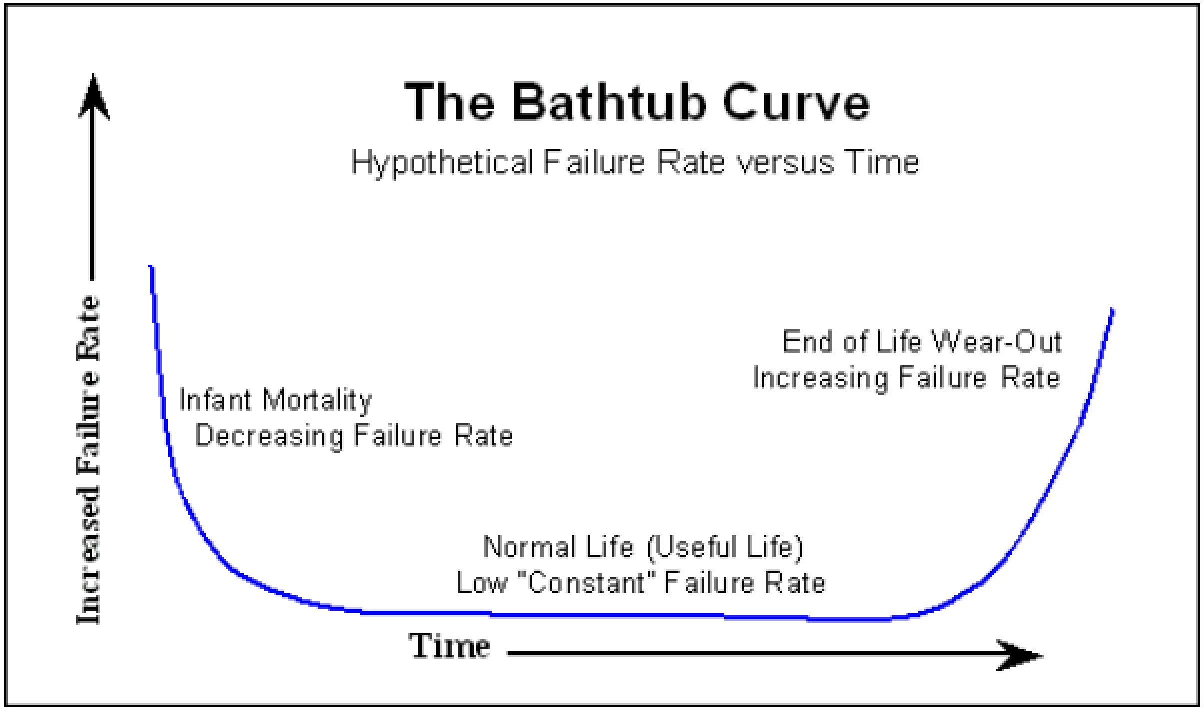
CQE Reliability



Bathtub Curve

- The “Infant Mortality” Phase is characterized by a high failure rate during early use, the causes of which are typically manufacturing errors. “Burn-in” of systems by simulating use before release can often detect these failures prior to the customer’s receipt.

- The “Useful Life” Phase is characterized by a constant failure rate, the causes of which are typically design related and can only be reduced by design enhancements.

- The “Wear-Out” Phase is characterized by an increase in the failure rate due to the aging of the system. Preventive maintenance and replacement of aging components can reduce the failure rate during this phase.

RELIABILITY

Probability concepts are the foundation for all system reliability calculations. Joseph Juran defines reliability as follows[3]:

the probability that an item (system) will perform a required function, under stated conditions, for a stated period of time.

- For repairable products, the **"mean time between failures" (MTBF)** is the average time between successive failures of the product:

$$\textbf{MTBF} = \frac{\textbf{Total Operating Time}}{\textbf{Total Number of Times Failed}}$$

- For non-repairable products (such as light bulbs or batteries), the **"mean time to failure" (MTTF)** is the average time a group of the same product operates before failing:

$$\textbf{MTTF} = \frac{\textbf{Total Operating Time}}{\textbf{Total Number of Failures}}$$

Similarly, the failure rate can be calculated from failure data by:

$$\lambda = \frac{1}{\text{MTBF (or MTTF)}}$$

EXAMPLE: Assume that a group of 10 light bulbs fails at 100, 600, 800, 900, 1000, 1000, 1100, 1100, 1200, and 1200 hours. What are the MTTF and the failure rate?

$$\text{MTTF} = \frac{100 + 600 + 800 + \ldots + 1200}{10} = \frac{9000}{10} = 900 \text{ hours}$$

$$\lambda = \frac{1}{\text{MTTF}} = \frac{1}{900} = 0.001111\ldots$$

Once the failure rate is known, a component's reliability can be predicted for a specific time period (t) as follows:

$$\mathbf{R = e^{-\lambda t}}$$

For the above example, the probability that one of these light bulbs will last for 1000 hours is:

$$R(t) = e^{-\lambda t} = R(1000) = e^{-(\frac{1}{900})1000} = e^{-1.111..} = 0.3292$$

What is the reliability of a system at 850 hours, if the average usage on the system was 400 hours for 1650 items and the total number of failures was 145? Assume an exponential distribution.

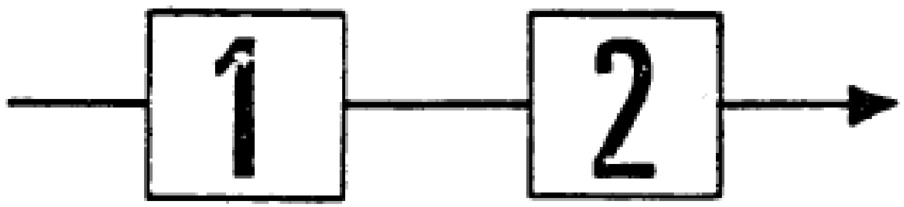
- ○ 0%
- ○ 36%
- ○ 18%
- ○ 83%

$$MTTF = \frac{total-operating-time}{total-number-of-failures} = \frac{400*1650}{145}$$

$$\lambda = \frac{1}{MTTF} = \frac{145}{400*1650} = 0.00022$$

$$R_s(850) = e^{-\lambda t} = e^{-0.00022(850)} = 0.83$$

Component 1 has an exponential failure rate of 3 X 10-4 failures per hour.
Component 2 is normally distributed with a mean of 600 hours and standard deviation of 200 hours.
Assuming independence, calculate the reliability of the system after 200 hours.



- 0.878
- 0.920
- 0.940
- 0.977

$$R_1 = e^{-\lambda t} = e^{-(0.0003)(200)} = e^{-0.06} = 0.9418$$

$$R_2 = 1 - P(-\infty \le z \le \frac{200-600}{200})$$

$$= 1 - P(-\infty \le z \le -2.0) = 1 - 0.0228 = 0.9772$$

$$\text{System Reliability} = R_s = R_1 * R_2 = 0.9418 * 0.9772 = 0.920$$

Table *A* Area under the normal curve

Proportion of the total area of the standard normal curve from $-\infty$ to z (z represents a normalized statistic)

z	0.09	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.01	0.00
−3.5	0.00017	0.00017	0.00018	0.00019	0.00019	0.00020	0.00021	0.00022	0.00022	0.00023
−3.4	0.00024	0.00025	0.00026	0.00027	0.00028	0.00029	0.00030	0.00031	0.00033	0.00034
−3.3	0.00035	0.00036	0.00038	0.00039	0.00040	0.00042	0.00043	0.00045	0.00047	0.00048
−3.2	0.00050	0.00052	0.00054	0.00056	0.00058	0.00060	0.00062	0.00064	0.00066	0.00069
−3.1	0.00071	0.00074	0.00076	0.00079	0.00082	0.00085	0.00087	0.00090	0.00094	0.00097
−3.0	0.00100	0.00104	0.00107	0.00111	0.00114	0.00118	0.00122	0.00126	0.00131	0.00135
−2.9	0.0014	0.0014	0.0015	0.0015	0.0016	0.0016	0.0017	0.0017	0.0018	0.0019
−2.8	0.0019	0.0020	0.0021	0.0021	0.0022	0.0023	0.0023	0.0024	0.0025	0.0026
−2.7	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034	0.0035
−2.6	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041	0.0043	0.0044	0.0045	0.0047
−2.5	0.0048	0.0049	0.0051	0.0052	0.0054	0.0055	0.0057	0.0059	0.0060	0.0062
−2.4	0.0064	0.0066	0.0068	0.0069	0.0071	0.0073	0.0075	0.0078	0.0080	0.0082
−2.3	0.0084	0.0087	0.0089	0.0091	0.0094	0.0096	0.0099	0.0102	0.0104	0.0107
−2.2	0.0110	0.0113	0.0116	0.0119	0.0122	0.0125	0.0129	0.0132	0.0136	0.0139
−2.1	0.0143	0.0146	0.0150	0.0154	0.0158	0.0162	0.0166	0.0170	0.0174	0.0179
−2.0	0.0183	0.0188	0.0192	0.0197	0.0202	0.0207	0.0212	0.0217	0.0222	0.0228
−1.9	0.0233	0.0239	0.0244	0.0250	0.0256	0.0262	0.0268	0.0274	0.0281	0.0287
−1.8	0.0294	0.0301	0.0307	0.0314	0.0322	0.0329	0.0336	0.0344	0.0351	0.0359
−1.7	0.0367	0.0375	0.0384	0.0392	0.0401	0.0409	0.0418	0.0427	0.0436	0.0446
−1.6	0.0455	0.0465	0.0475	0.0485	0.0495	0.0505	0.0516	0.0526	0.0537	0.0548

Area under the Normal Curve

- Component 2 is normally distributed with a mean of 600 hours and standard deviation of 200 hours. calculate the reliability of the component 2 after 200 hours.
- R(200)= 1 – 0.0228 = 0.9772

CQE Exam Question - 1972

- Series reliability problem
- Reliability (System)
- = R(Component 1) X R(Component 2)
- = 0.9418 x 0.9772
- = 0.920

CQE Exam Question - 1972