Standards & Quality

Standards and Quality practices in production, construction, maintainence & services

- → Maintenance
- → Sampling
- → Quality
- → Quality control tool
- → Process Capability

- → Six sigma
- → TQM
- → ISO
- → Quality in service sector
- → Quality in construction

- → Inventory
- → line balancing
- → L.P.P.

} Industrial Engineering (ME) (tech)

Maintenance

Reliability: The reliability of a product or system can be defined as the probability that the product will perform its required function under specific condition for a certain period of time.

$$\boxed{R = f(\text{time})}$$

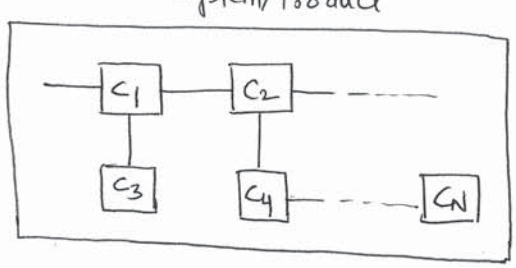
at $t = 0 \Rightarrow R = 100\%$

$t \uparrow \Rightarrow$ Reliability $\downarrow$

Note: Reliability is ~~used to~~ measure of quality of product over long run.

Now,

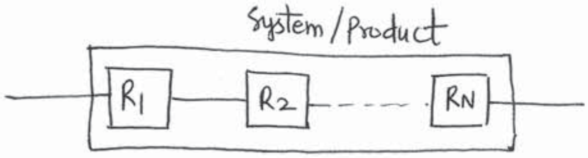
System/Product



c = component

"Reliability of system will depend upon the reliability of individual component."

For series connection,



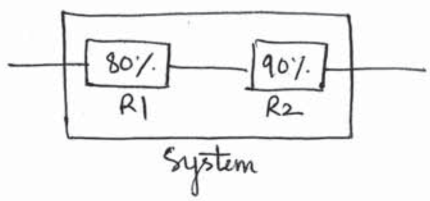
$$\boxed{R_S = R_1 \times R_2 \times \ldots \times R_N}$$

Reliability
efficiency
Performance

R_S = Reliability of system
R_1 = Reliability of component – ①
R_2 = " " " – ②
R_n = " " " – ⓝ

Q. Assume that a product has 2 component. Both of which must work for the product to function. Component 1 has reliability of 80% and component 2 has reliability of 90%. Compute the reliability of the system.

Sol^n:



$R_T = R_1 \times R_2$
$= 0.8 \times 0.9$
$= 0.72$
$= 72\%$

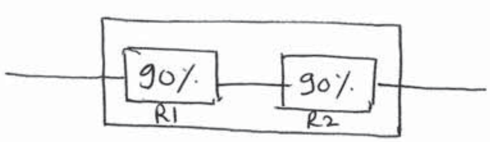
Statement ①: The reliability of the system is always less than (or) equal to the reliability of individual component when they are connected in series.

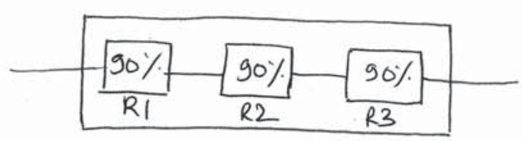
$$R_S \leq \{R_1, R_2, \ldots, R_n\}$$

for equal:

① When all the component have 100% reliability.
② When there is a single component.

Q. Compute the reliability of system.





Sol^n:

$R_S = R_1 \times R_2$
$= 0.9 \times 0.9$
$= 0.81$
$= 81\%$

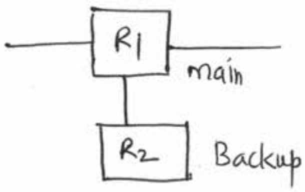
$R_S = 0.9 \times 0.9 \times 0.9$
$= 0.729$
$= 72.9\%$

Statement (2): As the no. of component in the series increases the reliability of the system will decrease.

How to increase the reliability of system –

Parallel Connection

critical component

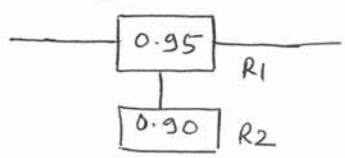


$$\boxed{R_S = R_1 + R_2(1 - R_1)}$$

R_S = Reliability of system
R_1 = Reliability of component – (1)
R_2 = " " " – (2)

Q. Two power generator provide electricity to a facility i.e main and back up generator. The main generator has reliability of 0.95 and back up has the reliability of 0.9. What is the reliability of the system.

Soln:



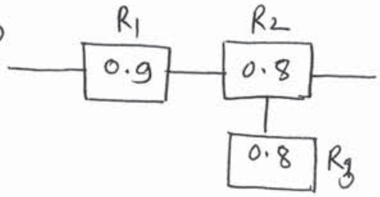
$$R_S = R_1 + R_2(1 - R_1)$$
$$= 0.95 + 0.90(1 - 0.95)$$
$$= 0.995$$
$$= 99.5\%$$

Statement–(3): The reliability of system is always greater than or equal to the reliability of individual component when they are connected in parallel.

$$\boxed{R_S \geq \{R_1, R_2, \ldots, R_n\}}$$

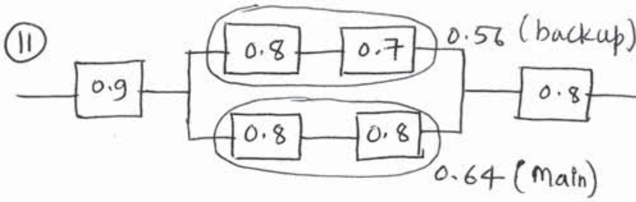
Statement (4): As the no. of component in the parallel increases, the reliability of the system will increase.

Q (I)



$$R_S = R_1 \times \{R_2 + R_3(1-R_2)\}$$
$$= 0.9 \times [0.8 + 0.8(1-0.8)]$$
$$= 0.864 = 86.4\%$$

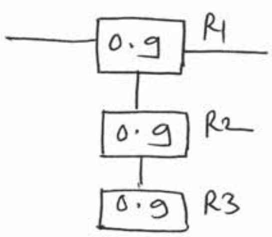
(II)



if we take 0.56 (main)
0.64 (backup)
answer will be same

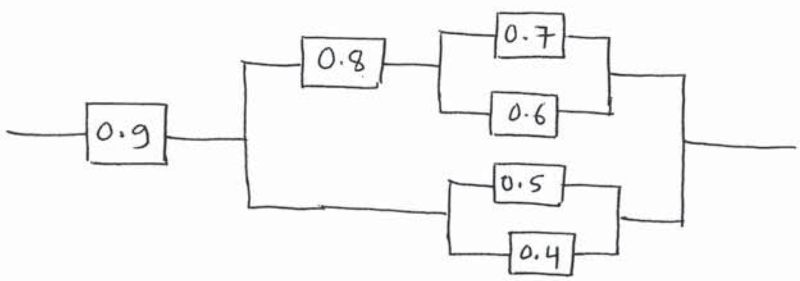
$$R_S = 0.9 \times [0.64 + 0.56(1-0.64)] \times 0.8$$
$$= 0.6059$$

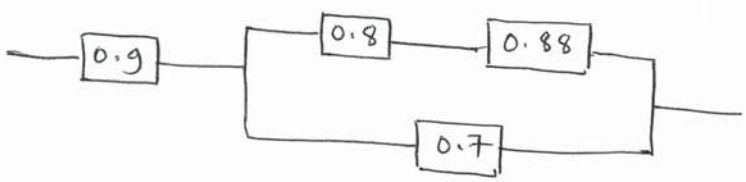
(III)

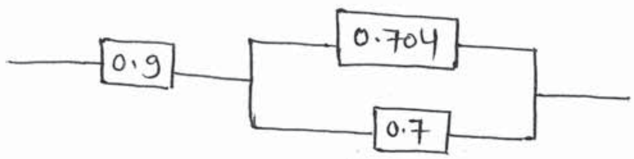


$$R_S = R_1 + R_2(1-R_1) + R_3(1-R_1)(1-R_2)$$
$$= 0.9 + 0.9(1-0.9) + 0.9(1-0.9)(1-0.9)$$
$$= 0.999$$
$$= 99.9\%$$

(IV)







$= 82.00\%$

Reliability Prediction using exponential Distribution

It is one of the most commonly distribution in reliability prediction and it is used to predict the probability of survival to a particular time.

Normal Distribution
lognormal "
Gamma "
Weibull "
Exponential "

$R = f(\text{time})$

Pdf $f(t) = \lambda e^{-\lambda t}$ (exponential distri.)

$$\boxed{R(t) = 1 - F(t)}$$

$$R(t) = 1 - \int_0^t f(t)\,dt$$

$$= 1 - \int_0^t \lambda e^{-\lambda t}\,dt$$

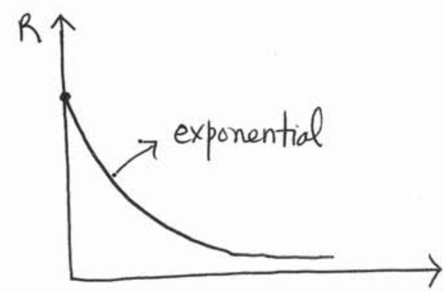
$$\boxed{R(t) = e^{-\lambda t}}$$

$F(t) \rightarrow$ CDF
$F(t) = \int f(t)\,dt$

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

t = time
R = Reliability
λ = failure rate

At $t = 0$,
$R = 100\%$.



Note:

Weibull $\Rightarrow$ failure rate increases (or) decreases w.r.t. time
Exponential $\Rightarrow$ failure rate remain constant w.r.t. time

For $\lambda = ?$

1. MTTF $\rightarrow$ Mean time to failure
2. MTBF $\rightarrow$ Mean time between failure
3. MTTR $\rightarrow$ Mean time to Repair

- **MTTF : Mean time to failure**

→ It referred as average time an item ~~may be expected~~ may be expected to function before failure.

→ It is used for non-repairable item.

e.g. bulb (4) → 3000 hr, 4000 hr, 5000 hr, 4000 hr

$$MTTF = \frac{3000 + 4000 + 5000 + 4000}{4} = \underline{\underline{4000}}$$

- **MTBF : Mean time between failure**

→ It refers to time between two failure.

→ It is used for repairable item.

$$\boxed{MTBF = \frac{\text{Total device hour}}{\text{No. of Repair}}}$$

eg. Total device hour = 20,000
No. of Repair = 4

$$MTBF = \frac{20,000}{4} = 5000$$

- **MTTR : Mean time to Repair**

$$\boxed{MTTR = \frac{t_1 + t_2 + \dots + t_i + \dots + t_n}{n}}$$

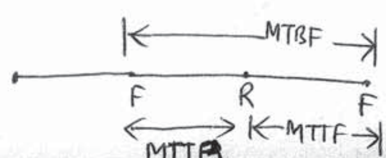
t_i = repair time for ith failure.

Q. (a) MTBF = MTTF − MTTR

✓(b) MTBF = MTTF + MTTR

(c) MTBF = MTTF × MTTR

(d) MTTF = MTBF × MTTR



$$\boxed{MTBF = MTTF + MTTR}$$

If $MTTR = 0 \Rightarrow \boxed{MTBF = MTTF}$

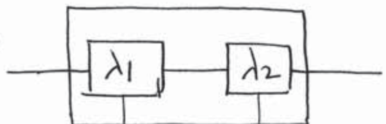
Note: MTBF can be used for both repairable and non-repairable item.

For λ

$$\boxed{\lambda = \frac{1}{MTTF}} \Rightarrow \text{Non-repairable Items} \Rightarrow \boxed{R(t) = e^{-\frac{1}{MTTF}t}}$$

$$\boxed{\lambda = \frac{1}{MTBF}} \Rightarrow \text{repairable Items} \Rightarrow \boxed{R(t) = e^{-\frac{1}{MTBF}t}}$$

ex:



$R_1 = e^{-\lambda_1 t}$ $\quad R_2 = e^{-\lambda_2 t}$

$$R_s = R_1 \times R_2$$
$$= e^{-\lambda_1 t} \times e^{-\lambda_2 t}$$
$$= e^{-(\lambda_1 + \lambda_2)t}$$

Q. The reliability of a repairable product by exponential distribution is given in hour as

$$R(t) = e^{-0.004t}$$

and mean time to repair is 20 hr. The MTTF for the product in hr is —

a) 250 b) 230 c) 270 d) 150

Soln: $R(t) = e^{-0.004t} \Rightarrow R(t) = e^{-\frac{1}{MBTF}t}$

$$0.004 = \frac{1}{MTBF} \Rightarrow \boxed{MTBF = 250}$$

$$MTBF = MTTF + MTTR$$
$$250 = MTTF + 20$$
$$\boxed{MTTF = 230}$$

Availability

It is the probability that a component (or) a system is performing its required function at a given point of time when it is used under the stated operating condition.

Maintainability

It is the probability that a failed component (or) system will be restored to a specific condition within a period of time when maintenance is performed according to the prescribed procedure.

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

$$\boxed{A = \frac{MTBF}{MTBF + MTTR}}$$

A for non-repairable product → 0 or 1

$$\boxed{A = f(R, M, S)}$$

S → Supply effectiveness

Availability   Reliability   Maintainability

$$\boxed{A = \frac{MTBF}{MTBF + MTTR + MTWS}}$$

MTWS = Mean time waiting supply

Q Suppose that a certain software product has mean time between failure of 10,000 hr and has mean time to repair of 20 hr. If the product is used by 100 customers. What is the availability.

(a) 80% (b) 90% (c) 98% (d) 99.8%

Soln: $A = \frac{10,000}{10,000 + 20} = 99.8\%$