A STUDY ON PREVENTIVE MAINTENANCE MODELLING APPLIED TO JUTE MILLS MACHINERY

A THESIS

BY

MD. JASHIM UDDIN

Submitted to the Department of Industrial and Production Engineering, BUET, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN INDUSTRIAL AND PRODUCTION ENGINEERING

September, 1983

BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY, DHAKA.

A STUDY ON PREVENTIVE MAINTENANCE MODELLING
APPLIED TO JUTE MILLS MACHINERY

A THESIS

BY

MD. JASHIM UDDIN

Approved to style and content by:

1. Dr. A.B.M. Zohrul Kabir — Chairman
Assistant Professor, IPE
BUET, Dhaka

2. Dr. A.F.M. Anwarul Haque — Member
Professor & Head, IPE
BUET, Dhaka.

3. Dr.-Ing. M. Anwarul Azim — Member
Professor, IPE, BUET
Dhaka

4. Dr. M. Mizanur Rahman — Member
Associate Professor, IPE
BUET, Dhaka

5. Mr. S. A. Chowdhury — Member (External)
Director (PMDE), BJMC
Dhaka

September, 1983

Bangladesh University of Engineering and Technology, Dhaka.

CERTIFICATE

This is to certify that this work has been done by me and it has not been submitted elsewhere for the award of any degree or diploma or for publication.

Counter signed 7.9.1983

Supervisor

Signature of the candidate

LIST OF CONTENTS

<u>Page No.</u>

NOTATIONS

$f(t)$	=	Probability density function (Pdf)
$R(t)$	=	Reliability function
$F(t)$	=	Cumulative density function
β	=	Shape parameter
η	=	Scale parameter
t	=	Failure time
$r(t)$	=	Instantaneous failure rate or hazard rate
ln	=	Natural logarithm
ti	=	ith failure time
tr	=	rth failure time
$h(t)$	=	Hazard function
$H(t)$	=	Cumulative hazard function
Cp	=	Cost of preventive replacement
Cf	=	Cost of a failure replacement
Tp	=	Time required to make a preventive replacement
Tf	=	Time required to make a failure replacement
M(tp)	=	Meantime to failure when preventive replacement occurs at tp
tp	=	Preventive replacement age
C(tp)	=	$\int_{tp}^{\infty} f(t)\, dt$
ρ	=	Relative failure cost ($= \frac{Cf}{Cp}$)
$\hat{t}p$	=	Optimal replacement age
θ	=	Relative failure time

A C K N O W L E D G E M E N T

The author expresses his deep gratitude to Dr. A.B.M. Zohrul Kabir, Assistant Professor of Industrial and Production Engineering Department, BUET, Dhaka for his close supervision, inspiring guidance, valuable advice and counsel in every step of the thesis work.

The author gratefully acknowledges his indebtness and tenders his sincere thanks to Dr.-Ing. M. Anwarul Azim, Dean, Faculty of Mechanical Engineering, BUET, Dhaka for his advice, help and encouragement.

The author also tenders his sincere gratitude to Dr. A.F.M. Anwarul Haque, Professor & Head of the Department of Industrial and Production Engineering, BUET, Dhaka for his guidance and advice, specially during the one month stay of Dr. A.B.M. Zohrul Kabir at abroad.

Finally, but not the least, the author expresses his thanks to Mr. A.K.M. Siddiqur Rahman for typing the thesis patiently and neatly.

Md. Jashim Uddin

SUMMARY

(30)

Any typical jute mill consists of a large number of machineries, which in turn, have a large number of component parts. Proper maintenance of these machineries is extremely important not only for meeting the production objective but also for the profitability of the industry itself. Typical maintenance policies that are applicable to jute mills machineries, are preventive maintenance and periodic inspection. In this work, a thorough study of preventive maintenance has been made. Failure modes of each equipment have been investigated to identify critical components which are liable for the complete breakdown of the equipment. Failure history has been collected from a typically medium sized jute mill. Data has been analysed to determine appropriate failure distribution. Weibull failure distribution has been used throughout the work, because of its wide applicability. Distribution parameters have been estimated by the Maximum Likelihood Estimator Method and the graphical method of Hazard Plotting. Maintenance plan for each equipment has been developed on the basis of cost minimization and downtime minimization. Computer programmes have been written for data analysis and for solving mathematical models. Problems of data collection have been discussed and a format for data sheet has been suggested.

CHAPTER 1: INTRODUCTION

1.1 General Introduction

Maintenance of machinery and equipments is vitally important not only for industrial profitability but also for national economy. Machine of whatever type, however cheap or expensive, however simple or complex is liable to breakdown. Apart from breakdowns, machines tend to wear or deteriorate with use and the passage of time. This change in state naturally affects their efficiency, which in turn affects the quality of manufactured product. In other ways, this fact has two important implications. (i) The increasing cost of the maintenance necessary to obtain continuing reliability of the machine and (ii) The obsolescence of the machine.

Although maintenance of machines is concerned primarily with keeping machines operational, the development of an effective maintenance plan or programme should start at the design stage or at the stage when acquisition of the machine is to be decided having due regard to maintainability considerations and the logistics of support schemes. The effectiveness of the maintenance plan needs to be re-evaluated throughout the life of the machine. Huge sums of money can be saved if the maintenance of machinery is carried out by formulating maintenance strategies on the basis of proper analysis of cost and downtime.

However, a shorter term "Maintenance Plant" is needed for the maintenance of machines by the adoption of appropriate maintenance policies. Strategy and plan are interrelated because maintenance cost influences unit replacement which inturn affects the maintenance plan. The maintenance organisation needed to execute the maintenance work load is dependent upon the maintenance plan.

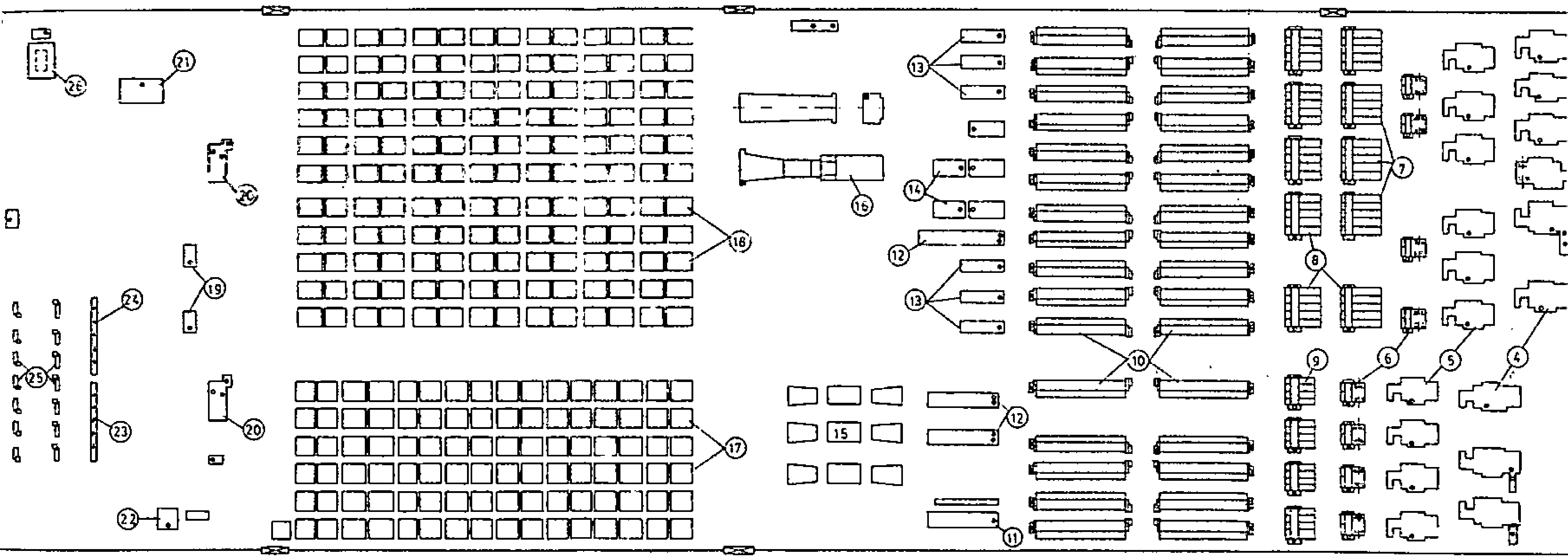
To solve any maintenance problem there are often a large number of alternative decisions that can be taken. For example, for a component subject to sudden breakdown one may have to decide whether to repair or replace it, while it is in an operating state, or only on its failure, whether to replace similar components in groups when one perhaps has failed, etc. Thus it is seen that the function of the maintenance department is to a large extent concerned with identifying the appropriateness of various decisions to control the condition of machine to be in line with the objectives of the organisation.

1.2 Machinery Layout Plan of a Medium Sized Jute Mill

For the application of preventive maintenance models, data has been collected from Nabarun Jute Mills Ltd., Dhaka, a typically medium-sized jute mill of the country. The layout of various machineries of this mill has been given in Figure 1.2.1. It can be seen that there are two main sections in the mill; top section is known as hessian or light yarn side and bottom section is known as sacking or heavy yarn side.

NABARUN JUTE MILLS LIMITED

MACHINERY LAYOUT PLAN



1. Emulsion plant
2. Softner machine
3. Hard waste T/card
4. Breaker card machine
5. Finisher card machine
6. 1st Drawing
7. 2nd Drawing
8. 3rd Drawing
9. Finisher drawing
10. Spinning frame
11. Twist frame
12. Low cop machine
13. Mack roll machine
14. Mack cop machine
15. Dry beaming machine
16. Hibbert dressing machine
17. Sacking loom
18. Hessian loom
19. Damping machine
20. Calender machine
21. Lapping machine
22. Cutting machine
23. Hemming sewing machine
24. Herrackle sewing machine
25. Overhead sewing machine
26. Baling press machine

Fig. 1.2.1

1.3 Present Maintenance Policies and Actions

At present, there is no scientifically based maintenance policy for Jute Mills machinery. In most of the cases, maintenance is carried out in the haphazard way. Because of this haphazard maintenance system, the general condition of the Jute Mills machinery is deteriorating day by day.

1.3.1 Present Unplanned Preventive Maintenance Policy

Present preventive maintenance policy which is followed in Jute Mills, is not done in a planned way. There is no fixed time interval to take a machine for preventive maintenance action. Sometimes, suddenly a machine is taken for preventive maintenance and dismantled thoroughly without considering the inventory position of the necessary spares and availability of repair facilities of the workshop. Because of this, benefit from carrying out of preventive maintenance is not obtained at all. Unscheduled and so called preventive maintenance have not reduced the number of failures appreciably. Downtime due to maintenance and the associated cost remain very high. Moreover, huge quantity of production is being lost. Analysis of downtime and cost is a precondition before taking a machine for preventive maintenance, but this type of analysis has never been carried out in Jute Mills.

1.3.2 Present Inspection Policy

The purpose of the inspection policies is to inspect the machine & rectify the minor defects which may eventually cause complete breakdown. But in Jute Mills, although inspections are carried out, these are not performed at regular - -

intervals. Present inspection policy is merely a rule of thumb, rather than any scientifically developed method. But inspection of some critical equipments is very important for detection and correction of minor defects before any major breakdown occurs, which may cause heavy production loss. For example, an deffective inspection policy for an Emulsion plant which is a single machine can help preventing a major breakdown of the plant. Any breakdown of this plant can cause the whole mill being shutdown within two to three hours time. Similarly for a sudden failure of Hibbert dressing machine, 150 looms of a 250 loom unit Jute Mills may have to be closed down within four to five hours time.

1.3.3 Present Lubrication Actions

As far as possible, the "Lubrication schedule" should be fixed by giving proper considerations to the following lubrication informations.

1. No. of application points.
2. Frequency of each application.
3. Method used.
4. Amount required.
5. Type of lubricant required.

But in Jute Mills, application of the lubricants are not done as per above "Lubrication schedule", though the manufacturers of the machineries concerned have supplied many lubrication manuals and charts have been prepared in those manuals as close as possible to the above lubrication informations. As there is no training scheme to train the oilman how to apply oil, consumption of oil and lubricants is increasing. On the otherhand, due to the non-application of oil and lubricants in all application points of the machinery, the rate of wearout of all types of components is increasing day by day.

1.4 Objective and Scope of the Present Work

The primary objective of the Thesis is to determine the optimal preventive replacement age for each machines by applying preventive maintenance models and considering replacement cost and downtime.

In order to meet this primary objective there are some secondary objectives which are:

i. Identification of critical components for each machines

ii. Determination of failure distributions to best fit failure characteristics and history of each machines

iii. Determination of cost and savings for the developed maintenance policy.

Replacement problems are a particular class of maintenance problems, which in general, include inspection, overhaul and repair, organisation structure, reliability, scheduling and sequencing besides the replacement ones. In the present work, two preventive maintenance models have been studied and their solutions have been carried out to find out the appropriate maintenance policies of Jute Mills machinery.

Chapter 1 covers the flow chart of both Hessain and Sacking side machinery of a medium sized Jute Mill and the description of existing maintenance policies followed in Jute Mills.

Chapter 2 covers the introduction to common maintenance policies, types and justification for application of preventive maintenance models, description of different failure distributions and data analysis for estimating Weibull distribution parameters. Owing to the versatility of the Weibull distribution in accomodating a wide variety of distributions, it has been used throughout this work.

In chapter 3, machineries' component lists have been prepared.

Chapter 4 is concerned with the data collection and data analysis of various equipments, chart for failure history of Nabarun Jute Mill machinery and values of Weibull distribution parameters both in Maximum Likelihood Estimators and graphical methods.

Chapter 5 covers the determination of correct maintenance policies which include model for an age replacement policy relating to the expected replacement cost per unit time and model for an age replacement policy relating to the total downtime per unit time and discussion on effectiveness of the proposed policies.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to Common Maintenance Policies

Any rule that assigns a specific action to any possible realisation of the machines life is called a maintenance policy. More precisely, a maintenance policy is a function whose range is the set of possible maintenance actions. As the nature and effect of failure of the different machines and their components are not same, it is rare that there is to be a single policy which is applicable to all machines in a production system. The common maintenance policies are given below.

2.1.1 Preventive Replacement Policies and Models

When a component of a machine is replaced upon failure, the replacement is termed as failure removal, breakdown replacement or corrective maintenance action. However, the same component may be replaced prior to failure in order to prevent an unscheduled interruption, even when it is functioning properly. Such a replacement of an operational component is called a preventive replacement or preventive overhaul. Thus, preventive maintenance involves a watchfull programme of cleaning, servicing, and replacement of plant facilities. The various objective functions for the modelling may be maximization of profit, minimization of total maintenance cost, minimization of downtime etc. The preventive maintenance models have been studied in general by Jorgenson, Macall, and Radner (1) and Jardine (2) G. Weiss (3) proposed that an age replacement policy would be beneficial if the expected time to an inservice failure were a decreasing function of the age of replacement. G.H. Hard (4) also considered the question of the beneficility of a replacement policy. He based his consideration solely on the failure rate. In his opinion, replacement should be considered if the failure rate is increasing. A detailed study by Flehinger (5) considered the expected number of failures and the expected number of planned replacements in a specified interval. It seems that age replacement for an infinite time span has received most attention in the literature. Morse (6) shows how to determine the replacement interval by minimizing expected cost per unit time, when such an optimal interval exists. The derivation of an optimum age replacement interval corresponding to a finite time span is basically much more difficult problem. Barlow and Proschan (7) prove the existence of such an optimal policy. Optimum block replacement policies for an infinite time span within a more general setting have been studied by Savage (8). However, his formulation does not seem readily applicable, since he leaves the expression for the cost as a function of the replacement interval in general form. In the present work, the preventive maintenance models which have been discussed,are age replacement policy relating the expected replacement cost per unit time and age replacement policy relating the total downtime per unit time.

2.1.2 Inspection Policy

The basic purpose of an inspection policy is to determine, the state or condition of the machine at any specified time or interval. In order to reduce the number of breakdowns, one can periodically inspect the machine and rectify any minor defects which may eventually cause complete breakdowns. The state or position of the machine, good or failed, can only be determined by an inspection, for example, by checking the output quality of the machine. In constructing the inspection model, usually, it is assumed that inspection will reveal the state of the equipment with certainty. But in reality, this may not be the case. Kamins(9), Coleman and Abrams (10) have included this possibility in their studies. They have recognized two imperfections; firstly, the inspection procedure may fail to detect an existing failure and secondly, inspection may register a failure when the equipment is good. The objective function of the inspection policies are minimization of downtime, or in other words, maximization of availability, minimization of total cost etc.

2.1.3 Condition Based Maintenance Policy

It is defined as the maintenance carried out in response to a significant deteriotion in an equipment as indicated by a change in a monitored parameter of the equipment condition. On indication of deteriotation, the equipment can be scheduled for shutdown at a time in advance of failure. Consequently, the amount of unnecessary preventive replacement can be reduced.

There are two major reasons for not employing condition based maintenance in certain circumstances. First, not all causes of plant failure can be detected in advance. Second, condition monitoring is by its nature, costly in manpower, monitoring equipment or both. It is worth while, only in the cases, where the cost of condition monitoring is lower than the expected reduction in maintenance labour costs and availability costs, or where safety of personnel is a relevant consideration. In Jute Mills, condition based maintenance policy is not followed. Kelly and Harris (11) published considerable works in this field.

2.2 Types of Preventive Maintenance Policy and Justification for an Application

Basically, there are two types of preventive maintenance policies of interest, one is the periodic policy (age replacement) and another is the sequential policy. A periodic policy is one in which a component is replaced as soon as it fails, or as soon as it reaches specified age, whichever occurs first. This is the simplest and best known of the periodic maintenance policies and is appropriate for an investment process with an "Unlimited" life time. A sequential policy, on the otherhand, is always more advantageous when the lifetime of the investment process is "finite". It differs from the periodic policy in that the mandatory replacement age is re-calculated after each replacement. Applications of sequential policies include situations in which the equipment is subject to rapid technological change and therefore possesses a relatively short life time.

For the justification of preventive replacement actions, two important criteria must be satisfied.

(i) The total cost of replacement must be greater after a failure than before where "Cost" is the appropriate criterion. If some other criterion,such as downtime is taken as the appropriate criterion, then that criterion is substituted in place of cost. However, this sort of situation may be caused by greater loss of production since replacement after failure is unplanned, or failure of one piece of plant may cause damage to other equipment.

(ii) Preventive replacement may be advantageous only if the failure rate is increasing. As an illustration of this point, a case can be considered where the failure rate of the equipment is constant. By the definition of failure rate, replacement before failure does not affect the probability that the equipment will fail in the next instant, given that it is good now. Since replacement costs are positive, it will never be advisable to do preventive replacement, i.e. replacing the equipment before failure.

2.3 Failure Distributions

There are three basic ways in which the pattern of failures can change with time. The failure rate may be decreasing, increasing or constant (DFR,IFR or CFR). It is commonly suggested that the best maintenance for a machine which shows constant failure rate is only to carryout maintenance when a breakdown occurs. A CFR is also typical of complex systems subject to repair or overhaul, where different components exhibit different failure rate patterns and parts of the system may have different ages. The combination of different failure rate patterns tends to a CFR as the system complexity increases. In section 2.2, it has been indicated that one of the necessary conditions for replacing equipment before failure, i.e. preventive replacements, is that the distribution of time to failure for the equipment exhibits wearout, or equivalently, the failure rate increases with age. Exponential distribution possesses constant failure rate. An interesting point to note about the hyper exponential distribution is that with an increase in time, the failure rate decreases. This may be interpreted as an improvement in the equipment with time and may be the case with equipment which requires small adjustments after an overhaul or replacement to get it completely operational. The distributions which possess an increasing failure rate are the Normal, the Gamma, and the Weibull distribution. The probability density functions (f (t)), cumulative distribution functions (F (t)), reliability functions (R (t)) and failure rates or hazard rates (h (t)), for the above distributions can be found in any book on statistical distributions and also in the books of Jardine (2), Patrick D.T O'Connor (12) and Savage (8). However, in the present work, the Weibull distribution has been chosen to analyse failure characteristics of the machines. The discussion will be centered on first, the relative merits of the probability distributions and then how to calculate f (t), F (t), R (t) and h (t) of Weibull distribution only. The mode of the distributions which show CFR and DFR has been discussed above. Now, only the relative merits of Normal, Gamma and Weibull distributions are being discussed.

The normal (or Gaussian) distribution is applicable, for instance, when a random failure is the consequence of a large number of small and independent "shocks". Practical example of this distribution can be found in the failures of large and busengines. However, many life length distributions of practical applications are obviously not normal, because of their marked skewness. The normal distribution is characterised by its mean and standard deviation.

The gamma family of distributions, which is characterised by a shape parameter and a scale parameter, is skewed and therefore may be more natural to use than the normal family, have an increasing failure rate when the shape parameter is greater than 1. However, this distribution can be expected to occur in redundant systems where each duplicate part has an identical exponential (or gamma) distribution of failures.

The Weibull family of distribution is characterised by two or three parameters-shape, scale and location parameter. When the shape parameter is one, it is equivalent to the negative exponential distribution, and when this value is large, (for example 3.5), it approximates the normal distribution. This family of distributions appears to fit a large number of failure characteristics of equipment. Weibull (13) used this to describe fatigue failure, Kao (14), for vacuum tube failure and Lieblein (15) and Zelen (15) for ball bearing failure.

From extreme value theory it is found that if a system consists of several components and if the system fails for the failure of any components then the failure distribution of the system is a Weibull distribution. However, over the years, the Weibull distribution has grown in importance and is perhaps the most popular parametric family of failure distribution at the present time.

All the above three distributions with increasing failure rate, differ mainly in tail probabilities and so, in some cases, if may be found that one or more distributions fit the failure characteristics. It has already been mentioned in section 1.4, that the Weibull distribution is chosen here to analyse the failure characteristics of the equipments.

The two parameter Weibull probability density function (Pdf) is given by,

$$f(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1} \exp\left(-\left(\frac{t}{\eta}\right)^{\beta}\right) \quad \ldots \quad (2.3.1)$$

The reliability function is given by,

$$R(t) = \exp\left[-\left(\frac{t}{\eta}\right)^{\beta}\right] \quad \ldots \quad (2.3.2)$$

The cumulative density function (Cdf) for this distribution is given by,

$$F(t) = 1 - \exp\left[-\left(\frac{t}{\eta}\right)\right], \quad \ldots \quad (2.3.3)$$

and corresponding instantaneous failure rate or hazard rate is given by,

$$r(t) = \frac{f(t)}{1 - F(t)}$$

i.e.

$$r(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1} \quad \ldots \quad (2.3.4)$$

2.4. Data Analysis for Estimating Weibull Distribution Parameters

The available methods for the estimation of the two parameters (β, η) of the Weibull distribution, include the maximum likelihood estimators (MLE), the best linear invariant estimators (BLIE), the good linear invariant estimators (GLUE), and the least squares. In addition to these methods, some graphical techniques such as hazard plotting and Weibull paper plotting are also available.

In the present work, MLE method and Hazard plotting methods have been applied for the estimation of the two parameters (β, η) of the Weibull distribution.

2.4.1 Maximum Likelihood Estimators (MLE) Method

The method was developed primarily for life testing situation. But, it can be applied easily for replacement situation as well. In the maximum likelihood procedures, for the first r failures arranged in ascending order of time and from a sample of n items on test, the shape parameter, β is obtained by the solution of the equation:

$$\frac{\sum_{i=1}^{r} t_i^{\hat{\beta}} \ln t_i + (n-r)\, t_r^{\hat{\beta}} \ln t_r}{\sum_{i=1}^{r} t_i^{\hat{\beta}} + (n-r)\, t_r^{\hat{\beta}}} - \frac{1}{\hat{\beta}} = \frac{1}{r} \sum_{i=1}^{r} \ln t_i \quad \ldots (2.4.1)$$

where, ln is the natural logarithm, t_i is the ith failure time. After determining $\hat{\beta}$, the scale parameter, $\hat{\eta}$, can be estimated by,

$$\hat{\eta} = \left[\frac{\sum_{i=1}^{r} t_i^{\hat{\beta}} + (n-r)\, t_r^{\hat{\beta}}}{r}\right]^{\frac{1}{\hat{\beta}}} \quad \ldots \quad (2.4.2)$$

For a complete sample case, r = n, the above equation reduces to

$$= \frac{\sum_{i=1}^{n} t_i^{\hat{\beta}} \ln t_i}{\sum_{i=1}^{n} t_i^{\hat{\beta}}} - \frac{1}{\hat{\beta}} = \frac{1}{n} \sum_{i=1}^{n} \ln t_i \quad \ldots \quad (2.4.3)$$

and,

$$\hat{\eta} = \left[\frac{\sum_{i=1}^{n} t_i^{\hat{\beta}}}{n}\right]^{\frac{1}{\hat{\beta}}} \qquad \ldots \quad (2.4.4)$$

It is clear from the equation (2.4.1), $\hat{\beta}$ can not be solved with a single failure. Estimation of $\hat{\beta}$ and $\hat{\eta}$ can only start after the second failure. The major problem with MLE is that estimation of $\hat{\beta}$ is highly biased when there are only a few failure. However, data collected for the analysis of present work, contains more than three failures in case of all machines, The resulting bias in the estimated parameters can be considered as negligible.

2.4.2 Hazard Plotting Method

The hazard function h (t) for a distribution of time to failure is defined in terms of the cumulative distribution function F(t) and its derivation , which is the probability density function, f (t), as follows:

$$h(t) = \frac{f(t)}{1 - F(t)}$$

The cumulative hazard function H(t) is

$$H(t) = \int_0^t h(t)\,dt$$

$$= \int_0^t \frac{f(t)\,dt}{1 - F(t)}$$

$$= -\ln\left[1 - F(t)\right]$$

For the Weibull distribution,

$$h(t) = \frac{\beta}{\eta}\, t^{\beta-1}$$

Therefore,

$$H(t) = \left(\frac{t}{\eta}\right)^{\beta} \qquad \ldots \quad (2.4.5)$$

$$\text{or, } \ln t = \left(\frac{1}{\beta}\right) \ln H + \ln \eta \qquad \ldots \quad (2.4.6)$$

By this relationship, ln t is a linear function of ln H. Thus Weibull hazard paper is simply loglog graph paper. From equation, (2.4.6) it is clear that the slope of the straight line plot equals $1/\beta$, this fact is used to estimate β.

For, H = 1 (100 %), the corresponding time t equals η, this rule is used to estimate η graphically. For hazard plotting, the basic steps involved are as follows:

(i) To order the n sample times (both failed and unfailed time) from smallest to largest.

(ii) To label the times with reverse ranks, that is, the first time is labelled n, then n − 1 and the n th is labelled 1.

(iii) To mark the failure times to distinguish from the unfailed times, because the hazard value is calculated involving the failed items only.

(iv) To calculate the hazard value for each failure omitting unfailed items.

(v) To calculate the cumulative value for each failure as the sum of its hazard value and the hazard value of all preceding failure times. The sample cumulative hazard values provide a nonparametric estimate, of the cumulative function of the true distribution.

(vi) To plot cumulative hazard value Vs. sample failure times on a loglog graph paper. Nelson (18) mentions that Weibull hazard paper is available commercially.

(vii) By eye, to fit a straight line through the data points. If the plot is reasonably straight, one may conclude that distribution adequately fits the data.

(viii) To estimate β and η as mentioned before.

As an alternative to plotting, equation (2.4.6) can be solved by computer programme also. The method can not be used before the second failure. In addition, estimates of the parameters are likely to be biased.

CHAPTER 3: CRITICAL COMPONENTS OF MACHINERY

3.1 Introduction to Critical Components of Machinery

Except few, a good number of Jute Mills machinery contains about 500-2000 component parts. All of them are not critical for production. Generally, for a failure of noncritical component, normal production target is not suffered; because in most of the cases, maintenance of these components can be carried out in running condition of the machine and it does not exceed an hour to repair or replace the same. Unlike process or nuclear industry, the failures of critical components of Jute Mills machinery do not possess any catastrophic or major failure which very often result in danger to people or extensive damage to property. But their failures can cause huge quantity of production loss and thus prevent production objective being met. Identification of critical components for each of the Jute Mills machineries is important in formulating a systematic maintenance plan. The machinewise critical component chart is prepared here from the failure history of Hukumchand Jute Mills Limited.

3.2 Chart for Critical Components of Each Machines

1. EMULSION PLANT

Main units or sections	Critical parts in main units or sections	Probable cause of failure
1	2	3
Transmission	Vibrating element	Wearout
	Puralator filter element	Dislocation of joints at soldered points
Pump	Yoke bearing	Dislocation & wearout of balls
	Piston bearing	-do-
	Pump filter	Dislocation of joints at soldered points
	Gear box gasket	Damage after use
	'0' Seal 0.S-19	Tearout
	'0'Seal 0.S-29	-do-
	'0'Seal 0.S-32	-do-
	Nulip ring 4-017	-do-
	Nulip ring 4-025	-do-
	Nulip ring 4-032	-do-
Pump gear box	Gear box gasket	Damage after use
	'0' Seal 0.S-13	Tearout
	'0' Seal 0.S-22	-do-
	Oil retaining bush	Wearout
	Driving wheel seal	Tearout
Rapisonic pump	Sealed ball bearing	Dislocation & wearout of balls
	Gland seal hycar	Tearout
	'0' ring - body	-do-
	'0' ring - bypass	-do-
	'0' ring - 2nd in let	-do-
	Valve spring	Breakage or less tensioned
	Nylon washer	Tearout
	Helicoil insert	-do-

2. SOFTNER MACHINE

1	2	3
Metering system	Metering valve	Wearout
	Stop valve	Wearout or leakage
	Metering electrical system	Shortcircuit
Main body	Gable	Crack or wearout
	Upper bush	Wearout
	Lower bush	Wearout
	Upper roller	Crack or wearout
	Lower roller	-do-
Drive unit	Main drive Motor	Burnout
	Gear box	Breakage or wearout of different parts
	Vee belt	Tearout

3. HARDWASTE TEASER CARD

1	2	3
Stop motion, Gear and chain drive	Stop motion pinion, 18Tx5DP	Breakage or wearout of teeth
	Stop motion pinion, 20Tx5DP	-do-
	Stop motion sproket, 76Tx5/8"P	-do-
	Pitch pin	-do-
	Pitch pin wheel, 90T x 6DP	-do-
	Compound sleeve sproket, 22T x $\frac{5"}{8}$P	-do-
	Worker sprocket, 76T x $\frac{5"}{8}$P	-do-
	Stripper sprocket, 25T x $\frac{5"}{8}$P	-do-
	Stripper & worker drive chain 8' - 0 Long x 5/8"P	Wearout of links
Drive units & conveyor drive	Vee belt no.1250	Tearout
	Motor	Burnout
	Delivery rollersprocket, 19T x 5/8"P	Breakage or wearout of teeth
	Tension sprocket	-do-
	Bevel box sprocket	-do-

4. BREAKER CARD

(Types JF-1 & JF-2, Manufacturer: Fraser)

1	2	3
	Feed roller bearing, 602-90762-00 (For both JF-1 & JF-2)	Dislocation & wearout of rollers
	Feed roller wheel (For JF-2)	Wearout
	Pitch pin wheel, 100T (For both JF-1 & JF-2)	-do-
	Fluted roller bearing, 910-10920-00 (For JF-2)	Dislocation & wearout of balls
Feed arrangement	Hand roller bearing, 603-90175-00 (For both JF-1 & JF-2)	-do-
	Intermediate stud bearing, 602-02025-90 (For both JF-1 & JF-2)	-do-
	Gear wheel, 105T (For both JF-1 & JF-2)	Breakage or wearout
	Intermediate pinion, 15T (For JF-2)	-do-
	Guide roller drive wheel, 38T	Wearout
	Stripper sprocket, 20T x $\frac{5''}{8}$	-do-
Worker and stripper roller	Guide roller bearing, 602-90530	Dislocation and wearout of roller
	Guide roller wheel, 75T	Breakage or wearout
	Worker sprocket, 95T x $\frac{5''}{8}$	-do-
	Intermediate shaft pulley	Wearout or breakage
	Motor - 15 H.P	Burnout
	Taper locker bush, 42 mm.	Wearout
Drive unit	Motor pulley	Breakage or wearout
	Vee belt B-section 1500	Wearout
	Taper locker bush 50 mm.	Wearout
	Centrifugal clutch Vee pulley	Breakage or wearout

Contd. BREAKER CARD

1	2	3
	Doffer wheel, 105T	Breakage or wearout
	Plumber block bearing, 602-90456-00	Dislocation & wearout of balls
	Drawing roller drive sprocket, 40T x 5/8"P	Breakage or wearout
Doffer roller	Pinion, 13T	-do-
	Pinion, 34T	-do-
	Gear wheel, 30T	-do-
	Bearing, 602-90177-00	Dislocation & wearout of balls
	Bearing, 602-02020-90	-do-
	Delivery roller sprocket, 48T (Duplex)	Breakage or wearout
	Tension sprocket, 22T (Duplex)	-do-
Delivery & roll former unit	RF Drive sprocket, 24T	-do-
	Compound sprocket, 30T-39T	-do-
	Leather roller wheel, 15T	-do-
	Roll driver shaft gear, 66T	-do-
	Seal, ½" bore	Tearout
	Piston ring	Wearout
Oil controller	Oil seal, 1" bore	Tearout
	Dowty seal, $\frac{3}{8}$" B.S pipe	Tearout
	Sealed ring	-do-

5. FINISHER CARD

(Type: JF-3 & JF-4, Manufacturer: Fraser)

1	2	3
	Feed roller bearing, 602-90162-00 (	Dislocation & wearout of rollers
	Pitch pin wheel, 106T	Wearout
Feed arrangement	Feed roller wheel, 49T	-do-
	Feed stripper gear, 25T	-do-
	Compound gear wheel, 80T	-do-
	Pitch pin	Breakage or wearout
	Guide roller drive wheel, 38T	Breakage or wearout
	Stripper sprocket, 21T x $\frac{5''}{8}$ P	-do-
Worker & stripper roller	Guide roller bearing, 602-90530	Dislocation & wearout of rollers
	Worker sprocket 95T x $\frac{5''}{8}$ P	Breakage or wearout
	Intermediate shaft pulley	Wearout or breakage
	Motor - 15 H.P	Burnout
	Taper locker bush, 42 mm.	Wearout
	Motor pulley	Breakage or wearout
Drive unit	Vee belt B-section 1560	Tearout
	Vee belt B-section 3200	-do-
	Taper locker bush, 50 mm.	Wearout
	Centrifugal clutch Vee pulley	Breakage or wearout
	Doffer wheel, 105T	Breakage or wearout
	Plumber block bearing, 602-90456-00	Dislocation & wearout of balls
	Drawing roller sprocket, 40T x 5/8" P	Breakage or wearout
	Pinion, 13T	-do-
Doffer roller	Pinion, 34T	-do-
	Bearing, 602-90177-00	Dislocation & wearout of balls
	Bearing, 602-02020-90	-do-
	Gear wheel	Breakage or wearout
	Bearing, 602-90175-00	Dislocation & wearout of balls

Contd. FINISHER CARD

1	2	3
	Bearing, 602-02025-40	Dislocation & wearout of balls
	Bearing, 602-90575-00	-do-
Delivery & roll former unit	Delivery roller sprocket, 48T (Duplex)	Breakage or wearout of
	Tension sprocket, 22T (Duplex)	-do-
	RF Drive sprocket, 24T	-do-
	Oil seal, ¾" bore	Tearout
	Piston ring	Wearout
Oil controller	Oil seal, 1" bore	Tearout
	Dowty seal, $\frac{3}{8}$" B.S pipe	Tear out
	Sealed ring	Tearout

G. 1ST DRAWING MACHINE

(Type: Push bar, Manufacturer: James Mackie & Sons)

1	2	3
	Delivery roller bushes	Wearout
	Vee belt	Tearout
	Shear pin	Breakage or wearout
Faller & upper section	Oilite bush for back roller block	Wearout
	Flannel strip for revolving rubber	Damage after use
	Faller bar pins	Breakage & plent of pins
	Flannel sleeves	Damage after normal use
	Chain for revolving rubber drive	Wearout of links
Drive section	Duplex chain wheel	Breakage or wearout
	Warm stud	-do-
	Coil spring	Breakage or less tensioned

Contd. 1ST DRAWING MACHINE

1	2	3
Can packer section	Can packer can runner	Wearout
	Can packer trip lever	-do-
	Slide rod bush	-do-
	Can packer ratched rod	-do-
	Can packer arm	wearout or crack
Coiler motion section	Coilder motion intermediate	Breakage or wearout
	Coiler plate	Wearout or crack
	Coiler base plate	-do-
	Key for coiler motion shaft	-do-
Feed section	Bearing	Dislocation & wearout of balls
	Brammer belt	Wearout
	Worm shaft bracket bush	Wearout
	Chain wheel on back roller	Breakage or wearout
	Gearing support bracket	Wearout or crack
	Shear pin bush	Wearout
	Fluted roller axle	-do-

7. 2ND DRAWING MACHINE

(Type: Screw gill, double can, Manufacturer: James Mackie & Sons)

1	2	3
Upper section	Bush for delivery roller bracket	Wearout or crack
	Front roller pinion	Breakage or wearout
	Chain	Wearout of links
	Can runner	Wearout
	Slide rod bush (Top)	Wearout
	Slide rod bush (Bottom)	-do-

Contd. 2ND DRAWING MACHINE

1	2	3
Can packer section	Can packer stud pinion	Breakage or wearout
	Can packer runner	Wearout
	Can packer runner stud	-do-
	Can packer ratchet rod pawl	-do-
Motor & drive section	Electric motor	Burnout
	Motor pulley	Breakage or wearout
	Chain wheel on sliver roller	-do-
	Chain idler	-do-
	Chain wheel double carrier	-do-
	Thrust bearing	Dislocation & wearout of balls
Faller and boss section	Faller pins	Breakage or blunt of pins
	Top faller screw	Wearout
	Faller spring bracket	Wearout or crack
	Faller spring	Breakage or less tensioned
	Bottom faller screw	Wearout
	Delivery pressing roller boss	-do-
	Felt sleeve for revolving rubber	Damage after use
Coiler motion section	Coiler motion intermediate	Breakage or wearout
	Coiler plate	Wearout or crack
	Coiler base plate	-do-
	Coiler plate stud	-do-

8. 3RD DRAWING MACHINE

(Type: Screw gill, Triple cam, Manufacturer: James Mackie & Sons)

1	2	3
	Bush for delivery roller bracket	Wearout
	Front roller pinion	Breakage or wearout
Upper section	Chain	Wearout of links
	Cam runner	Wearout
	Slide roller bush (Top)	-do-
	Slide roller bush (Bottom)	-do-
	Can packer stud pinion	Breakage or wearout
	Can packer runner	Wearout
Can packer section	Can packer runner stud	-do-
	Can packer ratchet pawl	-do-
	Motor	Burnout
	Motor pulley	Breakage or wearout
	Taper bush for frame pulley	Wearout
Motor and drive section	Chain wheel on sliver roller	Breakage or wearout
	Chain idler	-do-
	Chain wheel double carrier	-do-
	Thrust bearing	Dislocation & wearout of balls
	Faller pins	Breakage or blunt of pins
	Top faller screw	Wearout
	Faller spring bracket	Wearout or crack
	Faller spring	Breakage or less tensioned
Faller and boss section	Bottom faller screw	Wearout
	Delivery pressing roller boss	-do-
	Felt sleeve for revolving rubber	Damage after use
	Faller motion intermediate	Breakage or wearout
	Coiler plate	Wearout or crack
Coiler motion section	Coiler base plate	-do-
	Coiler plate stud	Wearout

9. FINISHER DRAWING

(Type: Screw gill, Double can, Manufacturer: James Mackie & Sons)

1	2	3
	Bush for delivery roller bracket	Wearout
	Front roller pinion	Breakage or wearout
Upper section	Chain	Wearout of links
	Can runner	Wearout
	Slide roller bush (Top)	-do-
	Slide roller bush (Bottom)	-do-
	Can packer stud pinion	Breakage or wearout
	Can packer runner	Wearout
Can packer section	Can packer runner stud	-do-
	Can packer ratchet rod pawl	-do-
	Motor	Burnout
	Motor pulley	Breakage or wearout
	Taper bush for frame pulley	Wearout
Motor and drive section	Chain wheel double carrier	Breakage or wearout
	Chain idler	-do-
	Chain wheel on sliver roller	Wearout
	Thrust bearing	Dislocation & wearout of balls
	Faller pins	Breakage or blunt of pins
	Top faller screw	Wearout
	Faller spring bracket	Wearout or crack
Faller and boxes section	Faller spring	Breakage or less tensioned
	Bottom faller screw	Wearout
	Delivery pressing roller boss	-do-
	Felt sleeve for revolving rubber	Damage after use
	Coiler motion intermediate	Breakage or wearout
	Coiler plate	Wearout or crack
Coiler motion section	Coiler base plate	-do-
	Coiler plate stud	Wearout

10. SPINNING FRAME

(Types 4¼" A.D & 5¼" S.D. Manufacturer: James Mackie & Sons)

1	2	3
Bottom and rack section	Builder chain	Wearout of links
	Ball bearing	Dislocation & wearout of balls
	Chain runner	Wearout
	Lifter bracket	-do-
	Rack pinion	Breakage or wearout
Tape driving section	Driving tape	Tearout
	Tin tension & guide pulley	Wearout
	Tension pulley slide	-do-
	Tin tension pulley housing	-do-
Front section	Oilite bush for front pressing roller	Wearout
	Apron (For 4¼" A.D)	Tearout
	Rubber pressing roller boss	Wearout
	Detector (R.H & L.H)	-do-
	Detector link for stop motion	-do-
	Axle spindle (For 4¼" A.D)	-do-
Heart lever section	Heart runner	Wearout or crack
	Heart double carrier pinion	Breakage or wearout
	Heart wheel	-do-
	Heart lever	-do-
	Ball bearing for heart runner	Dislocation & wearout of balls
Gear side	Roller bearing	Dislocation & wearout of rollers
	Draft chain wheel	Breakage or wearout
	Draft chain pinion	-do-
	Power grip driving belt	Tearout
	Chain for draft gearing	Wearout of links

Contd. SPINING FRAME

1	2	3
	Builder double carrier wheel	Breakage or wearout
	Builder double carrier pinion	-do-
Drive units	Top hand wheel pinion	-do-
	Builder shaft wheel	-do-
	Motor	Burnout
	Motor pulley	Breakage or wearout

11. TWIST FRAME

Manufacturer: James Mackie & Sons)

1	2	3
	Heart lever	Wearout or crack
	Heart double carrier pinion	Breakage or wearout
Heart lever section	Heart runner	Wearout
	Ball bearing for heart runner	Dislocation & wearout of balls
	Aluminium friction disc	Wearout
	E.L.B. type wharve	Defect in wharve bearing
Front section	Flyer (Open leg)	Wearout
	Dead spindle	-do-
	Tag end retainer	-do-
	Rack pinion	Wearout or breakage
	Builder chain	Wearout of links
Bottom section	Twist D.C chain wheel	Breakage or wearout
	Lifter bracket	Wearout or crack
	Top hand wheel pinion	Breakage or wearout
	Builder shaft wheel	-do-
Drive section	Builder D.C. wheel	-do-
	Motor	Burnout
	Lenix belt	Tearout

12. COP WINDING MACHINE

Manufacturer: James Low & Co.

1	2	3
Drive section	Motor pulley	Breakage or wearout
	Vee belt	Tearout
	Motor	Burnout
Main shaft & cop section	Spiral pinion, 21T x 11DP	Breakage or wearout
	Spiral pinion, 56T x 11DP	-do-
	Cop cone	Wearout
	Spindle	Wearout of threaded portion
	Half clutch	Wearout
Bottom section	Foot step bracket	Wearout & crack
	Spindle housing	-do-
	Cop bearing	Dislocation & wearout of ball
	Spindle gun metal bush	Wearout
	Eccentric arm bearing	-do-
	Packing wood	Crack

13. ROLL WINDING MACHINE

(Type: Mark II, Manufacturer: James Mackie & Sons)

1	2	3
Drive & Automatic section	Motor	Burnout
	Motor pulley	Wearout or breakage
	Ball bearing for idler pulley, L.S9	Dislocation & wearout of balls
	Roller bearing for idler pulley, RLS9	Dislocation & wearout of rollers
	Flad driving belt	Tearout
	Lifter bracket	Wearout or crack
	Damper bracket	Wearout
	Ratchet Toe	-do-
	Damper spring	Breakage or less tensioned

Contd. ROLL WINDING MACHINE

1	2	3
	Thrust bearing, W1¼"	Dislocation & wearout of balls
Gear box unit	Roller bearing, RLS10	Dislocation & wearout of rollers
	Oil seal (LJ213)	Tearout
	Oil seal (LJ223)	-do-
	End lap guard	Wearout
	Bottom lap guard	-do-
	Roller bearing, RLT	Dislocation & wearout of rollers
Scroll shaft section	Scroll roller boss (Plain)	Wearout
	Scroll roller boss (Key wayed)	-do-
	Centre lap guard (Top)	Breakage or wearout
	Centre lap guard (Bottom)	-do-
	Ball bearing, LT	Dislocation & wearout of balls
Tension device section	Bottom tension spring	Breakage or less tensioned
	Spring retainer	Wearout

14. COP WINDING MACHINE

Manufacturer: James Mackie & Sons

	Motor	Burnout
Drive section	Motor pulley	Breakage or wearout
	Lenix belt	Tearout
	Bearing	Dislocation & wearout of balls
	Cop spindle	Wearout
	Tension rod	Breakage
Cop spindle section	Cop cone	Wearout
	Automatic system	Defects in the system
	Lever spring	Breakage or less tensioned
	Tensioned pulley	Wearout
	Slide spindle bush	-do-

Contd. COP WINDING MACHINE

1	2	3
	Connecting arm	Breakage or crack
	Connecting arm bearing	Dislocation & wearout of balls
	Connecting arm bracket	Breakage or crack
Connecting arm & control section	Connecting arm rod	Breakage or wearout
	Centre bracket	Wearout of centre hole
	Cutter	Blunt
	Cutter spring	Breakage or less tensioned

15. DRY BEAMING MACHINE

Manufacturer: LEPCo.

1	2	3
	Pressing roller	Wearout
	Drawing roller	-do-
Upper portion	Spool hanger	-do-
	Pressing roller bracket	Wearout or crack
	Spring	Breakage or less tensioned
	Main driving pinion	Wearout or breakage
	Feed roller	Wearout
Lower portion	Main shaft bracket	Wearout or crack
	Driving pinion key	Wearout

16. HIBBERT DRESSING MACHINE

(Type: 9 cylinders, Manufacturer: Hibbert & Co.

	Gun metal pinion	Breakage or wearout
	Conical wheel face-I	Wearout
	Conical wheel face-II	-do-
	Conical wheel face-III	-do-
	Conical wheel face-IV	-do-
	P.I.V. gear box chain, RC-35G	Wearout of balls & links
	Gear box bearing	Dislocation & wearout of balls
	Wall work chain	Dislocation & wearout of links & balls
	Driving chain	Wearout of links

17. SACKING LOOM

(Size: 37¾" R.S. Manufacturer: LEPCo.)

1	2	3
	Picking shaft	Wearout
	Picking shaft spring	Breakage or less tensioned
	Lay block	Breakage or crack
Top section	Buffer	Wearout
	Buffer housing	-do-
	Picking arm	Breakage or crack
	Picking cone	Wearout
	Motor 1 - 1.5 H.P	Burnout
	Motor pulley	Wearout
	Vee belt no. 850	Tearout
Gearing and drive units	Machine pulley	Wearout or breakage
	Compound pinion, 90/55T	Breakage or wearout
	Pin roller pinion, 90T	-do-
	Centre shaft pinion, 25T	-do-
	Ratchet pinion, 40T	-do-
	Crank shaft	Breakage or wearout
	Centre shaft	Wearout
	Sword shaft	-do-
	Connecting arm	Breakage or wearout
	Crank shaft bush	Wearout
Centre and lower section	Centre shaft bush	-do-
	Sword shaft bush	-do-
	Wyper	-do-
	Treadle ball	-do-
	Treadle lever	-do-
	Truck plate	-do-

18. HESSIAN LOOM (With Loader System)

(Sizes 42½" R.S. & 48½" R.S. Manufacturer: LJFCo.)

1	2	3
Top section	Picking shaft	Wearout
	Picking shaft spring	Breakage or less tensioned
	Lay block	Breakage or crack
	Buffer	Wearout
	Buffer housing	-do-
	Picking arm	Breakage or crack
	Picking cone	Wearout
Gearing and drive units	Motor 1 – 1.5 H.P	Burnout
	Motor pulley	Wearout
	Vee belt no. 85	Tearout
	Machine pulley	Wearout or breakage
	Compound pinion, 90/45T	Breakage or wearout
	Pin roller pinion, 90T	-do-
	Centre shaft pinion, 25T	-do-
	Ratchet pinion, 40T	-do-
Centre and lower section	Crank shaft	Breakage or wearout
	Centre shaft	Wearout
	Sword shaft	-do-
	Connecting arm	Breakage or wearout
	Crank shaft bush	Wearout
	Centre shaft bush	-do-
	Sword shaft bush	-do-
	Wyper	-do-
	Treadle ball	-do-
	Treadle lever	-do-
	Truck plate	-do-
Automatic system	Cam	Wearout
	Actuating lever	-do-
	Weft gate	Breakage or wearout
	Weft fork	-do-
	Cop plunger	-do-
	Cop detector	-do-

19. DAMPING MACHINE

Manufacturer: T.C. Keay

1	2	3
Drive unit	Motor	Burnout
	Motor pulley	Breakage or wearout
	Vee belt	Tearout
	Leather belt	Tearout
Upper section	Main shaft arbor	Wearout
	Main shaft key	-do-
	Driving pinion	Breakage or wearout
	Sprinkler plate	Wearout

20. CALENDER MACHINE

Manufacturer: FLTM

1	2	3
	Motor	Burnout
	Vee belt, A-71	Tearout
	Oil pump bucket	-do-
	Motor brake shoe	Wearout
	Vee belt, B-120	Tearout
	Motor pulley	Breakage or wearout

21. LAPPING MACHINE

Manufacturer: T.C. Keay

1	2	3
	Motor	Burnout
	Motor pulley	Breakage or wearout
	Vee belt, A-105	Tearout
	Bottom cam	Wearout
	Heckle	Damage after use
	Spring	Breakage or less tensioned
	Driving shaft	Wearout
	Driving shaft pinion	Breakage or wearout
	Brake shoe	Wearout

22. CUTTING MACHINE

Manufacturer: T.C. Kony

1	2	3
	Cutting blade	Decrease of sharpness
	Fibre pinion, 44T	Breakage or wearout
	Motor	Burnout
	Motor pulley	Breakage or wearout
	Blade bolts	Wearout of thread
	Cloth adjusting bolt	Wearout of thread

23. HEMMING SEWING MACHINE

Manufacturer: Union Special

1	2	3
	Needle no.156/75	Wearout
	Looper, AS2GXA	-do-
	Feed lift cam	Breakage
	Pressure foot no.802200	-do-
	Collar	Wearout
	Feed dog, no.00205	Breakage or wearout
	Tension disc, 80676	Wearout
	Tension part, 80046	-do-
	Tension ferrule	-do-
	Needle bar bush	Breakage or wearout
	Looper rocker	Wearout
	Fork	-do-

24. HERRACKLE SEWING MACHINE

Manufacturer: Union Special

1	2	3
	Looper no. 81208	Wearout
	Needle no. 156/70	Breakage or wearout
	Looper rocker	Wearout
	Cone stud	Breakage
	Clamp screw	Wearout

Contd. HERACKLE SEWING MACHINE

1	2	3
	Throat plate	Wearout
	Spreader, 81207	-do-
	Thread retainer	-do-
	Connecting rod	-do-
	Screw	-do-
	Feed dog	Breakage or wearout
	Spreader rocker	Wearout
	Tube	-do-
	Needle bar bush	-do-
	Pressure foot	-do-
	Tension disc, 60876	-do-
	Tension ferrule	-do-
	Tension spring	Breakage or less tensioned
	Ball stud no. 00675	Wearout

25. OVERHEAD SEWING MACHINE

Manufacturer: D.G. Mack Donald

1	2	3
	Worm pinion, 34T	Breakage or wearout
	Top pinion, 32T	-do-
	Bottom pinion, 32T	-do-
	Needle , S.W.G. no.4,5,6.	Breakage or wearout
	Needle pad	-do-
	Needle cone	Wearout
	Centre pinion	Breakage or wearout
	Centre bush	Wearout
	Overhead chain	Wearout of links

23. BALING MACHINE

Manufacturer: John Shaw & Co.

1	2	3
	'O' ring (Different size)	Tearout
	Oil seal (Different size)	-do-
	Deri Sine pump	Different defects inside the pump
	H.D. coupling	Wearout
	Relief valve (L.P)	-do-
	Relief valve (H.P)	-do-
	Connecting pipe (Different size)	Tearout of end sections
	Monoradial pump	Different defects inside the pump
	Filter	Breakage of net or deposite of dirt

CHAPTER 4: DATA COLLECTION AND DATA ANALYSIS

4.1 Introduction

Without proper data collection and subsequent analysis, it is not possible to develop an effective and cost optimal maintenance strategy, for any machine. At the outset of any attempt to setup a collection system, one must consider several important questions, which are summarised as follows:

a) Which data should be collected ?

b) How should they be collected ?

c) What are the best methods of processing the data ?

d) Can the results of all this effort be presented in a meaningful way ?

Answers to these questions are not straight forward, mostly they are interdependent and require changing of the system after careful review of the effectiveness. So, it is obviously necessary to establish the benefits to be gained from the results before establishing any system. Now, the basic information required is about the original cost as well as the cost of maintenance during useful life of the machine. In order to determine the maintenance cost and downtime correctly, one should also consider the questions like how often does the machine breakdown, how much production time is lost and cost of lost production during the repair, what is the cost in terms of maintenance manpower and replaced component parts.

It is also desirable to know the time lost in waiting for manpower or the supply of components and the length of time that repairs take. Apart from cost data, one must have information also about the failure mode of the machine and effect of each type of failure.

As records of the different maintenance functions that are carried out in the present system are not kept correctly and scientifically, great difficulties have been faced in respect of collecting different data of the jute mills machinery. Though the mill was commissioned in the year 1970, only three years failure data i.e. from the period of 1st January, 1979 to 31st December 1981 has been collected in case of all machines except sewing machines of the mill, due to nonavailability of correct data. However, for sewing machines data collected only for a period of two years. But this will not hamper to develop the maintenance policy for sewing machines also, because number of failures and associated cost, downtime etc. are much higher than the other machines. In general, data has been collected more or less correctly during the above mentioned periods.

It has also been mentioned earlier that data has been collected for critical parts only. So, the resultant policy will be developed on the basis of failure history of critical components only.

To develop a good maintenance policy, the following proforma for data collection may be proposed (Table 4.4.1).

Table 4.4.1: Statement of Repair and Overhauling work

Proforma: 400 x 300 mm sheet

Name of the machine	Running time at failure/ Preventive overhaul	Operating time between failures/ overhaul	Name of the failed components
1	2	3	4

Causes of failure	Number of maintenance crew worked	Cost Involved			
		Man	Material	Lost production	Total
5	6	7	8	9	10

4.2 Failure History of Machines (Tables)

1. EMULSION PLANT

*. asterisk indicates preventive overhaul

Running time at failure/ preventive overhaul (in hours)	Operating time between failures/Overhaul (in hours)	Name of the failed components	Causes of failure	Downtime due to failures/ preventive overhauls (in hours)	Total cost of failures/ preventive maintenance		
					Repair/ replacement cost (Tk.)	Lost Production cost (Tk.)	Total cost (Tk.)
1	2	3	4	5	6	7	8
450	450	Pump filter	Tornout of net	3.5	60	2100	2160
900	450	'O' Seal 0.4-19	Damaged by oil & emulsion	1.5	35	900	935
1250	350	Sealed ball bearing	Balls dislocated and wornout	2.5	50	1500	1550
1445	195	'O' Seal 0.5-35	Damaged by oil & Emulsion	1.5	40	900	940
*1550	*105	" "	" "	*6.0	510	2410	2920
2065	515	Valve spring	Tornout	2.0	20	1200	1220
2870	804	Gland seal hycar	Damaged by oil & emulsion	2.5	65	1500	1565
3640	770	'O' seal 0.5-13	-do-	1.5	40	900	940
4890	1250	'D' ring-body	Tornout	3.0	45	1000	1045
*5750	*860	" " "	" " "	*3.25	470	2118	2588
6910	1160	Du-lip ring 4-017	Wornout	2.5	60	1500	1560

Contd. EMULSION PLANT

1	2	3	4	5	6	7	8
7600	770	'O' seal 0.3-19	Damaged by oil & emulsion	1.5	35	900	935
8290	[illegible]	Sealed ball bearing	Balls dislocated & wornout	2.5	60	1500	1560
8060	630	Pump filter	Tornout	2.5	55	1500	1555
9162	362	Ou-lip-ring, 4-032	Tornout	1.0	20	600	620
*10025	*863	- - -	- - -	*6.75	670	2745	3415
10150	125	'C' seal 0.4-32	Damaged by oil & emulsion	2.5	55	1500	1555
10930	780	Piston bearing	Balls dislocated & wornout	1.5	40	900	940
11250	320	Oil retaining bush	Wornout	2.5	45	1500	1545
11840	570	Gear box gasket	Tornout	2.0	20	1200	1220
*11900	*140	- - -	- - -	*5.62	945	2295	3240
12570	590	Yoke bearing	Balls dislocated & wornout	2.5	160	1500	1660
13018	448	Valve spring	Tornout	3.0	50	1200	1250
*13075	*57	- - -	- - -	*4.5	334	1836	2170
13990	915	'C' ring-2nd inlet	Tornout	3.0	48	1800	1848
14320	330	'C' seal 0.9-29	Damaged by oil & emulsion	1.5	40	900	940

Failure = 65.3 Failure = 20,830

Preventive =*28.12 Preventive= 14,341

2. SOFTNER MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
866	866	Metering valve	Wornout	1.5	180	450	630
1474	608	Stop valve	Wornout	2.0	120	600	720
*2245	*771	- - -	- - -	*2.25	270	495	765
3618	1373	Gable	Found crack	3.0	60	900	960
4558	940	Metering system	Wornout	1.5	180	450	630
*6072	*1514	- - -	- - -	*3.0	290	645	935
8215	2143	Upper bush	Wornout	3.0	80	900	900
8805	590	Stop valve	Wornout	2.5	120	750	870
9681	876	Metering system	Wornout	1.5	180	450	630
*10786	*1105	- - -	- - -	*4.12	425	870	1295
11504	710	Lower bush	Wornout	3.0	110	900	1010
*12063	*1359	- - -	- - -	*2.62	185	570	755
13232	309	Softner roller	Brokenout of flutes	4.0	695	1200	1895
13925	673	Vee belt	Tornout	1.5	220	450	670
*14060	*135	- - -	- - -	*5.25	2040	1095	3135
14400	340	Softner roller	Brokenout of flutes	3.5	812	1050	1862

Failure = 27.0 Failure = 10,857

Preventive=17.24 Preventive= 6,085

3. HARD WASTE TEASER CARD

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
693	693	Driving pinion	Brokenout of some teeth	2.0	70	400	470
1274	581	Cylinder staves	Found blunt & broken pins	3.5	580	1100	1680
*2428	*1154	- - -	- - -	*5.5	875	1118	1993
3761	1333	Doffer staves	Found blunt & broken pins	4.5	480	900	1345
4622	861	Upper container	Found crack	3.0	384	1100	1484
*5807	*1265	- - -	- - -	*7.5	1147	1536	2683
6226	359	Driving arbor key	Wornout	1.5	20	300	320
7430	1004	Feed roller staves	Found broken & blunt pins	2.5	540	1000	1540
*8323	*1393	- - -	- - -	*4.0	606	445	1051
9568	845	Pinion	Brokenout of some teeth	1.5	55	400	455
10864	1196	Cylinder staves	Brokenout of one stave	2.5	580	900	1300
11709	845	Drive unit	Found defect in the unit	2.5	243	700	943
*12860	*1151	- - -	- - -	*5.0	1045	786	1831
13345	485	Upper container	Found crack	3.0	724	1800	2524
13852	507	Cable	Found crack	3.5	266	900	1166
*14308	*456	- - -	- - -	*8.0	1185	1595	2780

Failure = *32.0   Failure = 13,307

Preventive = 30.0   Preventive = 12,806

4. BREAKER CARD MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
340	340	Pinion, 13T	Brokenout of some teeth	2.0	60	320	380
800	540	Bearing, 602-02020-90	Ball dislocated & wornout	3.5	190	560	750
*1090	*210	" " "	" " "	*4.12	445	494	939
1590	500	Stripper sprocket	Brokenout of some teeth	2.5	75	400	475
1800	290	Bearing,602-02025-40	Ball dislocated & wornout	3.0	230	480	710
2470	590	Delivery roller sprocket	Found crack	1.5	56	240	296
3024	554	Tension sprocket	Found crack	2.0	65	820	385
*3450	*426	" " "	" " "	*3.62	398	645	1043
3570	220	Motor - 15 H.P	Burnout	4.5	606	720	1326
4040	370	Doffer wheel,1057	Brokenout of some teeth	3.5	210	560	770
4600	560	Vee belt no.1560	Tornout	1.0	320	160	400
5080	400	Bearing,602-00162-00	Balls dislocated & tornout	3.0	230	480	710
*5200	*200	" " "	" " "	*6.0	1575	694	2269
5682	402	Drawing roller wheel	Brokenout of some teeth	2.5	90	400	490
6240	550	Compound wheel	Brokenout of some teeth	2.5	120	400	520
6468	228	Circlip (external)	Found loose	1.0	05	160	165
7255	787	Pitch pin wheel	Wornout	2.0	85	320	405

Contd. BREAKER CARD MACHINE

1	2	3	4	5	6	7	8
7805	550	Bearing,602-90170-00	Balls dislocated & wornout	3.5	575	560	1135
*8090	*205	- - -	- - -	*9.0	848	1014	1850
8160	70	Worker sprocket	Brokenout of some teeth	1.5	70	240	310
8906	746	Bearing,602-90177-00	Balls dislocated & wornout	3.0	305	480	865
9200	374	Motor pulley	Wornout of centre hole	4.0	165	640	805
10350	1070	Vee belt no.3200	Tornout	1.0	470	160	630
10560	210	Gear wheel, 30T	Wornout	2.5	90	400	490
*10870	*310	- - -	- - -	*8.25	1230	934	2164
11360	430	Bearing,602-90163-00	Wornout of balls	3.0	425	480	905
11060	500	Pinion, 34T	Brokenout of some teeth	1.5	70	240	310
12290	430	Circlip - 48 mm.	Found loose	1.0	05	160	165
13342	1052	Conveyor belt	Tornout	1.5	230	240	470
13504	162	Circlip - 20 mm.	Found loose	1.0	05	160	165
*13724	*220	- - -	- - -	*6.0	904	608	1509
14008	234	Pinion - 18T	Brokenout of some teeth	2.0	55	320	375
14384	376	Bearing,602-90575-00	Balls dislocated & wornout	3.0	425	480	905

Failure = 63.0 Failure = 15,392

Preventive = 39.0 Preventive = 9,064

5. FINISHER CARD MACHINE

*. asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
554	554	Stripper drive sprocket	Brokenout of some teeth	2.0	75	300	375
1164	610	Intermediate gear wheel	Wornout of centre hole	2.0	85	300	385
*1704	*50	- - -	- - -	*4.12	374	431	805
2083	312	Worker sprocket	Brokenout of some teeth	1.5	65	225	290
2674	580	Doffer wheel	Wornout of centre hole.	2.5	290	375	665
2885	211	Tension sprocket	Brokenout of some teeth	2.0	145	300	445
3426	541	Bearing,602-90162-00	Balls dislocated & wornout	3.0	230	450	680
3608	182	Cylinder wheel bracket	Found crack	3.0	70	450	520
4076	468	Compound gear wheel	Wornout of some teeth	2.5	120	375	495
*4254	*178	- - -	- - -	*6.75	605	693	1298
4568	314	Vee belt no. 1560	Tornout	1.5	320	225	545
4972	404	Bearing,602-02028-40	Balls dislocated & wornout	3.0	230	450	680
5887	915	Intermediate stud	Wornout	2.0	55	300	355
*6326	*439	- - -	- - -	*6.0	712	618	1230
7408	1082	Compound wheel	Brokenout of some teeth	2.0	120	300	420
7881	473	Motor pulley	Wornout	3.0	165	450	615

Contd. FINISHER CARD MACHINE

1	2	3	4	5	6	7	8
8594	713	Vee belt no. 3200	Tornout	1.0	470	150	620
9208	614	Feed roller bearing	Balls dislocated & wornout	3.0	450	450	900
*9583	*375	" " "	" " "	*5.5	1120	843	1963
10602	1020	Motor - 15 H.P	Burntout	4.5	606	875	1481
10801	119	Circlip	Found loose	1.0	05	150	155
11244	443	Fluted roller gear	Brokenout of some teeth	2.0	180	300	480
11383	139	Circlip	Found loose	1.0	05	150	155
11808	425	Tension bracket	Brokenout	2.5	85	375	460
*12504	*696	" " "	" " "	*5.0	1042	768	1792
12698	194	Worker sprocket	Wornout of some teeth	2.5	70	375	445
13008	310	Delivery roller arbor	Wornout of key portion	2.0	55	300	355
13750	742	Bearing,602-02025-90	Balls dislocated & wornout	3.5	450	525	975
*13921	*171	" " "	" " "	*7.5	845	768	1613

Failure =	52.5	Failure =	12,506
Preventive =	34.87	Preventive =	8,701

6. 19T DRAWING MACHINE

*. asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
365	365	Faller bar	Found broken & blunt pins	2.5	170	450	620
852	407	Flannel sleeves	Damaged after normal use	2.0	425	360	785
1243	391	Cam porker ratchet rod	Wornout	2.5	56	450	506
*1405	*162	- - -	- - -	*4.0	525	765	1245
1896	491	Drawer belt	Tornout	1.0	160	180	340
2528	632	Bearing	Balls dislocated & wornout	2.5	240	450	690
2810	282	Vee belt	Tornout	1.0	145	180	325
*3248	*438	- - -	- - -	*3.0	675	545	1215
3598	350	Faller bar pins	Brokenout of most of the pins	2.5	183	450	635
*4034	*436	- - -	- - -	*2.0	384	405	789
4128	94	Front roller arbor	Wornout	1.5	15	270	285
4843	715	Oilite bush	Wornout	2.0	65	360	425
*5416	*573	- - -	- - -	3.0	214	589	790
5808	392	Shear pin	Brokenout	1.0	10	90	100
6718	229	Grease nipple	Deposited dirt	2.0	05	360	365
*7674	*956	- - -	- - -	*3.0	154	550	712
8073	399	Faller bar pins	Brokenout of most of the pins	2.5	185	450	635

Contd. 16X DRAWING MACHINE

1	2	3	4	5	6	7	8
8092	849	Chain	Wornout of links	1.5	650	270	920
9228	336	Flannel sleeves	Damaged after normal use	2.0	425	360	785
*9717	*409	" " "	" " "	*3.0	1366	576	1922
10320	603	Can packer can runner	Wornout	2.0	65	360	425
10874	554	Coiler plate	Brokenout of some teeth	2.0	78	360	438
11228	354	Can packer arm	Brokenout	2.5	45	450	495
11408	180	Can packer runner	Wornout	2.5	184	450	634
*11912	*504	" " "	" " "	*5.0	407	945	1352
12074	162	Can packer trip lever	Brokenout	1.5	40	270	310
12084	610	Coiler motion inter-mediate	Brokenout of some teeth	2.5	55	450	505
*13340	*432	" " "	" " "	*4.0	240	765	1005
13506	246	Faller bar pins	Found broken & blunt pins	2.5	160	450	610
13901	315	Vee belt	Tornout	1.0	145	180	325
*14177	*276	" " "	" " "	*3.0	429	594	1023
14292	115	Flannel sleeves	Damaged after normal use	2.0	425	360	785
			Failure =	48.5			Failure = 12,388
			Preventive =	30.0			Preventive = 10,062

7. 2ND DRAWING MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
486	405	Coiler plate	Brokenout of some teeth	2.0	84	320	404
1014	520	Felt strip	Damaged after normal use	2.5	375	400	775
1876	862	Faller bar	Brokenout of most of the pins	2.5	225	400	625
2409	613	Bearing for pressing roller	Balls dislocated & wornout	3.0	220	400	700
*2725	*236	- - -	- - -	*6.0	095	996	1091
3164	439	Can packer runner	Wornout	2.5	104	400	504
3703	539	Delivery pressing roller	Wornout of rubber portion	2.0	95	320	415
*4226	*443	- - -	- - -	*3.0	345	516	861
4901	659	Chain	Wornout of links	1.5	650	240	890
5429	540	Spring	Less tensioned	1.0	70	160	230
*6270	*841	- - -	- - -	*2.0	945	356	1301
6743	473	Thrust bearing	Balls dislocated & wornout	2.5	305	400	705
7350	607	Coiler motion intermediate pinion	Brokenout of some teeth	2.5	75	400	475
*8478	*1120	- - -	- - -	*3.0	381	516	897
8698	220	Faller bar	Brokenout of most of the pins	3.0	195	480	675
9102	404	Bush for back shaft bearing	Wornout	2.0	48	320	368

Contd. 2ND DRAWING MACHINE

1	2	3	4	5	6	7	8
9014	632	Vee belt	Tornout	1.0	145	160	305
*10603	*703	- - -	- - -	*4.0	560	676	1236
11204	601	Coiler plate	Brokenout of some teeth	1.5	101	400	501
11696	492	Shear pin	Brokenout	1.5	15	80	95
*12079	*303	- - -	- - -	*2.0	318	356	674
12648	569	Delivery pressing roller	Wornout of upper portion	2.5	69	400	469
13001	333	Can packer runner	Wornout	2.5	164	400	564
13774	773	Can packer ratchet rod pawl	Found crack	2.0	147	320	467
*13924	*158	- - -	- - -	*4.0	355	676	1031
14203	279	Filler bar	Brokenout of most of the pins	2.5	105	400	505
			Failure =	40.5		Failure =	9,852
			Preventive =	24.0		Preventive =	7,891

8. 3RD DRAWING MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
518	510	Roller bar	Brokenout of most of the pins	2.5	185	300	485
1002	544	Delivery pressing roller boss	Wornout of upper portion	1.5	110	180	290
1376	314	Ball bearing	Balls dislocated & wornout	2.5	205	300	505
*1804	*420	- - -	- - -	*4.0	550	507	1057
2103	299	Felt strip	Damaged after normal use	2.5	375	300	675
2745	642	Spring	Less tensioned	1.0	055	120	175
*3448	*703	- - -	- - -	*3.0	509	387	896
4245	797	Front delivery spout	Wornout partially	2.0	65	240	305
4851	610	Back roller small gear intermediate	Brokenout of some teeth	2.0	75	240	315
5104	243	Thrust bearing	Balls dislocated & wornout	3.0	340	360	700
5810	706	Coiler plate	Brokenout of some teeth	2.5	85	300	385
*6306	*576	- - -	- - -	*5.0	670	627	1297
6920	534	Roller bar	Brokenout of most of the pins	2.5	185	300	485
7140	220	Chain wheel on sliver roller	Brokenout of some teeth	3.0	70	360	430
*7580	*540	- - -	- - -	*4.0	320	507	827
7930	250	Vee belt	Tornout	1.0	145	120	265

Contd. 3RD DRAWING MACHINE

1	2	3	4	5	6	7	8
8440	510	Can packer can	Wornout of some portion	2.5	75	300	375
8892	452	Double carrier chain wheel	Brokenout of some teeth	2.5	85	300	385
*9308	*416	" " "	" " "	*3.0	334	387	721
10246	338	Motor	Burntout	4.0	470	480	950
10093	647	Front revolving rubber lever	Found crack	2.5	65	300	365
*11455	*562	" " "	" " "	*4.0	470	507	970
11906	451	Faller bar	Brokenout of most of the pins	3.5	165	300	465
12504	678	Pinion on chain wheel	Brokenout of some teeth	3.0	120	360	480
12093	309	Bearing	Balls dislocated & wornout	3.0	270	360	630
13205	912	Back shaft pinion	Wornout of some teeth	2.5	95	300	395
*13756	*551	" " "	" " "	*8.0	673	987	1660
13903	147	Coiler motion spur wheel	Brokenout of some teeth	3.0	72	360	432
14336	433	Rear back roller	Wornout	3.5	89	420	509

Failure = *53.0
Preventive = 31.0

Failure = 10,001
Preventive = 7,420

9. FINISHER DRAWING MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
417	417	Flannel sleeves	Damaged after normal use	2.5	90	450	540
926	509	Front roller bracket	Found crack	3.0	90	540	630
1417	491	Chain wheel on delivery roller	Brokenout of some teeth	2.0	70	360	430
*1006	*309	- - -	- - -	*5.0	712	927	1639
2374	560	Faller bar	Brokenout of most of the pins	2.5	175	450	625
2568	194	Ratchet wheel	Brokenout of some teeth	2.5	96	450	546
*3092	*524	- - -	- - -	*3.0	402	567	969
3306	214	Collar plate	Brokenout of some teeth	2.5	70	450	520
4167	861	Bearing	Balls dislocated & wornout	3.0	240	540	780
*4703	*536	- - -	- - -	*4.0	387	747	1134
5265	562	Vee belt	Tornout	1.0	160	180	340
5426	161	Sliver guide rod bracket	Found crack	2.0	75	360	435
6015	589	Chain wheel on double carrier	Brokenout of some teeth	2.5	95	450	545
*6628	*613	- - -	- - -	*3.0	447	567	1014
7259	631	Faller bar	Brokenout of most of the pins	2.5	170	450	620
7405	146	Chain	Less tensioned	1.5	660	270	930
8106	70	Bush for bracket	Wornout	2.5	65	450	515
*8694	*588	- - -	- - -	*3.0	944	567	1511

Contd. FINISHER DRAWING MACHINE

1	2	3	4	5	6	7	8
9205	511	Bearing	Balls dislocated & wornout	3.0	270	540	810
9702	577	Pressing roller boss	Wornout of some portion	1.5	120	270	390
*10404	*702	- - -	- - -	2.0	726	747	1473
10303	319	Presser	Found crack	2.0	110	360	470
11506	703	Spring	Less tensioned	1.0	70	180	250
12040	534	Delivery pinion	Wornout	3.0	130	540	670
*12436	*396	- - -	- - -	*3.0	430	567	997
12694	283	Can packer runner	Wornout	2.5	170	450	620
13040	346	Chain wheel on sliver roller	Brokenout of some teeth	2.5	110	450	560
*13843	*803	- - -	- - -	*4.0	374	747	1121
13944	101	Stop motion cam	Wornout	2.0	75	360	435
14342	398	Chain idler	Brokenout of some teeth	2.5	95	450	545
			Failure =	50.0		Failure =	12,206
			Preventive =	27.0		Preventive =	9,858

10. SPINNING FRAME MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
350	350	Drawing roller bearing	Balls dislocated & wornout	2.5	100	150	330
425	75	Builder double carrier wheel	Brokenout of some teeth	2.5	101	150	251
476	51	Drawing roller bearing	Balls dislocated & wornout	2.5	180	150	330
*714	*238	- - -	- - -	*4.0	502	276	778
885	171	Retaining roller bearing	Balls dislocated & wornout	2.0	140	120	260
1217	332	Chain for bottom cutting rod	Wornout of links	1.0	480	60	540
1593	376	Drawing roller bearing	Balls dislocated & wornout	2.5	180	150	330
2436	843	Power grip driving belt	Tornout	1.0	120	60	180
2978	542	Bell crank for knock of lever	Brokenout	1.5	145	90	235
3452	474	Heart lever	Found crack	2.5	404	150	554
*3640	*188	- - -	- - -	*6.0	1264	396	1600
3817	177	Rack pinion	Brokenout of some teeth	2.0	45	120	165
4554	737	Drawing roller bearing	Balls dislocated & wornout	2.5	180	150	330
5364	810	Retaining roller bearing	Balls dislocated & wornout	2.0	140	120	260
5936	572	Ball bearing	Balls dislocated & wornout	3.0	210	180	390
6673	737	Driving tape	Tornout	1.5	60	90	150

Contd. SPINNING FRAME MACHINE

1	2	3	4	5	6	7	8
*7210	*537	- - -	- - -	*6.0	742	396	1130
7991	701	Heart wheel	Brokenout of some teeth	2.5	95	150	245
8240	249	Drawing roller bearing	Balls dislocated & wornout	2.3	180	150	330
8859	619	Chain for draft gearing	Wornout of links	1.5	160	90	250
9210	351	Spring for and builder base	Less tensioned	1.0	45	60	105
9750	540	Drawing roller bearing	Balls dislocated & wornout	2.5	80	150	230
*10460	*710	- - -	- - -	*6.0	606	405	1011
11600	1140	Chain for jocky pulley lever	Wornout of links	1.5	65	90	155
11900	292	Pressing roller boss	Wornout of rubber	1.5	1600	90	1690
12695	795	Apron roller	Brokenout of threaded portion	1.0	110	180	290
13240	454	Drawing roller bearing	Balls dislocated & wornout	2.5	180	150	330
			Failure =	47.5		Failure =	7,930
			Preventive =	22.0		Preventive =	4,507

11. TWIST FRAME MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
406	405	Heart lever	Found crack	2.5	220	150	370
1200	712	Builder double carrier wheel	Brokenout of some teeth	1.5	90	90	180
2054	885	Builder chain	Wornout of links	2.0	440	120	560
*2670	*616	- - -	- - -	*4.5	690	198	888
3708	1038	Lonix belt	Tornout	1.5	300	90	390
4292	584	Lifter bracket	Wornout of some portion	3.0	120	180	300
5614	1322	Spring	Less tensioned	1.5	60	90	150
*6518	*904	- - -	- - -	3.0	874	198	1072
7784	1266	Wherve	Defect in the bearing	2.5	600	150	750
8506	722	Flyer	Wornout of eye	2.0	500	220	720
9601	1295	Heart lever	Found crack	2.5	220	150	370
10486	605	Motor	Burntout	4.0	660	240	900
*11624	*1138	- - -	- - -	*4.0	2454	258	2712
12407	783	Pinion	Brokenout of some teeth	2.5	80	150	230
12988	581	Builder chain	Wornout of some links	2.0	340	120	460
*13671	*683	- - -	- - -	*4.5	380	198	578
14265	594	Flyer	Wornout of some eyes	2.0	460	120	580

Failure = 29.5	Failure = 6,360
Preventive = 16.0	Preventive = 5,250

12. COP WINDING MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
264	264	Eccentric arm bearing	Balls dislocated & wornout	2.5	800	500	1300
*536	*272	- - -	- - -	*2.0	875	445	1320
874	338	Centre pinion-50T	Wornout of some teeth	2.0	600	400	1000
1290	424	Spiral pinion - 24T	Wornout	2.5	450	500	950
1546	240	Spindle	Damaged thread portion	2.0	665	400	1065
*2084	*538	- - -	- - -	*4.0	1804	845	2649
2176	92	Half clutch	Wornout	1.5	210	300	510
*2492	*316	- - -	- - -	*2.0	320	445	765
2904	412	Spiral pinion - 24T	Wornout	3.0	445	600	1045
3318	414	Centre pinion - 58T	Wornout	2.5	700	500	1200
*3827	*509	- - -	- - -	*3.0	1342	645	1987
4012	185	Half clutch	Wornout	2.0	340	400	740
4564	552	Spindle	Wornout of thread portion	2.5	450	500	950
*5039	*475	- - -	- - -	*3.0	1160	645	1805
5218	179	Packing wood	Found crack	1.5	40	300	340
5463	245	Centre pinion - 50T	Wornout of some teeth	3.0	540	600	1140
5704	241	Packing wood bearing	Balls dislocated & wornout	3.0	610	600	1210
*5926	*222	- - -	- - -	6.0	2024	1245	3269
6300	382	Half clutch	Wornout	2.0	320	400	720

Contd. COP WINDING MACHINE

1	2	3	4	5	6	7	8
6523	215	Spiral pinion - 21T	Wornout	2.5	620	500	1120
*6004	*201	" " "	" " "	*2.0	945	445	1390
7020	225	Spindle	Wornout of thread portion	2.5	580	500	1080
7126	97	Packing wood	Found crack	1.5	00	300	300
7442	316	Centre pinion - 58T	Wornout of some teeth	3.0	710	600	1310
*7509	*67	" " "	" " "	*5.0	1470	1045	2515
7924	415	Half clutch	Wornout	2.5	280	500	780
*8220	*296	" " " "	" " "	#2.0	340	445	785
8376	196	Spindle	Wornout of thread portion	2.0	480	400	880
8508	132	Centre pinion - 58T	Wornout of some teeth	3.0	680	600	1280
*8874	*366	" " "	" " "	#3.0	1244	645	1889
8913	39	Spiral pinion - 21T	Wornout of some tooth	2.5	620	500	1120
9246	333	Motor	Burntout	3.0	450	600	1050
*9510	*264	" " "	" " "	*4.0	1240	845	2085
9746	236	Spindle	Wornout of thread portion	2.5	530	500	1020
9902	156	Packing wood	Found crack	1.5	110	300	410
10325	423	Half clutch	Wornout	2.0	340	400	740
*10501	*176	" " "	" " "	*4.0	845	845	1690
10789	200	Centre pinion - 58T	Wornout of some teeth	3.0	720	600	1320

Contd. COP WINDING MACHINE

10920	137	Spiral pinion - 2ET	Wornout	2.5	420	500	920
*11208	*202	- - -	- - -	*3.0	690	645	1345
11929	121	Spindle	Wornout of thread portion	2.5	520	500	1020
11608	279	Half clutch	Wornout	2.0	400	400	800
11012	204	Packing wood	Found crack	1.5	120	300	420
*12046	*231	- - -	- - -	*4.0	1230	845	2075
12324	278	Centre pinion - 58T	Wornout of some teeth	2.5	490	500	990
12494	170	Packing wood bearing	Balls dislocated & wornout	3.0	610	600	1210
*12578	*124	- - -	- - -	*3.0	1340	645	1985
12998	330	Spiral pinion - 2ET	Wornout of some teeth	3.0	620	600	1220
*13508	*520	- - -	- - -	*2.0	714	445	1159
13789	281	Half clutch	Wornout	2.0	200	400	600
13805	16	Vee belt	Tornout	1.0	180	200	380
13989	204	Spindle	Wornout of thread portion	2.5	540	500	1040
*14076	*07	- - -	- - -	*4.0	991	845	1836
14201	125	Eccentric arm pinion	Brokenout of some teeth	2.0	125	400	525
14384	183	Centre pinion - 58T	Wornout of some tooth	3.0	872	600	1472

Failure = 89.0 Failure = 35,410

Preventive = 56.0 Preventive = 30,631

13. BACK ROLL WINDING MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
540	540	Ball bearing for scroll roller	Balls dislocated & wornout	3.0	260	240	500
950	410	Lifter bracket	Wornout of centre hole	2.0	120	160	280
1409	459	Bottom lap guard	Found crack	2.5	46	200	246
*1700	*571	- - -	- - -	*5.0	540	418	966
1920	120	Damper spring	Less tensioned	1.5	68	120	188
2625	705	Roller bearing	Rollers dislocated & wornout	2.5	235	200	435
3245	620	Bottom tension spring	Less tensioned	1.0	45	80	125
4084	839	Ball bearing for scroll roller	Balls dislocated & wornout	2.5	260	200	460
*4880	*790	- - -	- - -	*3.0	616	498	1114
5260	300	Centre lap guard(Top)	Wornout	1.5	46	120	166
6130	870	Flat driving belt	Tornout	1.0	1252	80	1332
7040	910	Ball bearing	Balls dislocated & wornout	2.5	260	200	460
7960	920	Oil seal	Tornout	1.0	30	80	116
8890	930	Spring retainer	Wornout	1.5	116	120	236
9970	1000	Centre lap guard(Bottom)	Wornout	1.5	46	120	166
10860	890	Bottom lap guard	Wornout	1.5	46	120	166
*11670	*810	- - -	- - -	*6.0	1593	490	2091

Contd. MACK ROLL WINDING MACHINE

1	2	3	4	5	6	7	8
12150	400	End lap guard	Found crack	1.5	46	120	166
12870	720	Lifter bracket	Wornout of centre hole	2.5	120	200	320
*13490	*620	- - -	- - -	4.0	2070	338	2408
13924	434	Scroll roller boss	Wornout	3.0	1993	240	2233
14290	366	Scroll roller boss ---Key wayed	Wornout	2.0	1993	160	2153
			Failure = Preventive =	34.5 21.0		Failure = Preventive =	9,748 6,579

14. MACK COP WINDING MACHINE

*. asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
434	434	Cop cone	Wornout	2.0	347	220	567
958	524	Automatic system	System defected	1.5	43	165	208
1206	349	Bearing	Balls dislocated & wornout	2.5	265	275	540
*1884	*578	- - -	- - -	4.0	742	458	1200
2208	324	Cop spindle	Wornout	2.5	470	275	745
2317	109	Automatic system	System defected	1.5	46	165	211
2598	201	Centre bracket	Wornout of centre hole	4.5	325	495	820
3074	476	Automatic system	System defected	1.5	54	165	219

Contd. MACK COP WINDING MACHINE

1	2	3	4	5	6	7	8
*3447	*373	- - -	- - -	*5.0	1036	560	1604
3906	459	Lenix belt	Tornout	1.5	1240	165	1405
4574	660	Cop spindle	Wornout of thread portion	2.5	495	275	770
*4850	*276	- - -	- - -	*3.0	1841	348	2189
5254	404	Centre bracket	Wornout of centre hole	4.0	472	440	912
5908	651	Motor pulley	Wornout	3.0	256	330	586
*6302	*397	- - -	- - -	*5.0	802	560	1370
6409	107	Automatic system	System defected	1.5	44	165	205
6947	530	Cop cone	Wornout	2.0	264	220	484
7224	277	Knives	Sharpness decreased	3.0	334	330	664
*0017	*793	- - -	- - -	*4.0	712	458	1170
8485	468	Cop spindle	Wornout of thread portion	2.5	425	275	700
8910	425	Bearing	Balls dislocated & wornout	2.5	269	275	540
9270	360	Automatic system	System defected	1.5	58	165	223
*9563	*293	- - -	- - -	*4.0	763	458	1221
9804	241	Centre bracket	Wornout of centre hole	4.0	355	440	795
10174	370	Slide rod bush	Wornout	1.5	60	165	225
*10938	*598	- - -	- - -	*5.0	809	568	1377

Contd. MACK COP WINDING MACHINE

1	2	3	4	5	6	7	8
11456	513	Cop cone	Wornout	-2.5	368	273	643
11600	152	Circular pulley	Wornout	2.0	64	220	284
11842	234	Motor	Burntout	4.0	404	440	844
11904	62	Automatic system	System defected	1.5	56	165	221
*12320	*416	- - -	- - -	*6.0	1021	678	1699
12548	228	Cop spindle	Wornout of thread portion	2.5	485	275	760
*12864	*316	- - -	- - -	*2.0	514	238	752
13459	595	Centre bracket	Wornout of centre hole	4.5	460	495	955
13804	345	Cop cone	Wornout	1.5	69	165	234
*14048	*244	- - -	- - -	4.0	*624	458	1082
14302	254	Bearing	Balls dislocated & wornout	2.5	265	275	540
			Failure =	69.0		Failure =	16,596
			Preventive =	42.0		Preventive =	13,664

15. DRY BEAMING MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
506	506	Pressing roller	Wornout	4.0	106	1200	1306
1492	986	Driving pinion	Brokenout of some teeth	3.0	110	900	1010
2478	986	Driving shaft arbor	Wornout	3.0	54	900	954
*3062	*584	" " "	" " "	*6.0	414	1827	2241
3754	692	Beaming roller	Wornout of its side	3.0	134	900	1034
4260	506	Main shaft bracket	Found crack	2.0	70	600	670
*4996	*736	" " "	" " "	*4.0	378	1227	1605
6108	1112	Ink pan	Damaged after normal use	3.0	295	900	1195
*6970	*862	" " "	" " "	*2.0	385	627	1012
7894	924	Driving pinion	Wornout of some teeth	3.5	135	1050	1185
9406	1512	Spool hanger	Found loose fitting	2.5	150	750	900
*10272	*866	" " "	" " "	*4.0	445	1227	1672
10912	640	Feed roller	Wornout	3.0	115	900	1015
11698	786	Pressing roller bracket	Found crack	2.0	120	600	720
*12470	*772	" " "	" " "	*4.0	502	1227	1729
12830	300	Driving pinion	Wornout	1.5	25	450	475
13624	794	Spring	Less tensioned	1.0	75	300	375
*13910	*294	" " "	" " "	*2.0	260	627	887
14375	457	Motor pulley	Wornout	3.0	135	900	1035
			Failure =	34.5		Failure =	11,970
			Preventive =	22.0		Preventive =	9,144

16. HIBBERT DRESSING MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
1417	1417	Pump bucket	Wornout	3.0	165	2400	2565
*3240	*1823	" " "	" " "	*6.0	2620	4818	7438
4760	1520	Conical wheel face, II & III	Wornout	4.0	2050	3200	5250
6525	1765	Wall work chain	Wornout of links	1.0	80	800	880
8184	1659	Conical wheel face, I	Wornout	4.0	2050	3200	5250
9676	1492	Drawing roller	Wornout	1.0	240	800	1040
11587	1911	P.I.V. Gear chain, RC-356	Wornout of links and balls	6.0	7560	4800	12360
*12655	*1068	" " "	" " "	12.0	8670	9610	18280
13577	922	Gear box bearing	Wornout	7.0	45000	5600	50600
13941	364	Conical wheel face, IV	Wornout	1.0	20	800	820
14364	423	Gear chain, RC-356	Wornout	3.5	2050	2000	4050
			Failure =	30.5		Failure =	83,215
			Preventive =	18.0		Preventive =	25,866

17. SACKING LOOM MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
308	300	Lay block	Found crack	2.5	320	25	345
672	364	Crank shaft bush	Wornout	2.0	42	20	62
1098	426	Crank shaft	Wornout	6.0	166	60	226
1854	756	Centre shaft pinion	Wornout of some teeth	2.0	65	20	85
*2160	*306	- - -	- - -	0.0	470	89	559
3094	934	Cloth roller	Wornout & found crack	3.0	240	30	270
3859	765	Motor pulley	Wornout of some teeth	3.0	130	30	160
4272	413	Centre shaft bush	Wornout	3.0	136	30	166
*4782	*510	- - -	- - -	*6.0	423	69	492
5468	606	Crank shaft pinion	Wornout of some teeth	2.0	72	20	92
5918	444	Machine pulley	Wornout	3.0	110	30	140
6353	44	Picking shaft	Wornout	2.5	190	25	215
6986	633	Vee belt	Less tensioned	1.0	230	10	240
*7528	*542	- - -	- - -	*5.0	594	59	655
7870	350	Treadle lever	Wornout	2.5	63	25	90
0720	842	Wyper	Wornout	6.0	127	60	187
*9398	*670	- - - -	- - - -	6.0	217	69	286
9804	406	Centre shaft	Wornout	4.0	320	40	360
10572	600	Lay block	Found crack	4.5	325	45	370

Contd. SACKING LOOM MACHINE

1	2	3	4	5	6	7	8
10957	306	Lay bolt	Wornout	2.0	42	20	62
11205	240	Picking arm	Found crack	1.5	55	15	70
11540	343	Cam shaft bush	Wornout	3.0	146	30	176
*12079	*531	- - -	- - -	*6.0	943	89	1032
12582	303	Lay block	Wornout & crack	3.5	136	35	171
12704	122	Crank shaft	Brokenout	2.0	60	20	80
13120	424	Wyper shaft	Wornout	2.5	240	25	265
*13764	*636	- - -	- - -	*3.9	465	59	524
14052	200	Lay block	Found crack	5.0	145	50	195
14820	268	Picking shaft	Wornout	3.0	70	30	100
			Failure =	69.5		Failure =	4,127
			Preventive =	34.92		Preventive =	3,545

10. HESSIAN LOOM MACHINE (With loader system)

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
312	302	Centre shaft	Wornout	3.0	320	15	335
702	320	Motor pulley	Wornout	1.0	230	05	235
1214	512	Crank shaft	Wornout	6.0	172	30	202
1475	261	Top plunger	Wornout	2.0	90	10	100
2420	945	Picking arm	Wornout & crack	2.0	45	10	55

Contd. HESSIAN LOOM MACHINE (With loader system)

1	2	3	4	5	6	7	8
*3196	*776	- - -	- - -	*8.0	945	49	994
3453	257	Centre shaft bush	Wornout	1.5	55	7.5	62.5
4504	1121	Machine pulley	Wornout	3.0	110	15	125
4973	300	Lay block	Wornout	2.0	70	10	80
5723	750	Picking shaft	Wornout	2.5	190	12.5	202.5
*6400	*605	- - -	- - -	*6.0	367	39	406
6974	566	Pin roller	Wornout & found crack	3.0	340	15	355
7781	807	Crank shaft pinion	Brokenout of some teeth	3.0	250	15	265
8406	625	Crank shaft bush	Wornout	3.5	142	17.5	149.5
*8773	*367	- - -	- - -	6.0	672	39	711
9804	1031	Centre shaft pinion	Brokenout of some teeth	3.5	156	17.5	173.5
10373	569	Motor pulley	Wornout	3.0	135	15	150
10946	573	Crank shaft	Brokenout	6.0	178	30	208
11810	864	Treadle lever	Wornout	2.5	60	12.5	82.5
*12756	*946	- - -	- - -	*8.0	490	49	539
12976	220	Weft fork	Wornout	2.0	84	10	94
13415	439	Motor	Burntout	6.0	606	30	636
13806	391	Centre shaft bush	Wornout	3.0	270	15	285
*13904	*173	- - -	- - -	7.0	924	44	968
14294	390	Wyper shaft	Wornout	3.0	120	15	135
				Failure = 61.5		Failure =	3,930.5
				Preventive = 35.0		Preventive =	3,610

19. DAMPING MACHINE

*, Asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
874	874	Vee belt	Less tensioned	1.0	185	800	985
2068	1194	Motor pulley	Wornout	3.0	220	2400	2620
*4826	*2758	- - -	- - -	*3.0	600	2409	3009
6258	1432	Pinion	Brokenout of some teeth	3.0	126	2400	2526
8478	2220	Sprinkler plate	Wornout	3.5	160	2800	2960
10163	1685	Motor	Burntout	4.0	610	3200	3810
*12454	*2291	- - -	- - -	*6.0	940	4009	5749
14259	1805	Main shaft	Wornout	3.0	110	2400	2510
				Failure = 17.5			Failure = 15411
				Preventive = 9.0			Preventive = 8038

20. CALENDER MACHINE

*, Asterisk indicates preventive overhaul

905	905	Gear box	Grease decreased	3.0	1470	4000	5470
2570	1504	Vee belt	Less tensioned	1.0	180	800	960
*4429	*1859	- - -	- - -	*4.0	1894	3227	5121
6564	2135	Oil pump	Bucket defected	3.5	552	2000	3352
8069	1505	Motor	Burntout	6.0	608	4800	5408
10120	2051	Vee belt	Less tensioned	1.0	160	800	960
*11746	*1626	- - -	- - -	*10.5	1706	5627	7333
12690	944	Paper roller	Wornout of its side	4.0	213	3200	3413
14217	1527	Gear box	Grease decreased	3.5	1246	2800	4046
				Failure = 24.0			Failure = 23,609
				Preventive = 14.5			Preventive = 12,454

21. LAPPING MACHINE

*, Asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
2014	2014	Hackle	Brokenout of some pins	3.0	670	600	1270
*4752	*2738	- - -	- - -	*2.0	945	427	1372
7064	2312	Spring	Less tensioned	1.0	90	200	290
10438	3374	Hackle	Brokenout of some pins	3.5	370	700	1370
*12504	*2066	- - -	- - -	3.0	620	627	1247
14309	1805	Pinion	Wornout of some teeth	2.0	135	400	535
			Failure =	9.5		Failure =	3465
			Preventive =	5.0		Preventive =	2619

22. CUTTING MACHINE

*, Asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
1224	1224	Cutting blade	Sharpness reduced	4.0	940	1600	2540
2920	1696	Pinion	Brokenout of some teeth	2.5	214	1000	1214
*4874	*1954	- - -	- - -	*4.0	1470	1627	3097
7168	2294	Cutting blade	Sharpness reduced	4.5	780	1800	2580
8671	1503	Vee belt	Less tensioned	1.0	210	400	610
10894	2223	Adjusting bolt	Wornout	2.0	40	800	840
*12578	*1684	- - -	- - -	5.0	1342	2027	3369
14209	1631	Cutting blade	Sharpness reduced	4.0	820	1600	2420
			Failure =	18.0		Failure =	10,204
			Preventive =	9.0		Preventive =	6,466

23. HEMMING SEWING MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
96	96	Needle no. 156/75	Wornout	1.5	145	300	445
528	432	Looper AS26XA	Wornout	2.0	170	400	570
644	116	Needle no. 156/75	Wornout	1.5	145	300	445
* 960	*316	- - -	- - -	*8.0	1244	1618	2862
1040	80	Needle no. 156/75	Wornout	2.0	145	400	545
1105	140	Feed lift cam	Brokenout	2.5	285	500	785
1296	110	Needle no. 156/75	Wornout	2.0	145	400	545
1936	640	Pressure foot no.802200	Wornout	2.5	218	500	718
2208	272	Needle no. 156/75	Wornout	1.5	145	300	445
2624	416	Collar	Brokenout	2.0	120	400	520
3152	528	Needle no. 156/75	Wornout	1.5	145	300	445
*3274	*122	- - -	- - -	*10.0	1263	1818	3081
3304	30	Feed dog no.80205	Brokenout	3.0	235	600	835
3620	316	Needle no. 156/75	Wornout	2.0	145	400	545
3989	369	Looper no. AS26XA	Wornout	1.5	170	300	470
*4029	* 40	- - -	- - -	*6.0	643	1218	1861
4166	137	Needle no. 156/75	Wornout	1.5	145	300	445
4348	182	Feed dog no.80205	Brokenout	2.0	235	400	635
4487	139	Looper no. AS26XA	Wornout	1.5	170	300	470
4628	141	Needle no. 156/75	Wornout	1.5	145	300	445
*4742	*114	- - -	- - -	*2.0	342	418	760
4862	120	Tension disc 80676	Brokenout	1.5	55	300	355

Contd. HEMMING SEWING MACHINE

1	2	3	4	5	6	7	8
4996	134	Tension part 00046	Wornout	2.0	110	400	510
5256	260	Looper no. A52GXA	Wornout	1.5	170	300	470
5520	264	Needle no. 156/75	Wornout	2.0	145	400	545
5548	28	Looper no.A52GXA	Wornout	1.5	170	300	470
5794	244	Needle no.156/75	Wornout	2.0	145	400	545
*5834	* 40	- - -	- - -	*8.0	890	1610	2500
6092	258	Tension ferrule	Wornout	2.0	165	400	565
6336	244	Needle no. 156/75	Wornout	1.5	145	300	445
6498	162	Feed lift comp HA43X	Wornout	2.5	285	500	785
6634	136	Needle no. 156/75	Wornout	2.0	145	400	545
*6682	* 48	- - -	- - -	*6.0	940	1218	2158
6824	142	Needle bar bush	Wornout	2.5	175	500	675
6872	48	Looper no. A52GXA	Wornout	1.5	170	300	470
6898	26	Fork 00630	Wornout	2.0	144	400	544
*6912	*14	- - -	- - -	*4.0	464	818	1282
7216	304	Looper rocker	Wornout	1.5	226	300	526
7280	64	Rocker	Wornout	2.0	135	400	535
7608	328	Looper rocker	Wornout	2.5	228	500	728
				Failure = 62.0 Preventive = 44.0			Failure =17909 Preventive= 14692

24. HERRACKLE SEWING MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
300	308	Looper no.81200	Wornout	2.5	220	550	770
* 421	*113	- - -	- - -	*2.0	166	440	606
435	64	Needle no. 156/70	Wornout	1.5	155	330	485
536	51	Looper rocker	Wornout	2.0	245	440	685
558	22	Looper	Wornout	2.0	186	440	626
*595	* 37	- - -	- - -	*4.0	502	880	1382
647	52	Cone stud	Wornout	2.5	142	550	692
663	16	Clasp screw	Wornout of thread portion	1.5	70	330	400
758	95	Throat plate	Brokenout	3.0	165	660	825
*811	*53	- - -	- - -	*4.0	246	880	1126
859	40	Spreader	Wornout	2.5	204	550	754
1008	149	Thread retainer	Brokenout	3.0	116	660	776
1036	28	Needle no. 156/70	Wornout	1.5	155	330	485
1128	92	Connecting rod	Wornout	3.0	166	660	826
1154	26	Spreader 81207	Wornout	2.5	125	550	675
1287	133	Screw	Wornout of thread portion	1.5	45	330	375
1506	219	Spreader	Brokenout	2.5	204	550	754
1909	403	Needle no. 81207	Wornout	2.0	220	440	660
1947	38	Feed dog	Brokenout	3.0	374	660	1034
*2144	*197	- - -	- - -	*12.0	1054	2640	3694
2164	20	Spreader rocker	Wornout	2.5	276	550	826
2188	24	Tube 00630	Brokenout	2.0	127	440	567
2274	86	Rocker	Brokenout	2.0	245	440	685
*2352	*78	- - -	- - -	*4.0	427	880	1307
2620	376	Needle no. 156/70	Wornout	1.5	155	330	485
2714	86	Spreader no. 81207	Wornout	2.5	125	550	675

Contd. HERRACKLE SEWING MACHINE

1	2	3	4	5	6	7	8
2094	200	Needle no. 156/70	Wornout	1.5	155	330	485
3218	222	Looper no. 01200	Wornout	2.5	220	550	770
2625	409	Needle no. 156/70	Wornout	1.5	155	330	485
3643	18	Needle bar bush	Wornout	3.0	227	660	887
*3760	*117	- - -	- - -	*8.0	787	1760	2547
3908	148	Spreader rocker	Wornout	2.0	147	440	587
4016	108	Pressure foot	Brokenout	1.5	97	330	427
4144	120	Tension disc	Wornout	1.5	55	330	385
4214	70	Tension ferrule	Brokenout	2.0	146	440	586
4272	58	Needle no. 156/70	Wornout	1.5	155	330	485
4364	92	Tension spring	Less tensioned	1.5	45	330	375
*4509	*145	- - -	- - -	*6.0	469	1320	1789
4704	195	Tension spring	Less tensioned	1.5	45	330	375
4876	172	Tension ferrule	Brokenout	2.0	146	440	586
5440	864	Spreader 01207	Wornout	2.5	125	550	675
5587	147	Feed dog	Brokenout	2.0	374	660	1034
5738	151	Needle no. 156/70	Wornout	1.5	155	330	485
*6010	*272	- - -	- - -	*6.0	660	1320	1980
6093	83	Connecting rod	Brokenout	3.0	125	660	785
6258	163	Ball stud no.00675	Wornout	2.0	48	440	488
6760	510	Needle no. 156/70	Wornout	1.5	155	330	475
7008	242	Looper no. 200	Wornout	2.0	220	440	660
7102	174	Throat retainer	Brokenout	1.5	116	330	446
7760	578	Tension disc	Wornout	1.5	55	330	385
			Failure =	89.5		Failure =	25,385
			Preventive =	46.0		Preventive =	14,439

25. OVERHEAD SEWING MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
83	80	Worm pinion	Wornout of some teeth	2.0	55	240	295
187	99	Bottom pinion - 32T	Wornout of some teeth	2.0	40	240	280
294	107	Needle, S.W.G = 4	Blunted	1.5	70	180	250
379	85	Needle pad	Brokenout	3.0	110	360	470
393	14	Needle, S.W.G = 4	Blunted	1.5	70	180	250
430	37	Worm pinion	Wornout of some teeth	2.0	55	240	295
661	231	Needle pad	Brokenout	3.0	115	360	475
*784	*123	- - -	- - -	*10.0	438	1200	1638
1040	256	Worm pinion	Wornout of some teeth	2.0	55	240	295
1096	56	Needle, S.W.G = 4	Brokenout	1.5	70	180	250
1194	98	Worm pinion	Brokenout of some teeth	2.0	55	240	295
1214	20	Bottom pinion	Wornout of some teeth	2.0	48	230	278
1366	152	Needle, S.W.G = 4	Wornout	1.5	70	170	240
1593	227	Needle pad	Wornout	3.0	115	360	475
1676	83	Needle, S.W.G = 4	Wornout	1.5	70	180	250
1692	16	Worm pinion	Wornout of some teeth	2.5	55	300	355
*1759	*77	- - -	- - -	*9.0	385	1440	1825
1984	215	Needle, S.W.G = 5	Blunted	1.5	70	180	250

Contd. OVERHEAD SEWING MACHINE

1	2	3	4	5	6	7	8
2060	76	Needle cone	Wornout	2.5	115	360	475
2173	113	Worm pinion	Brokenout of some teeth	2.0	55	210	265
2391	218	Bottom pinion, 32T	Wornout of some teeth	2.0	40	240	288
2442	51	Needle, S.W.G.= 4	Wornout	1.5	70	180	250
2520	86	Centre pinion	Wornout of some teeth	2.0	45	240	280
*2655	*127	- - -	- - -	*6.0	465	960	1425
2992	337	Needle pad	Wornout	3.0	115	360	475
3205	213	Needle, S.W.G. = 4	Blunted	1.5	70	180	250
3277	72	Needle, S.W.G. = 4	Blunted	1.5	70	180	250
3523	246	Needle cone	Wornout	1.5	70	180	250
3596	73	Needle, S.W.G. = 4	Blunted	2.5	115	360	475
*3824	*228	- - -	- - -	*6.0	302	720	1022
3984	160	Worm pinion	Brokenout of some teeth	2.0	55	240	295
4006	22	Needle, S.W.G. = 4	Wornout of tip	1.5	70	180	250
4069	82	Needle cone	Wornout	2.5	115	360	475
*4214	*126	- - -	- - -	*4.0	214	480	694
4464	250	Centre bush	Wornout	3.0	65	360	425
4704	240	Needle, S.W.G.= 4	Blunted	1.5	70	180	250
4748	44	Needle pad	Wornout	3.0	115	360	475

Contd. OVERHEAD SEWING MACHINE

1	2	3	4	5	6	7	8
4809	61	Bottom pinion, 32T	Brokenout of some teeth	2.0	48	240	200
4805	76	Overhead chain	Wornout of links	1.5	580	240	820
5096	211	Needle pad	Wornout	3.0	115	360	475
5164	211	Worm pinion	Brokenout of some teeth	2.0	55	240	295
*5308	*144	" " "	" " "	*9.0	456	1440	1895
5560	360	Needle pad	Wornout	3.0	115	360	475
5591	23	Needle, S.W.G. = 4	Blunted	1.5	180	250	430
5744	153	Needle, S.W.G. = 4	Blunted	1.5	70	180	250
5830	85	Needle pad	Wornout	1.5	70	180	250
*6012	*182	" " "	" " "	*6.0	264	720	984
6168	154	Bottom pinion, 32T	Wornout of some teeth	1.5	70	180	250
6332	106	Needle pad	Wornout	1.5	70	180	250
6372	20	Centre bush	Wornout	3.0	65	180	245
*6509	*137	" " "	" " "	*4.0	178	480	658
7040	531	Worm pinion	Brokenout of some teeth	1.5	70	180	250
7600	560	Needle, S.W.G = 4	Blunted	1.5	70	180	250
			Failure =	89.0		Failure	=15,023
			Preventive =	54.0		Preventive	=10,102

26. BALING PRESS MACHINE

*, asterisk indicates preventive overhaul

1	2	3	4	5	6	7	8
416	416	'C' ring	Tornout	2.0	60	2400	2460
912	496	'O' ring	Tornout	2.0	60	2400	2460
1360	448	¾" sealing ring	Tornout	1.5	85	1800	1885
1520	160	'C' ring	Tornout	2.0	60	2400	2460
1632	112	¾" sealing ring	Tornout	1.5	85	1800	1885
2320	688	Oil seal	Damaged by oil	2.0	45	2400	2445
*2640	*320	- - -	- - -	*8.0	355	9600	9955
2920	272	'C' ring	Tornout	2.0	60	2400	2460
4160	1240	Oil seal	Damaged by oil	2.0	45	2400	2445
4832	672	'C' ring	Tornout	1.5	60	1800	1860
6512	1680	Oil seal	Damaged by oil	2.0	45	2400	2445
6880	360	'C' ring	Tornout	2.0	60	2400	2460
*6912	*34	- - -	- - -	*6.0	346	7200	7546
7616	702	Oil seal	Damaged by oil	2.0	45	2400	2445
8084	468	¾" sealing ring	Tornout	1.5	85	1800	1885
8132	48	Dosi sino pump	Damaged most of the parts	4.0	50000	4800	54800
9584	1452	'C' ring	Tornout	2.0	60	2400	2460

Contd. BALING PRESS MACHINE

1	2	3	4	5	6	7	8
*10725	*1141	- - -	- - -	*2.0	48086	12000	50006
11216	401	Oil seal	Damaged by oil	2.0	45	2400	2445
11920	704	'O' ring	Tornout	1.5	60	1800	1860
*12070	*150	- - -	- - -	*2.0	230	2400	2630
12280	210	LP sealing ring	Tornout	1.5	65	1800	1865
12320	48	'O' ring	Tornout	2.0	60	2400	2460
12800	472	Mono radial pump	Damaged some parts	2.0	274	2400	2674
13232	432	Oil seal	Damaged by oil	1.5	45	1800	1805
14032	000	Relief valve,PR-3(L.P)	Wornout of thread portion	2.5	270	3000	3270
*14128	*96	- - -	- - -	*6.0	596	7200	7796
14182	54	H.D. coupling	Wornout	2.5	200	3000	3200
			Failure =	45.5			Failure = 96,715
			Preventive =	24.0			Preventive = 77,933

4.3 Data Analysis

The failure data for each machine given in the previous section has been analysed to find the best fit Weibull distribution and also to find the mean and standard deviation of the failure times. The shape and scale parameters of the Weibull distributions have been calculated by the Maximum Likelihood Estimator (MLE) method and the graphical method of hazard plotting. In the MLE, the shape (β) and scale (η) parameters are estimated by the equations 2.4.3 and 2.4.4 which are:

$$\frac{\sum_{i=1}^{n} t_i^{\hat{\beta}} \ln t_i}{\sum_{i=1}^{n} t_i^{\hat{\beta}}} - \frac{1}{\hat{\beta}} = \frac{1}{n} \sum_{i=1}^{n} \ln t_i \qquad \ldots \quad (2.4.3)$$

and,

$$\hat{\eta} = \left[\frac{\sum_{i=1}^{n} t_i^{\hat{\beta}}}{n} \right]^{\frac{1}{\hat{\beta}}} \qquad \ldots \quad (2.4.4)$$

The solution of equation 2.4.4 is straightforward once the value of $\hat{\beta}$ is known; but the value of $\hat{\beta}$ will have to be estimated by trial and error, if manual computation is carried out. Otherwise the equation 2.4.3 can be solved for $\hat{\beta}$ by computer programme and the technique of Newton - Raphson can be applied. By this technique an initial value of $\hat{\beta}$ is given (usually any approximation) and then successive iterations are carried out by,

$$\hat{\beta}_{i+1} = \hat{\beta}_i - \frac{F(\hat{\beta}_i)}{F'(\hat{\beta}_i)} \qquad \ldots \quad (4.3.1)$$

where, i is the iteration number and $F(\beta_i)$ and $F'(\beta_i)$ are respectively the function and the functional derivative of $\hat{\beta}$ obtained by rearranging the equation 2.4.3.

The listing of the computer programme is given in Appendix-I.

The mean and standard deviation of the Weibull distribution are given by

$$\text{Mean, } \mu = \eta \Gamma\left(1 + \frac{1}{\beta}\right) \qquad \ldots \quad (4.3.2)$$

and,

$$\text{standard deviation, } \sigma = \left[\Gamma\left(1 + \frac{2}{\beta}\right) - \left\{\Gamma\left(1 + \frac{1}{\beta}\right)^2\right\}\right]^{\frac{1}{2}} \qquad \ldots \quad (4.3.3)$$

where, $\Gamma(\ )$ indicates the gamma function. The value of the gamma function can be obtained from the published tables. Alternately this can be estimated by the formula ,

$$\Gamma(n) = n^n e^{-n} \sqrt{\left\{\frac{2\pi}{n}\left(1 + \frac{1}{12n} + \frac{1}{288n^2} + \cdots\right)\right\}} \qquad \ldots \quad (4.4.4)$$

for large value of n. For values of n greater than 1, the above formula gives accurate values of gamma function upto three decimal points, which is good enough for engineering approximation.

The estimates of Weibull parameters by MLE and hazard plotting for each of the machines, are given in Table 4.3.1.

Sample method of estimation for some machines of the Weibull distribution parameters by hazard plotting is given in Appendix-II.

Table 4.3.1: Values of Weibull Distribution Parameters both by MLE Method & Graphical Method

Name of the machines	MLE Method				Graphical Method			
	β	η (hrs)	μ (hrs)	σ (hrs)	β	η (hrs)	μ (hrs)	σ (hrs)
1. EMULSION PLANT	2.15	712.16	631.17	300.04	1.80	700.00	621.68	341.18
2. SOFTNER MACHINE	2.62	1095.07	973.76	397.61	2.17	1090.00	966.05	467.82
3. HARD WASTE T/CARD	2.34	1191.61	1056.75	470.52	2.12	1130.00	1001.53	495.34
4. BREAKER CARD MACHINE	2.22	551.83	489.12	231.98	2.00	580.00	514.30	260.18
5. FINISHER CARD MACHINE	2.06	604.25	535.68	272.44	2.11	580.00	514.07	255.34
6. 1ST DRAWING MACHINE	2.09	534.19	481.48	240.31	1.91	530.00	470.55	265.78
7. 2ND DRAWING MACHINE	2.84	690.98	616.19	234.08	2.94	670.00	598.36	220.12
8. 3RD DRAWING MACHINE	2.72	607.93	541.25	213.79	2.50	630.00	559.46	230.38
9. FINISHER DRAWING MACHINE	2.31	600.93	532.02	244.18	2.03	570.00	505.39	259.96
10. SPINING FRAME MACHINE	1.91	601.75	534.25	290.36	1.87	600.00	533.06	295.39
11. TWIST FRAME MACHINE	3.36	1012.39	909.94	296.34	3.37	1040.00	934.89	303.65
12. LOW COP WINDING MACHINE	1.01	257.14	256.39	254.25	1.92	345.00	306.25	165.69
13. RACK ROLL WINDING MACHINE	2.96	776.80	694.03	253.63	2.50	720.00	639.38	272.44
14. HACK COP WINDING MACHINE	2.24	479.93	425.38	202.81	2.00	500.00	443.43	231.19
15. DRY BEAMING MACHINE	3.10	968.26	866.04	303.59	2.86	900.00	856.36	323.02
16. HESSIAN DRESSING MACHINE	2.64	1563.18	1390.35	563.77	2.07	1560.00	1382.08	698.87
17. SACKING LOOM	2.63	601.23	534.69	217.52	2.78	630.00	560.91	221.42
18. HESSIAN LOOM	2.31	713.45	632.63	289.59	2.15	690.00	611.54	299.63
19. DAMPING MACHINE	2.63	2150.39	1912.36	778.66	2.47	1980.00	1757.78	757.21
20. CALENDER MACHINE	4.20	1817.53	1655.80	431.41	3.90	1800.00	1605.89	429.56
21. LAPPING MACHINE	4.51	2839.78	2595.15	642.56	3.80	2200.00	2589.20	630.20
22. CUTTING MACHINE	5.58	2011.84	1861.43	376.92	4.43	2000.00	1852.72	369.56
23. HEMMING SEWING MACHINE	1.54	245.95	221.40	146.59	1.46	245.00	222.05	154.38
24. HERRACKLE SEWING MACHINE	1.36	200.55	179.25	135.26	1.31	190.00	175.29	134.06
25. OVERHEAD SEWING MACHINE	1.38	191.17	168.25	128.51	1.32	180.00	165.82	126.67
26. BALING PRESS MACHINE	1.33	630.10	579.43	438.68	1.25	580.00	540.43	434.66

CHAPTER 5: DETERMINATION OF PREVENTIVE MAINTENANCE MODELS

5.1 Introduction

Replacement problems are a particular class of maintenance problems. Usually, replacement problems can be classified as either deterministic or probabilistic (stochastic). In case of deterministic problems, the timing and outcome of replacement policies are assumed to be known, with certainty. Here, the machine is not subject to failure but the operating cost increases with use. To reduce this operating cost, a replacement is to be performed. It is assumed that after the replacement, the trend in operating costs is known in the sense that the replacement action returns the machine to the as new condition and continues to provide the same services as the replaced component parts. If these assumptions hold, then various costs used in the analysis are always invariant between replacements, of course, this assumption does not hold where technological improvement of the machine is taken into account.

In the case of probabilistic problems, the timing and outcome of the replacement action can depend on chance. So, maintenance of stochastically failing machine involves problems of decision making under uncertainty. Two sources of uncertainty are distinguished. First, it is impossible to predict with certainty when a failure will occur, or more generally, when the transition point from one state of the machine to another will occur. Second, if may be impossible to determine the actual state of the machine with any accuracy unless a definite maintenance action is taken. During operation, the machine under consideration is assumed to occupy one of several states, the two extreme states being "good" and "failed". The two boundary states enclose a set of intermediate states that denote different degrees of deterioration. The movement from state to state is governed by a probability mechanism whose law may be completely known, partially known or unknown, by the decision maker. In the simplest situation, of course, the machine may be described as being good or failed, and the corresponding probability law may be described by the distribution of time between completion of the replacement action and failure. The time to failure is a random variable whose distribution may be termed the machines failure distribution.

Corresponding to these sources of uncertainty mentioned above, are two distinct models for stochastically failing machine; "preventive" maintenance models in which the state of the machine is always known with certainty, and "preparedness" maintenance models in which the state of the machine (at least for some of its components) is known with certainty unless some definite maintenance action is taken. In this work, only the first type of model has been considered.

With the preventive maintenance model, the assumption is that the machine operation provides assurance that the actual state of the machine is known with certainty. Alternately, it may be assumed that the machine is kept in storage for its later use (particularly when emergency arises) but is under continuous surveillance. It makes it possible to determine the actual state of the machine without any further maintenance action.

5.2 Model for an Age Replacement Policy to Minimize the Expected Replacement Cost Per Unit Time

In the age replacement policy, instead of making preventive replacements at fixed intervals, thus increasing the possibility of performing a preventive replacement shortly after a failure replacement, the time at which the preventive replacement occurs depends on the age of the equipment. When failures occur failure replacements are made.

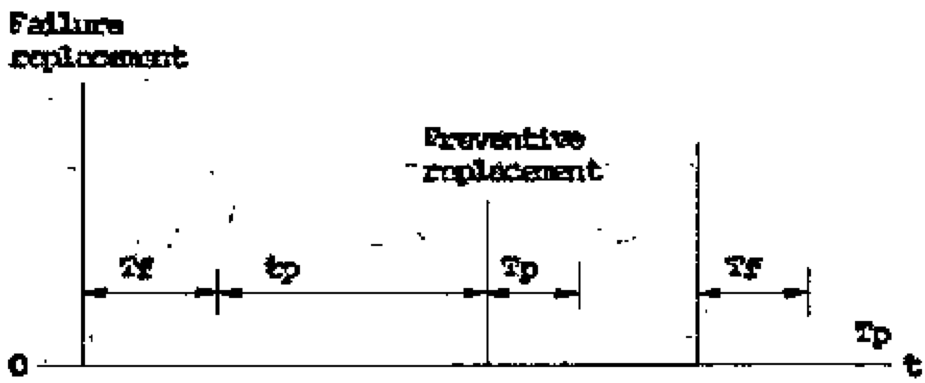


Figure - 5.2.1

From the figure, it can be seen that the age based policy incorporates two possible cycles of operation. One cycle being determined when equipment reaches its planned replacement age plus time to effect the preventive replacement and the other due to a failure occuring before the planned replacement time plus time to effect the failure replacement. Fig.5.2.2 illustrates this point.

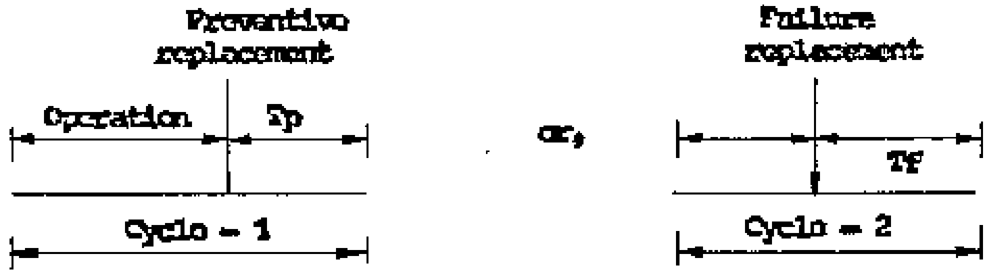


Figure - 5.2.2

This model is also well develop and for more details one may refer to Jardine(2), Kabir(17). Here a brief description is given. The objective is set to determine the optimal preventive replacement age of the equipment in order to minimize the total expected replacement cost per unit time.

Let, Cp is the cost of a preventive replacement,

Cf is the cost of a failure replacement,

Tp is the time required to make a preventive replacement,

Tf is the time required to failure replacement,

f(t) is the probability density function of the failure times of the equipment

M(tp) is the meantime to failure when preventive replacement occurs at time tp

C(tp) is the total expected cost per unit time for preventive replacement at tp, and

R(tp) is equal to $\int_{tp}^{\infty} f(t)dt$.

The total expected replacement cost per unit time,

$$C(tp) = \frac{\text{Total expected replacement cost per cycle}}{\text{Expected cycle length}}$$

Total expected replacement cost per cycle

= Cost of a preventive cycle x probability of a preventive cycle.
+ cost of a failure cycle x probability of a failure cycle

$= CpR(tp) + Cf\,[1 - R(tp)]$

Expected cycle length

= Length of a preventive cycle x probability of a preventive cycle
+ Expected cycle length of a failure cycle x probability of a failure cycle.

$$= (tp + Tp)\ R(tp) + [M(tp) + Tf]\ [1 - R(tp)], \text{ where,}$$

$$M(tp) = \frac{\int_0^{tp} tf(tp)dt}{1 - R(tp)}$$

Now, the total expected replacement cost per unit time, is

$$C(tp) = \frac{Cp \times R(tp) + Cf \times [1 - R(tp)]}{(tp + Tp)\ R(tp) + [M(tp) + Tf]\ [1 - R(tp)]} \quad \ldots \quad \ldots \quad (5.2.1)$$

Here, $(tp + Tp)\ R(tp) + [M(tp) + Tf]\ [1 - R(tp)]$

$$= tpR(tp) + TpR(tp) + M(tp)\ [1 - R(tp)]\ Tf\,[1 - R(tp)]$$

$$= tpR(tp) + \int_0^{tp} tf(t)dt + TpR + Tf\ [1 - R(tp)]$$

$$= \int_0^{tp} R(t)dt + TpR(tp) + Tf\ [1 - R(tp)] \quad \text{(Integrating by parts)}$$

Substituting this into equation, (5.2.1)

$$C(tp) = \frac{Cp\ R(tp) + Cf\ \ 1 - R(tp)}{\int_0^{tp} R(t)dt + Tp\ R(tp) + Tf\ [1 - R(tp)]} \quad \ldots \quad \ldots \quad (5.2.2)$$

This is the model for an age replacement policy, relating the total expected replacement cost per unit time to the replacement age tp.

Saving in percentage of cost of a policy of "replace at failure only" is calculated by,

$$= 1 - \frac{\frac{C(tp)}{Cp} \times \text{Mean failure time}}{\rho}$$

$$\text{where,} \quad \rho = \frac{Cf}{Cp} \quad \ldots \quad \ldots \quad (5.2.3)$$

5.3 Model for an Age Replacement Policy to Minimise the Total Downtime Per Unit Time

Due to difficulties in costing or the desire to get maximum throughput or utilization of equipment, the replacement policy required may be one which minimizes total downtime per unit time. The basic conflicts are that as the preventive replacement frequency increases there is an increase in downtime due to these replacements, but a consequence of this is a reduction of downtime due to failure replacements. The objective of this model is to determine the optimal age tp at which preventive replacements should occur such that total downtime per unit time is minimized. The policy which has been illustrated in Fig.5.2.1 will be same for this model also, and there are two possible cycles of operation.

The total downtime for preventive replacements, once the machine becomes of age tp (keeping the earlier notation) is

$$D(tp) = \frac{\text{Total expected downtime/cycle}}{\text{Expected cycle length}}$$

Total expected downtime/cycle

= Downtime due to a preventive cycle x probability of a preventive cycle + Downtime due to a failure cycle x probability of a failure cycle.

$$= Tp\,R(tp) + Tf\left[1 - R(tp)\right]$$

Expected cycle length

$$= (tp + Tp)\,R(tp) + \left[H(tp) + Tf\right]\left[1 - R(tp)\right]$$, (As per section 5.2.1)

Therefore,

$$D(tp) = \frac{Tp\,R(tp) + Tf\,[1 - R(tp)]}{(tp + Tp)\,R(tp) + [M(tp) + Tf]\,[1 - R(tp)]} \quad \ldots \qquad (5.3.1)$$

This is a model of the problem relating replacement age to total downtime.

The denominator of the equation can be reduced as per in section 5.2.1, equals to

$$\int_0^{tp} R(t)\,dt + Tp\,R(tp) + Tf\,[1 - R(tp)]$$

Substituting this into equation (5.3.1)

$$D(tp) = \frac{Tp\,R(tp) + Tf\,[1 - R(tp)]}{\int_0^{tp} R(t)\,dt + Tp\,R(tp) + Tf\,[1 - R(tp)]} \quad \ldots \quad \ldots \qquad (5.3.2)$$

The improvement of an optical age replacement policy from a "replacement at failure only" policy is calculated by,

$$= 1 - \frac{\frac{D(tp)}{Tp} \times \text{Mean failure time}}{\theta} \times 100\%$$

$$\text{where, } \theta = \frac{Tf}{Tp} \quad \ldots\ldots \qquad (5.3.3)$$

5.4.1 Solution of the Models by Computer Programme

In the present work, two preventive maintenance models which have been discussed in sections 5.2 and 5.3 have been solved by computer programme to find out the maintenance policies for jute mills machineries. The failure characteristics of each of the machineries have been determined by fitting Weibull distribution, the parameters of which have been tabulated in Table 4.3.1

The equation of the two models are,

$$C(tp) = \frac{C_p R(tp) + C_f \left[1 - R(tp)\right]}{\int_0^{tp} R(t)dt + Tp\, R(tp) + Tf \left[1 - R(tp)\right]}$$

and,

$$D(tp) = \frac{Tp R(tp) + Tf \left[1 - R(tp)\right]}{\int_0^{tp} R(t)dt + Tp\, R(tp) + Tf \left[1 - R(tp)\right]}$$

The listings of the computer programmes are given in Appendix – III & IV and the resultant policies for each of the machines are given in Tables 5.4.1 and 5.4.2.

Regarding the solution procedure by computer programme, the following points are to be mentioned. The determination of optimal preventive maintenance age considering minimization of cost hasbeen illustrated in figures 5.4.1. and 5.4.2. In the figures, C(tp) has been plotted against tp showing the possible trends of the curves. At the initial stage, the total maintenance cost is generally become higher, then decreases gradually. But after passing of certain age, again, total maintenance cost increases. In the present work, the time at which expected cost is minimum has been found by comparing two cost values at a time and then this minimum cost has been compared with failure maintenance cost to find out which one is lower. If the preventive policy cost is lower, then there exists a preventive maintenance and that is printed.

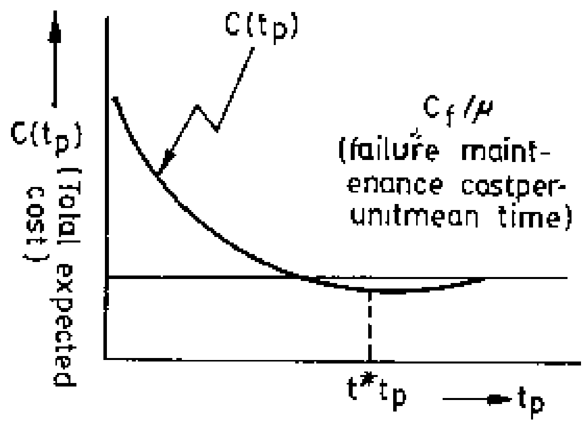


Fig. 5.4.1

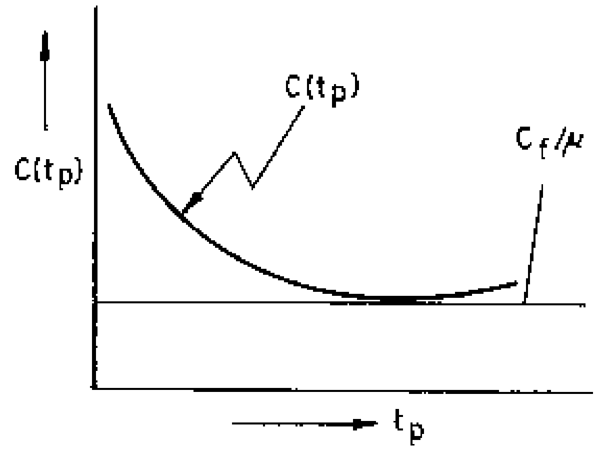


Fig. 5.4.2.

If the failure maintenance cost is lower which has been shown in fig. 5.4.2, the best policy is to carry out failure maintenance only. In this case, usually, the expected cost C(tp) gradually decreases with tp but does not cross (Cf/) line. The computation has been carried out upto a tp value at which the failure probability is 99.9%. This may be time consuming but sounder in determining the existance of tp.

The same solution procedure has been followed for down time model.

Table 5.4.1: Resultant Maintenance Policies for each Machines on the Basis of Minimization of Cost Model

Name of the machines	Relative cost of failure replacement, Cf/Cp	Optimal age, tp in shift (1 shift = 8 hours)	Savings in percentage	Cost per shift
1. EMULSION PLANT MACHINE	2.084	84	13.59	0.023
2. SOFTNER MACHINE	1.577	149	5.75	0.012
3. HARD WASTE T/CARD	1.287	260	2.92	0.003
4. BREAKER CARD MACHINE	1.560	92	12.49	0.022
5. FINISHER CARD MACHINE	1.437	132	9.08	0.020
6. 1ST DRAWING MACHINE	1.221	Replace on failure only		0.020
7. 2ND DRAWING MACHINE	1.249	130	6.40	0.015
8. 3RD DRAWING MACHINE	1.346	104	10.15	0.018
9. FINISHER DRAWING MACHINE	1.230	Replace on failure only		0.019
10. SPINNING FRAME MACHINE	1.729	111	9.18	0.024
11. TWIST FRAME MACHINE	1.211	170	3.31	0.010
12. LOW COP WINDING MACHINE	1.156	Replace on failure only		0.036
13. HACK REEL WINDING MACHINE	1.482	104	7.07	0.016
14. HACK COP WINDING MACHINE	1.215	Replace on failure only		0.023
15. DRY BEAMING MACHINE	1.309	149	4.01	0.012
16. TUBBERT DRESSING MACHINE	3.242	120	26.01	0.013
17. SACKING LOOM	1.164	Replace on failure only		0.017
18. HESSIAN LOOM	1.006	Replace on failure only		0.014
19. DAMPING MACHINE	1.917	239	8.41	0.007
20. CALENDER MACHINE	1.896	170	18.41	0.007
21. LAPPING MACHINE	1.323	351	3.46	0.004
22. CUTTING MACHINE	1.570	212	13.61	0.006
23. HEMMING SEWING MACHINE	1.219	Replace on failure only		0.044
24. HERRACKLE SEWING MACHINE	1.793	Replace on failure only		0.065
25. OVERHEAD SEWING MACHINE	1.487	Replace on failure only		0.072
26. BALING PRESS MACHINE	1.241	Replace on failure only		0.018

Table 5.4.2: Resultant Maintenance Policies for each Machines on the Basis of Minimization of Downtime Model

Name of the machines	Relative time of failure replacement, Tf/Tp	Optimal age, tp in shift (1 shift = 8 hours)	Improvement in percentage	Downtime per shift
1. EMULSION PLANT MACHINE	1.621	116	7.70	0.067
2. SOFTNER MACHINE	1.567	150	5.46	0.026
3. HARD WASTE T/CARD	1.067	Replace on failure only		0.030
4. BREAKER CARD MACHINE	1.616	86	12.46	0.113
5. FINISHER CARD MACHINE	1.494	121	9.04	0.038
6. 1ST DRAWING MACHINE	1.616	93	9.86	0.091
7. 2ND DRAWING MACHINE	1.607	82	10.84	0.059
8. 3RD DRAWING MACHINE	1.775	71	14.22	0.087
9. FINISHER DRAWING MACHINE	1.855	76	12.18	0.082
10. SPINNING FRAME MACHINE	2.160	80	11.22	0.079
11. TWIST FRAME MACHINE	1.045	105	11.83	0.028
12. LOW COP WINDING MACHINE	1.590	Replace on failure only		0.347
13. MACK ROLL WINDING MACHINE	1.645	93	9.47	0.045
14. MACK COP WINDING MACHINE	1.642	74	15.07	0.130
15. DRY BEAMING MACHINE	1.567	110	7.96	0.037
16. [illegible] DRESSING MACHINE	1.693	195	4.09	0.021
17. SACKING LOOM	1.939	65	18.44	0.106
18. HESSIAN LOOM	1.760	96	11.52	0.086
19. DAMPING MACHINE	1.955	226	9.00	0.008
20. CALENDER MACHINE	1.657	192	14.42	0.013
21. LAPPING MACHINE	1.919	275	19.18	0.003
22. CUTTING MACHINE	2.009	192	25.70	0.007
23. HEMMING SEWING MACHINE	1.415	Replace on failure only		0.281
24. HERRACKLE SEWING MACHINE	1.944	Replace on failure only		0.403
25. OVERHEAD SEWING MACHINE	1.647	Replace on failure only		0.536
26. BALING PRESS MACHINE	1.097	Replace on failure only		0.084

CHAPTER 6: CONCLUSION AND FUTURE WORK

6.1 Conclusion

From the research regarding the applicability of preventive maintenance policies to jute mills machineries, the following points have become apparent.

i) Since almost all the machineries comprise a large number of component parts, classification of failures and thereby identifying critical parts make the task of developing any effective maintenance policy easier.

ii) Optimal maintenance policy is very much dependent upon the failure mode of the machineries and the cost and time to effect maintenance. So, data should be collected with extreme care and with clear objective.

iii) From the results of the data analysis (Table 4.3.1), it is clear that almost all equipments show wearout characteristics except low cop winding machine, hemming sewing machine, herrackle sewing machine, overhead sewing machine and baling press machine. These five machines fail more or less randomly.

iv) Maintenance policies based on both cost and downtime minimisation have been determined (Tables 5.4.1 and 5.4.2). The resulting policies differ slightly, which is quite expected because in case of downtime minimization, maximisation of availability of the machineries is of utmost importance. For the five machines mentioned above, both models show breakdown maintenance as optimal policy.

For machines like 1st drawing machine, finisher drawing machine, sack cop winding machine, sacking loom and hessian loom, cost model has shown failure replacement as optimal whereas downtime model has shown preventive maintenance as optimal. The reason for this is that there is no cost advantage in carrying out preventive maintenance. For hard waste T/card, downtime model has shown preventive maintenance as ineffective; this is because both failure maintenance and preventive maintenance take almost similar time.

6.2 Scope of Future Work

i) In this work, data from one jute mill has been analyzed to find out the appropriate failure distribution for each machine. Data from few more jute mills need to be analyzed to determine more representative and appropriate failure distribution. Since jute industry is of great importance to the national economy, a data base may be established under the control of the appropriate authority.

ii) Maintenance policies have been determined on the basis of individual machines. But, in a jute mill, usually there is a number of indentical machines in each section of the process. In this sort of situation, preventive maintenance age can be expected to be longer if percentage utilization of the machineries can be sacrificed a little but still achieving a target production. So, a study can be carried out in this respect.

iii) It was assumed that at the time of preventive maintenance, all critical items should be checked and replaced. A more appropriate policy would be to determine critical components failure distributions and then making a prior plan which items to be replaced at the time of preventive maintenance.

iv) Optimality of combined periodic inspection and preventive replacement of critical items should be studied.

v) Lubrication is important for certain machineries. Proper lubrication longers the life of equipment by reducing wear and tear. Detailed study of lubrication in respect of proper agent, lubricating points, and frequency should be carried out.

vi) Lastly, some methods should be developed for checking the effectiveness of maintenance.

APPENDIX – I

```
NTRAN IV 360N-FO-479 3-8                MAINPGM              DATE   21/08/83          TIME       18.
      C      PROGRAMME FOR EVALUATING WEIBULL DISTRIBUTION
      C      PARAMETERS
             DIMENSION T(40), X(40), Y(40), XY(40), YS(40), XYS(40), YF(40),
            1TF(40)
             READ (1,900)  N1
         900 FORMAT(I2)
             DO 999 IX=1,N1
             READ (1,100) N, IR
         100 FORMAT(2I2)
             READ (1,101) (T(I), I=1, N)
             READ (1,101) (TF(I1),I1=1,IR)
         101 FORMAT(13F6.1)
             B1=1.0
             B=B1
             WRITE (3,110)IX
         110 FORMAT (1H1///5X,'EXAMPLE',I2,/,9('*'))
             DO 102 J=1,N
             Y(J)=ALOG(T(J))
         102 YS(J)=Y(J)**2
             DO 103 J2=1,IR
         103 YF(J2)=ALOG(TF(J2))
             S3=0.0
             DO 105 K1=1,IR
         105 S3=S3+YF(K1)
             P3=(1.0/FLOAT(IR))*S3
         108 DO 106 J1=1,N
             X(J1)=T(J1)**B1
             XY(J1)=X(J1)*Y(J1)
         106 XYS(J1)=X(J1)*YS(J1)
             S1=0.0
             S2=0.0
             S4=0.0
             DO 104 L=1,N
             S1=S1+XY(L)
             S2=S2+X(L)
         104 S4=S4+XYS(L)
             G=(S1/S2)-(1.0/B1)-P3
             GP=(((S2*S4)-(S1**2))/(S2**2))+(1.0/(B1**2))
             R=G/GP
             IF(ABS(R).LT.0.001) GO TO107
             B1=B1-R
             IF(B1.LE.0.0)GO TO111
             GO TO113
         111 B1=B+1.0
             B=B1
             GO TO 113
         113 GO TO 108
         107 ETA=(S2/IR)**(1.0/B1)
             FMT=ETA*YY(1.0+(1.0/B1))
             SD=SQRT((ETA**2)*(YY(1.0+(2.0/B1))-((YY(1.0+(1.0/B1)))**2)))
             WRITE(3,109)B1,ETA,FMT,SD
         109 FORMAT(3X,'SHAPE PARA=',F5.2,5X,'SCALE PARAM=',F10.3,5X,'MEAN LIF
            1E=',F8.3,5X,'STD DEV=',F10.3)
         999 CONTINUE
             STOP
             END
```

TRAN IV 360N-FO-479 3-8 YY DATE 21/08/83 TIME 18.(

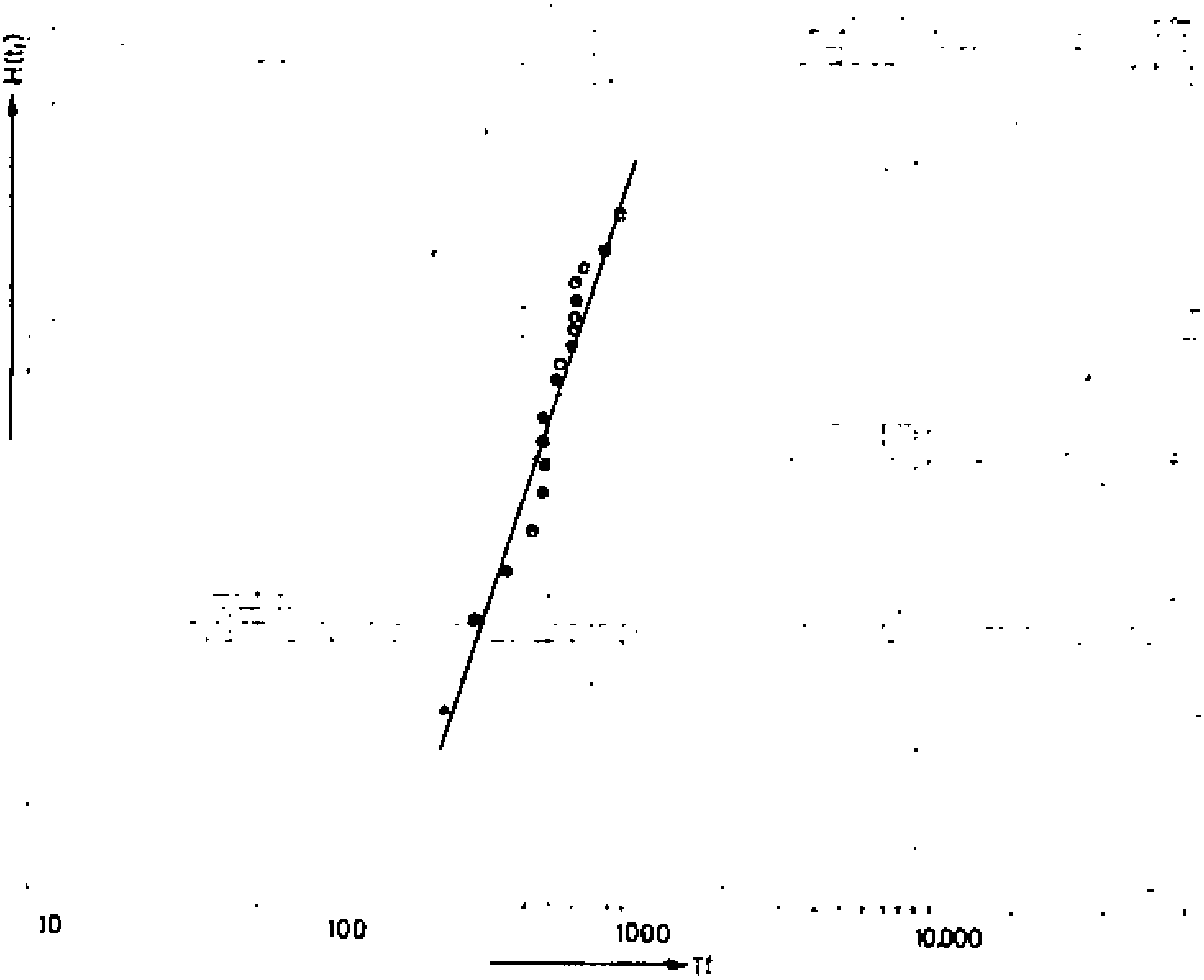
```
      FUNCTION YY(T)
      YY=(T**T)*EXP(-T)*SQRT((2.0*3.1416)/T)*(1.0+(1.0/(12.0*T))+(1.0/(2
     188.0*(T**2))))
      RETURN
      END
```

MAIN SYMBOLS OF PROGRAMME FOR EVALUATING WEIBULL DISTRIBUTION

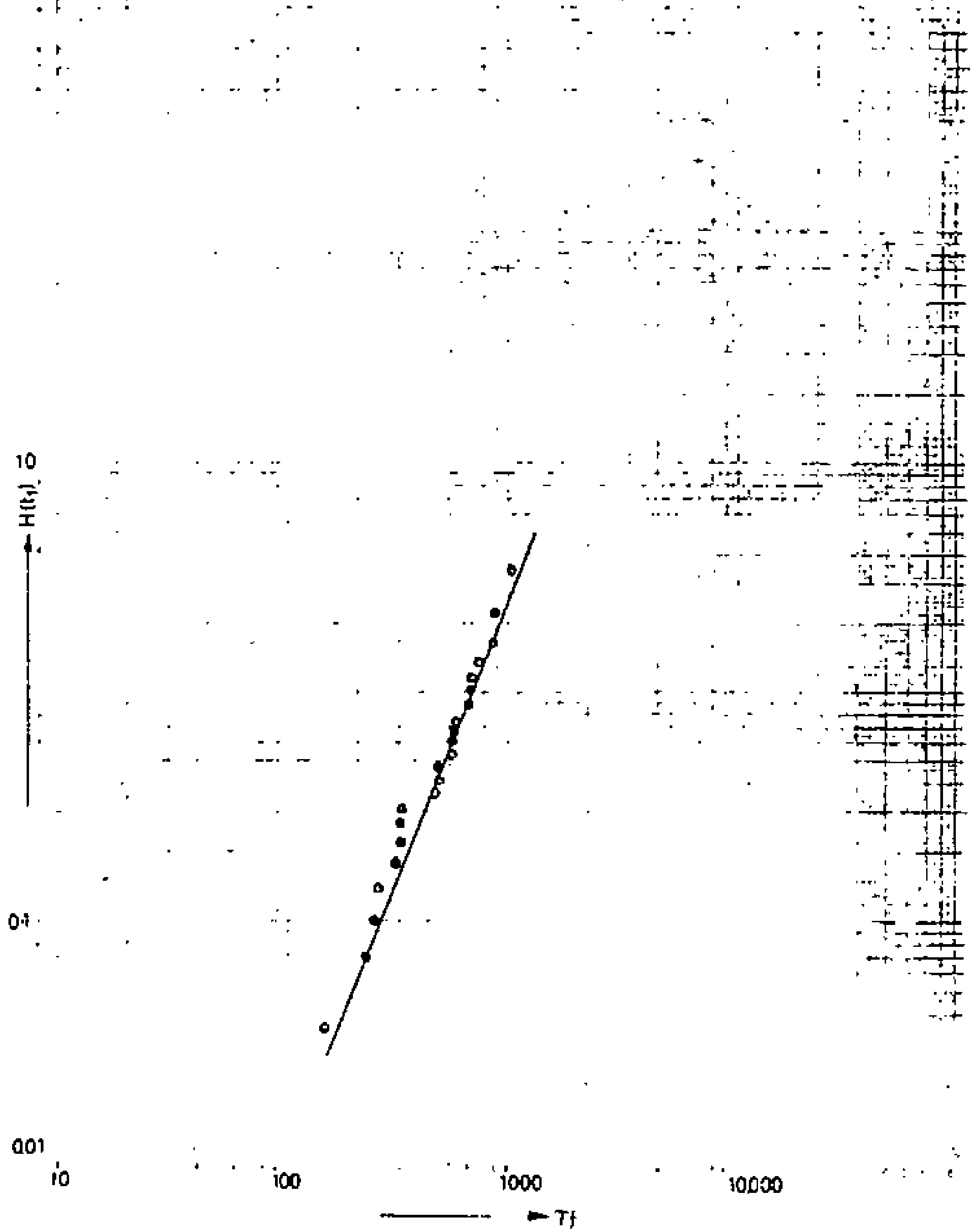
ALOG	=	Natural logarithm
B	=	Shape parameter of the fitted Weibull Distribution
EX	=	Exponential distribution
ETA	=	Scale parameter of the fitted Weibull Distribution
FMT	=	Meantime to Failure of a Component
IR	=	The number of failure times
N	=	The number of failure and preventive overhaul times
NI	=	The number of data set to be run
SQRT	=	Square root
SD	=	Standard deviation
T	=	A dummy variable used with function subprogramme YY
YY	=	An approximate relationship for evaluating Gamma function
I,IJ,J, JI,J2, KI,L	=	Loop index variables

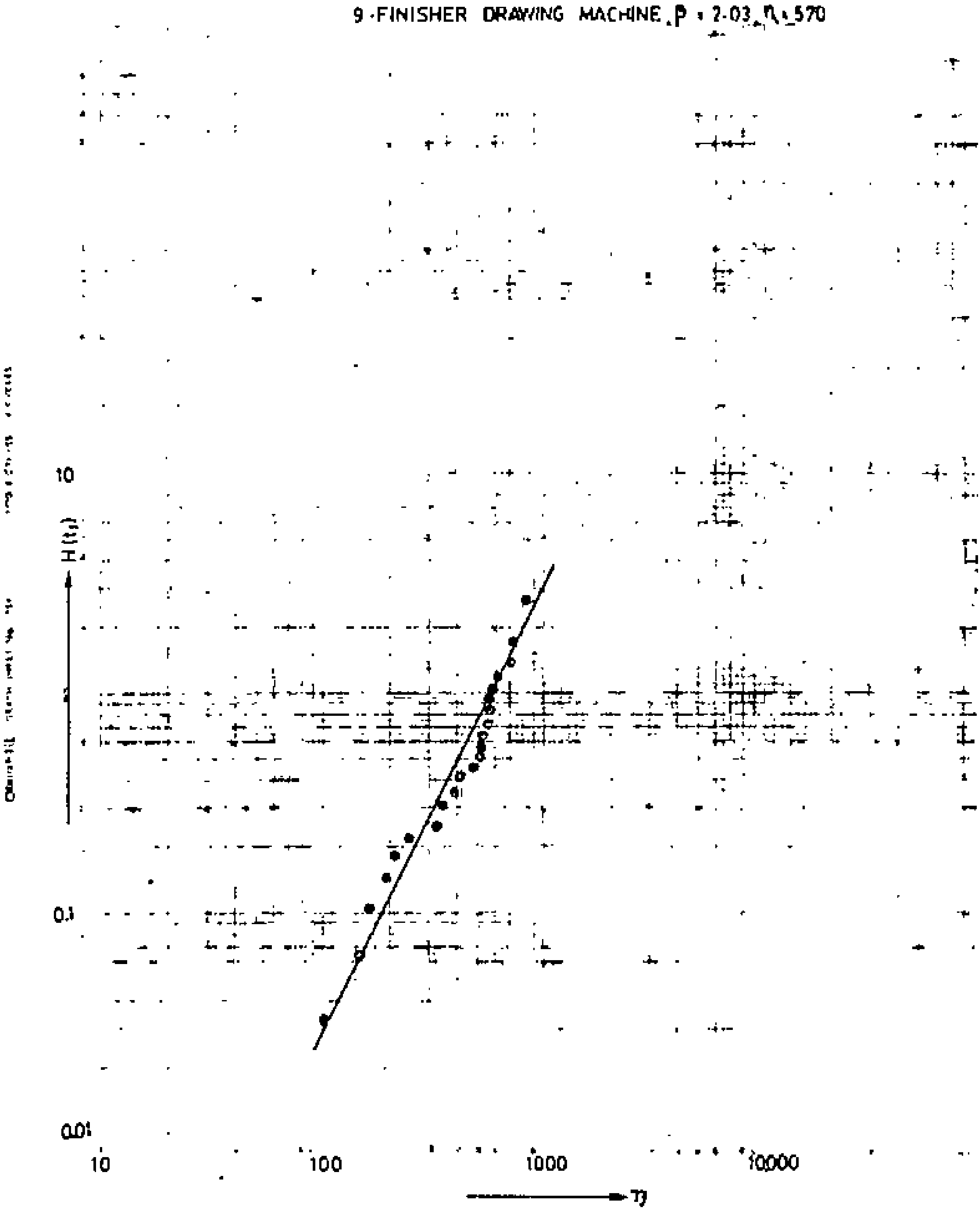
APPENDIX - II

7. 2ND. DRAWING MACHINE, β = 2.94, η = 670



B. 3RD. DRAWING MACHINE, $\beta = 2.5$, $\eta = 630$




9-FINISHER DRAWING MACHINE, β = 2·03, η = 570
H(t)
10
0.1
0.01
10
100
1000
10000
η

APPENDIX – III

```
TRAN IV 360N-FO-479 3-8            MAINPGM            DATE   25/08/83        TIME    17.

C       FINDING PREVENTIVE REPLACEMENT AGE
        DIMENSION BF(600),CRL(600),F(600),RL(600),EX(600),COST(600),WFR(
       1600)
        COMMON BF,CRL,F,WFR,RL,EX,COST,B,ETA,N,FMT,NC
        DO 560 KX=1,8
        READ(1,579) N,B,ETA,TI,TF,CP,CF,FMT
  579   FORMAT(I3,4F6.2,2F8.2,F6.2)
        CALL ZKI
        WRITE(3,150)
  150   FORMAT(6X,17H RELATIVE COST OF,8X,8H OPTIMAL,7X,11H SAVINGS I I,4X,
       19H COST PER,/,5X,20H FAILURE REPLACEMENT,3X,4H AGE,8X,11H PERCENTA
       2GE,4X,13H UNIT TIME,/)
        RA=CF/CP
        IT=2
        COST(IT)=(RL(IT)+(RA*BF(IT)))/(CRL(IT)+(TI*RL(IT))+(TF*BF(IT)))
        COPA=COST(IT)
        IT=3
   32   COST(IT)=(RL(IT)+(RA*BF(IT)))/(CRL(IT)+(TI*RL(IT))+(TF*BF(IT)))
        IF(COST(IT)-COPA) 30,31,31
   30   COPA=COST(IT)
        IF(IT-NC) 180,181,181
  180   IT=IT+1
        GO TO 32
   31   ITP=IT-1
        SVGA=100.0*(1.0-((COPA*FMT)/RA))
        IF(SVGA) 34,34,35
   35   CONTINUE
        WRITE(3,151) RA,ITP,SVGA,COPA
  151   FORMAT(13X,F6.3,17X,I3,11X,F5.2,12X,F5.3)
        GO TO 560
   34   CONTINUE
  181   COPF=RA/FMT
        COPA=COPF
        WRITE(3,152) RA,COPA
  152   FORMAT(1X,T14,F6.3,12X,'REPLACE ON FAILURE ONLY',T65,F5.3)
  560   CONTINUE
        STOP
        END
```

```
C       SUBROUTINE FOR WEIBULL ANALYSIS
        SUBROUTINE ZKI
        DIMENSION BF(600),CRL(600),F(600),RL(600),EX(600),COST(600),WFR(
       1600)
        COMMON BF,CRL,F,WFR,RL,EX,COST,B,ETA,N,FMT,NC
C       FINDING WEIBULL PROBABILITIES
        DO 69 KK=1,N
        EX(KK)=(FLOAT(KK)/ETA)**B
   69   BF(KK)=1.0-EXP(-EX(KK))
        NC=N+1
   72   EX(NC)=(FLOAT(NC)/ETA)**B
        BF(NC)=1.0-EXP(-EX(NC))
        IF(BF(NC)-0.995) 71,71,70
   71   NC=NC+1
        GO TO 72
   70   CONTINUE
        DO 82 LI=1,NC
   82   RL(LI)=1.0-BF(LI)
        F(1)=BF(1)
        DO 75 KJ=2,NC
   75   F(KJ)=BF(KJ)-BF(KJ-1)
C       FINDING HAZARD RATE
        DO 81 LL=1,NC
   81   WFR(LL)=F(LL)/RL(LL)
        CRL(1)=(1.0+RL(1))/2.0
        DO 83 LJ=2,NC
   83   CRL(LJ)=CRL(LJ-1)+((RL(LJ-1)+RL(LJ))/2.0)
        RETURN
        END
```

APPENDIX - IV

```
RTRAN IV 360N-FO-479 3-8          MAINPGM               DATE    21/08/83        TIME      13

C       FINDING PREVENTIVE REPLACEMENT AGE
        DIMENSION BF(600),CRL(600),F(600),RL(600),EX(600),TIME(600),WFR(
       1600)
        COMMON BF,CRL,F,WFR,RL,LX,TIME,B,ETA,N,FMT,NC
        DO 580 NX=1,6
        READ(1,379) N,B,ETA,TI,TF,CP,CF,FMT
  379   FORMAT(I3,4F6.2,2F8.2,F6.2)
        CALL ZRL
        WRITE(3,150)
  150   FORMAT(1H1///6X,17H RELATIVE TIME OF,8X,8H OPTIMAL,5X,12H IMPROVEMEN
       1,5X,9H TIME PER,/,5X,20H FAILURE REPLACEMENT,8X,4H AGE,7X,11H PERC
       2ENTAGE,4X,10H UNIT TIME,/)
        RA=TF/TI
        IT=2
        TIME(IT)=((TI*RL(IT))+(TF*BF(IT)))/(CRL(IT)+(TI*RL(IT))+(TF*BF(IT)
       1))
        COPA=TIME(IT)
        IT=3
   32   TIME(IT)=((TI*RL(IT))+(TF*BF(IT)))/(CRL(IT)+(TI*RL(IT))+(TF*BF(IT)
       1))
        IF (TIME(IT)-COPA) 30,31,31
   30   COPA=TIME(IT)
        IF(IT-NC) 180,181,181
  180   IT=IT+1
        GO TO 32
   31   ITP=IT-1
        SVGA=100.0*(1.0-((COPA*FMT)/TF))
        IF (SVGA) 34,34,35
   35   CONTINUE
        WRITE(3,151) RA,ITP,SVGA,COPA
  151   FORMAT(10X,F6.3,17X,I3,11X,F5.2,12X,F5.3)
        GO  TO  580
   34   CONTINUE
  181   CORF=TF/FMT
        COPA=CORF
        WRITE(3,152) RA,COPA
  152   FORMAT(1X,T14,F6.3,12X,'REPLACE ON FAILURE ONLY',T65,F5.3)
  580   CONTINUE
        STOP
        END
```

```
C      SUBROUTINE FOR WEIBULL ANALYSIS
       SUBROUTINE ZK1
       DIMENSION BF(600),CRL(600),F(600),RL(600),EX(600),TIME(600),WFR(
      1600)
       COMMON BF,CRL,F,WFR,RL,EX,TIME,J,ETA,N,FMF,NC
C      FINDING WEIBULL PROBABILITIES
       DO 69 KK=1,N
       EX(KK)=(FLOAT(KK)/ETA)**B
   69  BF(KK)=1.0-EXP(-EX(KK))
       NC=N+1
   72  EX(NC)=(FLOAT(NC)/ETA)**B
       BF(NC)=1.0-EXP(-EX(NC))
       IF(BF(NC)-0.995) 71,71,70
   71  NC=NC+1
       GO TO 72
   70  CONTINUE
       DO 82 LI=1,NC
   82  RL(LI)=1.0-BF(LI)
       F(1)=BF(1)
       DO 75 KJ=2,NC
   75  F(KJ)=BF(KJ)-BF(KJ-1)
C      FINDING HAZARD RATE
       DO 81 LL=1,NC
   81  WFR(LL)=F(LL)/RL(LL)
       CRL(1)=(1.0+RL(1))/2.0
       DO 83 LJ=2,NC
   83  CRL(LJ)=CRL(LJ-1)+(RL(LJ-1)+RL(LJ))/2.0
       RETURN
       END
```

MAIN SYMBOLS OF PROGRAMME FOR FINDING PREVENTIVE REPLACEMENT AGE

B = Shape parameter of the Failure distribution

BF = Cumulative distribution of a component

CF = Cost of a failure maintenance

CORF = Total cost of failure maintenance/unit time

COST = Total cost of preventive maintenance/unit time

CP = Cost of a preventive maintenance

CRL = Integral value of reliability function

ETA = Scale parameter of the failure distribution

F = Probability density function of a component

FMT = Meantime to failure of a component

IT = Preventive maintenance age

N = Preassigned time units upto which density and reliability functions are calculated in the first instance

NC = Time unit when the probability of failure is atleast 99.5%

NX = Number of machines for which preventive maintenance age is to be calculated

RA = Ratio of CF to CP (for minimization of cost model) and
= Ratio of TF to TP (for minimization of downtime model)

RL = Reliability function of a component

SVGA = Percentage savings from the chosen maintenance action

TF = Time required to effect a failure maintenance

TI = Time required to effect a preventive maintenance

WFR = Hazard rate of a component

R E F E R E N C E S

1. Jorgenson, D.W. McCall, JJ and Radner, R. : "Optimal Replacement Policy" The Rand Corporation, North Holland Publishing Company, 1967.

2. Jardine, A.K.S. : "Maintenance, Replacement & Reliability" Pitman Publishing, 1973.

3. Weiss, G. : "On the Theory of Replacement of Machinery with a Random Failure Times", Naval Research Logistics Quarterly, Vol. 3, No. 4, Pp. 279-293, 1956

4. Herd, G.R. : "Failure Rates", ARINC Monograph 2, Aeronautical Radio Inc., 1955.

5. Flehinger, B.J. : " A General Model for the Reliability Analysis of Systems under various preventive Maintenance Policies", Ann. Math. Static. Vol. 33, No. 1, Pp. 137-156, 1962.

6. Morse, P.M. : "Queues, Inventories, and Maintenance" John Wiley & Sons, 1958.

7. Barlow, R.E and Proschan, F : "Properties of Probability Distributions with Monotone Hazard Rate, Ann. Math. Statis. Vol. 34, No. 2, 1963.

8. Savage, I.R. : "Cycling", Naval Research Logistics Quarterly, Vol. 3, No. 3, Pp. 163-175, 1963.

9. Kamins, M. : "Determining Checkout Intervals for Systems Subject to Random Failures", The Rand Corporation Research Memorandum, RM-2578, June, 1960.

10. Coleman, J and Abrams, T.J. : "Mathematical Model for Operational Readiness", Operations Research, Vol. 10, No. 1, Pp. 126-138, January-February, 1962.

11. Kelly, A and Harris, M.J. : "Management of Industrial Maintenance", Newnes Butter Worth, London - Boston, 1978.

12. O'Connor, P.D.T. : "Practical Reliability Engineering,", British Aerospace Dynamics Group, Stevenage, Heyden & Sons Co., 1981.

13. Weibull, W. : "A Statistical Distribution Function of Wide Applicability", Journal of Applied Mechanics, Vol. 18, Pp. 293-297, 1951.

14. Kao, J.H.K. : "Computer Methods for Estimating Weibull Parameters in Reliability Studies", IRE Transactions on Reliability and Quality Control, PGRQC-13, Pp. 15-22, July, 1958.

15. Lieblein, J. & Zelen, M : "Statistical Investigation of the Fatigue Life of Deep Groove Ball Bearings", Journal of Research, National Bureau of Standards, Vol. 57, Pp. 273-316, 1956.

16. Nelson, W. : "Theory and Applications of Hazard Plotting for Censore Failure Data", Technometrics, vol. 14, No.4, Pp. 945-966, November, 1972.

17. Kabir, A.B.M.Z. : "Solution Procedures for Replacement Problems", Unpublished M.Sc. Thesis, University of Birmingham (U.K), 1977.