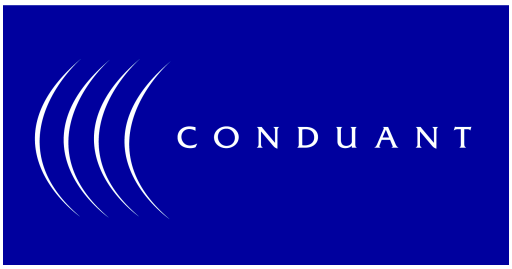


Review of Mark V Incident at JIVE on March 1, 2003.

March 23, 2003

1501 South Sunset Street, Suite C, Longmont, CO 80501
Telephone: 303.485.2721 Fax: 303.485.5104
www.conduant.com

Overview

This document reviews the events and findings related to the incident at the JIVE facility on Saturday, March 1, 2003.

Conduant Corporation was notified on Monday, March 3, 2003 that a Mark V system had caught fire while located at the JIVE facility. The fire protection system automatically alerted the fire department and switched off the power.

JIVE identified the source of the fire as an area on the backplane near the 12V fan connectors. It posted 4 photos of the damaged area on its web site at http://www.jive.nl/jive/techinfo/mk5_photo.html.

The system was returned to Conduant Corporation in an unaltered condition on Wednesday, March 12.

The general methodology followed to learn the cause of the incident has been to:

1) document the initial state and successive states with photographs.
2) document the initial state and successive states with resistance values as indicated by a digital ohm meter.
3) document the initial state and successive states with notes kept in a computer file.
4) systematically isolate connections and components from the system in a "peel-the-onion" fashion, documenting these activities as described above.
5) review the Gerber files for the backplane, particularly in areas of power distribution.

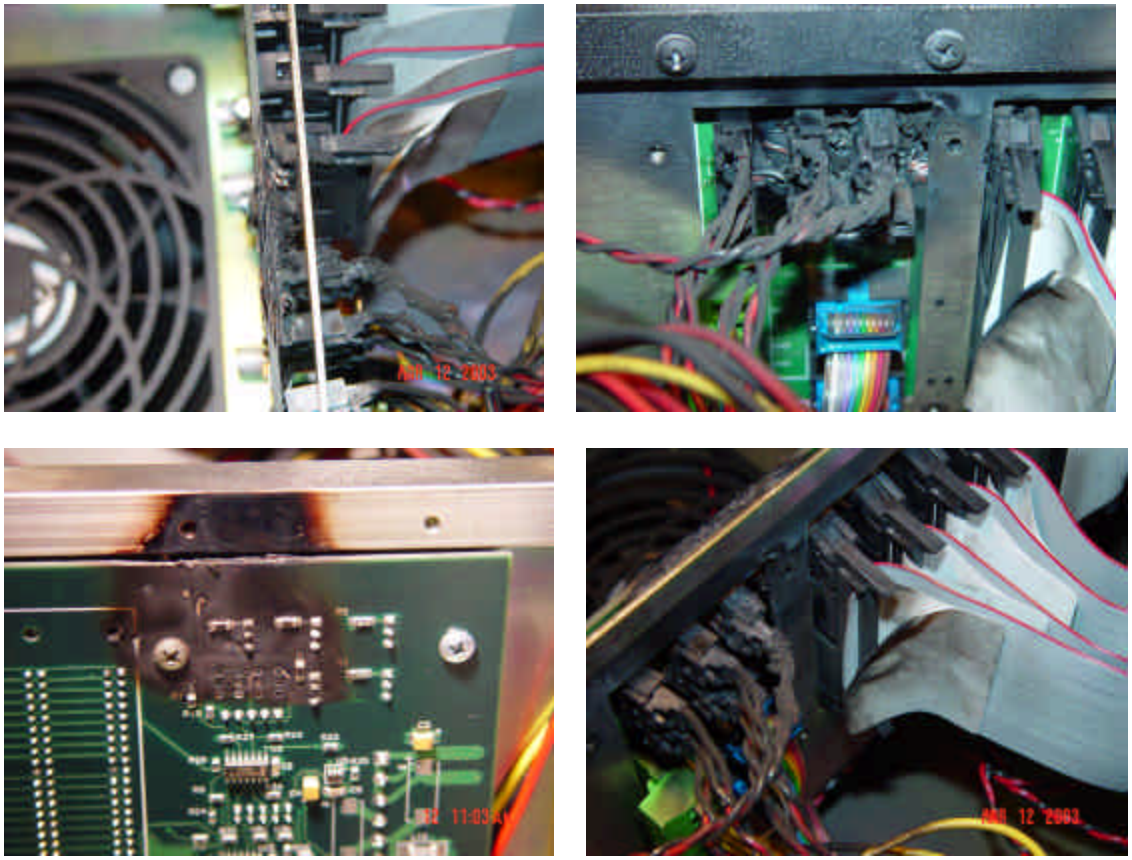
To date, 169 photographs have been taken to document the process. Many of them are redundant or not specifically relevant to the area of damage. For that reason, only a select group of photos is used in this report. Each photo is a JPEG file with resolution of 2560x1920 and is about 2MB each. Most of the images in this report have been cropped and enlarged to highlight the areas of interest. All raw photos are available on request.

Details of this particular Mark V

This Mark V system, S/N BR-RS-8189, was shipped as individual subassemblies. These were later assembled in the field to produce a finished Mark V system. This backplane, SN 01100302, was shipped pre-mounted to the chassis using the Conduant assembly process that is described later in this report. At the time it was shipped, it did not have the mounting hardware that secures the 12V FET switches to the backplane. Because it was returned with the FET hardware in place, it is clear that this backplane has been removed and replaced at least once in the field since it left Conduant.

Summary Details and Observations

The following four pictures show an overview of the damage as the system was received from JIVE.



Different views of damaged area of system before disassembly.

Without isolating any circuits and with the power off, resistance 12V-GND is 2.4ohms and 5V-GND is 0.9ohms. In both cases, these are very low but not low enough to be a short circuit.

The screw on front side of motherboard to the left of J15 appears electrically isolated from GND, 5V, and 12V. All other screws easily show short to GND. Additional pressure on the screw makes intermittent connection down to 400 ohms.

The insulation on red wires from J14 and J15 appears to be melted together. Further testing indicates that they are shorted together, though they should read about 1 ohm due to the two 0.5 ohm resistors between those two points.

There was no obvious damage on any wires on the power supply harness either on the unused leads or on the leads running up to the backplane. There were no visible scorch marks on any sheet metal other than in the obvious burn area.

A couple of the backplane screws that were not in the area of the damage were removed. They were noticeably very tight.

Fan wires were systematically isolated. Subsequent testing of individual fans showed that fans operate properly. They draw about 0.5A at startup and about 300 ma once up to speed.

All transistors, integrated circuits, and capacitors were removed from the backplane. None of these changes affected the low resistances from the planes to GND.

The area around J15 and the adjacent screw appeared to be the hottest area. ATA connector J5 shows heat damage on the side near the screw. Fan connector J15 is melted on all sides and adjacent fan connectors are melted on the sides facing J15. Connectors that are further away also show little evidence of extreme heat, though they are covered with "ash". The white pull tab on the ATA cable that was connected to J5 showed heat damage. The insulation on the wires connected to J15 melted together and to the J15 connector housing.

All the backplane screws were removed and the backplane itself was removed from the chassis. The next four photos show different perspectives damage to the rear of the board after it was removed from the chassis.

Different views of back side of backplane after removal.

The picture below is of the mounting screw near J15. Even with the screw removed, it is difficult to measure continuity from one end to the other without scraping down to the metal.

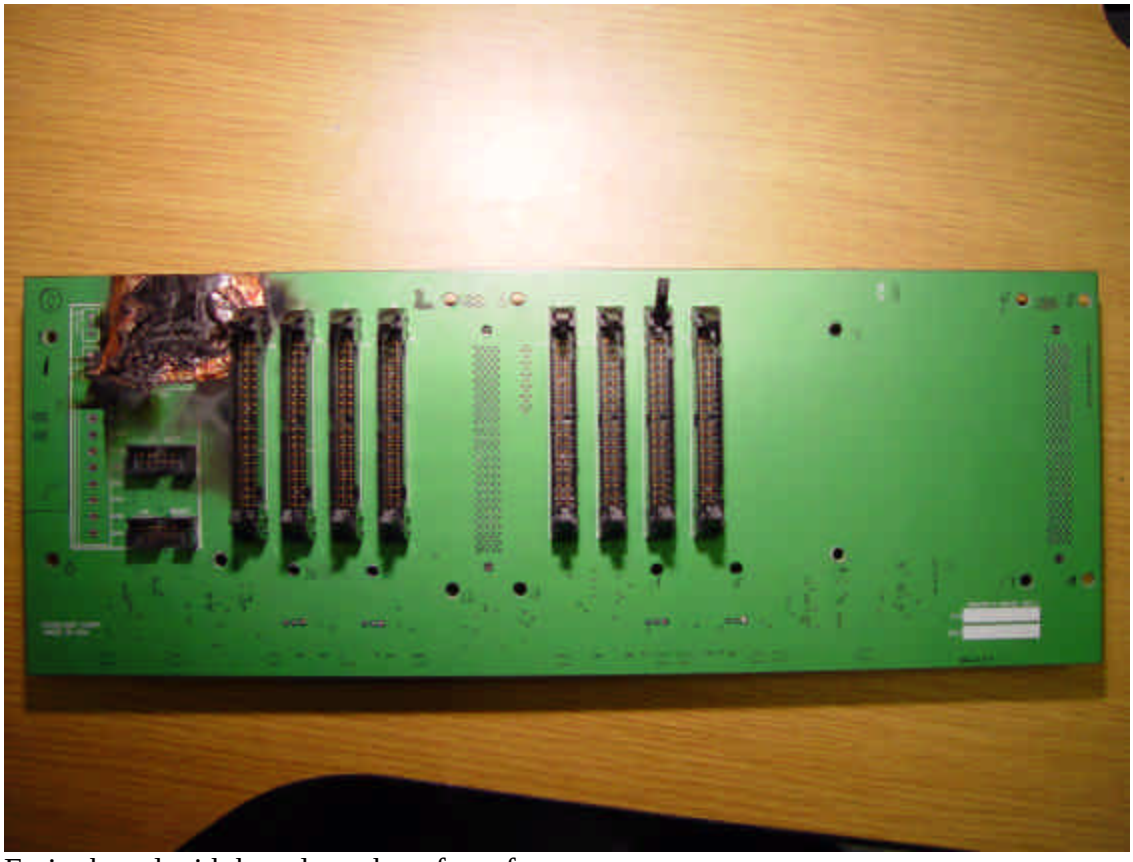
The screw removed from the mounting hole near J15.

J15 was noticeably hotter than the other fan connectors. All sides of it were melted. The solder that held the connector in place appears like it became very hot, along with solder on a couple other fan connectors. The sides of all the adjacent connectors facing J15 were also melted while sides of those other connectors facing away showed little signs of heat damage. The insulation on the wires connected to J15 was also severely melted, much more so than those on other fan connectors.

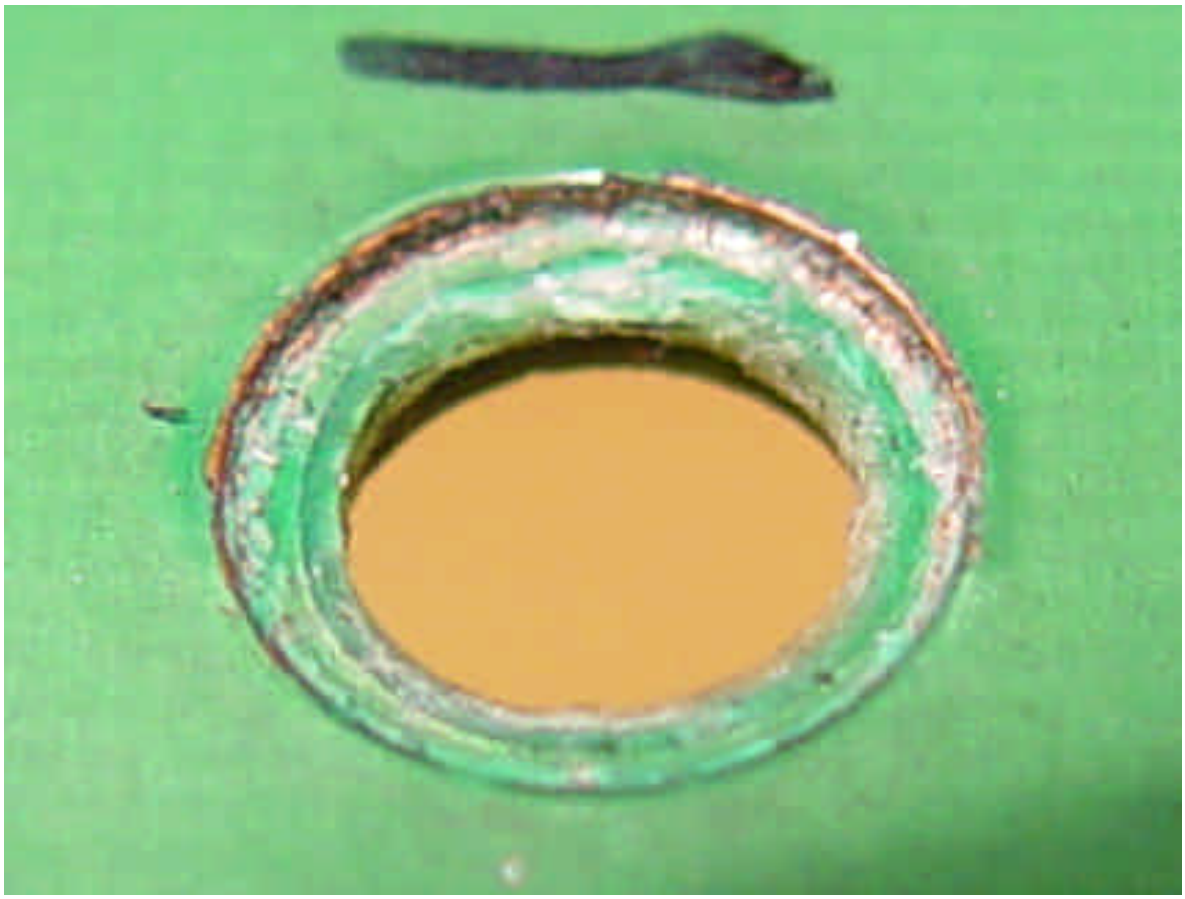
While detached from the backplane, the 5V and 12V outputs from the power supply still function properly, delivering the proper voltages while lightly loaded.

Mounting hole damage

The pictures below show impressions left on the board around some of the other holes that were not involved in the burn damage. Some show deep impressions into the board made by the standoffs while others show that the impressions actually exposed copper from the GND and 5V planes. The last picture shows the impression left around the standoff in the burn area once the board was removed. Because this area is blistered, there is no positive way to determine how compressed it was before the damage.

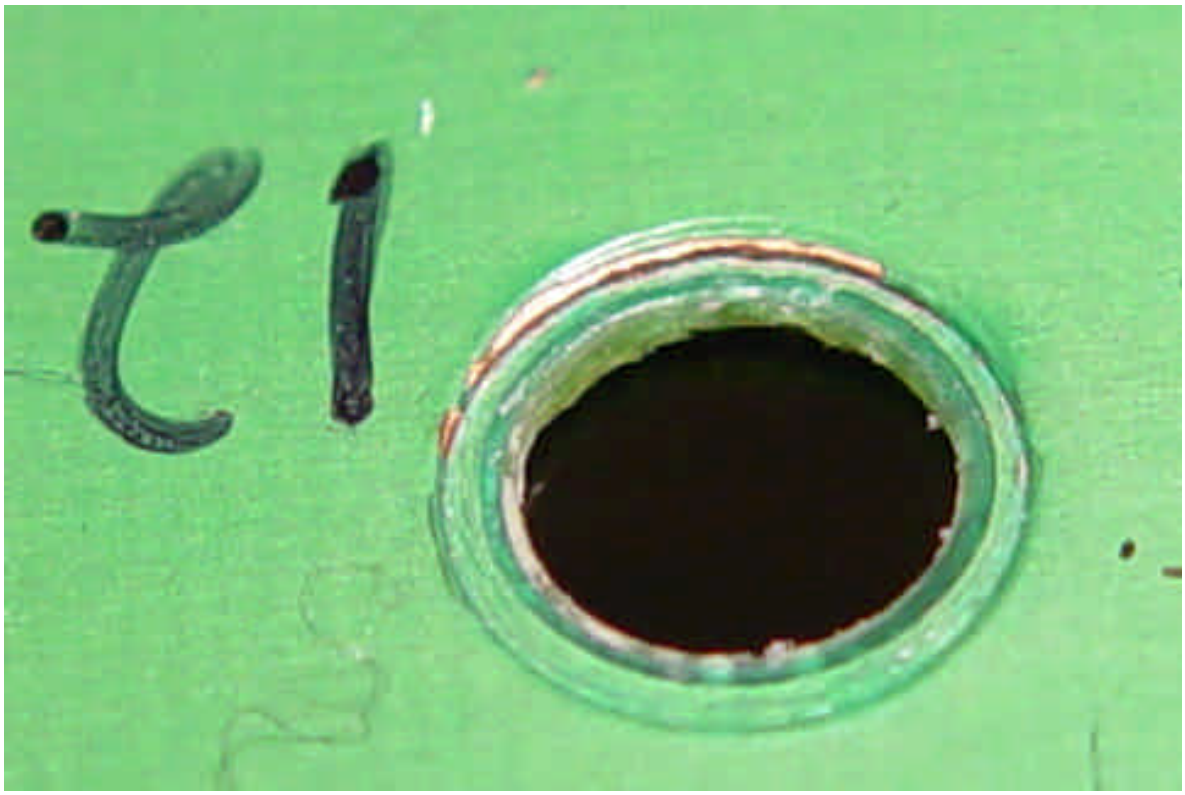


Entire board with board numbers for reference.

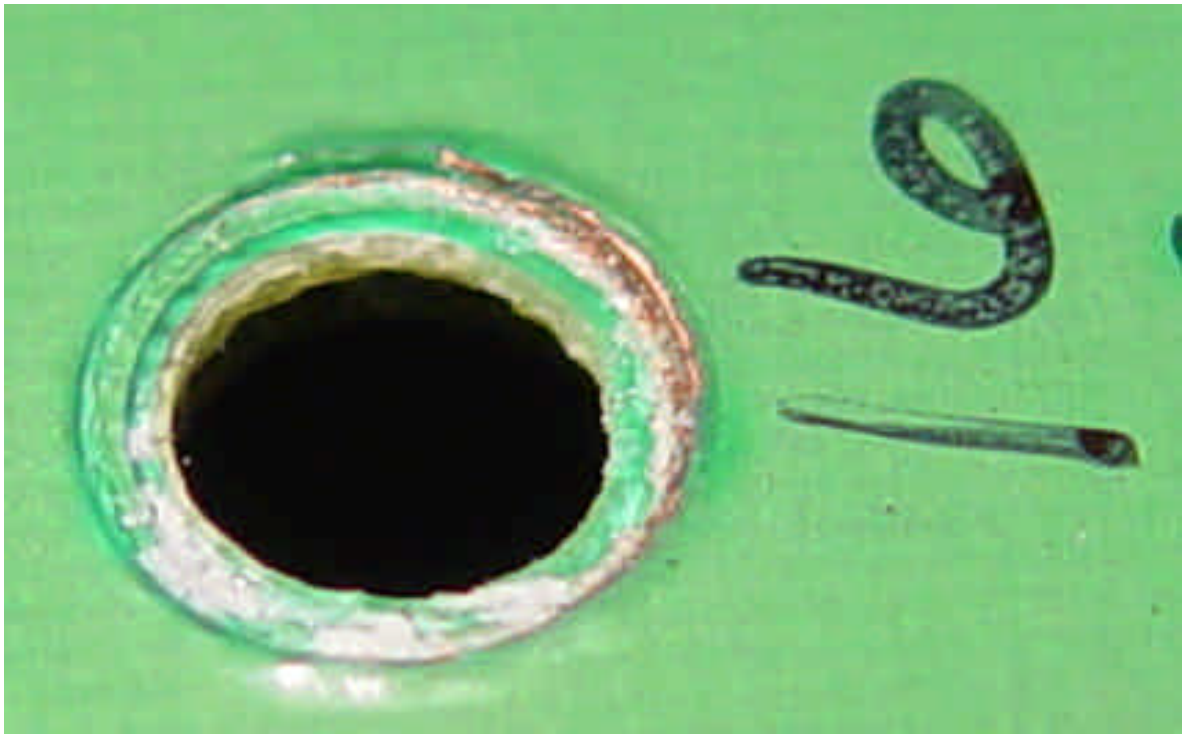


Hole number 1.

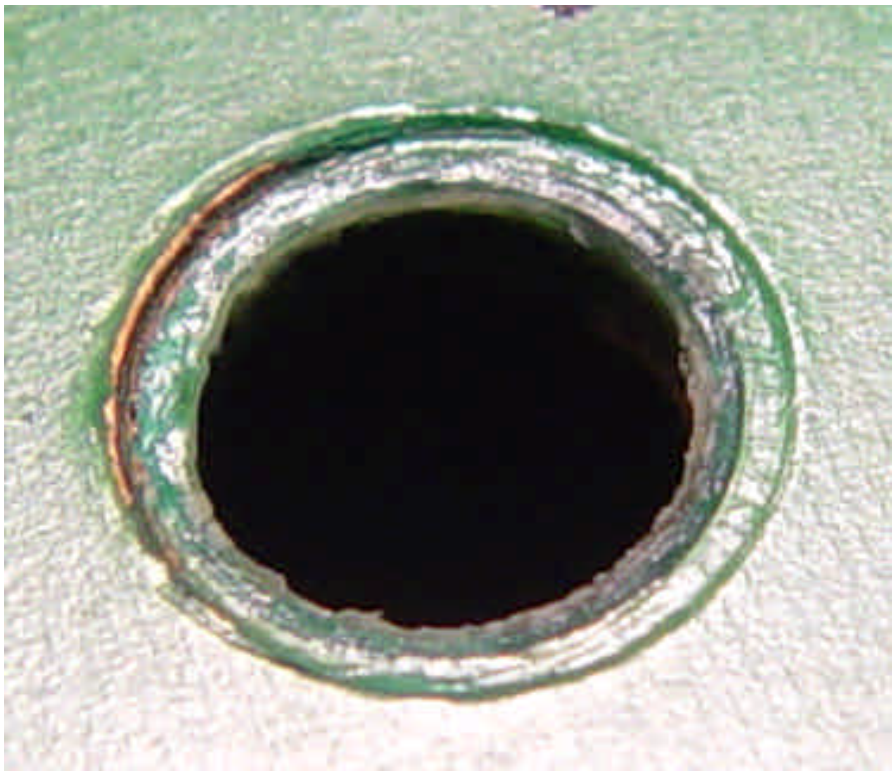
Hole number 9.



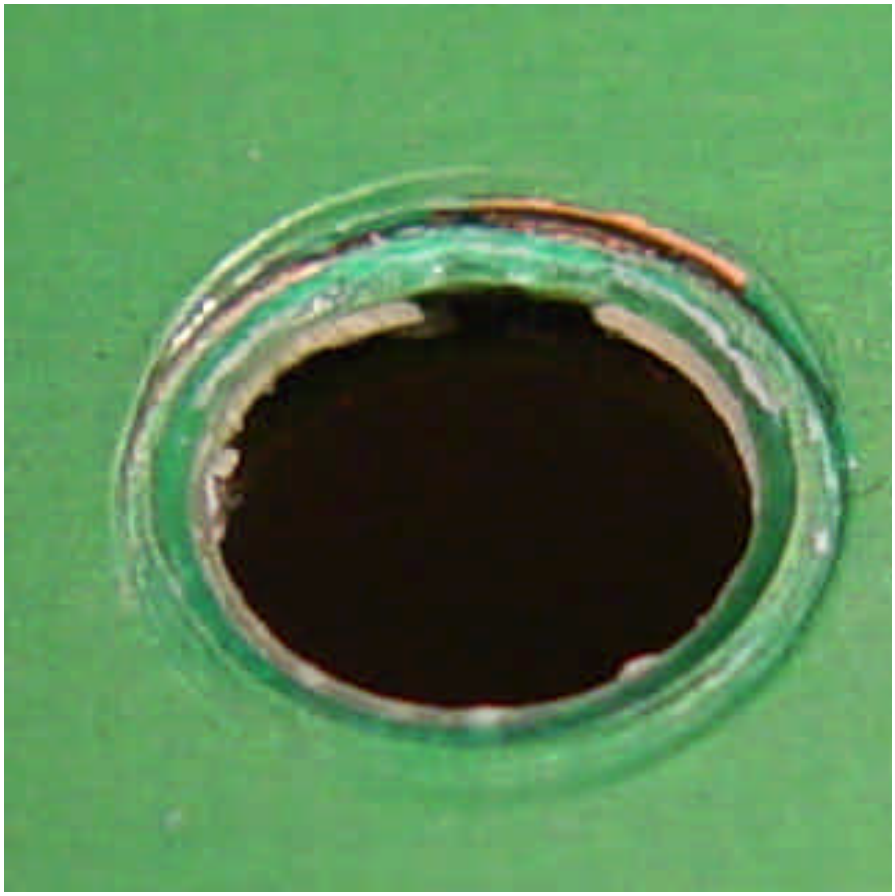
Hole number 12.



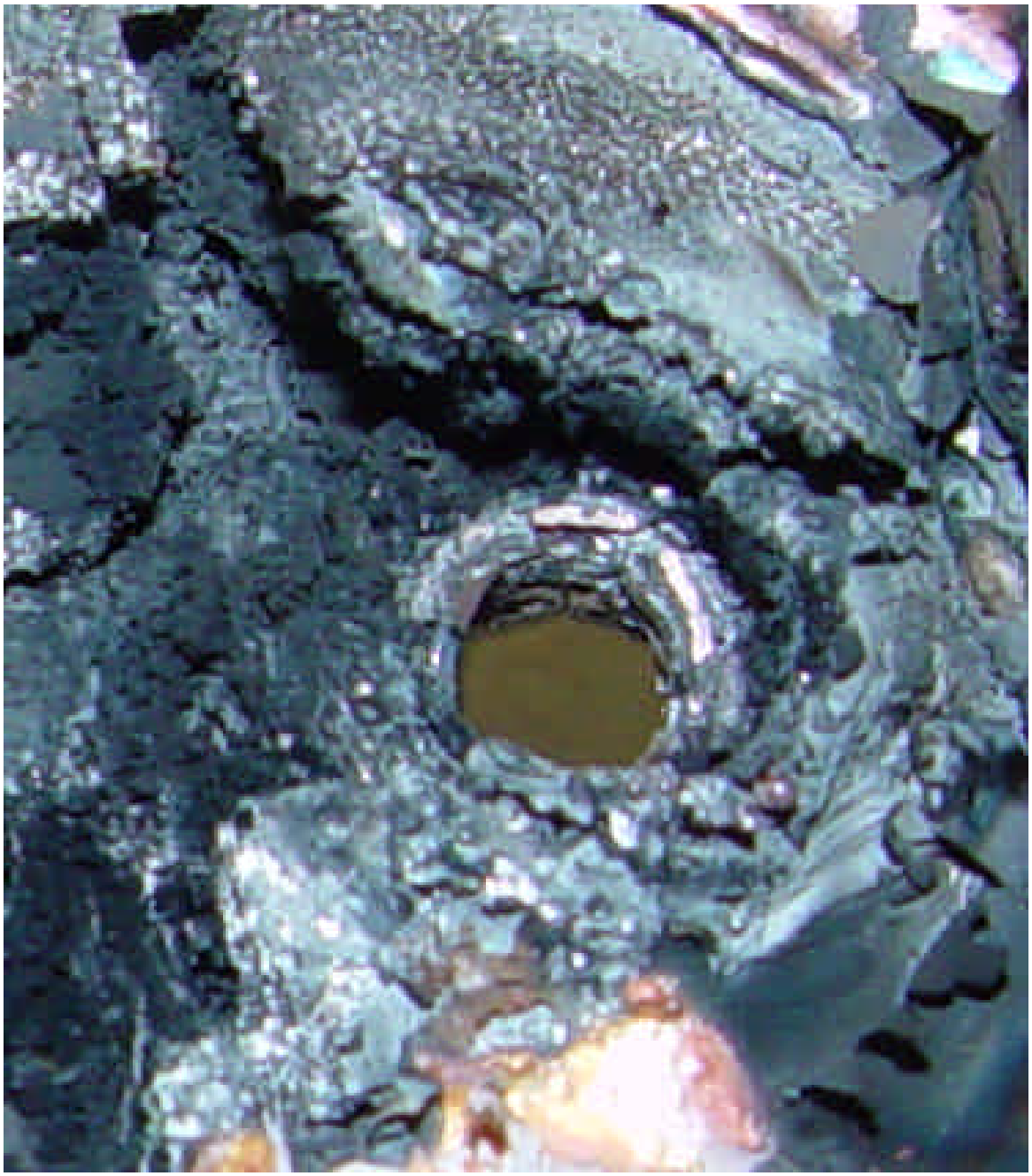
Hole number 16.



Hole number 17.



Hole number 18.



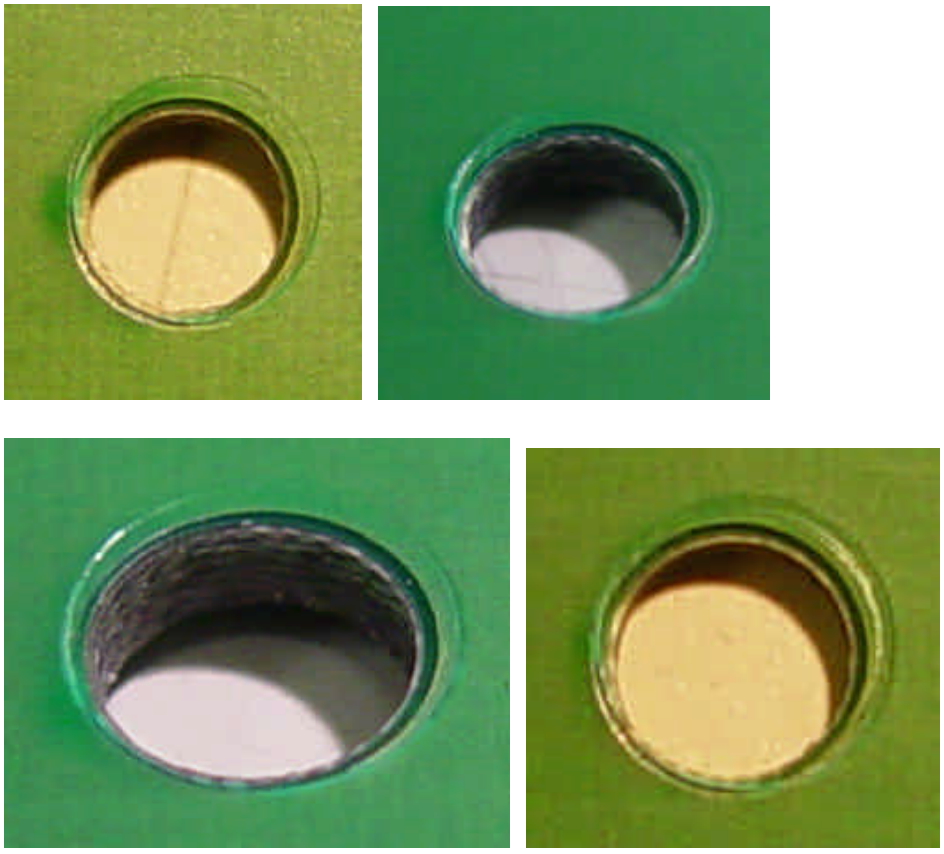
Hole number 6.

Review of Conduant assembly process and attempts to reproduce the compression damage

Conduant uses a Milwaukee cordless screwdriver in its assembly process. This review is to examine the level of impressions made in backplanes by the Milwaukee driver at different settings and also by deliberately excessive tightening by hand. For this experiment, a brand new backplane board was used.

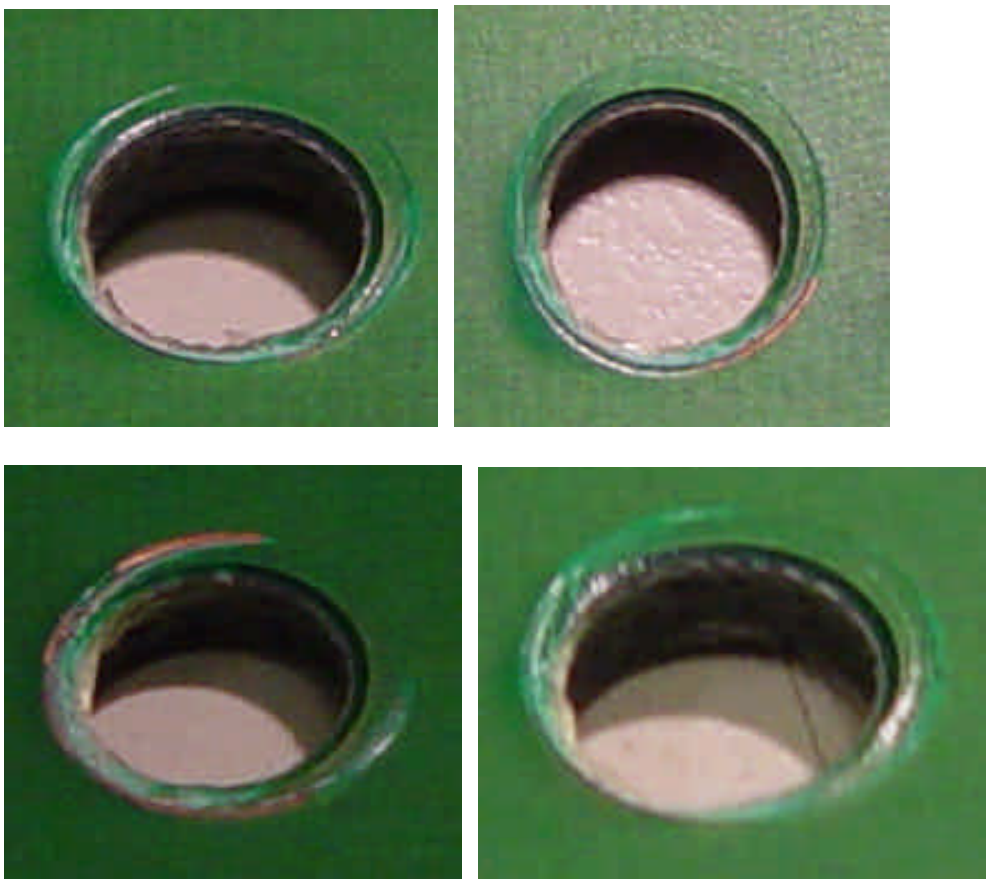
The normal assembly process uses this driver running at "2 speed" with the clutch setting at 3. According to the Operator's Manual, these settings correspond to an approximate torque of 10.5 inch-lbs**. With these Conduant factory settings, there are no visible impressions where the standoffs meet the board.**

Adjusting the clutch setting to 3.5, 4.0, and 4.5 produced increasingly more noticeable indentations on the rear of the backplane. At "2 speed" and a clutch setting of 4.5, the manual represents this as an approximate torque of 17.5 inch-lbs. The following 4 pictures show the impressions on 4 different holes made with these settings.



Impressions on 4 different mounting holes with Milwaukee driver settings at 166% of the Conduant manufacturing standards.

The clutch was then adjusted to its maximum value of 6. A "2 speed" and clutch setting of 6 corresponds to an approximate torque of 26 in-lbs. With these settings, the copper GND plane directly under some of the standoffs is now exposed and would explicitly connect backplane GND to the chassis GND through the underlying standoff. Impressions made with these settings are shown in the next four pictures.



Impressions on 4 different mounting holes with Milwaukee driver settings at 248% of the Conduant manufacturing standards.

Because the cordless screwdriver did not produce compression representative of that on the returned board, an attempt was made to greatly increase the torque by hand tightening the screws. Consistently, the heads of the screws broke off before any such indentations could be made.

Plane layers in relevant area

The backplane is an 8 layer board, with identical GND planes in layers 8 (bottom), 4, and 2. Layer 6 is a split power layer that carries both 5 and 12 V. In the area of interest, layers 2, 4, and 8 at GND and layer 6 at 5V are directly between the screw head and the standoff. On layer 6, the 12V area of the plane runs under the fan connectors.

Other experiments

1) On a different backplane, fan connectors were loaded with high wattage 30 ohm resistors. When powered, these resistors drew about 33% more current than the fans returned in the failed system. There were no indications of heat buildup around the fan connectors.

Presumed failure mechanism

It is believed that the primary cause of the failure is severe over-tightening of the screw at hole six. The tightening sufficiently compressed and deformed the copper plane layers between the screw head and the associated standoff so as to create a resistive connection between the GND plane on layer 8 and the 5V plane on layer 6. The connection did not draw sufficient current to cause the power supply to shutdown, but it did draw enough current to generate significant heat. The screw in the hole shows considerable damage but it is not known if the screw was part of the conductive path.

The high current in the 5V portion of the split power plane caused that plane to significantly heat its border with the 12V portion of the plane. The damage caused by that heat resulted in a formation of another low resistance path between 12V and GND, perhaps under J15. While generating significant heat, neither path to GND drew sufficient current to trip the shutdown circuits in the power supply.

Conduant was unable to intentionally inflict the kind of compression around the mounting holes that was obvious on the returned board. As indicated earlier, it is known that the backplane was removed and replaced at least once since it left Conduant. It is believed that an assembly tool such as an impact driver may have been used at some time in a mounting process since the backplane left Conduant. Such a tool might deliver its force in repeatedly short bursts that might allow the screw to get tighter without sheering off.

Immediate Action Required

As is the case with this backplane, other backplanes have also been removed and replaced since they left Conduant, if for no other reason, to add the FET hardware kit in the field. Any backplanes which may have been subjected to excessive tightening for any reason should be removed and inspected for damage on both sides of the board around the mounting holes.

Conduant will generate a technical bulletin for use by clients who perform TK200 assembly operations in the field. It will include a warning regarding excessive tightening of mounting hole screws. It will also include specific torque and liquid fastener requirements.

Longer Term Solution

Conduant is reviewing updates to the backplane. One update being considered is to increase the clearance of copper around the mounting holes, thus making the backplane more tolerant of excessive torque.

Conduant will notify the VLBI community of additional actions or information when it becomes available.