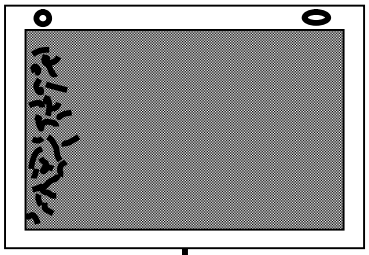
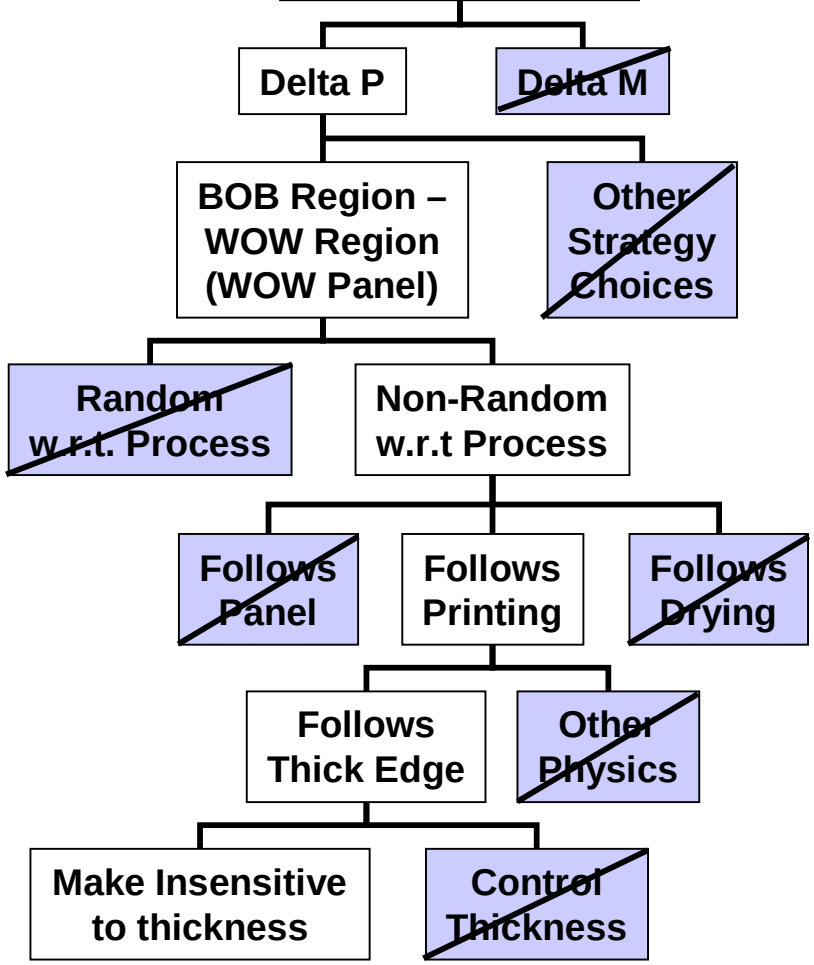
Case Study: Carbon Cracks

- Carbon paste is screen printed on EL lamp panels and dried in a conveyor oven.
- After the oven, some panels have cracks in the carbon layer.
- Cracks can not be reworked, so the panels are scrapped.
- Defect strategy led to an interaction between deposit thickness and curing temperature.
- Irreversible corrective action: Reduce sensitivity to deposit thickness by changing curing process
- Assign new project to reduce variation in deposit thickness

Solution Tree for Carbon Cracks



The Green Y is the presence of eggshell cracks in the carbon layer of lamp panels printed with carbon.



Reason for split

Defects visible with naked eye.

Concentration Diagram: eggshell defects on the left edge, which has excellent leverage in the process.

Defects only occur on the edge, which is very non-random relative to the process.

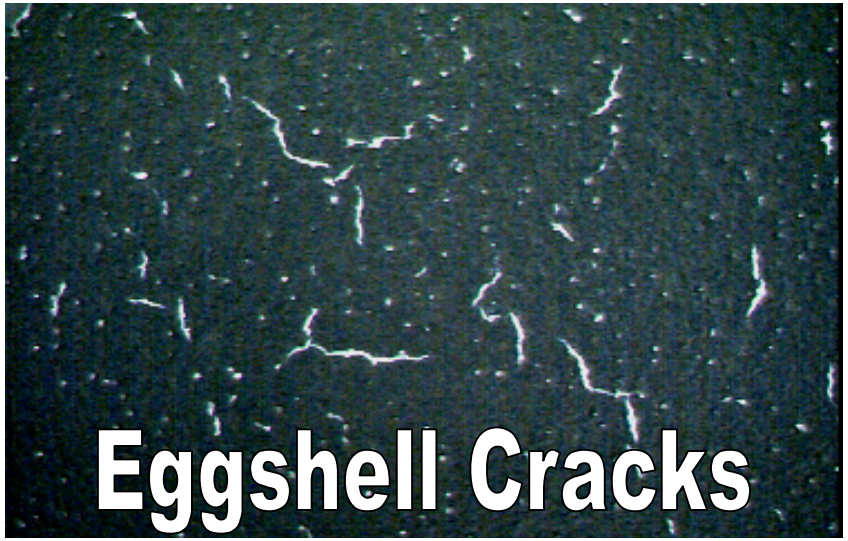
Operations search: dictionary splits converged on the print process as owning the Red X.

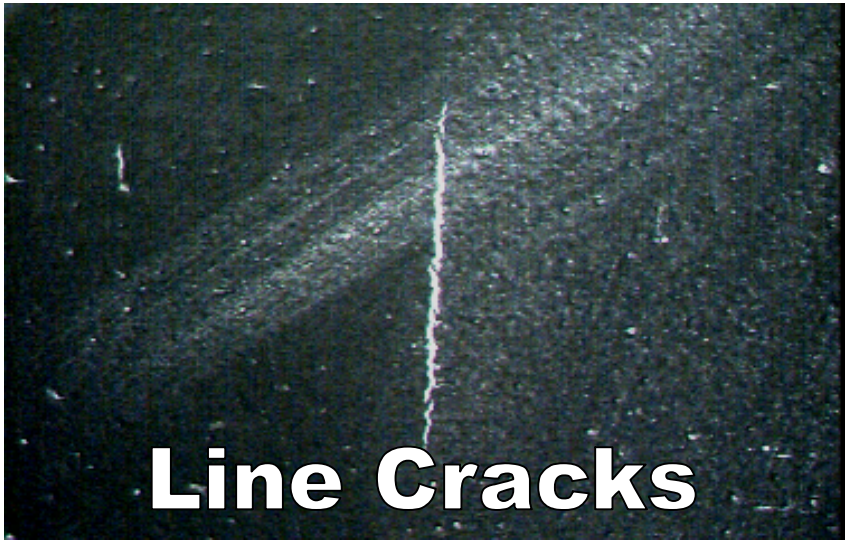
Cracks follow a thick deposit. Can move it from side to side.

Strategy choice: thickness hard to control. Make insensitive by lowering drying temperature. Passes B vs. C. Green Y run chart confirms effectiveness.

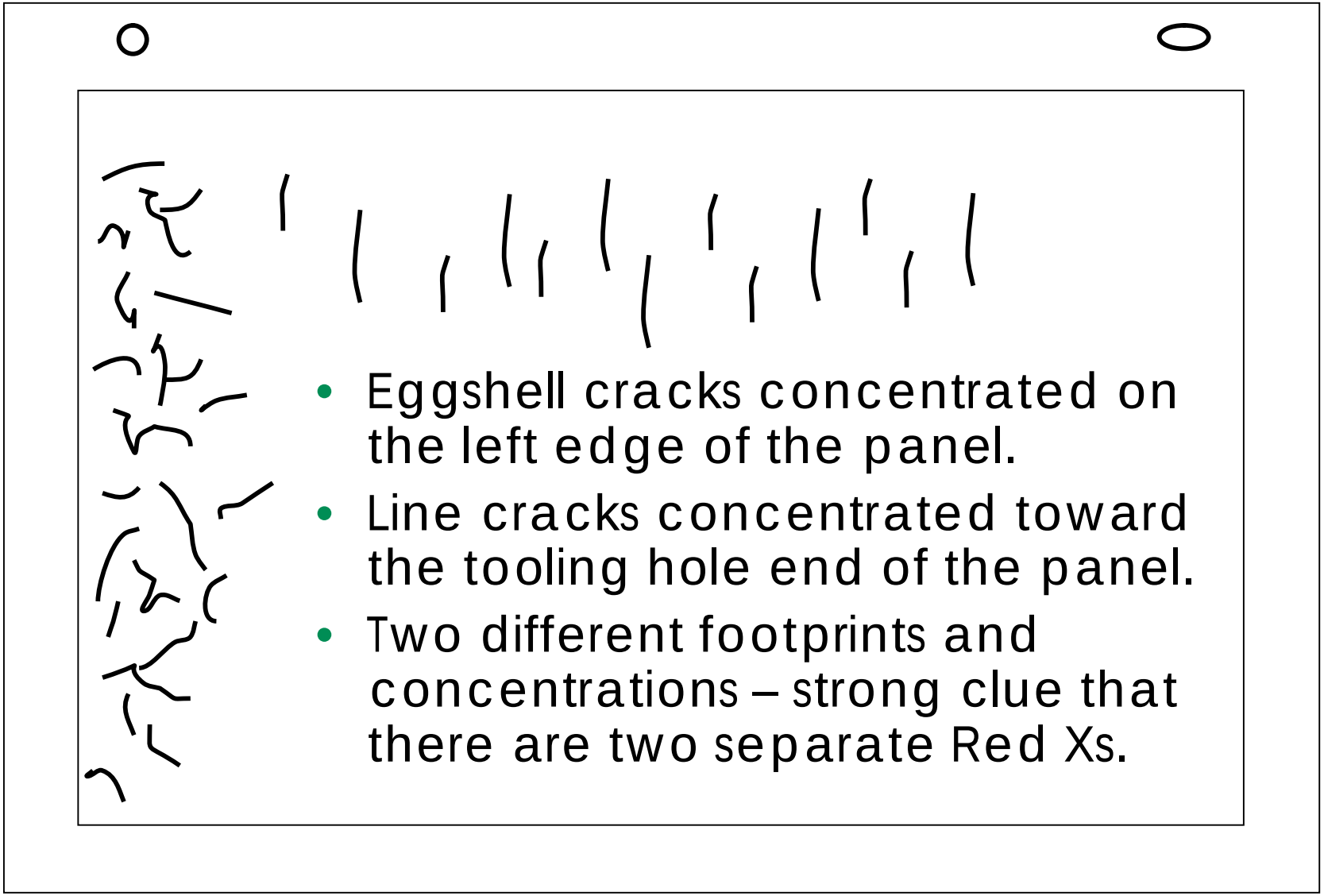
Carbon Cracks – Green Y

- Further inspection of the cracks revealed two defect footprints:
  - Line cracks
  - “Eggshell” cracks

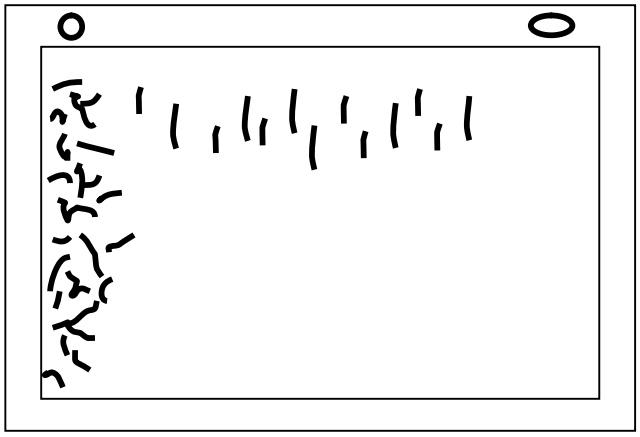




Carbon Cracks – Concentration Diagram

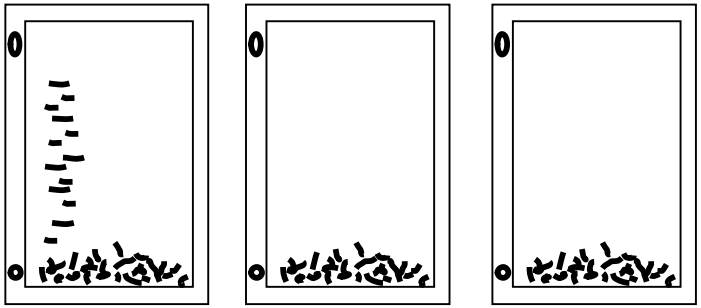


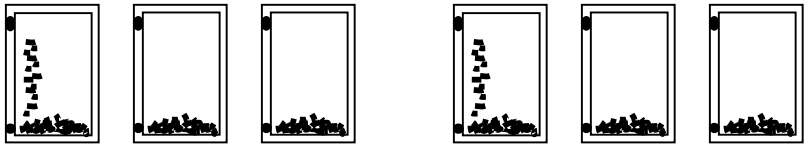
Carbon Cracks – Strategy Diagram



Flood

Print





WOW
0.5% Scrap

BOB
20% Scrap

BOB Point – WOW Point (WOW Region)

BOB Region – WOW Region (WOW Panel)

BOB Panel – WOW Panel (WOW Group)

BOB Group – WOW Group (WOW Run)

BOB Run – WOW Run

Notes

Large contrast: eggshell and line cracks look different. Small leverage.

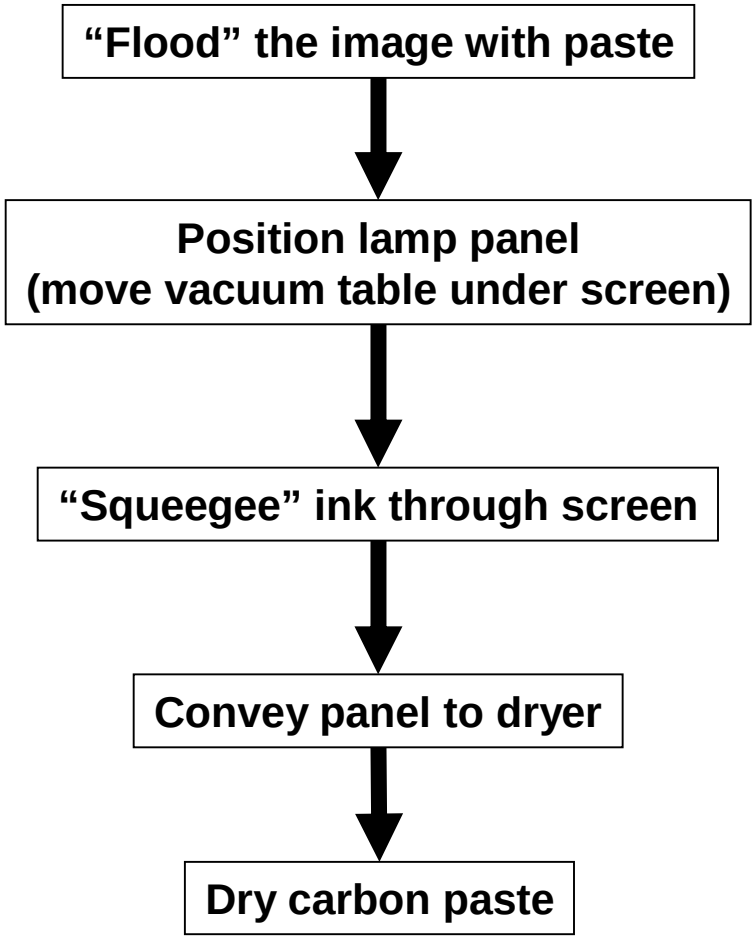
Large contrast: eggshell cracks on the edge of panels; line cracks toward tooling holes. **Excellent leverage**.

Some contrast: line cracks only occur on some panels. Possible leverage by watching the process. No contrast for eggshell.

No contrast: all parts of the run are the same.

Large contrast: WOW runs have > 20% scrap; BOB runs are nearly crack-free. Not much leverage.

Carbon Cracks – Process Flow

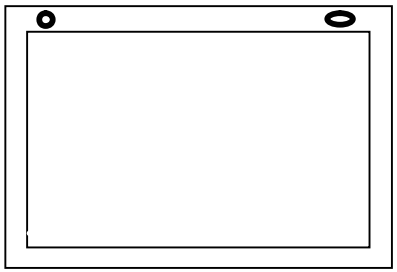


- Lamp panels come in, get printed, then dried.
- ***Cracks seen only after drying***.

Carbon Cracks – Split #1

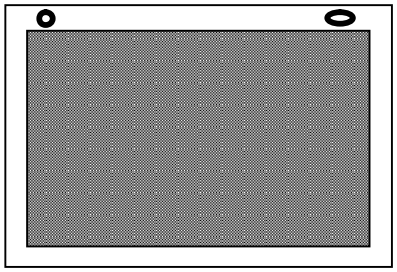
Red X lives here

Position Panel



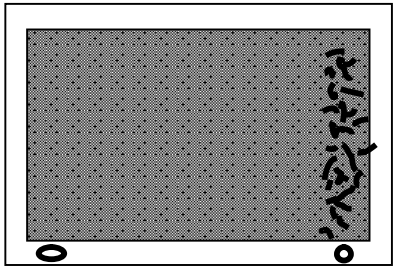
Panel with Phosphor and Dielectric layers already printed and dried.

Print Paste on Panel



Panel with wet carbon paste. Rotate 180 degrees before drying.

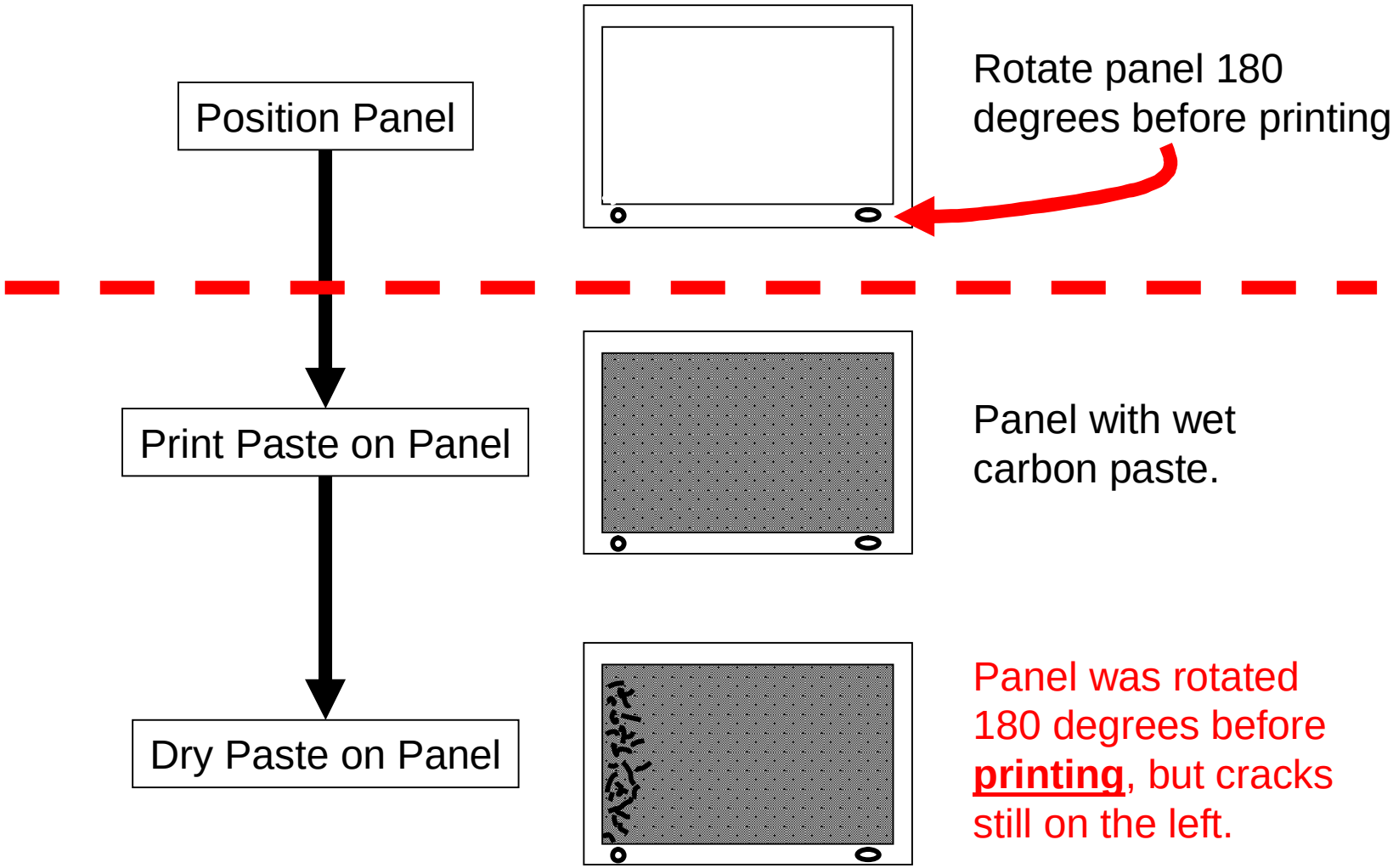
Dry Paste on Panel



Panel was rotated 180 degrees before **drying**, but cracks still on the left.

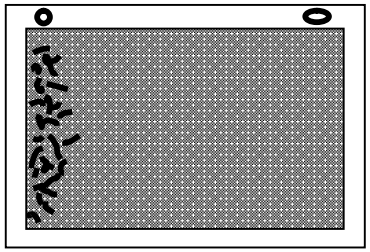
Result: Cracks stay on the left side relative to the process.
Conclusion: The Red X lives before drying (printing or the panel).

Carbon Cracks – Split #2

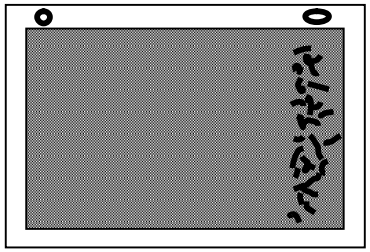


Result: Cracks stay on the left side relative to the process.
Conclusion: The Red X lives in the **print process**.

Moving the Cracks



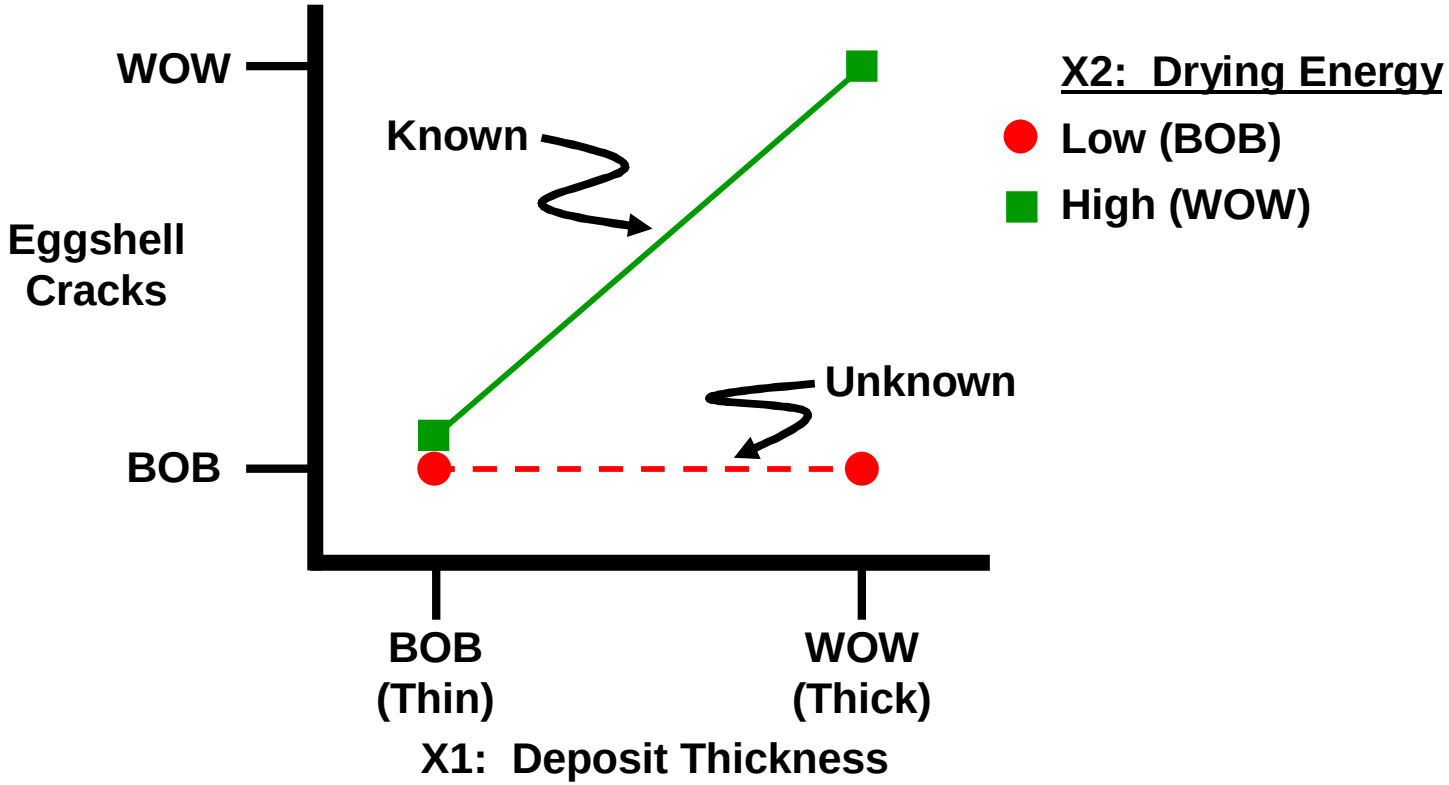
Measurements of deposit thickness of WOW panels from production showed that the WOW side was thicker (wedge pattern shown for illustration).



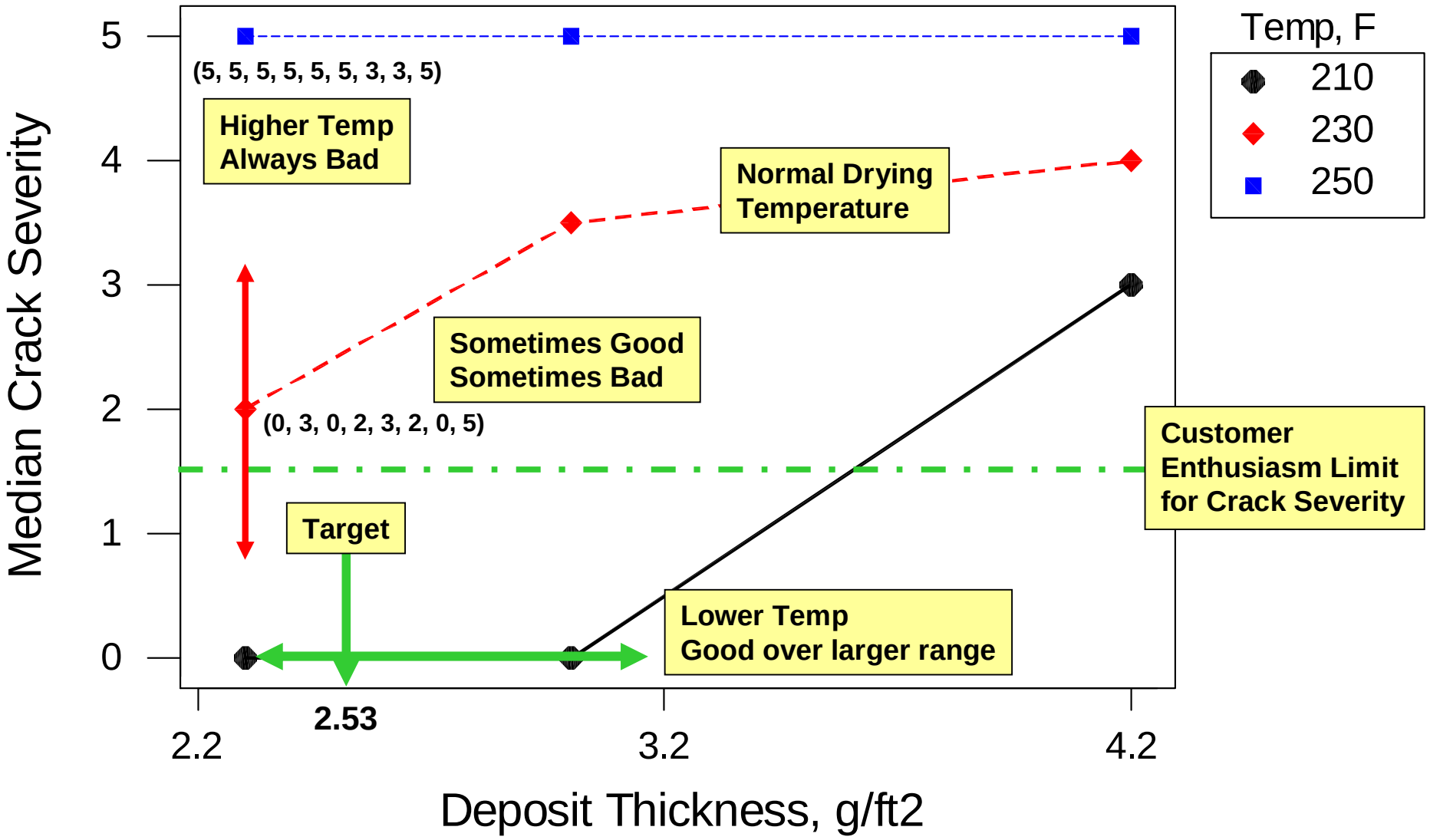
Reversed the profile of deposit thickness by adjusting the squeegee. Defects moved to the other side of the panel. Conclude that the defects follow deposit thickness.

Concept Diagram

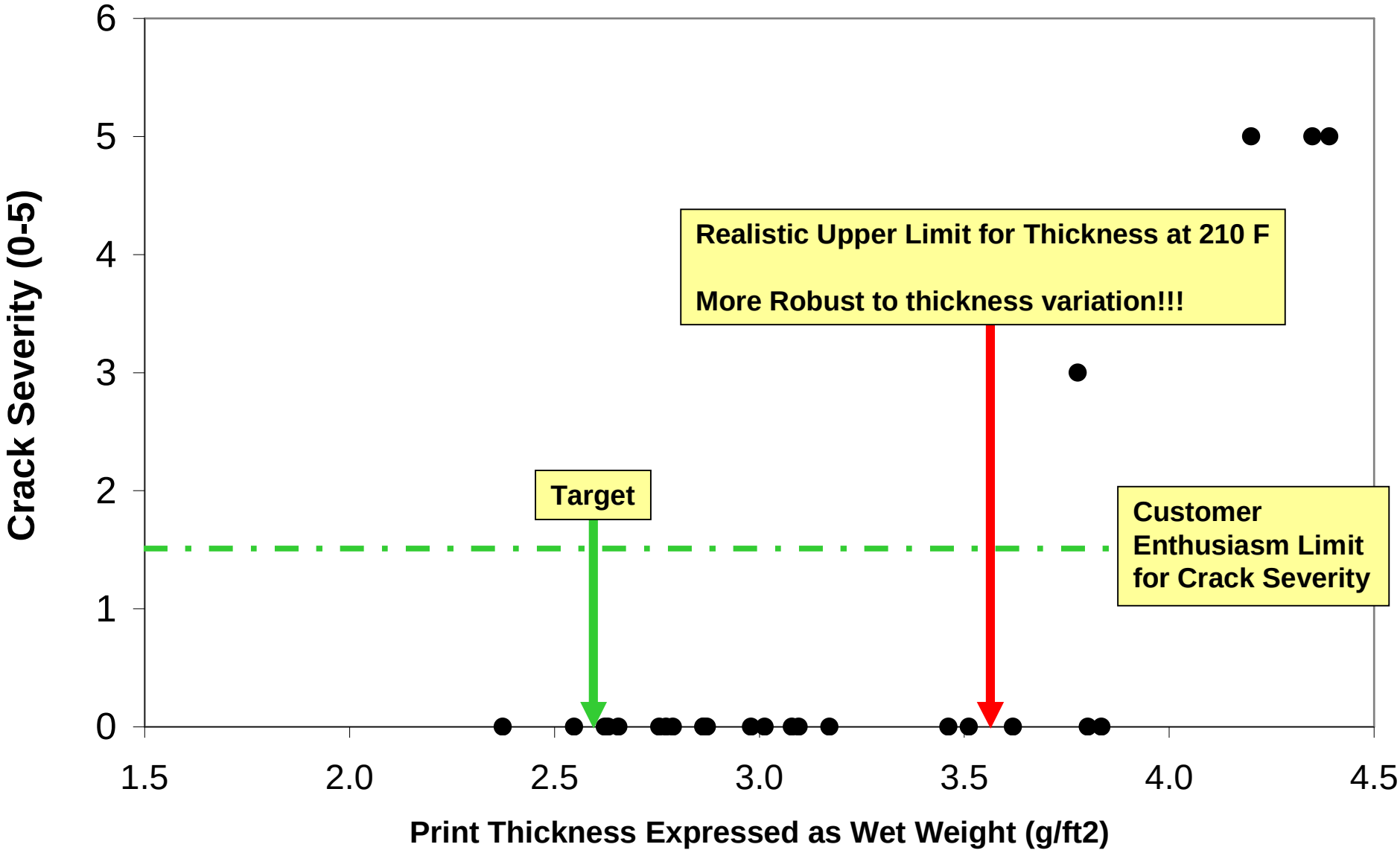
- Is there another X that would simply make deposit thickness irrelevant?



Sensitivity of Cracks to Oven Temperature & Thickness



Tolerance for Thickness at Lower Drying Temperature



Summary of Carbon Cracks Investigation

- Concentration Diagram showed leveragable non-random pattern.
  - Eggshell cracks only on the edge.
- Operations Search converged on the Red X process step.
  - Followed printing.
- Leveraged the BOB-WOW contrast on the edge.
  - Thicker deposit = WOW.
- Moved the defect to the other side by changing the deposit thickness profile.
  - "Understand it first, then fix it."
- Physics of cracking: energy vs. strength
  - Things break when energy > strength.
- Concept Diagram
  - Identified a potentially friendly interaction.
- **Permanent corrective action**
  - Reduce the energy: Change the temperature of the oven; confirmed to eliminate the defect 100%.