What caused the corrosion: The Answer

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Spoiler Alert: If you haven't read "The Problem" yet, head there first.

Last month, the problem was presented to you (details and pictures). Here is a summary of the problem.

- PCBAs were being severely corroded in the area of south China, Hong Kong, and Japan.
- The main elements present in the corrosion were sulfur and chlorine.
- The corrosion was conductive enough to allow current flow between conductors that thermally degraded the PCB. At the burned points, the voltage differential was about 180VAC.
- The PCBAs were damaged while in operation. PCBAs manufactured simultaneously at the same location but kept as spares at the customer's sites did not show any signs of corrosion.
- The PCBAs were arranged vertically in the enclosed cabinet with forced air flow diagonally across them.
- The air conditioning is operated only during the day. The computer room is kept at 20C and 50%RH during the day. The air conditioning is shut down at night, and the temperature and humidity rise quickly to about 30C and 80%-85% RH.

Origin of the Corrosive Elements:
The prime suspect, sulfur corrosion, also known as creep corrosion, is not very conductive. Even with the 180VAC difference between adjacent conductors, it would not be able to conduct enough current to burn the PWBs. The assemblies would fail from signal disruptions long before the creep corrosion would be able to conduct enough to burn the printed wiring boards (PWBs).

However, sulfur and, to a certain extent, chlorine, were the main contaminants that were inducing the corrosion. The sulfur originated in the environment. Much of this area of the world uses coal to create electricity. The coal contains many sulfurous compounds which are released into the atmosphere when it is burned. There are also other sources of sulfurous compounds in the environment such as from rubber or tire manufacturing facilities, oil refineries, etc. The environment was determined to be the source of the sulfur.

Chlorine was only found in a few areas on the PCBAs. Many of the systems were located near the ocean. The chlorides may have been the result of ocean spray making its way into the computer environment, or may be from human sources, such as perspiration, spittle, fingerprints, etc. The source could have been the manufacturing environment or the installation engineers.

Both of these elements are commonly found in corrosion products on PWBs. But the failures they produce generally take much longer than two years, and the damage is not likely to include burning of the PCB. These corrosives were aided by an additional factor to induce the damage so quickly. The search is narrowed to determine the third factor.

The Third Factor:

Look closely at Figures 1 and 2. The appearance of both are similar to corrosion products formed by repetitive wettings and dryings of a liquid. Figure 1 contains a “tree ring” appearance where liquid water spreads out and then dries at intervals. Figure 2 looks similar to dendritic growth except that dendritic growth has a single origin where all materials originate. It does not have multiple connected centers from which growth continues. This formation is possible if water droplets containing the corrosive elements were splashed onto the PWB at these locations, initiating new areas of growth.

Figure 1

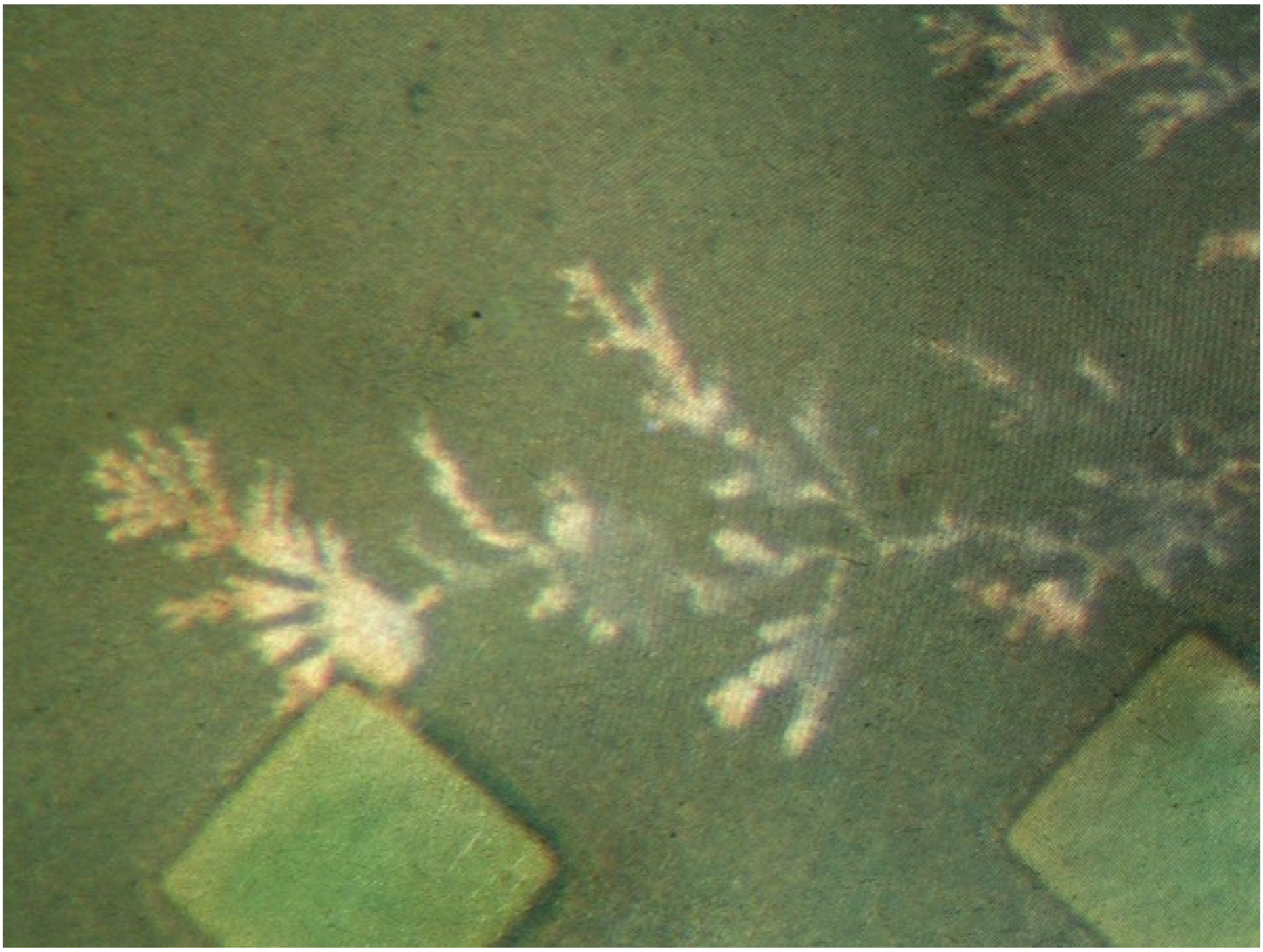

Figure 2

Working from the hypothesis that liquid water was the cause, we still have several unanswered questions. The PCBAs are mounted vertically. How could liquid water get onto them? The cabinet has a solid top and side surfaces making it extremely difficult to splash water onto the PCBAs. The PCBAs were installed in the cabinet and then not removed until they failed eliminating the possibility of something splashing on them while they were outside the cabinet.

The daytime air conditioned temperature was 20C with 50%RH. Each evening the air conditioning is shut off and hot, humid air quickly enters the building. Could water form on the PCBAs by condensing of this humid air? If this were true, it would account for the fact that nearly all of the corrosion was initiated at vias, not on the solder mask. The corrosion spread across the solder mask but the origin was at the via structures. These metal structures are connected to buried copper planes within the PCBA. They would also have the largest heat transfer capability of the PCBA surface, much greater than the laminate or solder mask.

The evening hot humid air was measured at 30C and 80%RH. The dew point of this combination is 26C (Reference http://en.wikipedia.org/wiki/Dew_point; http://www.dpcalc.org/). The daytime operating temperature of the PCBAs was 20C. Water would condense quickly onto the PCBAs when the hot humid air hit them. Liquid water, with electrolytes dissolved in it, could conduct the current necessary to thermally degrade the PCBs..

However there are a couple of loose ends that still need to be explained. First, the measured relative humidity of the air did not increase above 80%. This can be explained because the temperature and humidity sensors in the equipment were isolated from the bulk materials of the equipment and were surrounded by good airflow. Both the thermal sensor and the humidity sensor changed temperature simultaneously. There was not a significant delay while the bulk materials were changing. The PCBAs are massive and contain a lot of copper which can retain a significant amount of thermal energy. They would not heat instantaneously. They would take minutes to change temperature when the hot, humid air was introduced. The PCBAs could easily remain below the dew point temperature for a significant amount of time allowing water to condense on them.

Second, the Corrosion Test Plates experienced little corrosion during the sixty days of testing. These plates were hung in the air, near the ceiling, where they had good airflow. They are very thin, do not have much mass, and have a large surface area, which would allow them to change temperatures quickly enough that the humidity did not condense on them.

The Solution:
The solution to this issue was to keep the air conditioning running all the time in the computer room. If full time air conditioning was not possible, it was necessary to prevent the outside air from entering the room until the equipment had enough time to increase its temperature above the dew point when the outside air was introduced into the room.

The information contained in the answer was enough to eliminate the manufacturer or the design organization from any fault. The manufacturer was able to point to their standard specification for humidity, which contained the statement that 80% humidity is allowed as long as it was non-condensing. The failures were not due to the manufacturer, they were due to the customer’s environment.

So, how did you do?

Also See:
- What caused the corrosion: The Question
- Flux residues can cause corrosion on PCBs
- Successful PCB grounding with mixed-signal chips
- Wet Chemistry