TWENTIETH ANNUAL

TestConX™

March 3 - 6, 2019

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Mesa, Arizona

Archive

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Wafer Sort
At Extreme Temperatures

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TestConX

Mesa, Arizona ● March 3 - 6, 2019

2000 - 2019 20 YEARS ANNIVERSARY

TERADYNE

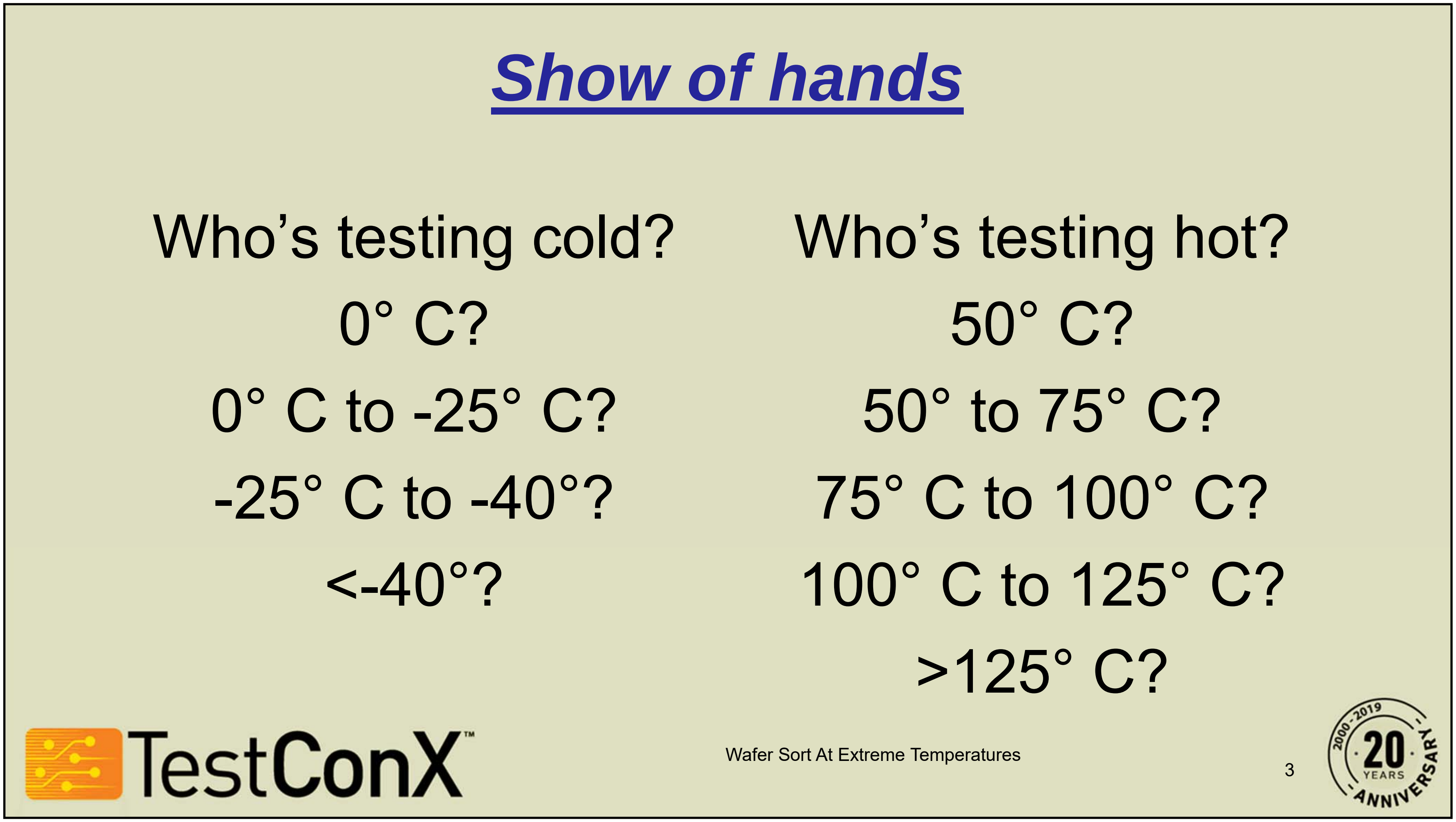
Welcome to the Badlands!

COLD!

-40 to -70° C

HOT!

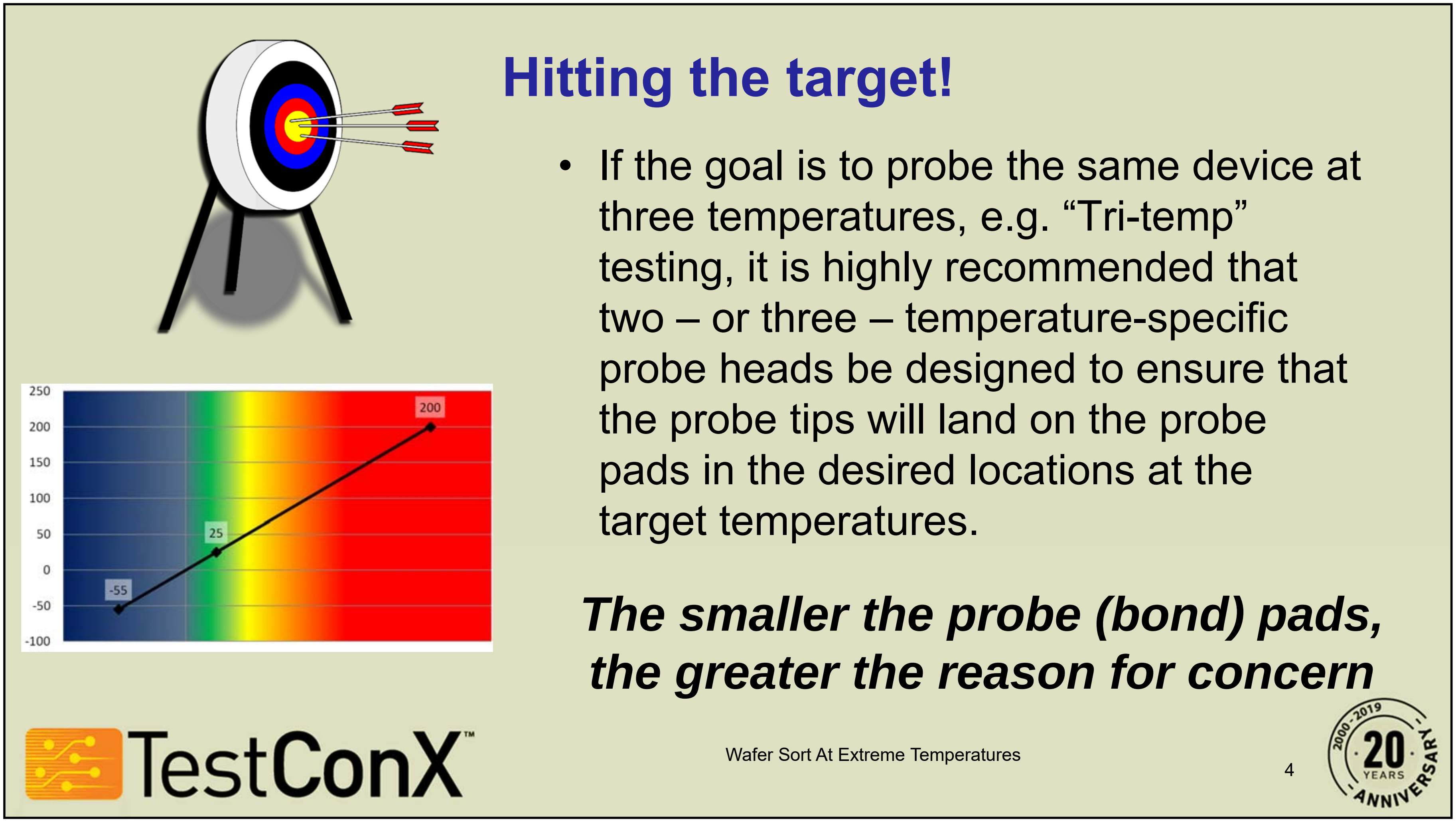
+125 to 200° C



Show of hands

Who's testing cold?
0° C?
0° C to -25° C?
-25° C to -40°?
<-40°?

Who's testing hot?
50° C?
50° to 75° C?
75° C to 100° C?
100° C to 125° C?
>125° C?

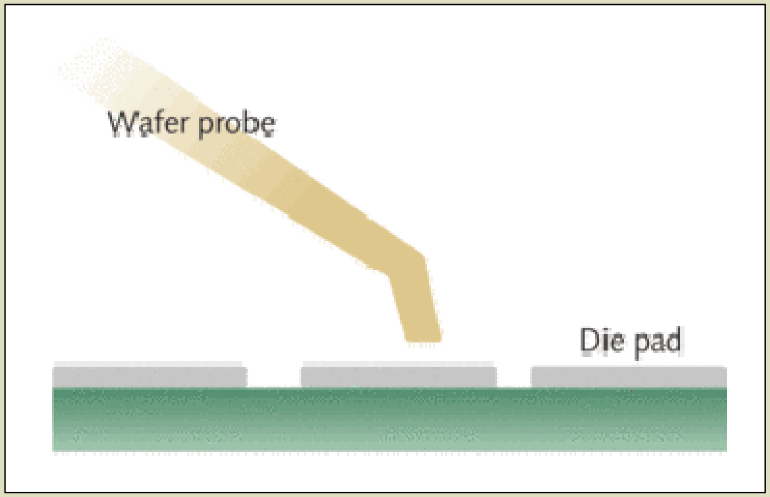


Hitting the target!

- If the goal is to probe the same device at three temperatures, e.g. “Tri-temp” testing, it is highly recommended that two – or three – temperature-specific probe heads be designed to ensure that the probe tips will land on the probe pads in the desired locations at the target temperatures.

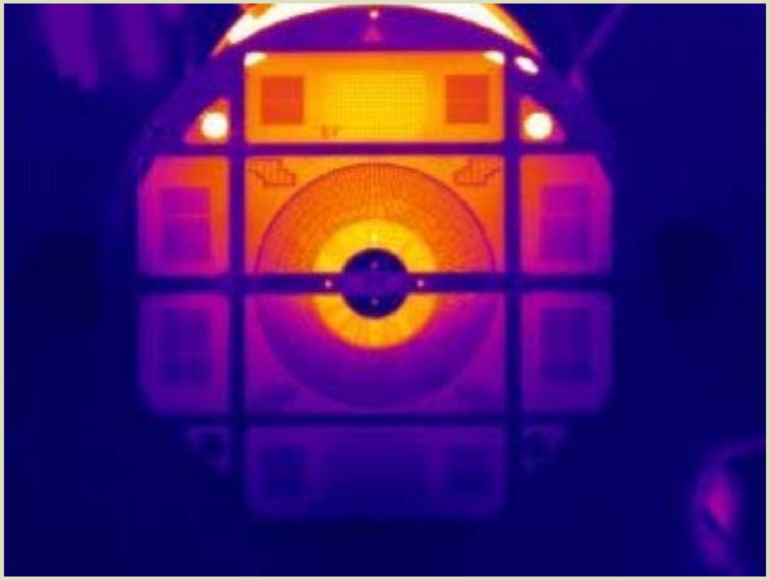
The smaller the probe (bond) pads, the greater the reason for concern

Hitting the target — again and again!



- The probe head and the probe card X-Y plane expansion / contraction will not perfectly match the CTE (Coefficient of Thermal Expansion) of wafers
- As probe temperatures change there will be variation of location of the probe tips within the touchdown pattern, hence the practice of utilizing temperature-range-specific probe heads

For Hot Sort the Wafer Chuck is the Heat Source



- Motion of the wafer chuck affects the probe card assembly temperature profile, therefore the probe needles' z-position
- Getting a wafer, checking probe tip height with the prober's upward-looking camera, probe tip cleaning / polishing – all of these steps move the wafer chuck away from the probe head for several minutes.

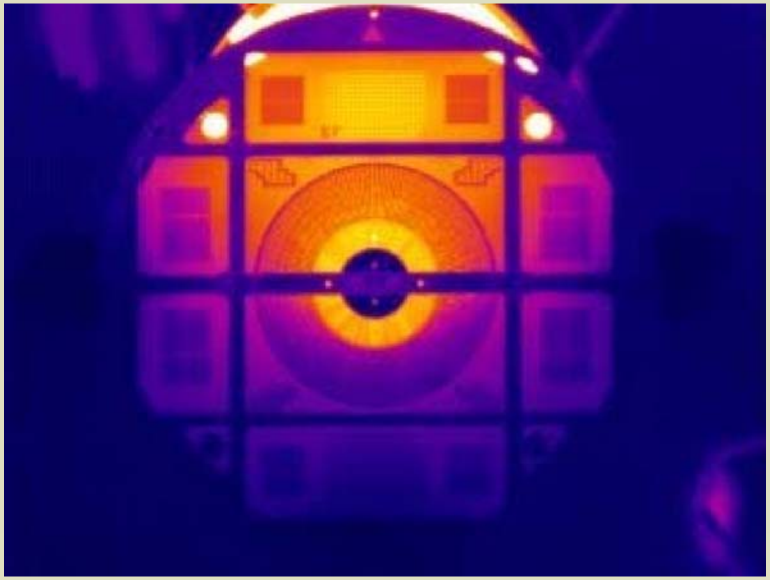
Image from:

IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

probing@hot temperature
a new thermal approach to probing accuracy

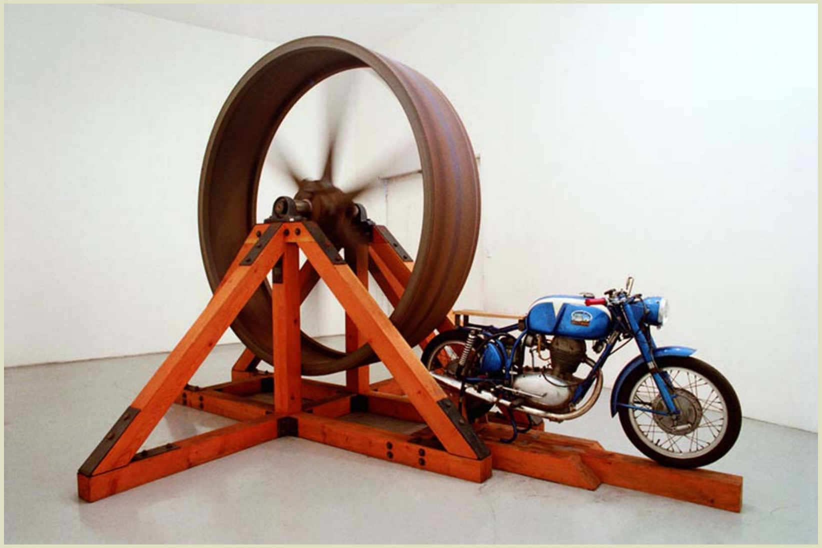
Harald Berger
Walter Seitz
Klemens Reitinger
Robert Stoiber

Why this is a problem

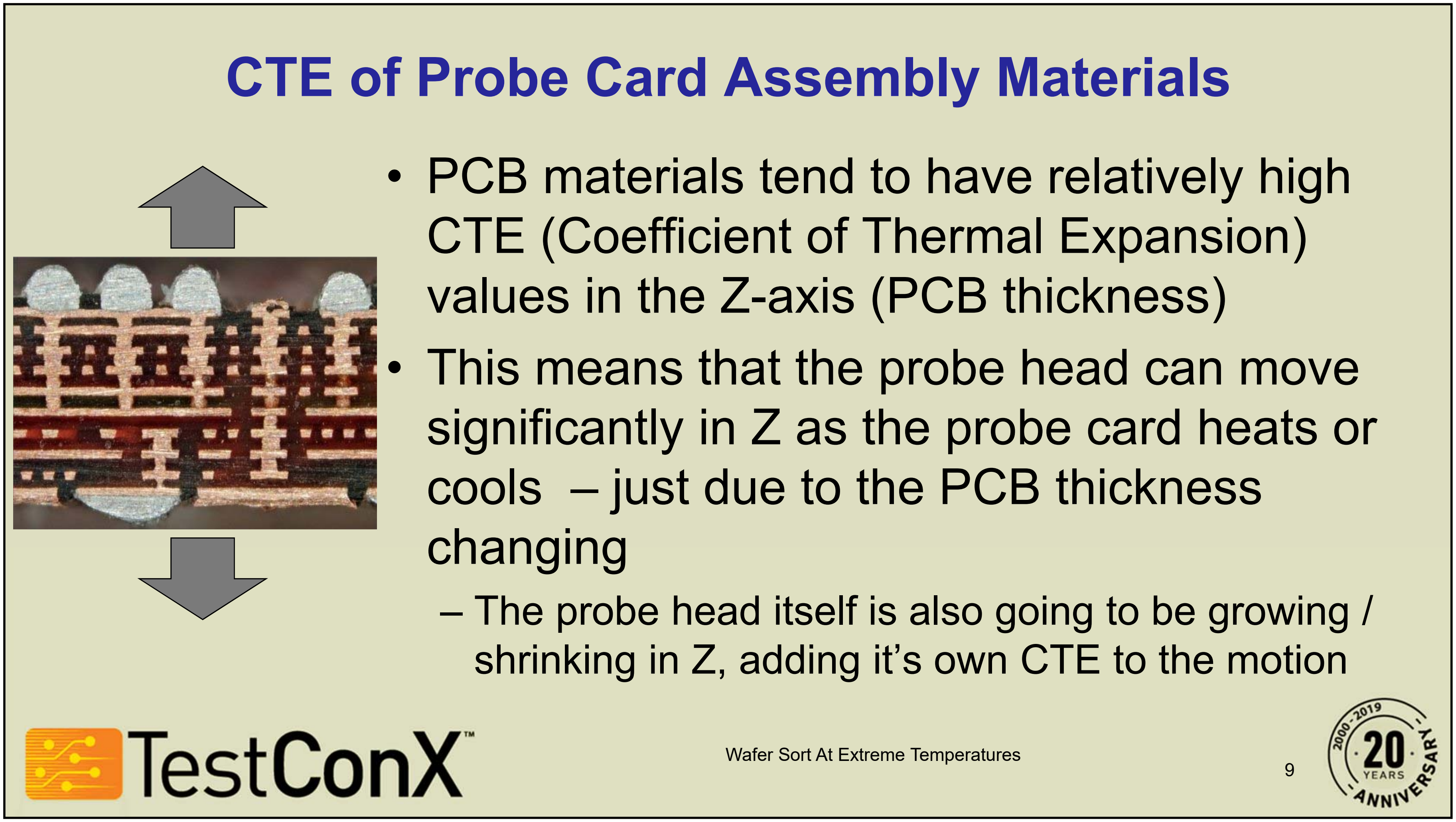


- Process steps that move the chuck away from the probe head will result in significant cooling (or heating) of the probe card assembly, potentially on just one side, which in turn means that the probe needles can move significantly and unpredictably in Z during these process steps

Thermal Mass (Flywheel Effect) to the Rescue:



- Designing in a large mass of thermally-bonded metal above the probe head that heats during the prober / probe card soak phase helps maintain probe card and probe head temperature during those periods when the chuck isn't under the probe head



CTE of Probe Card Assembly Materials

- PCB materials tend to have relatively high CTE (Coefficient of Thermal Expansion) values in the Z-axis (PCB thickness)
- This means that the probe head can move significantly in Z as the probe card heats or cools – just due to the PCB thickness changing
  - The probe head itself is also going to be growing / shrinking in Z, adding it's own CTE to the motion

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Wafer Sort At Extreme Temperatures

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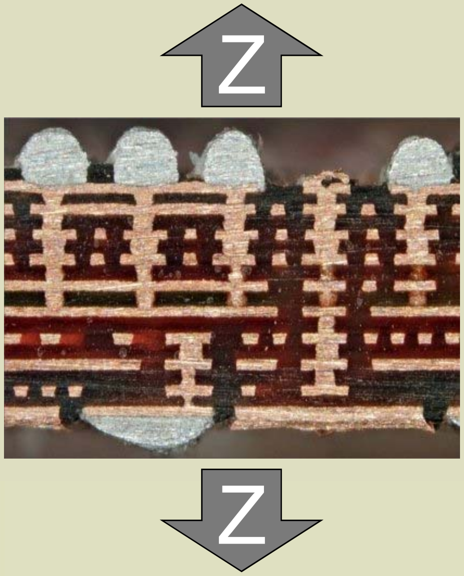
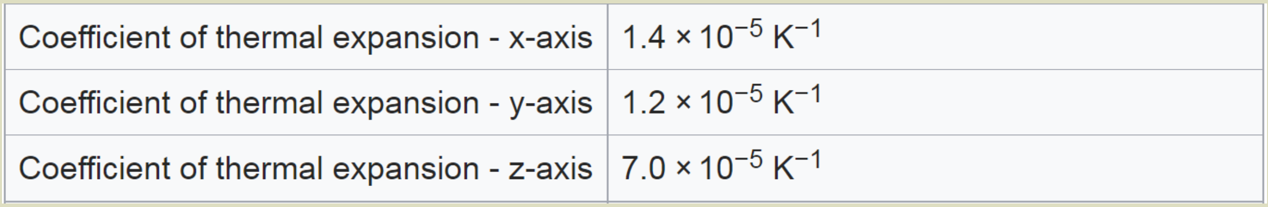
CTE of Probe Card Assembly Materials



- Data from Wikipedia for FR-4:

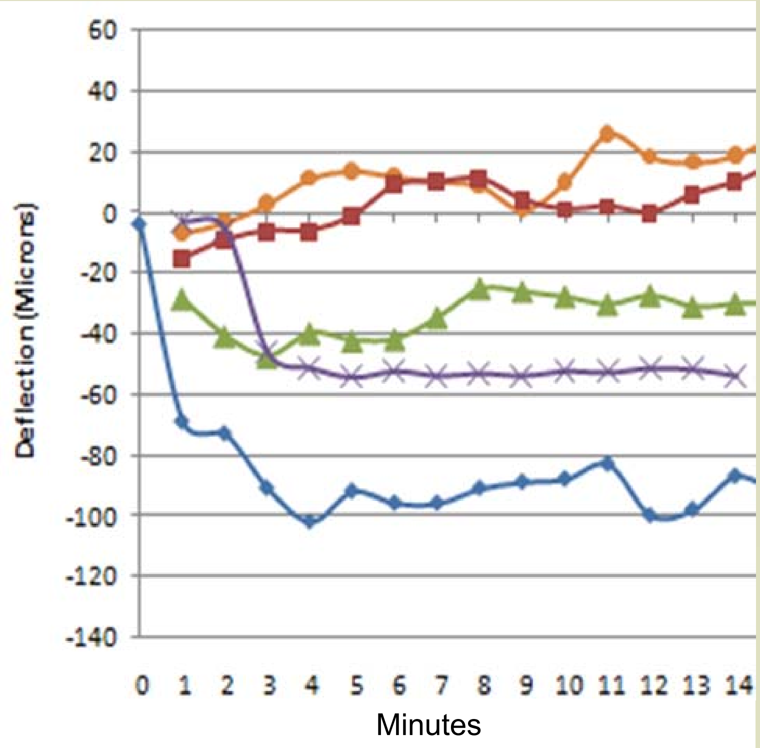


Coefficient of thermal expansion - x-axis	$1.4 \times 10^{-5}\ \mathrm{K}^{-1}$
Coefficient of thermal expansion - y-axis	$1.2 \times 10^{-5}\ \mathrm{K}^{-1}$
Coefficient of thermal expansion - z-axis	$7.0 \times 10^{-5}\ \mathrm{K}^{-1}$

CTE of Probe Card Assembly Materials, cont.

- The probe card stiffener will also be growing and shrinking due to its own, different CTE in the X-Y plane, resulting in bowing of the probe card either upwards or downwards
- This motion is driven by the construction of the probe card, the probe head, the design and material of the probe card stiffener, whether there's a heat shield on the probe card assembly and the design of the wafer sort interface

Watch the probe tips dance!



- A spring-probe-style probe card used to collect this data
- The PCB and the probe head are expanding or contracting, causing probe needle Z-Movement
- ***The BLUE line is the Z height of the average of 4 needles on one probe head***
- The **ORANGE**/**RED**/**PURPLE**/**GREEN** lines are locations on the PCB near the probe head at 12/3/6/9 o'clock positions.
- The graphic illustrates that some things are going up, some down, some essentially not moving, etc.

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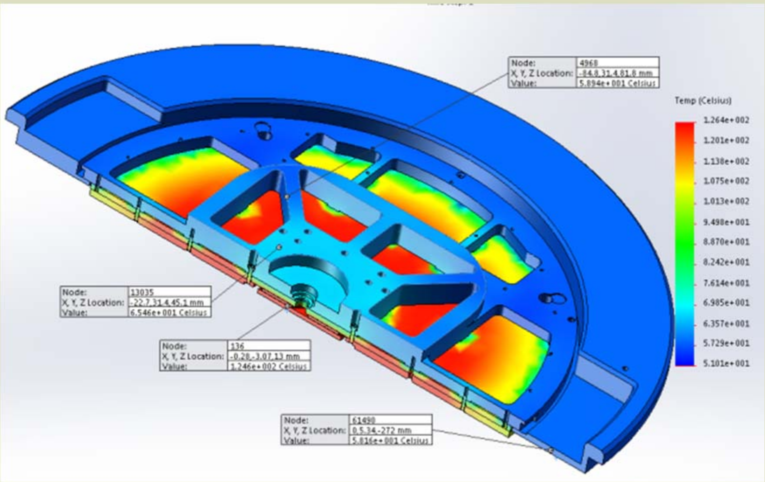
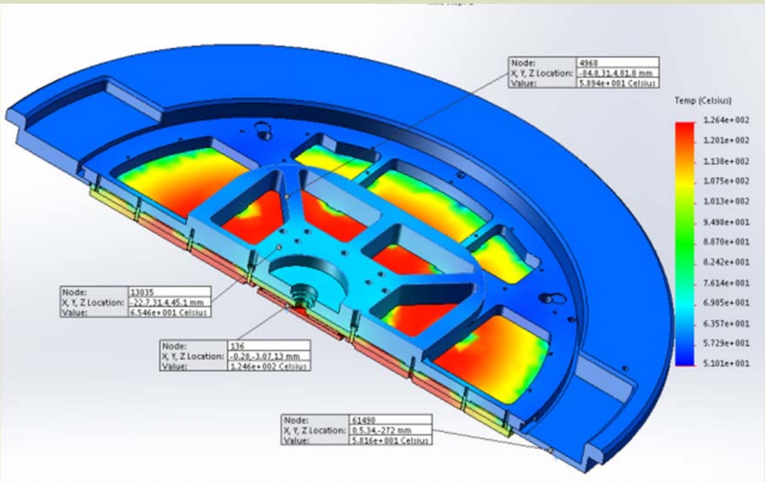
Typical Hot Sort Probe Card Temperatures



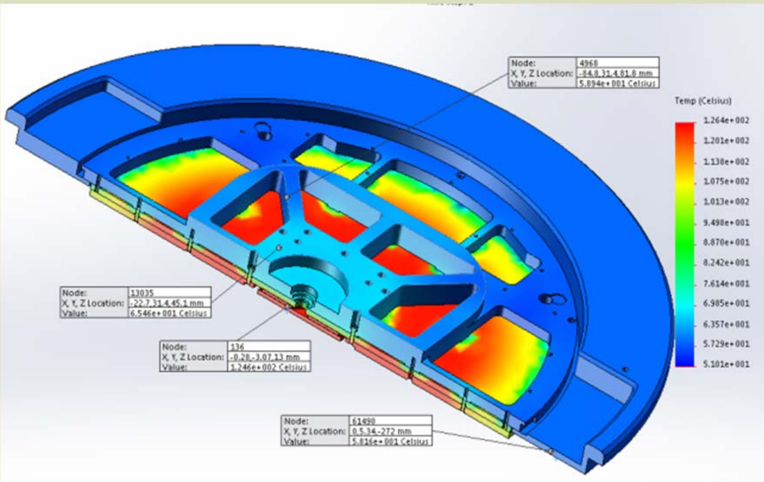
- Conductivity is a significant source of heat transfer in wafer sort. This heat transfer is a function of probe head size (% of wafer being touched down upon) and the ΔT between the probe head and the chuck set point
  - This means that test time can change not just the probe card temperature but also the magnitude of Z-deflection seen during temperature sort

Typical Hot Sort Probe Card Temperatures, cont.



- Thermal radiation is also a significant driver
  - For extreme hot sort, a metallic wafer-side heat shield – with an air gap between the shield and the PCB – is a great idea to keep the PCB / probe card stiffener cooler

Typical Hot Sort Probe Card Temperatures, cont.



- A Rule of Thumb is that tester side of the probe card PCB will reach a metastable temperature of ambient plus 1/3rd the ΔT relative to ambient
- For example, this RoT predicts that a 150°C sort temp will drive the <u>tester</u> side of the probe card PCB to roughly 63°C

$$T_{tester\ side} = 20 + \left(\frac{150 - 20}{3}\right) = 63°$$

The Wafer Touchdown Pattern Matters

VS.

- **DO THIS**: One way to stabilize / manage the temperature of the probe card and head is to use a spiral touchdown pattern, one which moves progressively towards or away from the center of the wafer.

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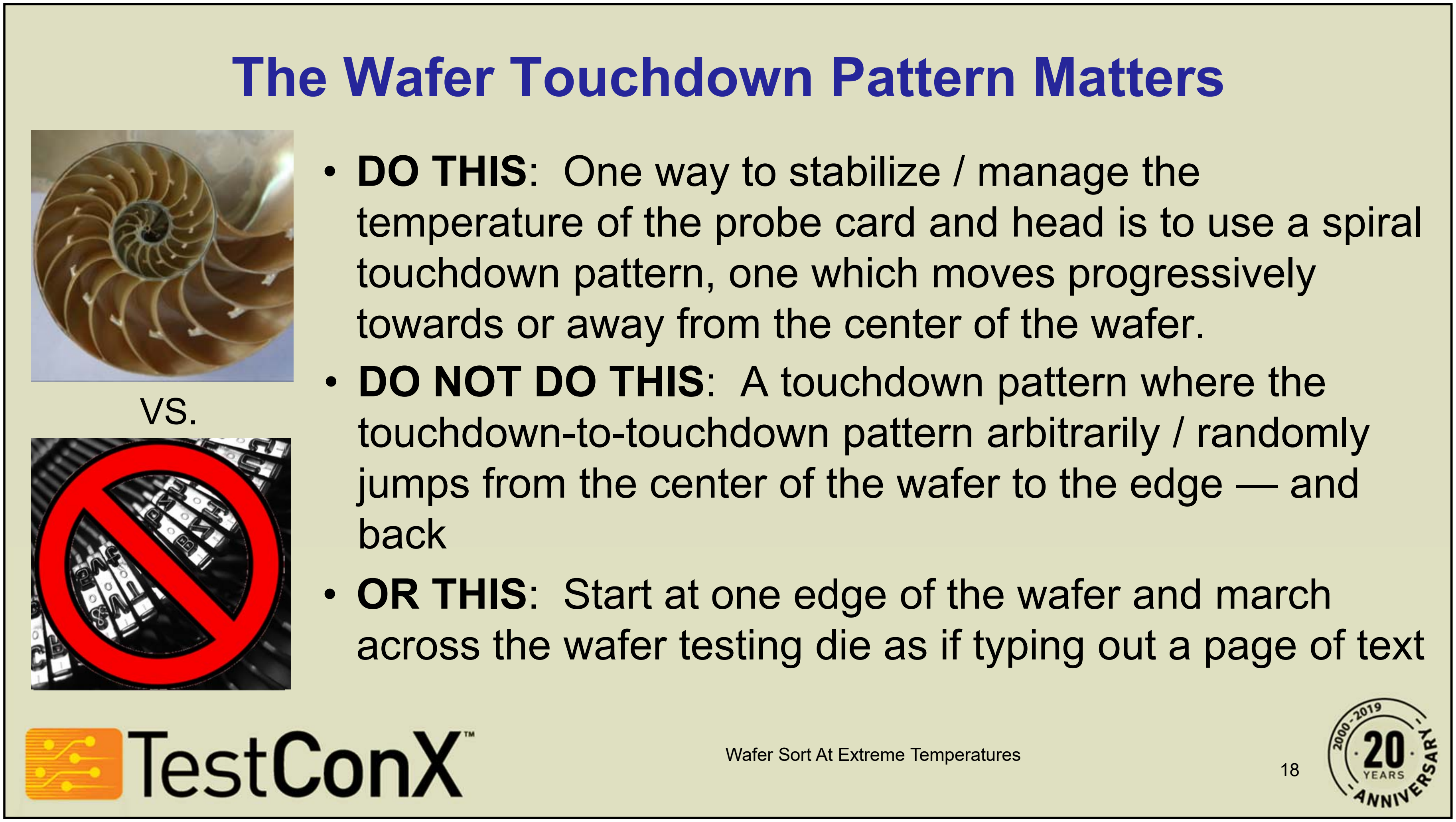
- **DO NOT DO THIS**: A touchdown pattern where the touchdown-to-touchdown pattern arbitrarily / randomly jumps from the center of the wafer to the edge — and back



The Wafer Touchdown Pattern Matters

VS.

- **DO THIS**: One way to stabilize / manage the temperature of the probe card and head is to use a spiral touchdown pattern, one which moves progressively towards or away from the center of the wafer.
- **DO NOT DO THIS**: A touchdown pattern where the touchdown-to-touchdown pattern arbitrarily / randomly jumps from the center of the wafer to the edge — and back
- **OR THIS**: Start at one edge of the wafer and march across the wafer testing die as if typing out a page of text

-40° Case Study

- **Accretech UF3000EX**
  - Prober software requires dew point 5° C less than the target chuck temperature to allow the chiller to hit the set point.
    - *Optimal ΔT is ≤-10°C*
  - To achieve -40° chuck temp the prober cavity dew point needs to be at least ≤-45° C (optimally ≤-50° C)
- **24 Slot UltraFLEX Tester with UltraProbe interface**
  - Saw issues with reaching -40° chuck temperature
  - The existing cold seal solution allowed test head fans to draw air from prober cavity
    - *Not possible to maintain target dew point of ≤-50° C*

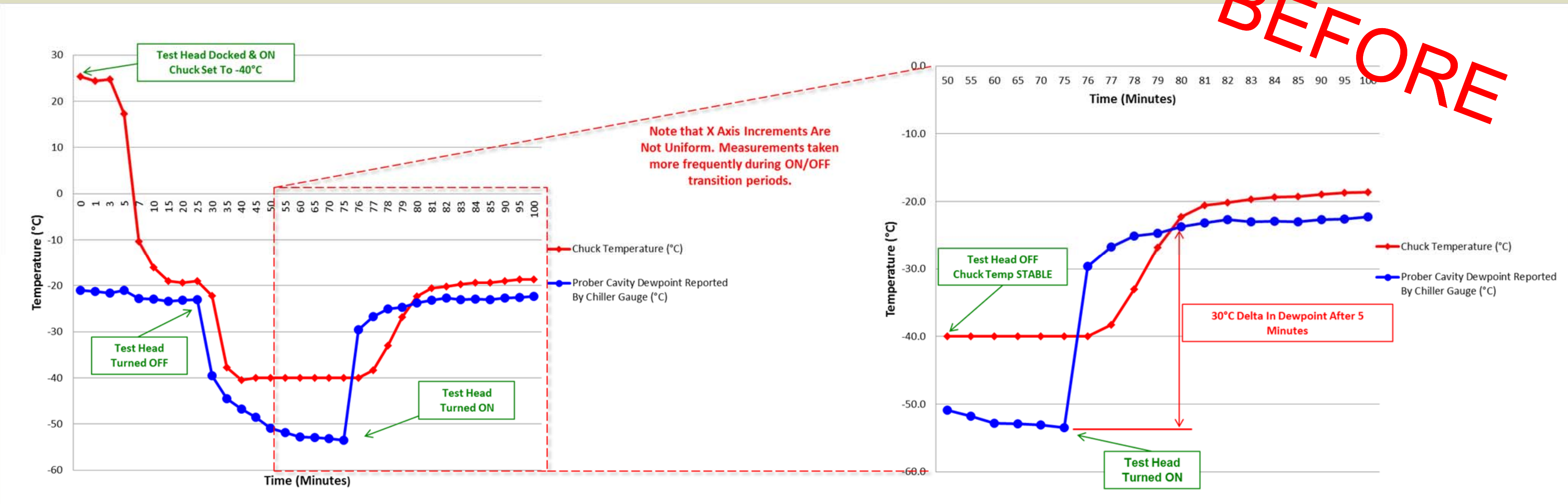
-40° Case Study, cont.

- Input Air Dew Point
  - Recommended
    - House Input: -90° C
    - Post prober air dryer: ≤-70° C
  - Required
    - At prober input: ≤-70° C
    - Room: ≤ 6° C

-40° Case Study, cont.

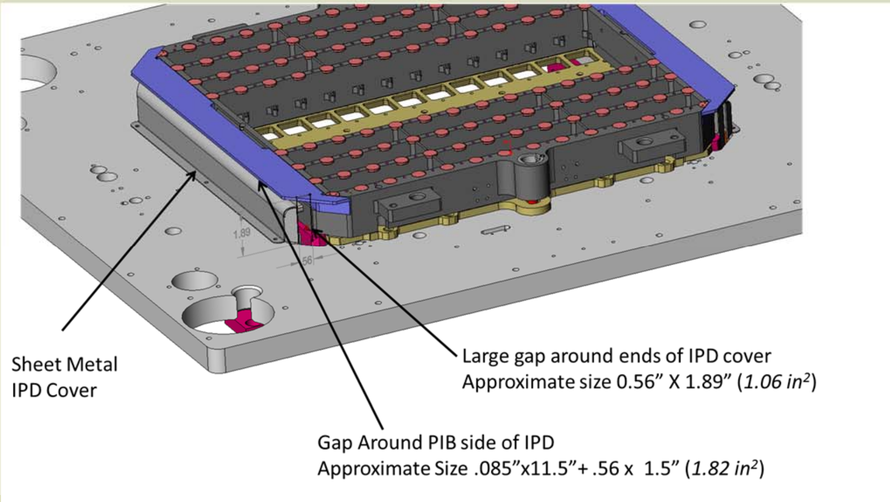
Chuck Temperature vs. Dewpoint
(Tester Turned On After Stabilization)

BEFORE



-40° Case Study, cont.

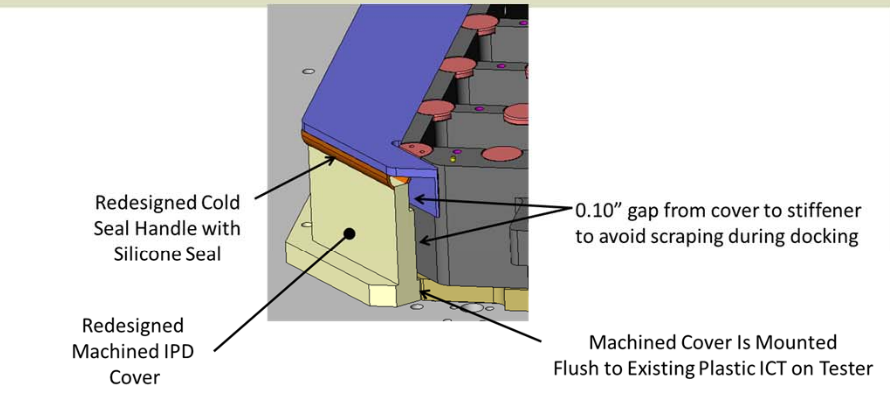
Primary Leakage Path from Prober Cavity:



Sheet Metal
IPD Cover

Large gap around ends of IPD cover
Approximate size 0.56” X 1.89” (*1.06* in^2)

Gap Around PIB side of IPD
Approximate Size .085”x11.5”+.56 x 1.5” (*1.82* in^2)



Redesigned Cold
Seal Handle with
Silicone Seal

Redesigned
Machined IPD
Cover

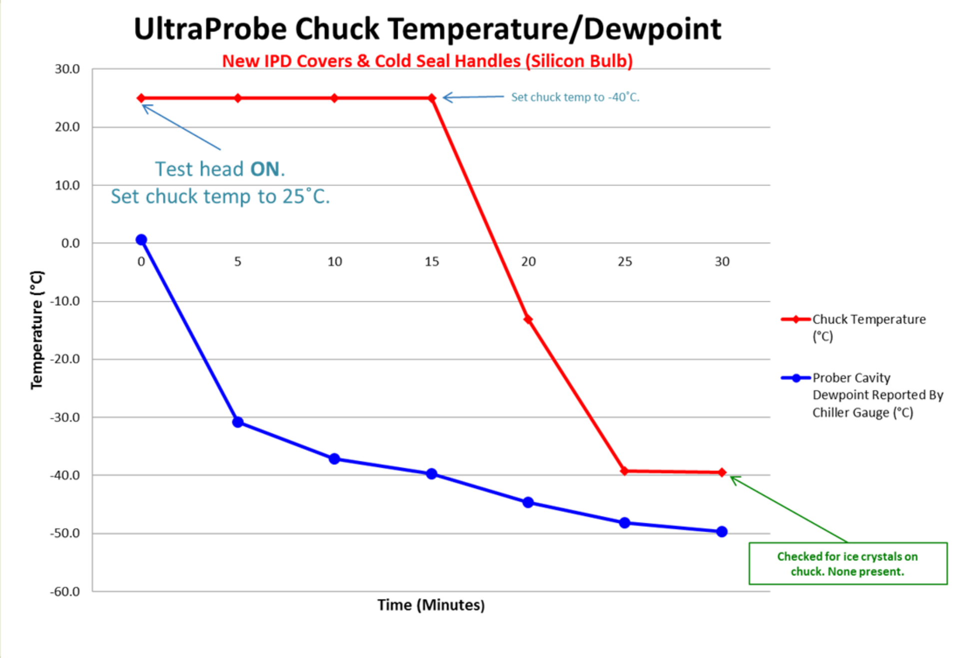
0.10” gap from cover to stiffener
to avoid scraping during docking

Machined Cover Is Mounted
Flush to Existing Plastic ICT on Tester

BEFORE

AFTER REDESIGN

-40° Case Study, cont.



AFTER

Four Characterization Runs – Same Results Each Run

Summary: The Hot and Cold Sort Bottom Line

- The thermally-driven dance of all of the system components in Z has multiple, <u>significant</u> potential consequences:
  - Overdrive will change as material expansion and contraction take place
  - Overdrive changes will move the centroid of the scrub marks in unintended / unanticipated ways
  - If overdrive exceeds the manufacturer’s specifications the probe head will be damaged
  - If overdrive is insufficient otherwise good parts will be binned as bad or underperforming due to out-of-spec’ CRes, reducing test yield

Summary: Ensuring Success at the Extremes

- Extreme temperature guidelines are dependent upon application:
  - – The prober should soak for at least two hours after reaching target chuck temperature before starting sort
  - – Probe card soak – at least 15 minutes with the probe tips ~ 250µm above the wafer – e.g. not touched down
  - – After probe card soak use the upward-looking camera to set the zero-point for probing
  - – Re-check periodically to ensure in-spec' probe needle overdrive

Ensuring Success at the Extremes, cont.

- Additional Probing guidelines for cold sort:
  - Complete sealing of prober cavity for cold sort
    - Seal any seams or metal-on-metal interfaces
  - For cold sort meet or exceed Teradyne-recommended Facility CDA purge air temperature / dew point specs
  - Use the new Cold Seal Option with UltraFLEX when probing at ≤-20° C
  - Clean *Dry* Air or N_2 purge is essential for cold, recommended for extreme hot sort (>*125° C*)