In this, our second article on the Thermal Curve, we’ll discuss how electronic components fail during expansion and contraction and demonstrate how to artificially induce the Thermal Curve to find expansion and contraction problems inside solid-state components. We’ll also cover some do’s and don’ts when artificially inducing the Thermal Curve.

Solid state components (primarily transistors, diodes and integrated circuits (ICs)), can experience problems during expansion and contraction, yet they may operate just fine once they have reached normal operating temperature. It’s the reason behind many of the intermittent problems that seem to plague us from time to time. When you get right down to it, many intermittent problems may not be so random and unpredictable after all. In fact, any time a customer’s complaint concerns something intermittent and there is a vehicle computer or control unit involved, it means solid state component failures may be the cause. That’s when you should immediately think of the Thermal Curve.

As the customer describes the problem, trace The Thermal Curve in your mind to see if the customer experiences the problem at about the same place on the Thermal Curve. If the problem always seems to have the same failure pattern, the problem may be related to a solid state component failure inside a computer or controller.

In “Thermal Curves, Part One” (December 1997), we documented two personal examples of problems that were caused by temperature. These examples demonstrated the value of Thermal Curve theory because much of the vehicle’s history before the failure and after the repair was available to document the chain of events. Refer to the previous article to refresh you memory on how Thermal Curve “theory” can be applied to actual vehicle problems.

When a customer’s description of a problem shows a pattern (the problem always seems to appear in the same general area of the Thermal Curve), you have some definite clues as to what is happening, when it is happening, and the conditions that are producing the problem. Armed with this information, it is more likely that you will be able to duplicate the conditions that create the problem in the shop by artificially inducing the Thermal Curve.

If you are able to place the suspect electronic circuit into the same general area of the Thermal Curve, the problem will often “miraculously” appear. Well, many times it does. Then again, sometimes the problem doesn’t appear because conditions that produce the failure are very narrow and it is difficult to exactly reproduce the conditions to duplicate the problem in the shop.

Applying the Thermal Curve to the problem at least provides some definite clues about the nature of the problem and explains why the problem doesn’t occur again after the faulty electronic component is...
replaced. Suffice it to say that the Thermal Curve has been so successful in locating intermittent solid state problems that experienced electronic technicians are quick to artificially induce the Thermal Curve when troubleshooting any solid state circuit suspected of having an intermittent problem.

Not all electronics technicians will call it The Thermal Curve, but they will know that temperature changes cause expansion and contraction failures of solid state components that otherwise might go unnoticed in the ideal conditions of a shop. It may take actual driving conditions to provide the conditions under which an electronic component fails. Why not take advantage of the Thermal Curve phenomena in the shop by artificially inducing the expansion and contraction of vehicle electronic components? You may find some “intermittent” problems may actually be quite predictable, even in the shop. Let’s see how electronic components are built and what this can tell us about thermal failures.

**Transistors And The Thermal Curve**

*Figure 1* shows a close up of the transistor component parts and their connections in a typical transistor driver. The actual transistor material is very small and surrounded by a large section of epoxy material to seal the transistor during the manufacturing process. The epoxy material is mounted to a metal tab for bolting to the chassis’ heat sink, which keeps transistor operating temperatures in safe limits (we hope). The three external transistor leads are connected to the actual transistor using internal wires running from the external leads where they enter the epoxy and connect to the actual transistor material.

This is quite a mix of dissimilar materials. All metallic parts, such as internal wires, external leads and the metal tab have the fastest expansion and contraction rates. The epoxy case and the semiconductor material expand and contract at slower rates. When all things are working as they should, the transistor is able to perform its function through all normal temperatures, without any interruption in
The different expansion and contraction rates of the transistor’s parts do not prevent the transistor from maintaining good electrical contact and the transistor performs properly.

A defect in any part of the transistor may cause a momentary or permanent break in electrical contact between two transistor parts. This causes the transistor to fail to operate properly. Transistor failure can occur at any point on the Thermal Curve, depending on the imperfection in the transistor’s construction or the transistor defect that develops. Each time conditions occur that cause the problem, the transistor fails whether the conditions are caused by normal driving or by artificially inducing the Thermal Curve.

If a problem occurs in a transistor during the warm-up portion of the Thermal Curve, expansion between the different materials inside the transistor are probably not maintaining proper electrical contact during expansion. A temporary open circuit inside the transistor can cause a transistor to completely fail. Internal materials continue to expand as other circuit components produce heat. A temporary open circuit problem inside the transistor may eventually expand and make contact again, restoring normal transistor operation once the transistor has reached operating temperature from the radiant heat of adjacent components. The circuit may jump back to life as if nothing was wrong.

The same thing can happen on the cool down side of the Thermal Curve as transistor internal parts contract back to normal size. If the vehicle is started while a transistor is having difficulty contracting back to normal size, a problem will be discovered that is not apparent unless the vehicle is restarted during the cool down side of the Thermal Curve. Crazy isn’t it!

ICs and the Thermal Curve

Another electronic component that is highly sensitive to expansion and contraction from the heat generated during operation is the Integrated Circuit, or IC for short. A typical IC is shown in Figure 2. The IC contains thousands and maybe even millions of microscopic transistors encased in a large plastic/epoxy case. Thin wires connect the IC terminals to external pins on the IC case. There are lots of places inside an IC where expansion and contraction problems can occur. All parts have to expand together and there isn’t a lot of room for error at the microscopic level inside an IC. Expansion and contraction problems due to changing temperatures account for many IC failures.

Chip Resisters and Chip Capacitors

Modern electronic circuit assembly uses CHIP components nicknamed because they are small, like “chips” of a resistor or capacitor. They are so small they must be held with a tweezers with pointed tips when being changed on a printed circuit board. A chip component is placed flat on the printed circuit board and soldered at each end to the copper print, as shown in Figure 3. If the chip component is not soldered correctly, it will make and break contact during temperature-induced expansion and contraction. This will create an intermittent problem that may be sensitive to vibration, as well as temperature.

Figure 4 shows how a chip resistor is soldered to a printed circuit board. Faulty solder connections, called cold solder joints, can also produce the same intermittent problems as a poorly soldered chip component. Cold solder joints may also be sensitive to vibration. Sometimes vibration cracks the solder holding the chip resistor to the printed circuit board.
and an intermittent connection develops. This creates a problem as the chip resistor, connecting solder, and the copper print all expand or contract at different rates.

The next step is to maintain the components at operating temperature or slightly higher than operating temperature by deftly applying heat. The object is to keep the electronics at operating temperature, without getting the electronics so hot that it burns up or melts the solder connections. Any problems with circuit operation are problems occurring during the top portion of the Thermal Curve. Maintain operating temperature as long as you think necessary to verify proper operation.

To cool down the circuit, turn OFF the hair dryer and spray selected electronic components or a portion of the circuit with an approved electronic circuit coolant spray available in small spray cans at your local electronic parts distributor. The coolant spray produces a rapid cooling effect at the component level, and reveals intermittent problems occurring during contraction. Any problems with circuit operation are problems occurring during contraction or the “down-ramp of the Thermal Curve.”

By swinging the electronics through rapid warm-up and cool-down cycles (as many as three of four times in quick succession), many faulty solid state devices and faulty connections reveal their expansion or contraction problems.

Untrained technicians view these problems as eerie, unpredictable, unexplainable, and detestable intermittent problems. You will know better, now that you know what to look for. Think back to the vehicle problems you have encountered in the past. Now that you know about the Thermal Curve, do any of those problem vehicles from the past have any relation to the properties explained by the Thermal Curve?

Armed with this new information, perhaps you won’t have to say to the customer: “It seems to be working fine right now - bring it back when it’s acting up.” Well, at least you might not have to say it quite as often.

—By Vince Fischelli