Weibull Analysis

It's <u>Not</u> About Complicated Statistics.

Weibull Analysis Tells The "Medicine" You Need For Solving Your Problems.

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Wallodi Weibull

English Pronunciation: Wah-Low-D Y-Bull

- Wallodi Weibull (1887-1979) invented the life data analysis technique. He lived most of his life in Sweden working on problems with materials, fatigue, strength, rupture, and bearing fatigue life.
- His statistics are based on a concept of failure of the weakest link in a chain.
- His most famous Weibull engineering paper was published by ASME in 1951.

Weibull Plots For Components

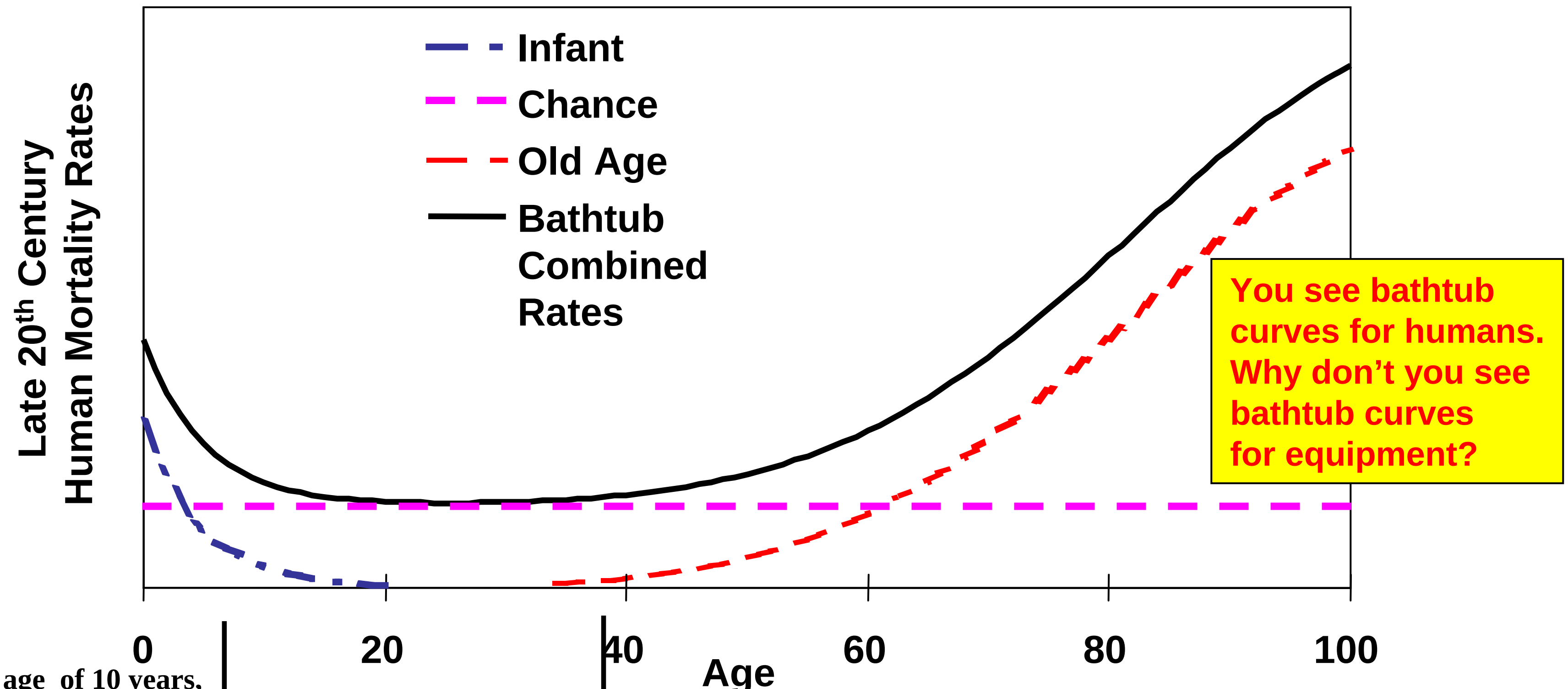
- Collect age-to-failure data for each component. This is tombstone data: time at death less time at birth = age-to-failure.
- Each age-to-failure data for components is plotted in rank order as the X-value.
- The Y-value is determined by Benard's median rank calculation to reduce bias in the plot.

What Does The Data Say?

- We have 3 similar units operating for less than a year. We've had 5 failures. The ages-to-failure (hours of operating time) are: 1200, 2200, 3000, 4500, 5100 as shown in rank order. (X-axis data)
- The Y-axis plot position in Benard's rank order is: 12.96%, 31.48%, 50%, 68.52%, 87.04%.
- **What's the failure mode? What's the characteristic life (typical life) of the component?**

The Bathtub Curve Tells About Human Failure Rates

Average Age At Death: 20th Century 77 yrs, 17th Century 32 yrs--Why?

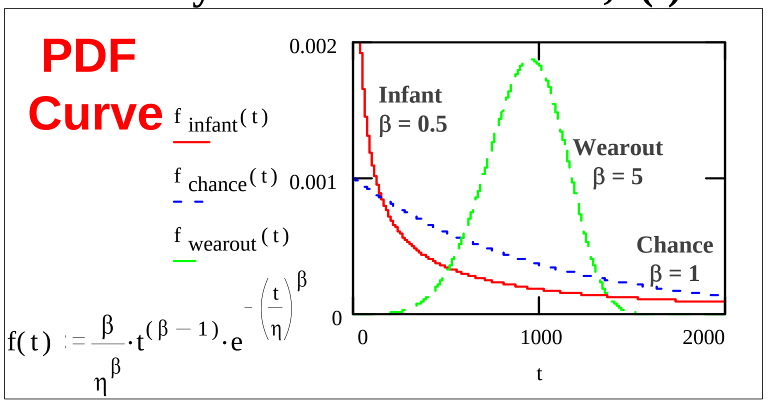


Beyond the age of 10 years, infant mortality is not a big problem ------------------->

<---------------Beyond age 40, wear-out becomes a problem

Failure Statistics Weibull Distributions

Probability distribution function, f(t)

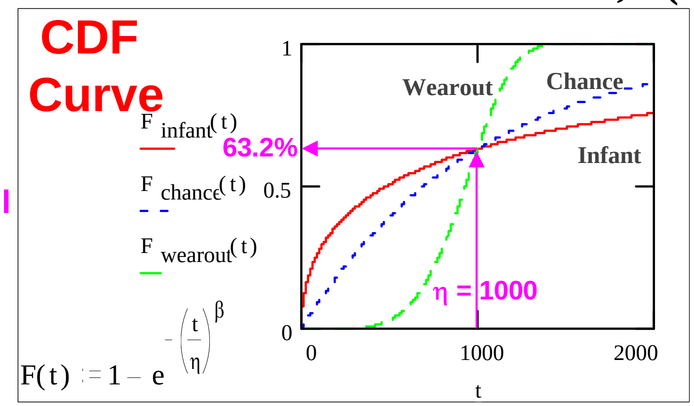


$\eta = 1000$ <—Characteristic life for all curves

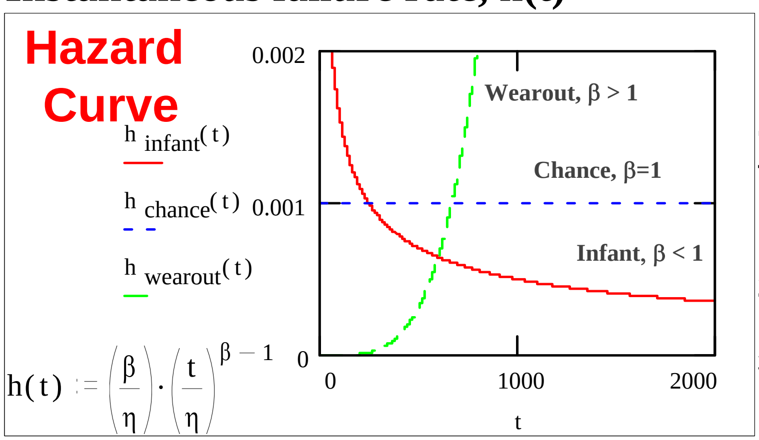
MTTF = $\eta * \Gamma(1/\beta + 1)$
and when $\beta = 1$ then $\eta = $ MTTF

For components, Weibull shape factor β tells you the failure mode while η tells the characteristic life which is a measure of durability.

Cumulative distribution function, F(t)



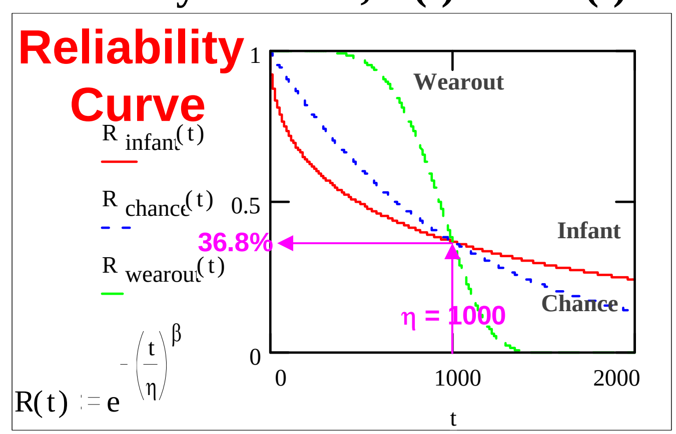
Instantaneous failure rate, h(t)



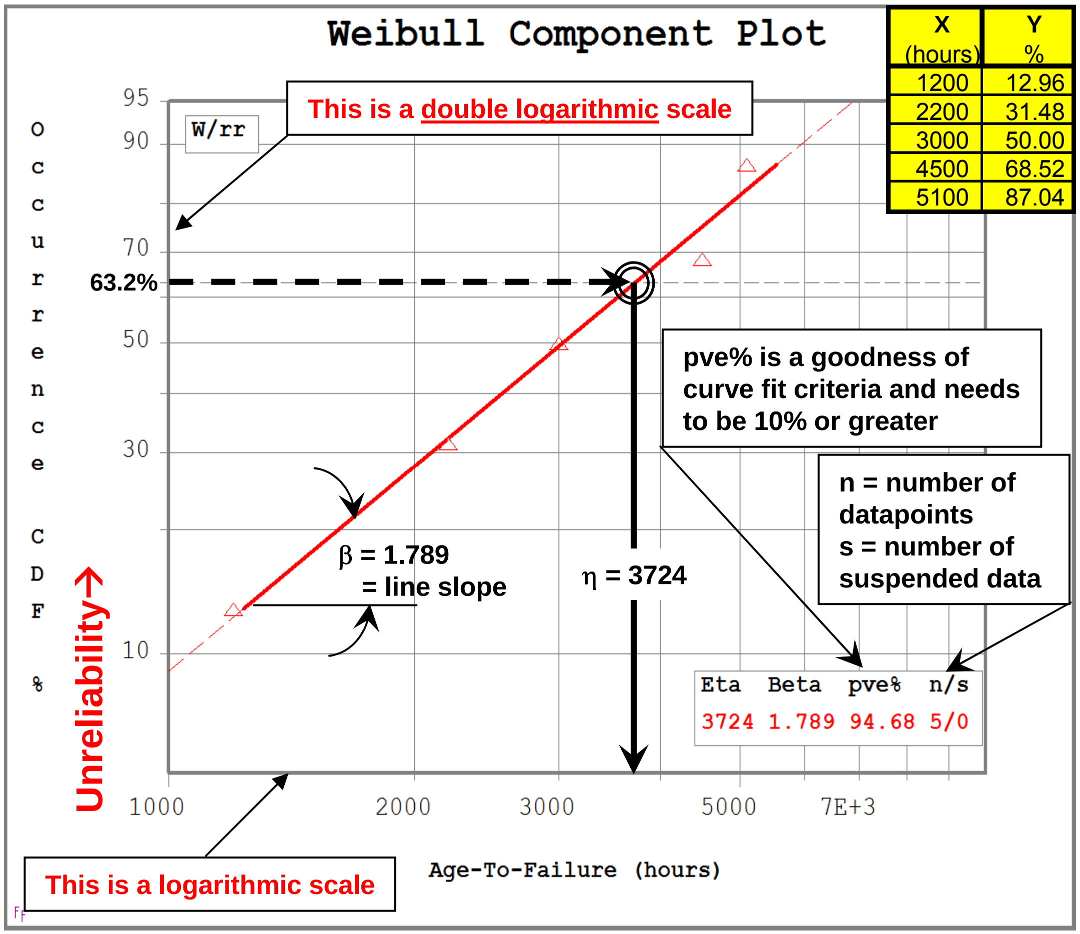
<—Weibull β's tell about failure rates:

1) infant failure modes $\beta < 1$,
2) chance failure modes $\beta = 1$, or
3) wearout failure modes $\beta > 1$.

Reliability function, R(t) = 1 - F(t)



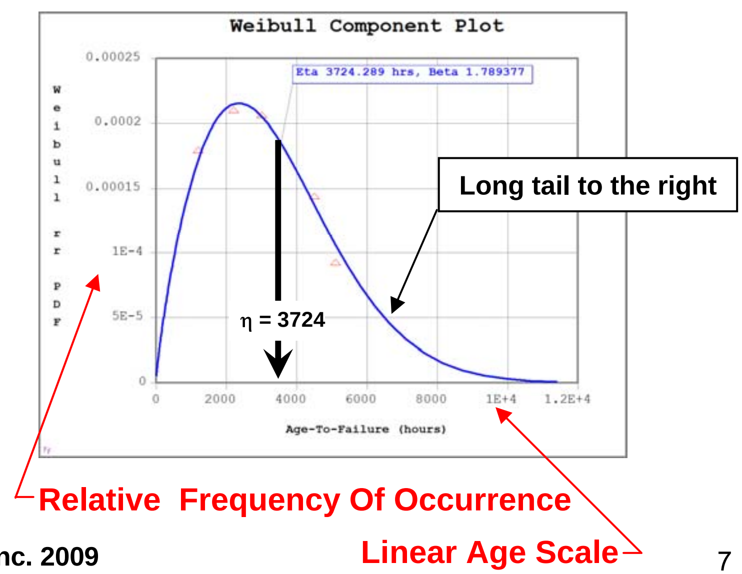
What Does The Plot Tell Us?



X (hours)	Y %
1200	12.96
2200	31.48
3000	50.00
4500	68.52
5100	87.04

The red trendline tells what percent of the population will die by a give time.

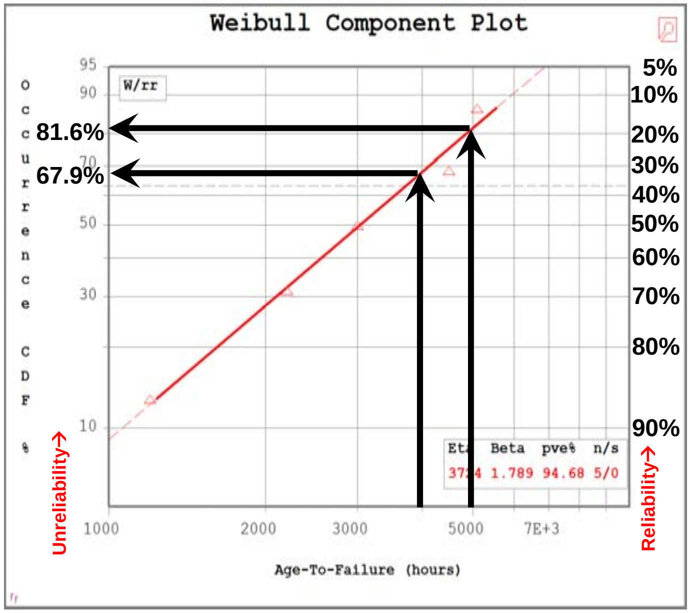
- For components:
  β < 1 = infant mortality
  β ≈ 1 = chance failures
  β > 1 = wear out failures
- For components
  η = characteristic life as this distribution has a long tail to the right



Why Weibull's

- They tell **HOW** things die—i.e. you get technical support for failure modes
- They give objective evidence for FMEA's to guide RCM decisions with **facts—not opinions**
- They **use data** from your CMMS (or from stores, or from purchasing, or from maintenance work orders, etc.)
- They **make sense from the apparent non-sense of failure details** to answer business questions for maintenance and engineering

Conditional Reliability

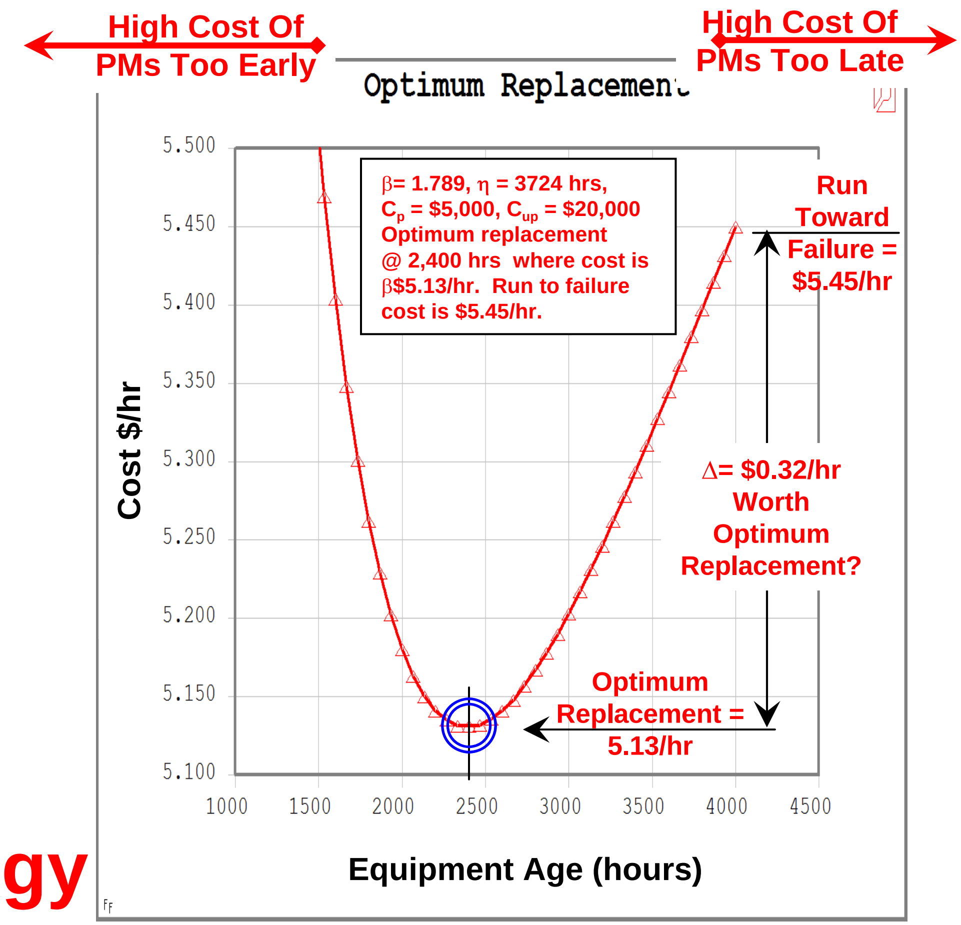


- Suppose I have a similar component that is **still alive at 4,000 hours**. From the graph the probability of failure is 67.9% or reliability is 32.1%.
- What probability do I have for the component **surviving for a life of 5,000 hours**? From the graph the probability of failure is 81.6% or reliability is 18.38%.
- **Condition reliability** for living another 1000 hrs = R(5000hrs)/R(4000 hrs) = 18.38%/32.1% = 57.25%
- **Probability of survival = 57.25%** ← **Your odds for living another 1000 hours are better than you had for getting from 0 hours to 4000 hours.**
  Probability of failure = 42.75%,

Use Weibulls To Do Timed Replacements?

Use previous Weibull data

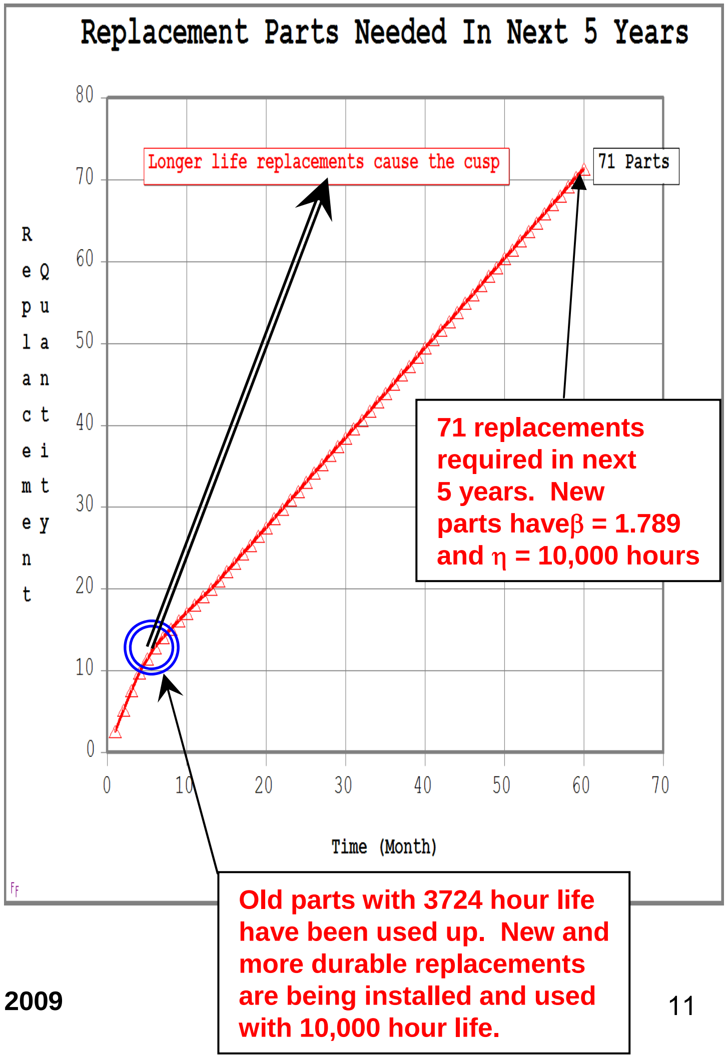
- Cost for a planned replacement = $5,000
- Cost of an unplanned replacement = $20,000
- Run to failure? Do a timed replacement?—If so, when?
- Weibull's and $'s save arguments and time!!
- **When in doubt—use your brains + technology**



Use previous Weibull data

Use Weibulls To Predict How Many Replacements?

- We have the following parts in service: 1@3000 5@2000, 6 @1500, 10@1000hrs. When they fail we'll replace with η = 10,000 hrs upgrades.
- How many parts will we need in the next 5 years?



Weibull Analysis Of Failures

- Weibull analysis of failure data tells how the component died (infant, chance or wear-out). The failure mode suggests specific corrective action. **What**
- One set of math handles tailed data. **Why**
- Use age-to-failure data (and use production data for <u>process Weibulls</u>). **When**
- About 85-95% of all life data makes a straight line on a Weibull plot. When in doubt, use the Weibull plots for life data. **Where**

Sharpen Your Technical Skills With Weibull Analysis

- Use your CMMS failure data to be fact driven with failure modes determined by technical Weibull analysis
- Use Weibull analysis to forecast future failures
- Use Weibull analysis for timed replacement decisions based on financial decisions
- Use Weibull analysis to support your RCM technical decisions by providing persuasive arguments and crisp decisions for money saving actions
- **Which are <u>you</u> using?** Weibull technical facts about failure modes? Or seat of pants opinion for engineering and maintenance conclusions.

Reading Resources

- Weibull's Biography: **Free Download**
  http://www.barringer1.com/weibull_bio.htm
- Weibull's Collection Of Technical Papers **Free Download**
  http://www.barringer1.com/wa.htm
- The New Weibull Handbook, 5th edition **US$98**
  http://www.barringer1.com/tnwhb.htm
- International Weibull Standard IEC-61649-2008 **~US$250**
  http://www.iec.ch
- Worked Out Weibull Examples **Free Download**
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