

Making Sense of Reliability Specifications

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Introduction

“The drive maker is claiming *One Million* hours MTBF. That’s 114 years! Do they really think that’s a legitimate specification?”

Yes! It is. I have heard this complaint and refutes like it many, many times over the years I have been involved with customers in the technology arena. I saw a post like this just days ago within an industry forum, and a similar post was displayed on Wikipedia for years...

In this series, we will take a common sense look at Reliability, and I’ll explain why this spec *is* legitimate. Truth is, hard drives exceed these specs in many cases. Read on to understand this confusing subject.

The Specification in Question

- In this series, we will define and explore practical demonstration examples for the following metrics:
 - Reliability Life Cycle (the Bathtub Curve)
 - Mean Time To Failure (MTTF)
 - Mean Time Between Failures (MTBF)
 - Annualized Failure Rate (AFR)
 - Product Useful Life
- Each of these is commonly used in the Hard Drive industry

Goals and Objectives

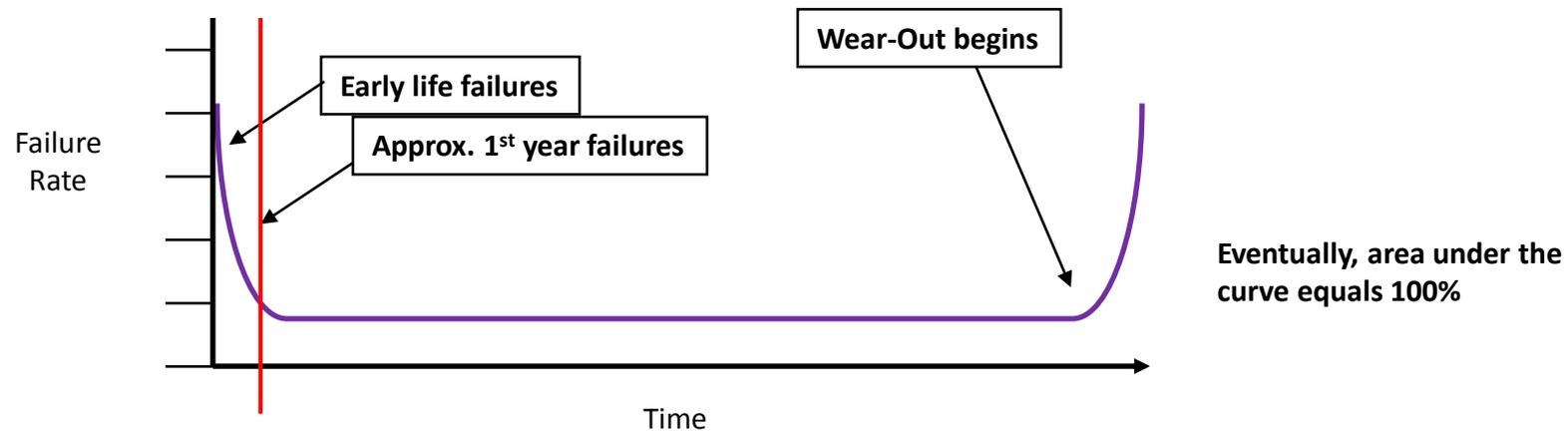
- Reliability mathematics and the many ways it can be applied, are very complicated
- Our goal for this series to introduce the newcomer to the basics, so that reliability specifications become meaningful, and not misunderstood
 - At the end of the series, resources to allow the reader to go further into the subject, as desired, are provided
- The primary goal of this tutorial is for the student to fully comprehend why:
 - *While it may seem counter intuitive, Reliability of a product and its Useful Life, are in no way connected*

The Basics

- If a device is repaired after a failure, and returned to service, the correct Reliability metric is MTBF, since it can fail more than once
 - Mean Time Between Failures
 - An automobile is a good example
- For a device that is replaced after failure, the correct metric is MTTF
 - Mean Time To Failure
 - A light bulb is a good example
- Since this is the only practical difference between the two metrics, they are commonly interchangeable

The Bathtub Curve

- It is assumed that all components, products and systems follow the “Bathtub Curve” of failure
 - An early life failure rate occurs, followed by a decreasing random failure rate, stabilizing to a low level but continuous random failure rate
 - This is eventually disturbed by the population beginning to “wear-out” and ultimately, all the units within the population fail



MTTF Demonstration

- First, for this math demo of how to establish an MTTF for a product, we have to agree on the product, and the definition of failure..
- So, let's use a product we all understand and one for which we can easily agree on the definition of failure:

The Light Bulb!



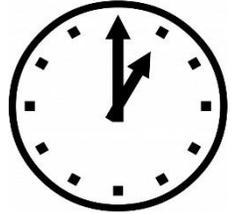
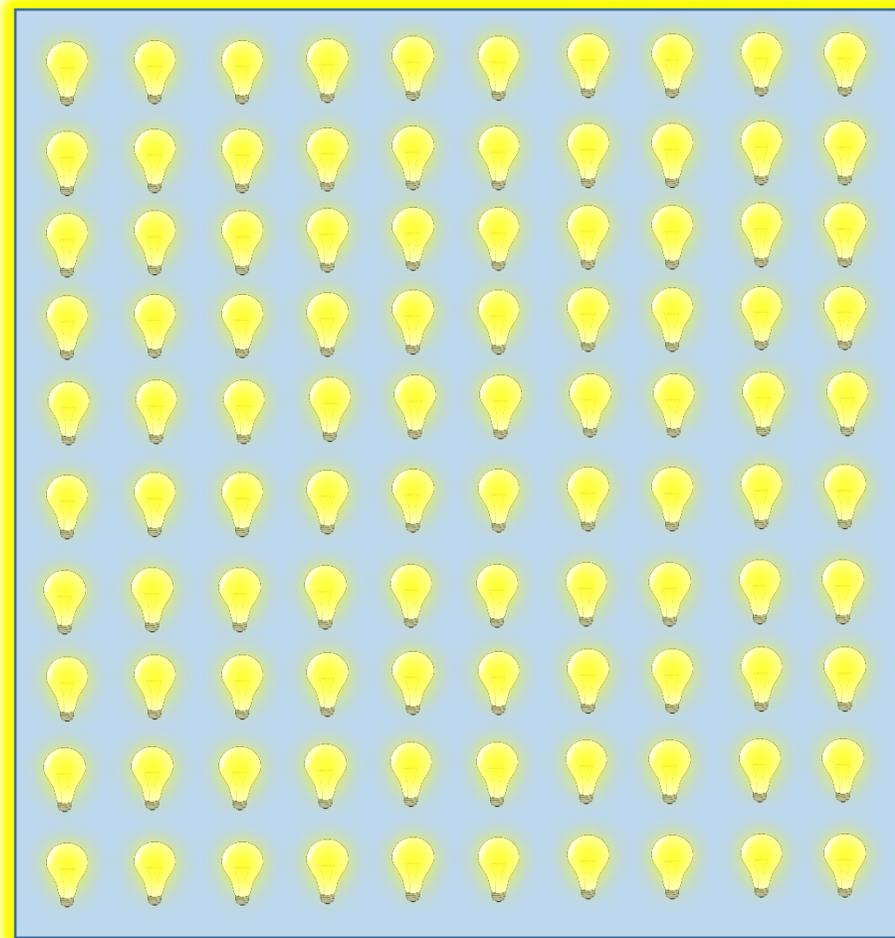
- OK, so we're a light bulb tester, and the manufacturer has asked us to demonstrate the Reliability of their new bulb

Test Setup

- Let's assume we have carefully considered all of the possible uses, and stressors that could affect our test (For HDD tests, this is a significant exercise)
- We'll use one secure power source for all the bulbs, and the same socket type, stuff like that
- We'll consider the size, scale, cost, labor, and time, to complete the test
- We'll make the test as "large" as is practical. Larger samples provide greater resolution in the result

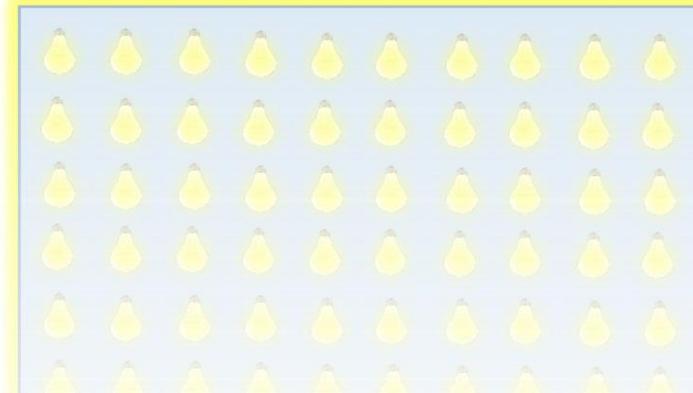
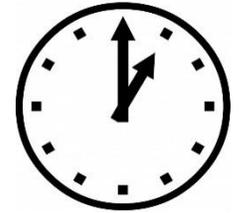
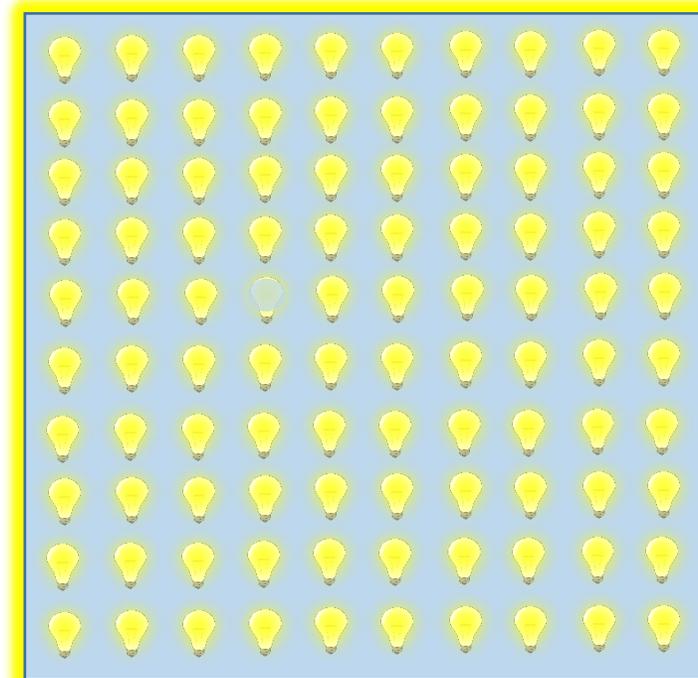
Test Setup

- We'll start with 110 brand new, carefully handled bulbs
- We'll place 100 of them into our test fixture, keeping 10 in reserve for replacements
- We'll flip the switch to "ON", and start the clock



MTTF Demo Test

- Now, we wait, carefully keeping track of the amount of “useful light” the bulbs have demonstrated, as well as any failures....
- 10 hrs goes by, no failures
- 50 hrs, no failures...
- At 100 hrs, we have our first failure!
- So far, our test has “demonstrated” 10,000 hours of useful light production
 - Each hour of runtime, times the sample size equals 100 hours of “light”
 - $100 \times 100 = 10,000$

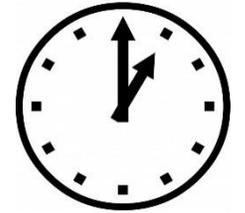
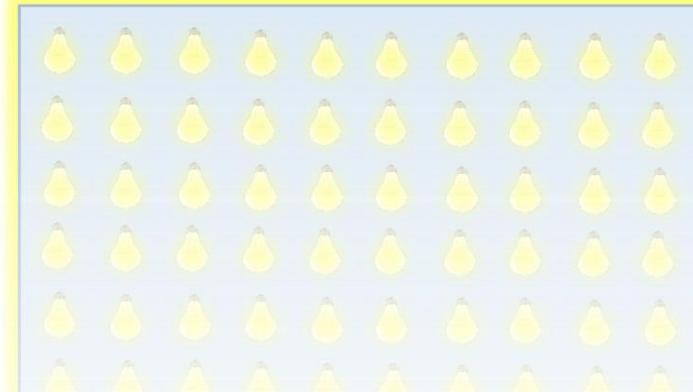
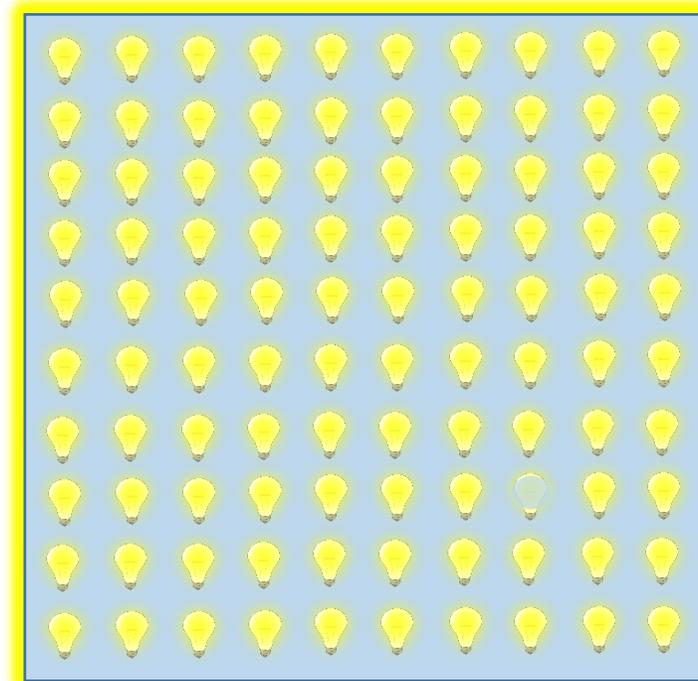


MTTF Demo Test

- We'll use a spare to replace the bad bulb for each failure
 - This keeps the math simple, and prevents the loss of resolution in the test
- 200 hrs, no new failures...
- At 250 hrs, we have our second failure!

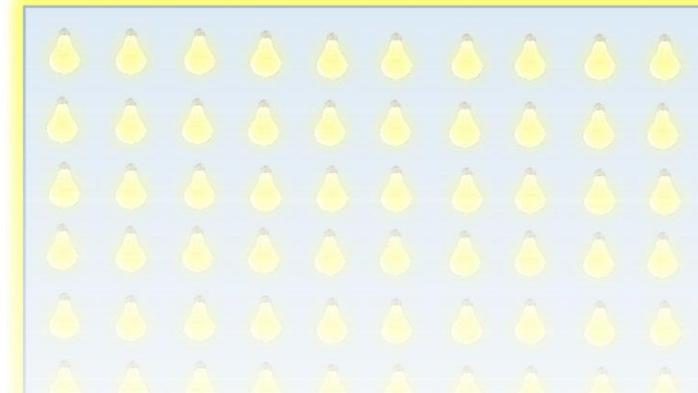
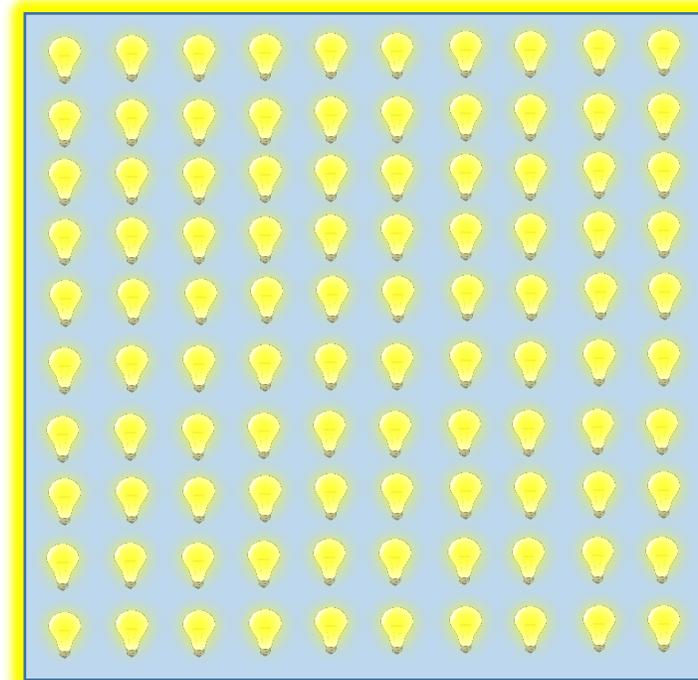
- Now, our test has “demonstrated” 25,000 hours of useful light production
 - With two failures

$$100 \text{ bulbs} \times 250 \text{ hrs} = 25,000 \text{ hrs}$$



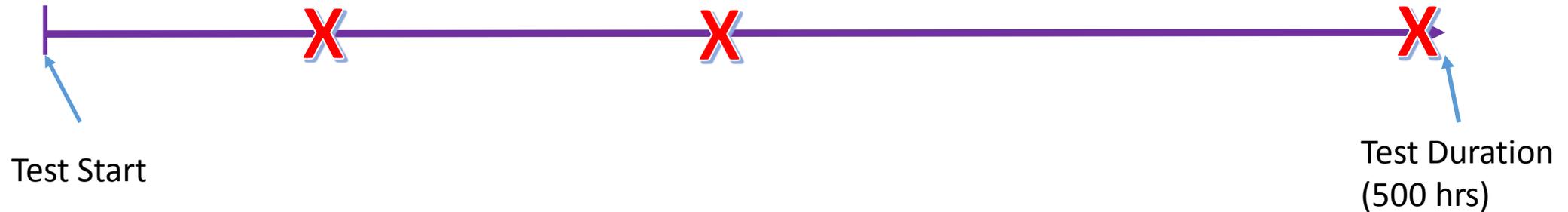
MTTF Demo Test

- At 500 hours, we see our third failure, and agree to end the test
 - This test took 21 days to complete
 - Let's look at the results
 - Our test has “demonstrated” 50,000 hours of useful light production
 - With three failures
- 100 bulbs X 500 hrs = 50,000 total hours



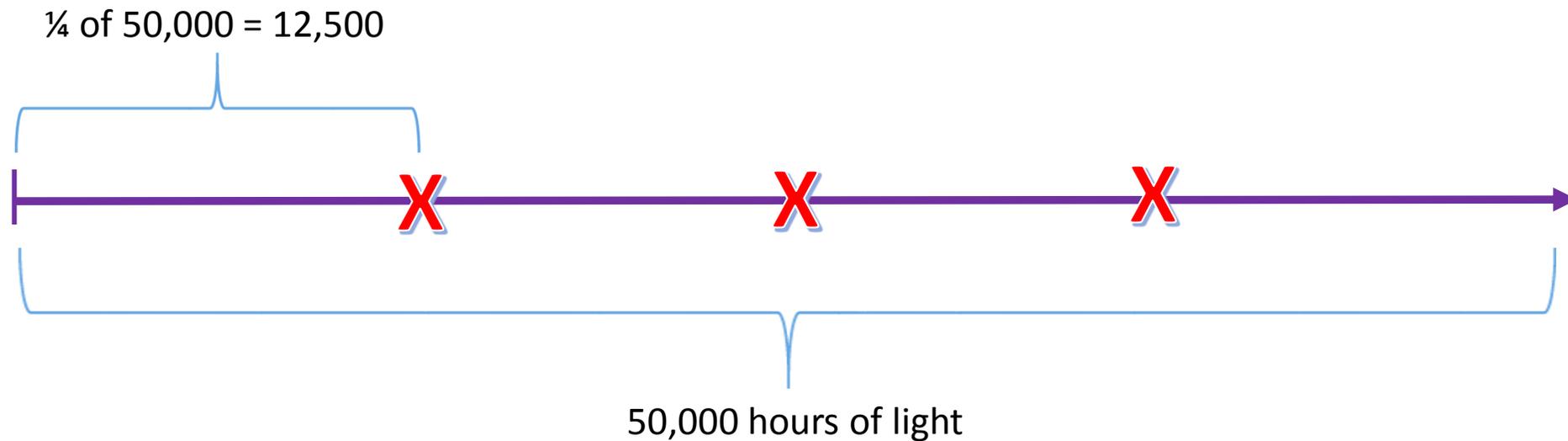
MTTF Test Results

- Our test demonstrated 50,000 hours, with 3 failures
 - We saw failures here, here, and here,



MTTF Test Results

- But if we “Mean Average” the Time/Failures, we see four increments of time
 - Remember, the goal is predict the next failure, based upon the test results



MTTF Test Conclusions

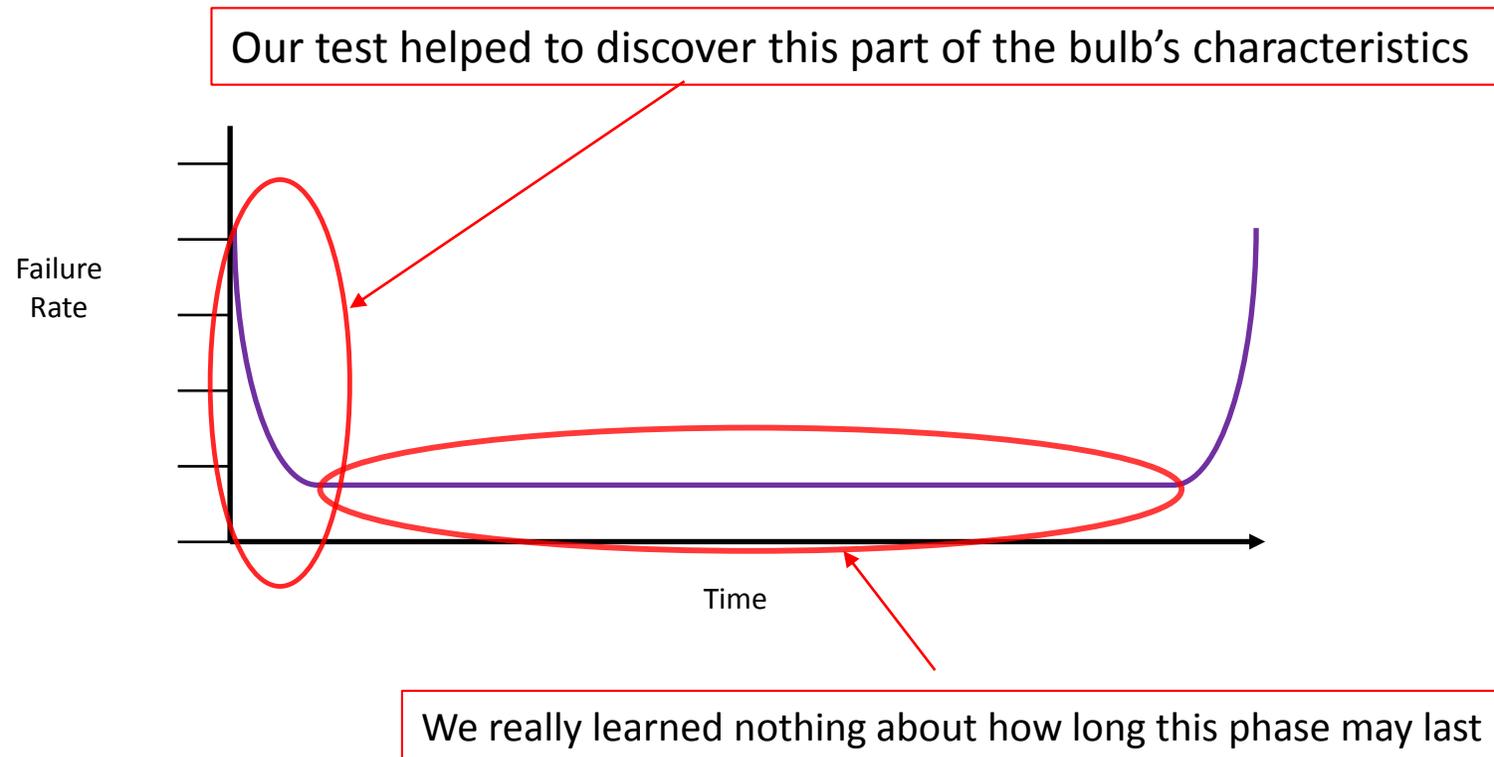
- Our test yielded the following results:
 - Sample size: 100
 - Test Duration: 500 hours (21 days)
 - MTTF Demonstrated: 12,500 hours
- What did we learn about the life expectancy for this type of bulb?

Nothing!

- To accurately define Useful Life, we would have to run the test until the population exhibits the wear-out phase

MTTF Test Conclusions

- Remember the Bathtub Curve?



MTTF Calculation

- MTTF is intended to be used in conjunction with the first year of service life for a large population of drives.
 - MTTF does not address useful life of a single drive.
- MTTF of 750K hours means that of a large group of drives operating during the first year, on average, will accumulate 750,000 hours of total run time amongst the population before the first drive fails.
- The next subsequent failure, will occur on average, only after an additional cumulative 750,000 hours.
 - MTTF could also be specified within the useful design life, which is specified at 5 years.
- From this starting point, we can derive the AFR

Reliability Projection Analysis

- In order to convert the testing results to a projection of reliability, a mathematic model must be used. While there are many reliability analysis models, the hard drive industry typically uses one called Weibull Analysis
- **AFR and MTBF Calculations:**
 - The Weibull shape (Beta) and scale (Eta) parameters are estimated using Maximum Likelihood Estimation (MLE) method from the test data. AFR (Annualized Failure Rate) and MTBF (Mean Time Between Failures) are then calculated.

$$F(t) = 1 - e^{-\left(\frac{t}{\eta}\right)^\beta}$$

- **Weibull Cumulative Distribution Function (CDF):**

$$\text{First Year } MTBF \approx \frac{POH}{-\ln(1 - AFR)}$$

POH = Power-On-Hours = 2400 hours/year for PC use,
and 8760 hours/year for surveillance video use

[Learn Weibull Basics Here](#)

Field Usage Stressors Affecting AFR

- When the component is quoted for reliability, it is under “normal” usage scenarios, with no known reliability detractors
- There are several field usage stressors that are known to degrade HDD reliability
 - Excessive temperature
 - Excessive humidity
 - Forced On-Track dwell
 - High write duty cycle
 - High frequency shocks
 - High frequency / amplitude vibration

Why Design Life and Reliability are Separate

- It makes sense that a *Reliable* product will last a long time. Let's consider a couple of examples:
- The Birthday Candle
 - With only two components and no moving parts, the Birthday Candle is a very simple product, with only one possible use.
 - An audit of this product would likely demonstrate phenomenally high levels of Reliability, with perhaps only one in billions having a flaw great enough to prevent normal use
 - But the useful life is....maybe 6 minutes.
- Since each and every one burns about the same 6 minutes, this is a legitimate example of high reliability, with short useful life

Why Design Life and Reliability are Separate

- Let's look at another example of the opposite case
- A German built Diesel automobile, circa 1950
 - Capable of being driven over a Half-Million miles, with several of these models documented as doing so, it is recognized as one of the longest lasting cars ever made
 - However, with non-insulated electrical terminals, primitive battery technology, easy clogging, low capacity fuel filters and a fuel pump design prone to developing leaks, one of these cars could break-down and strand a user over a hundred times during it's lifetime.
- This product represents a long life, but low reliability device

HDD Design Life

- Useful component life expectation for an individual HDD is referred to as Design Life
- Established as 5 years by early PC HDD competitors in the 1980s, and based upon a model of component level life tests
 - This included ball-bearing motors and red oxide based recording media, and is now considered out of date
- Manufacturer testing indicates that the actual Design Life of an HDD is > 5 years, but only validates with testing for the 5 year expected usage period.
- While there are many drives running at much older ages, drive makers are not likely to make claims that are not easy to validate

Resources for a Deeper Dive Into Reliability

- The following internet links provide some useful information about Reliability and methods of Reliability measurement and analysis
 - http://en.wikipedia.org/wiki/Reliability_engineering
 - http://en.wikipedia.org/wiki/Weibull_distribution
 - <http://www.weibull.com/basics/reliability.htm>
 - <http://www.sre.org/>