



# Wafer Sort At Extreme Temperatures



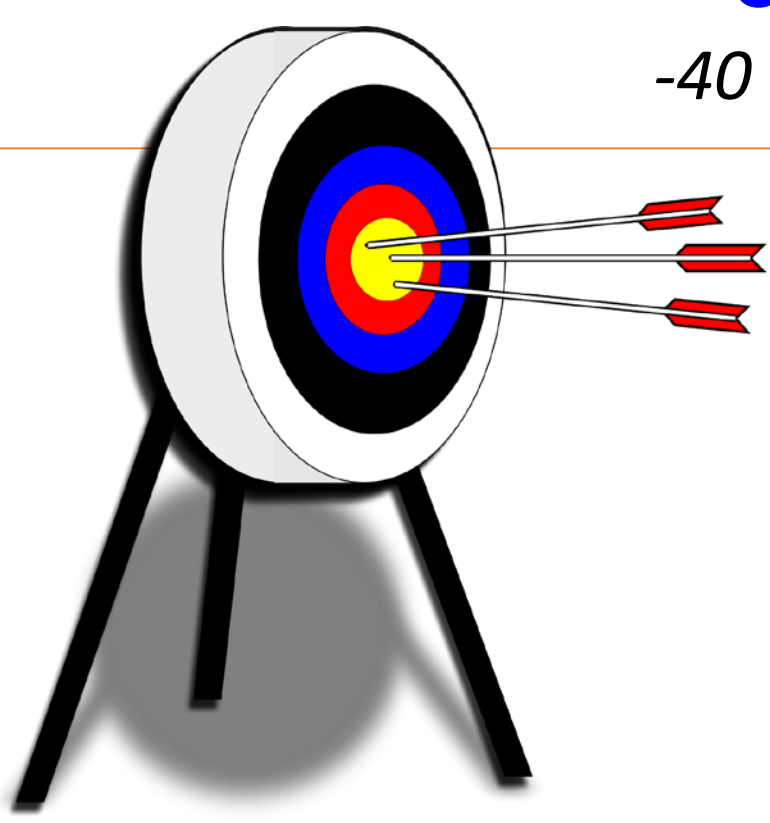
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Teradyne, Inc.

## Welcome to the Badlands!

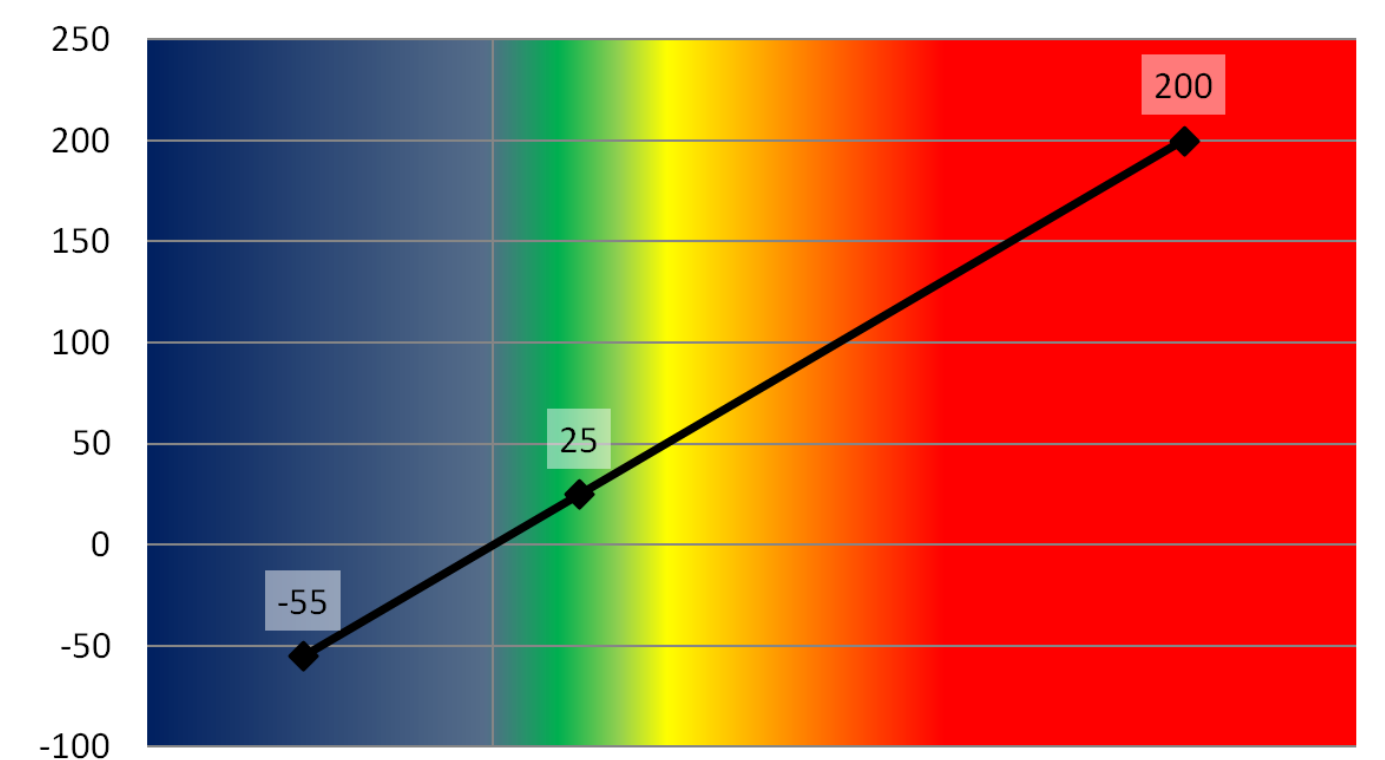
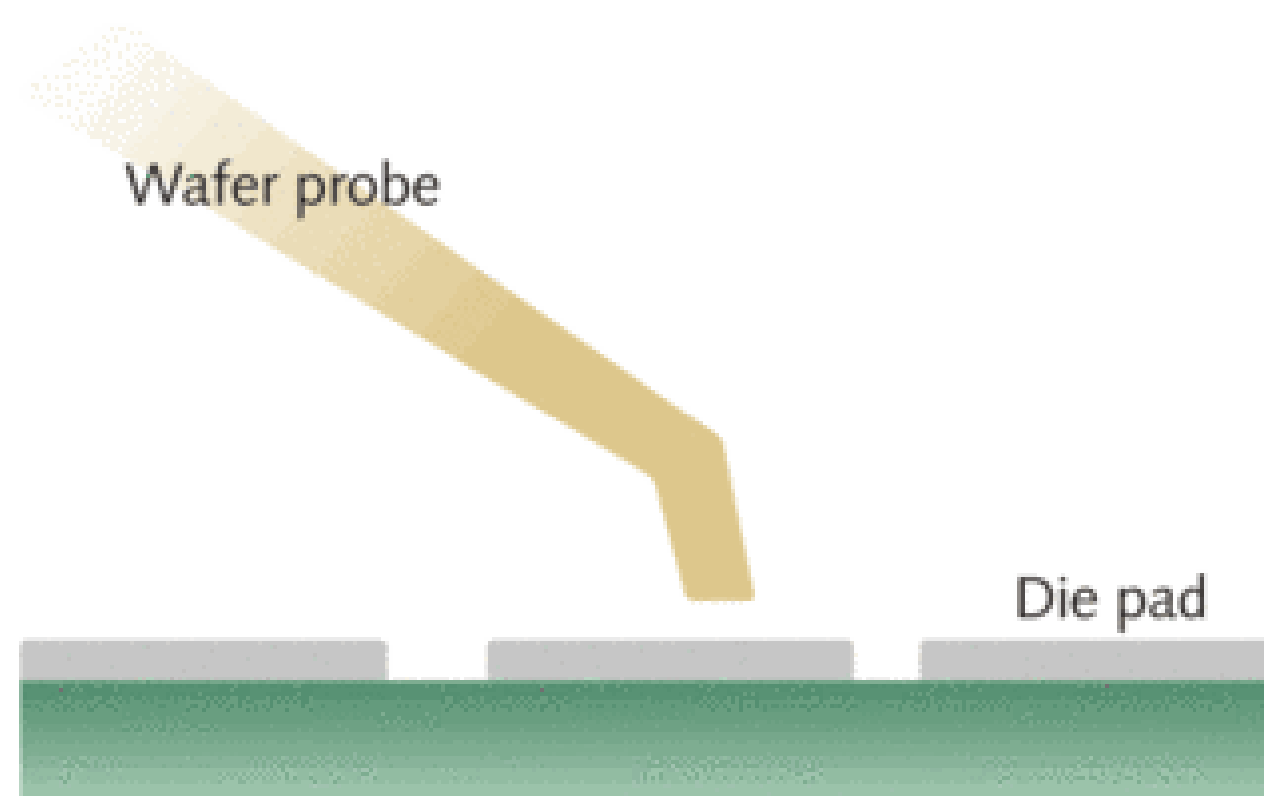


**COLD!**  
-40 to -55° C

**HOT!**  
+125 to 200° C



### Hitting the target!



- If the goal is to probe at three temperatures 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 pads, the greater the concern***

- The probe head and the probe card X-Y plane expansion / contraction do 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

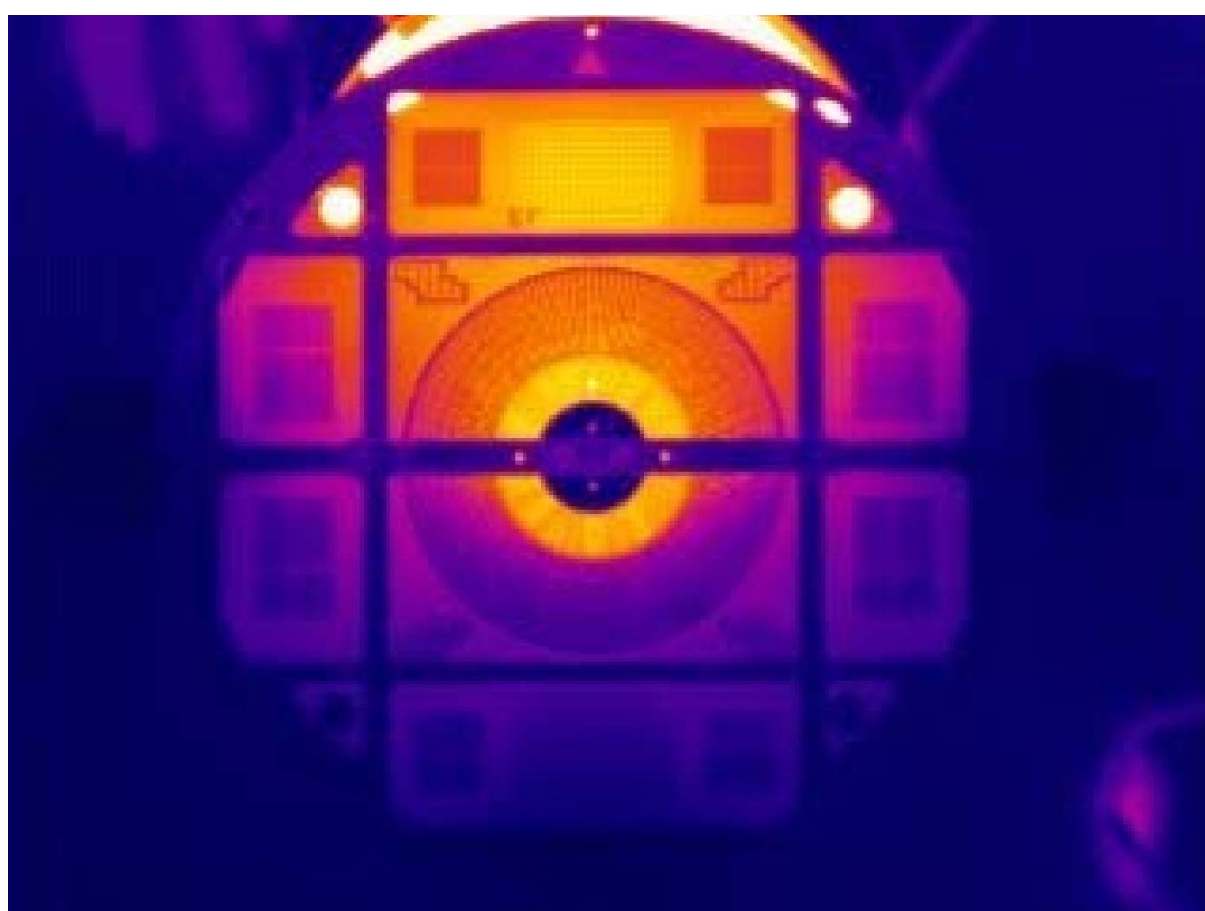
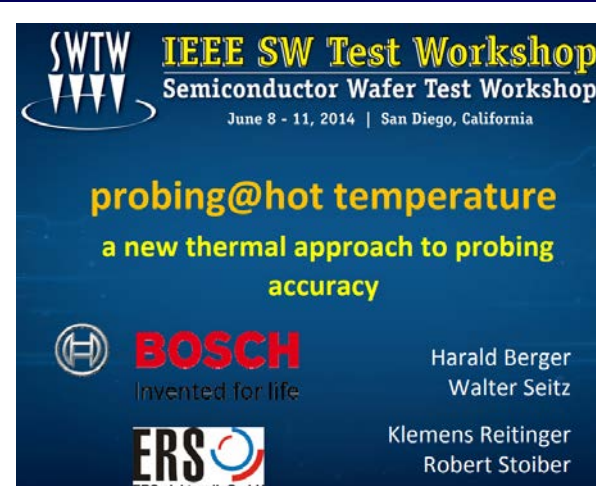


Image from:



- 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 move the wafer chuck away from the probe head for several minutes.
- Process steps that move the chuck away from the probe card will result in significant asymmetric cooling (or heating) of the probe card assembly, which in turn means that the probe needles can move significantly in Z during these process steps

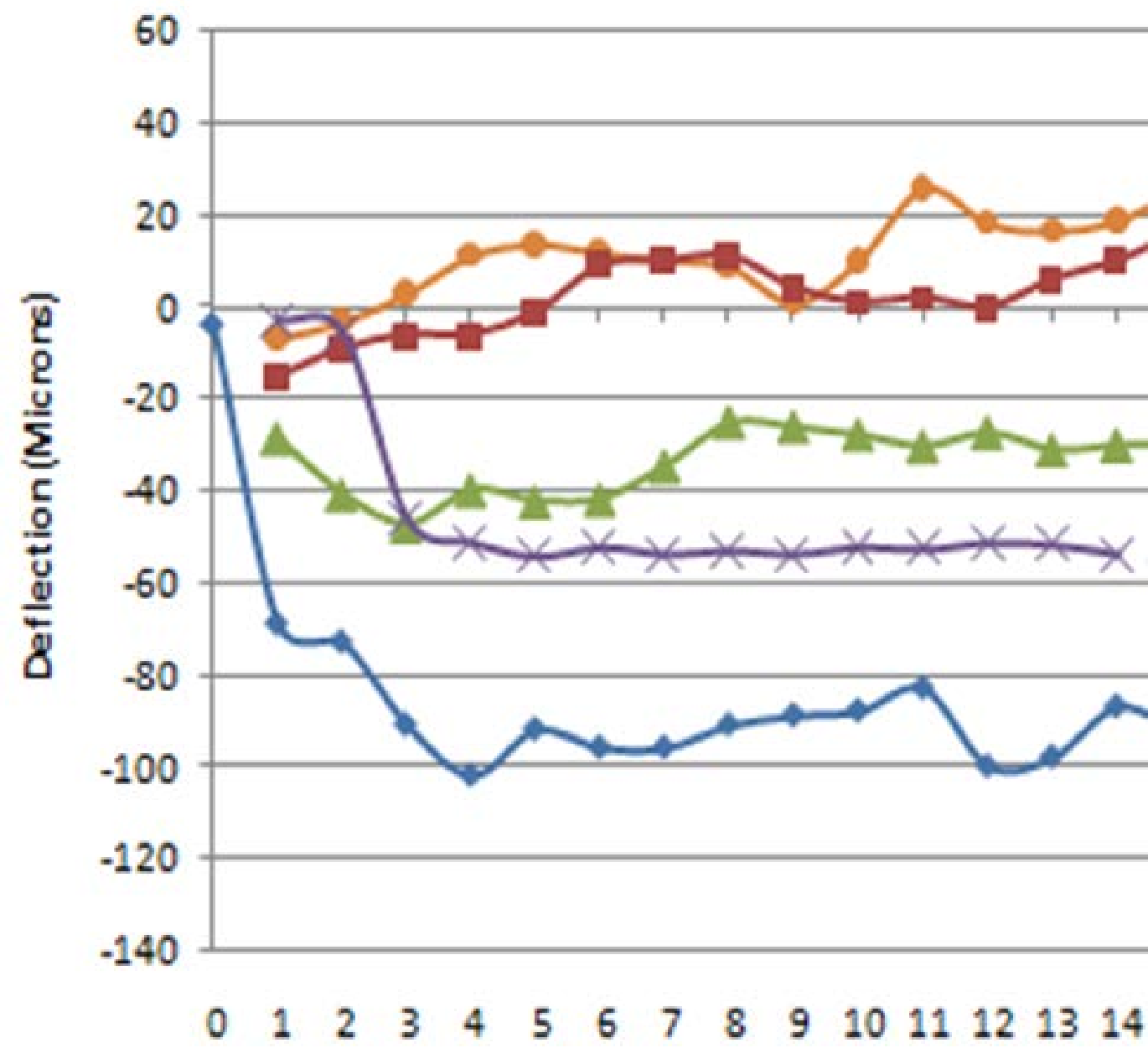
### Thermal Mass (Flywheel Effect) to the Rescue:

- Designing in a large mass of thermally-bonded metal above the probe head stabilizes probe card and probe head temperature during those periods when the chuck isn't under the probe head



# CTE of Probe Card Assembly Materials

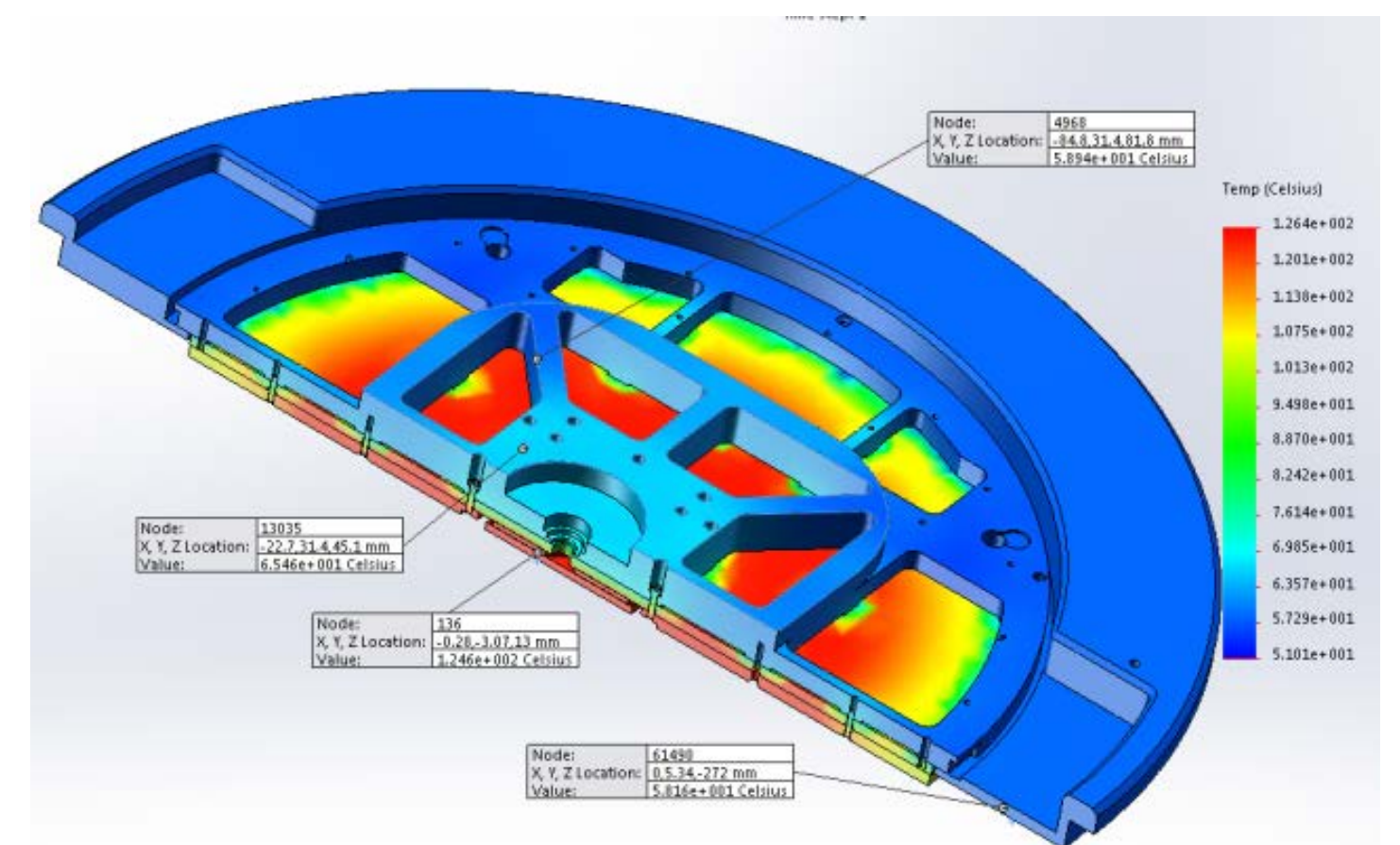
- PCB materials tend to have high CTE (Coefficient of Thermal Expansion) values in the Z-axis (thickness):
  - This means that the probe head can move significantly in Z as the probe card heats or cools – just due to the PCB thickness changing
- The probe card stiffener will also be growing and shrinking 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 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



- POGO Probe Card used to collect data
- PCB is expanding or contracting causing probe card Z-Movement
- X Scale on the graphic is TIME in MINUTES
- BLUE in the Z height of the average of 4 needles on one probe head
- ORANGE/RED/PURPLE/GREEN lines are locations on the PCB near the probe head at 12/3/6/9 o'clock positions.
- Graphic illustrates that some things are going up, some down, some not moving, etc.

# 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  $\Delta T$  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
- Radiation is also a significant driver
  - For 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
- A rule of thumb is that tester side of the probe card PCB will reach a temperature of ambient plus 1/3rd the  $\Delta T$  relative to ambient, for example this RoT predicts that a 150°C sort temp will drive the tester side of the probe card PCB to roughly 65°C

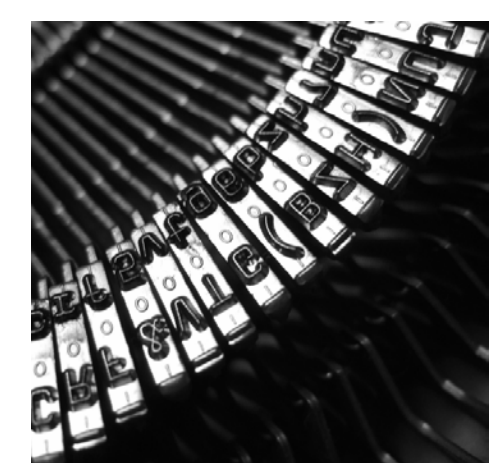


# The Wafer Touchdown Pattern Matters

- **DO THIS:** One way to stabilize / manage the temperature of the probe card / 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



VS.

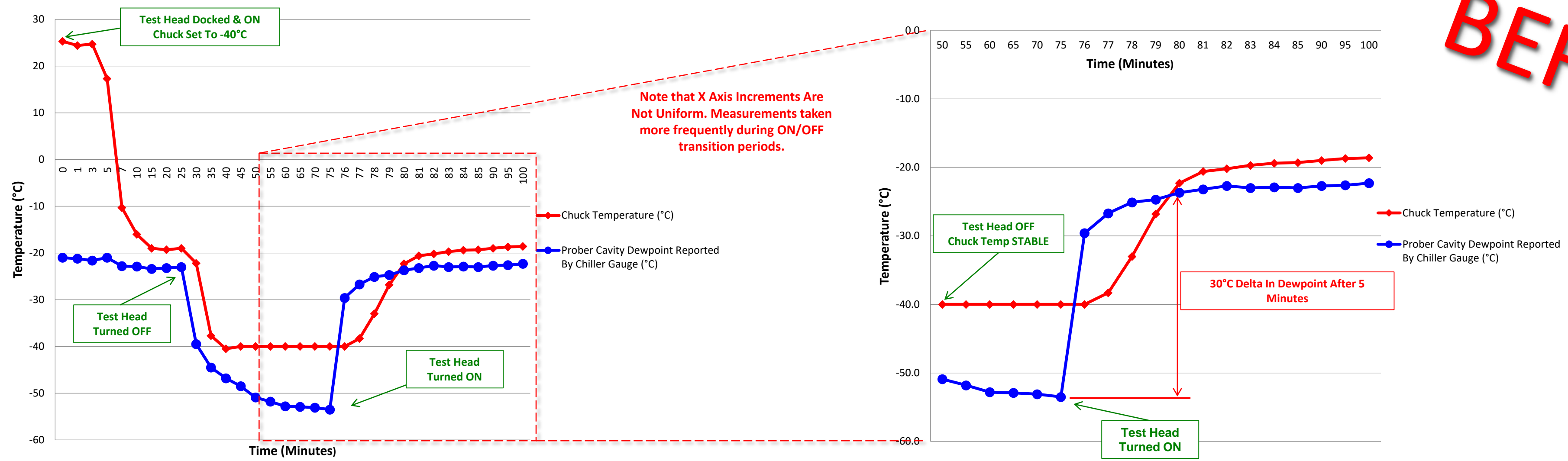


## -40° Case Study

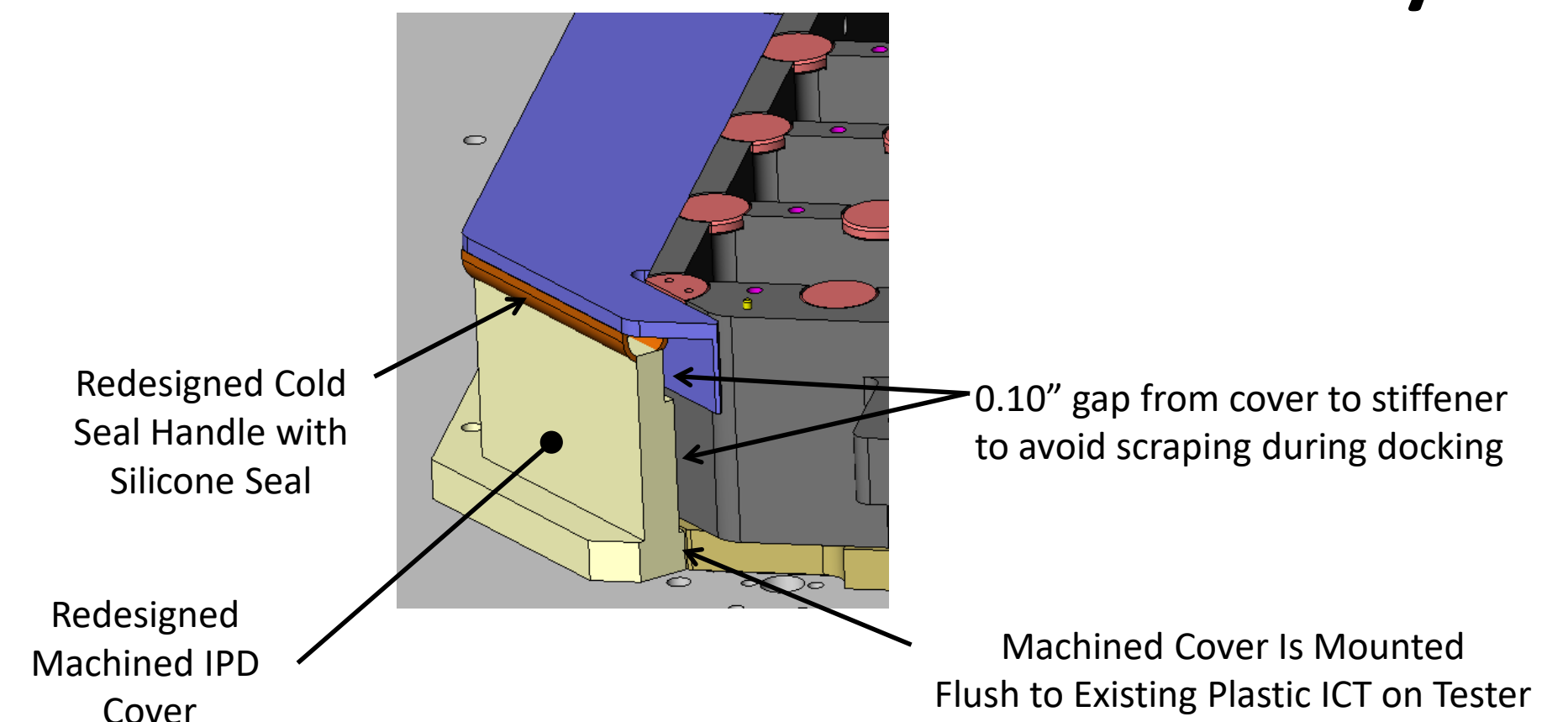
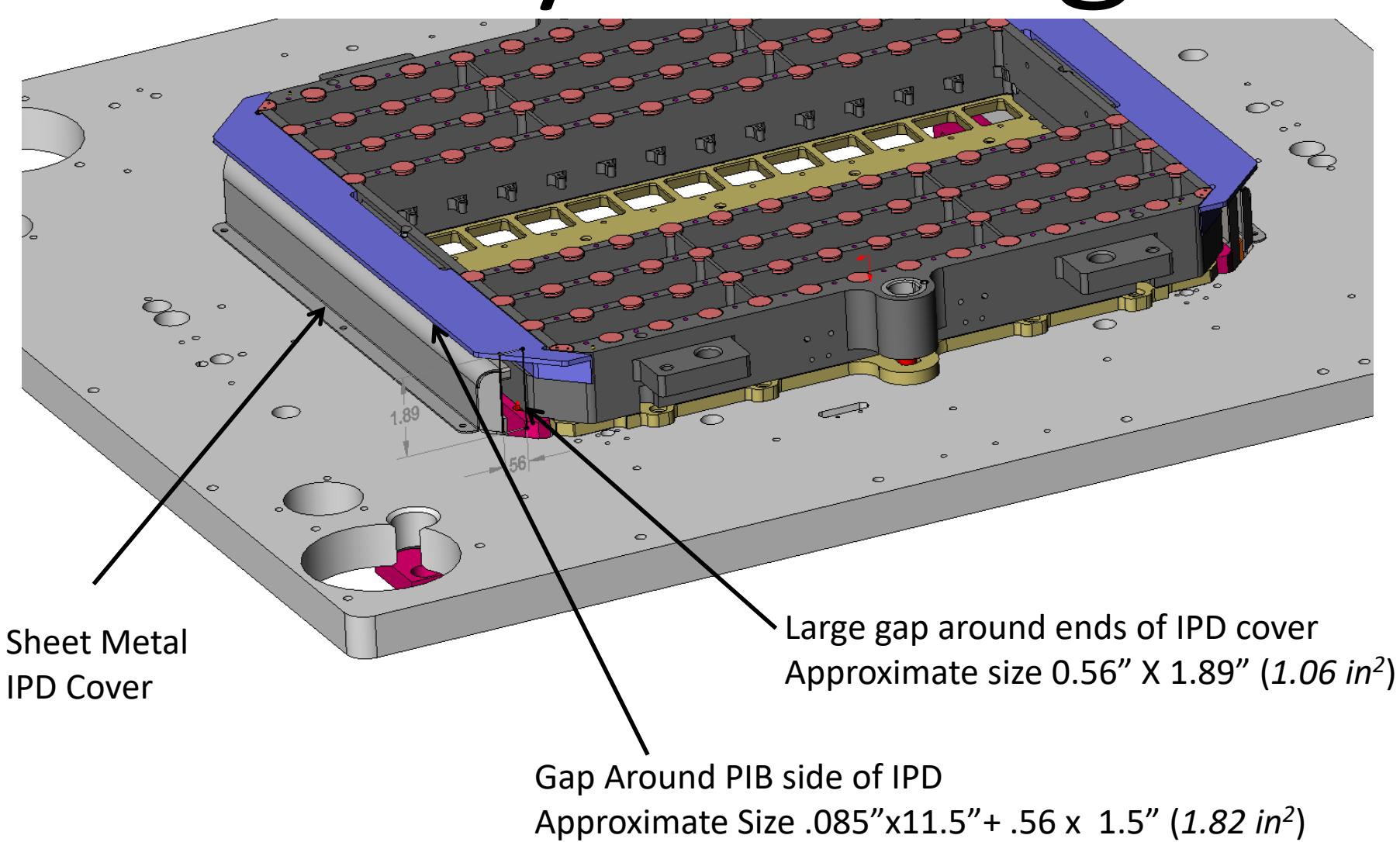
- Accretech UF3000EX
  - Prober software requires dew point 5°C less than the chuck temperature to allow the chiller to try to hit a set point.
    - Optimal  $\Delta$  is  $\leq -10^\circ\text{C}$
  - To achieve  $-40^\circ\text{C}$  chuck temp the prober cavity dew point needs to be  $\leq -45^\circ\text{C}$  (optimally  $\leq -50^\circ\text{C}$ )
- 24 Slot UltraFLEX Tester with UltraProbe
  - Issues with reaching  $-40^\circ\text{C}$  chuck temperature ( $\leq -50^\circ\text{C}$  prober cavity dew point)
  - Existing cold seal handle solution allowed test head fans to draw air from prober cavity
    - Difficult to maintain dew point of  $\leq -50^\circ\text{C}$
- Input Air Dew Point
  - Recommended
    - House Input:  $-90^\circ\text{C}$
    - Post prober air dryer:  $\leq -70^\circ\text{C}$
  - Required
    - At prober input:  $\leq -70^\circ\text{C}$
    - Room:  $\leq 6^\circ\text{C}$

# -40° Case Study, continued

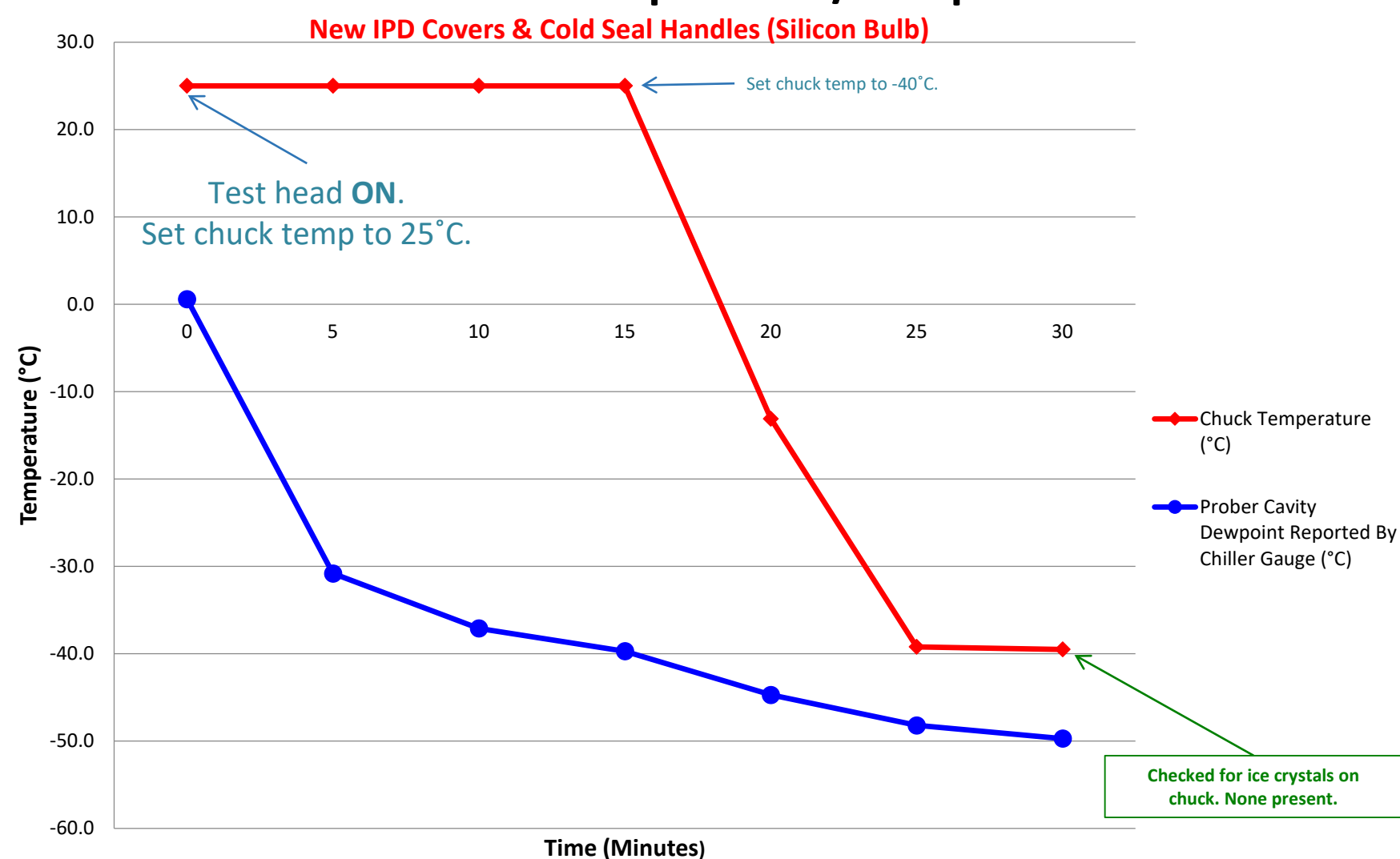
Chuck Temperature vs. Dewpoint  
(Tester Turned On After Stabilization)



## Primary Leakage Path from Prober Cavity:



UltraProbe Chuck Temperature/Dewpoint



Four  
Characterization  
Runs – Same Results  
Each Run

AFTER

## The Hot and Cold Sort Bottom Line

- The thermally-driven dance of all of the system components in Z has multiple significant 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

## 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
  - 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
- Additional Probing guidelines:
  - Complete sealing of prober cavity for cold sort
    - Seal any seams or metal-on-metal interfaces
  - For cold sort meet or exceed Teradyne-recommended facilities CDA purge specs
  - Use new Cold Seal Option with UltraFLEX when probing at  $\leq -20^{\circ}\text{C}$
  - Clean Dry Air or  $\text{N}_2$  purge is essential for cold, recommended for extreme hot sort ( $>125^{\circ}\text{C}$ )