Letters to the Editor

Off the bathtub and onto the roller-coaster curve

While awaiting Kam Wong's final article in the above series, may I draw your attention to two worrying features of the two that have appeared to date ('The bathtub does not hold water any more', **4**, (3), 279–282 (1988) and 'The roller-coaster curve is in', **5**, (1), 29–36 (1989))?

In the first place, Figure 7 in the second article looks suspiciously like a probability density function, and not a hazard function; it is of the latter, of course, that the bathtub curve is a special case. This suspicion is aroused both by the labelling of the ordinate as 'failure rate', and by the wearout portion being bell-shaped rather than monotonic.

Secondly, and more fundamentally, it remains unclear whether Wong's target is the whole concept of the hazard function, or the belief that it commonly has a bathtub shape. If the argument is that we should make things so well that the possibility of failure does not need to be contemplated, then discussion of the hazard function, whatever its shape, is beside the point. However, it seems more likely that Wong is asking us to accept the inevitability of at least some failures when they are non-random, but urging us to 'find the failure cause so that the problem [of unreliability] can be solved' when the hazard function is constant, i.e. the exponential law applies.

This surely implies a rejection of fundamental statistical teaching about the exponential distribution and its discrete corollary, the Poisson. A much-quoted early application of this distribution (e.g. M. J. Moroney, *Facts from Figures*, Penguin, 1953, p. 89) was to show that there was no single identifiable cause for the incidence of Prussian cavalrymen killed by horsekicks during a certain period in the last century. Or, as we are reminded in a more recent British Standard on reliability, 'the exponential distribution may mean that an item is subject to several failure modes but that none of them is dominant' (BS 5760: Part 2: 5.1, 1981). The inference must be that it is not the exponential failure pattern, but rather its absence, which points the way to curable causes of unreliability.

This same standard, incidentally, does give ample acknowledgement to those who challenge the importance attached to the bathtub curve in many publications, even though the Standard was written no later than Wong's own reported disaffection with the concept. Those of us responsible for educating engineers need urgent advice on what we should teach about reliability; as a first step, it would be helpful to learn how far Wong's views coincide with those in the Standard.

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Author's reply:

I appreciate very much Mr. Bedwell's comments on my two papers. At least he is taking my views seriously. As the readers might know, I started talking about the demise of the bathtub curve in 1981. My view was generally ignored by the reliability practitioners. Even today my views on the basic failure characteristic curve for electronics are not recognized in any of the standards in the whole world.

About the target of my papers, I am aiming at the broad target of stopping reliability practitioners from making the same mistakes as I did. Let me tell you my mistakes:

1. Reliability predictions: my predictions were way off. See my paper in this issue entitled, 'What is wrong with the existing reliability prediction methods?' (p. 251).
2. Environmental stress screening: I had recommended cutting back on environmental stress screens because I did not recognize the roller-coaster hump at the time, thereby passing more failures to the customers.
3. Reliability demonstration: I had recommended use of more systems in demonstration tests because I did not recognize the decreasing failure rate characteristics at the time, thereby increasing the rejection risk.

The smaller target is to characterize the electronics failure rate as a function of stress application, e.g. ageing time and stress cycles, be it in the form of hazard rate or failure rate under repair and replacement. If the hazard rate curve turns out to be a bathtub it will be fine with me, but so far it has not. The ultimate characterization of the failure rate can only be a reflection of what we did, right or wrong, in designing, building and testing of electronics and should not be used as a golden rule to guide our actions. However, an understanding of how the failure rates came about would certainly help us in finding ways to eliminate the failures.

I apologize for not being mathematically rigorous in my papers. The reason is that I had not crystallized in my mind how the part hazard rate curves propagate up to form the system hazard rate curve or the system failure rate curve with repairs.

When Planck was investigating radiation emission from materials under thermal excitation he found discontinuities in the spectrum that were not explainable via the theories of that time. It took the development of the theory of quantum mechanics before the newly found material properties could be explained. What I have done in my two papers is to report the failure rate properties, with the conclusion that the exponential theory does not fit the phenomena. A plausible mathematical model has yet to be developed. I am still working on part three of the series of papers. The third paper will contain some new ideas of mine on how the failure rate curves are formed.

Mr. Bedwell's observation on Figure 7 is correct. The author of the original figure most likely intended the curve to be a probability density function. However, if the quantity of failures at the front end of the curve is small, e.g. a few per cent of the total, the front end of the hazard rate curve would look about the same as the density function.

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