

W&M geometry board assembly update

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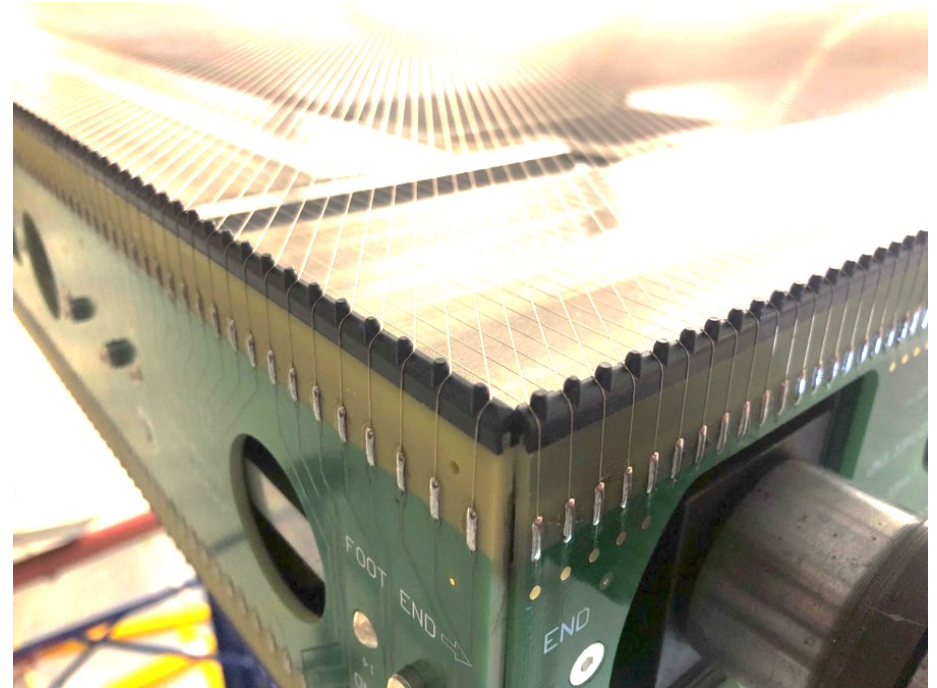
13 Mar 2024

Outline

- Reminder of scope and procedure
- Update on glue loading and QC testing of strip adhesion
- Tooth strip alignment and QC
- Status

W&M is adding the tooth strips for the US APAs

- Wrap (geometry) boards are procured, QC'd in the UK, and then shipped to W&M
 - They do not have electrical components
 - They position the wires, provide anchor points, and make electrical connection front-to-back
- At W&M, we wash the boards, add the tooth strips, trim the strips, clean, package and ship to Chicago
 - Scope is 14 APAs worth of boards
- W&M started production for Chicago in June, 2023



The process

- Boards are shipped to W&M from the UK
- We visually inspect, log shipment in to DG as they arrive
- Wash the boards (in DI-fed laboratory washer); bake the boards to dry at 250F / 121C, let cool
- Load strips with epoxy, mount strips on boards, align in fixtures
- Unmount fixture and clean squeeze out & re-fixture 3 times;
- Check strip alignment WRT to “v” clamp; let cure until next day in fixture
- 6 additional days to full cure
- Machined tooth strips to length using a dedicated fixture on a CNC mill
- QC, methanol rinse, bake at 200F / 93C, cool
- Sealed in antistatic bag, desiccant

[11 days from opening bag to completed and bagged]



Update on epoxy loading and strip attachment

Backstory

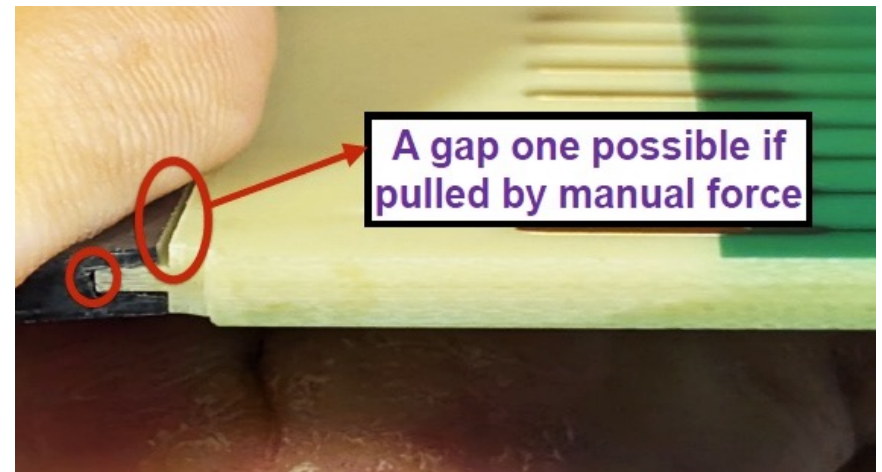
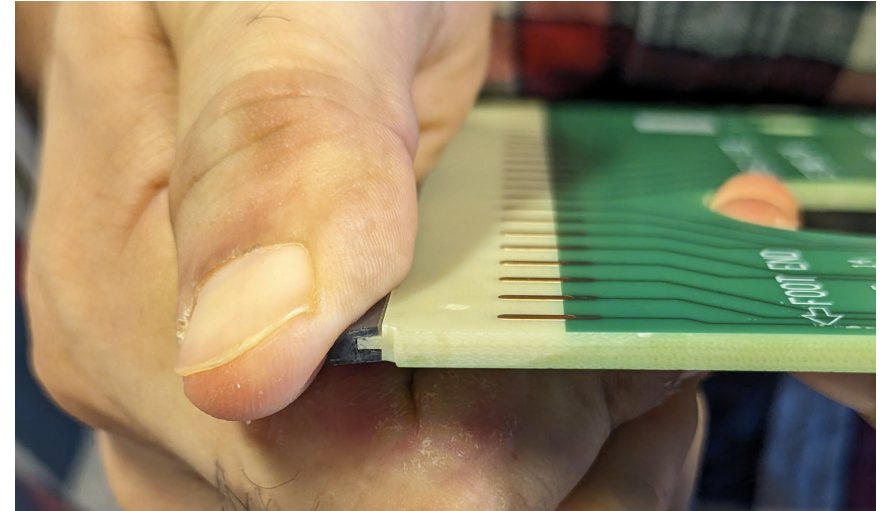
- During CERN week, the UC team reported APA 1 boards with poorly-attached strips (for their V layer on APA1)
- UC reverse shipped the boards (not in use for the X layer) to W&M to repair these and investigate what the issue
- We will manually pull tested all of the boards,
 - Investigation showed that these APA 1 boards with issues were all very early production (summer)
 - Roughly 30 boards failed
 - The issue was too little epoxy loading in early production
- We shipped back to UC, Jeff and Zubair visited UC the next week
 - UC reported additional issues on boards we'd pulled tested at W&M
 - They showed us how they were testing the strips [slide], which was different than our tests

Background on W&M epoxy loading

- Initial work was completed with reject boards from Manchester
 - These all had tongues that were too thin (too thick don't fit in strips)
 - Tool path and loading developed with these boards
 - Initially loading tests always required more epoxy to fill the void between strip and tongue
- With good boards we had to reduce the epoxy to reduce waste/mess
 - Went too far...
 - We saw some failure when the strips were being machined – started pull testing
 - On the following weeks, we added more epoxy back; then added more epoxy in the ends

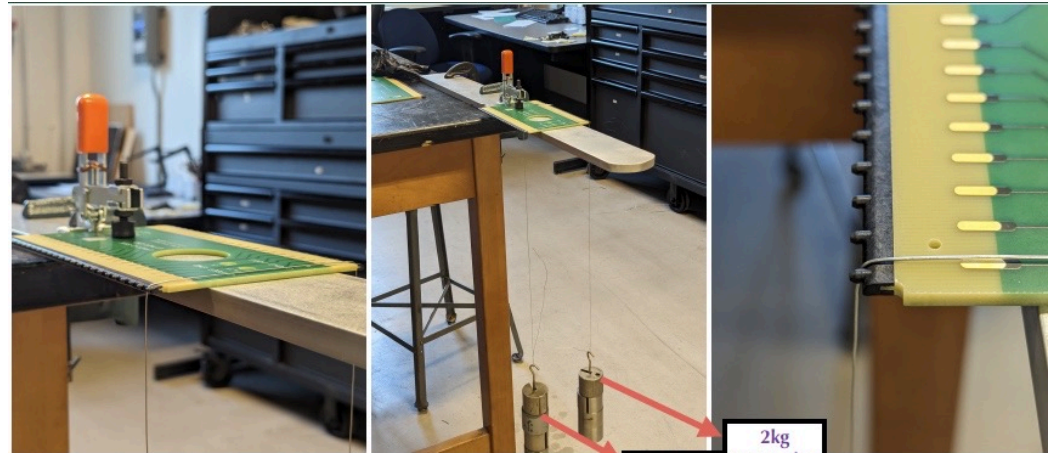
UC's bend test

- Our QC testing had been manual pull tests – pulling outward (left in the figure)
 - Our tests showed that we would break the strips before they become detached
- UC was bending the strips downward
 - Makes sense, this is the direction the wire load the strip – found real problem
 - One could hear “breaking glass” sounds on the rejected boards – this lead the the epoxy bond being weakened and the strip being able to be removed by pulling
- Concerns on the test itself
 - This was manual bend test was testing the boards with forces well beyond their specifications
 - Tests are bending the tongue itself when creating the gap
- Conclusion
 - Visible epoxy in between the strip and tongue strip the end of the board always meant the board was good



Systematic testing at W&M

- Developed a specification-based test
- The idea is to tension the strips in the location and force based on actual wire tension specification
- Initial test (right) right 20x max tension in the wire
 - A board that showed a gap in the manual tests didn't budge in these extreme, but systematic tests
- Developed a more systematic test based on loading to max wire tension with a safety factor [slide]



1. Setup to do measurement quantitatively
2. A total of 4kgs (40N) of force is suspended on the boards

Same board as previous slide

Quantitative

- Final loading (implemented last fall) is in excess of the PSL/UK specification
 - This is to ensure consistent epoxy squeeze out along the boards and at ends
 - Each strip is massed to ensure proper load
 - Massing strips shows that we currently load 50% more than specified
 - Massing the final loaded boards, after cleaning squeeze out, to show it is at specification

QC at W&M

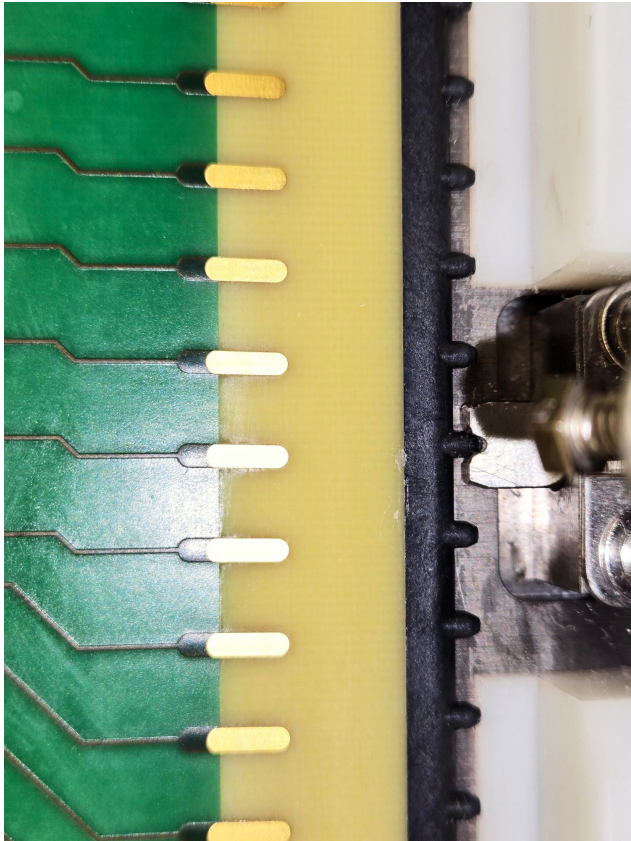
- All strips massed after loading
- Simple loading test
 - Loading is 2x the strength of the APA wires
 - Used a magnifying hoop to look for displacement/gap between strip and board
 - Testing each board this way
 - Tests performed after full cure and trimming
- Visual inspection
 - Hard to check the epoxy at the end of the strips before trimming; checking for visible epoxy beyond the strip in the groove
 - Follow-on check visual check after trimming



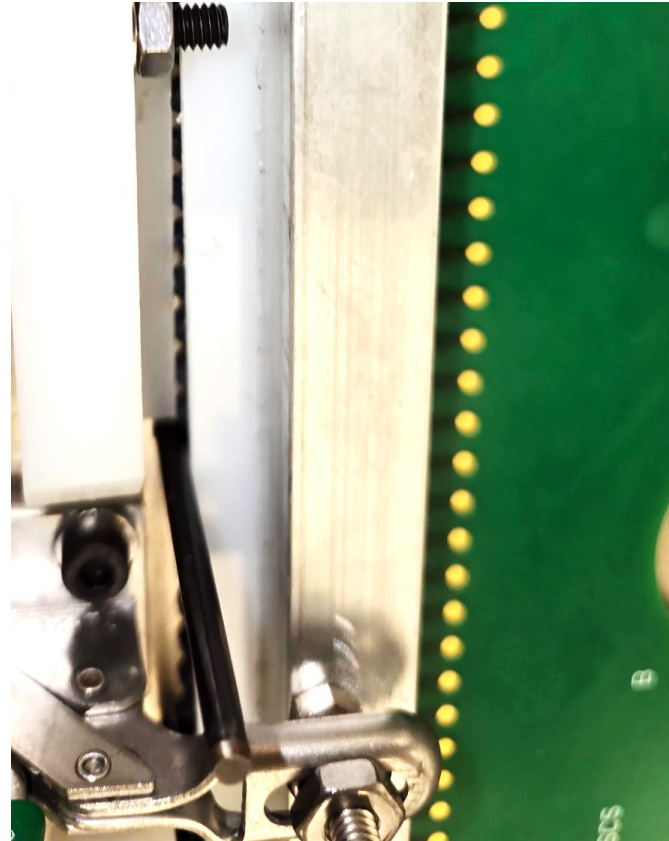
Strip alignment issue

- UC found 3 v-layer side boards with the tooth strips displaced from nominal position
 - They were displaced far enough that the wires wouldn't pass over the pads.
 - Luckily, these were not boards that get glued in place
- It would have been obvious at the time it was placed in the fixture
 - It particular to the way these long side boards are nearly the same length as their strips
 - It cannot, though, be wrong if the board was properly installed in the fixture [slide]
- Conclusion this was fundamentally a training issue
 - We traced these boards to a particular short-term worker who, no longer working with us – had not reinforced the critical nature of this alignment
 - Given the significance of the issue have modified/reinforced our QC
 - Each board is retested in the fixture to ensure that the "V" is properly seated by a different person before being sent for trimming
 - Signed off in the tracking spreadsheet for the board
 - Local version of procedures were update accordingly

Side boards (pegs)



end boards (dragon's teeth)



Status

Production and QC validation

- The APA 1 U layer, consisting entirely of modern boards (instead of early production boards) will be shipped to UC tomorrow
- The APA1 G layer will follow next week
- The intention is that the UC team examines the boards for strip adhesion (ideally with Zubair on site too)
- The goal is that to help build confidence in current production and beyond such that (eventually) UC is comfortable using the boards without having to repeat QC testing on each board
- Planning a W&M procedure review – based on UK and adapted for local situation

Inventory

- Received a shipment of the long U/V boards from the UK in January
- Includes enough boards for 3+ APAs
- Limited by the number of “U SIDE BOARD ASSEMBLY W/ SLOT – MIDDLE” type boards