Maintenance Engineering

Maintenance reduces business risk.Gives high level of Availability,Reliability and assets operability.

Maintenance functions :

- Basic functions
- Composite functions

BASIC FUNCTIONS :

- Replace
- Repair
- Overhaul
- Rebuild
- Service lubricate
- Inspect
- Test
- Adjust
- Align
- Calibrate

COMPOSITE FUNCTIONS :

- Protecting buildings,structures & plants
- Reducing downtime
- Economy in Maint dept
- Max utilisation of available resources
- Cost reduction and control
- Preparing maintenance budgets
- Trg of maintenance personnel

PRODUCT RELIABILITY ASPECT

RELIABILITY ENGG COVERS:-

- RELIABILITY
- MAINTAINABILITY
- AVAILABILITY

RELIABILITY DESIGN

RELIABILITY OF A PRODUCT IS THE PROBABILITY OF ITS PERFORMING ITS INTENDED FUNCTION OVER ITS SPECIFIED LIFE

$$R(t) = \frac{N - n}{N}$$

Out of N articles operating n fail during period t

FACTORS AFFECTING RELIABILITY

- COMPLEXITY OF PRODUCT
- COMPONENT RELIABILITY
- MANUFACTURING PROCESS
- ENVIRONMENTAL CONDITIONS

- OPERATION AND MAINTENANCE

MEASURE OF RELIABILITY:_

Life of a repairable item can be measured by –

- Failure Rate
- Mean time between Failures

Failure Rate : $\lambda = f/T$,

Where f= No.of failures during test interval

T = Total test time

FAILURE RATE

ITEM NO.	FAILURE TIME
1	25 HRS
2	45 HRS
3	70 HRS
4	92 HRS
5	128 HRS

FAILURE RATE

- FAILURE RATE = λ = $\dfrac{\text{NO.OF ITEMS WHICH FAILED}}{\text{TOTAL TEST HRS OF ALL ITEMS}}$

  = 5/(25+45+70+92+6*128) =0.005 PER HOUR

Calculation of Reliability :-

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

$R(t)$= Reliability for duration t

λ = Failure rate

If the constant failure rate of an item is .005 per hour, what is its reliability for 100 hrs of life.

$R(t) = e^{-\lambda t} = e^{-0.005 x 100}$

$= e^{-0.5}$

$= 0.606$

In a reliability test of a switch,5 failures were observed over a total of 100,000 operations.Planned life of the switch is 6000 operations.What is its reliability.

Failure rate $\lambda = 5/100{,}000 = 0.00005$

T = 6000 operations

$$R(t) = e^{-\lambda t} = e^{-0.00005x\ 6000} = 0.74$$

There are 74 % chances that the item will not fail in 6000 operations

Operating Life cycle:

There are three failures –

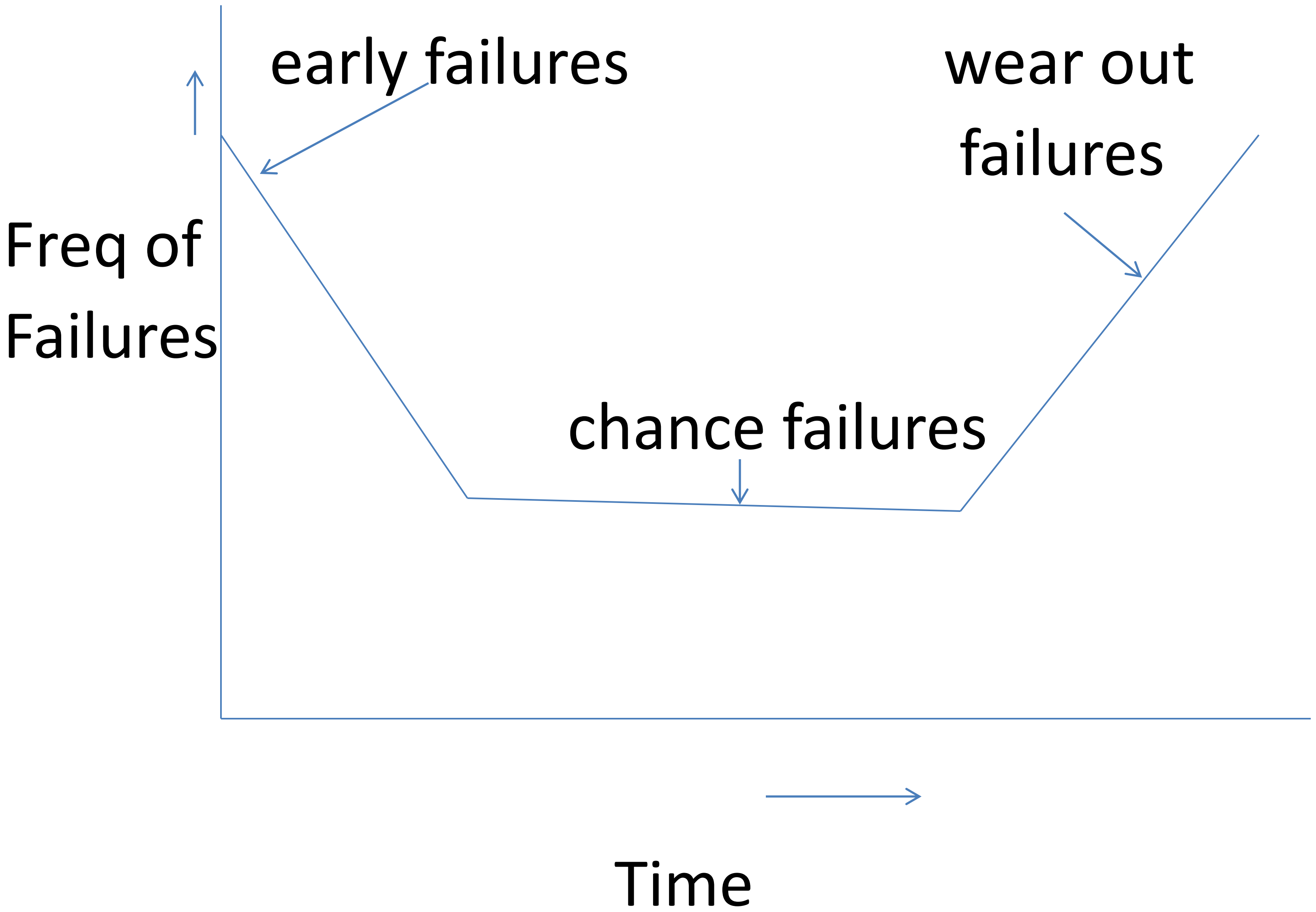
- Early failure
- Chance failure
- Wear out failure

RELIABILITY BATH TUB CURVE

CURVE EXHIBITS :-

- EARLY LIFE
- USEFUL LIFE
- WEAR OUT LIFE

OPERATING LIFE CYCLE CURVE



TYPES OF FAILURE:

- EARLY FAILURE- Variation in manufacturing process and poor quality control techniques during production.Occurs in early life of system operation e.g. electronics items etc.

- CHANCE FAILURE- During actual working of system.Failures are random,irregular and unexpected.Reliability techniques like duplicating components,having safety margins in design etc reduce chance failures

- WEAR OUT FAILURES- Ageing or wearing out of components cause this failure.Due to improper or no maintenance.Can be arrested by preventive maintenance.

- Mean time between failures (MTBF):

  $MTBF = m = T/f = 1/\lambda$

Where f= No.of failures during test interval

T = Total test time

This is also known as average time of

satisfactory operations of the system.Reliability

of the system is higher if MTBF is larger

MTTF

Mean time to failure:

$$\Theta = 1/n \sum t_i$$

Where t_1, t_2, t_3------ t_n are failure times of n items

in a life test.

If the item is non-repairable,MTTF is used

FAILURE RATE = λ =0.005 PER HOUR i.e.ITEM

EXPECTED TO FAIL 5 TIMES IN EVERY 1000

HRS.

MTTF=θ= 1000/5= 200 HRS.

THUS MTTF= 1/ λ

DESIGN OF RELIABILITY

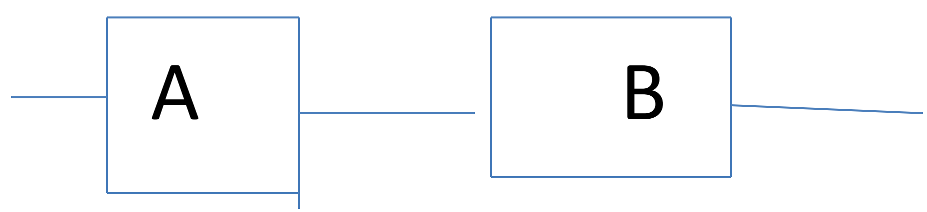
TWO FUNDAMENTAL RULES :-

- USE AS FEW PARTS AS POSSIBLE
- RELIABILITY OF EACH PART MUST BE HIGH AS ECONOMICALLY POSSIBLE

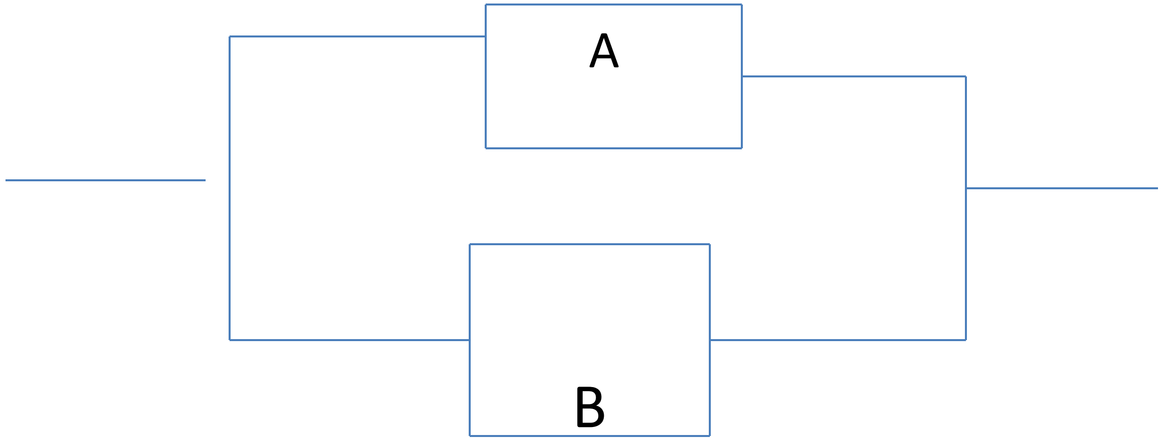
LOGIC DIAGRAMS:

These are block diagrams which show the functional relationship among the system elements.The system is represented as a number of functional blocks that are interconnected according to effect.3 possible type of interconnections:

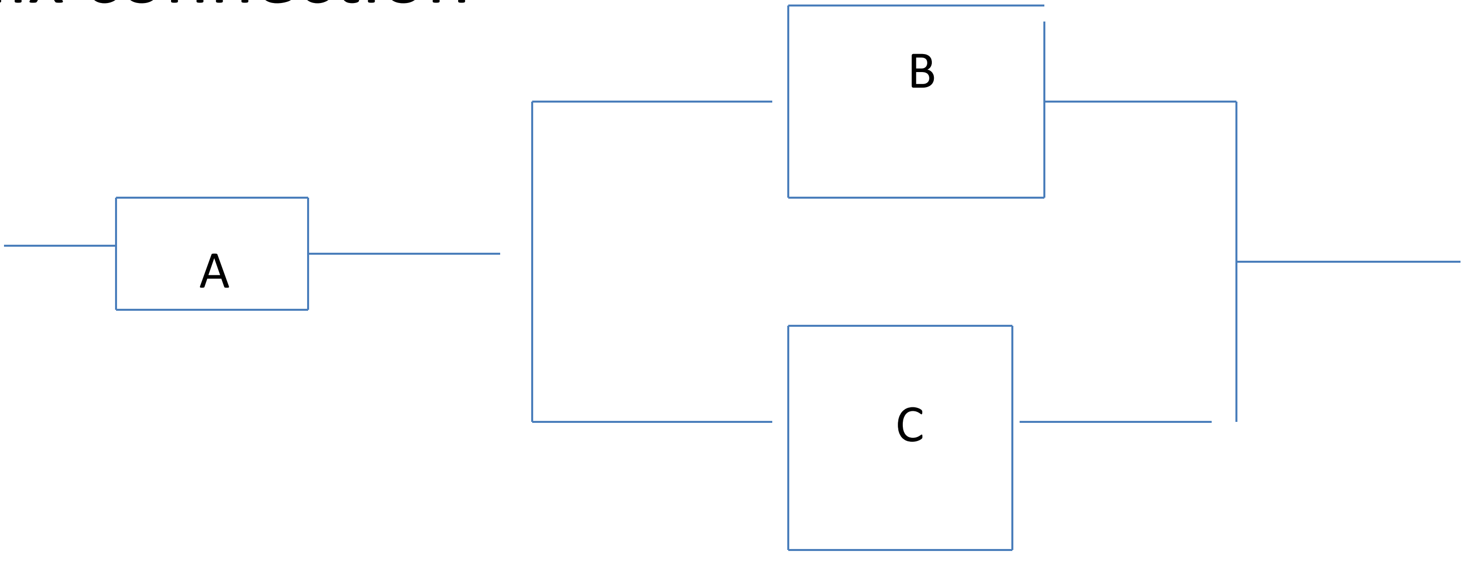
- Element in series



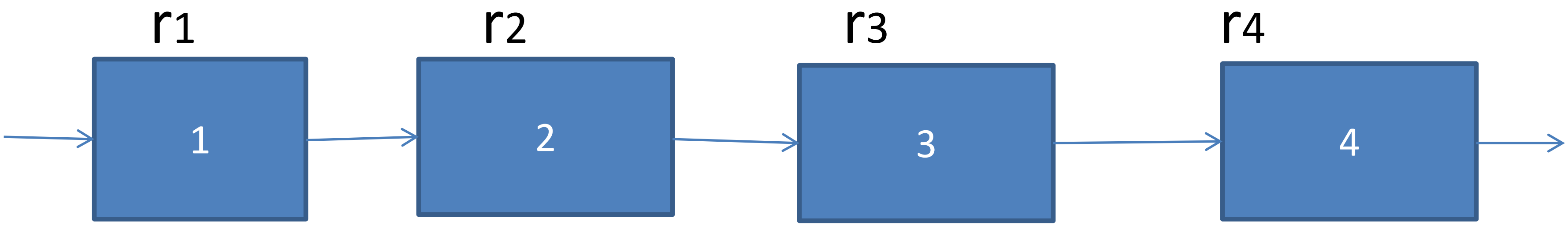
- Element in parallel



- Mix connection



(a) RELIABILITY OF PART IN SERIES.



Reliability $R = r_1 x r_2 x r_3$-------- rn

If $r_1=r_2=r_3= 0.9$

R= 0.9x0.9x0.9 =0.72

$R= (0.9)^{20}$

= 0.12

- As no. of parts are increased,reliability goes down
- Increase reliability of components e.g. 0.99x0.99x0.99 = 0.97

b) OTHER MEASURES TO IMPROVE RELIABILITY—

- DERATING
- CONTROL OF ENVIRONMENTS
- BURNING-IN OR RUNNING –IN
- REDUNDANCY

(c) RELIABILITY IN PARALLEL

(d) COMBINATION OF SERIES AND PARALLEL ELEMENTS

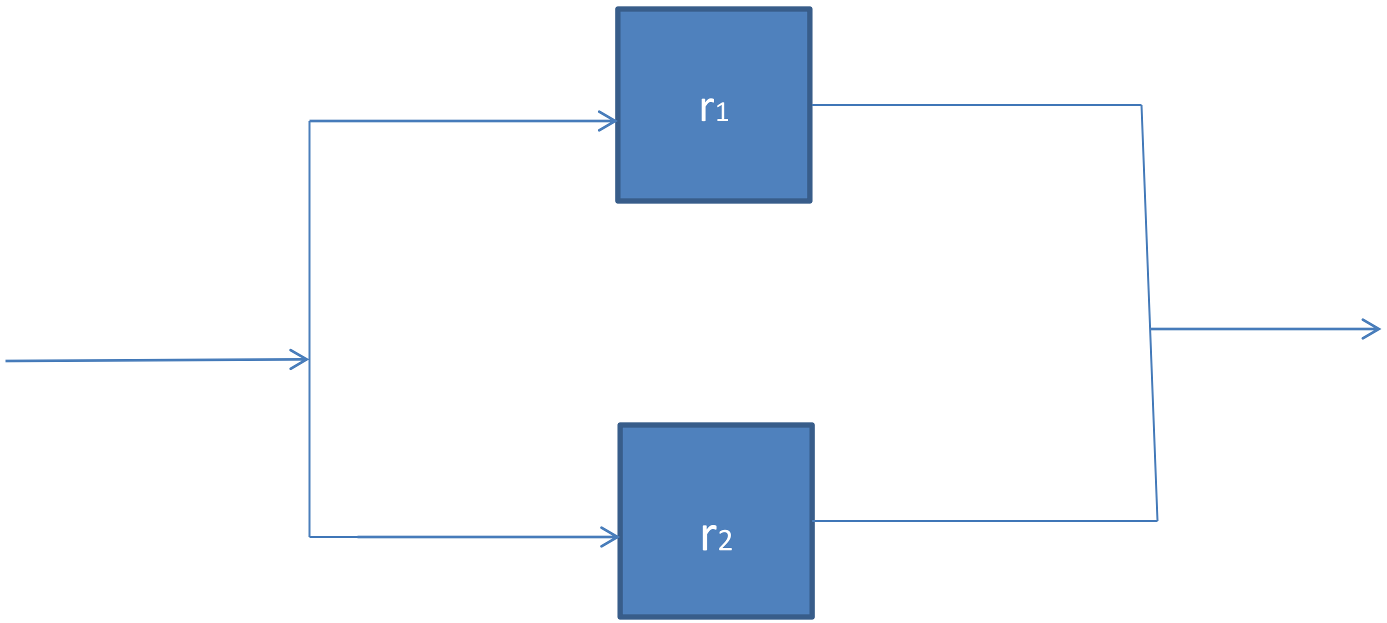
REDUNDANCY

It is not possible to produce highly reliable components as cost of manufacturing will be very high.

The system reliability can be improved by introducing redundancies i.e. deliberate creation of new parallel paths in the system.If R_a and R_b are in parallel,the system reliability will be

$$R_s = 1- (1- R_a)(1- R_b)$$

Reliability of parts in parallel:-



Failure $F_1 = 1 - R_1$ and $F_2 = 1 - R_2$

Prob of both elements failing $= F_1 X F_2$

$R = 1 - (1 - R_1)(1 - R_2)$

EVALUATION OF RELIABILITY

METHODS EMPLOYED:-

- ACCELERATED TESTING
- TEST OF INCREASED SEVERITY
- TESTING LARGE NUMBER OF PIECES

INTERPRETATION OF TEST RESULTS

- RELIABILITY TESTS MUST BE CAREFULLY PLANNEDTO OBTAIN MAXIMUM INFO.
- CORRECTLY INTERPRET THE RESULTS
- USE OF MATHEMATICAL FUNCTION FOR INTERPRETATION.

RELIABILITY CONTROL

- RELIABILITY IS BUILT IN PRODUCT DURING MANUFACTURE.
- MINOR FEATURES TO BE LOOKED INTO CAREFULLY.
- SPECIAL CHECKS AND CONTROLS TO BE INSTITUTED.
- SOME % OF FINISHED PRODUCT TESTED FOR DETECTION OF FLAWS

MAINTAINABILITY

DEFINED AS:-

- EQPT RESTORED TO ITS NORMAL EFFICIENCY
- PROBABILITY OF A SYSTEM RESTORED TO ITS NORMAL EFFICIENCY WITHIN A GIVEN TIME IF THE SPECIFIED MAINTENANCE IS CARRIED OUT.

FACTORS AFFECTING MAINTAINABILITY:--

- EASE OF FAULT LOCATION
- EASE OF REPAIR

FAULT LOCATION

TO BE FACTORED IN DURING DESIGN OF THE SYSTEM e.g.

- Provision of meters/lights on inst panels
- Viewing windows,test points etc.
- Alternative eqpts
- Proper color/number code
- Special test eqpt for fault detection
- Fault diagnosis manual

REPAIR OF EQPT

TO BE FACTORED IN DESIGN e.g.

- Easily accessible
- No jamming due to corrosion etc
- Fastening devices not to fall in system on removal
- Concept of modules
- To design special tools & have repair manuals
- Preventive maint can be easily carried out

MEAN TIME TO REPAIR

COLLECT DATA ON SUFFICIENT NUMBER OF FAILURES.

$$MTTR = \frac{\text{Total no. of hrs spent on repairs}}{\text{No.of failures}}$$

Smaller the MTTR,earlier eqpt can be put to work.Thus,MTTR is used as an index of Maintainability.

MAINTENANCE TIME

COMPOSITION:--

- REPORTING OF FAILURE
- ROUTING OF EQPT TO WKSHP
- INSPECTION OF EQPT
- ARRANGING TOOLS AND SPARES
- ACTUAL REPAIR OF EQPT
- FINAL TESTING
- RETURN OF EQPT

Availability

Availability is the probability of a system that it is operating satisfactorily at any point in time when used under stated conditions.

Reliability combined with maintainability gives availability.

Availability = uptime/uptime+downtime

This gives % of time system was available.

Inherent Availability

A_{inh} = MTBF/MTBF+MTTR

Reliability and maintainability trade off – Telephone system availability

For a four stroke car ,MTBF=600h

Mean time waiting for spares= 10 h

MTTR= 50h

Mean administrative time= 5 h

Calculate Availability

A = MTBF/MTBF+MTTR

A= 600/600+10+5+5= 600/665=0.9022

i.e.90.22% is the availability of the car

CONDITION MONITORING

CM is to monitor, a selected parameter of the component to assess machine condition.Four methods:

- Visual Monitoring
- Performance monitoring
- Vibration & Noise monitoring
- Wear debris monitoring

(a) Visual Monitoring:

- Using past experience as the basis of assessment
- Limited to visible and stationery components and parts of machines.

(b) Performance monitoring:

It is the measurement of output or the relationship between input and output.Performance deterioration can be related to the possible cause.Parameters can be pressure,force electric charge etc.

(c) Vibration and Noise monitoring:

Vibrations and sound patterns are used as signatures for analysis.e.g. bearings are used for measuring vibrations.

(d) Wear debris Monitoring:

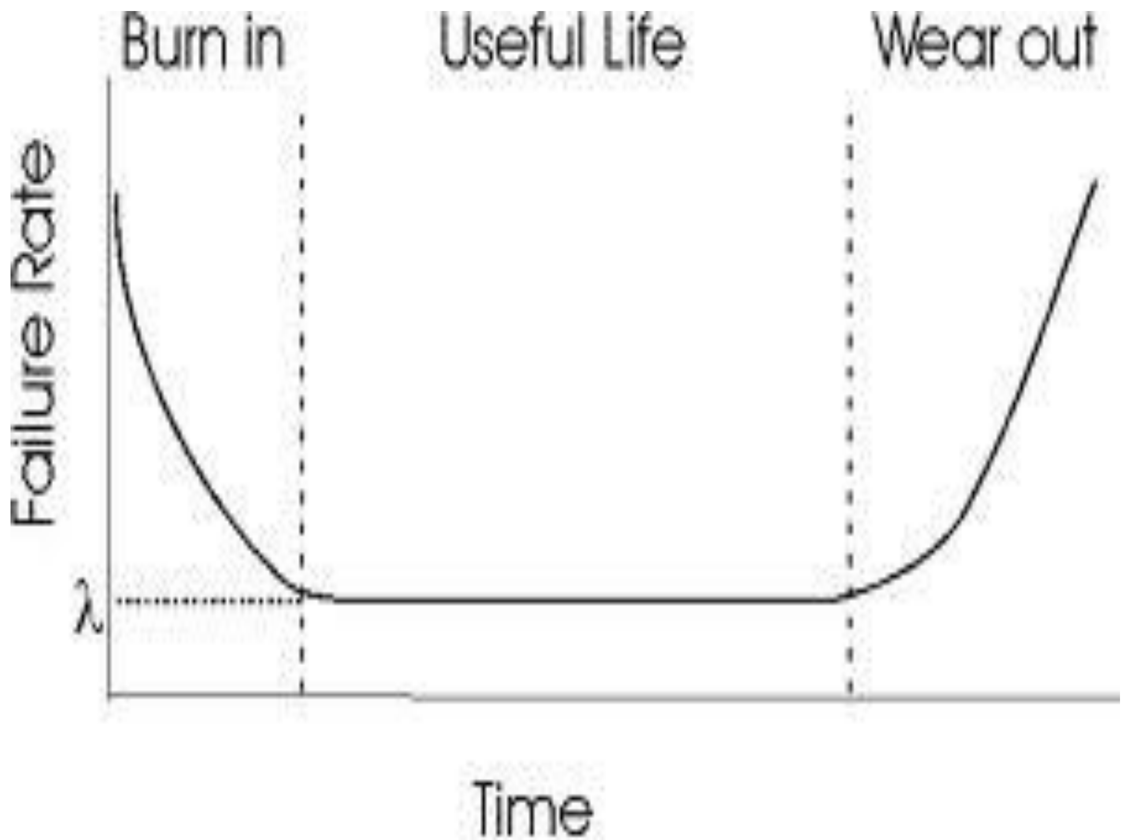
Analysis of lubricating oil by the presence of contaminants.Shows the degree of wear and wear rate of components.

FAILURE PATTERN (BATH TUB CURVE)

Complex products follow a familiar pattern of failure.Failure rate is plotted against time and the resultant curve is known as bath tub curve.There are three distinct zones.

- Infant mortality or early failure period(Burn in)
- Normal operating period(Useful Life)
- Wear outperiod (Wear out)

BATH TUB CURVE



- Burn in – High failure rate.Resulting from defects in manufacturing etc.which can be detected by debugging,running on or extended testing
- Useful life – The failure rate remains fairly constant.Chance failures.
- Wear out – Due to wearing out of parts.Failure rate increases due to increased wear.

ZERO DEFECT

CONCEPT WHICH PROMOTES A CONSTANT, CONSCIOUS DESIRE TO DO A JOB RIGHT,THE FIRST TIME .

- A MNGT TECHNIQUE
- EVERY FACILITY GIVEN TO THE WORKER
- DUE PUBLIC RECOGNITION

ORGANISATION OF ZERO DEFECT

PROGRAM INVOLVES:--

- MOTIVATION OF MANAGEMENT
- INDOCTRINATION OF SUPERVISORS/WORKERS
- CO-OPERATIVE ACTION BY MNGT/WORKERS
- LAYING DOWN TARGETS
- MEASUREMENT OF RESULTS
- RECOGNITION OF ACHIEVERS

QUALITY CIRCLES

SMALL GROUP OF MEMBERS WORKING TOGETHER WHO MEET TO ANALYSE AND RESOLVE i.e. WORK RELATED PROBLEMS i.e.

- 7 to 10 members
- Meeting informal and held regularly
- Atleast once a week for 1 hour
- Only matters related to work discussed
- Voluntary and workers highly motiovated

OBJECTIVES OF QC

- Solve problems giving satisfaction
- Opportunity to identify problems
- Improve qlty and productivity
- Inspire effective team work &develop leadership qualities
- Improve communication and relationships
- Develop

FUNCTIONING OF QC

- MEMBERS FROM SAME WORK AREA
- IDEAL SIZE IS 5 TO 10 MEMBERS
- NO. OF CIRCLES MAY BE MORE THAN ONE
- MEETINGS ONCE A WEEK FOR APPX ONE HOUR & VERY CLOSE TO WORK PLACE

STRUCTURE OF QCs

Basic elements of QC:-

- Top Management
- Steering Committee
- Co-ordinators
- Facilitators
- Leaders
- Members &
- Non-Members

LIMITATIONS OF QC

- Not a panacea for all problems
- Not a substitute for mngt planning / task force
- Peoples movement for improving work culture
- To make work more meaningful &effective
- Satisfaction to workers

FAILURE RATE

Reliability is the prob that the system will function over some time period t.

T is the continuous random variable – time to failure of the system. $T \geq 0$

$R(t) = Pr(T \geq t)$

Where $R(t) \geq 0$, $R(0) = 1$ and $\lim_{t \to \infty} R(t)=0$

$F(t) = 1- R(t) = Pr\ (T \leq t)$

F(t) is the prob that the failure occurs before time t

Where $F(0) = 0$

$\lim_{t \to \infty} F(t)=1$

R(t) – Reliability function

F(t) – Cumulative distribution function or failure prob at time t

f(t) – Probability density function or failure density function. It describes the shape of the failure distribution curve

HAZARD RATE

Hazard rate Z(t) is also known as instantaneous failure rate.The limit of the failure rate as the interval length approaches zero is the hazard rate.It can be written as --

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

Z(t) is known as instantaneous hazard rate or Failure rate function

HAZARD MODELS

Three types of models are considered:

- Constant hazard model

Hazard rate, $Z(t) = \lambda$

Where λ is failure rate and is constant and independent of time

Electronic components etc exhibit this characteristic.

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

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

$F(t) = 1-e^{-\lambda t}$

$MTTF = \int e^{-\lambda t} dt = 1/\lambda$

- LINEAR HAZARD MODEL

The hazard rate increases with time for components failing for example due to mechanical stresses

$Z(t) = bt, t > 0$

$R(t) = e^{- \int bt.dt} = e^{-bt^2/2}$

$f(t) = bt \exp(-bt^2/2)$

$MTTF = \int e^{-bt^2/2}.dt$

- NON LINEAR HAZARD MODEL

$Z(t) = at^{b}$

$R(t) = e^{-at^{b+1}/b+1}$

$f(t)= at^{b} \exp(-at^{b+1}/b+1)$

Also known as Weibull model

$$MTTF = \frac{1-(1/b+1)}{(b+1)\{a/b+1\}^{1/b+1}}$$