DEVELOPMENT OF MODELS FOR ASSESSMENT OF OPERATIONAL RELIABILITY AND POWER DISTRIBUTION RELIABILITY OF A POWER GENERATING SYSTEM

A Project Thesis

by

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CERTIFICATE

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

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ABSTRACT

In modern day life the requirement of power supply is increasingly becoming an absolute necessity. Efficient and effective power supply hinges on two factors, namely effective power generation and effective distribution. From the engineering view point, operational reliability is considered as a measure of system effectiveness. Operational reliability, in turn, is not based on a single quantitative measure. The most common premises have been, time-dependent reliability, steady-state availability and the like. In the present work, plant reliability of Khulna steam power station and distribution system reliability of Khulna industrial zone have been studied.

Power generation by steam is by far the cheapest but problematic. Any steam power plant consists of a large number of complex equipments which are liable to failure due to various causes. From the failure and maintenance records of the said plant, reliabilities of individual equipments and the overall system reliability have been calculated. Based on these, critical equipments have been identified and their modes of failures have been analysed. Possible reliability improvement by eliminating principal mode of failure of each critical equipment has been demonstrated. This has again been compared to reliability improvement which may be effected by installing standby unit of critical equipment. Overall system reliability improvement has also been shown.

Distribution system failures have been analyzed and found to be random in nature. For this case, reliability indices have been considered to be failure rate, mean failure duration and availability. These indices have been calculated for individual substations, feeders and load points. Overall system failure rate and mean failure duration have also been assessed.

For time-dependent reliability, Weibull reliability function has been used throughout. Distribution parameters have been calculated by Maximum Likelihood Estimator and hazard plotting methods.

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NOTATIONS

β	=	Shape parameter
η	=	Scale parameter
r	=	No. of failure
s	=	Failure rate
A	=	Availability
A_I	=	Intrinsic availability
$f_{F_{mn}}$	=	Frequency of failure
T_α	=	Mean downtime
$T_{F_{mn}}$	=	The mean duration of system failure
ε	=	Set
μ_A, μ_B	=	Repair rates

CHAPTER 1

INTRODUCTION

1.1 General Introduction

In this modern day of science, in which complex devices are utilized for scientific purposes a higher degree of reliable power supply is an absolute necessity. The public has grown accustomed to such a reliable service and by and large would not accept much lower standards. A high degree of reliability is also absolutely essential for some industrial customers, hospitals, etc. For this reason, reliability is and always has been, one of the major factors in the planning, design, operation and maintenance of power plant and distribution system equipments. This is generally achieved by the redesign of existing equipments, installation of redundant equipments, duplicating the safety trip system, improving the maintenance policy, increasing the rate of periodic inspection, etc. This work covers both power distribution system and power plant system.

The reliability of an electric supply system has been defined as the probability of providing the users with continuous service of satisfactory quality. The quality constraints refer to the requirement that the frequency and the voltage of the power supply should remain within prescribed tolerances. The actual degree of reliability experienced by a customer will of course, vary from location to location. In addition, different parts of the power network such as the generation, transmission, and distribution system will exhibit different reliabilities. It is easy to see that to achieve the degree of reliability quoted aboveat the customer level, each of these systems must provide an even higher degree of reliability.

Power plants are prime examples of system where a high degree of reliability is expected. The operation of a steam power plant involves many problems which causes shut-down of the plant. Since most of the equipments are complex mechanical units their control and protective devices are very complicated.

During operation, failure of the plant may occur for many reasons e.g. poor design of the equipments, improper installment, false signal of instruments and safety trip system, fluctuation of supply voltage or current, previous incompetent (incomplete and incorrect) maintenance of mechanical, electrical, electronic and pneumatic equipments. If the plant, operates with full load i.e. with maximum rated pressure and temperature the failure of any other plant in the grid system will cause failure of the plant (sudden change of load/frequency). In addition to these causes failure of the plant may also happen due to ageing phenomena and wrong action taken by the operator.

With regard to the measure of system performance or system effectiveness, the term "operational reliability" is fairly commonly used, though it does not have any well defined meaning in the field of reliability engineering.

However, the term may be interpreted as meaning time dependent reliability function in the short-term perspective and operational readiness and availability in the long-term perspective. The latter two terms are generally taken as steady state measures of system performance.

1.2 Power Plant to be Studied

Irrespective of the nature of operation, the treatment of reliability analysis is some for any type of steam power plant or for any complex plant in general. So, for this study, Khulna 60 MW steam power plant has been chosen because of its importance to the power supply in the western grid (western zone) of Bangladesh. This is one of the complex power stations in the country.

This power plant operates closer to its rated capacity, some time slightly more than the rated capacity, at very high pressure (1365 psi) and temperature (540^{o}C) at peak load hour. Moreover, most of its installed equipments and machineries are single unit in a flow train except a very few units where stand by redundancy, is available. This power plant generates 60 MW power at 11 KV. If the boiler is shut-down for any reason then it takes 5 to 6 hours to generate power after firing of boiler from hot condition and if the boiler is allowed to cool down then it takes more than 24 hours for generation of power.

Review of the plant life indicates that the plant suffers frequent shut-down/failure due to various troubles of equipments and machineries. The troubles might be reduced considerably if it is possible to identify the critical equipments and the trouble areas for which shut-down of the plant occurs and improving the situation by installing redundant equipments or duplicating the system of the troubled areas.

1.3 Distribution System to be Studied

Distribution network is a part of power system that delivers energy from the area supply stations to the customers. From the customers' point of view, the reliability of these systems is at least as important as the reliability of generation and transmission. A major part of service interruptions experienced by an individual customer has its origin in failures in the distribution system.

In comparison with the transmission network distribution system generally have a much simpler layout. Most are radial arrangements, and the components involved in the supply to a customer are in a series connection. Such radial networks can be best described in terms of zones and branches. A zone is a part of the circuit that can isolate or detach itself automatically or manually from the remaining circuit if a fault occurs in any of its links.

So for this study, Khulna industrial zone power supply system has been chosen, because Khalispur is the largest industrial area in southern Bangladesh so its power supply is important which has direct effect in the national economy.

1.4 Objective of the Study

The objectives of this research are the followings:-

i) To determine the operational reliability of each individual components and the over-all reliability of the power plant and the distribution system.

ii) To detect the critical components and major trouble areas.

iii) Determination of failure distribution to best fit failure characteristics.

iv) To suggest a policy to improve operational effectiveness of the plant and distribution system.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of Reliability

According to Kapur and Lamberson(1), "the reliability of a system is the probability that, when operating under stated environmental conditions, the system will perform its intended function adequately for a specified interval of times".

With this definition, the obvious problems are; (i) the acceptance of the probabilistic notion of reliability which admits the possibility of failure, (ii) the concept of adequate performance for system parameters that deteriorate slowly with time, and (iii) the judgement necessary to determine the proper statement of environmental conditions.

Clearly, the reliability is a function of the time specified and depends on the nature of the plant and its environment. The reliability function R(t) may be defined as

$$R(t) = Pr\{\text{ no failure in}(0,t)\}$$

where Pr {.} denotes probability.

2.2 Failure

Failure is defined in the British Standard Maintenance Glossary "the termination of the ability of an item to perform its required function". This can involve such failure categories as follows:

(1) Catastrophic failures which results in an immediate inability of a system to achieve its function.

(2) Performance failure associated with a reducing performance of the equipment.

(3) When the operation deliberately takes the equipment, out of service, even though it is producing at that time, its specified output.

2.2.1 Types of Failure

According to Collacott[2] there are three types of failures recognized in system and component reliability studies, namely infant mortality, random and time dependent failures.

2.2.1.1 Infant Mortality (early failure)

In the early life of a plant these failures can be identified as commissioning problems and are usually caused by one of the followings:

(i) Design faults - failure caused by inadequate design which will continue until the design is modified.

(ii) Manufacturing faults - the use of substandard components due to lack of quality control or poor workmanship in the assembly of units will produce early failure.

(iii) Construction faults - the initial assembly and setting up of plant items can produce additional stresses over and above the design values resulting in premature failure.

Plant and equipment which has been in use for several years and is obviously past its initial life period, it is still possible to get early failure characteristics. This is due to the maintenance activity itself whether in response to a breakdown or for preventive reasons. The most obvious reasons for these early failure characteristics are:

(a) Incorrect fault identification - usually because the symptom of failure has been corrected but not the underlying cause.

(b) Poor maintenance work - whilst this is the most difficult of categories to eliminate, it is unfortunately one of the most common causes of early failure.

It is desirable that all early failure modes are eliminated by appropriate action. In each case it is necessary to investigate the cause carefully so that one failure mode is not simply replaced by another.

2.2.1.2 Random Failure

Randomness of failure occurs when the probability of failure doesnot vary with the age of a unit (the hazard rate is constant). From an engineering point of view it would be expected that mechanical equipment would show wear-out charac teristics. With complex mechanical equipments there can be many different modes and although these may individually follow normal distributions with different means and standard deviations, when considered altogether these can produce an apparent exponential or even early failure distribution. In addition many faults can interact; for example, the failure of one component could lead to additional stresses on others through over heating, unbalance or vibration.

2.2.1.3 Time-dependent Failure

Time-dependent failure is nothing but wear out failure. Failure attributable to the normal process of wear is expected when the device was designed. From a maintenance point of view it is desirable to have equipment with a wear out type of failure distribution since this gives a much longer mean time between failure (MTBF), is much more predictable in the sense that the variation between the lives of the individual units is small, and it can be used as the basis of a preventive maintenance policy.

2.3 Failure Rate

The rate at which failures occur in a certain time interval (t_1, t_2) is called the failure rate during that interval. It is defined as the probability that a failure per unit time occurs in the interval, given that a failure has not occured prior to t_1, the begin ing of the interval. Thus the failure rate is

$$\frac{R(t_1) - R(t_2)}{(t_2-t_1)\ R(t_1)}$$

The rate in the above definition is expressed as failure per unit time; in reality the time units might be kilomet res, revolutions etc.

The probability of failure of a system in a given interval (t_1,t_2) can be expressed in terms of either the unreliability function as

$$\int_{t_1}^{t_2} f(t)dt = \int_{-\infty}^{t_2} f(t)\ dt - \int_{-\infty}^{t_1} f(t)\ dt = F(t_2) - F(t_1)$$

or interms of reliability function as

$$\int_{t_1}^{t_2} f(t)dt = \int_{t_1}^{\infty} f(t)dt - \int_{t_2}^{\infty} f(t)dt = R(t_1)-R(t_2)$$

2.4 Hazard Function (rate)

The hazard function is defined as the limit of the failure rate as the interval approaches zero. Thus the hazard function is the instantaneous failure rate. The hazard function h(t) is defined by

$$h(t) = \operatorname{Lt.}_{t'\to 0} \frac{R(t) - R(t+ t')}{t'.\ R(t)} = \frac{1}{R(t)} \left\{- \frac{d}{dt} R(t)\right\}$$

$$= \frac{f(t)}{R(t)}$$

2.5 Failure Distribution

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,CFR). The probability that some thing will fail at a prescribed instant is zero. Thus failure distributions are represented by function of time f(t), such that when integrated over a specified time interval t_1 to t_2, the probability of at least one failure during the interval is obtained.

$$F(t_1, t_2) = \int_{t_2}^{t_1} f(t)\,dt$$

According to[1] the common probability density distributions are, the hyper exponential, the negative exponential, the log-normal, the normal, the Gamma and the weibull distributions etc.

The weiball distribution[3] is an emperical distribution which appears to fit a large number of failure characteristics of equipments. The density function of the weibull distribution is

$$f(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1} \exp\left\{-\left(\frac{t}{\eta}\right)^{\beta}\right\} \quad \text{for } t \geq 0$$

where η is a scale parameter (sometimes termed characteristic life), β is a shape parameter, and η and β are positive. A high value of η indicates a good designed system. The shape parameter β defines the type of distribution. When β is equal to 0.5,1,2, and 3.4, the weibull is equivalent to the hyper exponential, the negative exponential, the log-normal and the normal distribution respectively.

2.6 Estimation of Weibull Distribution Parameters

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

Of all the methods mentioned above, MLE has attracted most attention. For life testing situations, where r failures have been observed from a sample of n items, Bain(4) gives the following equation for estimating β :

$$\frac{\sum_{i=1}^{r} t_{i:n}^{\beta} \ln t_{i:n} + (n-r) t_{r:n}^{\beta} \ln t_{r:n}}{\sum_{i=1}^{r} t_{i:n}^{\beta} + (n-r)\, t_{r:n}^{\beta}} - 1/\beta = \frac{1}{r} \sum_{i=1}^{r} \ln t_{i:n} \qquad (2.6.1)$$

where ln is the natural logarithm.

After determing β , the scale parameter η can be estimated by

$$\eta = \left[\frac{\sum_{i=1}^{r} t_{i:n}^{\beta} + (n-r)\, t_{r:n}^{\beta}}{r} \right]^{1/\beta} \qquad (2.6.2)$$

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

$$\frac{\sum_{i=1}^{n} t_i^{\beta} \ln t_i}{\sum_{i=1}^{n} t_i^{\beta}} - 1/\beta = \frac{1}{\eta} \sum_{i=1}^{n} \ln t_i$$

and

$$\eta = \left[\frac{\sum_{i=1}^{n} t_i^{\beta}}{n}\right]^{1/\beta}$$

Equation (2.6.1) for β can be solved by a numerical method such as the Newton - Raphson method. From equation (2.6.1) it is clear that β can not be obtained with a single failure, in a life-testing situation. Therefore estimation of β and η can only start after the second failure. But when the unfailed components have different ages; that is, if they are put into service at different times, the equation for β remains valid. The major problem with MLE is that the estimate of β is highly biased when there are only a few failures.

The method of Best linear invariant estimators (BLIE) has been developed by Mann, et al[5]. They have given the following relationships for evaluating estimates β and η .

$$\eta = \sum_{i=1}^{r} A(n,r,i)t_i \tag{2.6.3}$$

and $$1/\beta = \sum_{i=1}^{r} C(n,r,i)t_i \tag{2.6.4}$$

Mann, et al. have given the weighting factors $A(n,r,i)$ and $C(n,r,i)$ for $n \geqslant 2$ and $r \geqslant 2$; r is the number of observed failures and n is the number of items on test. Obviously, these formulations are valid for life-testing situation only. The main disadvantages of this method are that it can not be used before the second failure and the estimate β is highly biased for the first few failures.

The method of good linear unbiased estimators (GLUE) has been discussed by Bain[4]. the equations to be solved are:

(i) for $r < n$ (incomplete data),

$$1/\beta = \frac{r \ln t_{r:n} - \sum_{i=1}^{r} \ln t_{i:n}}{nK_{r,n}} \tag{2.6.5}$$

$$\ln \eta = \ln t_{r:n} - (C_{r,n}/\beta) \tag{2.6.6}$$

where the constants $K_{r,n}$ and $C_{r,n}$ are given in tabular forms for $n \geqslant 5$ or many be calculated by quadratic approximations provided by Bain.

(ii) for $r = n$ (complete data)

$$1/\beta = \frac{-\sum_{i=1}^{s} \ln t_{i:n} + \left\{s/(n-s)\right\} \sum_{i=s+1}^{n} \ln t_{i:n}}{nK_n} \tag{2.6.7}$$

$$\ln \eta = \left(\frac{1}{n} \sum_{i=1}^{n} \ln t_{i:n} \right) + r^{*}/\beta \tag{2.6.8}$$

where K_n is an unbiasing constant given in tabular form, $s = [0.84n]$ is the largest integer $\leq 0.84n$, and $r^* = 0.5772$ is the Euler constant.

Unlike MLE and BLIE, this method provides a good estimate of β for few failures. But, it also cannot be used before the scond failure. Another shortcoming with GLUE is that it is inapplicable when replacements are carried out on failure; because there is no single value of $t_{r:n}$.

The method of least squares is applicable only after all the equipments in the sample have failed; i.e., no censoring is allowed. Nevertheless, the method is effective in dealing with few failures with in engineering approximations. The determination of β and η by this method, is based on the inversion and double logarithmic transformation of the equation for the cumulative distribution function F(t) given by $F(t) = 1 - \exp\{-(t/\eta)^{\beta}\}$ which on transformation becomes

$$\ln \ln \left[1/\{1-F(t)\}\right] = \beta \ln t - \beta \ln \eta \qquad (2.6.9)$$

This is of linear form $Y = mX - Z$.

where $Y = \ln \ln \{1/1-F(t)\}$

$m = \beta$

$X = \ln t$

$Z = \beta \ln \eta$

There are several ways of calculating $F(t_1)$ for the ith failure three of which are as follows:

Choice	$F(t_i)$	
Meanrank	$i/(n+1)$	
Benards approximation	$(i-0.3)/(n+0.9)$	
Symmetrical sample cdf	$(i-0.5)/n$	(2.6.10)

Estimates of β and η can be obtained either graphically or by using a computer programme. In the programme, equation (2.6.9) and (2.6.10) can be solved by the least squares technique to estimate β ,while the scale parameter η is estimated by the following equation.

$$\eta = \exp\{ Y(\text{at } 63.2\%) + Z \} / \beta \qquad (2.6.11)$$

Equation (2.6.9) can also be solved graphically. Some special graph papers called 'weibull probability' papers are commonly used for plotting Y vs. X. In using such papers, the usual technique is to produce a 'best' fit line by eye. As an aid to this type of fitting, it should be noted that the line must pass through $(\bar{X},\bar{Y})$, where

$$\bar{X} = \frac{\sum_{i=1}^{n} \ln t_i}{n}$$

$$\bar{Y} = \frac{\sum_{i=1}^{n} \ln \ln \left\{1/\ 1-F(t_i)\right\}}{n}$$

Like all other methods mentioned before, the least squares method also can not be used for $n < 2$

Another graphical technique for estimating the weibull parameters is 'hazard plotting' which has been developed by Nelson[6]. The main differences of this method from the earlier one is that it uses cumulative hazard function $H(t)$ instead of cumulative distribution function $F(t)$ for a linear fit.

The hazard function $h(t)$ for a distribution of times 't' to failure is defined in terms of the cumulative distribution function $F(t)$ and its derivatives, which is the probability density $f(t)$, as follows;

$$h(t) = f(t)/\ 1-F(t) \tag{2.6.12}$$

The cumulative hazard function $H(t)$ of a distribution is the integral of the hazard function upto time t; that is:

$$H(t) = \int_{\infty}^{t} h(t)\ dt = -\ \ln\ \{1-F(t)\} \tag{2.6.13}$$

For the weibull distribution, the cumulative hazard function $H(t)$ can be written in the following form.

$$H(t) = (t/\eta)^{\beta}, \quad t > 0 \tag{2.6.14}$$

This can be rewritten to express times as a function of the cumulative hazard, namely:

$$\ln t = (1/\beta)\ \ln H + \ln \eta \tag{2.6.15}$$

By this relationship, $\ln t$ is a linear function of $\ln H$. Thus, weibull hazard paper is simply log-log graph paper.

From equation (2.6.15), it is obvious that the slope of the straight line plot equals $1/\beta$; this fact is used to estimate β with the aid of the shape parameter scale from a weibull hazard plot. For H=1 (100%) the corresponding time t equals η ; this fact is used to estimate η graphically.

For hazard plotting, the basic steps involved are as follows:

(i) Collect a number of failure dates/times for the same equipment (or a number of similar equipments).

(ii) Determine hours run between failures and order the times (both failed and unfailed times) from smallest to largest.

(iii) Label the times with reverse ranks, that is, the first time is labelled n, the second n-1, and the nth is labelled 1.

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

(v) Calculate the hazard value for each failure, omitting unfailed items, as 1/K, where K is its reverse rank.

(vi) Calculate the cumulative hazard value for each failure as the sum of its hazard value and the hazard values of all preceeding failure items.

(vii) Plot cumulative hazard values vs. sample failure times on a log-log graph paper.

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

(ix) In the weibull model d log H/d log t is β and when $H = 1$, $t = \eta$.

2.7 System Effectiveness and its Measures

System effectiveness(7) is the probability that the system can successfully meet an operational demand with in a given time when operated under specified conditions.

Effectiveness is obviously influenced by the way the equipment is designed and built. However, just as critical are the ways in which the equipment is used and maintained. In other words, system effectiveness can be materially influenced by the design engineer, the production engineer, the operator and the maintenance man. It can also be influenced by the logistic system that supports the operation and by the administration through personnel policy, rules governing equipment use, fiscal control, and many other administrative policy decisions.

The following are the various measures of system effectiveness; for example, serviceability, Maintainability, Repairability, Operational readiness, Availability and Intrinsic Availability.

Serviceability - it is defined as the case with which a system can be repaired. Serviceability is a characteristic of the system design and must be planned at the design state.

Maintainability - is defined as the probability that a failed system can be made operable in a specified interval of downtime. Here the downtime includes the total time that the system is out of service. Downtime is a function of the failure detection time, repair time, administrative time, and the logistics time connected with the repair cycle.

Repairability- the term repairability is more restrictive than maintainability and is concerned with only that segment of the maintenance cycle during which repairmen are actively repairing the system. Specially repairability is defined as the probability that a failed system will be restored to a satisfactory operating condition in a specified interval of active repair time.

Operational Readiness

The term operational readiness is defined as the probability that either a system is operating or can operate satisfactorily when the system is used under stated conditions. The operational readiness (O.R.) would be estimated by

$$O.R = \frac{\text{Operating time + idle time}}{\text{Operating time + idle time + downtime}}$$

Availability

Availability is defined as the probability that a system is operating satisfactorily at any point in time and considers only operating time and downtime, thus excluding idle time. Availability is a measure of the ratio of the operating time of the system to the operating time plus the down time. Thus it includes both reliability and maintainability. The availability function(A) would be estimated as:

$$A = \frac{\text{Operating time}}{\text{Operating time + downtime}}$$

$$A = \frac{\text{Mean time to failure}}{\text{Mean time to failure + Mean repair time}}$$

$$= \frac{\text{MTBF}}{\text{MTBF + MTTR}}$$

Intrinsic Availability

Intrinsic availability is defined as the probability that a system is operating in a satisfactory manner at any point in time when used under stated conditions. In this context, time is limited to operating and active repair time.

$$A_I = \frac{\text{Operating time}}{\text{Operating time + active repair time}}$$

$$A_I = \frac{\text{Mean time to failure}}{\text{Mean active repair time + Mean time to failure}}$$

[illegible]

RELIABILITY MODELS

3.1 System Reliability Models

In performing reliability analysis of a complex system it is almost impossible to treat the system in its entirety. The logical approach is to decompose the system into functional entities, composed of units, subsystems, or components. Each entity is assumed to have two states, one good and one bad. The subdivision generates a block-diagram description of system operations. Models are then formulated to fit this logical structure and the calculus of probability is used to predict the system reliability in terms of the sub-division reliabilities. Series and parallel structures often occur, and their reliability can be described very simply. In many cases the structure is of a more complicated nature and more general techniques are needed. It is assumed that each functional entity is independent of the others in the aforementioned models, but in many cases, this is not true. Dependent failures occur in standby systems, and systems which respond to a common environmental change. The models which govern these cases contain time-dependent conditional probabilities.

The formulation of a structural reliability model can be difficult in a large, sophisticated system and requires much approximation and judgement. The basic configurations of some reliability models are shown below.

3.1.1 Components in Series

The series configuration is probably the most commonly encountered model and, fortunately, is also the simplest to analyze. In a series system all subsystems must operate successfuly if the system is to function. The block diagram model of a series system is given in Fig. (3.1.1). For the series model

$$R_s = P[(E_1 \cap E_2 \cap \quad . \ . \ . \ . \quad \cap E_n)]$$

and because of our assumption of independence this becomes

$$= P(E_1)P(E_2) \quad . \ . \ . \ . \quad P(E_n)$$

$$R_s = \prod_{i=1}^{n} R_i \tag{3.1.1}$$

where,

E_i = event that subsystem i operates successfully.

$R_i = P(E_i)$ subsystem reliability

R_s = system reliability

where the right hand side indicates the product of the subsystem reliabilities.

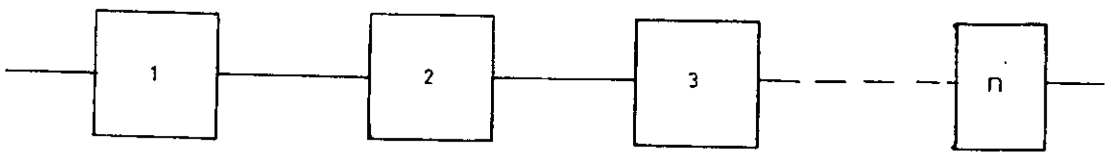


FIG.- 3.1.1

Equation (3.1.1) constitutes what is commonly called the product rule in reliability. Very often a products, design configuration will dictate that this rule be used in computing reliability . This is unfortunate because the system reliability decreases rapidly as the number of series components increases, and the reliability will always be less than or equal to the least reliable component. Thus for a series system

$$R_s \leqslant \min_i (R_i) \tag{3.1.2}$$

When the reliabilities of several series components are equal then

$$R_s = (R_e)^n \tag{3.1.3}$$

where R_e = reliability of several components when their reliabilities are equal to each other.

Again their may be n_1 components of R_1 reliabilities and n_2 components of R_2 reliability etc. in this case the over all reliability of the system.

$$R_s = (R_1)^{n_1}, (R_2)^{n_2}, (R_3)^{n_3} \tag{3.1.4}$$

3.1.2 Components in Parallel

A parallel system is a system that is not considered to have failed unless all components have failed.The reliability block diagram for a parallel system is given in Fig.3.1.2.

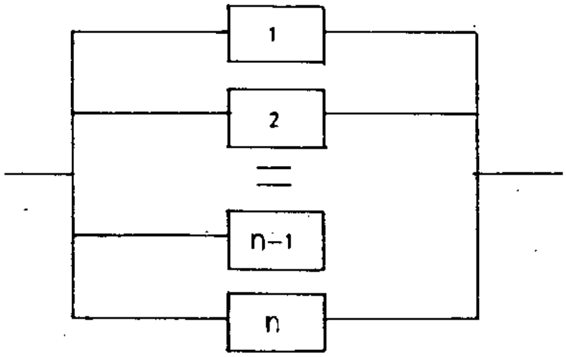


FIG - 3.1.2

The system reliability is calculated as follows. If we define F_s = unreliability (failure) of the system then,

$$F_s = P(\bar{E}_1 \cap \bar{E}_2 \quad \ldots\ldots \quad \cap \bar{E}_n)$$

where $\bar{E}$ is the complementary event. Assuming independence

$$F_s = P(\bar{E}_1)\, P(\bar{E}_2) \quad \ldots\ldots \quad P(\bar{E}_n)$$

or, $$F_s = \prod_{i=1}^{n} (1-R_i) \qquad (3.1.5)$$

Then the system reliability is given by the complementary probability

and $R_s = 1 - F_s$

$$R_s = 1 - \prod_{i=1}^{n} (1-R_i) \qquad (3.1.6)$$

In analysing a parallel system in this fashion it is implied that all sub-systems are activated when the system is activated and that failure do not influence the reliability of the surviving sub-systems.

3.1.3 Parallel and Series Combination

Combinations of parallel and series subsystems are easily analysed by successively collapsing subsystems into equivalent parallel or series components, considering the series arrangement of parallel subsystem shown in Fig. 3.1.3. To calculate the reliability of this system, first collapse the parallel system into equivalent series components. The reliabilities of individual components are R_a, R_b, R_c and R_d respectively. Then the equivalent series component reliabilities are,

$$R_{ab} = 1-(F_a)(F_b)$$

and $$R_{cd} = 1-(F_c)(F_d)$$

so the system reliability is

$$R_s = (R_{ab})(R_{cd}) = \{1-(F_a)(F_b)\}\ \{1-(F_c)(F_d)\}$$

$$= 1 - (F_a)(F_b)-(F_c)(F_d)+(F_a)(F_b)(F_c)(F_d) \qquad (3.1.7)$$

A second arrangement is shown in Fig. 3.1.4 where the banks of series systems are in parallel. The procedure here

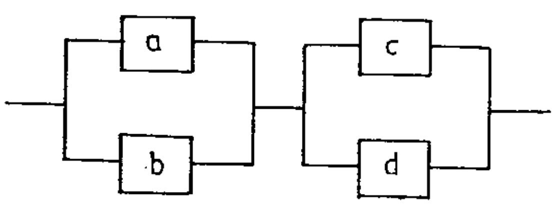


FIG-3.1.3

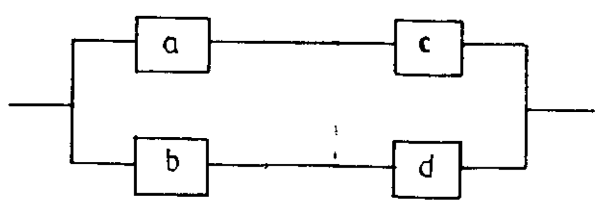


FIG-3.1.4

is to first collapse the series subsystem into equivalent parallel components. For this example let us use the subsystem reliabilities as before. Therefore the equivalent parallel components are

$$R_{ac} = (R_a)(R_c)$$

and $$R_{bd} = (R_b)(R_d)$$

This gives a system reliability of

$$R_s = 1 - (F_{ac})(F_{bd})$$

$$= 1 - (1-R_{ac})(1-R_{bd})$$

$$= R_{ac} + R_{bd} - (R_{ac})(R_{bd}) \qquad (3.1.8)$$

3.1.4 r-out of n-parallel System

For a system which has n components however, at least r-components must survive if the system is to continue operating.

The reliability for an r out of n system is given by

$$R_s = \sum_{x=r}^{n} \binom{n}{x} R^x (1-R)^{n-x} \qquad (3.1.9)$$

where R is the subsystem reliability and is assumed to be equal for all subsystems and

$$\binom{n}{x} = \frac{n!}{x!(n-x)!}$$

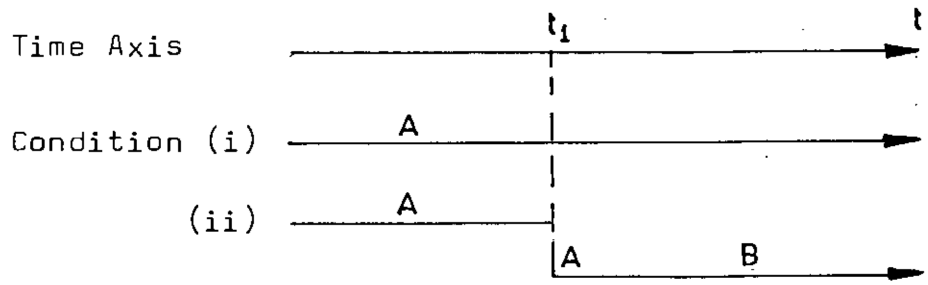
3.1.5 Stand-by Redundancy

In a system with redundant elements that are completely on stand-by, no time is accumulated on stand-by,elements untill the primary elements fails. For simplicity, it will first be assumed that stand-by elements cannot fail if de-energized, and that the necessary switching devices are failure free. If the system contains two elements. A and B, the reliability function has been given by Welker[8] as follows: The system will be successful at time t if either of the following two conditions holds (lettering A be the primary element):

i) A succeeds up to time t, or

ii) A fails at time $t_1 < t$ and B operates from t_1 to t.

The following diagram represents these two conditions:



Translation of the two conditions above to time dependent probabilities gives

$$R(t) = \int_t^\infty f_a(t)dt + \int_0^t \{f_a(t_1) \int_{t-t_1}^\infty f_b(t)dt\}\, dt,$$

where f(t) is the time-to-failure density function of an element. The first term of this equation represent the probability that element A will succeed until time t. The second term excluding the outside integral, is the density function of a failing exactly at t_1 and B succeeding for the remaining $(t-t_1)$ hour. Since t_1 can range from 0 to t, t_1 is integrated over that range. For exponential case where the element failure rates are λ_a and λ_b,

$$R(t) = \frac{\lambda_b}{\lambda_b-\lambda_a} \exp(-\lambda_a t) - \frac{\lambda_a}{\lambda_b-\lambda_a} \exp(-\lambda_b t)$$

which is a form of the mixed exponential. It can be shown that it does not matter whether the more reliable element is used as the primary or the standby element.

if $\lambda_a = \lambda_b = \lambda$,

$$R(t) = \exp(-\lambda t)(1+\lambda t)$$

For n elements of equal reliability

$$R(t) = \exp(-\lambda t) \sum_{r=0}^{n-1} \frac{(\lambda t)^r}{r!}$$

3.2 Distribution System Reliability

Distribution networks are the parts of power systems that deliver energy from the area supply stations to the customers, and often include the networks of local or municipal utilities. From the customers point of view, the reliability of these system is at least as important as the reliability of generation and transmission. A major part of service intruptions experienced by an individual customer has its origin in failures in the distribution system. In comparison with the transmission networks, distribution system generally have a much simpler layout. Most are radial arrangements, and the components involved in the supply of a customer are in a series connection.

3.2.1 Radial System with Perfect Switching

Load Point Reliability

The reliability indices at a given load point depend on the path of supply between that point and the source bus. The components on this path can be considered in series; those that are in a parallel connection are represented by equivalents in the series configuration. If all component availabilities are higher, then the frequency of failures fF_{mn} at a load point situated on branch n, zone m, can be computed as

$$fF_{mn} = \sum_{\alpha\varepsilon MN} \lambda_\alpha \tag{3.2.1}$$

where MN is the set of components on the path leading to and including the branch mn. The mean duration of system failure is

$$T_{F_{mn}} = \frac{\sum_{\alpha\varepsilon MN} \lambda_\alpha \mp_\alpha}{\sum_{\alpha\varepsilon MN} \lambda_\alpha} \tag{3.2.2}$$

Two parallel components A and B can be combined into a single equivalent α by using the equation for system of parallel components. The equivalent failure rate λ_α is approximately equal to the frequency of the double failure state $\bar{A}\ \bar{B}$, and therefore λ_α can be obtained as

$$\lambda_\alpha \simeq \lambda_A \lambda_B (T_A + T_B) \qquad (3.2.3)$$

The equivalent downtime T_α can be computed as

$$T_\alpha = 1/(\mu_A + \mu_B) = T_A T_B/(T_A + T_B) \qquad (3.2.4)$$

where the repair rates μ_A and μ_B are the reciprocals of the respective component repair times T_A and T_B. If a branch contains two components in parallel where, after a failure, both are tripped and service is restored by isolating the failed component and reconnecting the other through appropriate switching the equivalent failure rate λ_α becomes

$$\lambda_\alpha = \lambda_A + \lambda_B$$

and the mean down time is the mean switching time T_S.

System Reliability

While from the customer's point of view the load point reliability is of primary interest, indices are also available to measure the overall reliability performance of the entire system. Most of these indices are weighted averages of the load point indices over the whole system. Thus an over-all failure frequency index f_F can be defined as the total frequency of customer interruptions per customer served, and calculated by the equation.

$$f_F = \frac{\sum_{mn} C_{mn} \, f_{F_{mn}}}{\sum_{mn} C_{mn}} \tag{3.2.5}$$

where the load point frequencies are weighted by C_{mn}, the number of customers on branch mn. The mean system failure duration T_F can be defined as the average customer down-time, and computed as the total duration of customer interruptions per year devided by the number of customer interruptions per year.

$$T_F = \frac{\sum_{mn} C_{mn} \, f_{F_{mn}} \, T_{F_{mn}}}{\sum_{mn} C_{mn} \, f_{F_{mn}}} \tag{3.2.6}$$

In some publications, the mean customer down-time is interpreted without the use of the weights $f_{F_{mn}}$; that is, the mean system failure duration T_F' is calculated from the equation:

$$T_F' = \frac{\sum_{mn} C_{mn} \, T_{F_{mn}}}{\sum_{mn} C_{mn}} \tag{3.2.7}$$

Note that if the $T_{F_{mn}}$ values are not too far apart, $T_F \simeq T_F'$.

Another system reliability index frequency used is the average total interruption time per customer per year. This index, H_F, can be calculated from:

$$H_F = \frac{\sum_{mn} C_{mn} \; f_{F_{mn}} \; T_{F_{mn}}}{\sum_{mn} C_{mn}} \qquad (3.2.8)$$

From the above equation it is evident that

$$T_F f_F = H_F$$

3.2.2 Radial System with Imperfect Switching

It has pointed out previously that switching devices have the peculiar property of being able to develop several distinct types of failures. Each of these types, or failure modes, have a different effect on the system. In the following discussions, two of the switching equipment failure modes will be considered: false operations, and failures to operate when operation is required.

False Breaker Operations

A false operation (opening) of a breaker has essentially the same effect on the system as the failure of the corresponding branch. The duration of the ensuring interruption of service is, however, much shorter; it will last the time needed to reclose the breaker.

Breaker Failure to Operate - System Models

The evaluation of the effects of breaker failures to operate is somewhat more complex. Evidently any load point can be affected by a failure in any branch, if enough breakers on the path to the fault refuse to operate. A state space model to describe all the possibilities can be quite involved, and certain simplifications are needed to make the model more manageable.

Breaker Failure to Operate - load Point Indices

With perfect breakers, service at a given load point is interrupted only if a branch fail on the path between the source and the load point. If there is a possibility of breakers refusing to operate, service interruptions at the same load point can also occur as a result of failure in other branches. The causes of interruptions at a load point can be divided into the following categories.

(a) Failures of branches between the source bus and the load point.

(b) Failures of branches in higher zones than the zone of the load point, if the load point is on the path between the failed branch and the source, and if all breakers between the failed branch and the load point are stuck.

(c) Failures of branches elsewhere in the system, if the path to the failed branch and to the load point have a common section, and enough breakers fail to operate on the former path to cause an interruption of the latter.

Consider, for example, a load point on branch 21 in Fig. (3.2.1). A failure of type (a) would be the failure of branch 11; a failure of type (b) the failure of branch 41, with both B_{41} and B_{33} refusing to operate; a failure of type (c) the failure of branch 34, with both B_{34}, and B_{22} stuck, forcing B_{11} to operate.

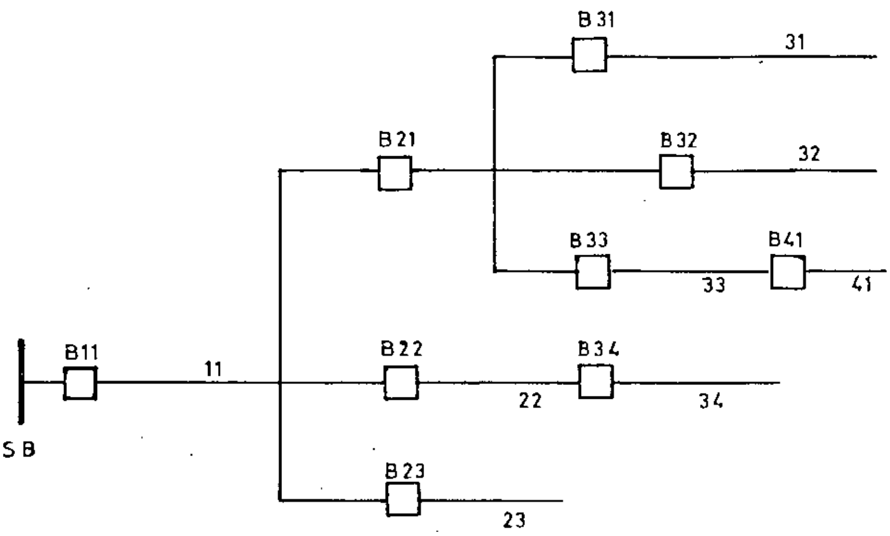


FIG - 3·2·1

3.2.3 A Looped System

A departure from the radial network concept is exhibited by the system shown in Fig. (3.2.2). While under normal conditions the normally open switch (NO) is open and therefore, the system operates like a radial network, upon a failure in one of the feeder sections, that section is isolated by the switches on both ends and the NO switch is closed; thus supply is provided as in a looped system to the customers at the far side of the failure, who would be left without service in a radial network.

In the following discussion, three alternatives of the system in Fig. (3.2.2) will be evaluated.

(a) The system as shown

(b) The system with all the switches in the main feeders permanently shorted and the NO switch removed. This would represent a radial operation.

(c) The system with only the NO switch removed. This represents a radial operation with somewhat more flexibility than in (b).

Case(a): The calculation of the load-point failure frequencies is exactly the same as for a radial system (the NO switch is open during normal operation). These frequencies are, therefore, given by Eqn. (3.2.1). For example, the frequency of interruptions at load point LP_7 becomes,

$$f_{F_7} = \lambda_1 + \lambda_2 + \lambda_{20} + \lambda_{18} + \lambda_{16} + \lambda_{14} + \lambda_{12} + \lambda_{17} \quad (3.2.9)$$

The mean failure durations at the various load points are given by Eqn.(3.2.2). In the case of LP_7, for example, the mean duration of interruptions, T_{F_7} is given by

$$T_{F_7} = 1/f_{F_7}\{\lambda_1 T_1 + \lambda_2 T_2 + \lambda_{16} T_{16} + \lambda_{17} T_{17} + (\lambda_{20} + \lambda_{18} + \lambda_{14} + \lambda_{12}) T_s\} \quad (3.2.10)$$

where, T_s = switching time

The overall system indices can be computed as before by Equations (3.2.5), (3.2.6) and (3.2.8).

Case(b): If all the switches in the feeders are shorted and the NO switch is removed, the system is reduced to a radial network which can be solved by the approach described in section (3.2.2). Four zones can be defined; zone 1 contains component 1, zone 2 component 2, zone 3 components 3,5,7,9, 11,12,14,16,18 and 20 and zone 4 components 4,6,8,10,13,15, 17, and 19.

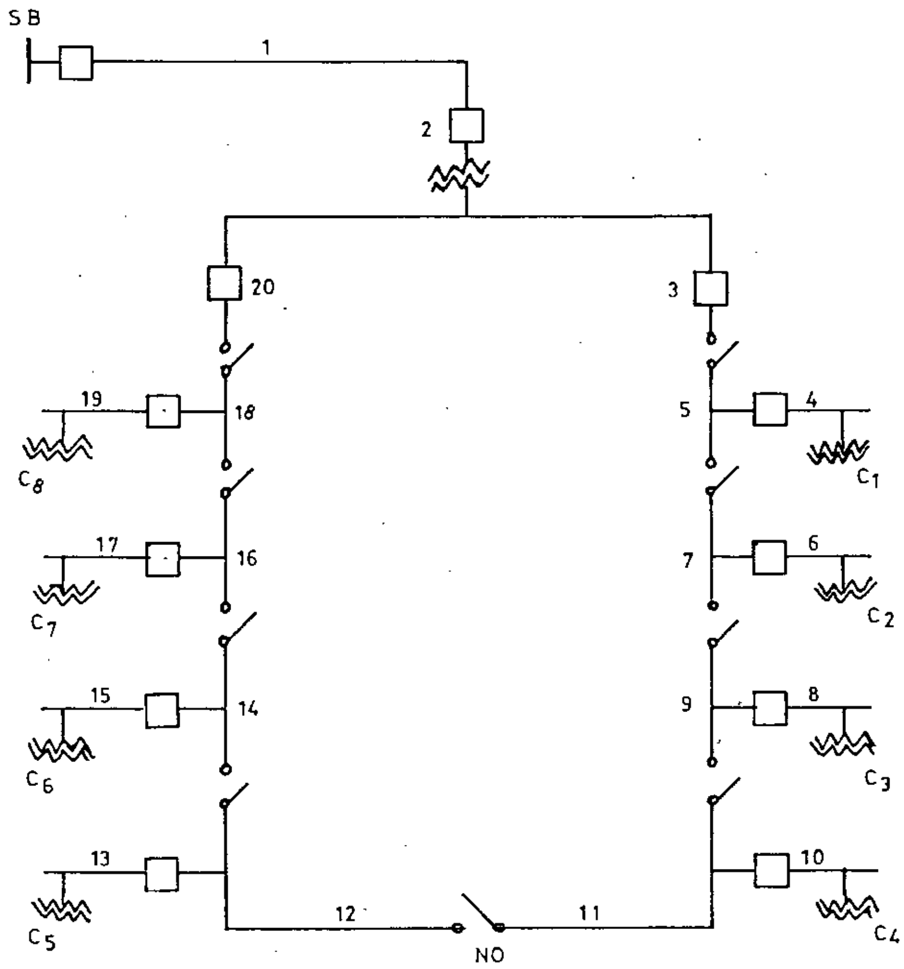


FIG-3.2.2

Case(c): If only the NO switch is removed, a radial system is obtained which, nevertheless, retains some switching facilities. There are 8 zones now, the failure frequencies are one again the some as in the case(a). The mean durations of interruptions at the various load points must be computed with a careful consideration of which failures can and which cannot be isolated from the load point in question. Considering LP_7, for example, the mean duration T_{F_7} is obtained as:

$$T_{F_7} = 1/f_{F_7}\{ \lambda_1 T_1 + \lambda_2 T_2 + \lambda_{16} T_{16} + \lambda_{17} T_{17} + \lambda_{18} T_{18} + \lambda_{20} T_{20} + (\lambda_{14} + \lambda_{12}) T_s\} \quad (3.2.11)$$

because when feeder sectors 14 or 12 fail, the failed sectors can still be isolated from LP_7 by switching while this does not hold for failures in 16, 17, 18 or 20. The mean downtimes now are in between their corresponding values in cases (a) and (b).

Note that, with a slight modification of the procedure in (a), such constraints as a restricted load capacity of the NO switch or a limited capacity of portions of the loop to supply load beyond their normal share can also be considered.

CHAPTER 4

DESIGN FEATURE OF 60 MW POWER PLANT AND KHULNA INDUSTRIAL ZONE DISTRIBUTION SYSTEM

4.1 PlantCapacity, Description and Control System

4.1.1 Power Plant Capacity

Rated out put capacity = 60,000 KW.

Speed = 3,000 R.P.M.

Rated Max. stem temperature before starting valve=535^{o}C

Max. steam temperature before starting valve = 545^{o}C

Rated steam pressure before starting valve = 90 Atm.a

Max. steam pressure before starting valve = 101 Atm.a

The following are the rated capacity of major equipments.

Equipments	Capacity
Boiler	260 ton/hour
Condenser (cooling area)	4,400 sq. metres
Water jet vacuum pump	450 cu. metres
Circulating water pump (C.W)	11,300 cu.metres/hr.
Horizontal lift pump	468 cu. metre/hr.
Condensate pump for Hydrogen cooling	230 cu. metre/hr.
Feed pump	310 tons/hour
F.D. Fan	38 cu.metre/sec.
I.D. Fan	70 cu. metre/sec.

4.1.2 Power Plant Description

The turbine of 60 MW steam power plant is two cylindric, condensing, impulse turbine with 5 non-regulated steam extractions. Regulation is done by means of 4(four) nozzle valves. This has high pressure and low pressure cylinders.

All the three rotors viz. High pressure cylinder, Low pressure cylinder and the generator rotor are connected by coupling.

The turbine is rotated by (passing) super heated steam with pressure and temperature of 1365 psi and 540^{0}C, generated in a boiler of capacity 260 tons/hr. The available heat energy is utilized by the turbine to role the generator.

There are nine burners in the boiler. For full capacity of the boiler at a time 7 burners are required to glow. The pressure atomising type burner produces atomisation by discharging the fuel through a small orifice aided by a sloted disc. The oil system is shown in Fig. 4.1.1.

In the lower and upper part of the combustion chamber, the boiler tubes are expanded into headers. The lower headers are fed through feed tubes or downcomers from the drum. The steam water mixture discharges through from the upper headers back into the drum.

Most economical operation at all loads indicates that a constant steam temperature at all steam flow is desirable

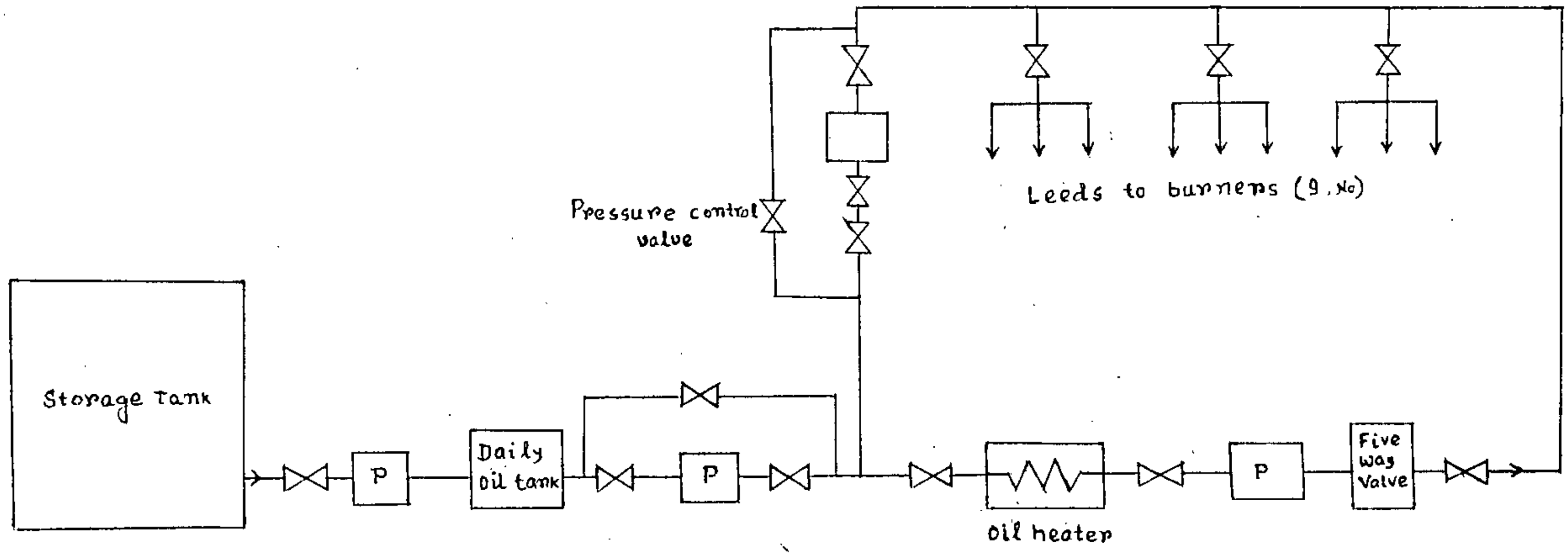


Fig. 4.1.1 Schematic Diagram of Oil System in the Simplest Form.

since super heat temperature decreases with increase of load for a radient type super heater and convection super heater performs in the opposite manner. They are installed in combination to get a flat charæteristics of temperature at all loads. The steam flows from the drum into the inlet part which form the first stage (radient), located in the front wall of the combustion chamber, while the second stage (convention part) is formed by vertically arranged spiral tubes, behind this, third stage (radient) is located, the exit part is formed by the fourth stage (convection). The steam mass then flows into the outlet piping towards the turbine. Flow diagram is shown in Fig. 4.1.2 and also shown by block diagram 4.1.3. Super heater diagram is shown in Fig. 4.1.4.

Exhaust steam from the turbine is condensed in the condenser cooled by the river water supplied by the circulating water pump (cooling water pump), two in number, one is stand by. The condensate water is pumped through the Low pressure heater into the feed tank. From feed tank the feed water is fed into the boiler drum through the High pressure Heater and Economizer by the feed pump. There are two feed pumps; one is always standby. The make up water is supplied from the water treatment plant which is shown in Fig.4.1.5.

The Economizer is made up of two stages. The feed water flows through the 1st stage and from it across a condenser where it condenses steam (the condensate is used for the

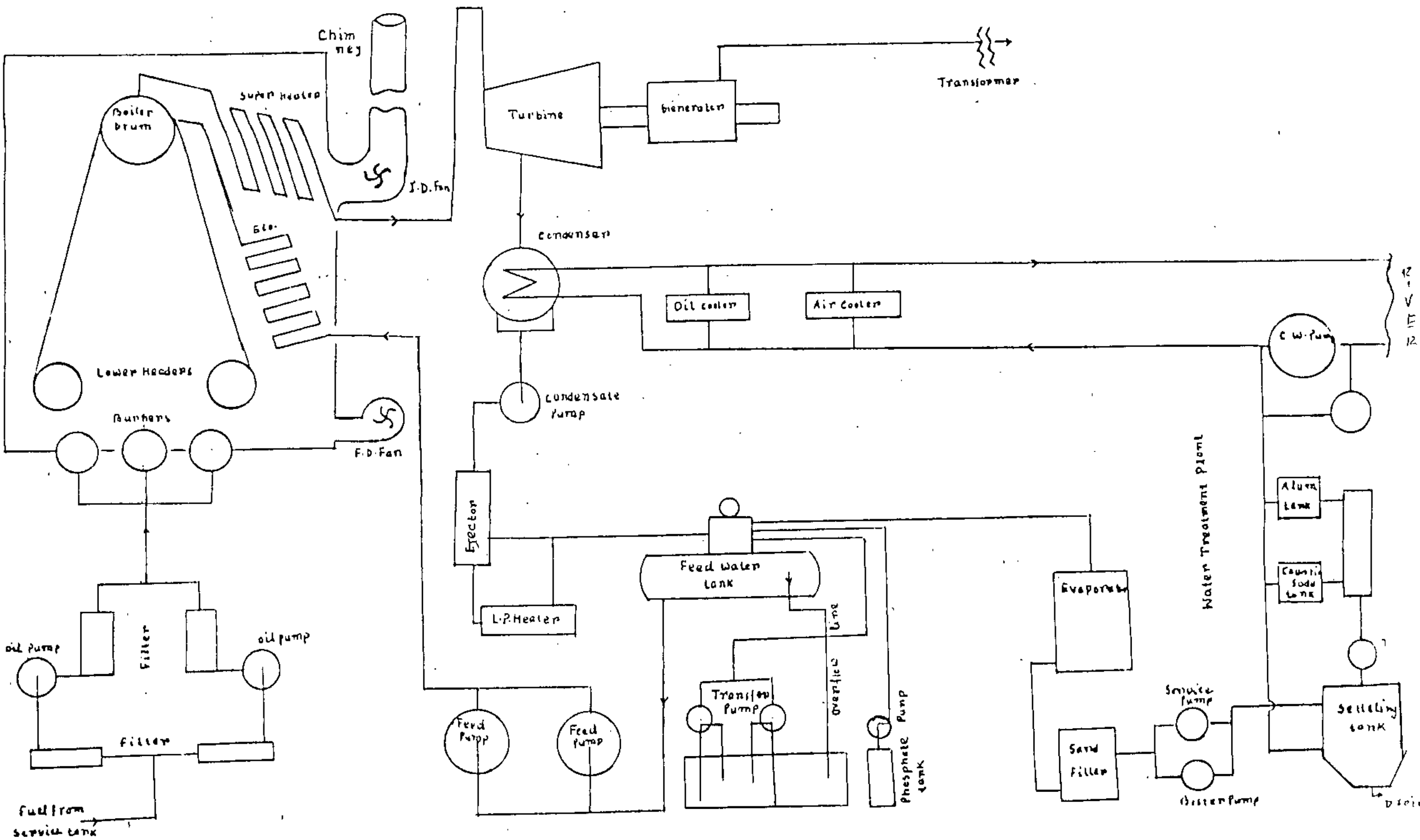


Fig. 4.1.2 Flow Diagram of the Plant.

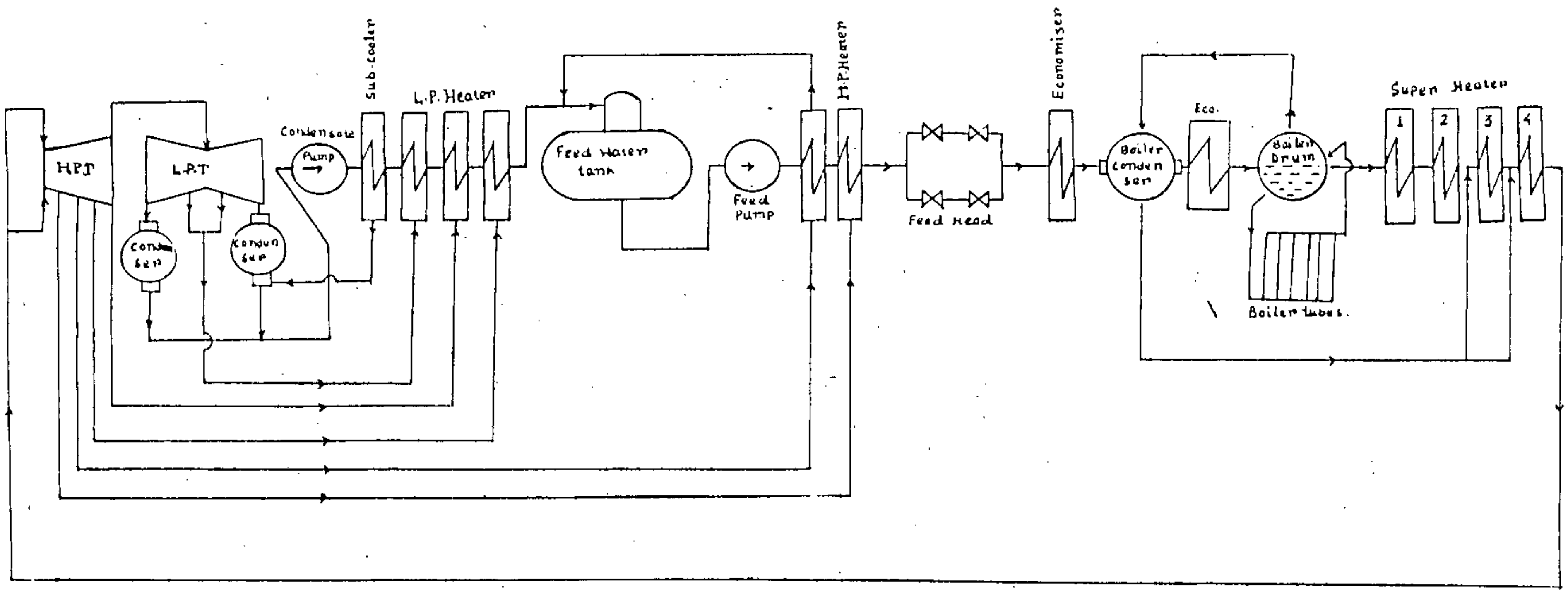


Fig. 4.1.3. Block Diagram of the Plant.

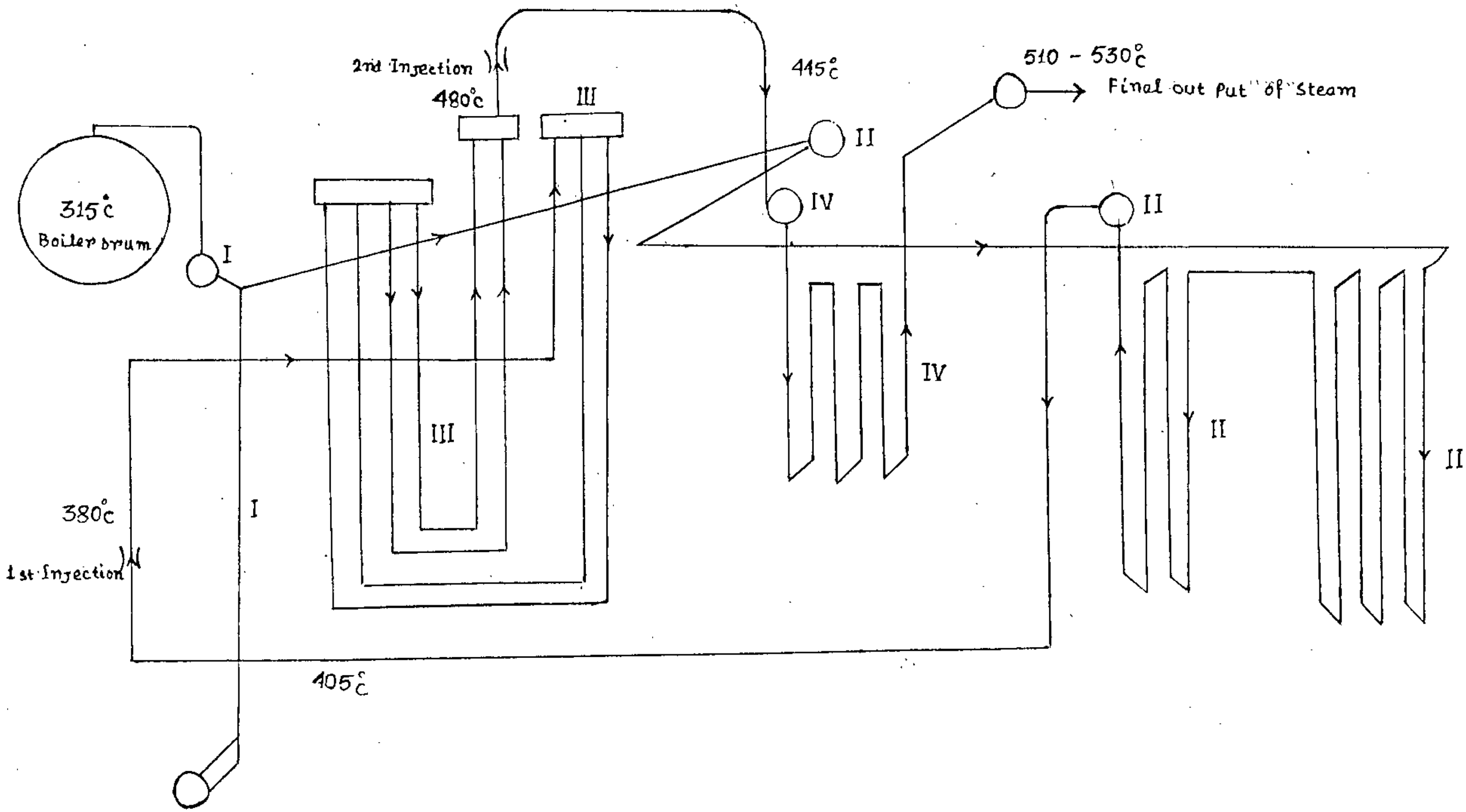


Fig. 4.1.4 Super heater Diagram.

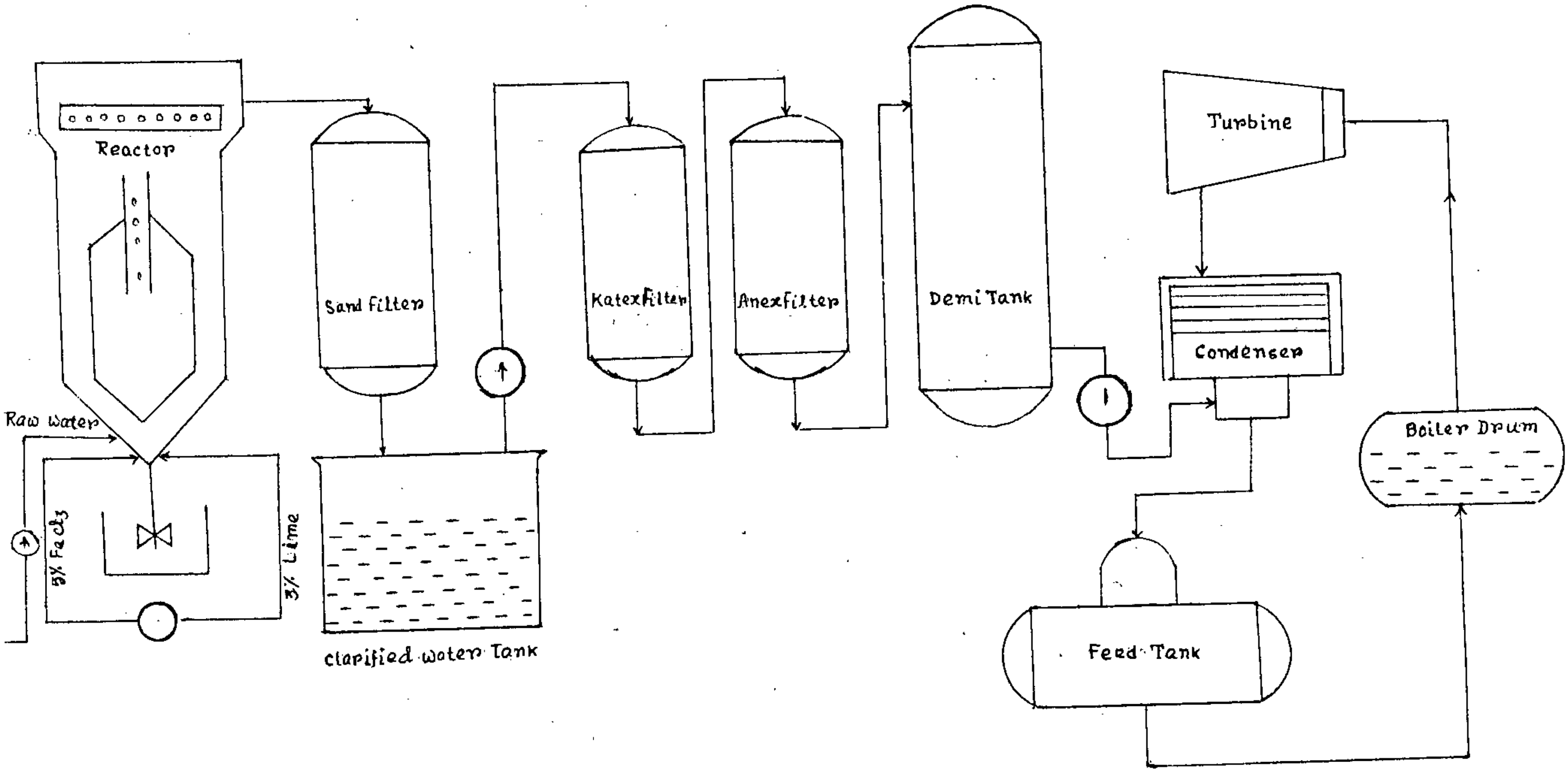


Fig. 4.1.5 Water Treatment Plant

control of super heated steam temperature by injection method) and then into the 2nd stage. From the second stage water flows into the drum.

The airheater is used so that the air flows through the tubes while flue gases flow perpendicularly outside the tubes.

The steam heated air preheater serves for preheating combustion air before it enters the air heater. The air is preheated to 70^{o}C where by flue gases, are prevented to cool below their dew point at the end of the air preheater. The purpose is to eleminate danger of corrosion.

4.1.3 Continuous Automatic Regulation of Process in the Boiler

The automatic control system of boiler operation enables to keep automatically the system parameters on the prescribed value, with an economical burning of black oil. It equally keeps the water level in the drum at the normal height to avoid trouble for the prevention of the superheated steam quality. The basic regulating circuits are:

a) Feed water control

b) Super heated steam temperature control

c) Combustion control.

(a) Feed water control

This control is of three pulses, with main signal from the water level in the drum and auxiliary signals from the quality of steam and feed water. These auxiliary signals are connected to the central regulator. All signals are generated in the adaptor for induction transmission to unit signal and processed by the centrally regulated proportional integrating method. The boiler has two independent feed water lines only one of them being in operation while the other forms a 100% reserve. Fig. 4.1.6.

(b) Superheated steam temperature control

It is governed by a signal from the superheated steam temperature behind the superheater. In the injection type hot water is sprayed directly into the steam (in between super heater no. II and III and IV). The water is evaporated into the steam and the temperature of the mixture is reduced. The carryingout member here is the injection control valve.

(c) Combustion control

This control is composed of

1) Black oil quantity control
2) Air quantity control
3) Draught control in the combustion chamber.

1) Black oil quantity control: The main signal is from the steam pressure at the boiler exit. The pressure is maintained constant by the change of the oil supply in the case of

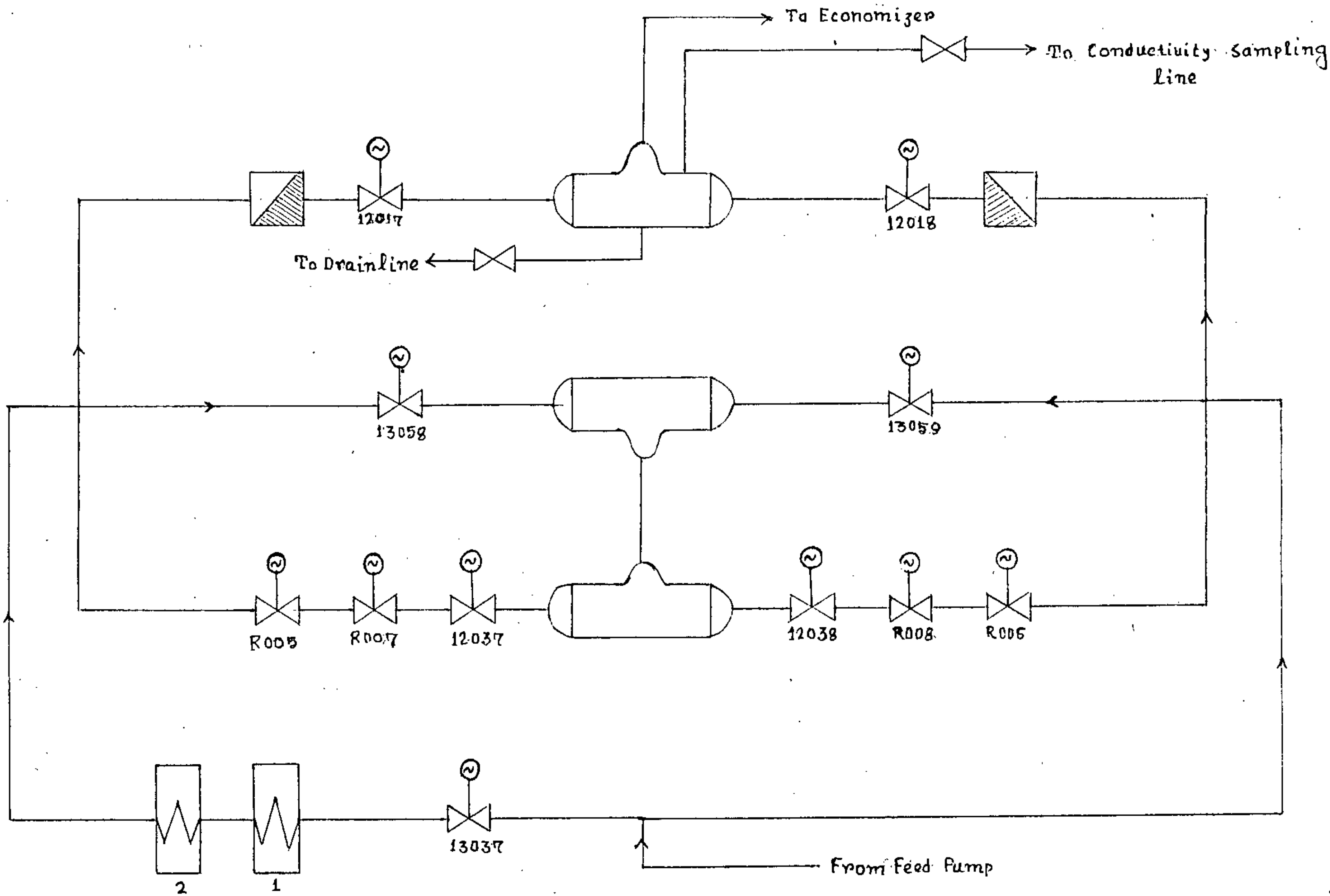


Fig. 4.1.6 Feed Water Control Circuit.

various loads of the boiler. The oil system is shown in Fig. 4.1.1.

2) Air quantity control: In order that the combustion process in the boiler is accomplished under optimum condition it is necessary to maintain a correct ratio between the quantity of air and fuel supplied to the boiler. And this regulation receives impulse from the fuel quantity and from carbon content in combustion products. The working members of the air control are the forced draught fans.

3) Draught control: The control signal is the draught or under pressure in the combustion chamber. The feed back is from the quantity of flue gases as measured, on the diffusers of drafts fans. The working member here are the control dampers of the axial regulation of induced draft fans.

4.2 Network Diagram of Distribution Area

Distribution network is a part of power system that delivers energy from the area supply station to the customers. A single-line diagram of Khulna industrial area (Khalispur) electric supply is shown in Fig. 4.2.1. In the figure only the study area is shown. Electricity is supplied to this area from three sub-stations, namely - Khalispur sub-station, Gate sub-station, Kohinoor sub-station. Supply to these sub-stations comes from 33 KV bus. Each sub-station has got one 33/11 KV transformer and from the sub-stations the load points (distribution transformers) are fed through six feeders. There are 23 (twenty three) distribution transformers (load points) under the study area. The feeders and distribution transformers are listed below:

Name of feeders	Locations
B.I.D.C. feeder	31
Khalispur feeder	32
Kohinoor feeder	33
Star + Crescent feeder	34
Charerhat fish Co. feeder	35
Rerolling feeder	36

Load points	Name	Locations
LP_1	Kashipur X-former	41
LP_2	Infront of Chitralli cinema	42
LP_3	Behind Chitralli cinema	43
LP_4	Infront of gate S/S	44
LP_5	Infront of Crescent	45
LP_6	Infront of Platinum	46
LP_7	Lal Hospital	47
LP_8	Goal Park	48
LP_9	Khalispur Pump	49
LP_{11}	K.I.T.C.	51

Load points	Name	Location
LP_{12}	Mohsin College	52
LP_{13}	Tintala Building	53
LP_{14}	Paurasava	54
LP_{15}	Kohinoor S/S	55
LP_{16}	T & T (Private)	56
LP_{17}	Infront of T & T	57
LP_{18}	Bihari Bazar	58
LP_{19}	Kadamtala	59
LP_{21}	Infront of Rerolling mill	61
LP_{22}	Rerolling mill	62
LP_{23}	Public Health	63
LP_{24}	Charerhat fish Co.	64
LP_{25}	Naval base	65

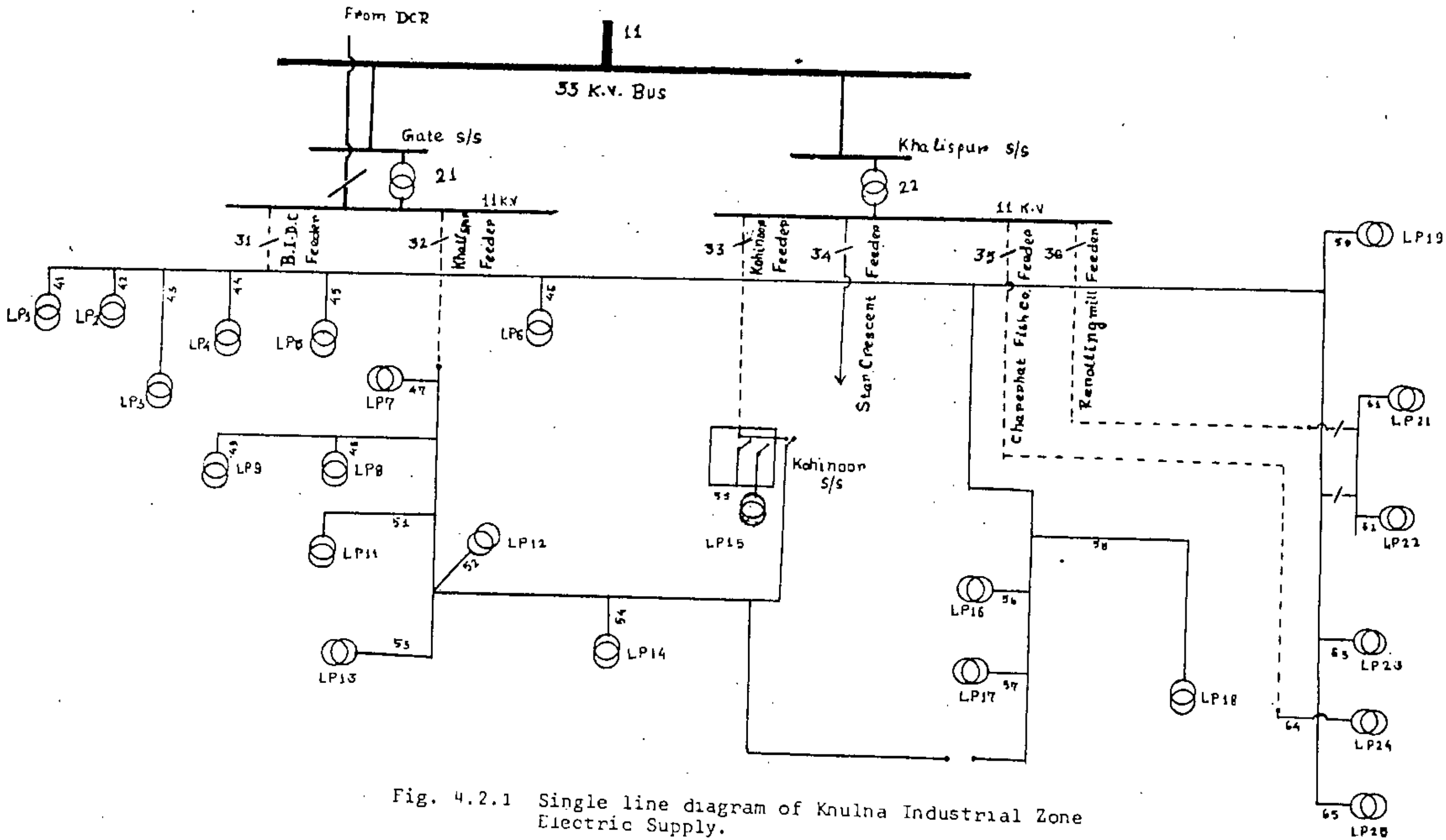


Fig. 4.2.1 Single line diagram of Knulna Industrial Zone Electric Supply.

CHAPTER 5

DATA COLLECTION AND DATA ANALYSIS

5.1 Power Plant Failures

5.1.1 Failure History of Khulna 60 MW Steam Power Plant

Without proper data collection and subsequent analysis it is not possible to predict operational reliability for any machine. In plant failure history, date and time of failure and startup, causes of failures and troubles, repairing time taken for the remedial measures as well as down time resulted for the failure of equipments and machinaries etc. are included. These are collected from the operational department of the plant. Plant failure records for five years (January 1979 to December 1983) have been considered for the present analysis. In this five year period there was a major overhaul, spanned from February 1981 to March 1982; so, the net period over which failures have recorded is four years. The failure history has been presented in Appendix-A and the proforma used for data collection is shown below.

Stopping time		Starting time		Down-time (hrs.)	Causes of failure		Remedial measures/ Remarks
Date	Time (hrs.)	Date	Time (hrs.)		Equip-ment failed	Cau-ses	
1	2	3	4	5	6	7	8

5.1.2 Operating Time Calculation of Equipment

In calculating operating time, the running periods for each items are seperated from the period considered (January 1979 to December 1983) in the failure history of the plant. By this way, operating times in between failures of each major equipment of the plant and the plant are calculated and are shown in Table 5.1.

The symbols used in column 4 & 9 of Table 5.1. are as follows:

M.F - Mechanical Fault, E.F - Electrical Fault, F.S - False Signal, I.F - Instrumental Fault, O.F - Operational Fault, L.F-Logistic induced Fault, O.H - Overhauling and * - Failure.

Table 5.1 Operating Time calculation of Equipments in Power Plant.

Equipment	Starting		Stopping		Operating time (days)	Down time (hrs)	Repair time (hrs)	Causes of failure
	Date	Time	Date	Time				
1	2	3	4	5	6	7	8	9
Power Plant	1.1.79	00.00	24.1.79	23.00	23.95	12.00	12.00	O.H
	25.1.79	11.00	*26.1.79	12.88	1.07	2.36	2.36	M.F
	26.1.79	15.45	* 3.2.79	7.98	7.70	8.51	-	L.F
	3.2.79	16.50	7.2.79	00.79	3.34	8.22	8.22	O.H
	7.2.79	9.00	* 8.2.79	15.50	1.28	2.76	-	E.F
	8.2.79	18.26	10.2.79	00.46	1.26	29.56	29.56	O.H
	11.2.79	6.03	*21.2.79	7.91	10.08	4.58	-	L.F
	21.2.79	12.50	*23.2.79	4.00	1.64	14.58	-	L.F
	23.2.79	18.59	*20.3.79	8.91	24.60	2.24	-	E.F
	20.3.79	11.16	30.3.79	23.08	10.50	201.44	201.44	O.H
	8.4.79	18.51	* 9.4.79	19.33	1.04	23.75	23.75	M.F
	10.4.79	15.08	*13.4.79	11.83	2.86	1.08	-	E.F
	13.4.79	12.91	*14.4.79	13.25	1.01	43.25	43.25	M.F
	16.4.79	8.50	17.4.79	20.60	1.52	21.78	21.78	O.H
	18.4.79	18.58	*20.4.79	7.05	1.51	25.61	-	E.F
	21.4.79	8.66	22.4.79	13.26	1.21	48.82	48.82	O.H
	24.4.79	14.08	*30.4.79	12.75	5.94	1.58	-	E.F
	30.4.79	14.33	7.5.79	5.66	6.63	28.67	28.67	O.H
	8.5.79	10.33	23.5.79	4.60	14.76	28.90	28.90	O.H

Table 5.1 (Contd..)

1	2	3	4	5	6	7	8	9
	24.5.79	9.50	*2.6.79	4.33	8.78	4.58	-	E.F
	2.6.79	8.91	*9.6.79	19.53	7.44	2.13	2.13	M.F
	9.6.79	21.66	11.6.79	10.11	1.53	140.79	140.79	O.H
	17.6.79	6.90	*18.6.79	10.39	1.16	1.91	1.91	M.F
	18.6.79	12.30	*23.6.79	11.66	4.98	2.79	2.79	"
	23.6.79	14.47	*30.6.79	15.16	7.03	2.50	-	E.F
	30.6.79	17.66	1.7.79	23.79	1.24	24.92	24.92	O.H
	3.7.79	00.70	7.7.79	23.91	4.96	21.40	21.40	"
	8.7.79	21.31	*11.7.79	18.88	2.90	00.20	-	F.5
	11.7.79	19.08	26.7.79	23.66	15.20	30.33	30.33	O.H
	28.7.79	6.00	*29.7.79	17.13	1.47	1.58	1.58	M.F
	29.7.79	18.71	31.7.79	22.60	2.16	38.60	38.60	O.H
	2.8.79	13.20	*3.8.79	19.58	1.27	21.25	21.25	M.F
	4.8.79	16.83	*5.8.79	13.91	0.84	3.00	3.00	"
	5.8.79	16.08	*7.8.79	1.53	1.39	1.41	1.41	O.F
	7.8.79	2.93	*8.8.79	15.25	1.50	2.33	2.33	"
	8.8.79	17.58	*9.8.79	13.29	0.82	1.47	1.47	"
	9.8.79	14.75	23.8.79	0.16	13.39	130.34	130.34	O.H
	28.8.79	10.50	*29.7.79	11.28	1.05	1.57	1.57	O.F
	29.8.79	12.83	*30.8.79	21.50	1.66	1.66	-	"
	30.8.79	23.16	1.9.79	23.05	1.99	25.77	25.77	O.H
	3.9.79	0.91	18.9.79	23.91	15.95	116.00	116.00	"
	23.9.79	19.91	*27.9.79	12.20	3.68	0.25	-	F.S
	27.9.79	12.45	30.9.79	0.08	2.48	25.67	25.67	O.H
	1.10.79	1.75	*9.10.79	13.25	8.48	2.00	2.00	O.F
	9.10.79	15.25	12.10.79	17.97	3.11	19.44	19.44	O.H
	13.10.79	13.41	*17.10.79	17.53	4.17	0.57	0.57	L.F
	17.10.79	18.10	28.10.79	23.75	11.23	22.83	22.83	O.H
	29.10.79	22.58	*31.10.79	23.50	2.03	5.11	-	F.S
	1.11.79	4.61	10.11.79	23.33	9.78	14.25	14.25	O.H
	11.11.79	13.58	21.11.79	22.90	10.38	11.46	11.46	O.H
	22.11.79	10.66	*4.12.79	1.41	11.61	3.09	3.09	M.F
	4.12.79	4.50	5.12.79	23.16	1.77	103.09	103.09	O.H
	10.12.79	6.20	*.12.12.79	6.75	2.02	0.17	-	O.F
	12.12.79	6.91	*13.12.79	8.25	1.07	3.80	3.80	E.F

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
	13.12.79	12.05	*17.12.79	9.33	3.88	2.17	-	O.F
	17.12.79	11.50	*19.12.79	21.41	2.41	9.84	-	E.F
	20.12.79	7.25	*21.12.79	7.45	1.02	1.66	1.66	M.F
	21.12.79	9.41	*30.12.79	2.00	8.69	8.15	8.15	E.F
	30.12.79	10.15	5.1.80	10.75	6.02	84.62	84.62	O.H
	8.1.80	23.37	*14.1.80	1.26	5.08	2.72	2.72	O.F
	14.1.80	4.00	15.1.80	11.75	1.33	13.75	13.75	O.H
	16.1.80	1.50	18.1.80	11.58	2.42	62.55	62.55	"
	21.1.80	2.13	27.1.80	4.39	6.09	14.02	14.02	"
	27.1.80	18.41	16.2.80	5.25	19.45	17.50	17.50	"
	16.2.80	22.75	18.2.80	11.16	1.26	163.17	163.17	"
	25.2.80	6.33	28.2.80	22.16	3.66	8.17	8.17	"
	29.2.80	6.33	2.3.80	7.61	2.05	14.39	14.39	"
	2.3.80	22.00	15.3.80	23.21	13.05	31.42	31.42	"
	17.3.80	6.63	23.3.80	0.60	5.75	39.18	39.18	"
	24.3.80	15.76	*28.3.80	8.41	3.70	2.84	-	E.F
	28.3.80	11.25	30.3.80	0.08	1.54	22.00	22.00	O.H
	30.3.80	22.08	1.4.80	22.33	2.01	158.05	158.05	"
	8.4.80	12.39	10.4.80	6.75	1.76	154.25	154.25	"
	16.4.80	7.00	18.4.80	22.66	2.65	47.72	47.72	"
	20.4.80	22.39	*22.4.80	0.01	1.10	0.95	0.95	M.F
	22.4.80	0.96	*23.4.80	8.50	1.32	3.93	3.93	"
	23.4.80	12.43	26.4.80	22.73	3.43	59.52	59.52	O.H
	29.4.80	10.25	3.5.80	8.36	3.92	11.47	11.47	"
	3.5.80	19.83	*5.5.80	12.58	1.69	4.16	-	E.F
	5.5.80	16.75	*9.5.80	10.75	3.92	2.08	-	"
	9.5.80	12.83	*18.5.80	7.91	8.80	14.13	14.13	O.F
	18.5.80	22.05	*23.5.80	9.11	4.46	2.39	-	E.F
	23.5.80	11.50	26.5.80	9.83	2.93	888.53	888.53	O.H
	2.7.80	10.36	*4.7.80	7.75	1.89	6.83	-	E.F
	4.7.80	14.58	*6.7.80	12.08	1.90	4.00	-	"
	6.7.80	16.08	18.7.80	16.00	12.00	278.47	278.47	O.H
	30.7.80	6.46	1.8.80	23.10	2.70	418.33	418.33	"
	19.8.80	9.43	5.9.80	23.75	17.60	456.33	456.33	"

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
	25.9.80	0.08	*26.9.80	9.25	1.38	196.15	196.15	M.F
	4.10.80	13.40	*15.10.80	18.16	11.94	90.12	90.12	F.S
	19.10.80	12.29	*8.11.80	13.66	20.05	129.62	129.62	M.F
	13.11.80	23.29	22.11.80	8.41	8.38	9.92	9.92	O.H
	22.11.80	18.33	*23.11.80	19.25	1.06	73.83	73.83	M.F
	26.11.80	21.08	*29.11.80	16.25	2.80	72.33	72.33	"
	2.12.80	16.58	*3.12.80	16.75	1.00	11.08	11.08	"
	4.12.80	3.83	* 6.12.80	7.16	2.13	145.79	145.79	"
	12.12.80	8.95	*16.12.80	3.85	3.78	57.40	57.40	"
	18.12.80	13.25	10.1.81	22.25	23.37	64.25	64.25	O.H
	13.1.81	14.50	16.1.81	11.33	2.87	29.82	29.82	"
	17.1.81	17.15	31.1.81	21.91	14.19	41.72	41.72	"
	2.2.81	15.63	*8.2.81	7.75	5.67	-	-	M.F
	7.4.82	3.01	*8.4.82	5.75	1.14	1.28	1.28	"
	8.4.82	7.03	*9.4.82	10.58	1.44	0.17	0.17	"
	9.4.82	10.75	*10.4.84	14.00	1.15	6.50	6.50	"
	10.4.82	20.50	*17.4.82	10.75	6.60	7.66	--	E.F
	17.4.82	18.41	*23.4.82	8.46	5.58	1.56	1.56	O.F
	23.4.82	9.93	30.4.82	23.23	7.55	50.52	50.52	O.H
	3 5.82	1.74	27.5.82	23.24	24.90	61.70	61.70	"
	30.5.82	12.95	*29.6.82	11.16	29.92	9.66	19.66	O.F
	29.6.82	20.83	*1.7.82	9.70	1.55	2.39	2.39	"
	1.7.82	12.08	*3.7.82	2.20	1.42	15.40	15.40	"
	3.7.82	17.70	*5.7.82	0.91	1.30	509.65	509.65	M.F
	26.7.82	1.56	1.8.82	22.86	6.88	195.55	195.55-	O.H
	5.8.82	21.41	*25.8.82	2.50	19.21	74.12	74.12	M.F
	28.8.82	23.61	1.9.82	23.08	3.98	14.92	14.92	O.H
	2.9.82	14.00	*3.9.82	23.00	1.37	1.33	1.33	O.F
	4.9.82	0.33	*5.9.82	5.59	1.22	7.33	7.33	"
	5.9.82	12.91	*10.9.82	21.41	5.35	1.42	1.42	"
	10.9.82	22.83	*12.9.82	6.00	1.31	5.91	5.91	"
	12.9.82	11.91	*13.9.82	22.91	1.45	1.50	1.50	"
	14.9.82	0.41	17.9.82	21.83	3.90	26.27	26.27	O.H
	19.9.82	0.10	*20.9.82	11.10	1.49	2.75	2.75	O.F
	20.9.82	13.85	*21.9.82	14.41	1.12	1.75	1.75	"

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
	21.9.82	16.16	27.9.82	23.50	6.30	121.75	121.75	O.H
	3.10.82	1.25	*4.10.82	6.21	1.20	5.78	5.78	O.F
	4.10.82	12.00	*15.10.82	5.00	10.70	7.33	7.33	"
	15.10.82	9.33	*26.10.82	9.10	10.99	2.06	2.06	E.F
	26.10.82	11.16	17.11.82	21.25	22.87	57.33	57.33	O.H
	20.11.82	7.58	*22.11.82	2.25	1.78	4.75	4.75	O.F
	22.11.82	7.00	*23.11.82	22.25	1.63	8.56	8.56	"
	24.11.82	6.81	10.12.82	23.39	16.70	184.94	184.94	O.H
	19.12.82	16.33	*20.12.82	23.50	1.29	37.91	37.91	O.F
	22.12.82	13.41	*23.12.82	14.53	1.08	0.27	-	E.F
	23.12.82	14.80	*26.12.82	16.80	3.08	49.86	49.86	O.F
	28.12.82	18.66	2.1.83	22.56	5.16	176.10	176.10	O.H
	10.1.83	1.66	*17.1.83	8.08	7.26	6.83	6.83	I.F
	17.1.83	14.91	*17.2.83	13.50	31.35	4.41	-	E.F
	17.2.83	17.91	*18.2.83	20.75	1.13	12.41	12.41	M.F
	19.2.83	9.16	*21.2.83	0.36	1.23	7.42	-	E.F
	21.2.83	7.79	*22.2.83	8.50	1.03	3.00	-	"
	22.2.83	11.50	8.3.83	11.61	14.00	23.89	23.89	O.H
	9.3.83	11.50	10.3.83	22.53	1.46	67.18	67.18	"
	13.3.83	17.71	24.3.83	22.49	11.20	48.10	48.10	"
	26.3.83	22.58	30.4.83	21.91	35.38	11.22	11.22	"
	1.5.83	9.13	2.5.83	22.50	1.56	42.00	42.00-	"
	4.5.83	16.50	14.5.83	22.95	10.45	70.58	70.58	"
	17.5.83	21.53	*18.5.83	23.33	1.11	13.17	-	E.F
	19.5.83	12.50	31.5.83	5.91	11.72	4.75	4.75	O.H
	31.5.83	10.66	16.6.83	22.97	16.51	66.28	66.28	"
	19.6.83	17.25	6.7.83	21.16	17.16	184.95	184.95	"
	14.7.83	14.11	*26.7.83	18.29	12.17	0.28	0.28	E.F
	26.7.83	18.56	8.8.83	1.50	12.28	56.71	56.71	O.H
	10.8.83	10.21	17.9.83	22.55	38.51	159.95	159.95	"
	29.9.83	14.50	6.11.83	21.70	38.30	207.05	207.05	"
	15.11.83	12.75	10.12.83	21.83	25.37	92.25	92.25	"
Boiler	1.1.79	00.00	10.2.79	0.47	40.00	29.56	29.56	O.H

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
	11.2.79	6.03	30.3.79	23.08	47.75	201.44	201.44	O.H
	8.4.79	18.51	*9.4.79	19.33	1.30	23.75	23.75	M.F
	10.4.79	15.08	*14.4.79	13.25	3.91	43.25	43.25	"
	16.4.79	8.50	*30.4.79	12.75	14.60	1.58	1.58	E.F
	30.4.79	14.33	7.5.79	5.66	6.63	28.67	28.67	O.H
	8.5.79	10.33	23.5.79	4.60	14.76	28.90	28.90	"
	24.5.79	9.30	11.6.79	10.11	18.00	140.79	140.79	"
	17.6.79	6.90	31.7.79	22.60	106.66	38.60	38.60	"
	2.8.79	13.20	23.8.79	0.16	20.54	130.34	130.34	"
	28.8.79	10.50	*27.9.79	12.20	30.08	0.25	-	F.S.
	27.9.79	12.45	*17.10.79	17.53	20.20	0.57	0.57	L.F
	17.10.79	18.10	*31.10.79	23.50	14.23	5.11	-	F.S
	1.11.79	4.61	18.2.80	11.16	108.21	163.17	163.17	O.H
	25.2.80	6.33	15.3.80	23.21	19.70	31.42	31.42	"
	17.3.80	6.63	10.4.80	6.75	24.00	154.25	154.25	"
	16.4.80-	7.00	26.4.80	22.73	10.62	59.59	59.59	"
	29.4.80	10.25	*26.9.80	9.25	150.00	196.15	196.15	M.F
	4.10.80	13.40	*23.11.80	19.25	50.25	73.83	73.83	"
	26.11.80	21.08	*29.11.80	16.25	2.75	72.33	72.33	"
	2.12.80	16.55	*6.12.80	17.16	3.62	145.79	145.79	"
	12.12.80	8.95	16.1.81	11.33	35.12	29.82	29.82	O.H
	17.1.81	17.15	8.2.81	7.75	-	-	-	-
	7.4.82	3.01	30.4.82	23.23	45.41	50.52	50.62	O.H
	3.5.82	1.75	27.5.82	23.25	24.90	61.70	61.70	"
	30.5.82	12.95	1.8.82	22.87	63.41	95.55	95.55	"
	5.8.82	21.41	*25.8.82	2.50	19.20	74.12	74.12	M.F
	28.8.82	23.61	27.9.82	23.50	30.00	121.75	121.75	O.H
	3.10.82	1.25	17.11.82	22.25	45.87	57.33	57.33	"
	20.11.82	7.59	10.12.82	23.39	20.66	184.95	184.95	"
	19.12.82	16.33	14.5.83	22.95	146.27	70.58	70.58	O.H
	17.5.83	21.53	16.6.83	22.97	30.04	66.28	66.28	"
	19.6.83	17.25	6.7.83	21.16	17.16	184.95	184.95	"
	14.7.83	14.11	17.9.83	22.55	65.27	207.95	207.95	"
	29.9.83	14.50	10.12.83	21.83	72.16	92.25	92.25	"

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
Turbine	1.1.79	00.00	*26.1.79	12.88	25.55	2.36	2.36	M.F
	26.1.79	15.25	*2.6.79	14.33	127.04	4.58	-	E.F
	2.6.79	8.91	*9.6.79	19.53	7.44	2.13	2.13	M.F
	9.6.79	21.66	11.6.79	10.11	1.52	140.79	140.79	O.H
	17.6.79	6.90	*18.6.79	10.39	1.14	1.91	1.91	M.F
	18.6.79	12.30	*23.6.79	11.66	4.98	2.79	2.79	"
	23.6.79	14.47	23.8.79	0.16	60.60	130.34	130.34	O.H
	28.8.79	10.50	18.9.79	23.91	21.54	140.00	140.00	"
	23.9.79	19.91	5.12.79	23.16	73.12	103.09	103.09	"
	10.12.79	6.25	*22.4.80	0.01	133.75	0.95	0.95	M.F
	22.4.80	00.97	8.2.81	7.75	-	-	-	-
	7.4.82	3.01	*8.4.82	5.75	291.00	1.28	1.28	M.F
	8.4.82	7.03	*9.4.82	10.59	1.15	0.17	0.17	"
	9.4.82	10.75	*10.4.82	14.00	1.13	6.50	6.50	"
	10.4.82	20.50	1.9.82	23.08	144.12	14.92	14.92	O.H
	2.9.82	14.00	17.11.82	22.25	76.33	57.33	57.33	"
	20.11.82	7.59	2.1.83	22.56	43.62	176.10	176.10	"
	10.1.83	1.66	*18.2.83	20.75	39.80	12.41	12.41	M.F
	19.2.83	9.16	8.3.83	11.61	17.10	23.89	23.89	O.H
	9.3.83	11.50	10.3.83	22.53	1.46	67.18	67.18	"
	13.3.83	17.71	30.4.83	21.91	48.16	11.22	11.22	"
	1.5.83	9.13	14.5.83	22.95	13.58	70.58	70.58	"
	17.5.83	21.53	31.5.83	5.91	13.37	4.75	4.75	"
	31.5.83	10.66	10.12.83	21.83	193.45	92.25	92.25	"
Generator	1.1.79	00.00	*8.2.79	15.50	38.62	2.76	-	E.F
	8.2.79	18.26	*20.3.79	8.91	39.58	2.24	-	"
	20.3.79	11.16	"20.4.79	7.05	30.83	25.61	-	"
	21.4.79	8.66	*30.6.79	15.16	70.29	2.50	-	"
	30.6.79	17.66	*13.12.79	8.25	165.60	3.80	3.80	"
	13.12.79	12.05	16.2.80	5.200	64.70	17.50	17.50	O.H
	16.2.80	22.75	18.2.80	11.60	1.50	163.17	163.17	"
	25.2.80	6.33	*28.3.80	8.41	32.08	2.84	-	E.F
	28.3.80	11.25	*9.5.80	10.75	42.00	2.08	-	"
	9.5.80	12.81	*23.5.80	9.11	13.75	2.39	-	"

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
	23.5.80	11.50	8.11.80	22.25	169.45	129.62	129.62	O.H
	13.11.80	14.50	8.2.81	7.75	-	-	-	-
	7.4.82	3.01	30.4.82	23.23	110.54	50.52	50.52	O.H
	3.5.82	1.75	*23.12.82	14.53	233.54	0.27	-	E.F
	23.12.82	14.80	*17.2.83	13.50	55.95	4.41	-	"
	17.2.83	17.91	*21.2.83	0.36	3.25	7.42	-	"
	21.2.83	7.79	*22.2.83	8.50	1.03	3.00	-	"
	22.2.83	11.50	18.5.83	23.33	85.50	13.17	-	"
	19.5.83	12.50	*26.7.83	18.26	68.25	0.28	0.28	"
	26.7.83	18.54	6.11.83	21.70	103.12	207.05	207.05	O.H
Vacuum-system	1.1.79	00.00	*5.8.79	13.91	216.58	3.00	3.00	M.F
	5.8.79	16.08	*7.8.79	1.53	1.39	1.41	1.41	O.F
	7.8.79	2.94	*8.8.79	15.25	1.51	2.33	2.33	"
	8.8.79	17.59	*9.8.79	13.28	0.82	1.47	1.47	"
	9.8.79	14.75	*29.8.79	11.26	19.83	1.57	1.57	"
	29.8.79	12.83	*30.8.79	21.50	1.36	1.67	1.67	"
	30.8.79	23.16	*9.10.79	13.25	39.58	2.00	2.00	"
	9.10.79	15.25	*30.12.79	2.00	80.45	8.15	8.15	E.F
	30.12.79	10.15	*14.1.80	1.28	14.62	2.72	2.72	O.F
	14.1.80	4.00	18.1.80	11.59	4.29	62.55	62.55	O.H
	21.1.80	2.13	18.2.80	11.16	28.37	163.17	163.17	"
	25.2.80	6.33	18.7.80	16.00	144.41	278.47	278.47	"
	30.7.80	6.47	1.8.80	23.10	2.69	418.33	418.33	"
	19.8.80	9.43	5.9.80	23.75	17.59	456.33	456.33	"
	25.9.80	00.08	8.2.81	7.75	-	-	-	-
	7.4.82	03.01	*23.4.82	8.46	151.50	1.56	1.56	O.F
	23.4.82	9.10	*29.6.82	11.16	67.08	9.66	9.66-	"
	29.6.82	20.83	*1.7.82	9.70	1.53	2.38	2.38	"
	1.7.82	12.08	*3.7.82	2.30	1.42	15.40	15.40	"
	3.7.82	17.70	*5.7.82	0.91	1.30	509.65	509.65	M.F
	26.7.82	1.56	*3.9.82	23.00	39.89	1.33	1.33	O.F
	4.9.82	0.33	*5.9.82	5.59	1.21	7.33	7.33	"
	5.9.82	12.91	*10.9.82	21.41	5.35	1.42	1.42	"

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
	10.9.82	22.83	*12.9.82	6.00	1.29	5.91	5.91	O.F
	12.9.82	11.91	*13.9.82	22.91	1.45	1.50	1.50	"
	14.9.82	0.41	17.9.82	21.83	3.89	26.27	26.27	O.H
	19.9.82	0.10	*20.9.82	11.10	1.45	2.75	2.75	O.F
	20.9.82	13.85	*21.9.82	14.41	1.46	1.75	1.75	"
	21.9.82	16.16	*4.10.82	6.21	12.58	5.78	5.78	"
	4.10.82	12.00	*15.10.82	5.00	10.70	7.33	7.33	"
	15.10.82	9.33	*22.11.82	2.25	36.70	4.75	4.75	"
	22.11.82	7.00	*23.11.82	22.25	1.63	8.56	8.56	"
	23.11.82	6.81	*20.12.82	23.50	27.70	37.91	37.91	"
	22.12.82	13.41	*26.12.82	16.80	4.12	49.86	49.86	"
	28.12.82	18.66	-	-				
I.D.Fan (left)	1.1.79	00.00	30.3.79	23.08	89.00	201.44	201.44	O.H
	8.4.79	18.52	*30.4.79	12.75	21.75	1.58	-	E.F
	30.4.79	14.33	7.5.79	5.66	6.60	28.67	28.67	O.H
	8.5.79	10.33	23.5.79	4.60	14.75	28.90	28.90	"
	24.5.79	9.50	7.7.79	23.91	44.60	21.40	21.40	"
	8.7.79	21.31	*11.7.79	18.88	2.89	0.20	-	F.S
	11.7.79	19.08	1.9.79	23.05	52.16	25.77	25.77	O.H
	3.9.79	0.92	*27.9.79	12.20	24.50	0.25	-	E.F
	27.9.79	12.45	*4.12.79	1.41	67.94	3.09	3.09	M.F
	4.12.79	4.50	5.12.79	23.16	1.77	103.09	103.09	O.H
	10.12.79	6.25	5. 1.80	10.75	26.18	84.62	84.62	"
	8.1.80	23.37	10.4.80	6.75	92.18	154.25	154.25	"
	16.4.80	7.00	18.4.80	22.66	2.65	47.72	47.72	"
	20.4.80	22.38	*23.4.80	8.50	2.38	3.93	3.93	M.F
	23.4.80	12.43	26.5.80	9.83	32.89	888.53	888.53	O.H
	2.7.80	10.36	18.7.80	16.00	16.25	278.47	278.47	"
	31.7.80	6.47	5.9.80	23.75	36.72	456.33	456.33	"
	25.9.80	0.08	*.3.12.80	16.75	69.35	11.08	11.08	M.F
	4.12.80	3.83	*16.12.80	3.85	12.00	57.40	57.40	"
	18.12.80	13.25	10.1.81	22.25	23.37	64.25	64.25	O.H
	13.1.81	14.50	16.1.81	11.33	2.86	29.82	29.82	"
	17.1.81	17.15	*8.2.81	7.75	21.60	-	-	M.F

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
	7.4.82	3.01	30.4.82	23.23	23.84	50.52	50.52	O.H
	3.5.82	1.75	10.12.83	21.83	586.83	92.25	92.25	"
	14.12.82	18.08	-	-				
I.D.Fan (Right)	1.1.79	0.00	17.4.79	20.80	107.85	21.78	21.78	O.H
	18.4.79	18.58	*30.4.79	12.75	11.75	1.58	-	E.F
	30.4.79	14.33	11.6.79	10.11	41.83	140.79	140.79	O.H
	17.6.79	6.90	*11.7.79	18.88	24.50	0.20	-	F.S
	11.7.79	19.08	18.9.79	23.92	69.20	116.00	116.00	O.H
	23.9.79	19.91	*27.9.79	12.20	3.70	0.25	-	E.F
	27.9.79	12.45	30.9.79	0.08	2.48	25.67	25.67	O.H
	1.10.79	1.75	*4.12.79	1.41	64.00	3.09	3.09	M.F
	4.12.79	4.50	5.1.80	10.75	32.26	84.62	84.62	O.H
	8.1.80	23.37	15.3.80	23.21	66.00	31.42	31.42	"
	17.3.80	6.63	1.4.80	22.33	15.65	158.05	158.05	"
	8.4.80	12.38	*23.4.80	8.50	14.85	3.93	3.93	M.F
	23.4.80	14.43	*8.11.80	13.66	199.00	129.62	129.62	"
	13.11.80	23.28	10.1.81	22.25	58.00	64.25	64.25	O.H
	13.1.81	14.15	16.1.81	11.33	2.95	29.82	29.82	"
	17.1.81	17.15	*8.2.81	7.75	21.60	-	-	M.F
	7.4.82	3.01	30.4.82	23.23	23.84	50.52	50.52	O.H
	3.5.82	1.75	24.3.83	22.48	355.86	48.10	48.10	"
	26.3.83	22.58	-	-				
C.W.pump (1)	1.1.79	00.00	7.2.79	0.78	37.03	8.22	8.22	O.H
	7.2.79	9.00	*3.8.79	19.58	177.48	21.25	21.25	M.F
	4.8.79	16.83	18.9.79	23.91	45.29	116.00	116.00	O.H
	23.9.79	19.91	21.11.79	22.90	59.08	11.46	11.46	"
	22.11.79	10.66	15. 1.80	11.75	54.04	13.75	13.75	"
	16.1.80	1.50	18.2.80	11.16	33.40	163.17	163.17	"
	25.2.80	6.33	28.2.80	22.16	6.66	8.17	8.17	"
	29.3.80	6.33	30.3.80	0.08	29.73	22.00	22.00	"
	30.3.80	22.08	26.4.80	22.73	27.02	59.52	59.52	"
	29.4.80	10.25	3.5.80	8.37	3.92	11.47	11.47	"

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
	3.5.80	19.84	*18.5.80	7.92	14.50	14.13	14.13	O.F
	18.5.80	22.05	1.8.80	23.10	75.00	418.33	418.33	O.H
	19.8.80	9.43	5.9.80	23.75	17.59	456.33	456.33	"
	25.9.80	0.08	8.2.81	7.75	-	-		
	7.4.81	3.01	17.11.82	22.25	361.08	57.33	57.33	O.H
	20.11.82	7.58	2.1.83	22.56	42.62	176.10	176.10	"
	10.1.83	1.66	8.8.83	1.50	210.00	56.71	56.71	"
	10.8.83	10.21	-	-				
C.W.pump (2)	1.1.79	0.00	1.7.79	23.78	182.00	24.92	24.92	O.H
	3.7.79	0.70	*29.7.79	17.13	26.41	1.58	1.58	E.F
	29.7.79	18.71	*3.8.79	19.58	5.00	21.25	21.25	M.F
	4.8.78	16.83	10.11.79	23.33	98.28	14.25	14.25	O.H
	11.11.79	13.58	15.1.80	11.75	64.92	13.75	13.75	"
	16.1.80	1.50	18.1.80	11.58	2.42	62.55	62.55	"
	21.1.80	2.13	27.1.80	4.39	6.09	14.02	14.02	"
	27.1.80	18.41	16.2.80	5.25	19.45	17.50	17.50	"
	16.2.80	22.75	18.2.80	11.16	1.52	163.17	163.17	"
	25.2.80	6.33	30.3.80	0.08	33.75	22.00	22.00	"
	30.3.80	22.08	*18.5.80	7.92	48.40	14.13	14.13	O.F
	18.5.80	22.05	26.5.80	9.83	7.49	888.53	888.53	O.H
	2.7.80	10.36	8.2.82	7.75	-	-	-	-
	7.4.82	3.01	30.4.82	23.23	244.70	50.52	50.52	O.H
	3.5.82	1.75	17.11.82	22.25	198.85	57.33	57.33	"
	20.11.82	7.58	2.1.83	22.56	43.62	176.10	176.10	"
	10.1.83	1.66	16.6.83	22.97	157.88	62.28	62.28	"
	19.6.83	17.25	8.8.83	1.50	49.34	56.71	56.71	"
	10.8.83	10.21	-	-				
Other causes	1.1.79	00.00	*3.2.79	7.79	32.30	8.51	-	L.F
	3.2.79	16.50	*21.2.79	7.91	17.62	4.58	-	"
	21.2.79	12.50	*23.2.79	4.00	1.64	14.58	[illegible]	"
	23.2.79	18.59	*13.4.79	11.83	48.70	1.08	-	E.F
	13.4.79	12.92	*12.12.79	[illegible]	242.75	0.17	-	O.F
	12.12.79	6.91	*21.12.79	7.75	9.00	1.66	1.66	M.F
	21.12.79	9.41	2.3.80	7.61	71.91	14.39	14.39	O.H

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
	2.3.80	22.00	23.3.80	0.60	20.08	39.18	39.18	O.H
	24.3.80	15.76	30.3.80	0.08	5.33	22.00	22.00	"
	30.3.80	22.08	*5.5.80	12.59	34.62	4.16	-	E.F
	5.5.80	16.75	5.9.80	23.75	4.30	456.33	456.33	O.H
	25.9.80	0.08	22.11.80	8.41	57.75	9.92	9.92	"
	22.11.80	18.33	31.1.81	21.91	70.16	41.72	41.72	"
	2.2.81	15.63	8.2.81	7.75	-	-	-	-
	7.4.82	3.01	*26.10.82	9.10	208.00	2.06	2.06	E.F
	26.10.82	11.16	31.5.83	5.91	216.00	4.75	4.75	O.H
	31.5.83	10.66	-	-				
Feed pump	1.1.79	00.00	26.7.79	23.66	207.00	30.33	30.33	O.H
	28.7.79	6.00	8.2.81	7.75	-	-	-	-
	7.4.83	3.01	*17.4.82	10.75	567.37	7.66	-	E.F
	17.4.82	18.41	17.11.82	22.25	208.15	57.33	57.33	O.H
	20.11.82	7.59	*17.1.83	8.08	58.04	6.83	6.83	I.F
	17.1.83	14.91	2.6.83	22.50	105.62	42.00	42.00	O.H
	4.5.83	16.50	14.5.83	22.95	10.26	70.58	70.58	"
	17.5.83	21.53	16.6.83	22.97	30.04	66.28	66.28	"
	19.6.83	17.25	-	-				
F.D.Fan	1.1.79	00.00	*30.4.79	12.75	119.50	1.58	-	E.F
	30.4.79	14.33	*27.9.79	12.20	150.00	0.25	-	F.S
	27.9.79	12.45	*15.10.80	18.16	410.00	90.12	90.12	"
	19.10.80	12.29	-	-				
Condenser	1.1.79	0.00	24.1.79	23.00	24.00	12.00	12.00	O.H
	25.1.79	11.00	30.3.79	23.08	64.50	211.44	211.44	"
	8.4.79	18.61	22.4.79	13.26	13.87	48.82	48.82	"
	24.4.79	14.08	1.7.79	23.79	68.37	24.94	24.94	"
	3.7.79	0.70	26.7.79	23.66	23.97	30.83	30.83	"
	28.7.79	6.00	23.8.79	0.16	25.75	130.34	130.34	"
	28.8.79	10.50	1.9.79	23.05	4.54	25.77	25.77	"
	3.9.79	0.91	18.9.79	23.91	15.95	116.00	116.00	"
	23.9.79	19.91	12.10.79	17.97	18.91	19.44	19.44	"

Table 5.1 (Contd.)

1	2	3	4	5	6	7	8	9
	13.10.79	13.41	21.11.79	22.90	38.37	11.46	11.46	O.H
	22.11.79	10.66	5.12.79	23.16	13.54	103.08	103.08	"
	10.12.79	6.25	5.1.80	10.75	26.18	84.62	84.62	"
	8.1.80	23.27	16.2.80	5.25	38.25	17.50	17.50	"
	16.2.80	7.75	28.2.80	22.16	12.62	8.17	8.17	"
	29.2.80	6.33	2.3.80	7.61	2.05	14.39	14.39	"
	2.3.80	22.00	15.3.80	23.21	13.05	31.42	31.42	"
	17.3.80	6.63	1.4.80	22.33	15.16	158.05	158.05	"
	8.4.80	12.39	10.1.81	22.25	277.41	64.25	64.25	"
	13.1.81	14.30	8.2.81	7.75	-	-	-	-
	7.4.82	3.01	27.9.82	23.50	199.54	121.75	121.75	O.H
	3.10.82	1.25	2.1.83	22.56	91.87	176.10	176.10	"
	10.1.83	1.66	16.6.83	22.97	157.87	66.28	66.28	"
	10.8.83	10.21	10.12.83	21.83	122.92	92.25	92.25	"
Oil cooler	1.1.79	00.00	1.7.79	23.79	182.00	24.92	24.92	O.H
	3.7.79	0.70	30.9.79	0.08	89.00	25.67	25.67	"
	1.10.79	1.75	16.1.81	11.33	472.37	29.82	29.82	"
	17.1.81	17.15	8.2.81	7.75	-	-	-	-
	7.4.82	3.01	17.9.82	21.83	185.37	26.27	26.27	O.H
Water heater	1.1.79	0.00	28.10.79	23.75	301.00	22.83	22.83	O.H
	29.10.79	22.59	8.2.81	7.75	-	-	-	-
	8.4.82	3.01	30.4.82	23.23	488.16	50.52	50.52	O.H
	3.5.82	1.75	17.9.82	21.83	137.83	26.27	26.27	"
	19.7.82	0.10	17.11.82	22.25	121.91	57.33	57.33	"
	20.11.82	7.59	16.6.83	22.97	208.62	66.28	66.28	"
Trans-former	1.1.79	0.00	*17.12.79	9.33	350.37	2.17	-	O.F
	17.12.79	11.50	*19.12.79	21.41	2.41	9.84	-	E.F
	20.12.79	7.25	*4.7.80	7.75	197.00	6.83	-	"
	4.7.80	14.59	*6.7.80	12.08	18.89	4.00	-	"
	6.7.80	16.08	8.2.81	7.75	-	-	-	-
	7.4.82	3.01	1.9.82	23.08	364.45	14.92	-	O.H
	2.9.82	14.00	-	-				

5.1.3 Weibull Distribution Parameters Estimation of Equipments

The methods for the estimation of the weibull distribution parameters, β and η are described elaborately in section 2.6. In this section Hazard Plotting method as well as MLE method are used for the estimation of weibull parameters. Graphical solution of Hazard plotting method for individual equipment are shown in Appendix-B. Computer programming was used to estimate the parameters by MLE methods (shown in Appendix-C). It should be mentioned here that both of these methods are applicable only when number of failures $r > 2$. But in analyzing operating time it has been found that some of the equipments suffered no failure' during the period considered, that equipments faced only maintenance. In such cases weibull parameters are estimated by considering the maintenaance date as failure. Application of all the methods mentioned above are shown in Table 5.2.

Table 5.2 Weibull Distribution Parameter Estimation of Equipments

Equipment	Number of Failure	Number of Maintenance	Number of Repair	Method Used					MTBF (Simple Average)
				MLE			Hazard Plotting		
				Shape Parameter β	Scale Parameter η	Mean life MTBF (μ)	Shape Parameter β	Scale Parameter η	
Boiler	11	23	32	0.73	162.84	137.95	0.65	165.00	114.54
Turbine	10	13	22	0.60	171.06	259.85	0.57	175.00	134.06
Generator	14	5	7	0.93	94.58	97.68	0.85	95.00	94.96
Vacuum System	27	6	33	0.59	26.37	40.45	0.50	35.00	35.02
I.D. Fan (left)	8	16	20	0.66	199.10	266.78	0.72	100.00	159.38
I.D. Fan (right)	7	11	14	0.75	183.16	217.30	0.75	140.00	159.38
C.W. Pump (1)	2	14	16	1.02	577.02	571.74	0.75	640.00	597.22
C.W. Pump (2)	3	14	17	0.64	843.60	1178.85	0.58	850.00	396.66

Table 5.2 (Contd...)

Equipment	Number of Failure	Number of Maintenance	Number of Repair	Method Used: MLE — Shape Parameter β	MLE — Scale Parameter η	MLE — Mean life MTBF (M)	Hazard Plotting — Shape Parameter β	Hazard Plotting — Scale Parameter η	MTBF (Simple Average)
Other Causes	8	7	9	0.81	134.00	151.21	0.71	120.00	130.02
Feed Pump	2	5	6	1.47	489.81	439.94	1.00	470.00	593.24
F.D. Fan	2	1	1	1.89	257.62	228.80	0.50	310.00	339.75
Transformer	4	4	1	0.61	309.45	455.22	0.95	200.00	229.03
Condenser	–	23	23	0.84	66.05	72.42	–	–	57.32
Oil Cooler	–	4	4	3.21	166.87	149.64	–	–	232.18
Water Heater	–	5	5	2.76	201.31	179.33	–	–	251.50
Power Plant	87	68	125	0.80	12.82	14.55	0.69	12.50	11.76

5.2 Distribution System Failures

5.2.1 Failure History of Khulna Industrial Zone Electric Supply

In distribution system failure history, date and time of failure and startup, causes of failures and troubles, remidual measures taken as well as downtime resulted for the failure of subtransmission line, feeders and distribution transformers are included. These are collected from the operational division of the Khulna Electric Supply. Distribution system failure records for one year has been collected for the present work starting from 1.7.82 to 3.7.83. The failure history has been presented in Appendix-D.

5.2.2 Operating time Calculation of Individual Components

In calculating operating time, the running periods for each item are seperated from the period considered in the failure history of the distribution system. Operating time for subtransmission line and feeders are calculated in two ways, one by including loadshade in the downtime and in the other by excluding load shade. In case of distribution transformer there was no loadshade, so, the operating time calculation are simple and in general form. By this way, operating times in between failures of each component of the distribution system are calculated and are shown in Table 5.3.

Table 5.3 Operating time calculation of Distribution system components.

The symbols used in column 7 are as follows:

L = load shade, O - Over current, M - Maintenance

E - Earth fault, S - Shutdown

Subtransmission line - 11

Date	Duration of failure		Downtime hrs.	Time to failure hrs.	Time to failure neglect. L/S	Causes of Failure
	From	To				
1	2	3	4	5	6	7
12.5.83	12-30	13-15	0.75	7596.50	7596.50	E

Gate sub-station incomming feeder - 21

2.7.82	03-13	10-22	7.15	27.21	-	L
2.7.82	10-38	10-55	0.28	0.26	-	"
4.7.82	00-38	00-59	0.35	37.71	65.18	E
15.7.82	12-30	13-22	0.86	275.52	"	L
15.7.82	17-10	17-29	0.30	3.80	-	"
26.10.82	17-42	17-52	0.16	264.21	"	"
5.11.82	21-05	21-07	0.03	203.21	746.74	E
6.11.82	11-20	14-05	1.75	14.21	14.21	"
19-11.82	17-40	17-45	0.08	315.38	-	L
21.11.82	17-42	17-43	0.01	47.95	363.33	O
22.11.82	10-14	11-03	0.81	16.51	16.51	"
1.12.82	14-12	15-20	1.13	219.15	219.15	E
19-12.82	11-54	11-56	0.03	428.56	428.56	"
20.12.82	17-21	17-48	0.45	29.41	-	L
5.2.83	11-14	14-10	2.93	1124.43	-	"
21.2.83	08-50	09-05	0.25	378.66	-	"
22.2.83	00-22	01-00	0.63	15.28	1547.78	E
22.2.83	02-02	02-05	0.05	1.03	1.03	"
25.2.83	08-50	09-05	0.25	78.75	-	L
3.4.83	21-50	22-03	0.21	900.75	979.50	E

Table 5.3 (Contd..)

Khalispur Sub-station Incomming.

1	2	3	4	5	6	7
3.7.82	16-15	17-20	1.08	64.25	-	L
5.7.82	16-25	17-20	0.91	47.08	-	"
15.7.82	22-24	22-35	0.81	245.06	-	"
3.8.82	18-42	18-44	0.03	452.11	808.50	E
4.12.82	07-26	07-27	0.18	12.70	12.70	"
10.12.82	18.29	18-30	0.01	154.88	154.88	"
12.1.83	07-20	07-22	0.03	37-16	37.16	"
14.1.83	17-40	17-42	0.03	58.30	58.30	O
12.2.83	18-18	18-18	0.01	696.58	696.58	E
25.2.83	07-30	07-32	0.03	301.20	301.20	"
1.3.83	18-35	18-36	0.01	107.05	107.05	"
7.3.83	15-37	17-02	0.41	141.01	141.01	M
15.3.83	14-18	14-20	0.03	189.26	189.26	E
11.4.83	13-55	13-56	0.01	647.57	647.57	"
20.4.83	11-53	13-25	1.53	213.94	213.94	M
17.5.83	15-01	16-58	1.98	649.60	649.60	E
8.6.83	11-20	11-23	0.05	522.36	-	Load change
8.6.83	19-16	19-18	0.03	7.88	530.24	E
22.6.83	10-25	10-45	0.33	326.91	326.91	M
25.6.83	18-50	18-52	0.03	80.08	80.08	E
3.7.83	18-30	18-45	0.25	191.63	191.63	M

BIDC Feeder - 31

1	2	3	4	5	6	7
3.7.82	02-32	03-08	0.60	50.53	-	L
6.7.82	10-53	13-06	2.21	79.75	130.28	M
8.7.82	05-55	07-40	1.75	16,81	16.81	"
8.7.82	17-00	18-16	1.30	9.33	-	L
15.7.82	16-15	17-31	1.26	165.98	-	"
16.7.82	13-38	14-00	0.36	20.11	-	"
17.7.82	02-24	02-48	0.40	12.40	-	"
17.7.82	07-47	08-38	0.85	5.00	-	"
17-7-82	13-35	14-25	0.83	4.95	217.77	M
25.7.82	20-51	22-05	0.23	198.43	198.43	"

Table 5.3 (Contd..)

1	2	3	4	5	6	7
2.8.82	16-30	22-00	5.50	186.41	186.41	E
11.10.82	11-25	16-00	4.58	205.41	205.41	M
26.10.82	18-01	18-02	0.01	262.01	262.01	E
1.11.82	13-02	13-22	0.33	115.00	115.00	M
8.11.82	19-42	19-44	0.03	174.33	174-33	E
16.11.82	13-15	15-30	1.58	185.51	185-51	"
20.11.82	11-00	12-00	1.00	91.50	-	L
22.11.82	09-07	09-08	0.01	43.11	134.61	E
26.11.82	17-38	17-42	0.06	104.50	104.50	"
2.12.82	12-20	12-45	0.41	138.63	-	Load change
24.12.82	20-07	21-20	1.21	535.36	673.99	E
25.12.82	11-24	12.45	1.35	14.06	14.06	M
13.1.83	19-43	20-16	0.55	462.97	462.97	E
21.1.83	10-00	13-45	3.75	181.73	181.73	M
30.1.83	12-46	13-30	0.73	215-01	215.01	E
30.1.83	15-05	16-00	0.91	1.58	1.58	"
5.2.83	16-10	16-55	0.75	144.60	-	Load change
6.2.83	18-00	18-03	0.05	25.08	169.24	E
18-2.83	20-45	21-35	0.81	290.70	-	L
7.3.83	15-45	16-15	0.50	442.16	-	"
16.3.83	19.55	20.08	0.21	219.66	-	"
20.3.83	21.10	21.11	0.01	97.03	1049.55	E
26.3.83	18.05	18-15	0.16	140.90	140.90	"
26.3.83	21-25	21-35	0.16	3.16	3.16	"
29-3-83	19-19	19-25	0.10	21.73	-	L
30.3.83	19-55	20-05	0.16	24.50	46.23	E
3.4.83	18-50	19-12	0.36	94-75	-	L
12.4.83	18-08	18-18	0.16	215.02	-	"
20.4.83	21-10	21-11	0.01	194.86	504.63	E
27.4.83	13-00	14-35	1.58	159.81	159.81	M
27.4.83	18-30	18-53	0.38	3.91	-	L
12.5.83	18-50	18-57	0.11	383.95	-	S
17-5-83	17-07	17-36	0.48	118.14	506.00	E
17-5.83	18-55	19-26	0.52	1.31	-	S
19.5.83	18-15	18-55	0.66	46.81	48.12	M

Table 5.3 (Contd.)

1	2	3	4	5	6	7
24.5.83	21-40	22-40	1.00	98.74	98.74	Failure
18.6.83	06-22	07-22	1.00	559.69	559.69	E
22.6.83	20-05	20-45	0.66	108.71	108.71	M
			Khalishpur Feeder - 32			
3.7.82	02-32	03-08	0.60	50.53	-	L
3.7.82	08-35	09-30	0.91	5.45	55.98	E
9.7.82	10-26	12-35	2.15	144.94	144.94	"
10.7.82	17-05	18-05	1.00	28.50	-	L
12.7.82	09-03	13-55	4.86	38.97	-	"
13.7.82	10-40	12-23	1.71	20.75	-	"
15.7.82	15-12	16-15	1.05	50.81	-	"
15.7.82	22-26	22-45	0.31	6.18	-	"
17.7.82	02-08	02-24	0.26	27.38	-	"
17.7.82	12-00	13-32	1.53	9.66	182.25	M
27.10.82	13-25	16-15	2.83	239.88	239.88	E
1.11.82	12-09	12-11	0.03	115.90	115.90	M
3.11.82	19-10	19-12	0.03	54.98	54.98	E
12.11.82	03-10	04-15	1.08	199.96	199.96	"
12.11.82	05-15	05-20	0.08	1.00	1.00	"
12.11.82	05-45	06-50	0.08	0.41	0.41	"
12.11.82	16-30	17-17	0.78	10.66	10.66	M
16-11-82	21-45	22-00	0.25	100.46	100.46	"
17-11-82	09-28	09-35	0.11	11.46	11.46	"
17.11.82	10-50	11-00	0.16	1.25	1.25	"
20.11.82	11-00	11-30	0.50	72.00	-	L
21.11.82	17-55	17-56	0.01	30.41	102.41	E
22.11.82	13-00	13-02	0.03	19.06	19.06	"
3.12.82	21-30	22-10	0.66	272.46	272.46	"
5.12.82	09-45	11-15	1.50	34.58	34.58	"
11.12.82	09-45	10-45	1.00	142.50	142.50	"
11.12.82	11-28	12-00	0.53	0.71	0.71	"
"	12-14	12-25	0.18	0.23	0.23	"
"	14-20	14-21	0.01	1.91	1.91	"
"	14.22	14-39	0.28	0.01	0.01	"

Table 5.3 (Contd.)

1	2	3	4	5	6	7
11.12.82	16-38	16-48	0.11	4.00	- 4.00	E
"	18-05	18-35	0.50	1.28	1.28	"
"	21-22	21-24	0.03	2.78	2.78	"
"	21-24	21-25	0.01	-	-	"
"	21-36	21-38	0.03	0.13	0.13	"
17.12.82	19-52	20-02	0.16	143.23	143.23	"
24.12.82	23-50	00-10	0.33	171.80	171.80	M
27.12.82	18-10	18-13	0.05	82.00	82.00	E
30.12.82	20-04	20-07	0.05	73.85	73.85	"
16.1.83	11-59	13-10	1.18	399.86	399.86	"
18.1.83	12-21	12-28	0.11	47.18	47.18	M
"	14-25	14-35	0.16	1.95	1.95	"
25.1.83	14-07	14-08	0.01	167.53	167.53	E
"	18-00	18-01	0.01	3.86	3.86	"
30.1.83	15-15	18-55	3.60	117.23	117.23	"
31.1.83	18.45	18-50	0.08	23.83	23.83	"
12.2.83	11-15	11-35	0.33	280.68	280.68	"
"	12-08	13-00	0.86	0.55	0.55	"
18.2.83	18-20	18-22	0.03	149.33	149.33	"
"	20-45	21-10	0.41	2.38	-	L
"	21-15	21-35	0.33	0.08	-	"
19.2.83	09-36	09-46	0.16	12.26	14.72	M
2.3.83	18-47	19-10	0.38	273.03	273.03	"
1.4.83	17-17	17-35	0.30	718.11	718.11	"
26.4.83	18-08	18-10	0.03	600.55	-	S
12.5.83	18-50	18-58	0.13	384.66	-	"
17.5.83	18-55	19-26	0.52	119.95	-	"
15.6.83	21-50	22-20	0.50	698.40	1803.56	M
29.6.83	15-55	16-15	0.33	329.58	329.58	Load change
			Kohinoor Feeder - 33			
4.7.82	02-27	03-07	0.66	74.45	74.45	E
5.7.82	07-55	12-40	4.75	28.80	-	L
11.7.82	21-35	21-45	0.16	152.91	181.71	O

Table 5.3 (Contd.)

1	2	3	4	5	6	7
12.7.82	09-37	11-25	1.80	11.86	-	L
13.7.82	11-48	12-22	0.56	24.38	-	"
25.7.82	11-45	12-30	0.75	287.38	323.62	M
3.9.82	13-57	14-20	0.38	961.45	961.45	E
28.9.82	19-38	20-05	0.45	605.30	605.30	M
1.10.82	15-02	15-55	0.88	66.96	-	L
"	18-25	19-10	0.75	2.50	-	"
3.10.82	07-07	07-48	0.68	35.95	-	"
27.10.82	17-57	18-07	0.16	586.15	691.56	E
12.11.82	09-50	11-03	1.21	375.71	375.71	"
1.12.82	14-12	15-23	1.18	723.15	723.15	"
2.12.82	11-08	11-10	0.03	19-75	-	Load change
4.12.82	07-37	10-20	2.38	44.46	64.21	E
5.2.83	11-07	11-42	0.58	24.78	24.78	M
"	15-29	16-04	0.58	3.78	-	Load change
1.3.83	18-35	19-05	0.50	578.51	582.29	E
6.4.83	20-00	20-27	0.35	864.91	-	L
"	21-35	21-43	0.13	1.13	-	"
26.4.83	18-05	18-15	0.16	476.41	-	S
29.6.83	15-55	16-55	1.00	69.66	-	Load change
"	19-55	19-17	0.03	2.33	1414.44	E
30.6.83	20-25	20-46	0.35	1.13	1.13	O

Star Crescent Feeder-34

2.7.82	16-42	18-40	1.96	40.42	-	L
3.7.82	13-23	15-11	1.80	18.71	59.13	E
5.7.82	07-55	10-55	3.00	40.73	-	L
"	17-45	18-38	0.88	9.83	-	"
6.7.82	18-10	18-17	0.11	23.53	-	"
"	19-26	19-48	0.36	1.15	-	"
11.7.82	20-25	22-15	1.83	120.45	195.69	O
12.7.82	05-39	05-42	0.05	7.40	7.40	"
13.7.82	19-28	19-47	0.31	37.76	-	L
17.7.82	03-03	03-38	0.58	79.26	-	"

Table 5.3 (Contd..)

1	2	3	4	5	6	7
18.7.82	02-42	03-07	0.41	23.06	-	L
"	14-55	15-34	0.65	11.80	-	"
29.10.82	18-25	18-40	0.25	242.85	394.73	E
12.5.83	16-50	21-59	5.15	4678.16	4678.16	M
21.6.83	22-05	22-40	0.58	960.10	960.10	Breaker failure
22.6.83	20-01	20-02	0.01	21.35	21.35	O
"	20-04	20-05	0.01	0.03	0.03	"
"	20-26	20-42	0.26	0.35	0.35	"
23.6.83	20-03	20-05	0.03	23.35	23.35	"
"	20-18	20-20	0.03	0.21	0.21	"
29.6.83	12-50	13-10	0.33	134.82	134.82	"
2.7.83	11-08	11-10	0.03	69.96	-	Load change
"	11-22	11-25	0.05	0.18	-	"

Charerhat Fish Co. Feeder - 35

29.9.82	10-20	12-48	2.33	2170.33	2170.33	M
29.10.82	18-25	18-42	0.28	749.61	749.61	E

Rerolling Feeder -36

3.7.82	10-07	11-00	0.88	58.11	-	L
4.7.82	05-34	05-45	0.18	18.56	76.67	Failure
"	06-36	06-42	0.10	0.85	0.85	E
5.7.82	07-07	12-39	5.53	24.41	-	L
10.7.82	17-06	18-02	0.93	124.45	-	"
"	19-05	19-45	0.66	1.05	-	"
12.7.82	09-37	13-20	3.71	37.86	-	"
"	19-08	20-15	1.11	5.80	-	"
13.7.82	10-38	11-34	0.93	14.38	-	"
15.7.82	15-05	17-30	2.41	51.51	-	"
16.7.82	12-15	15-22	3.11	18.75	-	"
"	23-36	00-10	0.56	8.23	-	"
17-7.82	02-08	03-03	0.91	25.96	-	"
"	07-50	10-15	2.25	4.78	-	"
18.7.82	12-58	13-59	1.01	26.71	-	"

Table 5.3 (Contd..)

1	2	3	4	5	6	7
19.7.82	14-15	14-55	0.66	24.26	368.15	E
22.7.82	12-08	12-54	0.77	69.21	69-21	M
2.8.82	21-01	22-00	0.98	272.11	272.11	E
7.8.82	10-45	11-15	0.50	108.75	108.75	"
19.9.82	21-37	22-30	0.88	298.30	298.30	M
23.9.82	07-56	07-58	0.03	81.43	81.43	E
25.9.82	00-25	00-28	0.05	40.55	40.55	"
26.9.82	04-15	04-16	0.01	27-78	27-78	"
2.10.82	18-42	19-20	0.63	158.43	-	L
6.10.82	10-20	10-35	0.25	87.00	245.43	M
"	18-06	18-07	0.01	7.51	7.51	O
10.10.82	18-15	18-50	0.59	72.13	-	L
11.10.82	16-38	16-59	0.35	21.80	93.93	M
25.10.82	18-51	19-33	0.70	337.86	-	L
26.10.82	09-46	09-47	0.01	14.21	-	"
31.10.82	10-30	11-20	0.83	120.88	472.95	M
17.11.82	10-30	11-00	0.50	407.15	407.15	"
21.11.82	06-55	07-25	0.50	91.91	-	L
"	07-30	07-31	0.01	0.08	91.99	E
"	10-33	10-50	0.28	3.03	3.03	M
23.11.82	09-05	09-45	0.66	46.25	46.25	"
26.11.82	17-10	17-13	0.05	79.41	79.41	E
1.12.82	15-25	16-08	0.71	118.03	118.03	"
11.12.82	09-15	09-35	0.33	133.11	133.11	Failure
15.12.82	07-48	07-50	0.03	94.21	94.21	E
21.12.82	17-01	18-02	1.01	153.18	153.18	M
4.1.83	20-15	20-35	0.33	338.21	338.21	"
30.1.83	16-45	18-40	1.91	620.16	620.16	E
31.1.83	10-30	11-55	1.41	15.83	15.83	M
5.2.83	16-10	16-25	0.25	124.25	-	Load change
7.2.83	10-15	10-28	0.21	41.83	166.08	M
12.2.83	17-01	17-46	0.75	126.55	126.55	"
13.2.83	10-25	10-40	0.25	16.65	16.65	"
18.2.83	14-40	16-25	1.75	124.00	124.00	"
24.2.83	19-07	19-40	0.55	146.70	146.70	"

Table 5.3 (Contd.)

1	2	3	4	5	6	7
25.2.83	00-04	02-40	2.60	4.40	4.40	E
"	06-30	07-30	1.00	3.83	3.83	"
"	07-40	08-45	1.00	0.16	0.16	"
28.2.83	13-45	14-15	0.50	77.00	77.00	M
7.3.83	12-31	12.58	0.45	166.25	166.26	"
15.3.83	14-18	14-40	0.36	193.33	193.33	E
"	16-22	17-05	0.71	1.70	1.70	M
16.3.83	17-35	17-45	0.16	24.50	24.50	"
19.3.83	10-40	10-55	0.25	64.91	64.91	"
"	13-35	14-00	0.58	2.66	-	Load change
27.3.83	19-45	19-58	0.21	197.75	200.41	M
6.4.83	20-05	20-29	0.30	240.11	-	L
11.4.83	13.55	13-58	0.05	113.43	353.54	E
26.4.83	17.35	17-36	0.01	363.61	363.61	O
"	18-05	18-15	0.16	0.51	-	S
12.5.83	09-35	10-05	0.50	375.33	-	"
28.6.83	18-35	18-45	0.16	1134.50	1510.34	Failure
"	19-45	20-05	0.33	1.00	1.00	"
"	20-30	20-43	0.20	0.41	0.41	E
"	20-43	20-55	0.21	-	-	"

Power supply history of distribution transformer (load point)

Load point - 1 (Feeder-31)

Table 5.3 (Contd..)

Date	Duration of failure From	To	Down time hrs.	Running time hrs..	Causes of failure
1	2	3	4	5	6
11.10.82	19-53	20-00	0.11	2467.08	F
12.10.82	08-39	10-15	1.60	12.65	"
"	11-55	12-10	0.45	1.66	"
15.10.82	00-50	01-10	0.66	60.66	"
18.10.82	22-15	22-20	0.08	93.08	"
5.11.82	18-45	19-00	0.25	452.41	"
12.11.82	20.40	21.00	0.33	169.66	"
17.11.82	20-10	20-42	0.53	119.16	"
23.12.82	15-35	15-50	0.25	858.88	"
25.12.82	20-32	20.50	0.30	52.70	"
11.1.83	11.30	12.05	0.58	392.66	"
24.1.83	19.00	19-15	0.25	318.91	"
12.2.83	20-35	20-57	0.36	462.91	"
17.3.83	21-20	22-05	0.75	792.38	"
19.3.83	11.15	11-45	0.50	37.16	"
31.3.83	08-50	09-00	0.16	285.08	"

Load point - 2 (Feeder-31)

18.10.82	20-15	20-30	0.25	2636.83	"
8.11.82	20-50	21-00	0.16	480.33	"
27.6.83	11-30	11-37	0.11	5534.50	"

Load point - 3 (F-31)

10.11.82	00-10	00-20	0.16	3168.16	"
26.11.82	21-25	21-35	0.16	405.08	"
7.5.83	09-15	09-40	0.41	3875.66	"
18.5.83	11-20	11-36	0.26	265.66	"
4.7.83	18-40	19-00	0.33	1111.06	"

Table 5.3 (Contd.)

Load point-4 (F-31)

1	2	3	4	5	6
4.7.82	09-44	09-49	0.08	81.73	F
3.8.82	16-06	16-14	0.14	726.28	"
25.10.82	21-01	21-05	0.06	1996.78	"
"	21-07	21-14	0.11	0.03	"
30.3.83	20-35	20-41	0.10	3743.34	"

Load point - 5 (F-31)

19.3.83	11-25	12-40	1.25	6275.41	"

Load point - 6 (F-36)

3.10.82	17-32	17-45	0.21	2273.53	"
17.11.82	16-58	17-13	0.25	1079.21	"
19.3.83	15-55	16-10	0.25	2926.69	"

Load point - 7 (F-32)

4.7.82	09-44	09-49	0.08	81.73	"
12.2.83	19-55	20-01	0.10	5362.10	"
8.3.83	22-01	22-20	0.31	674.00	"
23.3.83	09-00	09-30	0.50	346.66	"
16.5.83	09-20	10-05	0.75	551.83	"
22.6.83	18-05	19-25	1.33	896.00	"

Load point - 8 (F-32)

18.10.82	19-23	19-28	0.08	2635.36	"
18.10.82	20-55	20-56	0.01	0.83	"
26.10.82	20-30	20-37	0.11	191.56	"
3.11.82	20-10	20-15	0.08	167.65	"
8.11.82	18-50	19-00	0.16	118.58	"
16.11.82	23-50	00-11	0.35	196.83	"
26.11.82	20-07	20-23	0.26	263.93	"
18.2.83	19-16	19-40	0.40	2014.87	

Table 5.3 (Contd.)

Load point - 9(F-33)

1	2	3	4	5	6
29.9.82	17-58	18-10	0.20	2177.96	F

Load point - 11(F-32)

28.11.82	20-30	20-50	0.33	3596.50	"
19.1.83	14-25	14-35	0.16	1241.57	"
31.1.83	09-55	10-12	0.28	283.32	"
31.1.83	11-50	12-10	0.33	0.63	"

Load point - 12(F-32

25.10.82	20-34	20-50	0.26	2808.56	"

Load point - 13(F-32)

3.8.82	01-15	01-34	0.31	793.25	"
3.8.82	20-55	21-02	0.11	19.35	"
27.10.82	19-50	20-10	0.33	2038.79	"
28.10.82	19-25	19-37	0.20	23.24	"
22.11.82	17-05	17-18	0.21	597.46	"
4.12.82	10-45	11-25	0.66	281.45	"
27.12.82	10-38	10-44	0.10	551.21	"
30.12.82	13-20	13-50	0.50	74.50	"
31.12.82	18-48	19-48	1.00	28.96	"
1.3.83	10-10	10-50	0.66	1430.36	"

Load point - 14(F-32)

12.7.82	18-32	18-36	0.06	282.53	"
4.8.82	14-40	14-52	0.20	548.06	"
19.10.82	19-55	20-09	0.23	1109.05	"
24.10.82	10-41	10-55	0.23	110.53	"
3.11.82	21-24	21-43	0.31	250.48	"
21.11.82	19-33	20-00	0.45	429.83	"
11.12.82	16-25	16-35	0.16	476.41	"
12.12.82	12-20	13-36	1.26	19.75	"
21-12-82	10-05	10-20	0.25	212.48	"

Table 5.3 (Contd.)

1	2	3	4	5	6
22.12.82	13-30	13-50	0.33	27.16	F
25.1.83	16-10	16-35	0.40	794.33	"
22.3.83	13-20	13-27	0.11	1340.74	"
2.7.83	21-22	21-37	0.25	2455.90	"
		Load point - 15(F-33)			
29.9.82	18-17	18-28	0.18	2178.28	"
8.12.82	19-05	19-15	0.16	1656.51	"
10.12.82	19-50	20-14	0.40	48.58	"
11.12.82	20-05	20-16	0.16	23.79	"
12.12.82	17-05	17-20	0.25	20.83	"
12.12.82	22-00	22-40	0.66	4.66	M
15.12.82	23-30	24-00	0.50	72.50	F
19.12.82	14-57	14-59	0.03	86.95	M
1.3.83	19-45	20-08	0.38	292.71	F
19.5.83	19-50	20-05	0.25	1895.70	"
29.6.83	20-10	20-40	0.50	984.08	"
1.7.83	09-30	09-45	0.25	36.83	"
		Load point - 16 (F-36)			
26.9.82	02-15	02-50	0.58	2090.25	F
11.10.82	00-40	01-10	0.50	357.82	"
20.10.82	10-55	11-05	0.16	225.75	"
25.10.82	21-40	21-51	0.18	130.58	"
16.11.82	14-55	15-04	0.16	497.05	"
17.12.82	11-30	15-42	2.20	740.43	"
21.12.82	21-50	22-20	0.50	102.13	"
21.12.82	23-15	00-04	0.81	0.91	"
22.12.82	11-50	13-31	1.68	11.71	M
23.12.82	16-15	16-30	0.25	26.73	"
23.12.82	19-28	19-45	0.28	2.96	"
13.1.83	12-16	12-25	0.16	496.50	F
23.1.83	12-40	12-55	0.25	240.25	M
		Load point - 17(F-36)			
17.7.82	10-37	10-44	0.11	394.61	F

Table 5.3 (Contd.)

1	2	3	4	5	6
3.8.82	14-35	14-44	0.15	387.85	F
4.8.82	17-00	17-17	0.28	27.26	"
20.12.82	14-58	15-05	0.11	3309.68	"
		Load point - 18 (F-36)			
23.7.82	10-20	11-10	0.83	538.33	"
2.8.82	11-45	12-34	0.81	240.58	"
3.8.82	00-12	00-30	0.30	11.63	"
4.10-82	11-20	11-35	0.25	778.83	"
12.10.82	15-30	15-37	0.11	195.91	"
22.10.82	11-40	11-59	0.31	236.05	"
22-10-82	12-20	12-30	0.16	0.35	"
12.11.82	18-44	19-15	0.52	510.63	"
12.11.82	21-02	21-31	0.48	1.78	"
9.1.83	14-40	14-57	0.28	1385.15	"
9.1.83	15-35	15-47	0.20	0.63	"
14.1.83	08-49	09-00	0.18	257.03	"
25.1.83	19-30	19-55	0.41	274.50	"
5.2.83	19-00	19-10	0.16	263.08	"
5.2.83	19-32	19-45	0.21	0.36	"
13.2.82	12-05	12-20	0.25	184.33	"
18.2.83	19-05	19-20	0.25	126.70	"
25.6.83	21-37	21-45	0.13	3026.28	"
28.6.83	11-45	12-05	0.33	62.00	"
29.6.83	21-44	22-10	0.41	33.66	"
		Load point - 19 (F-36)			
4.1.83	11-50	12-36	0.76	4499.83	M
2.5.83	09-40	09-47	0.11	2829.06	F
25.6.83	20-15	20-45	0.50	1286.46	"
		Load point - 21(F-36)			
1.8.82	10-19	12-21	2.03	754.31	M
27.9.82	08-55	09-05	0.16	1364.56	F

Table 5.3 (Contd.)

1	2	3	4	5	6
9.1.83	09-45	09-55	0.16	2496.66	F
24.2.83	20-30	20-35	0.08	1114.58	"
11.4.83	15-05	15-37	0.53	1073.49	"
19.5.83	17-45	17-58	0.21	890.13	"
		Load point - 22 (F-36)			
3.8.82	00-40	01-40	1.00	792.66	F
3.8.82	12-50	13-06	0.26	11.16	"
23.9.82	10-30	10-50	0.33	1221.40	"
23.9.82	11-40	11-52	0.20	0.83	M
12.1.83	09-07	09-14	0.11	2661.24	F
8.4.83	15-25	15-40	0.25	2070.01	"
8.4.83	19-36	19-45	0.15	3.93	"
21.5.83	10-15	10-45	0.50	1022.50	M
5.6.83	09-30	09-45	0.25	358.75	F
24.6.83	23-40	23-50	0.16	469.91	"
		Load point - 23(F-36)			
4.8.82	19-00	19-15	0.25	835.00	F
7.8.82	20-00	20-20	0.33	72.75	"
26.9.82	01-25	02-00	0.58	1181.07	"
17.10.82	10-35	10-49	0.23	512.58	"
31.10.82	15-45	16-07	0.36	340.93	"
23.1.83	21-22	21-32	0.16	2021.25	"
19.2.83	09-50	10-00	0.16	636.30	"
19.2.83	19-35	19-47	0.20	9.58	"
		Load point - 24 (F-35)			
14.3.83	21-20	21-40	0.33	6165.33	F
14.3.83	21-45	21-55	0.16	0.08	M
27.3.83	23-25	23-37	0.20	313.50	F
		Load point - 25(F-36)			
5.4.83	15-25	16-05	0.66	6687.41	F

CHAPTER 6

RELIABILITY PREDICTION OF EQUIPMENTS

6.1 Power Plant Reliability

6.1.1 Reliability Predictions of the Plant & Equipment

In this chapter the reliability of each equipment of the plant and also the plant are predicted for different time period in days (say 0,5,10,20,30,40,50,100,150,200, 250,300,400 and 500) by using the formula R = exp $\{(-t/\eta)^{\beta}\}$, where β and η are the respective shape and scale parameters. There is only one stand-by system i.e. feed pump, but for the last 5 years only two failure suffered by the feed pump and there is no individual record of that failure. Since the number of failure are very less it is considered as single unit, The reliability of individual equipment and the plant are shown in Table 6.1.

Table 6.1 Reliability prediction of individual equipment and the plant.

Equipments	β	η	Time Days													
			0	5	10	20	30	40	50	100	150	200	250	300	400	500
			Reliability													
Boiler	0.73	162.84	1	0.9240	0.8772	0.8047	0.7467	0.6975	0.6549	0.4960	0.3885	0.3115	0.2539	0.2084	0.1445	0.1026
Turbine	0.60	171.06	1	0.8868	0.8335	0.7588	0.7033	0.6581	0.6199	0.4849	0.3967	0.3333	0.2848	0.2463	0.1891	0.1490
Generator	0.93	94.55	1	0.9367	0.8829	0.7889	0.7077	0.6365	0.5735	0.3467	0.2134	0.1329	0.0834	0.0527	0.0213	0.0088
Vacuum System	0.59	26.37	1	0.6876	0.5687	0.4276	0.3399	0.2784	0.2325	0.1112	0.0614	0.0367	0.0231	0.0150	0.0069	0.0034
I.D. Fan (left)	0.66	199.10	1	0.9158	0.8702	0.8029	0.7506	0.7069	0.6690	0.5299	0.4361	0.3666	0.3126	0.2645	0.2048	0.1598
I.D. Fan (right)	0.75	183.26	1	0.9350	0.8931	0.8268	0.7728	0.7263	0.6852	0.5296	0.4225	0.3433	0.2826	0.2348	0.1656	0.1194
C.W. Pump (1)	1.02	577.02	1	0.9921	0.9841	0.9681	0.9521	0.9363	0.9207	0.8459	0.7764	0.7122	0.6530	0.5985	0.5029	0.4214
C.W. Pump (2)	0.64	843.60	1	0.9631	0.9431	0.9128	0.8834	0.8674	0.8487	0.7744	0.7180	0.6715	0.6316	0.5967	0.5376	0.4887

Table 6.1 (Contd...)

Equipments.	β	η	Time Days 0	5	10	20	30	40	50	100	150	200	250	300	400	500
			Reliability													
Other causes	0.81	134.00	1	0.9326	0.8849	0.8071	0.7426	0.6868	0.6376	0.4643	0.3343	0.2507	0.1906	0.1464	0.0884	0.0547
Feed Pump	1.47	485.81	- 1	0.9987	0.9966	0.9908	0.9834	0.9747	0.9601	0.9064	0.9368	0.7618	0.6855	0.6104	0.4767	0.3514
F.D. Fan.	1.89	287.62	1	0.9994	0.9978	0.9920	0.9828	0.9707	0.9566	0.8455	0.6966	0.8365	0.3870	0.2619	0.0995	0.0296
Transformer	0.61	309.45	1	0.9923	0.8839	0.8284	0.7857	0.7502	0.7194	0.6050	0.5254	0.4644	0.4152	0.3745	0.3102	0.2615
Condenser	0.84	66.05	1	0.8918	0.8148	0.6930	0.5973	0.5188	0.4531	0.2424	0.1364	0.0791	0.0468	0.0282	0.0106	0.0041
Oil Cooler	3.21	166.87	1	0.9999	0.9998	0.9986	0.9958	0.9896	0.9789	0.8215	0.4856	0.1622	0.0241	0.0012	–	–
Water Heater	2.76	201.31	1	0.9999	0.9997	0.9982	0.9947	0.9884	0.9787	0.8644	0.6402	0.3729	0.1610	0.0487	0.0012	–
Power Plant.	0.80	12.82	1	0.6244	0.4405	0.2399	0.1388	0.0833	0.0512	0.0005	–	–	–	–	–	–

6.1.2 Reliability vs. Time Curve of Equipments

In this section predicted reliability vs. time curve of various equipments of the plant and the power plant, itself are shown in figure 6.1 to 6.9. The power plant reliability vs. time curve is shown in figure 6.10.

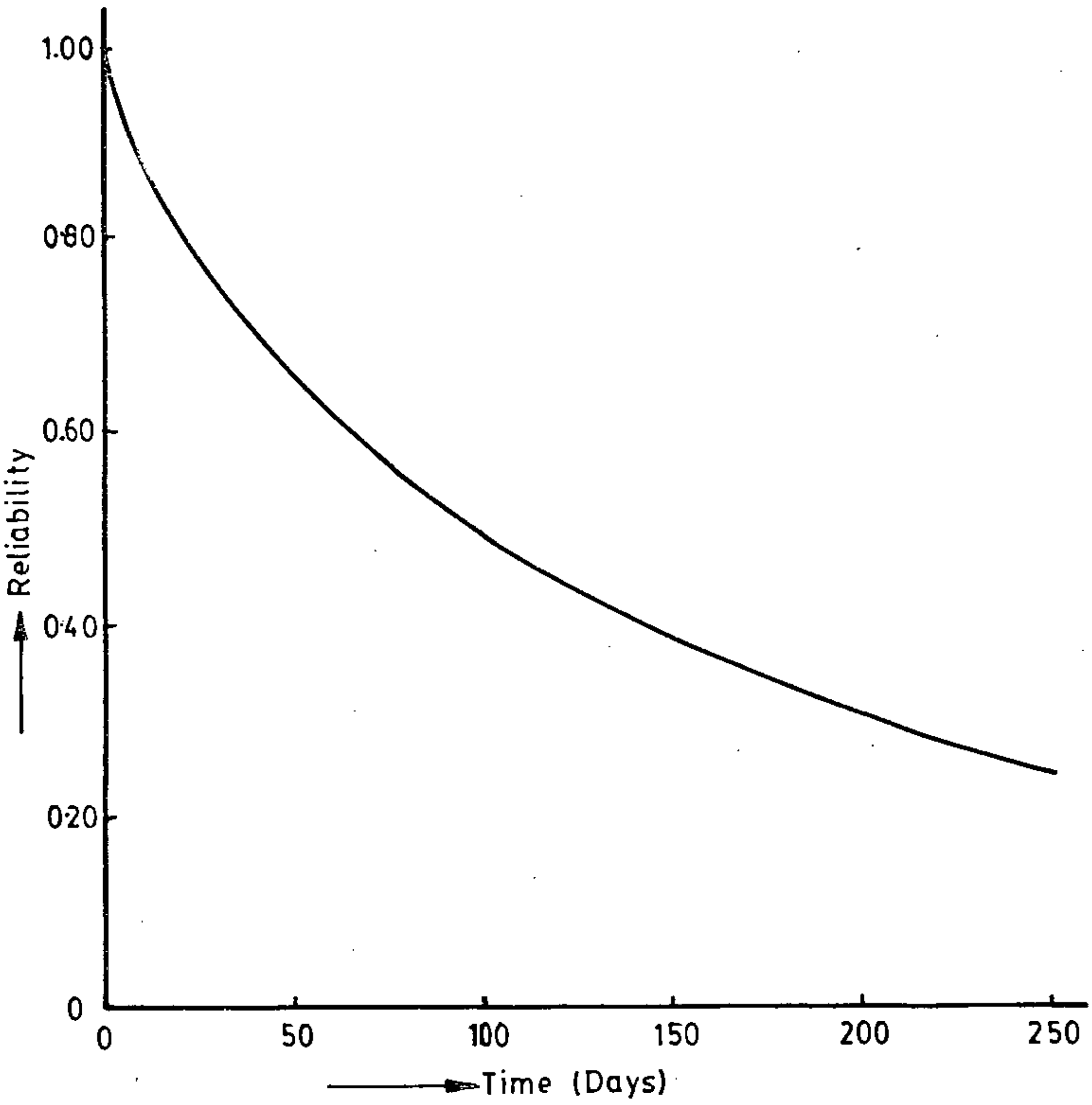


Fig. 6.1 Reliability Vs time curve of Boiler

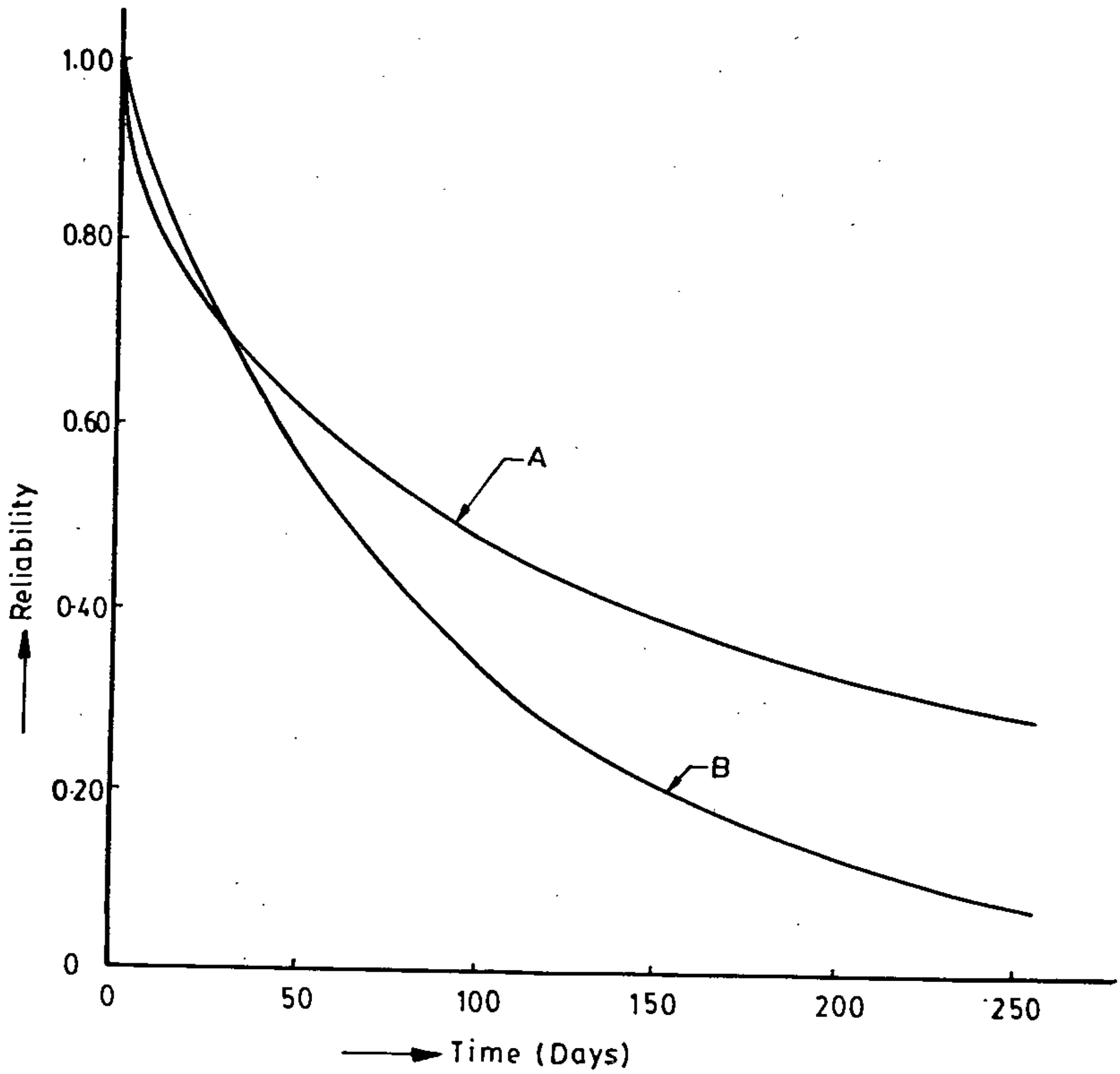


Fig. 6.2 A – Reliability Vs time curve of Turbine
B – Reliability Vs time curve of Generator

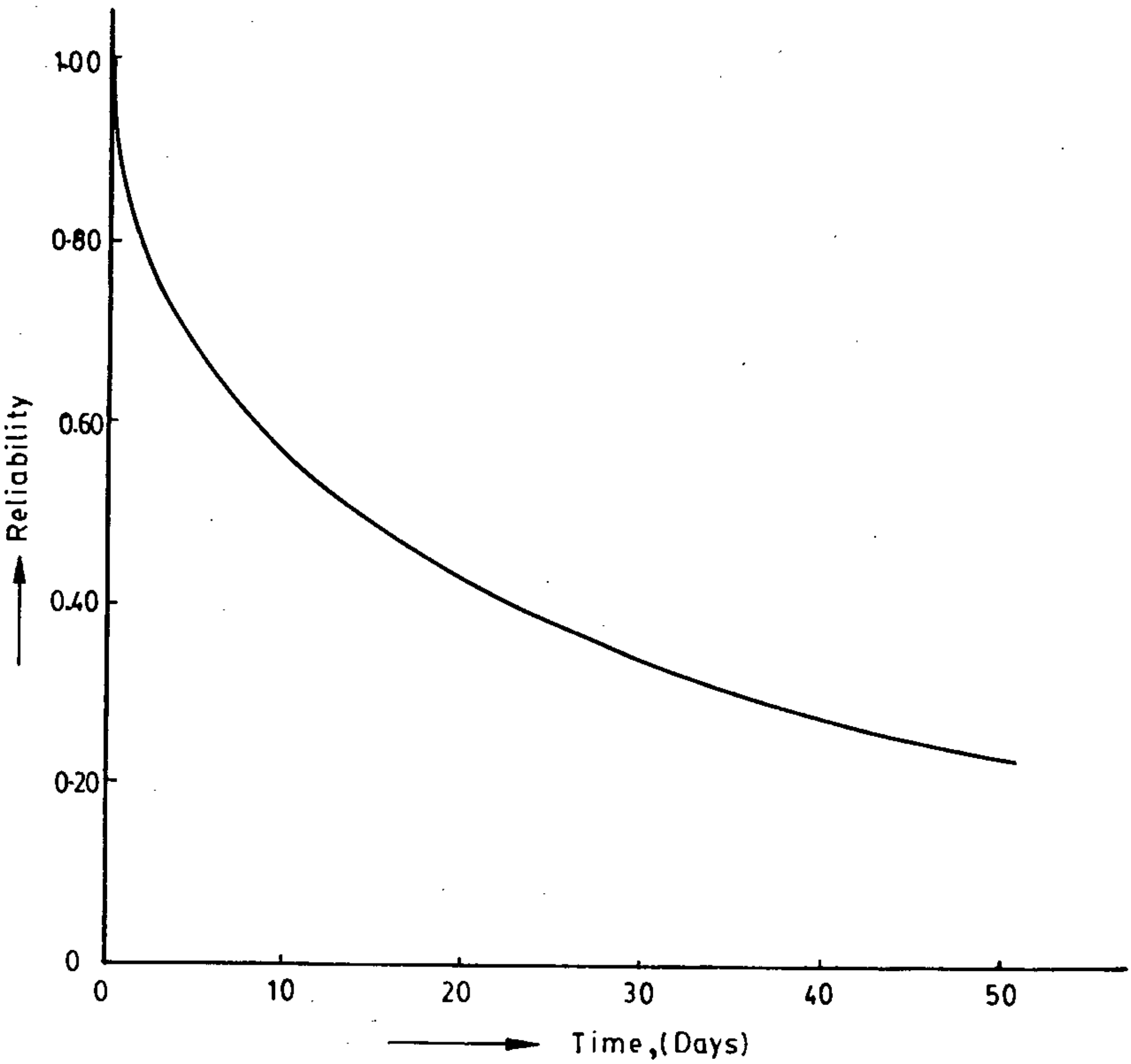


Fig.6.3 Reliability Vs time curve of vacuum system.

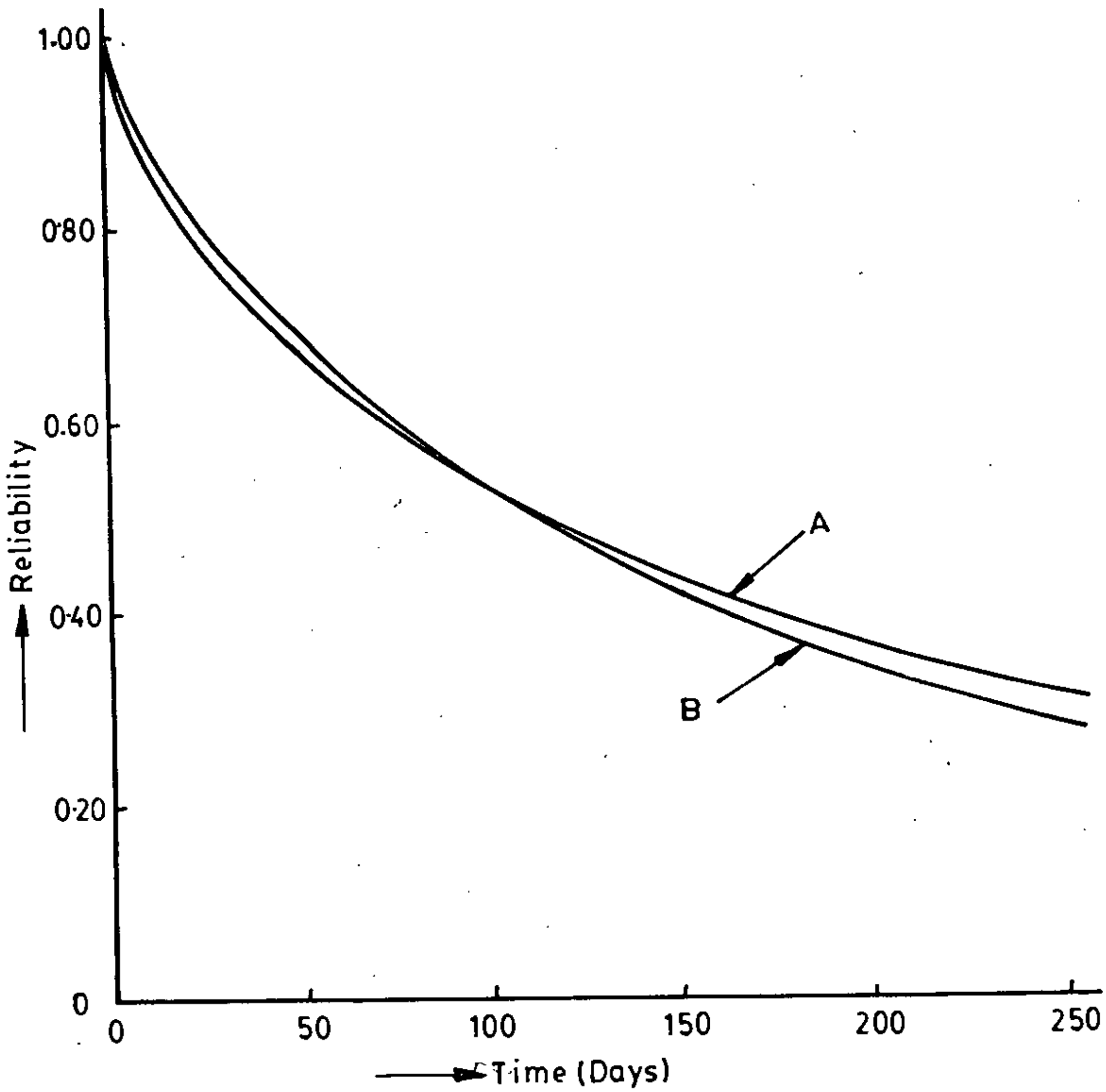


Fig. 6.4 Reliability Vs time curve of Equipment
A – I.D. Fan (left), B – I.D. Fan (right)

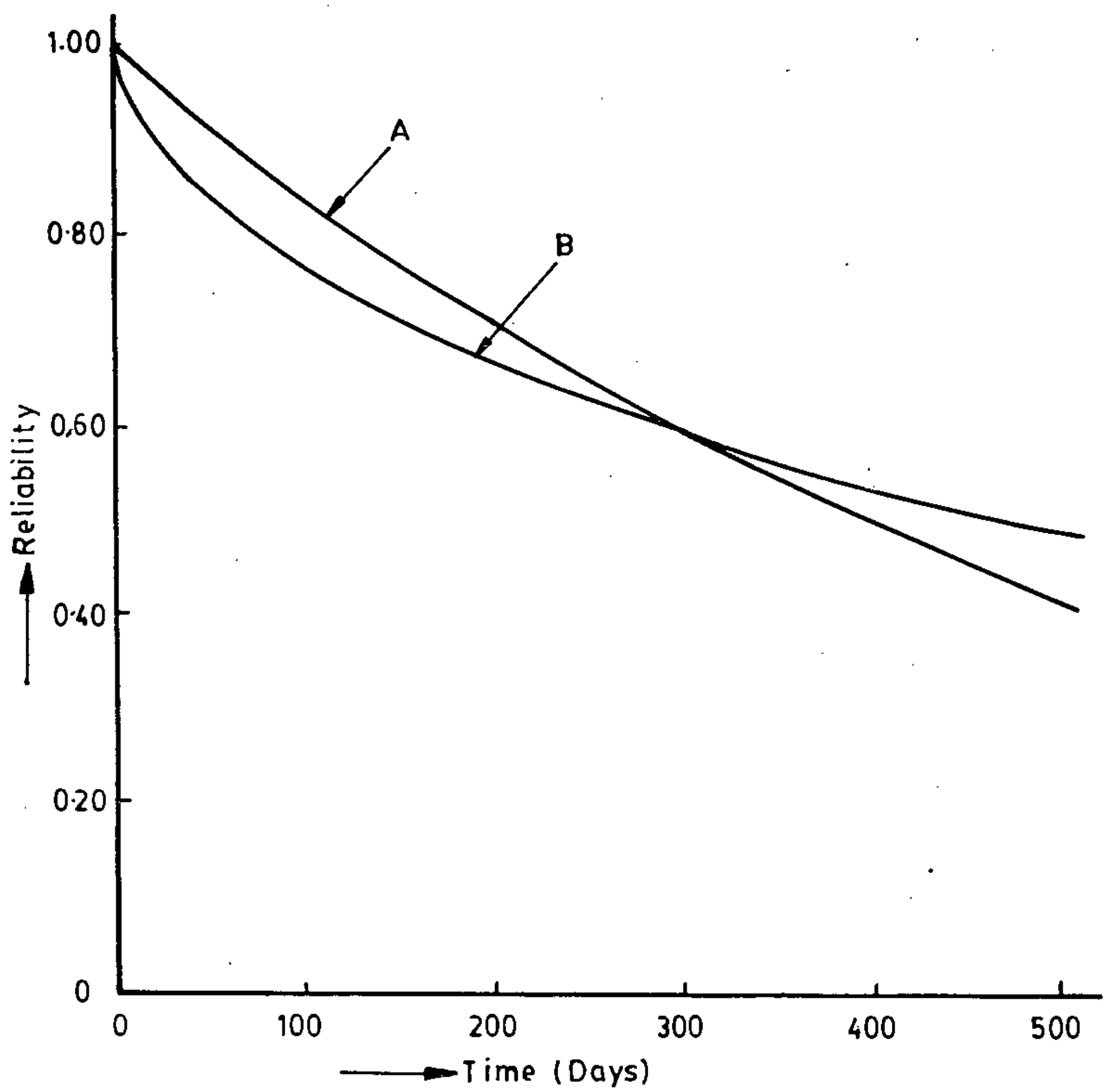


Fig. 6.5 A – C.W. Pump No-1
B – C.W. Pump No-2

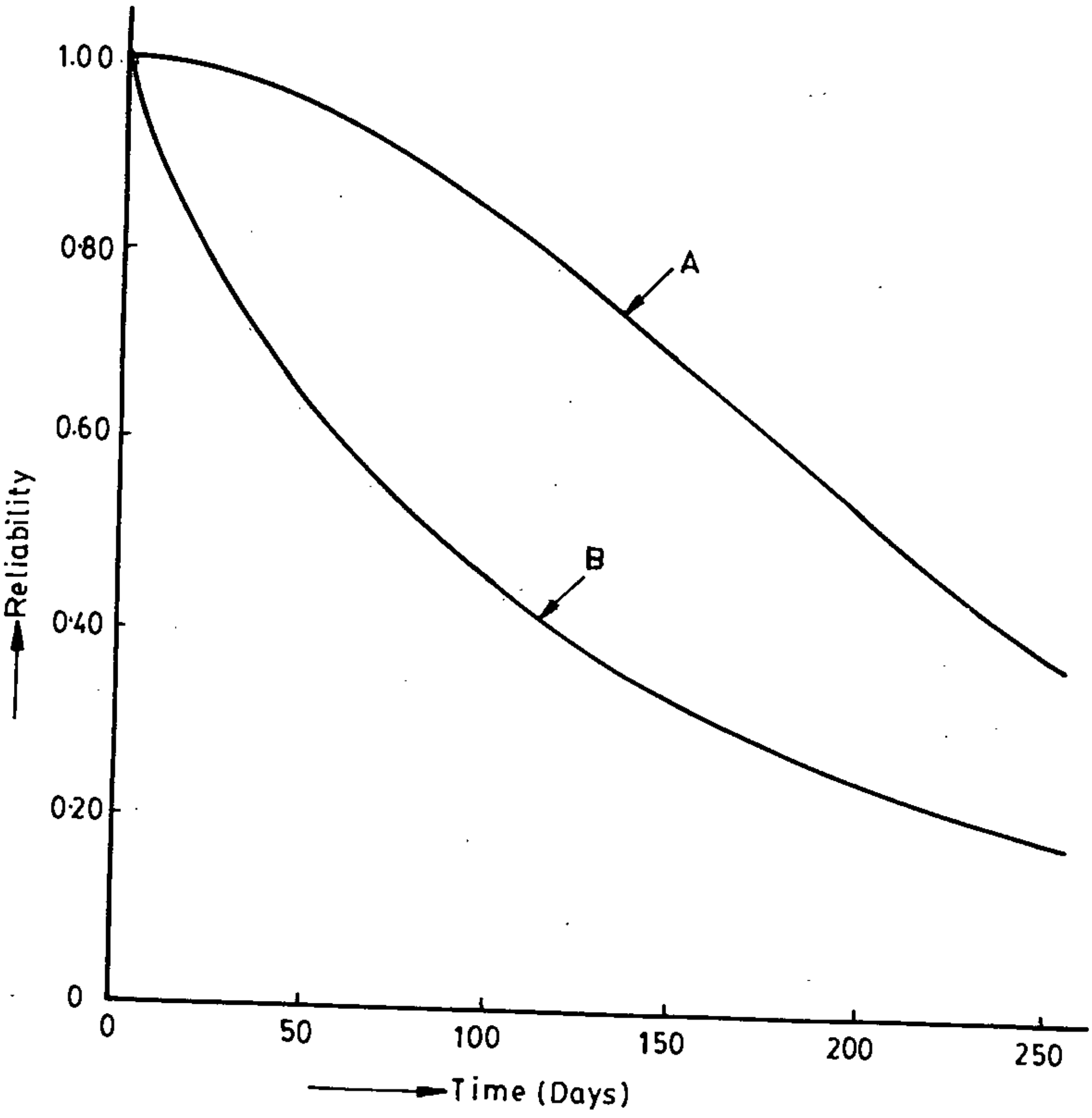


Fig.6.6 Reliability Vs time curve of Equipment
A– F.D. Fan, B– Other causes

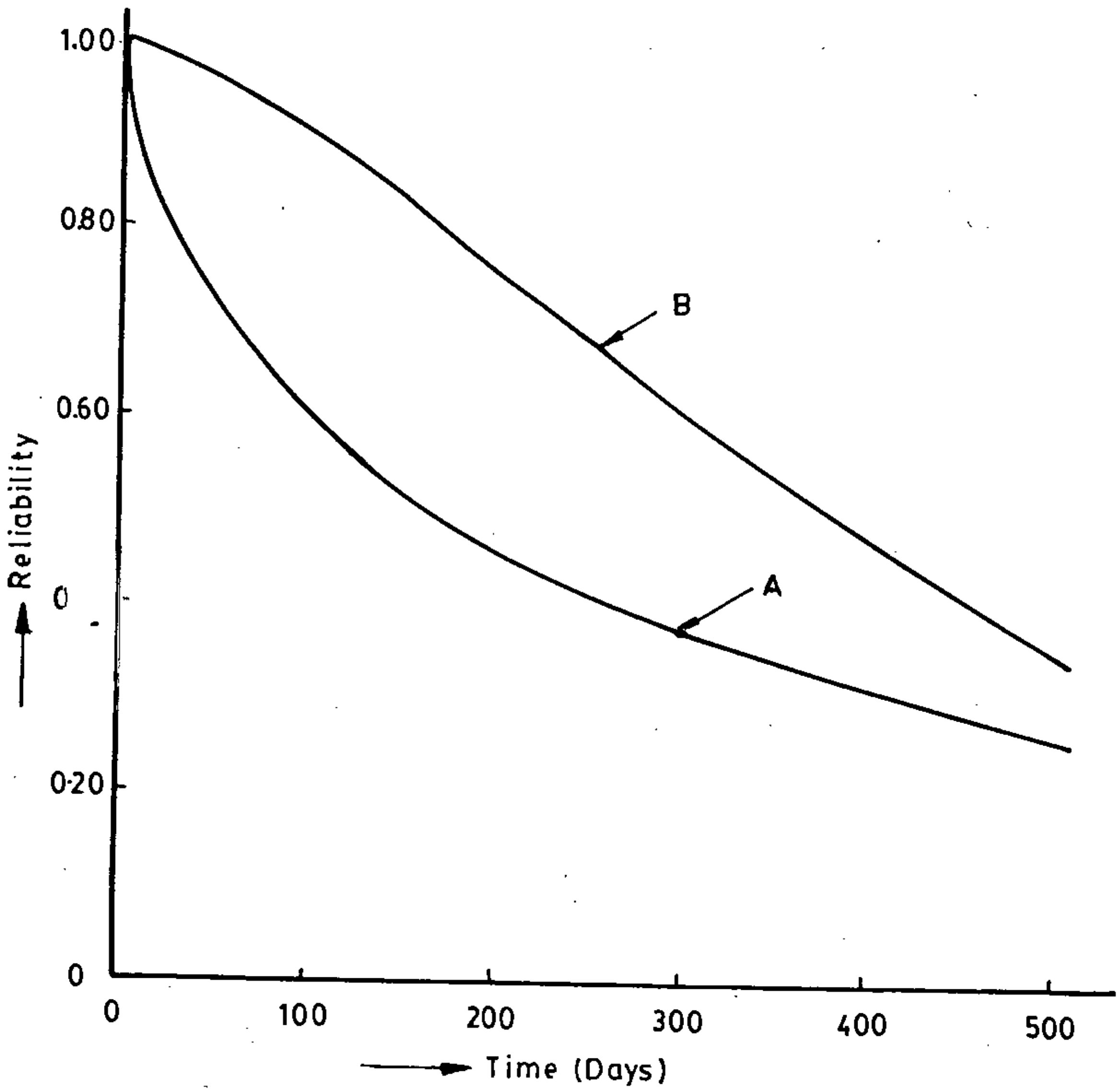


Fig.6.7 Reliability Vs time curve of A–Transformer
B–Feed pump

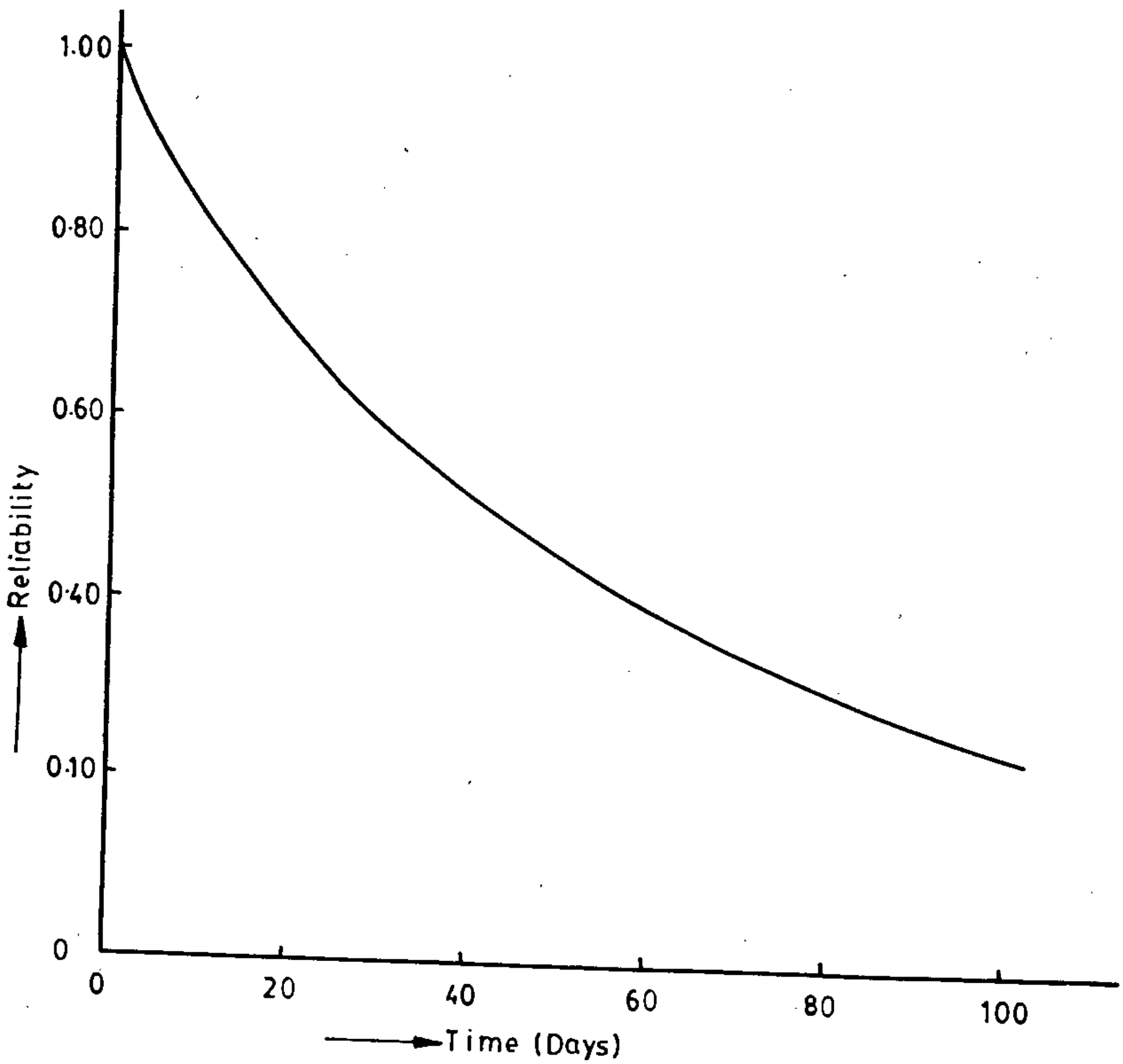


Fig. 6.8. Reliability Vs time curve of Equipment condenser.

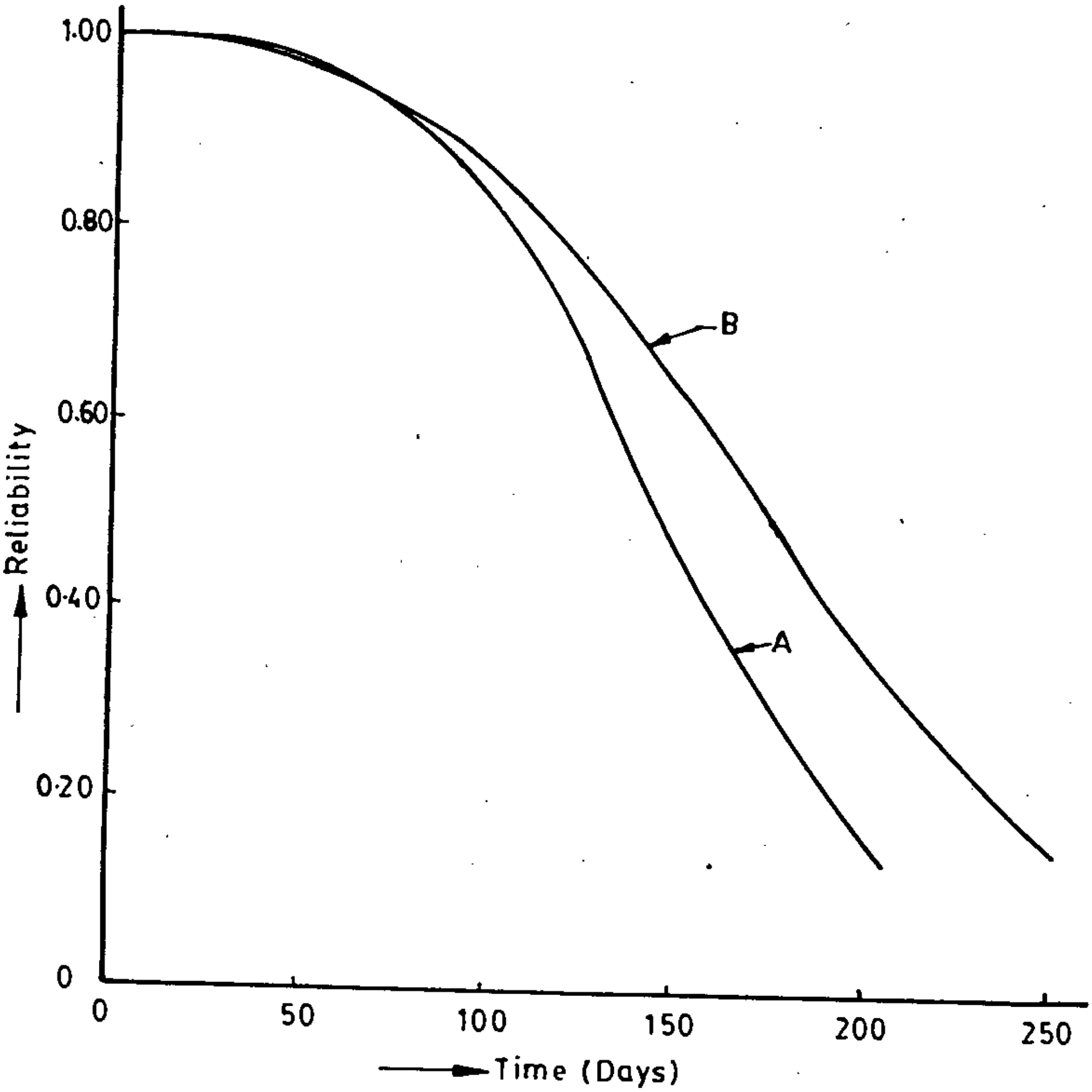


Fig. 6.9 Reliability Vs time curve of Equipment

A - Oil cooler

B - Water heater

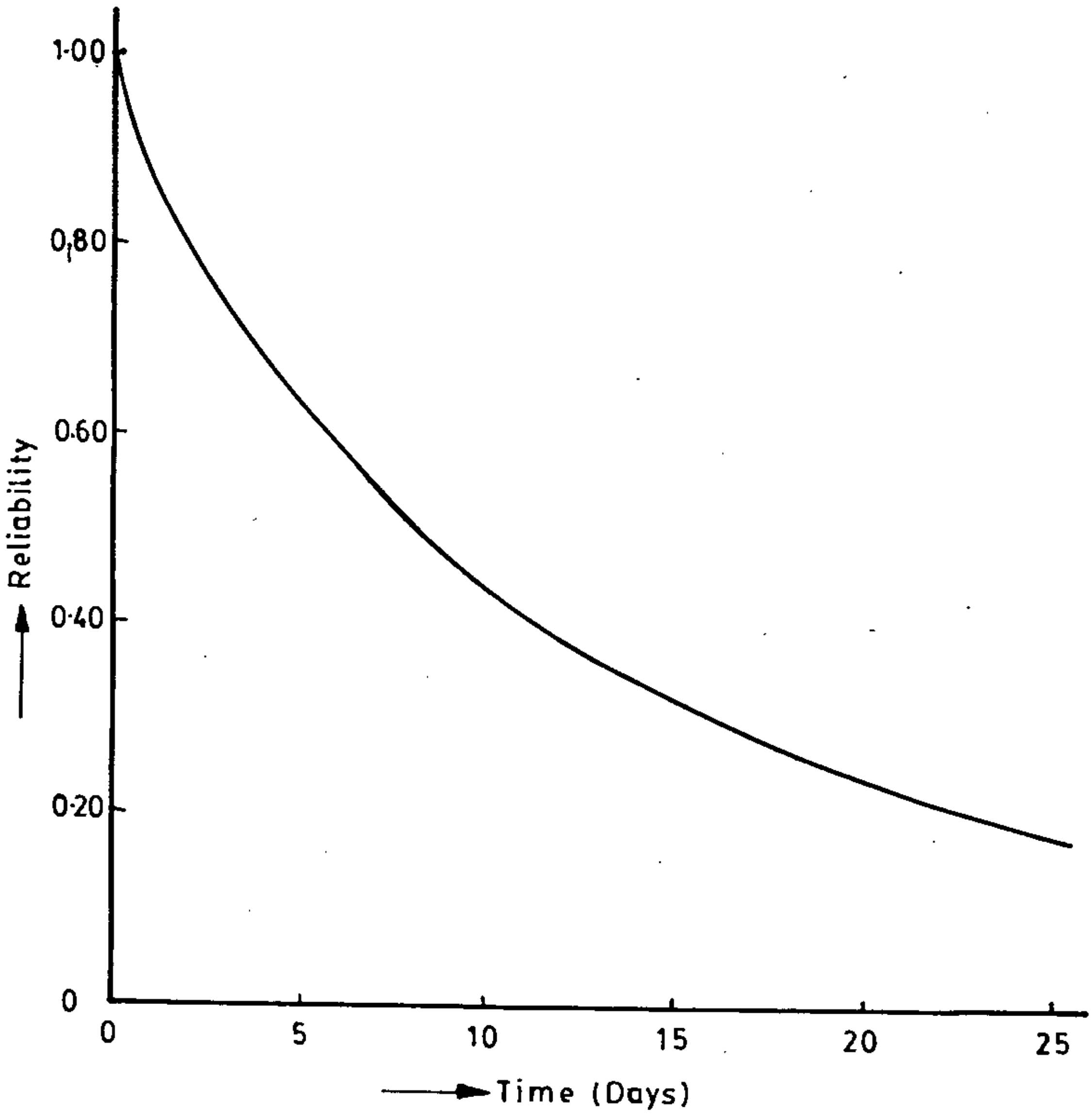


Fig. 6·10 Reliability Vs time curve of Power plant .

6.2 Distribution System Reliability

6.2.1 Distribution System Reliability Indices Calculations

In this section the reliability indices of each component of the distribution system and the overall relibility indices of the system itself for the study period are calculated. For the distribution system, the failure rate and downtime of the components are listed in Table 6.2.

In computing the various reliability indices it is assumed that all the interrupting devices work properly all the time. The load point indices are calculated by equations 3.2.1 & 3.2.2 and the results, along with descriptions of the paths to each load point are shown in Table 6.3.

The overall distribution system reliability indices are computed by equation 3.2.5 and 3.2.6 and the results are shown in Table 6.4.

Table 6.2 Distribution System Component Data.

Component 1	Branches Containing Component 2	Including Loadshade			Excluding Load shade		
		M.T.B.F (hrs) 3	Rate of Failure λ_α/yer 4	Downtime (hrs) T_α 5	M.T.B.F. (hrs) 6	Rate of Failure λ_α/yer 7	Downtime (hrs) T_α 8
Subtransmission Line (33KV)	11	7596.50	0.00013	0.75	7596.50	0.00013	0.75
Gate S/S (I) Feeder	21	219.10	0.0045	0.88	445.68	0.0022	0.50
Khalispur S/S (I) Feeder	22	245.07	0.0040	0.37	357.89	0.0027	0.28
B.I.D.C. Feeder	31	143.23	0.0069	0.87	322.54	0.0031	1.05
Khalispur Feeder	32	110.02	0.0090	0.60	274.70	0.0036	0.51
Kohinoor Feeder	33	240.95	0.0041	0.82	595.20	0.0016	0.68
Star Crescent Feeder	34	284.58	0.0035	0.81	333.64	0.0029	0.86
Charerhat Fish Co. Feeder	35	1459.97	0.0007	1.30	1459.97	0.0007	1.30
Rerolling mill feeder	36	108.70	0.0091	0.75	397.60	0.0025	0.52
Load Point-1 LP1	41	–	–	–	406.32	0.0024	0.45
" LP2	42	–	–	–	2875.44	0.0003	0.17
" LP3	43	–	–	–	1765.66	0.0006	0.26
" LP4	44	–	–	–	1373.04	0.0007	0.098
" LP5	45	–	–	–	6548.16	0.00015	1.25
" LP6	46	–	–	–	2106.24	0.0005	0.24

Table 6.2 (Contd...)

1	2	3	4	5	6	7	8
Load Point-7 LP7	47	–	–	–	1290.48	0.0008	0.51
" LP8	48	–	–	–	682.56	0.0014	0.18
" LP9	49	–	–	–	2177.96	0.0005	0.20
" LP11	51	–	–	–	1331.04	0.0007	0.27
" LP12	52	–	–	–	2808.56	0.0004	0.26
" LP13	53	–	–	–	594.00	0.0016	0.41
" LP14	54	–	–	–	1027.44	0.0009	0.25
" LP15	55	–	–	–	877.44	0.0011	0.31
" LP16	56	–	–	–	559.77	0.0018	0.75
" LP17	57	–	–	–	619.92	0.0016	0.16
" LP18	58	–	–	–	396.24	0.0025	0.33
" LP19	59	–	–	–	3518.88	0.0003	0.42
" LP21	61	–	–	–	1420.32	0.0007	0.53
" LP22	62	–	–	–	1139.04	0.0009	0.26
" LP23	63	–	–	–	703.92	0.0014	0.28
" LP24	64	–	–	–	3284.64	0.0003	0.23
" LP25	65	–	–	–	6687.41	0.0014	0.66

Table 6.3 Load Point Reliability Indices

Load Point	Branches in Series on Path to Load Point	Number of Customers	Including Load shade: $f_{Fmn} = \sum\lambda_\alpha$ (/yr)	Including Load shade: $T_{Fmn} = \frac{\sum\lambda_\alpha T_\alpha}{\sum\lambda_\alpha}$ (hr)	Excluding Load shade: f_{Fmn} (/yr)	Excluding Load shade: T_{Fmn} (hr)
1	2	3	4	5	6	7
1	11, 21, 31, 41	42	0.0139	0.797	0.0078	1.367
2	11, 21, 31, 42	24	0.0118	0.851	0.0057	1.690
3	11, 21, 31, 43	23	0.0121	0.839	0.0060	1.624
4	11, 21, 31, 44	15	0.0122	0.825	0.0061	1.581
5	11, 21, 31, 45	17	0.0116	0.872	0.0055	1.77
6	11, 22, 36, 46	31	0.0137	0.621	0.0058	1.04
7	11, 21, 32, 47	15	0.0144	0.684	0.0067	1.098
8	11, 21, 32, 48	27	0.0150	0.649	0.0073	0.986
9	11, 22, 33, 49	12	0.0087	0.578	0.0049	0.820
11	11, 21, 32, 51	19	0.0143	0.674	0.0066	1.08
12	11, 21, 32, 52	15	0.0140	0.682	0.0063	1.12
13	11, 21, 32, 53	22	0.0152	0.664	0.0075	1.01
14	11, 21, 32, 54	17	0.0145	0.667	0.0068	1.05
15	11, 22, 33, 55	20	0.0093	0.566	0.0055	0.774
16	11, 22, 36, 56	1	0.0150	0.65	0.0071	1.02
17	11, 22, 36, 57	30	0.0148	0.584	0.0069	0.895
18	11, 22, 36, 58	21	0.0157	0.587	0.0078	0.864
19	11, 22, 36, 59	12	0.0135	0.631	0.0056	1.08
21	11, 22, 36, 61	25	0.0139	0.631	0.0060	1.05
22	11, 22, 36, 62	1	0.0141	0.612	0.0062	0.992
23	11, 22, 36, 63	20	0.0146	0.602	0.0067	0.642
24	11, 22, 35, 64	1	0.0051	0.499	0.0038	0.577
25	11, 22, 36, 65	1	0.0133	0.638	0.0054	1.11

Table 6.4 Overall Reliability Indicies of Distribution System

Load Point	Location	Including Load shade			Excluding Load shade		
		Number of Customers C_{mn}	$C_{mn} \int F_{mn}$	$C_{mn} \int F_{mn} T_{F_{mn}}$	C_{mn}	$C_{mn} \int F_{mn}$	$C_{mn} \int F_{mn} T_{F_{mn}}$
1	41	42	0.583	0.465	42	0.327	0.447
2	42	24	0.283	0.241	24	0.136	0.231
3	43	23	0.278	0.233	23	0.138	0.224
4	44	15	0.183	0.150	15	0.091	0.144
5	45	17	0.197	0.172	17	0.093	0.165
6	46	31	0.424	0.263	31	0.179	0.186
7	47	15	0.216	0.147	15	0.100	0.110
8	48	27	0.405	0.262	27	0.197	0.194
9	49	12	0.104	0.060	12	0.058	0.048
11	51	19	0.27	0.183	19	0.125	0.135
12	52	15	0.21	0.143	15	0.094	0.105
13	53	22	0.334	0.222	22	0.165	0.166
14	54	17	0.246	0.164	17	0.116	0.121
15	55	20	0.186	0.105	20	0.110	0.085
16	56	1	0.015	0.009	1	0.007	0.007
17	57	30	0.444	0.259	30	0.207	0.185
18	58	21	0.329	0.193	21	0.163	0.141
19	59	12	0.162	0.102	12	0.067	0.072
21	61	25	0.347	0.219	25	0.150	0.172
22	62	1	0.114	0.008	1	0.006	0.006
23	63	20	0.292	0.175	20	0.134	0.086
24	64	1	0.005	0.003	1	0.004	0.002
25	65	1	0.013	0.008	1	0.005	0.006

6.2.2 Calculation Steps for overall Reliability Indices

The overall system reliability indices are computed by equations (3.2.5) and (3.2.6). Substituting the appropriate values from Table (6.4) we obtain

Including loadshade

$$f_F = \frac{5.54}{411} = 0.013/\text{Yr., customer} \qquad T_F = \frac{3.78}{5.54} = 0.682 \text{ hr.}$$

Excluding loadshade

$$f_F = \frac{2.67}{411} = 0\ 00649/\text{Yr., customer} \qquad T_F = \frac{3.03}{2.67} = 1.13 \text{ hr.}$$

CHAPTER 7

OPERATIONAL READINESS AND AVAILABILITY ASSESSMENT OF EQUIPMENTS

7.1 Operational Readiness and Availability Assessment of Power Plant

Availability and operational readiness is an important consideration in relatively complex systems, because high reliability of the system alone is not sufficient to ensure that the system will be available or ready to operate when needed. It is also necessary to ensure that it can be repaired quickly and that essential scheduled maintenance tasks can be performed quickly to reduce downtime and consequently idel time of the plant. So, in this chapter, availability of each equipment and the plant are assessed and results are shown in Table 7.1. The mean time between failure (MTBF) have been calculated by simple averaging and also from failure distribution parameters. Since the MTBF(MLE) is slightly larger than MTBF by simple averaging, resulting availabilities are slightly higher. Operational readiness could not be calculated due to unavailability of idle time of each equipment and the plant itself.

Table 7.1 Availability Assessment of Individual Equipment and the Plant

Equipment 1	Number of Failure 2	Number of Maintenance 3	Number of Repair 4	Running time (day) 5	Down time (day) 6	Repair time (day) 7	M.T.T.R $8=\frac{7}{4}$	MLE: M.T.B.F 9	MLE: Availability $10=\frac{9}{8+9}$	Simple Average: M.T.B.F 11	Simple Average: Availability $12=\frac{11}{8+11}$
Boiler	11	23	32	1259.92	119.45	119.25	3.72	197.95	0.981	114.54	0.968
Turbine	10	13	22	1340.62	44.48	44.28	2.01	259.89	0.992	134.06	0.985
Generator	14	5	7	1329.48	26.69	24.83	3.54	97.68	0.965	94.96	0.964
Vacuum System	27	6	33	945.75	87.67	87.67	2.66	40.45	0.938	35.02	0.929
I.D. Fan (left)	8	16	20	1275.06	109.73	109.14	5.48	266.78	0.979	159.38	0.966
I.D. Fan (right)	7	11	14	1115.32	37.90	37.81	2.70	217.30	0.987	159.33	0.983
C.W. Pump (1)	2	14	16	1194.44	67.24	67.24	4.20	571.74	0.992	597.22	0.993
C.W. Pump (2)	3	14	17	1190.00	69.35	69.35	4.07	1178.85	0.996	396.66	0.989

Table 7.1(Contd..)

Equipment 1	Number of Failure 2	Number of Maint. 3	Number of Repair 4	Running time (day) 5	Down time (day) 6	Repair time (day) 7	M.T.T.R $8=\frac{7}{4}$	MLE M.T.B.F 9	MLE Availability $10=\frac{9}{8+9}$	Simple Average M.T.B.F 11	Simple Average Availability $12=\frac{11}{8+11}$
Other causes	8	7	9	1040.16	26.05	24.66	2.74	151.21	0.982	130.02	0.979
Feed Pump	2	5	6	1186.49	11.70	11.38	1.89	439.94	0.995	593.04	0.996
F.D. Fan	2	1	1	679.50	3.83	3.75	3.75	228.80	0.983	339.75	0.989
Transformer	4	1	1	916.12	1.57	0.62	0.62	455.22	0.998	229.03	0.997
Condenser	-	23	23	1318.51	68.73	68.73	2.98	72.42	0.960	57.32	0.950
Oil Cooler	-	4	4	928.74	4.44	4.44	1.11	149.84	0.992	232.18	0.995
Water Heater	-	5	5	1257.52	9.30	9.30	1.86	179.33	0.989	251.50	0.992
Power Plant	87	68	125	1023.21	326.82	321.89	2.75	14.55	0.849	11.76	0.820

7.2 Availability Assessment of individual component in the distribution system

In this section the availability of each component in the distribution system are assesssed once by considering loadshade and again by excluding loadshade. The availability by excluding loadshade is high because the total downtime is less incomparison to that of availability including loadshade. The results are shown in Table 7.2.

Table 7.2 Availability Assessment of Individual Component in the Distribution System.

Component/ Load Point	Running time (hrs)	Including Loadshade		Excluding Loadshade	
		Downtime (hrs)	Availability	Downtime (hrs)	Availability
1	2	3	$4 = \frac{2}{2+3}$	5	$6 = \frac{2}{2+5}$
Subtransmission - 11	7596·50	0·75	0·999	0·75	0·999
Gate S/S(I) - -21	4382·04	18·46	0·995	5·75	0·998
Khalispur S/S(I)-22	5146·61	8·58	0·998	5·78	0·998
B.I.D.C. Feeder - 31	6875·19	59·99	0·991	37·30	0·994
Khalispur Feeder - 32	6491·60	53·70	0·991	28·95	0·995
Kohinoor Feeder - 33	6023·80	29·04	0·995	14·57	0·997
Star Creseent Feeder-34	6545·46	27·25	0·995	16·11	0·997
Charerhat Fish Co. -35	2919·94	11·19	0·995	8·39	0·996
Rerolling mill Feeder-36	7609·57	61·36	0·992	30·34	0·995
Load Point-1 LP1	6583·84	67·15	0·989	44·46	0·993
,, LP2	8651·66	60·51	0·992	37·82	0·995
,, LP3	8825·62	61·31	0·993	38·62	0·995
,, LP4	6548·16	60·48	0·990	37·79	0·994
,, LP5	6275·41	61·24	0·990	38·55	0·993
,, LP6	6279·43	62·07	0·990	31·05	0·995
,, LP7	7812·32	56·77	0·992	32·02	0·995

Table 7.2 (Contd..)

1		2	3	4	5	6
Load Point-8	LP8	5589.61	55.15	0.990	30.40	0.994
"	LP9	2177.96	29.24	0.986	14.77	0.992
"	LP11	5122.02	54.80	0.984	30.05	0.994
"	LP12	2808.56	53.96	0.981	29.21	0.989
"	LP13	5838.67	57.78	0.990	33.03	0.994
"	LP14	8057.25	56.94	0.992	32.19	0.995
"	LP15	7301.52	32.76	0.995	18.29	0.997
"	LP16	4923.07	71.07	0.985	40.05	0.991
"	LP17	4119.40	62.01	0.985	30.99	0.992
"	LP18	8127.81	67.94	0.991	36.92	0.995
"	LP19	8615.35	62.63	0.992	31.61	0.996
"	LP21	7693.73	64.53	0.991	33.51	0.995
"	LP22	8621.39	63.97	0.992	32.95	0.996
"	LP23	5609.46	63.63	0.988	32.61	0.994
"	LP24	6478.91	11.88	0.998	9.08	0.998
"	LP25	6687.41	62.02	0.990	31.00	0.995

CHAPTER 8

DISCUSSION ON RELIABILITY IMPROVEMENT

8.1 Discussion on Reliability Improvement

Comparing predicted values of reliability (Chapter-6) of individual equipment of the plant (after 40 days) it has been observed that Boiler, Turbine, Generator, Vacuum system, I.D. Fan (left),and other causes contribute relatively lower values of reliability (less than .7000). Now it necessitates the analysis of the failure history of the above mentioned equipments individually to find the causes for which lower reliability results. So it is advisable to find the sources of major fault, and then preventive measures would be taken for the same to improve reliability.

In this context, a list of individual equipments showing different faults during the period under consideration is prepared in Table 8.1 for the plant and the individual equipments of the plant. These tables are prepared by analyzing the failure history of the plant. The availability of individual equipment after excluding major faults also are shown in Table 8.8.

Table 8.1 Troubles of Equipments in the Power Plant

Equipment	Number of Faults					Total Faults for Equipments
	Instrumental Faults	Electrical Fault	Mechanical Fault	Operational Fault	Faults due to Poor logistics	
Boiler	2	1	7	-	1	11
Turbine	-	1	9	-	-	10
Generator	-	14	-	-	-	14
Vacuum System	-	1	2	24	-	27
I.D. Fan (left)	1	2	5	-	-	8
I.D. Fan (right)	1	2	4	-	-	7
C.W. Pump (1)	-	-	1	1	-	2
C.W. Pump (2)	-	1	1	1	-	3
Other Causes	-	3	1	1	3	8
Feed Pump	1	1	-	-	-	2
F.D. Fan	2	1	-	-	-	3
Transformer	-	3	-	1	-	4
Condenser	-	-	-	-	-	-
Oil Cooler	-	-	-	-	-	-
Water Heater	-	-	-	-	-	-
Powar Plant	5	24	27	27	4	87

From Tables 8.1 it has been found that major faults appeared in Boiler, Turbine and I.D. Fan (left) due to mechanical troubles, in Generator due to Electrical troubles, in Vacuum system due to operational troubles. Among other causes, logistic-induced faults have major contribution. Now question arises what would be the optimal policy to improve reliability utilizing proper technilogy to reduce major faults or installing stand by unit. Before comming to a conclusion, it will be useful to predict the reliability of each identified equipment for the following cases:

1. Excluding major faults of each identified equipment.
2. Considering stand-by unit of each identified equipment

Case-1:

For predicting reliability of each above mentioned equipment after excluding major faults, it is first required to calculate the operating time and then weibull parameters are to be estimated, all of which are shown in Table 8.2 and 8.3. The reliability are then calculated with the parameters obtained in Table 8.3 and shown in Table 8.4.

The symbols used in colum 4 & 9 of Table 8.2 are as that of table 5.1.

Table 8.2 operating time calculation of identified equipments after excluding major faults.

Equip-ments	Starting		Stopping		Operating time days	Down-time hour	Repair Time hour	Causes of failure
	Date	Time	Date	Time				
1	2	3	4	5	6	7	8	9
Boiler	1.1.79	0.00	10.2.79	0.47	40.00	29.56	29.56	O.H
	11.2.79	6.03	30.3.79	23.08	47.75	211.45	211.45	"
	8.4.79	18.51	*30.4.79	12.75	21.74	1.58	1.58	E.F
	8.5.79	10.33	23.5.79	4.60	14.76	28.90	28.90	O.H
	24.5.79	9.30	11.6.79	10.11	18.00	140.79	140.79	"
	17.6.79	6.90	31.7.79	22.60	44.66	38.68	38.68	"
	2.7.79	13.20	23.8.79	0.16	20.54	130.34	130.34	"
	28.8.79	10.50	*27.9.79	12.20	30.08	00.25	-	F.S
	27.9.79	12.45	*17.10.79	17.53	20.20	0.57	0.57	L.F
	17.10.79	18.10	*31.10.79	23.50	14.23	5.11	-	F.S
	1.11.79	4.61	18.2.80	11.16	109.28	163.70	163.70	O.H
	25.2.80	6.33	15.3.80	23.21	19.70	31.42	31.42	"
	17.3.80	6.63	10.4.80	6.75	24.00	154.25	154.25	"
	16.4.80	7.00	26.4.80	22.73	10.62	59.59	59.59	"
	29.4.80	10.25	16.1.81	11.33	263.00	29.82	29.82	"
	17.1.81	17.15	8.2.81	7.75	-	-	-	"
	7.4.82	3.01	30.4.82	23.23	45.41	50.52	50.52	"
	3.5.82	1.75	27.5.82	23.25	24.90	61.70	61.70	"
	30.5.82	12.95	1.8.82	22.87	63.41	95.55	95.55	"
	28.8.82	23.61	27.9.82	23.50	30.00	121.75	121.75	"
	3.10.82	1.25	17.11.82	22.25	45.87	57.33	57.33	"
	20.11.82	7.59	10.12.82	23.39	20.66	184.94	184.94	"
	19.12.82	16.33	14.5.83	22.95	146.27	70.58	70.58	"
	17.5.83	21.53	16.6.83	22.97	30.04	66.28	66.28	"
	9.6.83	17.25	6.7.83	21.16	17.16	184.95	184.95	"
	14.7.83	14.11	17.9.83	22.55	65.27	159.95	159.95	"
	29.9.83	14.50	10.12.83	21.83	72.16	92.25	92.25	"

Table 8.2 (Contd..)

1	2	3	4	5	6	7	8	9
Turbine	1.1.79	00.00	*2.6.79	14.33	152.60	4.58	-	E.F
	2.6.79	8.91	11.6.79	10.11	9.05	140.79	140.79	O.H
	17.6.79	6.90	23.8.79	0.16	66.72	130.34	130.34	"
	28.8.79	10.50	18.9.79	23.91	21.54	140.00	140.00	"
	23.9.79	19.91	*5.12.79	23.16	73.12	103.09	103.09	"
	10.12.79	6.25	8.2.81	7.75	-	-	-	-
	7.4.82	3.01	1.9.82	23.08	568.06	14.92	14.92	O.H
	2.9.82	14.00	17.11.82	22.25	76.33	57.33	57.33	"
	20.11.79	7.59	2.1.83	22.56	43.62	176.10	176.10	"
	10.1.83	1.66	8.3.83	11.61	57.40	23.89	23.89	"
	9.3.83	11.50	10.3.83	22.53	1.46	67.18	67.18	"
	13.3.83	17.71	30.4.83	21.91	48.16	11.22	11.22	"
	1.5.83	9.13	14.5.83	22.95	13.58	70.58	70.58	"
	17.5.83	21.53	31.5.83	5.91	13.37	4.75	4.75	"
	31.5.83	10.66	10.12.83	21.83	193.45	92.25	92.25	"
Generator	1.1.79	00.00	*3.12.79	8.25	347.34	3.80	3.80	E.F
	13.12.79	12.05	16.2.80	5.20	64.70	17.50	17.50	O.H
	16.2.80	7.75	18.2.80	11.16	2.26	163.17	163.17	"
	25.2.80	6.33	10.11.80	22.25	259.66	64.25	64.25	"
	13.1.81	14.50	8.2.81	7.75	-	-	-	"
	7.4.82	3.01	30.4.82	23.23	48.58	50.52	50.52	O.H
	3.5.82	1.75	*26.7.83	18.26	449.67	0.28	0.28	E.F
	26.7.83	18.54	6.11.83	21.70	103.12	207.05	207.05	O.H
Vacuum system	1.1.79	00.00	*5.8.79	13.91	216.58	3.00	3.00	M.F
	5.8.79	2.94	*30.12.79	2.00	147.00	8.15	8.15	E.F
	30.12.79	10.15	18.1.81	11.59	19.06	62.55	62.55	O.H
	21.1.80	2.13	18.2.80	11.16	28.37	163.17	163.17	"
	25.2.80	6.33	18.7.80	16.00	144.41	278.47	278.47	"
	30.7.80	6.47	1.8.80	23.10	2.69	418.33	418.33	"
	19.8.80	9.43	5.9.80	23.75	17.59	456.33	456.33	"
	25.9.80	0.08	8.2.81	7.75	[illegible]	[illegible]	[illegible]	-
	7.4.82	3.01	*5.7.82	0.91	225.23	509.65	509.65	kM.F
	26.7.82	1.56	17.9.82	21.53	53.84	26.27	26.27	O.H

Table 8.2 (Contd.)

1	2	3	4	5	6	7	8	9
Other causes	1.1.79	00.00	*13.4.79	11.83	102.50	1.08	-	E.F
	13.4.79	12.92	*12.12.79	6.75	242.75	0.17	-	O.F
	12.12.79	6.91	*21.12.79	7.75	9.00	1.67	1.67	M.F
	21.12.79	9.41	2.3.80	7.61	71.91	14.39	14.39	O.H
	2.3.80	22.00	23.3.80	0.60	20.08	39.80	39.80	"
	24.3.80	15.76	30.3.80	0.08	5.33	22.00	22.00	"
	30.3.80	22.08	*5.5.80	12.59	34.62	4.16	-	E.F
	5.5.80	16.75	5.9.80	23.75	123.30	456.33	456.33	O.H
	25.9.80	0.08	22.11.80	8.41	58.75	9.92	9.92	"
	22.11.80	18.33	31.1.81	21.91	70.16	41.72	41.72	"
	2.2.81	15.63	8.2.81	7.75	-	-	-	-
	7.4.82	3.01	*26.10.82	9.10	207.00	2.06	2.06	E.F
	26.10.82	11.16	31.5.83	5.91	216.00	4.75	4.75	
I.D.Fan (left)	1.1.79	00.00	30.3.79	23.08	89.00	201.44	201.44	O.H
	8.4.79	18.52	*30.4.79	12.75	21.75	1.58	-	E.F
	30.4.79	14.33	7.5.79	5.66	6.60	28.67	28.67	O.H
	8.5.79	10.33	23.5.79	4.60	14.45	28.90	28.90	"
	24.5.79	9.50	7.7.79	23.91	44.60	21.40	21.40	"
	8.7.79	21.31	*11.7.79	1.88	2.89	0.20	-	F.S
	11.7.79	19.08	1.9.79	23.05	52.16	25.77	25.77	"
	3.9.79	0.92	*27.9.79	12.20	24.50	0.25	-	E.F
	27.9.79	12.45	5.12.79	23.16	69.44	103.09	103.09	O.H
	10.12.79	6.25	5.1.80	10.75	26.18	84.62	84.62	"
	8.1.80	23.37	10.4.80	6.75	92.18	154.25	154.25	"
	16.4.80	7.00	18.4.80	22.66	2.65	47.77	47.72	"
	20.4.80	22.38	26.5.80	9.43	35.46	888.53	888.53	"
	2.7.80	10.36	18.7.80	16.00	16.25	278.47	278.47	"
	31.7.80	6.47	5.9.80	23.75	36.72	456.33	456.33	"
	25.9.80	0.08	*10.1.81	22.25	107.92	64.25	64.25	"
	13.1.81	14.50	16.1.81	11.30	2.86	29.82	29.82	"
	17.1.81	17.15	*8.2.81	7.75	21.60	-	-	M.F
	7.4.82	3.01	30.4.82	23.23	23.84	50.52	50.52	O.H
	3.5.82	1.75	10.12.82	21.83	586.83	92.25	92.25	"
	14.12.83	18.08	-	-				

Table 8.3 Weibull Parameters Estimation of Identified Equipment, after excluding major faults

Equipment	Number of Failure	Number of Mant.	Number of Repair	MLE Method			M.T.B.F (Simple Average)
				Shape Parameter β	Scale Parameter η	Meanlife M.T.B.F (μ)	
Boiler	4	22	24	0.88	387.45	412.74	314.91
Turbine	2	12	13	2.32	236.63	209.83	680.23
Generator	2	5	7	2.12	322.64	285.96	679.68
Vacuum System	3	6	9	8.03	211.21	199.25	284.92
I.D. Fan (left)	4	16	16	0.63	530.42	747.87	319.47
Other Causes	5	7	9	1.08	189.19	183.95	170.95
Powar Plant	27	68	81	0.79	51.51	58.65	40.48

Table 8.4 Reliability Prediction of identified equipment after excluding major faults

Equipment	β	η	Time Days													
			0	5	10	20	30	40	50	100	150	200	250	300	400	500
			Reliability													
Boiler	0.88	387.45	1	0.9784	0.9607	0.9289	0.8999	0.8730	0.8477	0.7378	0.6477	0.5715	0.5062	0.4496	0.3571	0.2856
Turbine	2.32	236.63	1	0.9998	0.9993	0.9967	0.9916	0.9838	0.9730	0.8724	0.7050	0.5060	0.3188	0.1746	0.0333	0.0820
Generator	2.12	322.64	1	0.9998	0.9993	0.9972	0.9934	0.9880	0.9809	0.9195	0.8203	0.6946	0.5572	0.4228	0.2051	0.0787
Vacuum System	8.03	211.21	1	1	0.9999	0.9999	0.9999	0.9999	0.9999	0.9975	0.9374	0.5217	0.0201	–	–	–
Other Causes	1.08	189.19	1	0.9804	0.9590	0.9153	0.8729	0.8295	0.7883	0.6048	0.4588	0.3454	0.2585	0.1926	0.1056	[illegible]
I.D.Fan (left)	0.63	530.42	1	0.9484	0.9213	0.8809	0.8490	0.8219	0.7979	0.7051	0.6370	0.5824	0.5367	0.4976	0.4332	0.3878

Case-2:

For reliability calculation of stand-by equipment, it is assumed that the failure pattern of stand-by unit will be similar to that of principal equipment. So, both the units will have same failure distribution and reliability. The formula used for the calculation of each proposed stand-by system are given as

$$R_s = 1 - (1 - R)^2$$

where R_s = Reliability of stand-by system

R = Reliability of existing unit

The reliability calculations are shown in Table 8.5.

Table 8.5 Reliability Prediction of Identified Equipments Assuming Stand by Redundant system of Each

Equipment	Time Days													
	0	5	10	20	30	40	50	100	150	200	250	300	400	500
	Reliability													
Boiler	1	0.9942	0.9849	0.9618	0.9358	0.9084	0.8805	0.7482	0.6260	0.5259	0.4433	0.3733	0.2681	0.1946
Turbine	1	0.9871	0.9722	0.9418	0.9119	0.8831	0.8555	0.7346	0.6360	0.5551	0.4884	0.4319	0.3424	0.2757
Generator	1	0.9959	0.9862	0.9562	0.9145	0.8678	0.8180	0.5731	0.3812	0.2481	0.1598	0.1026	0.0415	0.0159
Vacuum System	1	0.9022	0.8139	0.6723	0.5642	0.4792	0.4109	0.2100	0.1190	0.0720	0.0454	0.0297	0.0137	0.0077
I.D. Fan(left)	1	0.9933	0.9851	0.9611	0.9377	0.9140	0.8904	0.7790	0.6820	0.5988	0.5184	0.4663	0.3676	0.2940

For comparison, reliability vs. time curves of each identified equipment are drawn in figures 8.1 to 8.6. In each figure, there are three curves showing the following:

Curve-A: Reliability vs. time curve of existing equipment.

Curve-B: Reliability vs. time curve of existing equipment after excluding major faults and

Curve-C: Reliability vs. time curve of stand by system of the existing equipment.

Reliability vs. time curve of Boiler are shown in Fig. 8.1 for different cases. It has been found that reliability (curve-B) of the equipment slightly improved though major faults are excluded because the number of maintenance/over-hauls are more frequent which lower down the value of MTBF and scale parameter and ultimately the reliability, but at long run the reliability is better than the existing one (curve-A).

If a stand-by unit of Boiler is introduced, a slight reliability improvement of the equipment is obtained (curve-C). But it should be pointed out here that other factors e.g. cost involvement, space facilities etc. are to be considered before recommending any stand-by unit. In case of steam power plant stand-by unit of major equipment such as Boiler, Turbine Generator, Vacuum system are not possible due to space and cost involvement. Space is the major factor.

Refering to Figure 8.2 it has been found that reliability vs. time curve (curve-C) of stand-by I.D. Fan (left) is much better than (curve-B) after excluding major fault up to 200 days after that the curve-C cross curve-B and decreases gradually. The reliability vs. time curve after excluding major faults (curve-B) is better than that curve-A of existing system. But among the three curves the stand-by system gives much better result. If space permits then stand by I.D. Fan can be installed which will help to improve the overall reliability of the plant.

Refering to figures 8.3 to 8.6 it has been observed that reliability vs. time curves after excluding major faults (curve-B) of Turbine, Generator and Vacuum system show satisfactory results. Although stand-by system of each indicates improved reliability but not that of reliability after excluding major faults. The reliability vs. time curve after excluding major faults (curve=B) shown in Figure.8.5 of vacuum system decreases rapidly after certain time but still it is better than curve-A & curve-C.

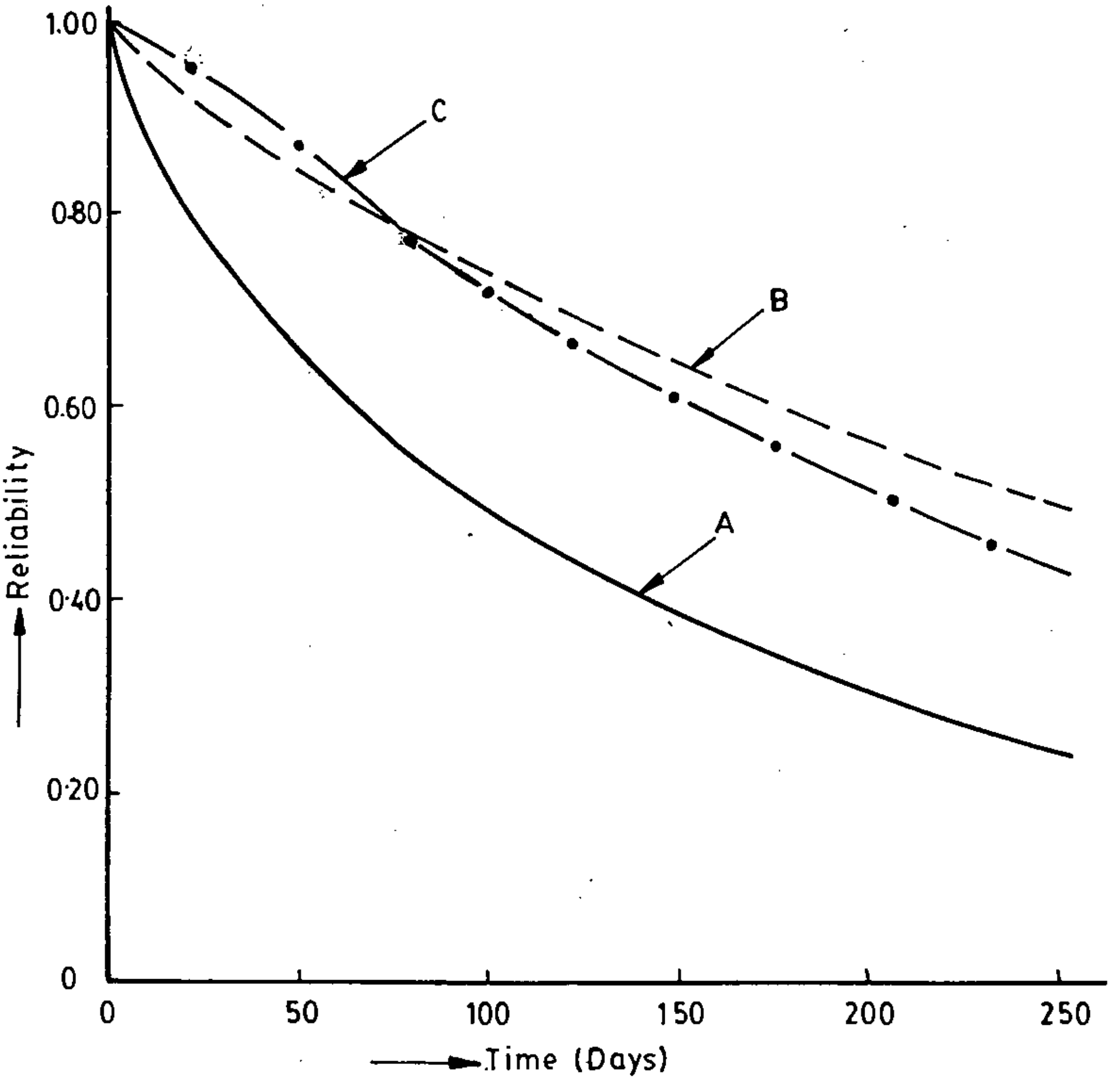


Fig. 8.1 Reliability Vs time curve of Boiler
A- Existing condition, B - Excluding major fault, C- Standby system.

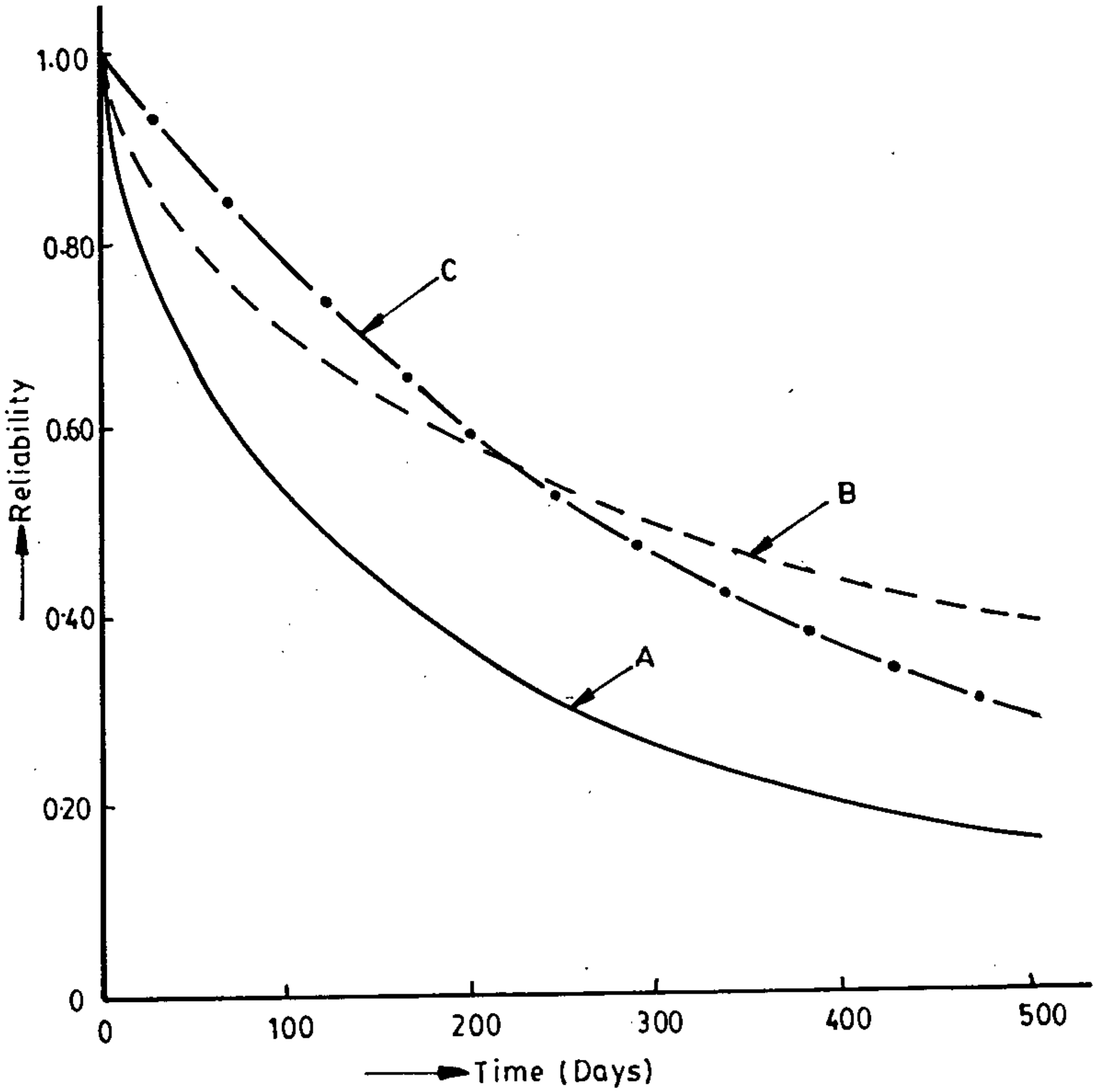


Fig. 8.2 Reliability Vs time curve of I.D. Fan (left)
A-Existing condition, B-Excluding major fault,
C-Standby system.

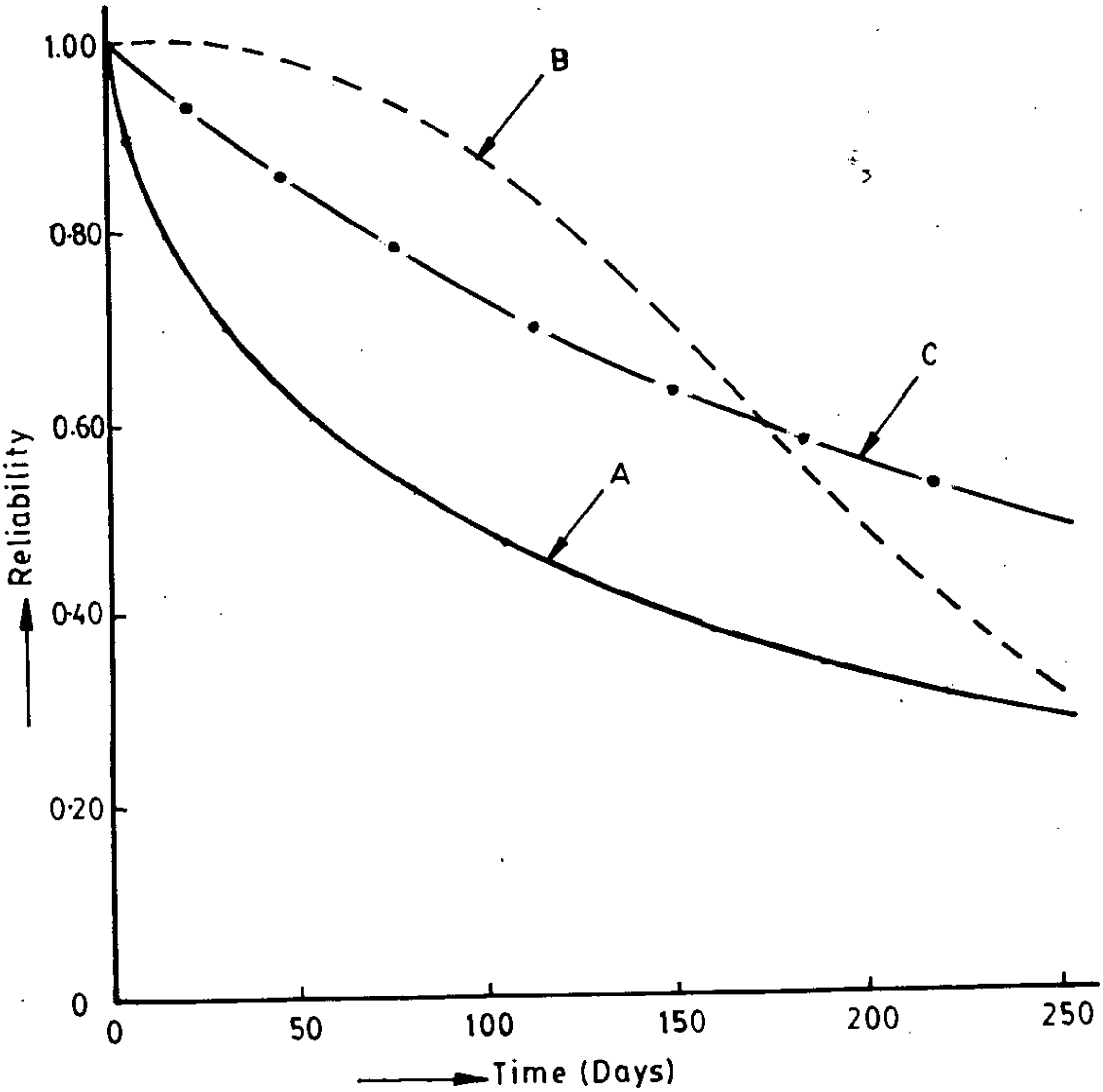


Fig. 8.3 Reliability Vs time curve of Turbine
A-Existing condition, B-Excluding major fault,
C-Stand by system .

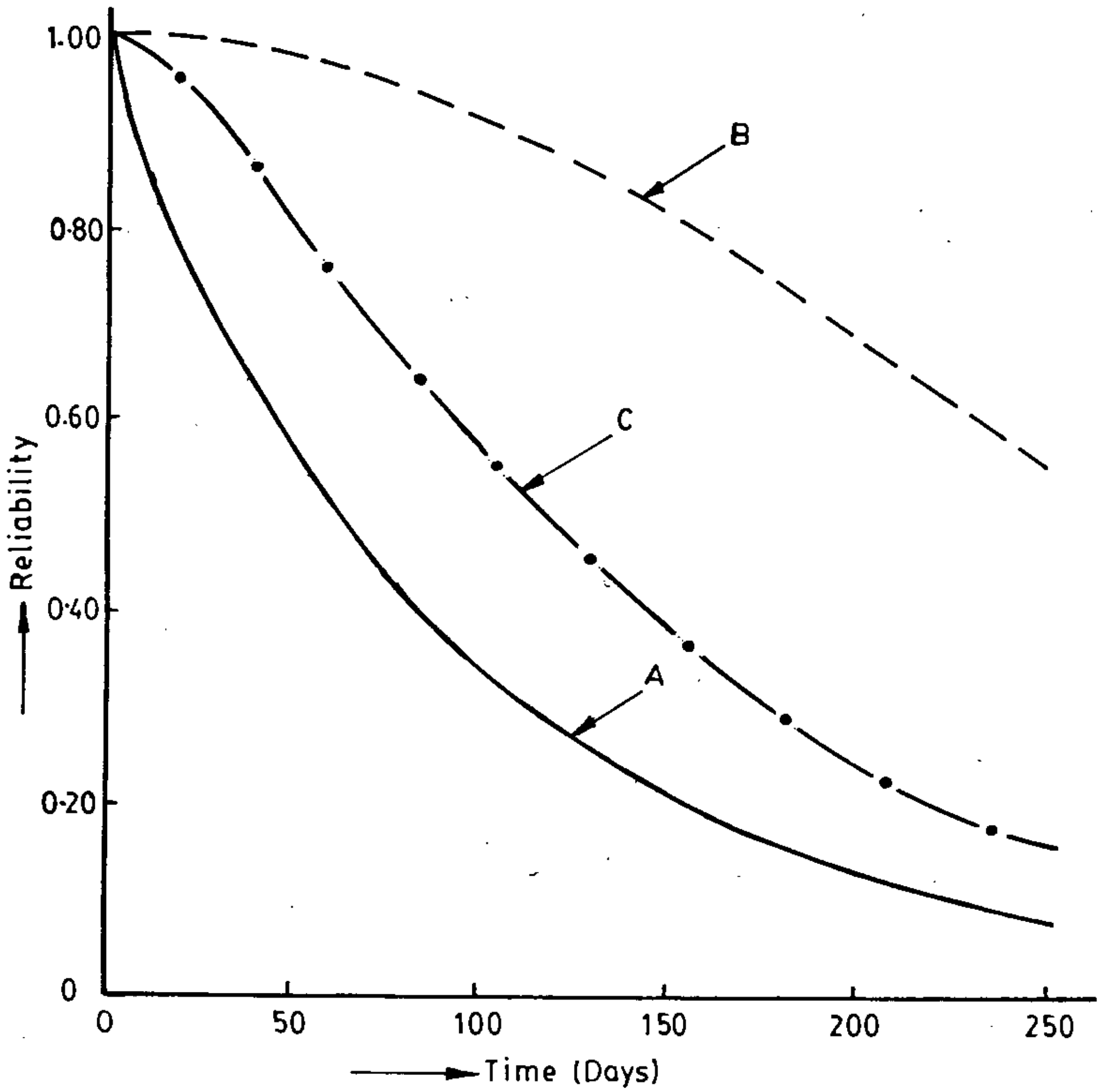


Fig. 8.4 Reliability Vs time curve of Generator
A-Existing condition, B-Excluding major fault, C-Stand by system.

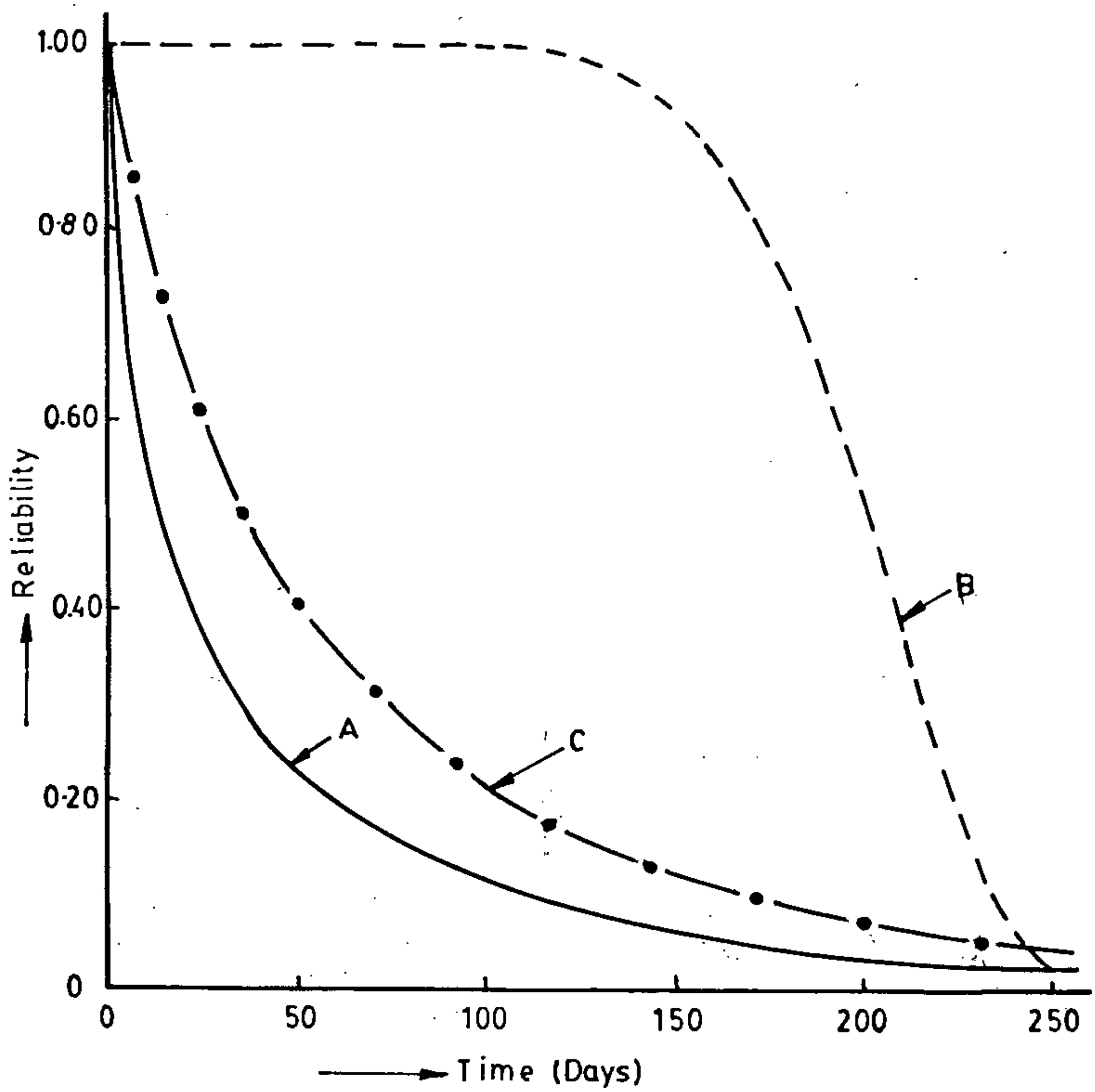


Fig. 8.5 Reliability Vs time curve of vacuum system
A - Existing condition, B - Excluding major fault,
C - Stand by system.

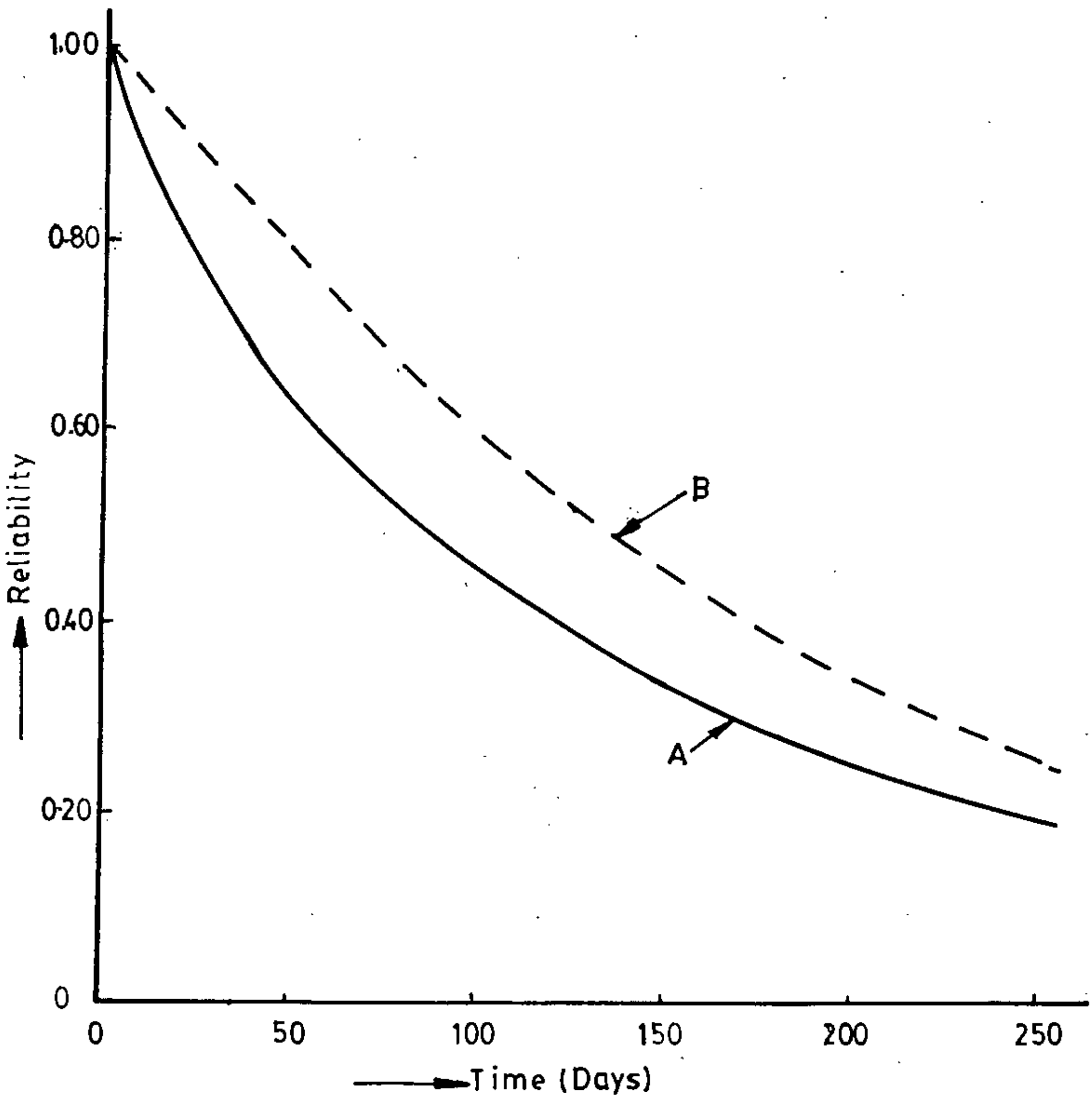


Fig. 8.6 Reliability Vs time curve of other causes
A- Existing condition, B - Excluding major faults.

8.2. Reliability Prediction of the Plant Including Proposed Improved System

The reliability prediction tables and reliability vs. time curves of the equipments are shown in Chapter-8. Now it is necessary to find to what extent the overall reliability of the plant increases if the major faults which are excluded from the failure list of the identified equipments are excluded from the power station failure data and then the calculations are done for reliability predictions. The data (after excluding the major faults) is shown in Table 8.6. The overall reliability of the plant including improved systems are predicted in Table 8.7. For comparison, the existing overall reliability of the plant is also shown in this table. The reliability vs. time curve of the improved system is shown in Figure 8.7.

Table 8.6 Operating time calculation of power plant after excluding major faults

The symbols used in column 3 and 8 are as that of table 8.6.

Starting		Stopping		Operating time days	Down-time hour	Repair-time hour	Causes of failure
Date	Time	Date	Time				
1	2	3	4	5	6	7	8
1.1.79	00.00	24.1.79	23.00	23.95	12.00	12.00	O.H
25.1.79	11.00	7.2.79	0.79	12.58	8.22	8.22	"
7.3.78	9.00	10.2.79	0.46	2.64	29.56	29.56	"
11.2.79	6.03	30.3.79	23.08	47.70	201.44	201.44	"
8.4.79	18.51	*13.4.79	11.83	4.68	1.08	-	E.F
13.4.79	12.91	17.4.79	20.60	3.32	21.78	21.78	O.H
18.4.79	18.58	22.4.79	13.26	3.77	48.82	48.82	"
24.4.79	14.08	*30.4.79	12.75	5.94	1.58	-	E.F
30.4.79	14.33	7.5.79	5.66	6.63	28.67	28.67	O.H
8.5.79	10.33	23.5.79	4.60	14.76	28.90	28.90	"
24.5.79	9.50	*2.6.79	4.33	8.78	4.58	-	E.F
2.6.79	8.91	11.6.79	10.11	9.05	140.79	140.79	O.H
17.6.79	6.90	1.7.79	23.79	14.70	23.92	23.92	"
3.7.79	0.70	7.7.79	23.91	4.96	21.40	21.40	"
8.7.79	21.31	*11.7.79	18.88	2.90	0.20	-	F.S
11.7.79	19.08	26.7.79	23.66	15.20	30.33	30.33	O.H
28.7.79	6.00	*29.7.79	17.13	1.47	1.58	1.58	M.F
29.7.79	18.71	31.7.79	22.60	2.16	38.60	38.60	O.H
2.8.79	13.20	*3.8.79	19.58	1.27	21.25	21.25	M.F
4.8.79	16.83	*5.8.79	13.91	0.84	3.00	3.00	"
5.8.79	16.08	23.8.79	0.16	17.33	130.34	130.34	O.H
28.8.79	10.50	1.9.79	23.05	4.52	25.77	25.77	"
3.9.79	0.91	18.9.79	23.91	15.95	116.00	116.00	"
23.9.79	19.91	*27.9.79	12.20	3.68	0.25	-	F.S
27.9.79	12.45	30.9.79	0.08	2.48	25.67	25.67	O.H
1.10.79	1.95	12.10.79	17.97	11.67	19.44	19.44	"
13.10.79	13.41	*17.10.79	17.03	4.17	0.57	0.57	L.F
17.10.79	18.10	28.10.79	23.75	11.23	22.83	22.83	O.H

Table 8.6 (Contd...)

1	2	3	4	5	6	7	8
29.10.79	22.58	*31.10.79	23.50	2.03	5.11	-	F.S
1.11.79	4.61	10.11.79	23.33	9.78	14.25	14.25	O.H
11.11.79	13.58	21.11.79	22.90	10.38	11.46	11.46	"
22.11.79	10.66	5.12.79	23.16	13.52	103.09	103.09	"
10.12.79	6.20	*12.12.79	6.75	2.02	0.17	-	O.F
12.12.79	6.91	*13.12.79	8.25	1.07	3.80	3.80	E.F
13.12.79	12.05	*17.12.79	9.33	3.88	2.17	-	O.F
17.12.79	11.50	*19.12.79	21.41	2.41	9.84	-	E.F
20.12.79	7.25	*21.12.79	7.45	1.02	1.66	1.66	M.F
21.12.79	9.41	*30.12.79	2.00	8.69	8.15	8.15	E.F
30.12.79	10.15	5.1.80	10.75	6.02	84.62	84.62	O.H
8.1.80	23.37	15.1.80	11.75	6.50	13.75	13.75	"
16.1.80	1.50	18.1.80	11.58	2.42	62.55	62.55	"
21.1.80	2.13	27.1.80	4.39	6.09	14.02	14.02	"
27.1.80	18.41	16.2.80	5.25	19.45	17.50	17.50	"
16.2.80	22.75	18.2.80	11.16	1.26	163.17	163.17	"
25.2.80	6.33	28.2.80	22.16	3.66	8.17	8.17	"
29.2.80	6.33	2.3.80	7.61	2.05	14.39	14.39	"
2.3.80	22.00	15.3.80	23.21	13.05	31.42	31.42	"
17.3.80	6.63	23.3.80	0.60	5.75	39.18	39.18	"
24.3.80	15.76	30.3.80	0.80	5.37	22.00	22.00	"
30.3.80	22.08	1.4.80	22.33	2.01	158.08	158.08	"
8.4.80	12.39	10.4.80	6.75	1.76	154.25	154.25	"
16.4.80	7.00	18.4.80	22.66	2.65	47.72	47.72	"
20.4.80	22.39	26.4.80	22.73	6.01	59.52	59.52	"
29.4.80	10.25	31.4.80	8.36	3.92	11.47	11.47	"
3.5.80	19.83	*5.5.80	12.58	1.69	4.16	-	E.F
5.5.80	16.75	*18.5.80	7.91	12.63	14.13	14.13	O.F
18.5.80	22.05	26.5.80	9.83	7.49	888.53	888.53	O.H
2.7.80	10.36	*4.7.80	7.75	1.89	6.83	-	E.F
4.7.80	14.58	*6.7.80	12.08	1.90	4.00	-	"
6.7.80	16.08	18.7.80	16.00	12.00	278.47	278.47	O.H
30.7.80	6.46	1.8.80	23.10	2.70	418.33	418.33	"
19.8.80	9.43	5.9.80	23.75	17.60	456.33	456.33	"

Table 8.6 (Contd..)

1	2	3	4	5	6	7	8
25.9.80	0.08	*15.10.80	18.16	20.75	90.12	90.12	F.S
19.10.80	12.29	*8.11.80	13.66	20.05	129.62	129.62	M.F
13.11.80	23.29	22.11.80	8.41	8.38	9.92	9.92	O.H
22.11.80	18.33	10.1.81	22.25	49.16	64.25	64.25	"
13.1.81	14.50	16.1.81	11.33	2.87	29.82	29.82	"
17.1 .81	17.15	31.1.81	21.91	14.19	41.72	41.72	"
2.2.81	15.63	*8.2.81	7.75	5.67	-	-	M.F
7.4.82	3.01	*17.4.82	10.75	10.32	7.66	-	E.F
17.4.82	18.41	30.4.82	23.23	13.20	50.52	50.52	O.H
3.5.82	1.75	27.5.82	23.25	24.90	61.70	61.70	"
30.5.82	12.95	*5.7.82	0.91	35.50	509.65	509.65	M.F
26.7.82	1.56	1.8.82	22.86	6.88	126.55	126.55	O.H
5.8.82	21.41	1.9.82	23.08	27.07	14.92	14.92	"
2.9.82	14.00	17.9.82	21.83	15.32	26.27	26.27	"
19.9.82	0.10	27.9.82	23.50	8.97	121.75	121.75	"
3.10.82	1.25	*26.10.82	9.10	23.32	2.06	2.06	E.F
26.10.82	11.16	17.11.82	22.25	22.87	57.33	57.33	O.H
20.11.82	7.58	10.12.82	23.39	20.65	184.94	184.94	"
19.12.82	16.33	2.1.83	22.56	14.26	176.10	176.10	"
10.1.83	1.66	*17.1.83	8.08	7.26	6.83	6.83	I.F
17.1.83	14.91	8.3.83	11.61	49.86	23.89	23.89	O.H
9.3.83	11.50	10.3.83	22.53	1.46	67.18	67.18	"
13.3.83	17.71	24.3.83	22.49	11.20	48.10	48.10	"
26.3.83	22.58	30.4.83	21.91	35.38	11.22	11.22	"
1.5.83	9.13	2.5.83	22.50	1.56	42.00	42.00	"
4.5.83	16.50	14.5.83	22.95	10.45	70.58	70.58	"
17.5.83	21.53	31.5.83	5.91	13.35	4.75	4.75	"
31.5.83	10.66	16.6.83	22.97	16.51	66.28	66.28	"
19.6.83	17.25	6.7.83	21.16	17.16	184.95	184.95	"
14.7.83	14.11	8.8.83	1.50	24.47	56.71	56.71	"
10.8.83	10.21	17.9.83	22.55	38.51	159.95	159.95	"
29.9.83	14.50	6.11.83	21.70	38.30	207.05	207.05	"
15.11.83	12.75	10.12.83	21.83	25.37	92.25	92.25	"

Table 8.7 Overall Reliability of the Plant including improved system

Equipment	Time Days													
	0	5	10	20	30	40	50	100	150	200	250	300	400	500
	Reliability													
Power Plant (improved system)	1	0.8534	0.7604	0.6227	0.5207	0.4409	0.3765	0.1847	0.0976	0.0539	0.0307	–	–	–
Power Plant (Existing system)	1	0.6244	0.4405	0.2399	0.1388	0.0833	0.0512	0.0005	0.0007	–	–	–	–	–

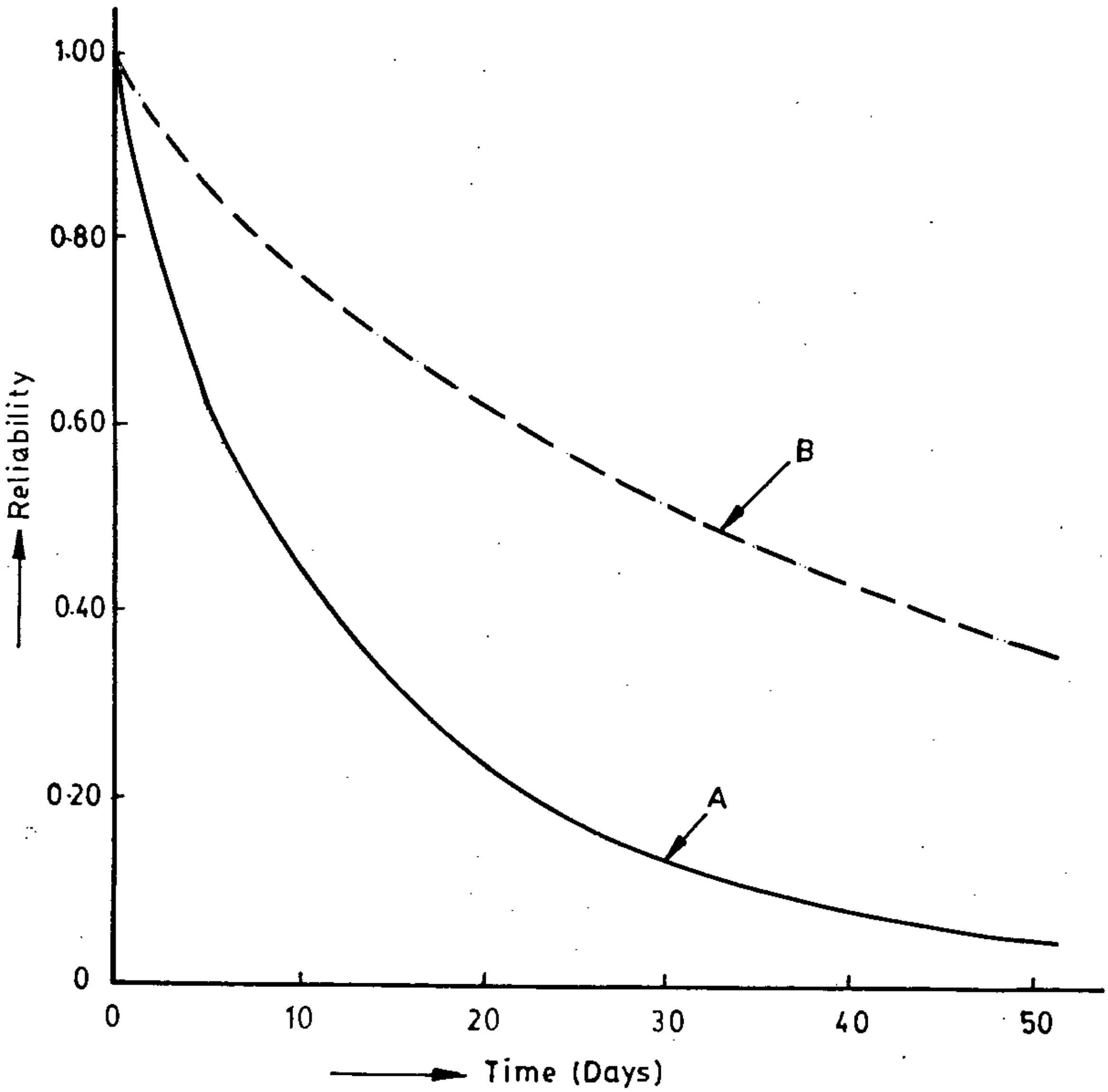


Fig.8.7 Reliability Vs time curve of Powerplant
A – Existing condition
B – Excluding major fault

Table 8.8 Availability of the Plant after Excluding major faults

Equipment	Number of Failure	Number of Repair	Number of Mant.	Running time (days)	Repair time (days)	Down time (days)	M.T.T.R	MLE		Simple	Average
								M.T.B.F	Availability	M.T.B.F.	Availability
1	2	3	4	5	6	7	$8 = \frac{6}{3}$	9	$10 = \frac{8+9}{8+9}$	11	$12 = \frac{11}{11+8}$
Boiler	4	24	22	1259.71	90.27	90.49	3.76	412.74	0.9909	314.92	0.9882
Turbine	2	13	12	1360.46	43.81	43.20	3.30	209.83	0.9845	680.23	0.9948
Generator	2	7	5	1359.35	21.10	21.10	3.01	285.96	0.9895	679.68	0.9955
Vacuum System	3	9	6	854.77	80.24	80.24	8.91	119.25	0.9304	284.92	0.9596
I.D. Fan (left)	4	16	16	1277.88	106.50	106.58	6.65	747.87	0.9911	319.47	0.9796
Power Plant	27	81	68	1093.17	285.03	287.01	3.51	58.65	0.9435	40.48	0.9202

CHAPTER 9

CONCLUSION AND FUTURE WORK

9.1 Conclusion

From the study of steam power plant, the following points are apparent.

1) From Table 6.1 it can be observed that the time-based reliability of the plant fall quickly. The probabilities of encountering a failure within the first 20 and 40 days of operation of the plant are 76.01% and 91.67% respectively.

From the reliability values of the individual equipments (Tables and figures of section 6.1) it can be seen that the main contributors to this low system reliability are Boiler, Turbine, Generator, Vacuum system, I.D. Fan (left) and also other causes (poor logistics). Among the above mentioned equipments, vacuum system is the main problem creator.

2) In Section 7.1 availability of individuals equipments and the plant have been calculated. The availability of individual equipments vary from 0.9980 (transformer) to 0.9382 (vacuum system) and for the plant itself, this value is 0.8490.

3) To improve the reliability of the plant, two alternatives were considered - eliminating major faults of each critical equipment as identified in (1) and considering installation

of identical stand-by units of these critical equipments. In Tables 8.1 failure type and numbers of failures of each equipment of the plant have been listed. It has been found that major faults appeared in Boiler, Turbine and I.D.Fan (left) due to mechanical troubles, in Generator due to electrical troubles, in vacuum system due to operational troubles.

Reliability have been recalculated for both the cases mentioned above and tables and graphs have been presented (Tables 8.4 and 8.5, figures from 8.1 to 8.6). It can be observed that almost in all cases the reliability of the equipments, after excluding major faults improve considerably except the I.D. Fan (left). In that case stand by unit gives better reliability. If the situation and space permit then stand-by I.D. Fan can be recommended.

In Table 8.7 power plant reliability value has been recalculated by considering the improved system (excluding the major faults). From the table as well as Figure 8.7 it can be observed that for the first 20 to 40 days of operation of the plant the reliability has improved from 24% to 62.27% and 8.33% to 44.09% respectively.

4) From the calculated reliability indices of distribution system (Section 6.2), it can be seen that the mean system failure duration is less(.682) i.e the average downtime of the system is low. If there is failure of power then it is for shortwhile

From the results it can be observed that the failure rate or frequency of failure is quite high.

The availabilities of individual components are high except a few. The high value of availability results from low downtime.

9.2 Scope of Future Work

From the analyses of the present study, it is apparent that some further works can be undertaken to improve reliability situations of Khulna Power Generation System and Transmission and Distribution System. These are listed below:

1. Methods of eliminating major mode of failure of the critical equipments should be thoroughly investigated and effectiveness of these methods should be evaluated from the technical as well as economic point of view. In this context optimal maintenance policies should be devised.

2. A centrally installed system availabilability reporting scheme should be developed in order to put the system operational history in desired and manageable form. A well-developed MIS will satisfy the above requirements and in addition will tremendously improve logistric support schemes.

3. Reliability demonstration technique should be developed to monitor the system reliability.

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APPENDIX-A

Failure History of Khulna 60 MW Power Plant

The symbol used in column 1 of Appendix-A are as follows:
*- Failure m-Maintenance

Failure Time		Start-up time		Down time	Causes of failure		Remedial measures/ Remarks
Date	Time hrs.	Date	Time hrs.	Hours	Equipment failed/overhaul	Causes	
1	2	3	4	5	6	7	8
m24.1.79	23.00	25.1.79	11.00	12.00	Condenser tube	Jammed	Cleaning of tubes
*26.1.79	12.89	26.1.79	15.25	2.36	Turbine	P.T of speed control system,was not working properly	Proper adjustment was made.
*3.2.79	7.99	3.2.79	16.50	8.51	Manually shutdown	Due to shortage of furnaceoil	-
m7.2.79	00.78	7.2.79	9.00	8.22	C.W. pump manually shutdown No.1	Due to breaking of chain	The chain was repaired
*8.2.79	15.50	8.2.79	18.26	2.76	Generator	Due to load fluctuation.	-
m10.2.79	00.47	11.2.79	6.03	29.56	Boiler	Repairing of boiler drum level meter	-
*21.2.79	7.92	21.2.79	12.50	4.59	Manually shutdown	Due to shortage of furnaceoil.	-
*23.2.79	4.00	23.2.79	18.58	14.58	Do	Do	-
*20.3.79	8.92	20.3.79	11.16	2.24	Generator	Nonuniform load	-
m30.3.79	23.08	8.4.79	18.52	201.44	I.D. Fan,Boiler, condenser(left)	Repairing of air heater ter tubes,cleaning of condenser,blocking of I.D. Fan with M.S. sheet.	-

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
*9.4.79	19.33	10.4.79	15.08	23.75	Boiler	Sample line leakage	It was repaired
*13.4.79	11.84	13.4.79	12.92	1.08	Fuel oil pump	Due to loss of 110V D.C.	-
*14.4.79	13.25	16.4.79	8.50	43.25	Boiler blowdown lines	Heavy leakage	Blowdown line was repaired.
m17.4.79	20.80	18.4.79	18.58	21.78	I.D. Fan(right)	I.D. Fan rope become lossen	The rope was tigh-tened
*20.4.79	7.05	21.4.79	8.66	25.61	Generator	Load fluctuation	-
m22.4.79	13.26	24.4.79	14.08	48.82	Condenser	Tube leakage	Defective tubes were pluged
*30.4.79	12.75	30.4.79	14.33	1.58	I.D Fan(both) F.D Fan and Burner	Suddently tripped	-
m7.5.79	5.66	8.5.79	10.33	28.67	I.D. fan(left) boiler	Repairing of boiler sample linea and I.D Fan alignment adjustment.	-
m23.5.79	4.60	24.5.79	9.50	28.90	Do	Do	-
*2.6.79	4.33	2.6.79	8.92	4.58	Turbine	The turbine suddenly tripped	-
*9.6.79	19.53	9.6.79	21.66	2.13	Turbine	Due to axial displa-cement of turbine shaft	It was adjusted.
m11.6.79	10.11	17.6.79	6.90	140.79	Boiler,Turbine I.D.Fan(right)	Maintenance of the following equipments	Maintenance work were done on H.P.rotor of turbine,alignment of I.D.Fan and brick work of combustion chamber.

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
*18.6.79	10.39	18.6.79	12.30	1.91	Turbine	Due to some fire in the insulator	-
*23.6.79	11.66	23.6.79	14.47	2.79	Turbine	Thrust bearing supporting ring shifted	The ring was adjusted
*30.6.79	15.16	30.6.79	17.66	2.50	Generator	Due to load fluctuation.	-
m1.7.79	23.78	3.7.79	00.72	24.92	Condenser, oilcooler C.W pump(No.2)	Manual shutdown	Reparing of C.W. pump chain,condenser tube cleaning, oil-cooler cleaning.
m7.7.79	23.91	8.7.79	21.31	21.40	I.D. Fan(left)	Alignment of I.D. Fan tightening of control rope.	-
*11.7.79	18.88	11.7.79	19.08	00.20	I.D. Fan(left)	Tripped showing overload.	False signal
m26.7.79	23.67	28.7.79	6.00	30.33	Condenser, feedpump	Cleaning of condenser,oil filter of feed pump	-
*29.7.79	17.13	29.7.79	18.79	1.58	C.W.pump(2)	Emission temperature increased due to problem in C.W. pump.	C.W.pump repaired
m31.7.79	22.60	2.8.79	13.20	38.60	Boiler	Replacement of orifice plate.	-
*3.8.79	19.58	4.8.79	16.83	21.25	C.W.pump(both)	Emission temp. increased due to due to problem in chain & brush.	Chain was repaired and the brushes were cleaned.

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
*5.8.79	13.08	5.8.79	16.08	3.00	Vacuum system	Due to problem in the ejector	-
*7.8.79	1.53	7.8.79	2.94	1.41	Do	Due to vacuum loss	Unidentified
*8.8.79	15.25	8.8.79	17.58	2.33	Do	Do	Do
*9.8.79	13.28	9.8.79	14.75	1.47	Do	Do	Do
m23.8.79	00.16	28.8.79	10.50	130.34	Turbine,Boiler condenser	Maintenance	Cleaning and blocking of condenser tubes. Replacement of oil seal in shaft turning gear and repairing of impulse safety valve
*29.8.79	11.26	29.8.79	12.83	1.57	Vacuum system	Vacuum osss	Unidentified
*30.8.79	21.50	30.8.79	23.16	1.66	Do	Do	Do
m1.9.79	23.05	3.9.79	00.92	25.77	I.D. Fan,(left) condenser	Maintenance	Blocking of I.D. Fan and cleaning of condenser
m18.9.79	23.91	23.9.79	19.91	116.00	Turbine,C.W. - pump(1) I.D. Fan(right) condenser	Manual shutdown	Reparing of thrust bearing of turbine shaft,cleaning of condenser,repairing of C.W. pump chain, blocing of right side of I.D. Fan.
*27.9.79	12.20	27.9.79	12.45	0.25	I.D.Fan(both) F.D. Fan Burners	Suddenly the foll-owing equipments tripped	Unidentified cause Again started and it and it become run normally.

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
m30.9.79	00.08	1.10.79	1.75	25.67	I.D.Fan(right) oilculer	Manual shutdown	Removal of blockage inside the duct of I.D. fan,cleaning of oil cooler
*9.10.79	13.25	9.10.79	15.25	2.00	Vacuum system	Emission temp. exceed the limit because of stopping one vacuum pump.	The pump again started
m12.10.79	17.37	13.10.79	13.41	19.44	Condenser	Manual shutdown	Tubes were pluged
*17.10.79	17.53	17.10.79	18.10	00.57	Boiler	Steam pressure decreased	Due to bad furnace oil
m28.10.79	23.75	29.10.79	22.58	22.83	Water heater	Leakage of valve No.13049	The value was repaired
*31.10.79	23.50	1.11.79	4.61	5.11	Boiler	Feed tank level meter was giving wrong signal(level)	It was readjusted
m10.11.79	23.33	11.11.79	13.58	14.25	C.W. pump(2)	Manual shutdown	One brush of C.W. pump was repaired
m21.11.79	22.90	22.11.79	10.66	11.46	C.W. pump(1) condenser	Do	Brush of C.W. pump repaired and condenser tubes were cleaned.
*4.12.79	1.41	4.12.79	4.50	3.09	I.D. Fan(both)	Suddenly I.O.Fan tripped due to problem in its flap	-

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
m5.12.79	23.16	10.12.79	6.25	103.09	Turbine I.D.Fan(left) condenser	Manual shutdown	Reparing oil seal of turning shaft,replacement of old I.D. Fan,cleaning of condenser tubes.
*12.12.79	6.75	12.12.79	6.92	0.17	Nozzle valves starting valve	Wrong operation	-
*13.12.79	8.25	13.12.79	12.05	3.80	Generator	Problem in AVR	-
*17.12.79	9.33	17.12.79	11.50	2.17	Transformer T-12	Tripped showing-overload	-
*19.12.79	21.41	20.12.79	7.25	9.84	Do	Tripped automatically	-
*21.12.79	7.75	21.12.79	9.41	1.66	Statting valve	Problem in Starting valve	-
*30.12.79	2.00	30.12.79	10.15	8.15	Vacuum system	Due to tripping of vacuum pump	-
m5.1.80	10.75	8.1.80	23.37	84.62	Condenser I.D.Fan(both)	Manual shutdown	Control flap of both the I.D.fan repaired, sealed up leakage tubes of condenser
*14.1.80	1.28	14.1.80	4.00	2.72	Vacuum system	Loss of vacuum	Unidentified cause
m15.1.80	11.75	16.1.80	1.50	13.75	C.W. pump(both)	Manual shutdown	Chain of C.W.pump repaired
m18.1.80	11.58	21.1.80	2.13	62.55	C.W. pump,(2) vacuum pump	Do	Checking up of C.W. pump sump and checking of vacuum pump.
m27.1.80	04.39	27.1.80	18.41	14.02	Do	Do	Do

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
m16.2.80	5.25	16.2.80	22.75	17.50	C.W.pump(2) condenser generator	Manual shutdown	Reparing screen of C.W. pump cleaning of conden-ser and generator top
m18.2.80	11.16	25.2.80	6.33	163.17	Boiler C.W. pump(both) generator, vacuum system	Do	Reparing C.W.pump, check-ing H_2 system of gene-rator, reparing of vacuum pump & Burners.
m28.2.80	22.16	29.2.80	6.33	8.17	C.W. pump, conden-ser	Do	C.W. pump(1) chain repairing & condenser cleaning
m2.3.80	7.61	2.3.80	22.00	14.39	Condenser, 132 KV switchyeard	Do	For the maintenance work of 132 K.V. switchyard & condenser cleaning.
m15.3.80	23.21	17.3.80	6.63	31.42	Condenser I.D.Fan(right) Injection valve of super heater.	Do	Condenser cleaning, I.D. Fan flap adjustment, leakage repairing of injection valve & f
m23.3.80	00.60	24.3.80	15.78	39.18	132 KV line	Do	For 132 KV line cons-truction
*28.3.80	8.41	28.3.80	11.25	2.84	Generator	Load fluctuation	-
m30.3.80	00.08	30.3.80	22.08	22.00	C.W. pump (both) 132 KV line	Manual shutdown	C.W.pump chain repairing Hocking up of BMPP at 132 KV switchyard.
m1.4.80	22.33	8.4.80	12.38	158.08	I.D. Fan(right) condenser	Manual shutdown	Repairing of I.D.Fan, plugging of leakage tubes.

Appendix-A (Contd.)

1	2	3	4	5	6	7	7
m10.4.80	6.75	16.4.80	7.00	154.25	I.D.Fan(left) Boiler tubes	Manual shutdown	Repairing of I.D.Fan and superheater tubes.
m18.4.80	22.66	20.4.80	22.38	47.72	I.D. Fan(left)	Do	Blocking of I.D.Fan
*22.4.80	00.01	22.4.80	00.96	0.95	Turbine	Trouble in control oil	-
*23.4.80	08.50	23.4.80	12.43	3.93	I.D. Fan(both)	Tripped due to vibration	It was checked and adjusted
m26.4.80	22.73	29.4.80	10.25	59.52	C.W.pump(1) boiler	Manual shutdown	Repairing bar screen of C.W.pump,W[illegible]ing of Economizer & [illegible]eater
m3.5.80	8.37	3.5.80	19.84	11.47	C.W. pump(1)	Do	Repairing chain
*5.5.80	12.58	5.5.80	16.75	4.16	-	Failure of 400 V supply due to short circuit	-
*9.5.80	10.75	9.5.80	12.83	2.08	Generator	Fluctuation of load	-
*18.5.80	7.92	18.5.80	22.05	14.13	C.W. pump(both)	Overflow of sediment tank	Water pumped out
* 23.5.80	9.11	23.5.80	11.50	2.39	Generator	Load fluctuation	-
m26.5.80	9.83	2.7.80	10.36	888.53	C.W. pump(2) I.D.Fan(left)	Manual shutdown	C.W.pump repairing, Alignment adjustment.
*4.7.80	7.75	4.7.80	14.58	6.83	Transformer	Suddenly,tripped	Unidentified cause.
*6.7.80	12.08	6.7.80	16.08	4.00	Do	Do	Do

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
m18.7.80	16.00	31.7.80	06.47	278.47	I.D.Fan (left) Vacuum pump	Manual shutdown	For repairing of vacuum pump and I.D. Fan.
m1.8.80	23.10	19.8.80	9.43	418.33	C.W.pump(1) vacuum pump	Do	Repairing of vaccuum pump & cleaning intake channel of C.W.pump.
m5.9.80	23.75	25.9.80	00.08	456.33	C.W.pump(1) I.D.Fan(left) vacuum pump, Chimney.	Do	Repairing of bush & middle bearing of C.W.pump.Alignment of I.D.fan,checking of vacuum pump and repairing of chimney.
*26.9.80	9.25	4.10.80	13.40	196.15	Boilder	Superheater tube leakage	It was repaired
*15.10.80	18.16	19.10.80	12.28	90.12	F.D.Fan(both)	Tripped showing overload	False signal
*8.11.80	13.66	13.11.80	23.28	129.62	I.D.Fan(Right)	Heavy damage of I.D.Fan due to vibration	The old one out of operation
m22.11.80	8.41	22.11.80	18.33	9.92	Grid sub-station	Manual shutdown	For maintenance
*23.11.80	19.25	26.11.80	21.08	73.83	Superheater tube	Tube leakage	It was repaired
*29.11.80	16.25	2.12.80	16.58	72.32	Superheater tube	Do	Do
*3.12.80	16.75	4.12.80	3.83	11.08	I.D.Fan(left)	Rope torneout	It was replaced
*6.12.80	7.16	12.12.80	8.95	145.79	Superheater tube	Tube leakage	It was welded

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
*16.12.80	03.85	18.12.80	13.25	57.40	I.D. Fan(left)	Brokedown of imp-ller fixing bolt	The bolts were replaced
m10.1.81	22.25	13.1.81	14.50	64.25	I.D.Fan(both) condenser generator	Manual shutdown	Checking and repairing of exciter,commutator and other related works to remove the sparking at carbon brushes. Blocking of condenser tubes. Checking and repairing of I.D.Fan.
m16.1.81	11.33	17.1.81	17.15	29.82	I.D.Fan(both) oilcooler fuel pump	Do	Repairing of I.D.Fan cleaning of oilcooler maintenance of fuel pump.
m31.1.81	21.91	2.2.81	15.63	41.72	-	Do	For construction work of 110 MW under 132 KV line.
*8.2.81	7.75	7.4.82	3.01	-	I.D.Fan(both)	-	OVERHAULING
*8.4.82	5.75	8.4.82	7.03	1.28	Turbine	Failure of gover-nor	It was replaced
*9.4.82	10.58	9.4.82	10.75	0.17	Do	Do	Do
*10.4.82	14.00	10.4.82	20.50	6.50	Do	Do	Do
*17.4.82	10.75	17.4.82	18.41	7.66	Feed pump(1)	Due to load fluctuation feed pump tripped	-
*23.4.82	8.37	23.4.82	9.93	1.56	Vacuum system	loss of Vacuum pressure	Checked and action was taken.

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
m30.4.82	23.23	3.5.82	1.75	50.52	I.D.Fan(both) C.W.pump(2) water heater Boiler.	Manual shutdown	leakage repairing at various section of boiler.Maintenance of I.D.fan,high pressure water heater,C.W pump
m27.5.82	23.25	30.5.82	12.95	61.70	Boiler,tubes	Leakage	It was repaired
*29.6.82	11.16	29.6.82	20.82	9.66	Vacuum system	Loss of V.press.	Unidentified cause
*1.7.82	9.70	1.7.82	12.08	2.39	Do	Do	Do
*3.7.82	2.30	3.7.82	17.70	15.40	Do	Do	Do
*5.7.82	00.92	26.7.82	1.57	509.65	Vacuum system	Breakdown of turbine expender	The turbine expander was replaced by a new one.
m1.8.82	22.86	5.8.82	21.41	195.55	Boiler tubes	Leakage of tubes	It was welded
*25.8.82	2.50	28.8.82	23.62	74.12	Do	Do	Do
m1.9.82	23.08	2.9.82	14.00	14.92	Turbine, X-former	Manual shutdown	R.P.M meter was out of order,oil was leaking from X-former.
*3.9.82	23.00	4.9.82	00.33	1.33	Vacuum system	Loss of V-press.	Un-identified cause
*5.9.82	5.58	5.9.82	12.91	7.33	Do	Do	Do
*10.9.82	21.41	10.9.82	22.83	1.42	Do	Do	Do
*12.9.82	6.00	12.9.82	11.91	5.91	Do	Do	Do
*13.9.82	22.91	14.9.82	00.41	1.50	Do	Do	Do

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
m17.9.82	21.83	19.9.82	00.10	26.27	Oilcooler,water heater,vacuum pump	Manual shutdown	Both vacuum pump checked,cleaning [illegible] no.2 oilcooler.[illegible] valve of L.P.[illegible] changed.
*[illegible].9.82	11.10	20.9.82	13.85	2.75	Vacuum system	Loss of V.press.	Unidentified caus[illegible]
*21.9.82	14.41	21.9.82	16.16	1.77	Do	Do	Do
m27.9.82	23.50	3.10.82	1.25	121.75	Condenser,Boiler drum discharge valve	Manual shutdown	Leakage repairing [illegible] boiler drum dis[illegible] valve, Pluging o[illegible] leakage condense[illegible]
*4.10.82	6.21	4.10.82	12.00	5.78	Vacuum system	Loss of V.pressure	Unidentified caus[illegible]
*15.10.82	5.00	15.10.82	9.33	7.33	Do	Do	Do
*26.10.82	9.10	26.10.82	11.16	2.06	6.6 KV supply	Failure of 6.6 KV	Supply resumed
m17.11.82	22.25	20.11.82	7.58	57.33	C.W.pump(both) turbine,feed pump,heater, Boiler	Manual shutdown	The plant made shut-down for the following repair work,(1) gland leakage of both-feed pump(2) Delivery valve of feed pump(3) gland leakage of both C.W.pump (4) leakage at blow down line,superheater drain line(5)R.P.M meter of turbine.
*22.11.82	2.25	22.11.82	7.00	4.75	Vacuum system	Loss of V.pressure	Unidentified cause
*23.11.82	22.27	23.11.82	6.81	8.56	Do	Do	Do

Appendix-A (Contd.)

1	2	3	4	5	6	7	8
m10.12.82	23.39	19.12.82	16.33	184.94	Boiler	Manual shutdown	Repairing of combustion chamber brick work.
*20.12.82	23.50	22.12.82	13.41	37.91	Vacuum system	Loss of v.pressure	Unidentified cause
*23.12.82	14.53	23.12.82	14.80	0.27	Generator	Under voltage trip	-
*26.12.82	16.80	28.12.82	18.66	49.86	V. system	Loss of V. Pressure	Unidentified cause
m2.1.83	22.56	10.1.83	1.66	176.10	Condenser, C.W. pump (both) turbine.	Manual shutdown	Cleaning sum of C.W. pump, checking, the bearing and coupling between H.P. & L.P. turbine. Cleaning of condenser tubes.
*17.1.83	8.08	17.1.83	14.91	6.83	Feed pump	Due to leakage at recirculating line	It was repaired
*17.2.83	13.50	17.2.83	17.91	4.41	Generator	Load fluctuation	-
*18.2.83	20.75	19.2.83	9.16	12.41	Turbine	Leakage at Secondary control oil line	
*21.2.83	00.36	21.2.83	7.78	7.42	Generator	Overload trip	-
*22.2.83	8.50	22.2.83	11.50	3.00	Do	Load fluctuation	-
m8.3.83	11.61	9.3.83	11.50	23.89	Turbine	Manual shutdown	For checking the axial displacement of turbine rotor which was showing maximum displacement.
m10.3.83	22.53	13.3.83	17.71	67.18	Do	Do	Thrust bearing shoe replacement.

Appendix-A (Contd.)

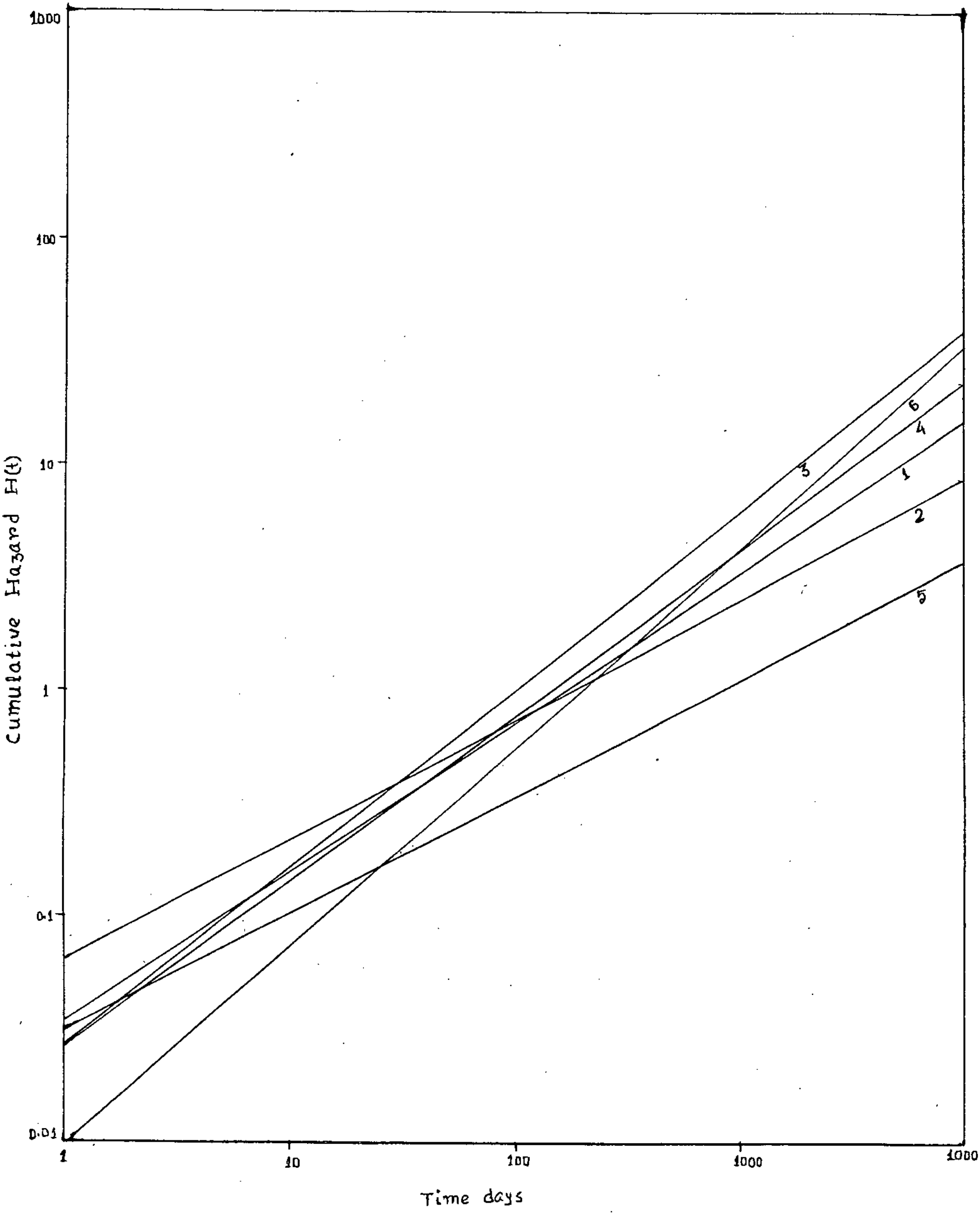
1	2	3	4	5	6	7	8
m24.3.83	22.48	26.3.83	22.58	48.10	I.D.Fan(right)	Manual shutdown	Bearing replacement
m30.4.83	21.91	1.5.83	19.13	11.22	Turbine	Do	Maintenance work to the turbine governor (system and oil system)
m2.5.83	22.50	4.5.83	16.50	42.00	Feed pump	Do	Repairing of by pass line.
m14.5.83	22.95	17.5.82	21.53	70.58	Feed pump, turbine, boiler	Do	Turbine oil centrifusin Repairing of feed pump delivery pressure meter and drum level meter.
*18.5.83	23.33	19.5.83	12.50	13.17	Generator	Load fluctuation	-
m31.5.83	5.91	31.5.83	10.66	4.75	Turbine	Manual shutdown	Repairing of R.P.M.mete
m16.6.83	22.97	19.6.83	17.25	66.28	C.W. pump(1) condenser, feed pump, boiler.	Do	Condenser cleaning repairing of feed pump gland leakage C.W.pump chain, boiler gauge glas
m.6.7.83	21.16	14.7.83	14.11	184.95	Boiler	Do	Leakage repairing of superheater tubes.
*27.7.83	18.29	26.7.83	18.57	0.28	Generator	Trouble at A.V.R	It was repaired
m8.8.83	1.50	10.8.83	10.28	56.71	C.W.pump(both) condenser	Manual shutdown	Cleaning the condenser and C.W.pump sump.
m17.9.83	22.55	29.9.83	14.50	159.95	Boiler tubes	Do	Repairing the leakage tubes.

Appendix-A (Contd.)

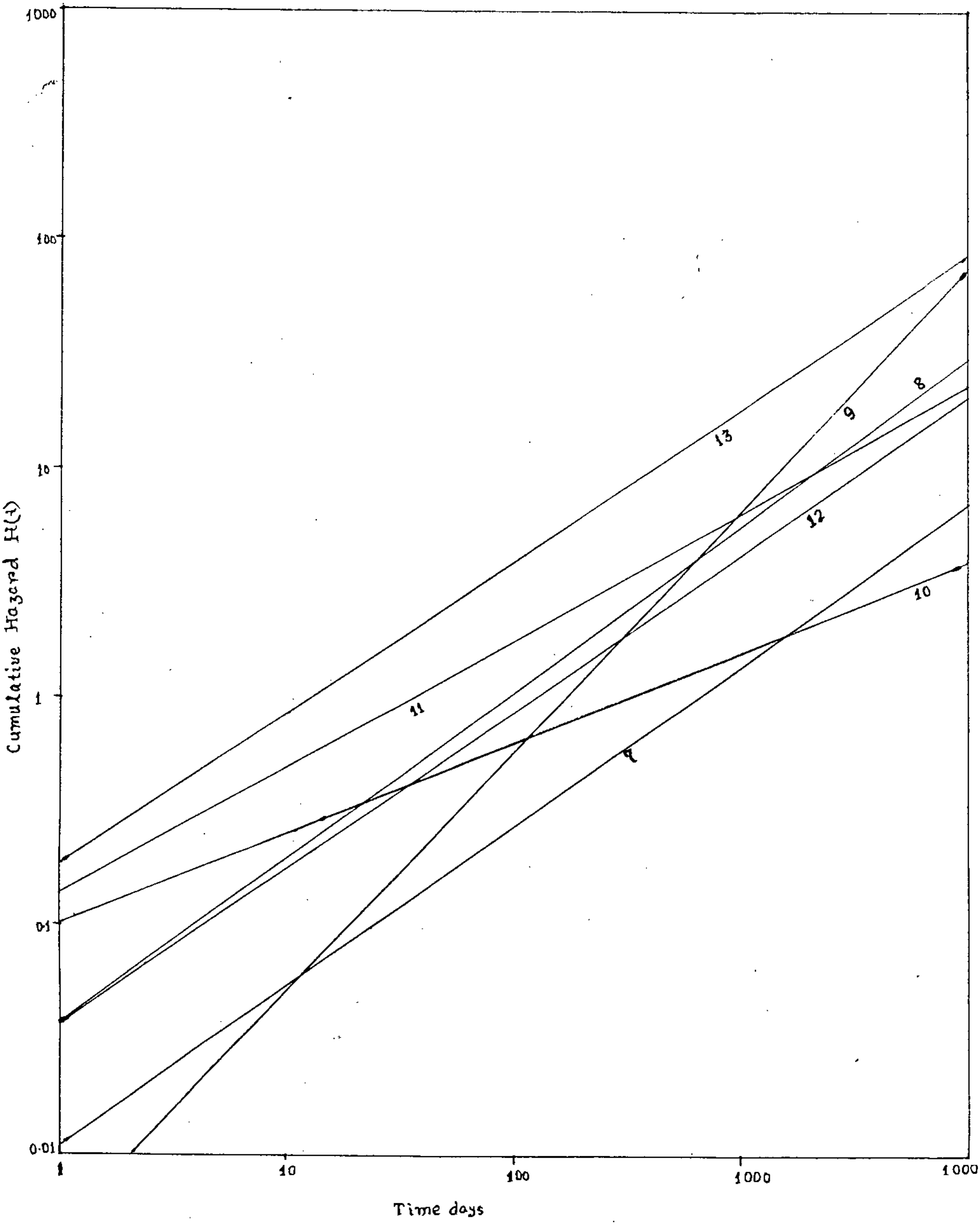
1	2	3	4	5	6	7	8
m6.11.83	21.70	15.11.83	12.75	207.05	Generator	Manual shutdown	Pluging of H_2 cooling condensate cooler leakage tubes and checking the turning gear.
m10.12.83	21.83	14.12.83	18.08	92.25	Turbine, boiler condenser, I.D.Fan(Left)	Do	Checking and repairing L.P. rear bearing of turbine. Repairing of broken brick work inside the combustion chamber. Cleaning of condenser. Alignment of I.D. Fan.

APPENDIX-B

GRAPHICAL SOLUTION OF HAZARD PLOTTING METHOD



Appendix-B (Contd..)



Equipments of Appendix B are as follows:

1. Boiler
2. Turbine
3. Generator
4. I.D. Fan (Right)
5. C.W. Pump (2)
6. Transformer
7. C.W. Pump (1)
8. I.D. Fan (left)
9. Feed pump
10. F.D. Fan
11. Vacuum system
12. Other causes
13. Power Plant

A APPENDIX – C

MLE Method for the estimation of weibull distribution parameters.

```
DOS FORTRAN IV 360N-FO-479 3-8              MAINPGM              DATE   20/09/84

      C     THE COMPUTER PROGRAMME USED FOR THE ESTIMITION OF WEIBULL
      C     DISTRIBUTION PARAMETER IS SHOWN BELOW
      C     PROGRAMME IS DONE BY MOKSUDUL HAQ.M.SC.(IPE)
             DIMENSION T(200), X(200), Y(200), XY(200), YS(200),
            1XYS(200), YF(200), TF(200)
             READ (1,900) N1
         900 FORMAT(I2)
             DO 999 IX=1,N1
             READ (1,100) N,IR
         100 FORMAT(2I3)
             READ (1,101) (T(I), I=1,  N)
             READ (1,101) (TF(II),II=1,IR)
         101 FORMAT(13F6.2)
             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 TO 113
         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+(1.0/B1)))**2)))
             WRITE(3,109)B1,ETA,FMT,SD
         109 FORMAT(5X,'SHAPE PARAM=',F5.2,5X,'SCALE PARAM='
            1,F10.3,5X,'MEAN LIFE=',F10.3,5X'STD DEV=',F10.3)
         999 CONTINUE
             STOP
             END
```

Appendix - C (Contd.)

DOS FORTRAN IV 360N-FO-479 3-8 MAINPGM DATE 20/09/84

```
0001        FUNCTION YY(Z)
0002        YY=(Z**Z)*EXP(-Z)*SQRT((2.0*3.1416)/Z)*(1.0+(1.0/
           1(12.0*Z))+(1.0/(288.0*(Z**2))))
0003        RETURN
0004        END
```

APPENDIX-D

Failure History of Khulna Industrial Zone Distribution System

The symbol used in column 2,6, and 7 of Appendix-D are as follows
I-Incoming, S/S - Substation, L-Load shade, E-Earth Fault,
O-Overcurrent, S-Shutdown

Note: Study period started from 1.7.82 at 00.00 hour.

Date	Feeder/ S/S	Duration of failure From	To	Down time Hours	Causes of Failure	Branches/ Load Point	Remarks
1	2	3	4	5	6	7	8
2.7.82	Gate S/S(I)	3-13	10-22	7.15	L	21	
"	"	10-38	10-55	0.28	"	21	
"	Crescent star	16-42	18-40	1.96	"	34	
3.7.82	Khalishpur	2-32	3-08	0.60	"	32	
"	BIOC	2-32	3.-08	0.60	"	31	
"	Khalishpur	8-35	9-30	0.91	E	32	
"	Rerolling	10-07	11-00	0.88	L	36	
"	Crescent star	13-23	15-11	1.80	E,O	34	
"	Khalishpur S/S S/S(I)	16-15	17-20	1.08	L	22	
4.7.82	Gate S/S(I)	00-38	00-59	0.35	E	21	
"	Kohinoor	2-27	3-07	0.66	E,O	33	
"	Rerolling	5-34	5-45	0.18	By hand	36	For changing isolator fuse
"	"	6-36	6-42	0.10	E	36	
"	"	9-44	9-49	0.08	By hand	LP4	For changing fuse at gate x-former.
"	Kohinoor	18-30	18-55	0.41	"	LP7	For changing H.T fuse of Lalhospital.

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
5.7.82	Rerolling	7-07	12-39	5.53	L	36	
"	Cresent star	7-55	10.55	3.00	"	34	
"	Kohinoor	7-55	12-40	4.75	"	33	
"	Khalishpur S/S (I)	16-25	17-20	0.91	"	22	
"	Crescent star	17-45	18.38	0.88	"	34	
6.7.82	BIDC	10-53	13.06	2.21	By hand	31	For maintenance work
"	Crescent star	18-10	18-17	0.11	L	34	
"	"	19-26	19-48	0.36	"	34	
8.7.82	8IDC	5-55	7-40	1.75	By hand	31	For maintenance work
"	"	17-00	18-16	1.30	L	31	
9-7.82	Khalishpur	10-26	12-35	2.15	E	32	
10.7.82	"	17-05	18-05	1.00	L	32	
"	Rerolling	17-06	18-02	0.93	"	36	
"	"	19-05	19-45	0.66	"	36	
11.7.82	Crescent star	20-25	22-15	1.83	O	34	
"	Kohinoor	21-35	21-45	0.16	"	33	
12.7.82	Crescent star	5-39	5-42	0.05	"	34	
"	Khalishpur	9-03	13-55	4.86	L	32	
"	Kbhinoor	9-37	11-25	1.80	"	33	
"	Rerolling	9-37	13-20	3.71	"	36	
"	Khalishpur	18-32	18-36	0.06	8y hand	LP14	For changing x-for fuse of housing.
"	Rerolling	19-08	20-15	1.11	L	36	
13.7.82	"	10-38	11-35	0.93	"	36	

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
13.7.82	Khalishpur	10-40	12-23	1.71	L	32	
"	Kohinoor	11-48	12-22	0.56	"	33	
"	Crescent star	19-28	19-47	0.31	"	34	
15.7.82	Gate S/S(I)	12-30	13-22	0.86	"	21	
"	Rerolling	15-05	17-30	2.41	"	36	
"	Khalishpur	15-12	16-15	1.05	"	32	
"	BIDC	16-15	17.31	1.26	"	31	
"	Khalishpur S/S(I)	22-24	22-34	0.18	"	32	
"	Gate S/S(I)	17-10	17-29	0.31	"	21	
"	Khalishpur	22-26	22-45	0.31	"	32	
16.7.82	Rerolling	12-15	15-22	3.11	"	36	
"	BIDC	13-38	14-00	0.36	"	31	
"	Rerolling	23-36	00-10	0.56	"	36	
17.7.82	Khalishpur	2-08	2-24	0.26	"	32	
"	Rerolling	[illegible]	[illegible]	[illegible]	"	[illegible]	
"	BIDC	2-24	2-48	0.40	"	31	
"	Crescent star	3-03	3-38	0.58	"	34	
"	BIDC	7-47	8-38	0.85	"	31	
"	Rerolling	7-50	10-15	2.25	"	36	
"	Khalishpur	12-00	13-32	1.53	By hand	32	
"	BIDC	10-37	10-45	0.11	"	LP17	For chaning x-for.fuse near T&T
"	"	13-35	14-25	0.83	"	31	For maintenance work

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
18.7.82	Crescent star	2-42	3-07	0.41	L	34	
"	Rerolling	12-58	13-59	1.00	"	36	
"	Crescent star	14-55	15-34	0.65	"	34	
19.7.82	Rerolling	14-15	14-55	0.66	E	36	
22-7-82	"	12-08	12-54	0.77	By hand	36	For maintenance work
23.7.82	BIDC	10-20	11-10	0.83	"	LP18	For changing Biharibazar x-for.fuse
25.7.82	Kohinoor	11-45	12-30	0.75	"	33	For maintenance work
"	BIDC	20-51	22-05	0.23	"	31	"
1.8.82	Rerolling	10-19	12-21	2.03	Mant.	LP21	x-for.infront of rerolling mill
2.8.82	BIDC	11-45	12-34	0.81	"	LP18	x-for fuse of Biharibazar
"	"	16-30	22-00	5.50	E,O	31	
"	Rerolling	21-01	22-00	0.98	"	36	
3.8.82	"	00-12	00-30	0.30	Fuse	LP18	x-for. fuse of Biharibazar
"	"	00-40	1-04	0.40	"	LP22	Rerolling mill x-for.fuse change
"	Kohinoor	1-15	1-34	0.31	"	LP13	For changing x-for.fuse of Tintala
"	Rerolling	12-50	13-06	0.26	H.T.fuse	LP22	x-for. fuse infront of rerolling mill
"	"	14-35	14-44	0.15	x-fuse	LP17	x-for.fuse infront T&T
"	Khalishpur S/S(I)	18-42	18-44	0.03	E	22	
"	Kohinoor	13-57	14-20	0.38	"	33	
"	"	20-55	21-02	0.11	By hand	LP13	x-former fuse change Tintala
4.8.82	Rerolling	17-00	17-17	0.28	"	LP17	x-for. fuse near T&T
"	"	19-00	19-15	0.25	"	LP23	x-for. fuse of public health
"	Kohinoor	14-40	14-52	0.20	"	LP14	x-for.fuse at housing.
7.8.82	Rerolling	10-45	11-15	0.50	E	36	

Appendix-D (Contd.)

7.8.82	Rerolling	20-00	20-20	0.33	By hand	LP23	Changing H.T. fuse of Public Health
19.9.82	"	21-37	22-30	0.88	"	36	Maintenance work
20.9.82	Fish Co	10-20	12-40	2.33	"	35	"
23.9.82	Rerolling	7-50	7-52	0.03	E	36	
"	"	10-30	10-50	0.33	By hand	LP22	H.T. fuse of rerolling x-former.
"	"	11-40	11-52	0.20	"	LP22	Maintenance work
25.9.82	"	00-25	00-28	0.05	E	36	
26.9.82	"	1-25	2-00	0.58	By hand	LP23	H.T. fuse of public health x-former
"	"	2-15	2-50	0.58	"	LP16	H.T loop of T&T x-former.
"	"	4-14	4-16	0.01	E	36	
27.9.82	"	8-55	9-05	0.16	By hand	LP22	H.T. fuse of x-for. infront of rolling
28.9.82	Kohinoor	19-38	20-05	0.45	"	33	Maintenance work
29.9.82	"	17-58	18-10	0.20	"	LP11	H.T fuse of x-for at pump house
"	"	18-17	18-28	0.18	L.T loop	LP15	Kohinoor x-for.
1.10.82	"	15-02	15-55	0.88	L	33	
"	"	18-25	19-10	0.75	"	33	
2-10-82	Rerolling	18-42	19-20	0.63	"	36	
3.10.82	Kohinoor	7-07	7.48	0.68	"	33	
"	Rerolling	17-32	17-45	0.21	By hand	LP6	H.T. fuse of x-for. in front of Platinum
4.10.82	"	11-20	11-35	0.25	"	LP18	x-for. fuse at Biharibazar
6.10.82	"	10-20	10-35	0.25	"	36	Maintenance work
"	"	18-06	18-07	0.03	O	36	
10.10.82	"	00-40	1-10	0.50	H.T fuse	LP16	at T&T x-former
"	BIOC	11-25	16-00	4.58	By hand	31	Maintenance work

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
11.10.82	Rerolling	16-38	16-59	0.35	By hand	36	Maintenance work
"	BIDC	19-53	20-00	0.11	L.T loop	LP1	Kashipur x-former
12.10.82	"	8-39	10.15	1.60	"	"	"
"	"	11-55	12-10	0.45	"	"	"
"	Rerolling	15-30	15-37	0.11	LT bushing	LP18	of Biharibazar x-former
15.10.82	BIDC	00-50	1-10	0.66	LT loop	LP1	at Kashipur x-former
17.10.82	Rerolling	10-35	10-49	0.23	-By hand	LP23	Isolator fuse at public health x-for.
18-10-82	Khalishpur	19-23	19-28	0.08	fuse	LP8	of goalpark x-former
"	"	20-55	20-56	0.01	"	LP8	"
"	BIDC	20-15	20-30	20.25	LT loop	LP2	Infront of Chitrali cinema
"	"	22-15	22-20	0.08	"	LP1	of Kashipur x-former
19.10.82	Rerolling	19-55	20-09	0.23	HT fuse	LP14	of housing x-former
20.10.82	"	10-55	11-05	0.16	"	LP16	of T&T x-former
22.10.82	"	11.40	11-59	0.31	Jamper	LP18	of Biharibazar x-former
"	"	12-20	12-30	0.16	"	LP18	"
24.10.82	"	10-41	10-55	0.23	H.T fuse	LP14	of housing x-former
25.10.82	"	18-51	19=33	0.70	L	36	
"	BIDC	20-01	20-05	0.06	LT loop	LP4	of gate x-former
"	"	21-07	21-14	0.11	H.T loop	LP-4	"
"	Khalishpur	20-34	20-50	0.26	H.T fuse	LP12	of Mohsin college x-former
"	Rerolling	21-40	21-51	0.18	"	LP16	of T&T x-former
26.10.82	"	9.46	9-47	0.01	L	36	
"	Gate S/S(I)	17-42	17-52	0.16	"	21	
"	BIDC	18-01	18-02	0.01	E	31	

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
26.10.82	Khalishpur	20-30	20-37	0.11	x-for fuse	LP8	Near Round park
27.10.82	"	13-25	16-15	2.83	E	32	
"	Kohinoor	17-57	18-07	0.16	"	33	
"	Khalishpur	19-25	19-37	0.20	x-for fuse	LP13	Near Tintala
28.10.82	"	19-50	20-10	0.33	x-for fuse	LP13	"
29.10.82	Crescent star	18.25	18-40	0.25	E	34	
"	Fish Co	18-25	18-42	0.28	"	35	
31.10.82	Rerolling	10-30	11=20	0.83	Mant.work	36	
"	"	15-45	16-07	0.36	By hand	LP23	H.T jumper of public health x-for.
1.11.82	Khalishpur	12-09	12-11	0.03	To remove	32	The crow from wire mear T.V centre
"	BIDC	13-02	13-22	0.33	Mant.work	31	
3.11.82	Khalishpur	19-10	19-12	0.03	E	32	
"	"	20-10	20-15	0.08	H.T.loop	LP8	of x-former at round park
"	"	21-24	21-43	0.31	Jumper	LP14	of x-for.mear thana
.82	Gate S/S(I)	21-05	21-07	0.03	E	21	
"	BIDC	18-45	19-00	0.25	LT loop	LP1	of x-for. at Kashipur
6.11.82	Gate S/S(I)	11-20	14-05	1.75	E	21	
8.11.82	BIDC	19-42	19-44	0.03	"	31	
"	Khalishpur	18-50	19-00	0.16	x-for fuse	LP8	at goal park
10.11.82	BIDC	00-10	00-20	0.16	"	LP3	Behind Chitrali cinema
12.11.82	Khalishpur	3-10	4-15	1.08	E	32	
"	"	5-15	5-20	0.08	"	32	
"	"	5-46	5-50	0.08	"	32	
"	Kohinoor	9-50	11-03	1.21	"	33	

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
12.11.82	Khalishpur	16-30	17-17	0.78	Mant.	32	To change pin insulator
"	Rerolling	18-44	19-15	0.52	By hand	LP18	x-for. L.T. Loop of B. Bazar
"	BIDC	20-40	21-00	0.32	x-for.loop	LP1	at Kashipur
"	Rerolling	21-02	21-31	0.48	"	LP18	of B. Bazar
16.11.82	BIDC	13-55	15-30	1.58	E/	31	
"	Rerolling	14-54	15-04	0.16	x-for.fuse	LP16	of T&T
"	Khalishpur	21-45	22-00	0.25	Mant.	32	
"	"	23-50	00-11	0.35	H.T.fuse	LP8	of goal park x-former
17.11.82	"	09-28	09-35	0.11	Mant.	32	
"	Rerolling	10-30	11-00	0.50	"	36	
"	Khalishpur	10-50	11-80	0.16	"	32	
"	Rerolling	16-58	17-13	0.25	x-for fuse	LP6	infront of platinum
"	BIDC	20-10	20-42	0.53	LT-loop	LP1	of x-former at Kashipur
19.11.82	Gate S/S(I)	17-40	17-45	0.08	L	21	
20.11.82	BIDC	11-00	12-00	1.00	"	31	
"	Khalishpur	11-00	11-30	0.50	"	32	
21.11.82	Rerolling	06-55	07-25	0.50	"	36	
"	"	07-30	07-31	0.01	E	36	
"	"	10-33	10-50	0.28	By hand	36	for mant. work
"	Khalishpur	17-55	17-56	0.01	E	32	
"	"	19-33	20-00	0.45	HT fuse	LP14	of x-for. at Housing
"	Gate S/S(I)	17-42	17-43	0.01	O	21	
22.11.82	"	10-14	11-03	0.81	"	21	
"	BIDC	09-07	09-08	0.01	E	31	
"	Khalishpur	13-00	13-02	0.03	"	32	

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
22.11.82	Khalishpur	17-05	17-18	0.21	H.T fuse	LP13	of x-former near Tintala
23.11.82	Rerolling	09-05	09-45	0.66	By hand	36	Mant. works
26.11.82	"	17-10	17-13	0.05	E	36	
"	BIDC	17-38	17-42	0.06	"	31	
"	Khalishpur	20-07	20-23	0.26	H.T fuse	LP8	of round Park x-former
"	BIDC	21-25	21-35	0.16	x-for.fuse	LP3	Behind Chitrali cinema
28.11.82	Khalishpur	20-30	20-50	0.33	"	LP11	of KITC
1.12.82	Gate S/S(I)	14-12	15-20	1.13	E	21	
"	Kohinoor	14-12	15-23	1.18	"	33	
"	Rerolling	15-25	16-08	0.71	"	36	
2.12.82	Kohinoor	11-08	11-10	0.03	By hand	33	Load changeover
"	BIDC	12-20	12-45	0.41	"	31	"
3.12.82	Khalishpur	21-30	22-10	0.66	E	32	
4.12.82	Khalishpur S/S(I)	07-26	07-36	0.18	"	22	
"	Kohinoor	07-37	10-20	2.38	"	33	
"	Khalishpur	10-44	11-25	0.66	x-for fuse	LP13	at Tintala
5.12.82	"	09-45	11-15	1.50	E	32	
8.12.82	Kohinoor	19-05	19-15	0.16	x-for fuse	LP15	of Kohinoor S/S
10.12.82	Khalishpur S/S(I)	18-29	18-30	0.01	E	22	
"	Kohinoor	19-50	20-14	0.40	H.T fuse	LP15	of Kohinoor x-former
11.12.82	Rerolling	09-15	09-35	0.33	H.T.jamper	36	Changing
"	Khalishpur	09-45	10-45	1.00	E	32	
"	"	14-22	14-39	0.28	"	32	

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
11.12.82	Khalishpur	11-28	12-00	0.53	O	32	
"	"	12-14	12-25	0.18	"	32	
"	"	14-20	14-21	0.01	Mant.works	32	
"	"	16-25	16-35	0.16	H.T.fuse	LP14	of Housing x-former
"	"	16-38	16-48	0.11	E	32	
"	"	18-05	18-35	0.50	"	32	
"	Kohinoor	20-05	20-15	0.16	H.T.fuse	LP15	Kohinoor x-former
"	Khalishpur	21-22	21-24	0.03	E	32	
"	"	21-24	21-25	0.01	"	32	
"	"	21-36	21-38	0.03	"	32	
12.12.82	"	12-20	13-36	1.26	By hand	LP14	for testing Housing x-former
"	Kohinoor	17-05	17-20	0.25	"	LP15	x-for. fuse at Kohinoor S/S
"	"	22-00	22-40	0.66	"	LP15	To check the Kohinoor x-former
15.12.82	"	23-30	24-00	0.50	H.T fuse	LP15	of Kohinoor x-former
"	Rerolling	07-48	07-50	0.03	E	36	
17-12.82	"	11-30	15-42	2.20	H.T fuse	LP16	of x-former at T&T
"	Khalishpur	19-52	20-02	0.16	E	32	
19.12.82	Gate S/S(I)	11-54	11-56	0.03	Breaker	21	Trouble at Diesel control room
"	Khalishpur	14-57	14-59	0.03	Mant.	LP15	To change Khinoor S/S x-form.
20.12.82	Rerolling	14-58	15-05	0.11	H.T.fuse	LP17	infront of T&T x-former
"	Gate S/S(I)	17-21	17-48	0.45	L	21	
21.12.82	Rerolling	10-05	10-20	0.25	H.T fuse	LP14	at Housing x-former
"	"	17-01	18-02	1.01	Mant. work	36	
"	"	21-50	22-20	0.50	"	LP16	at T&T x-former
"	"	23-15	00-04	0.81	"	LP16	"

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
22-12.82	Rerolling	11-50	13=31	1.68	By hand	LP16	For testing T&T x-former
"	Khalishpur	13-30	13-50	0.33	H.T.fuse	LP14	of Housing x-former
23.12.82	BIDC	15-35	15-50	0.25	L.T.wire	LP1	Near Kashipur
"	Rerolling	16-15	16-30	0.25	Mant.	LP16	For setting new x-for. at T&T
"	"	19-28	19-45	0.28	"	LP16	"
24.12.82	BIDC	20-07	21-20	1.21	E	31	
"	Khalishpur	23-50	00-10	0.33	Mant	32	
25.12.82	BIDC	11-24	12-45	1.35	"	31	
"	"	20-32	20-50	0.30	L.T.loop	LP1	of Kashipur x-former
27.12.82	Khalishpur	10-38	10-44	0.10	H.T. fuse	LP13	of Tintala x-former
"	"	18-10	18-13	0.05	E	32	
30.12.82	"	13-20	13-50	0.50	Mant.	LP13	for setting new x-former near Tintala
"	"	20-04	20-07	0.05	E	32	
31.12.82	Kohinoor	18-48	19-48	1.00	x-for.jamper	LP13	near tintala
4.1.83	Rerolling	11-50	12-36	0.76	Mant.	LP19	To set new x-for.near Kadamtala
"	"	20-15	20-35	0.33	"	36	
9.1.83	"	09-45	09-55	0.16	x-for.fuse	LP21	infront of rerolling mill x-for.
"	"	14-40	14-57	0.28	L.T.loop	LP18	of Biheribazar x-for.
"	"	15-35	15-47	0.20	"	LP18	"
11.1.83	BIDC	11-30	12-05	0.58	L.T. loop	LP1	of Kashipur x-former
12.1.83	Khalishpur S/S(I)	07-20	07-22	0.03	E	22	
"	Rerolling	09-07	09-14	0.11	H.T. fuse	LP22	Rerolling mill x-former
13.1.83	"	12-15	12-25	0.16	H.T. loop	LP16	of T&T x-former
"	BIDC	19=43	20-16	0.55	E	31	

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
14.1.83	Rerolling	08-49	09-00	0.18	H.T. fuse	LP18	of Biharibazar x-former
"	Khalishpur	17-40	17-42	0.08	O	22	
16.1.83	Khalishpur	11-59	13-10	1.18	E	32	
18.1.83	"	12-21	12-28	0.11	Mant.	32	
"	"	14-25	14-35	0.16	Do	32	
19.1.83	"	14-25	14-35	0.16	H.T. fuse	LP11	of KITC x-former
21.1.83	BIDC	10-00	13-45	3.75	Mant.work	31	
23.1.83	Rerolling	12-40	12-55	0.25	"	LP16	To set up new x-former
"	"	21-22	21-32	0.16	L.T.loop	LP23	of Public Health x-former
24.1.83	BIDC	19-00	19-15	0.25	H.T. fuse	LP1	of Kashipur x-former
25.1.83	Khalishpur	14-07	14-08	0.01	E	32	
"	"	16-10	16-35	0.40	By hand	LP14	Near Housing
"	"	18-00	18-01	0.01	E	32	
"	Rerolling	19-30	19-55	0.41	H.T.fuse	LP18	of B.Bazar x-former
30.1.83	BIDC	12-46	13-30	0.73	E1	31	
"	Khalishpur	15-15	15-55	3.60	"	32	
"	BIDC	15-05	16-00	0.91	"	31	
"	Rerolling	16-45	18-40	1.91	"	36	
31.1.83	Khalishpur	09-55	10-12	0.28	x-for.fuse	LP11	at KITC
"	Rerolling	10-30	11-55	1.41	Mant.	36	
"	Khalishpur	11-50	12-10	0.33	x-for fuse	LP11	at KITC
"	"	18-45	18-50	0.08	E	32	
5.2.83	Kohinoor	11-07	11-42	0.58	Mant.	33	
"	Gate S/S(I)	11-14	14-10	2.93	L	21	

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
5.2.83	Rerolling	16-10	16-25	0.25	By hand	36	Load change
"	BIDC	16-10	16-55	0.75	"	31	"
"	Kohinoor	15-29	16-04	0.58	"	33	"
"	Rerolling	19-00	19-10	0.16	x-for.fuse	LP18	of B.Bazar x-for.
"	"	19-32	19-45	0.21	"	LP18	"
6.2.83	BIDC	18-00	18-03	0.05	E	31	
7.2.83	Rerolling	10-15	10-28	0.21	Mant.	36	
12.2.83	Khalishpur	11-15	11-35	0.33	E	32	
"	"	12-08	13-00	0.86	"	32	
"	Rerolling	17-01	17-46	0.75	Mant.	36	
"	Khalishpur S/S (I)	18-17	18-18	0.01	E	22	
"	Khalishpur	19-55	20-01	0.10	H.T.fuse	LP7	of Lal hospital x-for.
"	BIDC	20-35	20-57	0.36	L.T loop	LP1	of Kashipur x-for.
13.2.83	Rerolling	10-25	10-40	0.25	Mant.	36	
"	"	12-05	12-20	0.25	x-for.fuse	LP18	of B.bazar
18.2.83	"	14-40	16-25	1.75	E	36	
"	Khalishpur	18-20	18-22	0.03	O	32	
"	Rerolling	19-05	19-20	0.25	H.T.fuse	LP18	of B.bazar
"	Khalishpur	19-16	19-40	0.40	"	LP8	of Round park x-for.
"	"	20-45	21-10	0.41	L	32	
"	"	21-15	21-35	0.33	"	32	
"	BIDC	20-45	21-35	0.81	"	31	
19.2.83	Khalishp-ur	09-35	09-45	0.16	Mant.	32	

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
19.2.83	Rerolling	09-50	10-00	0.16	H.T. fuse	L.P.23	of Public health x-for.
"	"	19-35	19-47	0.20	"	LP23	"
21.2.83	Gate S/S(I)	08-50	09-05	0.25	L	21	
22.2.83	"	00-22	01-00	0.63	E	21	
"	"	02-02	02-05	0.05	"	21	
24.2.83	Rerolling	19-07	19-40	0.55	"	36	
"	"	20-30	20-35	0.08	H.T.fuse	LP21	infront of rerolling mill x-for.
25.2.83	"	00-04	02-40	2.60	E	36	
"	"	06-30	07-30	1.00	"	36	
"	Khalishpur S/S(I)	07-30	07-32	0.03	"	22	
"	Rerolling	07-40	08-45	1.08	"	36	
"	Gate S/S(I)	08-50	09-05	0.25	L	21	
28.2.83	Rerolling	13-45	14-15	0.50	Mant.	36	
1.3.83	Khalishpur	10-10	10-50	0.66	x-for.	LP13	near Tintala
"	Khalishpur	18-35	18-36	0.01	E	32	
"	Kohinoor	18-35	19-05	0.50	"	33	
"	"	19-45	20-08	0.38	x-for.fuse	LP16	at Kohinoor S/S
2.3.83	Khalishpur	18-47	19-10	0.38	Mant.	32	
7.3.83	Rerolling	12-31	12-58	0.45	"	36	
"	Khalishpur S/S(I)	15-37	17-02	0.41	"	22	
"	BIDC	15-45	16-15	0.50	L	31	
8.3.83	Khalishpur	22-01	22-20	0.31	x-for.fuse	LP7	of Lal hospital x-for.
14.3.83	Fish.Co.	21-20	21-40	0.33	Mant.	LP24	x-for. Fish co.

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
14.3.83	Fish Co.	21-45	21-55	0.16	Mant.	LP24	x-for. of Fish co.
15.3.83	Khalishpur S/S (I)	14-18	14-20	0.03	E	22	
"	Rerolling	14-18	14-40	0.36	"	36	
"	"	16-22	17-05	0.71	Mant.	36	
16.3.83	"	17-35	17-45	0.16	"	36	
"	BIDC	19-55	20-08	0.21	L	31	
17.3.83	"	21-20	22-05	0.75	H.T.Loop	LP1	of Kashipur x-former
19.3.83	Rerolling	10-40	10-55	0.25	Mant	36	
"	BIDC	11-15	11-45	0.50	H.T.Loop	LP1	of Kashipr x-for.
"	"	11-25	12-40	1.25	x-for.	LP5	Mant. at Crescent gate
"	Rerolling	13-25	14-00	0.58	By hand	36	Line change
"	"	15-55	16-10	0.25	"	LP6	Fuse of platinum gate x-for.
20.3.83	BICD	21-10	21-11	0.01	E	31	
22.3.83	Khalishpur	13-20	13-27	0.11	x-for.fuse	LP14	at Paurasava
23.3.83	"	09-00	09-30	0.50	H.T. loop	LP7	of Lal hospital x-for.
26.3.83	BIDC	18-05	18-15	0.16	E	31	
"	"	21-25	21-35	0.16	"	31	
27.3.83	Rerolling	19-45	19-58	0.21	Mant.	36	
"	Fish co.	23-25	23-37	0.20	H.T. fuse	LP24	of Fish co. x-for.
29.3.83	BIDC	19-19	19-25	0.10	L	31	
30.3.83	"	19-55	20-05	0.60	E	31	
"	"	20-35	20-41	0.10	x-for.fuse	LP4	of gate x-for.
31.3.83	"	08-50	09-00	0.16	"	LP1	of Kashipur x-for.
1.4.83	Khalishpur	17-17	17-35	0.30	Mant.	32	

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
3.4.83	Gate S/S(I)	21-50	22-03	0.21	Trouble	21	at Diesel control room breaker
"	BIDC	18-50	19-12	0.36	L	31	
5.4.83	Rerolling	15-25	16-05	0.66	H.T.fuse	LP25	of Neval x-for.
6.4.83	Kohinoor	20-00	20-27	0.35	L	33	
"	Rerolling	20-05	20-29	0.30	"	36	
"	Kohinoor	21-35	21-43	0.13	"	33	
8.4.83	Rerolling	15-25	15-40	0.25	H.T.fuse	LP22	Rerolling ill x-for.
"	Kohinoor	19-36	19-45	0.15	"	LP22	"
11.4.83	Khalishpur S/S(I)	13-55	13-56	0.01	E	22	
"	Rerolling	13-55	13-58	0.05	"	36	
"	"	15-05	15-37	0.53	H.T fuse	LP21	of x-for. infront of rerolling mill.
12.4.83	BIDC	18-08	18-18	0.16	L	31	
20.4.83	Khalishpur S/S(I)	11-53	13-25	1.53	Mant.	22	
"	BIDC	20-10	21-11	0.01	E	31	
26.4.83	Rerolling	17-35	17-36	0.01	O	36	
"	"	18-05	18-15	0.16	By hand	36	Due to storm
"	Kohinoor	18-05	18-15	0.16	"	33	"
"	Khalishpur	18-08	18-10	0.03	"	32	
27.4.83	BIDC	13-00	14-35	1.58	Mant.	31	
"	"	18-30	18-53	0.38	L	31	
2.5.83	Rerolling	09-40	09-47	0.11	H.T. fuse	LP19	of Kadamtala x-for.
7.5.83	BIDC	09-15	09-40	0.41	H.T. loop	LP3	of x-for. behind Chitrali
12.5.83	Rerolling	09-35	10-05	0.50	By hand	36	Due to storm

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
12.5.83	33 KV(I)	12-30	13-15	0.75	E	11	
"	Crescent star	16-50	21-59	5.15	Mant.	34	
"	BIDC	18-50	18-57	0.11	By hand	31	Due to storm
"	Khalishpur	18-50	18-58	0.13	"	32	"
16.5.83	Khalishpur	09-20	10-05	0.75	L.T.Loop	LP7	of Lal hospital x-for.
17.5.83	Khalishpur S/S(I)	15-01	16-58	1.98	E	22	
"	BIDC	17-07	17-36	0.48	"	31	
"	Khalishpur	18-55	19-26	0.52	By hand	32	Due to storm
"	BIDC	18-55	19-26	0.52	"	31	"
18.5.83	"	11-20	11-36	0.26	x-for fuse	LP3	of behind Chitrali cinema
19.5.83	Rerolling	17-45	17-58	0.21	H.T fuse	LP21	of x-for. infront of rerolling mill.
"	BIDC	18-15	18-55	0.66	Mant.	31	
"	Kohinoor	19-50	20-05	0.25	L.T.loop	LP15	of Kohinoor S/S x-for.
21.5.83	Rerolling	10-15	10-45	0.50	By hand	LP22	for changing bush
24.5.83	BIDC	21-40	22-40	1.00	H.T.jamper	31	
5.6.83	Rerolling	09-30	09-45	0.25	H.T. fuse	LP22	of rerolling x-for.
8.6.83 "	Khalishpur S/S (I)	11-20	11-23	0.05	By hand	22	For line change
"	"	19-16	19-18	0.03	E	22	
15.6.83	Khalishpur	21-50	22-20	0.50	By hand	32	To save the cut out wire
18.6.83	BIDC	06-22	07-22	1.00	E	31	
21.6.83	Crescent star	22-05	22-40	0.58	Breaker fault	34	
22.6.83	Khalishpur S/S(I)	10-25	10-45	0.33	Mant.	22	

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
22.6.83	Khalishpur	18-05	19-25	1.33	L.T,loop	Lp7	of x-for. at Lal hospital
"	Crescent star	20-01	20-02	0.01	0	34	
"	"	20-04	20-05	0.01	"	34	
"	"	20-26	20-42	0.26	"	34	
"	BIDC	20-05	20-45	0.66	By hand	31	To save the cutout wire
23.6.83	Crescent star	20-03	20-05	0.03	0	34	
"	"	20-18	20-20	0.03	"	34	
24.6.83	Rerolling	23-40	23-50	0.16	x-for.fuse	LP22	of rerolling mill
25.6.83	Khalishpur S/S(I)	18-50	18-52	0.03	E	22	
25.6.83	Rerolling	20-15	20-45	0.50	H.T.fuse	LP19	of Kadamtala x-for.
"	"	21-37	21-45	0.13	"	LP18	of B.bazar x-for.
27.6.83	BIDC	11-30	11-37	0.11	L.T.loop	LP2	of x-for. infront of Chitrali
28.6.83	Rerolling	11-45	12-05	0.33	H.T. fuse	LP18	of B.bazar x-for.
"	"	18-35	18-45	0.16	Isolator fuse	36	
"	"	19-45	20-05	0.33	"	36	
"	"	20-43	20-55	0.20	E	36	
"	"	20-30	20-43	0.21	"	36	
29.6.83	Crescent star	12-50	13-10	0.33	E,0	34	
"	Khalishpur	15-55	16-15	0.33	By hand	32	Load change
"	Kohinoor	15-55	16-55	1.00	"	33	"
"	"	19-15	19-17	0.03	E	33	
"	"	20-10	20-40	0.50	x-for.fuse	Lp15	of Kohinoor S/S

Appendix-D (Contd.)

1	2	3	4	5	6	7	8
29.6.83	Rerolling	21-45	22-10	0.41	Mant.	LP8	Due to wire cuttingout
30.6.83	Kohinoor	20-25	20-46	0.35	0	33	
1.7.83	"	09-30	09-45	0.25	Bushing change	LP15	at Kohinoor S/S x-for.
2.7.83	Crescent star	11-08	11-10	0.03	By hand	34	Load change
"	"	11-22	11-25	0.05	"	34	"
"	Khalishpur	21-22	21-37	0.25	X-for.fuse	LP14	of Khalishpur Paurasava
3.7.83	Khalishpur S/S(I)	18-30	18-45	0.25	Mant.	22	
4.7.83	BIDC	18-40	19-00	0.33	H.T. fuse	LP3	of x-for. behind Chitrali