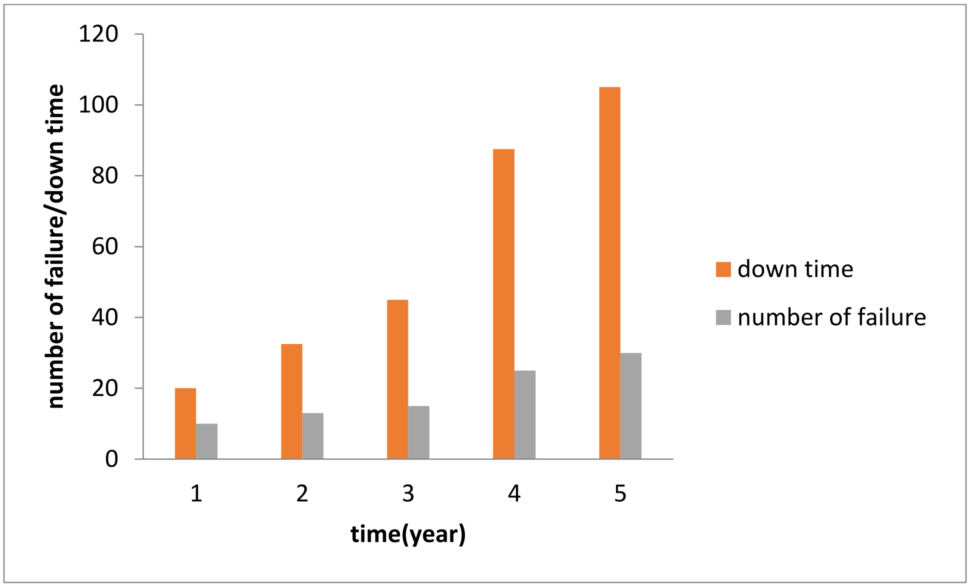

Figure 3: Number Failure of the Valve on Line A with Its Down Time against Time (Years)

Figure 3 is a bar chart showing the rate failure of valve on line A with the corresponding down time. From Figure 3 it is observed that the rate of failure of the valve increases with time. The failure rate in the first year could be attributed to infant failure due to manufacturer defects while the rest of the failure could be attributed to aging and as a result of over usage and wear of the components. The failures resulted to increase in the down time since the down time is a function of the repair time and the number of failures. Therefore as the rate of failure increases the down time increases significantly.

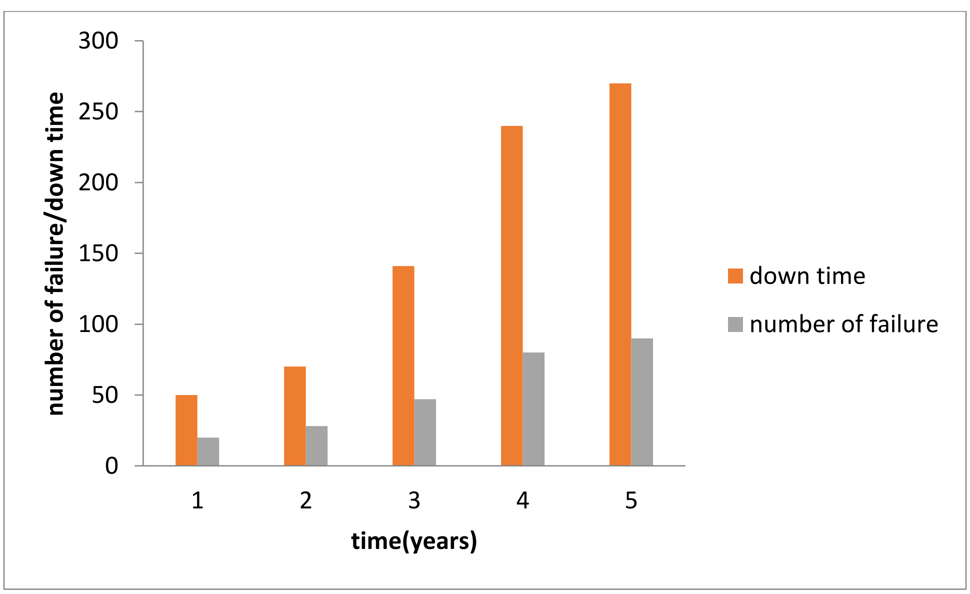

Figure 4: Number Failure of the Valve on Line B with Its Down Time against Time (Years)

Figure 4 is a bar chart showing the rate failure and the down time of valve on line B in relationship between increased in time. Figure 4 illustrates the relationship between both the rate of failure and the down time of valve in line B with increase in time. The down time increases rapidly compared to the rate of failure that has a slight increase as the year progresses, the rapid increase in the in the town time is function of product of the number of failure and the time to repair as the year increases more compound failed compared to the first year. The failure rate in the first year could be attributed to infant failure due to manufacturer defects while the rest of the failure could be attributed to aging and as a result of over usage and wear of the components. This failure causes increased in the down time since the down time is a function of the repair time and the number of failures. Therefore as the rate of failure increases, the down time increases significantly.

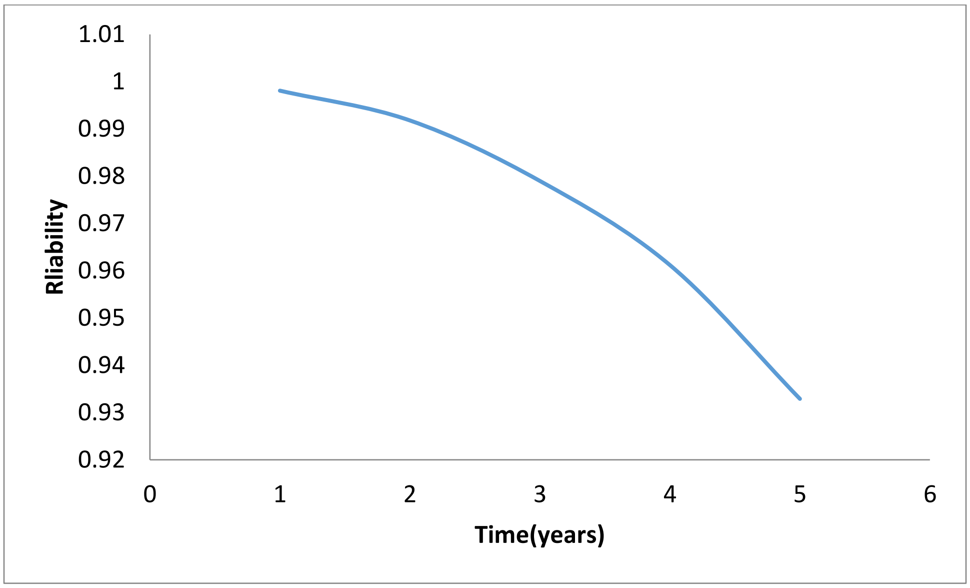

Figure 5: Reliability of the Valve on line A with its Down Time against Time (years)

From Figure.5 it is observed that the rate of reliability decreases with an increase in time. This is an indication that the valve parameters deteriorates or wear-out with time. As the failure rate increases the reliability of the component decreases. The decline in reliability could be attributed to ageing of the components. Figure 5 illustrates the slight decline in the reliability of the valve over five years period. In addition to the aging of the components there is an indication of other process parameters that can hamper the reliability of the valve, which contributed to high failure of the valve leading to a declined in reliability down the years. Also the random failure mode of valve could be attributed to the variation of process parameters.

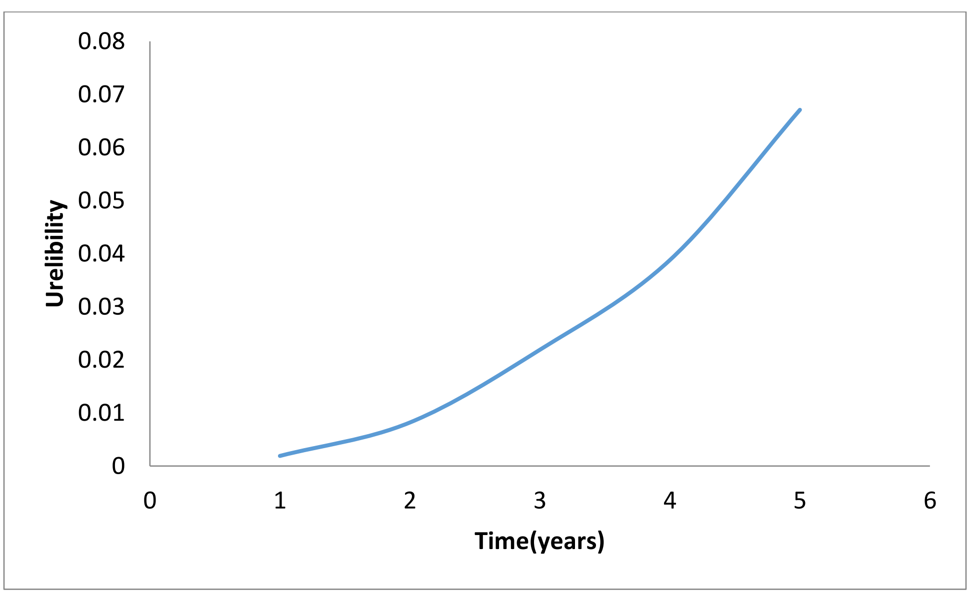

Figure 6: Unreliability of the Valve on line A with its Down Time against Time (years

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Figure 6 illustrates the rate of unreliability of the valve in relationship with time. It is clear that the rate of unreliability of the pump is a reverse of the reliability as unreliability increases with time. This is an indication that the pump parameters deteriorates or wear-out with time. As the failure rate increases the unreliability of the pump increases. The unreliability is seen as the sum of the failure. It is also a clear indication that unreliability increases with time this is due to the ageing of the components. Figure 6 illustrates a steady increase in the unreliability of the pump over the five-year period.

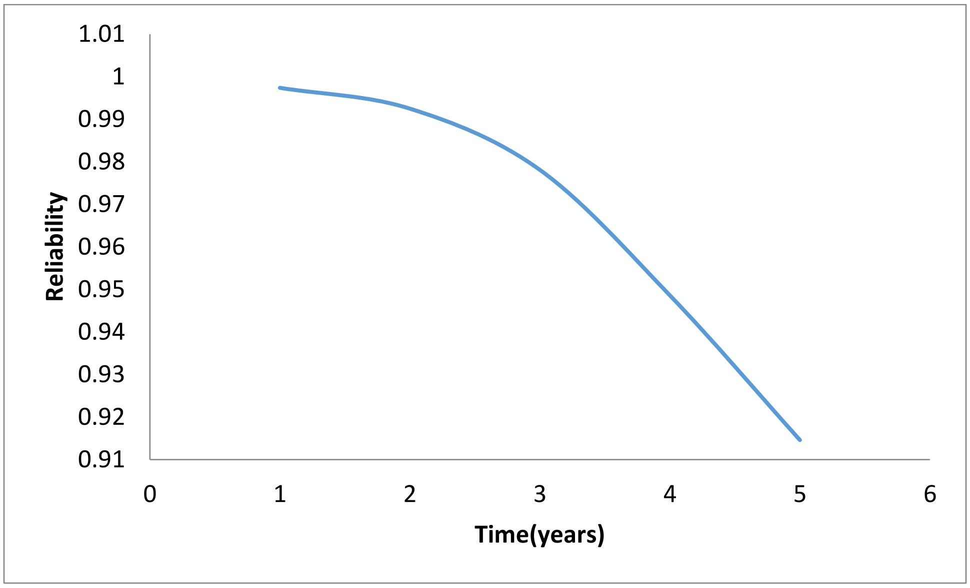

Figure 7: Reliability of the Valve on line B with its Down time against Time (years

The rate of reliability of the valve in line B in Figure 7 illustrates the clear rate of failure increases with an increase in time. This is an indication that the valve parameters deteriorates or wear-out with time. As the failure rate increases the reliability of the component decreases. It also confirms that reliability decreases with time this is due to the ageing of the components. Figure 7 illustrates a steady decline in the reliability of the valve over five years period. In addition to the aging of the components there is a high pressure and temperature of the inlet crude could contribute to high failure of the valve leading to a declined in reliability down the years. Valve B is failing due to continuous operation as well as the operating pressure, temperature, and lack of maintenance procedure.

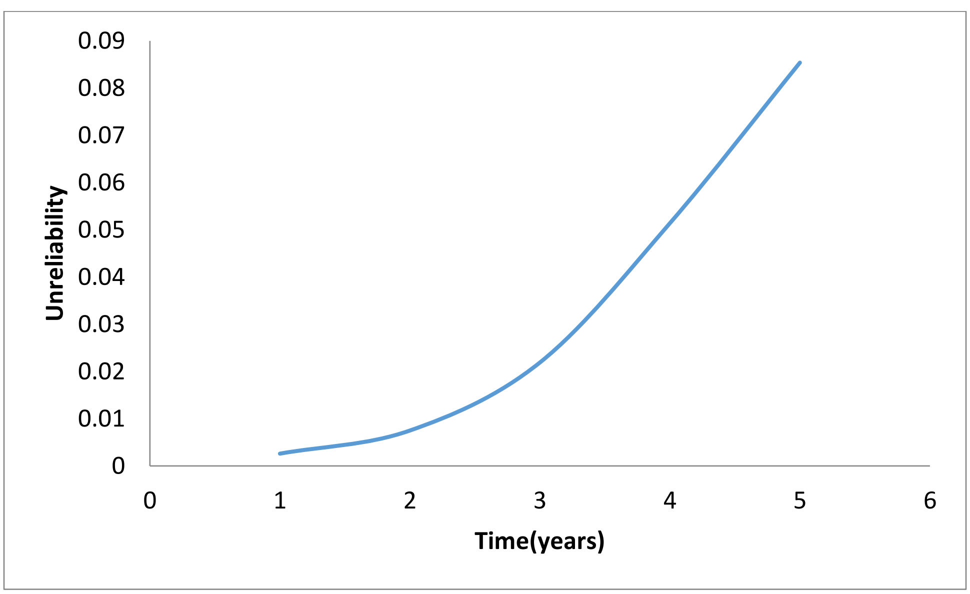

Figure 8: Unreliability of the Valve on line B with its Down Time against Time (years)

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Figure 8 illustrates the rate of change of unreliability of the pump in line B with time. From Figure 8 it is seen that the unreliability of the valve in line B increases with time. This is an indication that the valve parameters deteriorates or wear-out with time. As the failure rate increases the unreliability of the valve increases. The unreliability is seen as the function of the failed components. The failing of the component could be attributed to variety of parameters ranging from the temperature of the crude passing through the valve, the temperature and the operating condition of the valve. Figure 8 illustrates a steady increase in the unreliability of the valve over the five-year period.

4. CONCLUSION

This research work has be set out to evaluate the performance of ND refineries valves used in feed line to the distillation column operated in a parallel mode, one standby and the other active. Result obtained from the study reveals that the valve used are highly efficient; because of the high reliability obtained across the years is a clear indication that valves were reliable. The parameters investigated for five years were the failure rate of the valve, the downtime, reliability(R) and unreliability (UA), also the available (A) and unavailability of the pump were also evaluated from the data presented. From the analysis computed it is seen that the highest reliability was in the first year and the highest unreality was in the fifth year for all the four components valves A&B. this buttress that the reliability of the component were majorly time depended ,although other parameters were also responsible for the failure. The component failed in this order 30, 32 70, and 90 for valve B, valve A, Whereas the reliability decreases down the years from 1st year to the fifth year for all the components with components in line A having the highest reliability of 0.9984 for valve respectively and components on line B with the least reliability of 0.9981 for valve.

Finally reliability allows a component to perform without failing at a specified period under working conditions. Performance and quality are function of reliability. High performance grantee quality and it turn give rise to high reliability. The high performance of the valves describe the capabilities of the distillation unit. Therefore reliability engineering involves the preventing, assessing and managing failures. This research work has employed one of the tool of reliability engineering to ascertain the reliability of ND refineries valves.

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Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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