IPC Electronics Midwest 2010

Weigh/Bake/Weigh Testing To Determine Moisture Content in Printed Boards

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Biography:

Process Engineer and Supplier Quality Engineer

Joe has worked for over 30 years in Manufacturing Engineering and Quality Control with BAE Systems and its predecessor companies. Joe has a Bachelor's degree in Mechanical and Aerospace Engineering and graduated from GE's Manufacturing Management Program. He is a NARTE Certified ESD Engineer, and holds one US patent. He's contributed on several IPC committees developing standards; including the new IPC-1601 "Printed Board Handling and Storage Guidelines."

Executive Summary

Entrapped moisture within printed boards can expand during soldering operations, causing delamination or other damage. Available methods for determining moisture content may be destructive or non-destructive, and vary considerably in accuracy, equipment cost, and ease of use. This study assesses the methodology in the new test method IPC-TM-650 Method 2.6.28, and its applicability to the recently published IPC-1601 "Printed Board Handling and Storage Guidelines."

Moisture content was measured on samples of printed boards from various manufacturers, with differing laminate materials, constructions, and board thicknesses. Limitations and advantages of this test method are presented.

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Weigh/Bake/Weigh Testing for Moisture Content in Printed Boards

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Background

- Controlling moisture content in printed boards may prevent damage during soldering. Our previous study[1] measured moisture uptake and release in various environments.
- IPC-1601 “Printed Board Handling And Storage Guidelines” and IPC-TM-650 2.6.28 test method have since been issued.
  - IPC-1601 offers process control guidance, suggests <0.2% moisture content prior to dry packaging for PBs that will use tin/lead solder.
  - To determine moisture content, IPC-TM-650 2.6.28 calls for weighing before and after a 24-hour bake at 105 to 110° C.
  - These documents were intended for broad use by fabricators and users, while avoiding extra bakes or adding significant cost.

Given the tremendous variability in PB designs, how useful are these new IPC guidelines?

What we know

- Printed boards may be damaged during soldering, especially at lead-free temperatures.

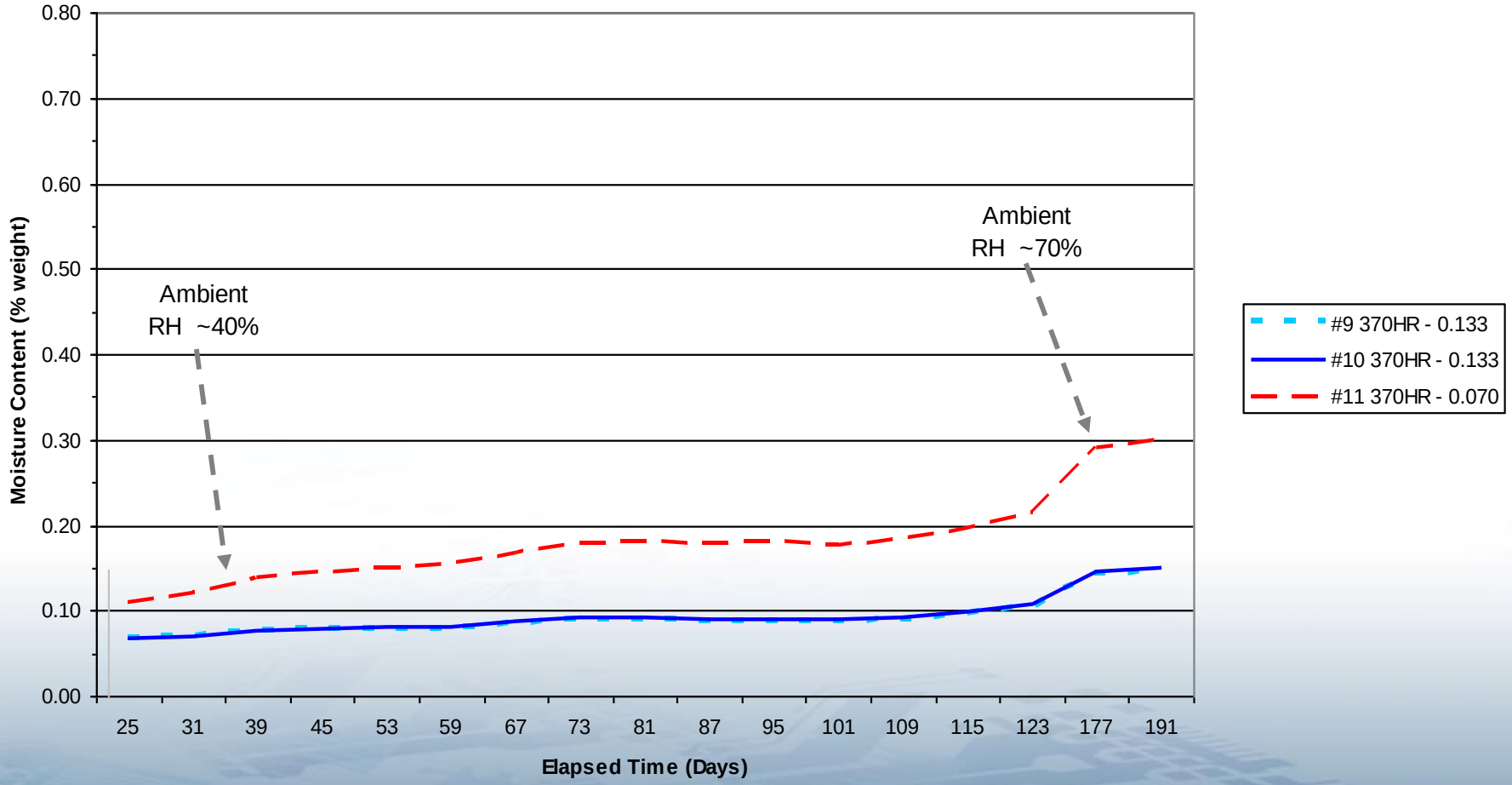
IPC-A-610E Fig. 10-17

- Risk varies with the laminate and other details of the design.
- In some cases, baking mitigates or eliminates risk.

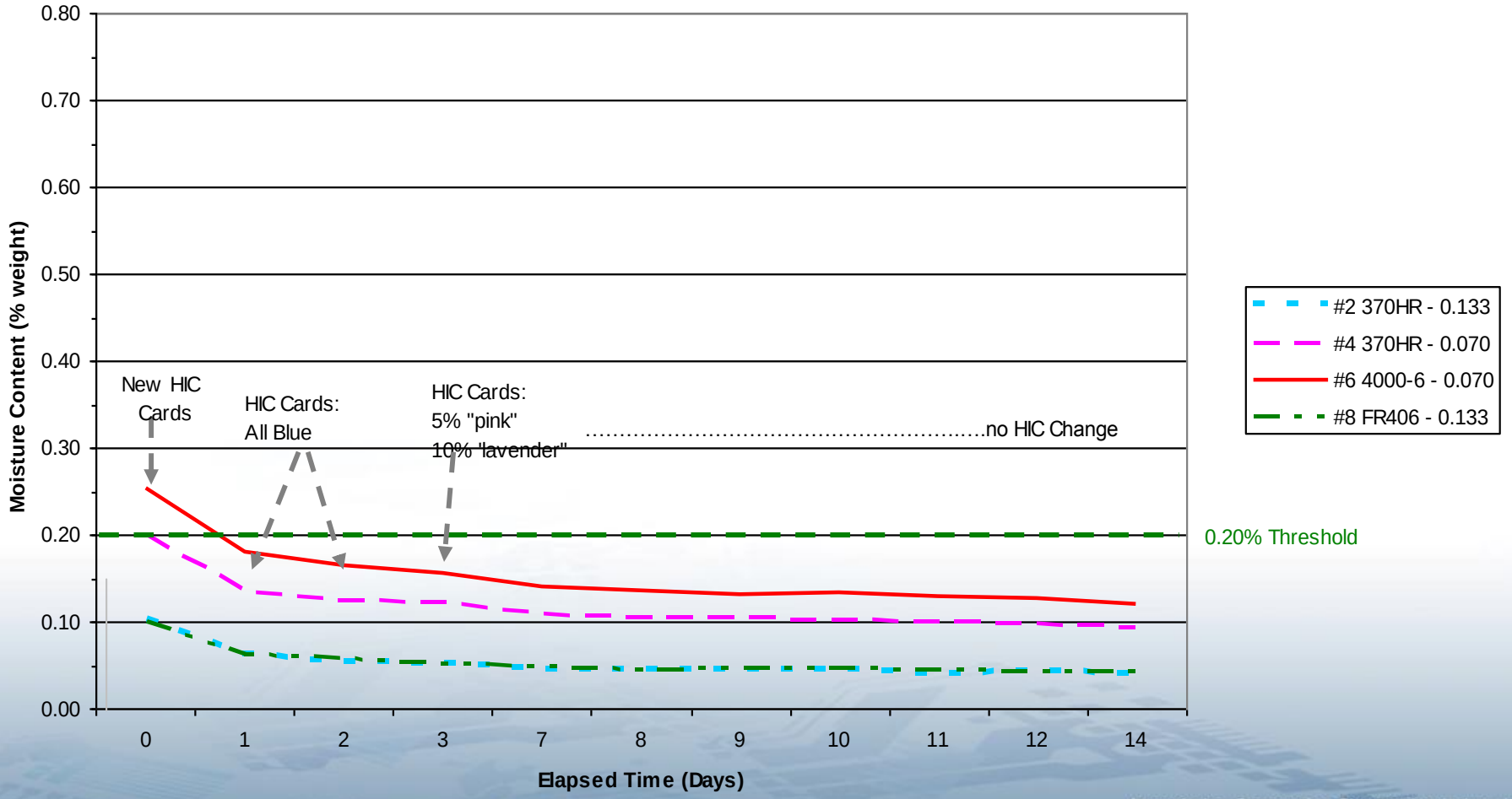
What we know (continued)

- During soldering, increased vapor pressure from entrapped volatiles may cause delamination or other damage.
- Volatile content inside most PBs is mostly water.
- Many laminates readily absorb moisture from the air.
- Rates of moisture uptake and release vary considerably depending on the laminate, the design, and environmental conditions during exposure.
- Our boards could be assembled and soldered within one week after they are shipped from the supplier.
- Baking to remove moisture should be avoided. It adds cost and cycle time and can compromise solderability.

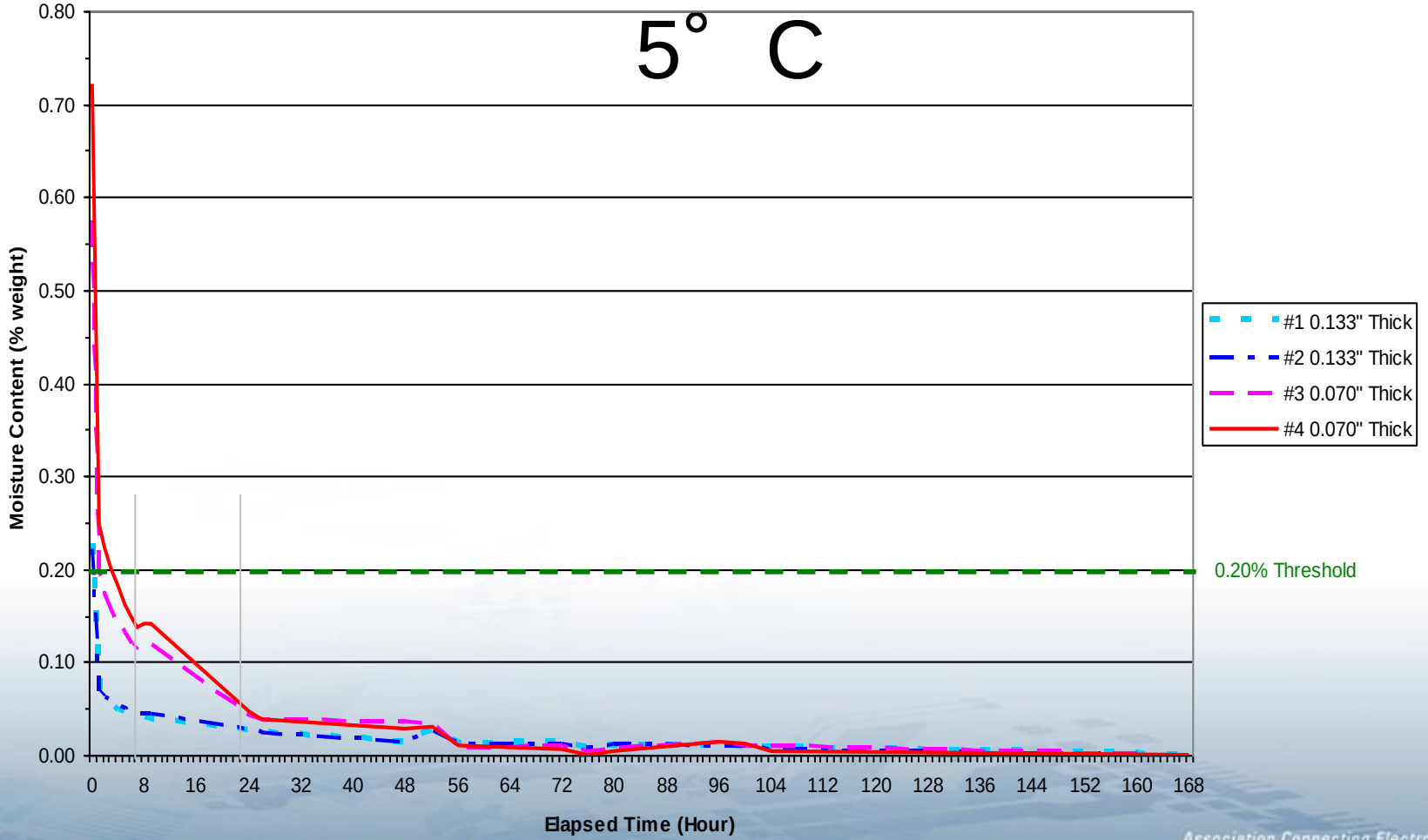
Ambient exposure of 370HR specimens



Moisture loss in a dry pack environment



370HR specimens baked At 100 ± 5° C



Conclusions from prior work

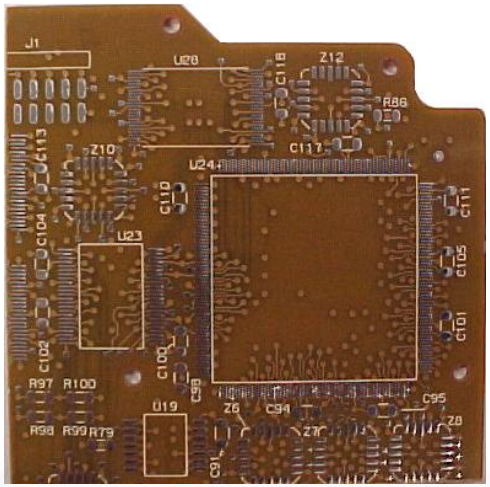
- The rate of moisture uptake for a PB in ambient conditions is extremely sensitive to RH.
- It is unlikely that a “dry” board at ambient will take on >0.2% moisture within seven days, even at 70% RH.
- Thinner boards absorb more moisture, as a proportion of their weight.
- A PB in a dry pack with desiccant will lose appreciable moisture within seven days.
- Baking at around 100˚ C will bring measurable moisture content well below 0.1% in less than 24 hours.

Moisture measurement techniques

- Options include gravimetric analysis, coulometric analysis, and microwave resonance.
- These methods involve tradeoffs; might not be readily adaptable to PB process control. (2,3)
- Weigh/bake/weigh testing has limitations, and may be less accurate in some cases, but it is:
  - Relatively simple and inexpensive.
  - Effective on finished PBs and samples containing copper.
  - Practical in shop environments for fabricators and users.
- IPC-TM-650 2.6.28 provides a consistent measurement technique that may have broad applicability.

Experimental method — samples

- All rigid board lots received during summer months included IPC-6012 Group A coupons and/or scrap board samples.
- All specimens were shipped in pink poly or other plastic bags (no desiccant).
- One specimen prepared per date code/lot:
  - Coupons sheared to ~5.5” long to fit in the analytical balance
  - If a coupon was unavailable, ~3” sq. sample was sheared from a scrap PB
- Specimens represent various laminates and constructions, from 4 to 20 layers, some with aluminum cores.



Experimental method — procedure

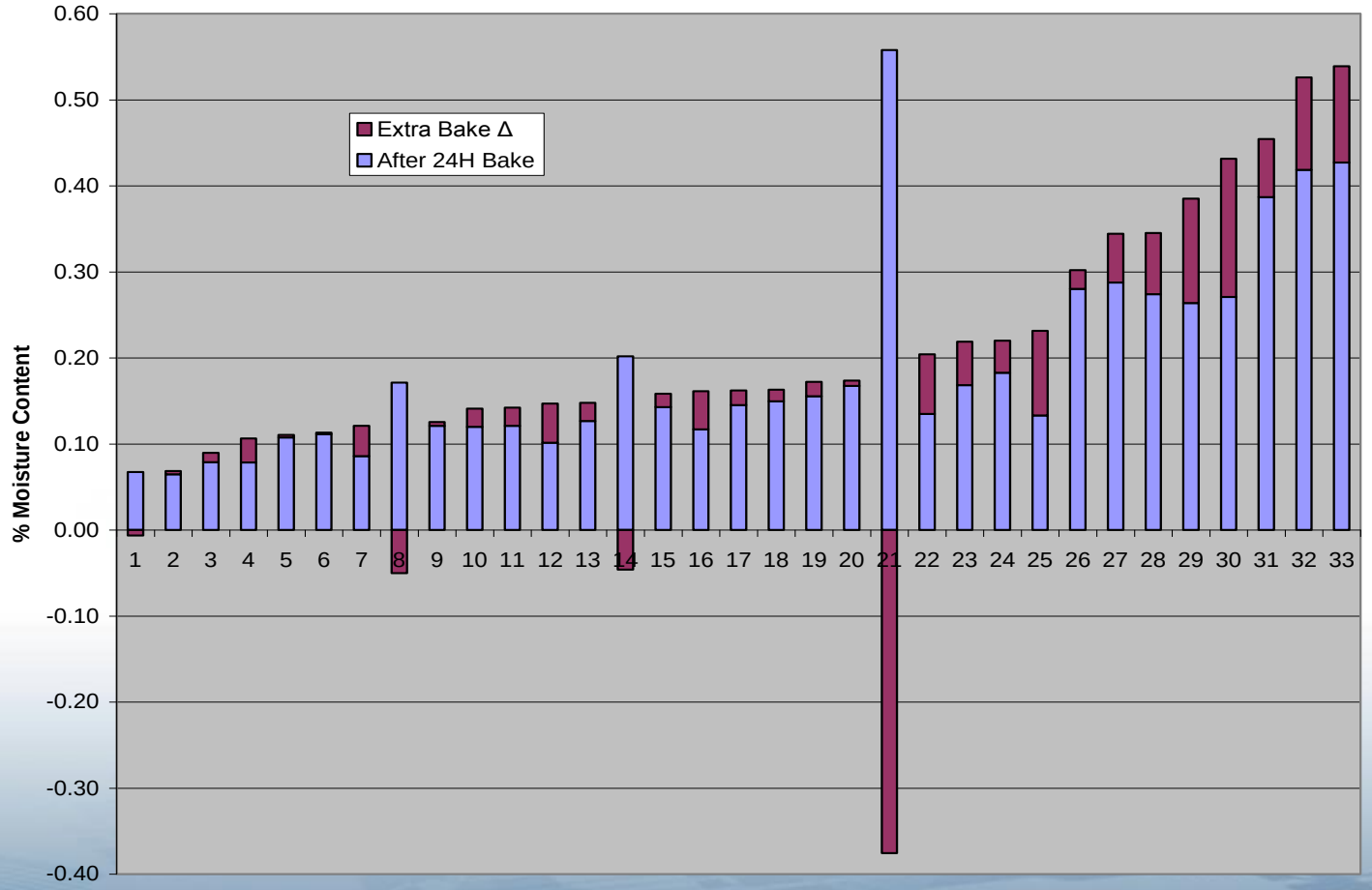
- Sheared surfaces were brushed lightly to remove any loose debris.
- Weigh/bake/weigh performed IAW IPC-TM-650 2.6.28:
  - Specimen handled using tongs or lint-free tissues.
  - Initial weight measured and recorded to ± 0.0001 gram.
  - Forced air recirculating oven, 24 hours at 105 –110° C
  - Weighed again, then returned to oven.
- Each specimen was then baked for at least 14 more days, and then weighed a third time.

$$\text{Moisture content} = \frac{\text{initial weight - post-bake weight}}{\text{Post-bake weight}}$$

Experimental limitations; caveats

- Handling practices and cycle times vary among suppliers.
- Specimens represent worst-case handling, not the state of actual boards when received. Specimens were kept in plastic bags with no desiccant from the time they left the supplier until the first weighing.
- The following specimen characteristics may vary considerably, but cannot be characterized easily:
  - Amount and distribution of Cu
  - Moisture content deep within the substrate, including “bound” moisture

Specimen moisture content



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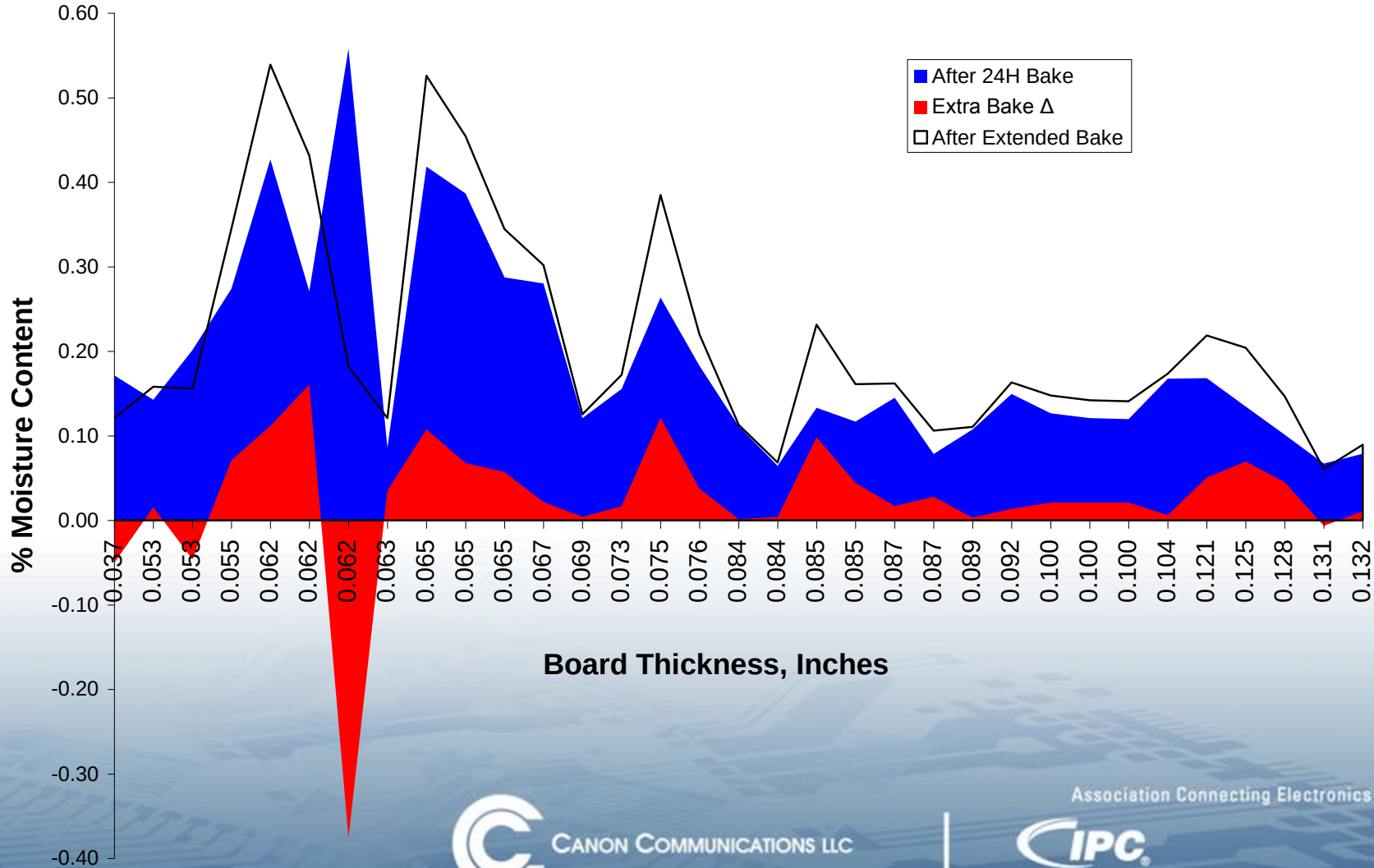
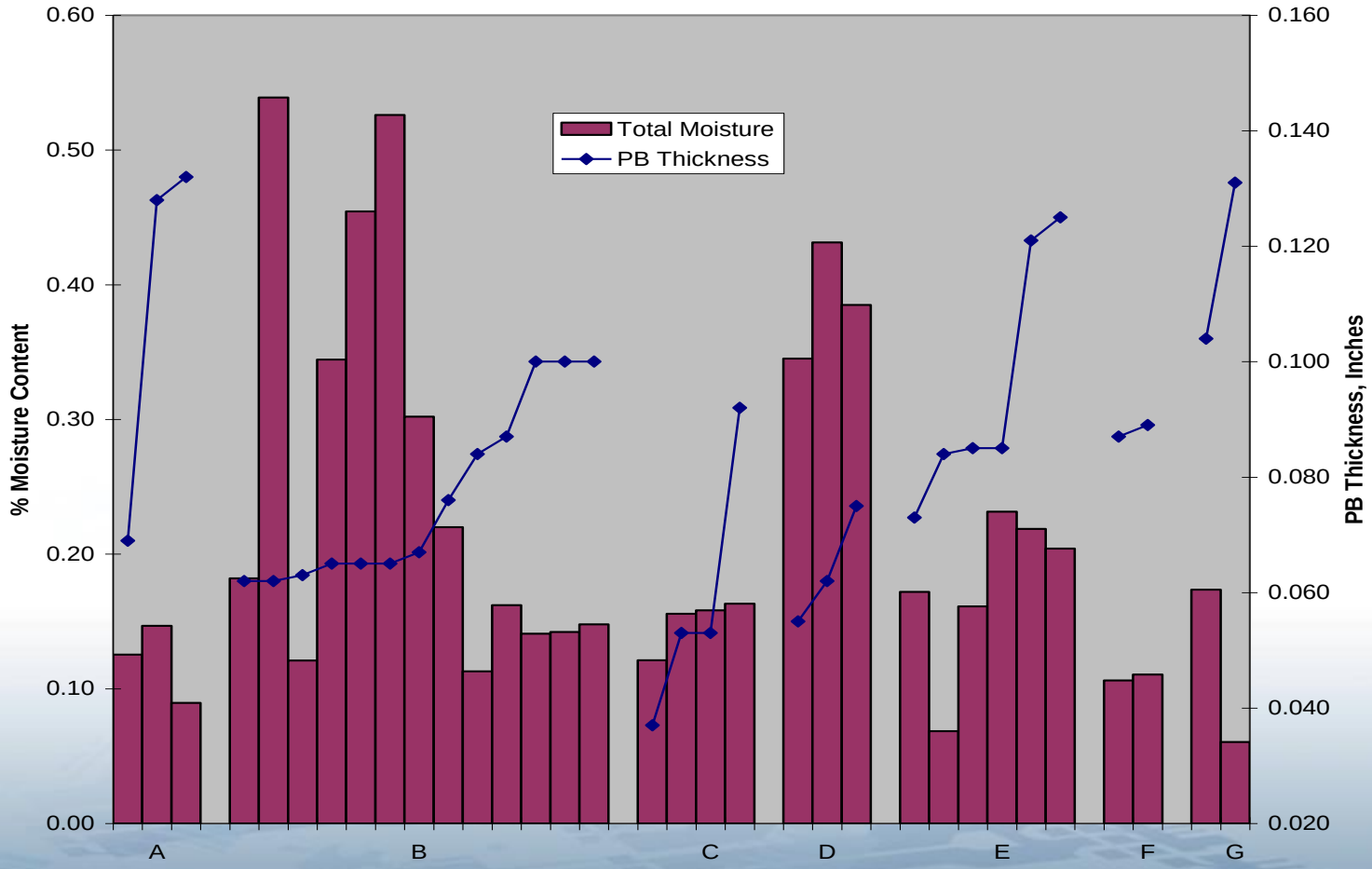
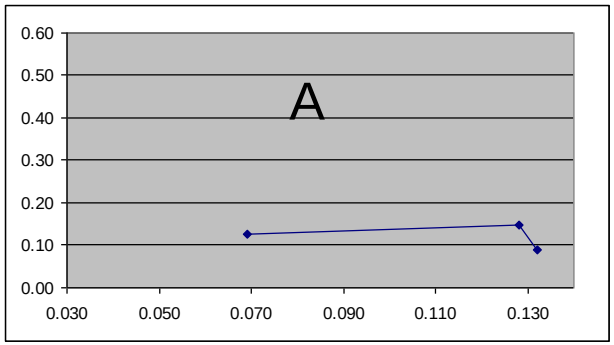
Percent moisture vs. board thickness

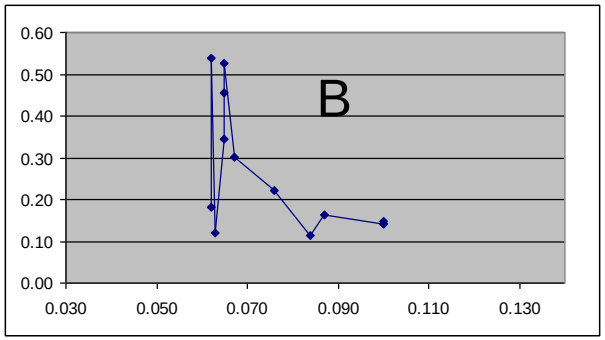


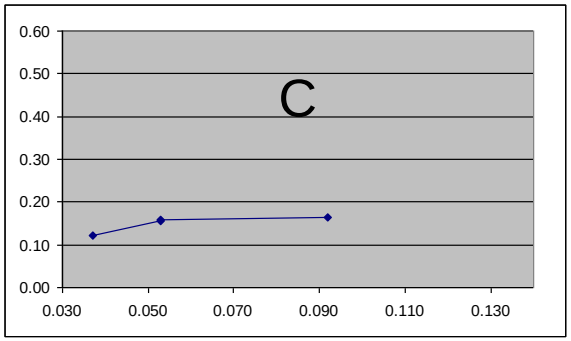
Moisture and thickness by supplier

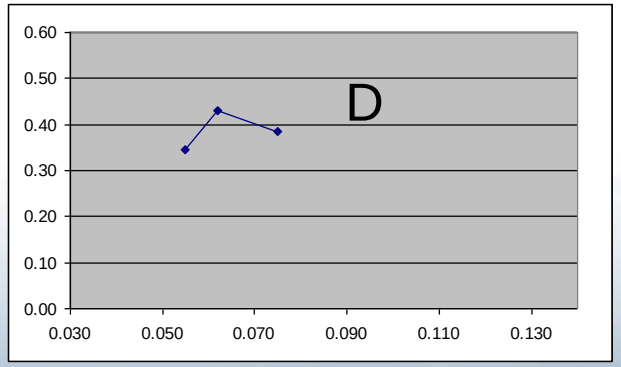


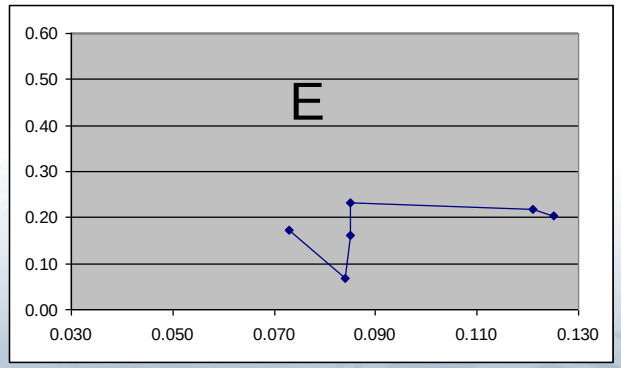
Moisture vs. thickness by supplier

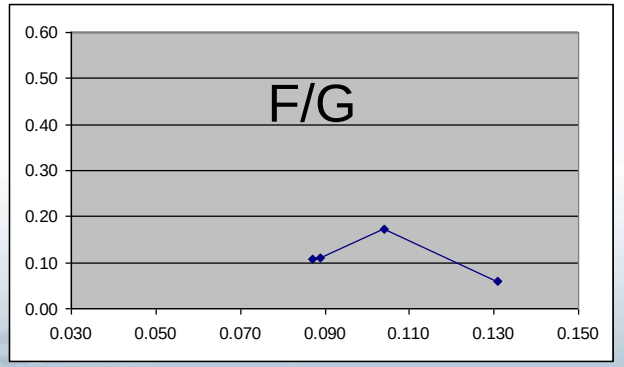




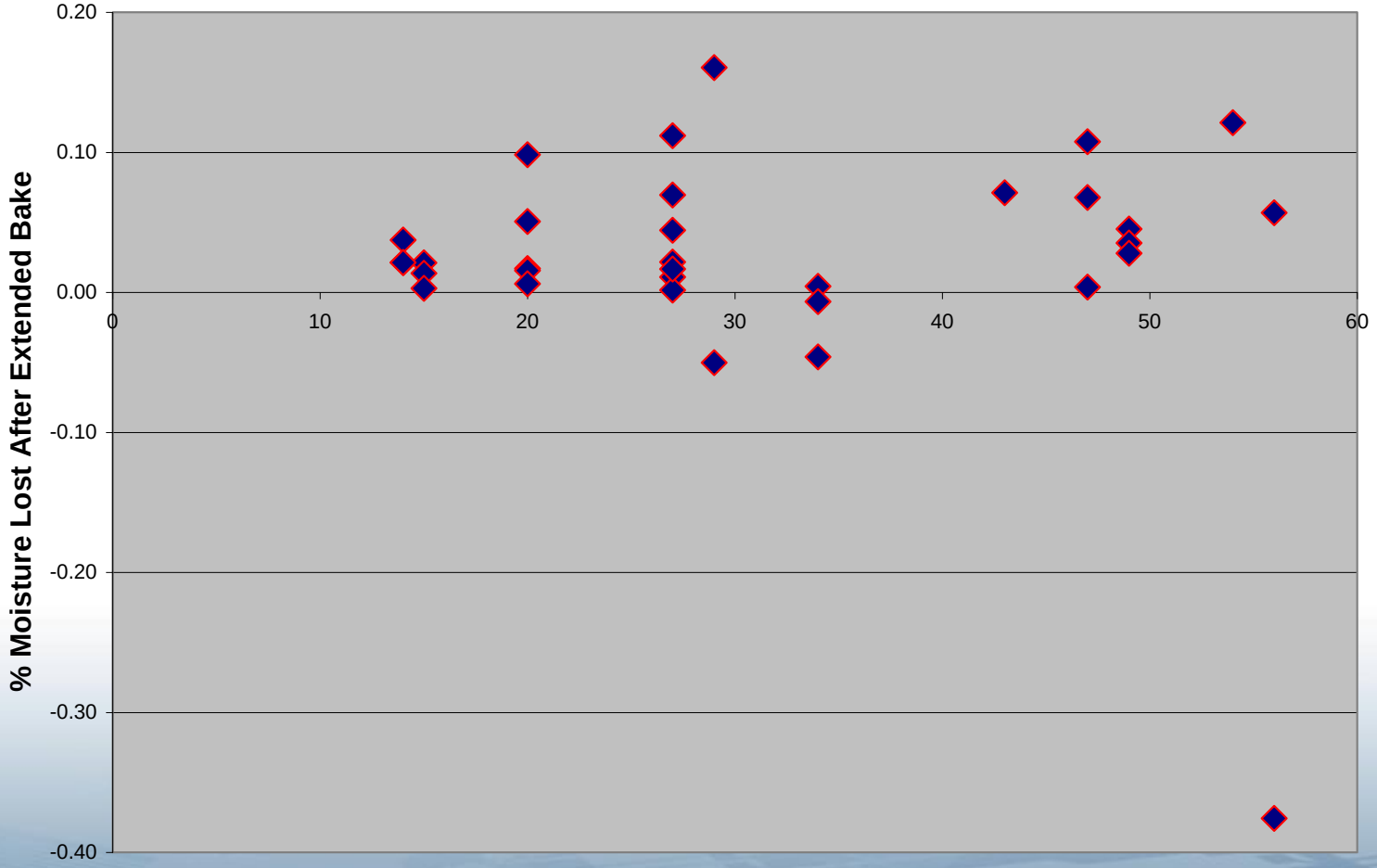








Moisture lost after extended bake



Conclusions

- Many of our PBs already are being received with <0.2% moisture content, even without dry pack, even during warmer months.
- The most significant variable affecting as-received moisture content in a PB is the supplier.
- Moisture content from individual suppliers varies considerably, regardless of PB thickness.
- With consistent application of best practices, our suppliers should be capable of meeting the 0.2% moisture requirement.
- In 88 percent of cases, IPC-TM-650 2.6.28 test method under-represented moisture content by 0.1% or less.

Questions for future work

- Is there a better way to measure moisture content on full-size PBs?
- How do we measure or estimate the copper content in a PB or a sample?
- Why do some samples gain weight after long bakes? Can this be explained by oxidation?

References

(1) J. Kane, S. Cook, L. Bill, T. Hartford, H. Fuerstenberg, "Water Vapor Uptake And Release In Printed Boards," presentation for IPC-Midwest 2009

(2) P. Carroll, S. Bell, M. Stevens, "Calibration Issues for Measurement of Moisture in Materials," NPL Report ENG 21, January 2010

(3) C. Hunt, M. Wickham, O. Thomas, L. Zou, "Assessment Of Moisture Content Measurement Methods For Printed Circuit Boards," APEX 2010