

## W&M tests of geometry board baking

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# PSL observations of early W&M boards

- W&M started production (adding tooth strips) of geometry boards for Chicago in June
- With the decision to wash+bake boards before shipping to APA sites early boards were sent to PSL (most of APA1)
- They inspected the boards and found a few small QC issues and one big issue
  - Small stuff wrong masking tape brand
  - Some stray bits of trimmed shims on boards
  - A board with a missing tooth
- The **bigger problem** was epoxy discolored and with reduced adhesion [slide]
- Not enough epoxy (esp. at ends of boards)
  - It was only very early boards that had this issue as we increased the amount of epoxy dispensed by the gluebot (mix-measure-dispense machine)
  - We have done extensive pull tests of boards, the tooth strips fracture before they can be removed

## “pink” epoxy issue



# Boards

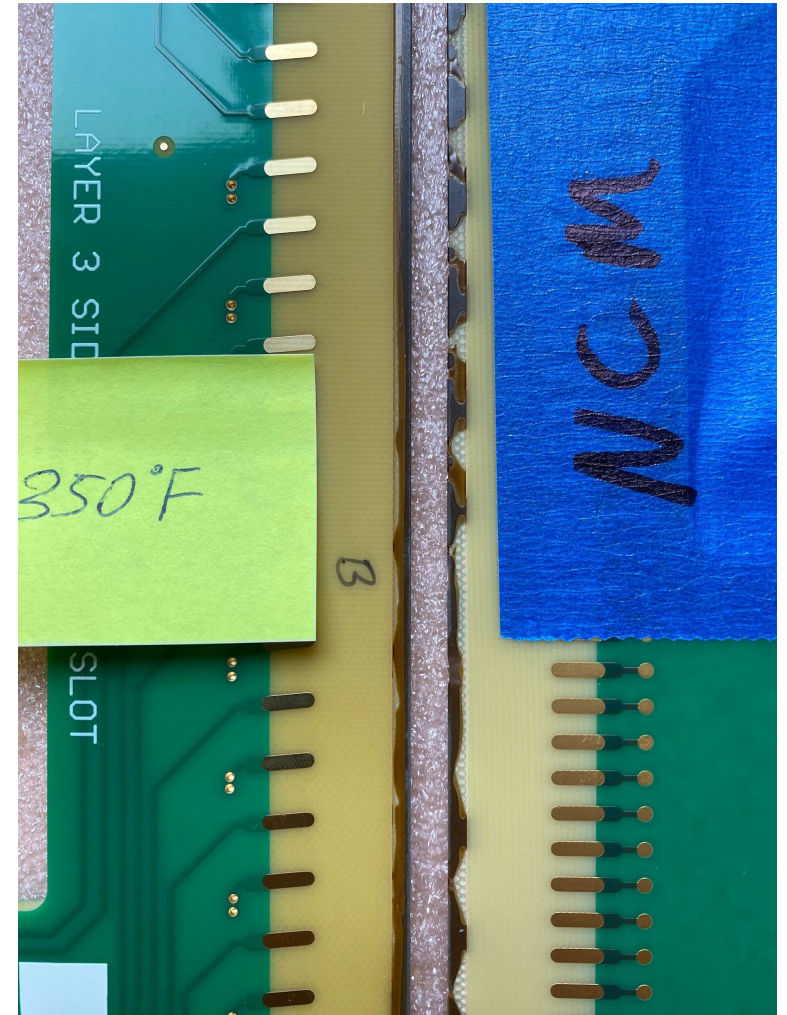
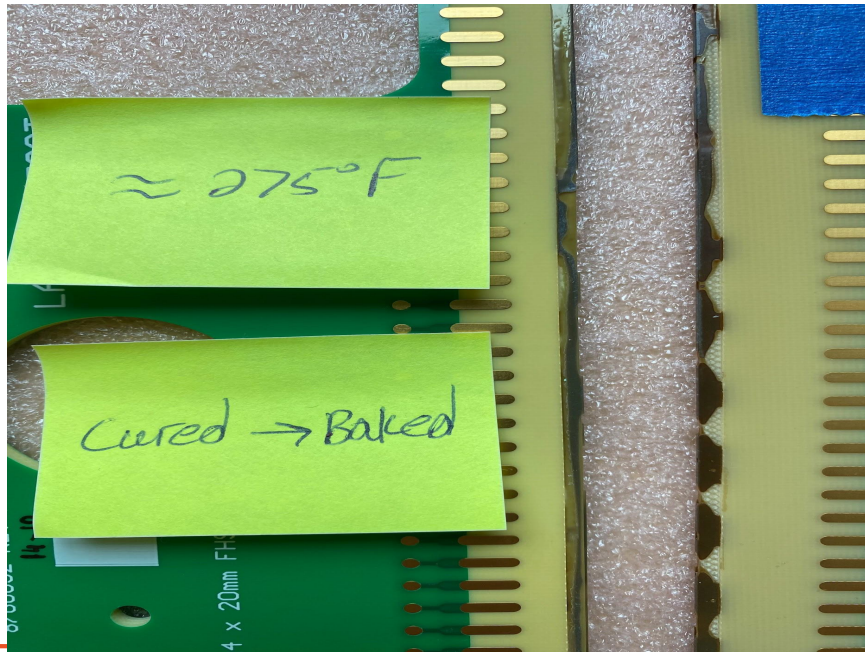
- Some of these boards were returned to W&M
  - The tooth strips came off easily and there was a color that we'd never seen before
    - The epoxy cures to grey
  - The boards themselves looked normal
- One could easily press a fingernail into the discolored epoxy, which isn't the case for properly cured and handled epoxy
- We halted board production with these observations
  - The first thing was to make sure we had the right unexpired adhesive, which we did
- We attempted to reproduce the problems
  - Machining boards?
    - This was where we first decided we needed additional epoxy – no issues with strips separating with the production loading
  - We were washing with Isopropyl
    - Did soak tests without any noticeable changes
  - Partially cured epoxy?
    - Tested that we were conservatively priming the static mixer before starting test, which we were
    - We are using 3M-recommended static mixers in duo-packs so there isn't opportunity for an incorrect mix
- Looked into baking process...

# Bake tests with geometry boards

- We have an inventory of test boards we used for preproduction (reject boards)
- We glued some of those boards and let them rest for the whole 7 days to full cure (we also tested 1 day curing)
  - We also prepared flat epoxy “coins” of epoxy
- PSL’s procedures called for 250F for 2 hours
  - Note that 3M called for 200F for 1 hour for accelerated curing of the epoxy
- Boards were baked in our lab oven at various temperatures including: 400F, 350F, 300F, and 275F
  - Later we baked 250F and 200F samples
  - Tested baking with the boards horizontal and vertical
  - We sampled boards after 1hr and 2hr
- We let them cool overnight
  - We did manual pill tests on the tooth strips and if they survived that tried with a vice grips pliers
  - With unbaked production boards the strips break before being removed
- At the elevated temperatures:
  - The epoxy was discolored and with weaker adhesion and the effect became more significant with higher temperatures
  - The boards themselves also discolor at temperatures above 300F



# Epoxy discoloration



# Test results

- At temperatures of 300F (149C) and above
  - Strips were easy to remove by hand
  - Epoxy was soft and significantly discolored
- At 275F (135C)
  - There was still some discoloration mostly visible in thin material
  - The strips were able to be removed with a pliers in some cases, others would fracture
  - One could still imprint the surface surface of the epoxy with a thumb nail
- 275F is too close to the recommended 250F production for my comfort
  - Tried lower temperatures
- At 250F (121C)
  - Minor discoloration (“taupe”)
    - Subtle enough to photograph well
    - Could make white scratch marks but couldn’t
    - Could partially separate strips before breaking
- At 200F (93C)
  - No visible discoloration
  - Cured epoxy too hard to mar with fingernail
  - Tooth trips broke before becoming to detached like unbaked boards

# Conclusions

- “pink” epoxy only appears when the board is heated to temperatures above 300°F, but there is still discoloration as low as 250F
  - Not sure who that happened, but maybe there was miscommunication locally
  - The oven dial and thermometer are both shown in
  - We verified oven thermostat was calibrated
- In the case of the old boards, they are consistent with baked at a temperature somewhere between 300°F and 350°F
  - They had pink epoxy with little to no board discoloration
- The current 250F baking process is softening the epoxy, causes minor discoloration and reducing the adhesion of the tooth strips
- At 200F, as recommended by the manufacturer for accelerated curing, does not seem to impact the epoxy
- **Recommend:** Abandon the 250F baking procedures for geometry board with epoxied tooth strips
  - I understand the UK is using 100C, we have not tested that temperature, but they say it’s OK too



# Why are we washing & baking completed boards?

- I think we all agree that boards need to be washed and baked sometime after delivery from the manufacturer
- These geometry boards have no soldered components
- The processes are (completed with gloves):
  - Epoxy and fixture the tooth strips to boards
  - Wipe epoxy “squeeze out” 3 times over the first hours with isopropyl soaked cloth
  - Cure overnight in the fixture and inspect
  - Machine (side mill) the tooth strips to length on a dedicated fixture
  - Wipe with isopropyl soaked cloth (e.g., if someone sneezed on it, or...)
  - Add the tape to mask boards
  - Wash/clean, bake, place in sealed bag with desiccant packet
- We store the boards in plastic totes sealed with gaskets (like done in the UK) between operations
- During use:
  - They spend up to two months at ambient dew point during winding at Chi and DL
  - They will spend up to 9 months in the cryostat at ambient dew point in the mine
  - Any heated drying we do at the end of preparation will be undone later in their use cycle
- My recommendation – a simple Isopropyl wash and dry after assembly seems to meet our goals
  - This is what we do with HVS divider boards