 BY JIM SYLIVANT • ENGINEERING CONSULTANT

# Blown fuse has a meltdown

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In midcareer, I became a component engineer. Soon after I arrived in my new department, I faced a problem that had been ongoing for some time. It seems that a simple fuse in a CRT display had been having high failure rates. My new department had thoroughly tested samples against its specifications. A previous test engineer had designed a test fixture so that he could test batches of this fuse for all spec items. The specification required the fuse to open at a certain percentage over its nominal rating within a certain number of milliseconds over a range of temperatures, as well as after shock and vibrations. The previous engineer had done a splendid job of testing to verify that the fuse met all specifications.

However, in the application, high failure rates continued. My first step was to measure actual current in the application to ensure that we had chosen the proper fuse. I found that, besides a small, brief start-up current, the nominal value quickly settled to values well within the fuse's rating. I didn't suspect the brief start-up surge of causing a problem. After going over previous test results and in-application testing, I could find no explanation for the high failure rate. In desperation, I sent some samples to our on-site materials lab and asked the folks there to measure the cross-section diameter of the fuse element and identify the alloy used. Fortunately, the lab assigned the job to a very competent materials engineer who went the extra mile by analyzing the fuse after subjecting it to brief current pulses. In a few days, I got back beautiful microphotographs showing an unexpected construction technique. The photos showed that, instead of using a single alloy of some low-melting-point metal, the element consisted of three types of metal. It had a large, circular, tungsten inner core. Over the tungsten was a thin plating of copper; yet another thin layer of silver lay over the copper. Even more surprising were the photos the engineer took after subjecting the fuse to brief overcurrents. He found that, by charging a capacitor to various voltages and discharging it by short-circuiting it with the fuse, he could create a controlled amount of surge current. The photos showed that, after some surges, the silver layer reached its melting point, causing it to liquefy. After more surges, the silver completely melted away, leaving only the tungsten core with its thin copper plating. Because silver has such high electrical conductivity, virtually all the current from the surges initially flowed entirely through the outer silver layer. Afterward, additional surges flowed mostly through the thin copper layer because copper has higher conductivity than tungsten. That layer eventually melted. Now, only the tungsten core with its high resistance remained. With more surges, all current now had to flow through the remaining tungsten core. As more surges occurred, the tungsten heated up enough to gradually grow thinner and finally disintegrate.

We then realized that this trilayer-construction technique gave the fuse the ability to "remember" the accumulation of brief overload-current surges. Each surge at power-on contributed to small changes that eventually caused the fuse to open. Steady-state testing had not revealed this characteristic. As a result of its trilayer construction and the metals used, the fuse had memory. The solution was to change to a conventional fuse with a single element of low-melting-point alloy—that is, one that did not possess memory. This realization was the beginning of many such discoveries—that you can diagnose most problems by going back to an understanding of the basics. EDN

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