DEFINITION OF RELIABILITY

“Reliability is the ability of an item to perform its intended function under stated operation conditions for a given period of time.”
The definition stresses on four significant elements:
1. Probability
2. Intended Function
3. Time
4. Operating Conditions.

1. Probability
Consideration of variation makes reliability a probability. It is possible to identify the frequency distribution of an item, which permits prediction of life of the item. e.g., the probability of an item functioning is 0.85 for 60 hours indicates that only 85 times out of 100, we would expect the item to be functioning for a period of 60 hours.

2. Intended Function
For an item to be reliable, it must perform a certain functions satisfactory when called upon to do, while considering the reliability of an item, the criteria of what is considered as the required function have to be exactly spelled out in advance. Thus, criteria must be established in all cases, which clearly specify and define what is considered as intended function.

3. Time
Time is the most important factor in the assessment of reliability, since it represents a measure of the period during which one can expect a certain degree of performance from an item.

4. Stated Conditions
The application and operating circumstances under which an item is put to use is an important component of reliability. As the operating conditions, change the reliability of an item also changes. Operating conditions such as temperature, humidity, torque, and corrosive atmosphere all have a definite effect on performance.

Thus, reliability can be stated as follows:
“The reliability of a 60 watts incandescent bulb has been estimated to be 0.95 for 1200 hours providing 20 candles output under 180-230 volts and at normal environmental conditions.”

Failure of an item represents unreliability. Thus, to compute the reliability of an item, it is necessary to understand the concept of failure. A deviation in the properties of an item from the prescribed conditions is considered as fault. A state of the fault is denoted as “Failure.”

An item is considered to have failed under one of the following conditions:

1. When it becomes completely inoperable.
2. When it is still operable, but no longer able to perform a required function.
3. When a serious deterioration makes the item unsafe for its continued use.

Causes of Failures:

There are many specific causes of failures of components and systems. Due to the complexity of the system, some are known and some are unknown. Some of the causes of failures are:

- Deficiencies in design.
- Improper selection of process and manufacturing technique.
- Lack of knowledge and experience.
- Errors of assembly.
- Improper service conditions.
- Inadequate maintenance.
- Variation in environmental and operating conditions.
- Human errors.

Nature of Failures:

An item may fail in many ways. An understanding of these failures help in taking appropriate corrective measures for achieving better reliability. The different modes of failure are:

1. **Catastrophic Failures:** In this case, a normally operating item suddenly becomes inoperative. Example: Blowing of a fuse or electric bulb.
2. **Degradation (Creeping) Failures:** These failures occur gradually because of change in some parameter with time. Example, change in resistance will affect the performance of a resistor.
3. **Independent Failures:** These are the failures, which occur independently and does not depend on failure of the other.
4. **Secondary Failures:** A secondary failure occurs as a result of some primary failure.
5. **Failure due to Improper Handling and Misuse:** e.g., overloading (stressing beyond the capacity).

Phases of Failures (Bath Tub Curve):

Analysis of failure data has shown that failures in general can be grouped in to different modes depending upon the nature of the failure. When a large number of units are put into operation, it is likely that there is large number of failures initially. These failures are called Initial Failures or Infant Mortality. After the initial failures, for a long period of time of operation fewer failures are reported but it is difficult to determine their cause. The failures during this period are often called random failures or catastrophic failures.
This is the period of normal operation. As the time passes, the units get worn out due to wear and tear and begin to deteriorate. Here in this period, the failures are due to wear and tear and due to ageing. This region is called the wear out region.
These three phases of failures are represented in below figure and the characteristics of each phase are shown in table below

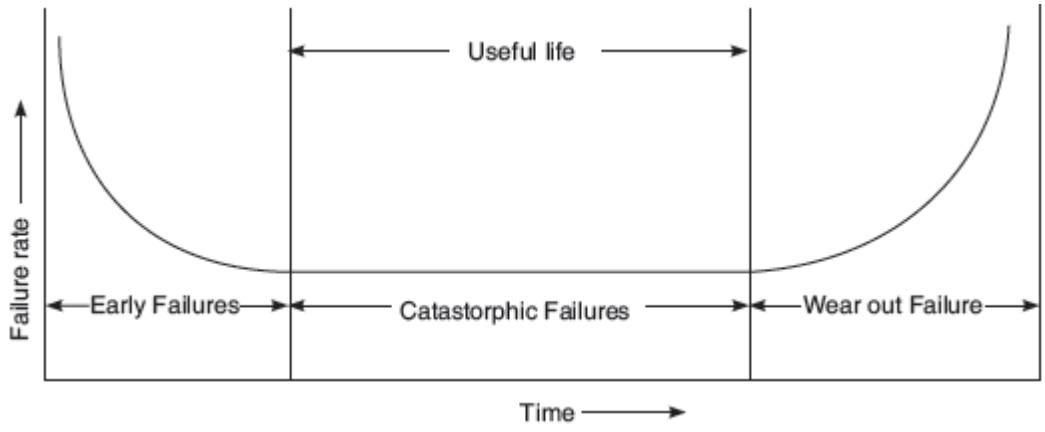

Fig: Bath Tub Curve

Table: Characteristics of Various Phases of Bath Tub Curve

1. **Early Failures**
   - These failures occur at the beginning due to the probability of defective design, manufacturing or assembly and quality control techniques during manufacturing.
   - These are eliminated by debugging or burn in process. The weak and substandard products/components that fail during early hours of system operation are replaced by good or tested components. Debugging is a method of accelerating the completion of early failures by operating the system continuously for number of hours, correcting them and then releasing the system for actual use.
   - Debugging is done generally prior to dispatch to the user to ensure the detection and elimination of early failures.
   - Warranty is based on the concept of early failures.
2. **Catastrophic (Chance) Failures**

   These failures are predominant during actual working of the system. They occur randomly and unexpectedly. The failure rate is fairly constant. These are caused due to sudden stress accumulation beyond the design strength of the material. This phase is called the useful life of the component. The failures at this stage can be minimised by introducing redundancy in the system.
3. **Wear Out Failures**

   The item is more likely to fail due to wear and tear and the number of failures will be high. This is a typical ageing problem. Proper care and maintenance will reduce the failures at this stage.

MEASURES OF RELIABILITY:

1. Failure Rate

Failure rate is expressed in terms of failures per unit time, i.e., as failures per hour, or failures per 100 or 1000 hours. Failure rate is the ratio of number of failures (f) during a specified test interval to the total test time of items undergoing test.

$$\lambda = \frac{f}{T}$$

λ = Failure rate

f = Number of failures during the test interval.

T = Total test time.

2. Mean Time Between Failures (MTBF)

MTBF is referred to as the average time of satisfactory operation of the system. Larger the MTBF, higher is the reliability of the system. It is applicable to repairable systems and is expressed in hours, e.g. If an item fails 8 times over a period of 40,000 hours of operation the MTBF would be 500 hrs. During the operating period, the failure rate is fairly constant MTBF is the reciprocal of the constant failure rate or the ratio of test time to number of failures.

3. Mean Time To Failure (MTTF)

This is applicable to non-repair systems. The mean time to failure is expressed as the average time an item is expected to function before failure. If we have the life test information on ‘n’ items with failure times t1, t2, ... tn, then the mean time to failure is defined as

$$\text{MTTF} = \frac{1}{n}\sum_{i=1}^{n} t_i$$