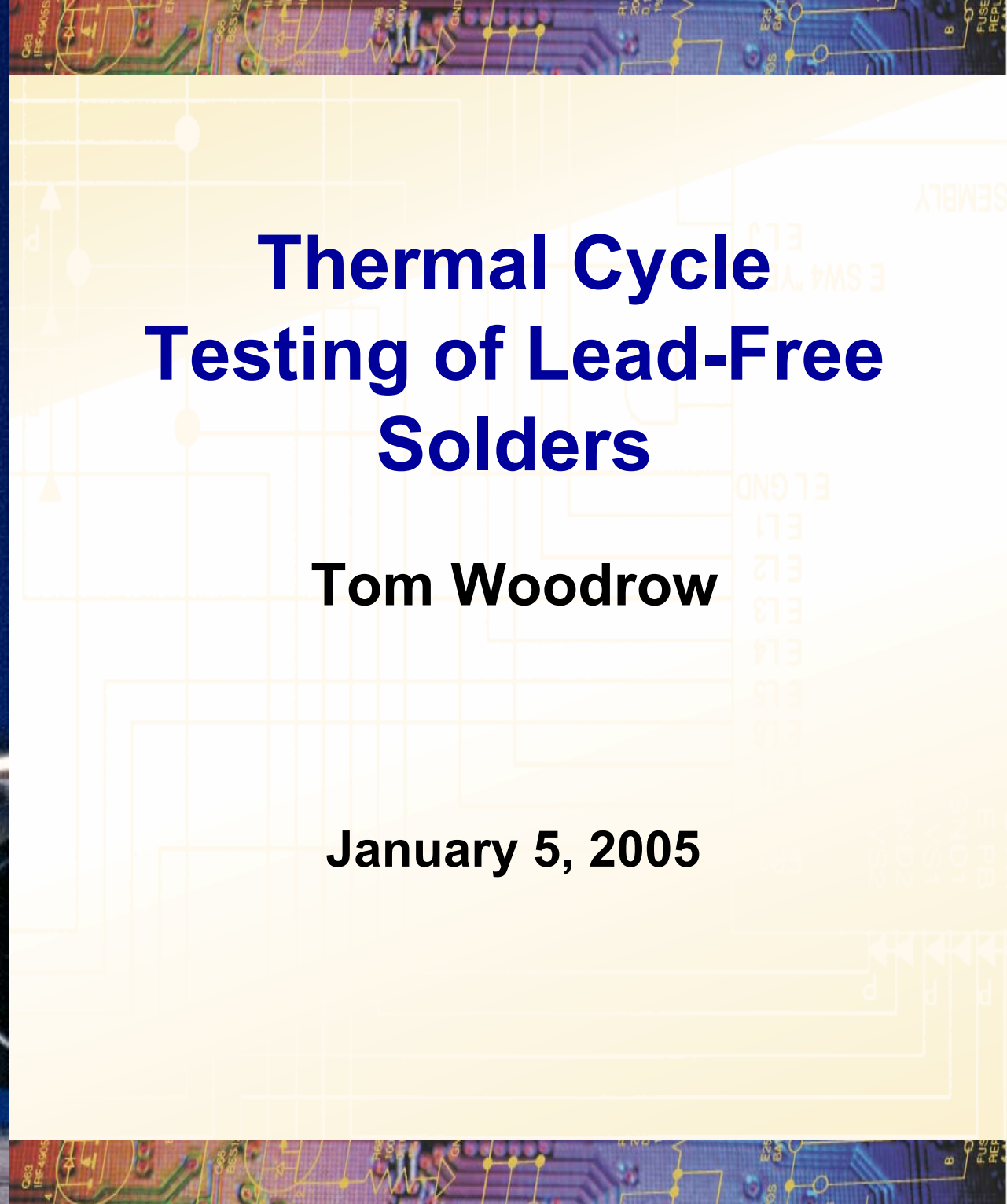




Thermal Cycle Testing of Lead-Free Solders

Tom Woodrow

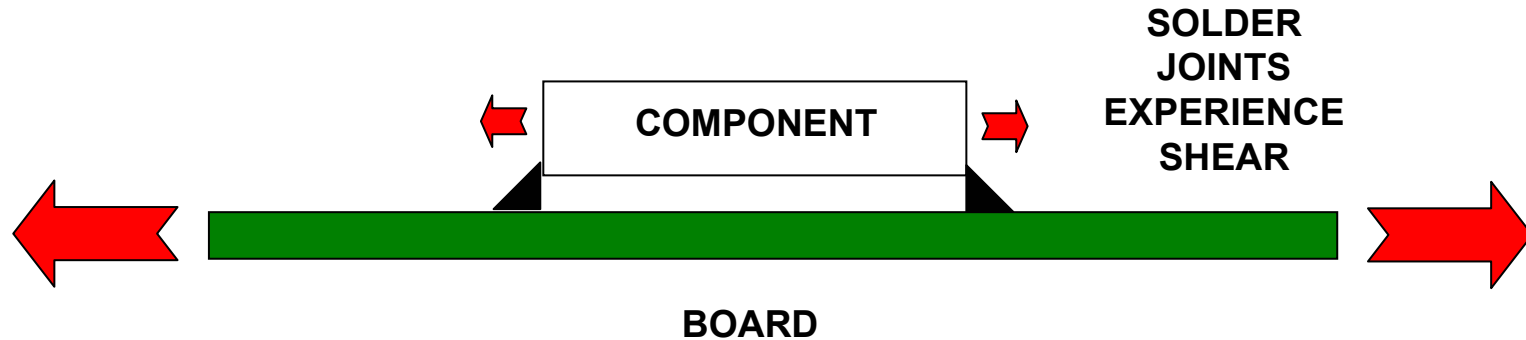
January 5, 2005



Reliability Testing of Solders

- Reliability of solder joints is traditionally determined by thermal cycling of joints until failure (Standards used: IPC-SM-785; IPC-9701; IPC-D-279)
- Thermal cycling is used because it most closely mimics conditions that cause solder joint failure in the field
- Thermal cycle testing of Pb-free solders yields performance data relative to a control (usually eutectic SnPb)

Thermal Cycle Damage

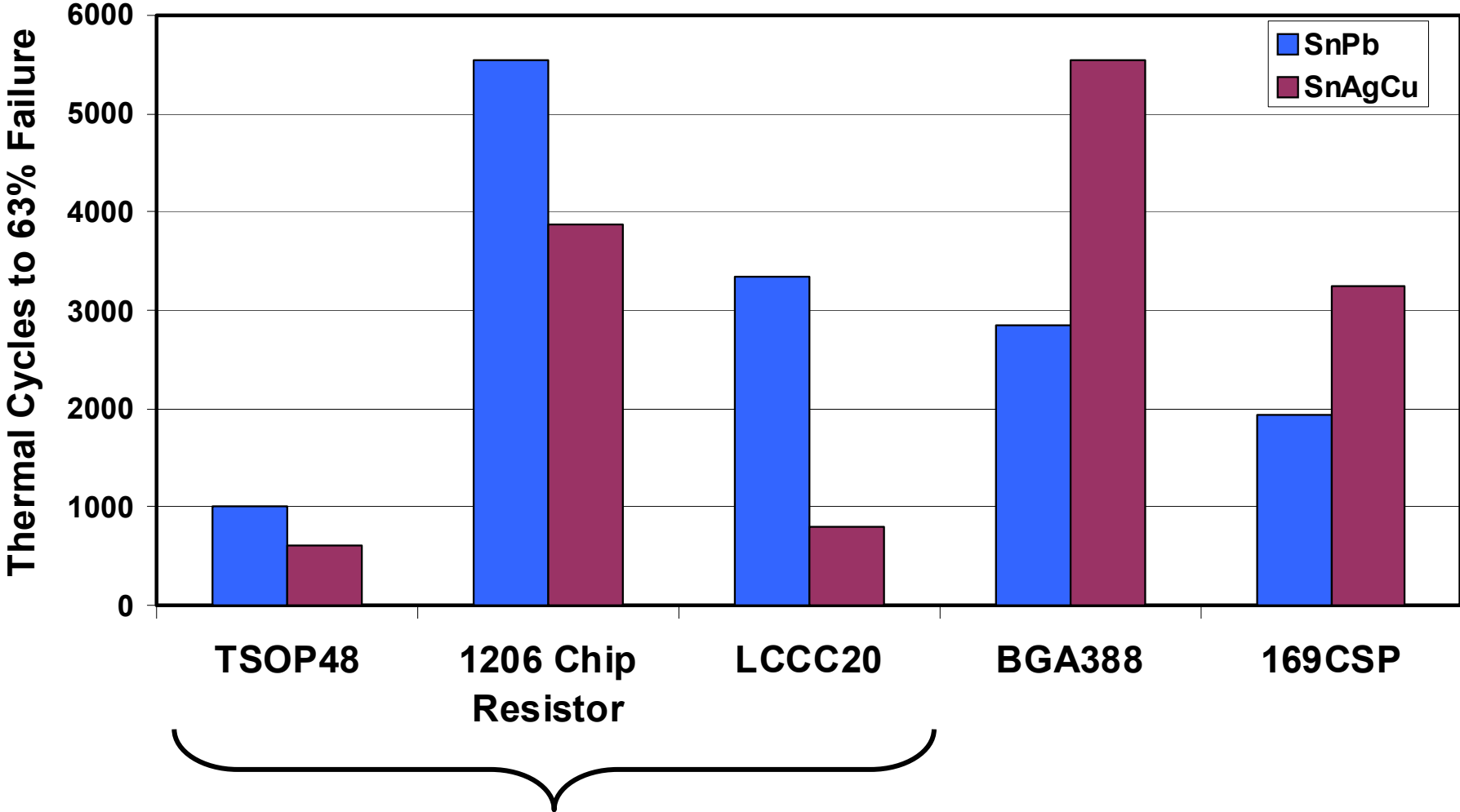


1. Joints experience stress as board heats up due to mismatch in CTE's of components and board
2. At the hot end of the thermal cycle, the solder relieves the stress by creeping. Creeping causes damage to the solder.
3. At the cold end of the thermal cycle, the solder is again stressed. Solder becomes load-bearing and stresses enlarge the cracks.

- The relative reliability of lead-free solders and SnPb solder depends on:
 - ✓ Component type being tested
 - ✓ Thermal cycle used
 - **Temperature delta**
 - **Dwell times**

Effect of Component Type on Reliability

-55° or -40°C to +125° Thermal Cycle



Components with large CTE mismatch with circuit board
(joints more stressed)

Effect of Delta T on Reliability

Component	Solder	Temp Cycle	N1%	Characteristic Life
2512 Chip Resistor	Sn37Pb	-55/125°C	333	746
2512 Chip Resistor	Sn3.9Ag0.6Cu	-55/125°C	213	681
2512 Chip Resistor	Sn37Pb	0/100°C	1183	2256
2512 Chip Resistor	Sn3.9Ag0.6Cu	0/100°C	606	3063

Smaller delta T induces less stress in joints.

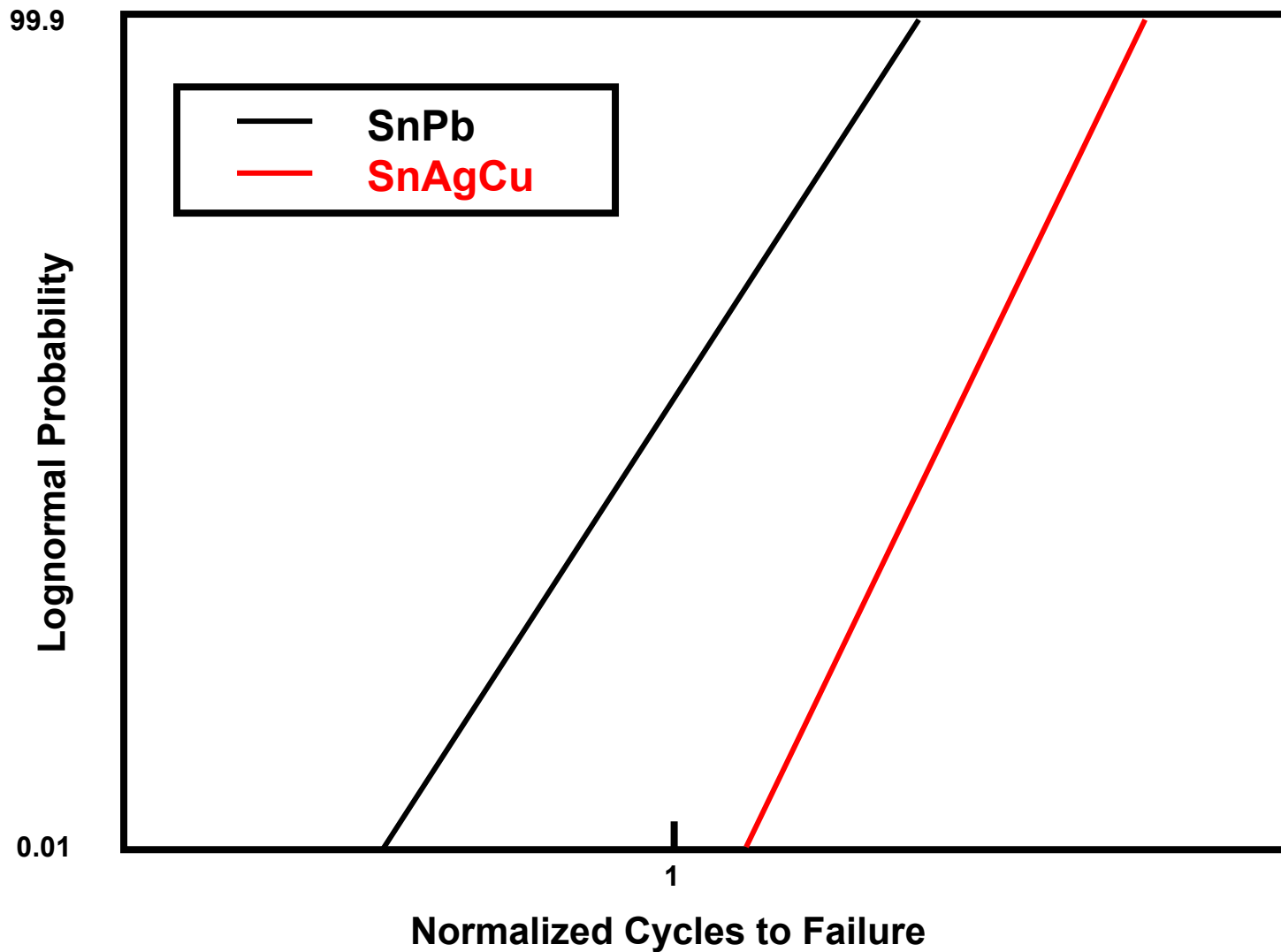
Swan, Geoff; Woosley, Alan; Vo, Nick; and Koschmieder, Thomas; "Development of Lead-Free Peripheral Leaded and PBGA Components to Meet MSL3 at 260°C Peak Reflow Profile", IPC APEX 2001, San Diego, CA, January 14-18, 2001, pp. LF2-6-1 to LF2-6-7.

Creep Damage

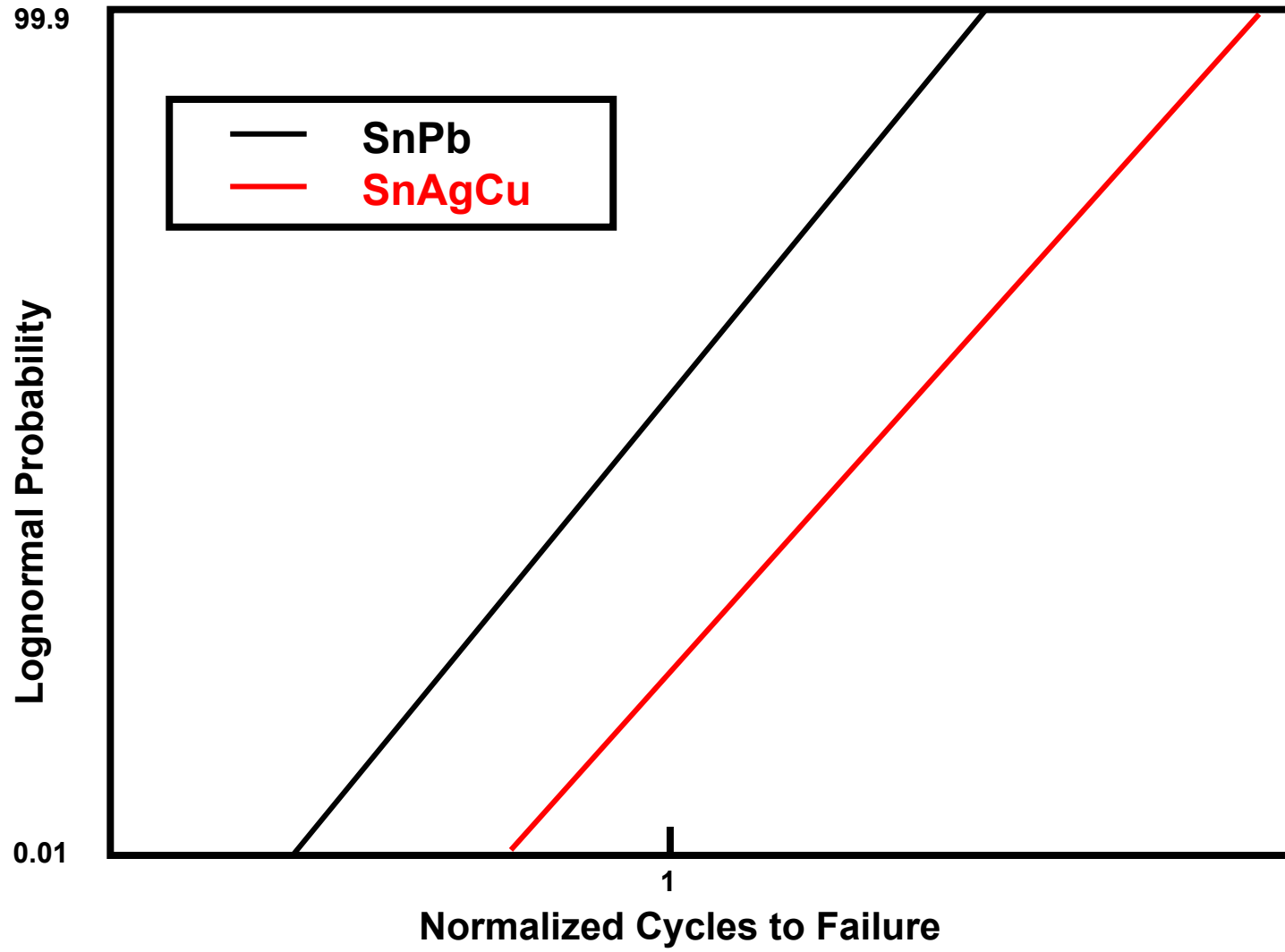
- Creep is associated with damage. Lead-free solders can be more creep resistant than SnPb. Creep is promoted by:
 - ✓ **A high stress condition**
 - a large CTE mismatch between the components/boards
 - a thermal cycle with a large delta T
 - ✓ Or, **a hotter upper dwell temperature (e.g., 125°C)**
- **Also, the longer the dwell time, the more the solder creeps**

The Bartelo Study

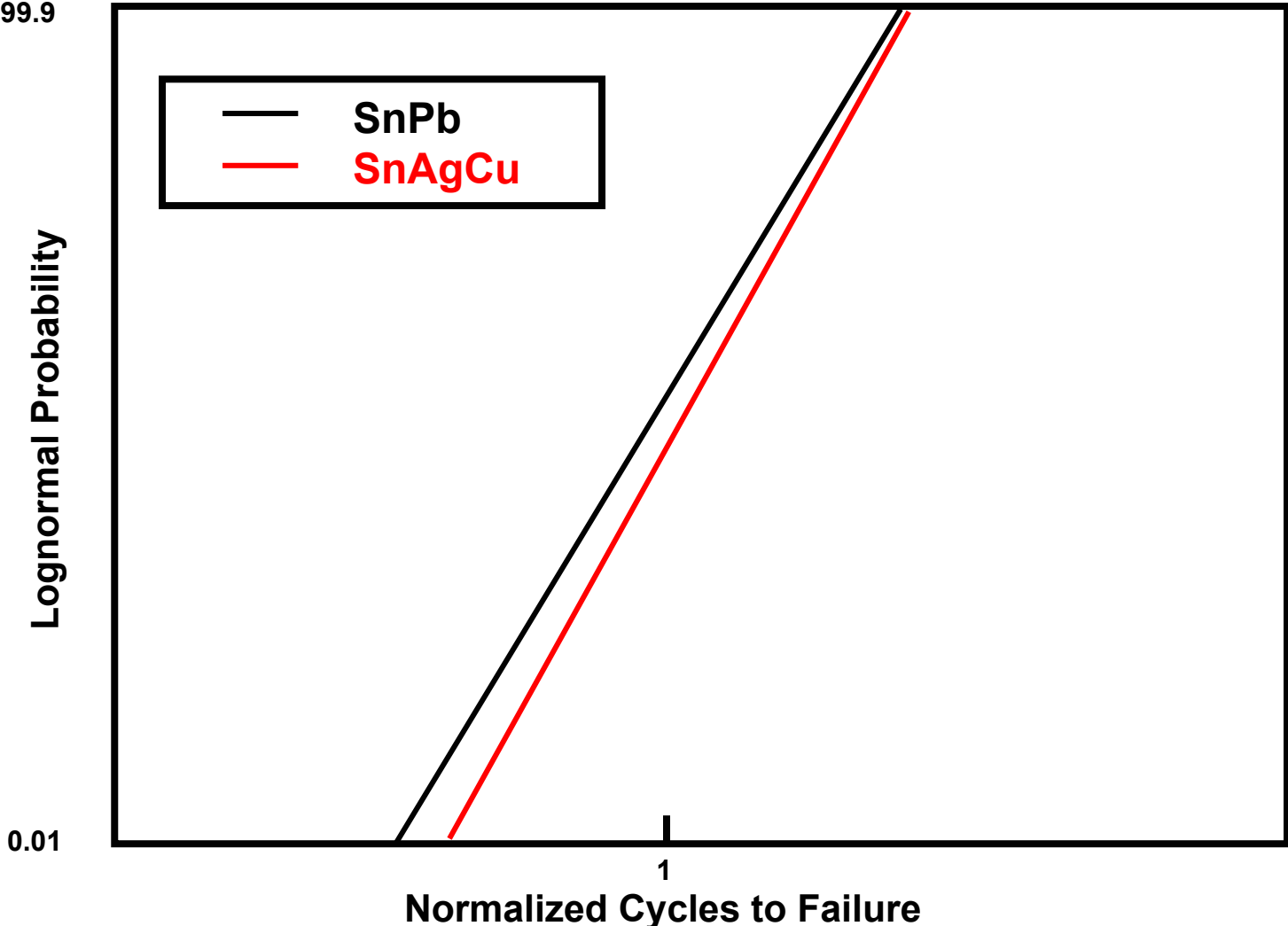
625 I/O CBGA 32x32x0.8mm
-40° to 60°C; 30 min Cycle Results
7 min. Dwells



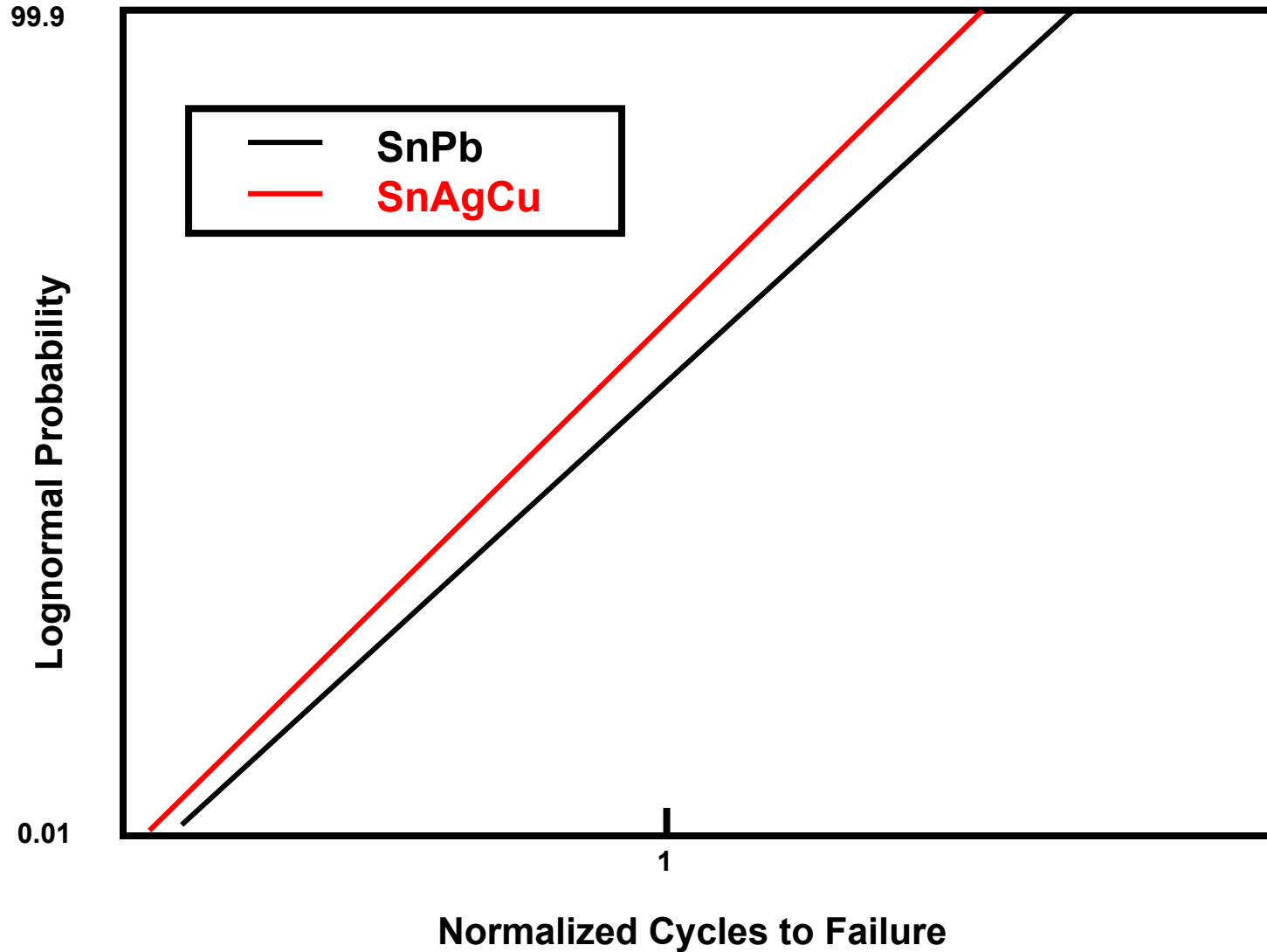
625 I/O CBGA 32x32x0.8mm
0 to 100°C; 30 min Cycle Results
7 Min. Dwells



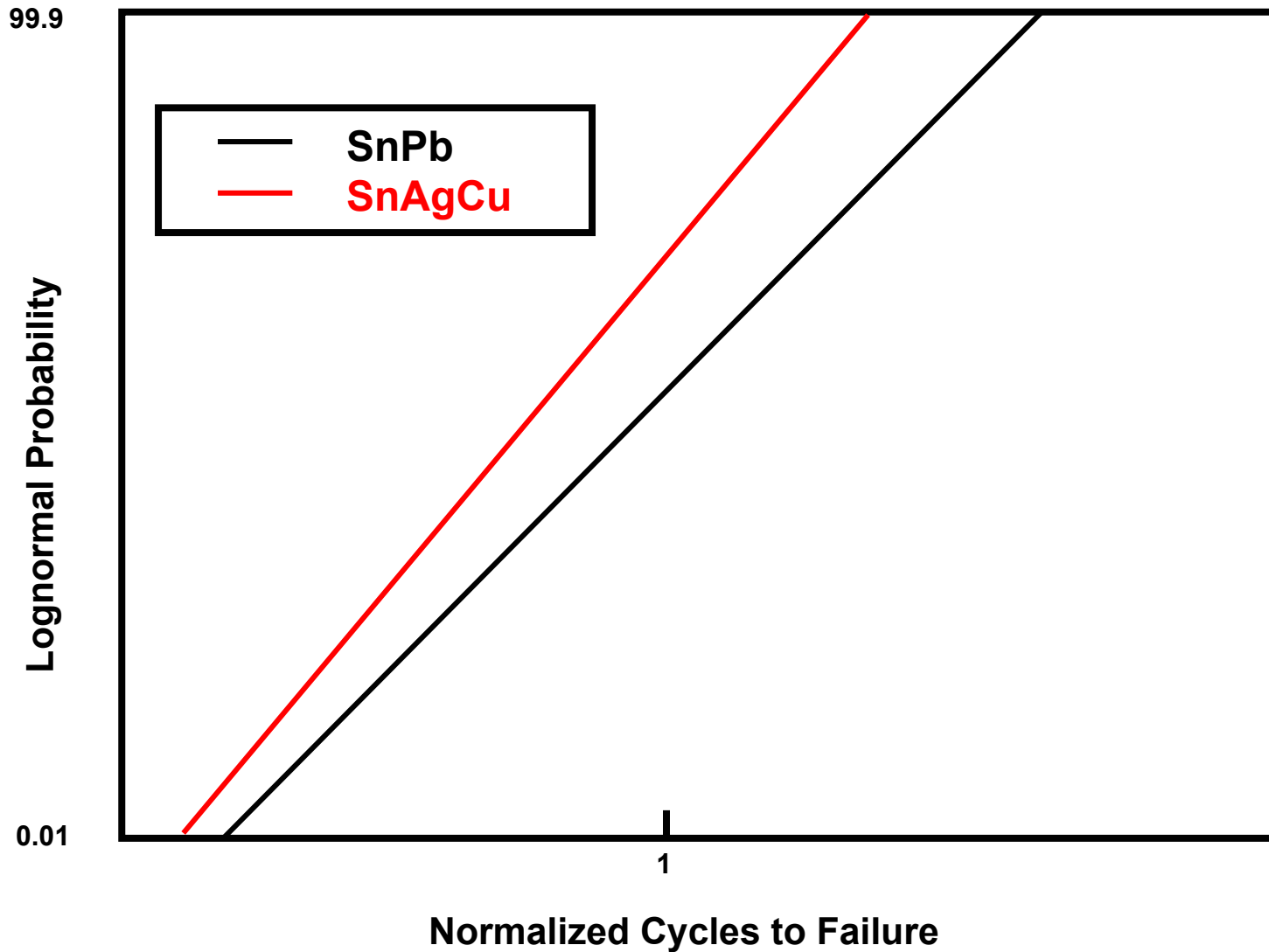
625 I/O CBGA 32x32x0.8mm
0 to 100°C; 240 min Cycle Results
110 min. Dwells



625 I/O CBGA 32x32x0.8mm
-40° to 125°C; 42 min Cycle Results
8 min. Dwells



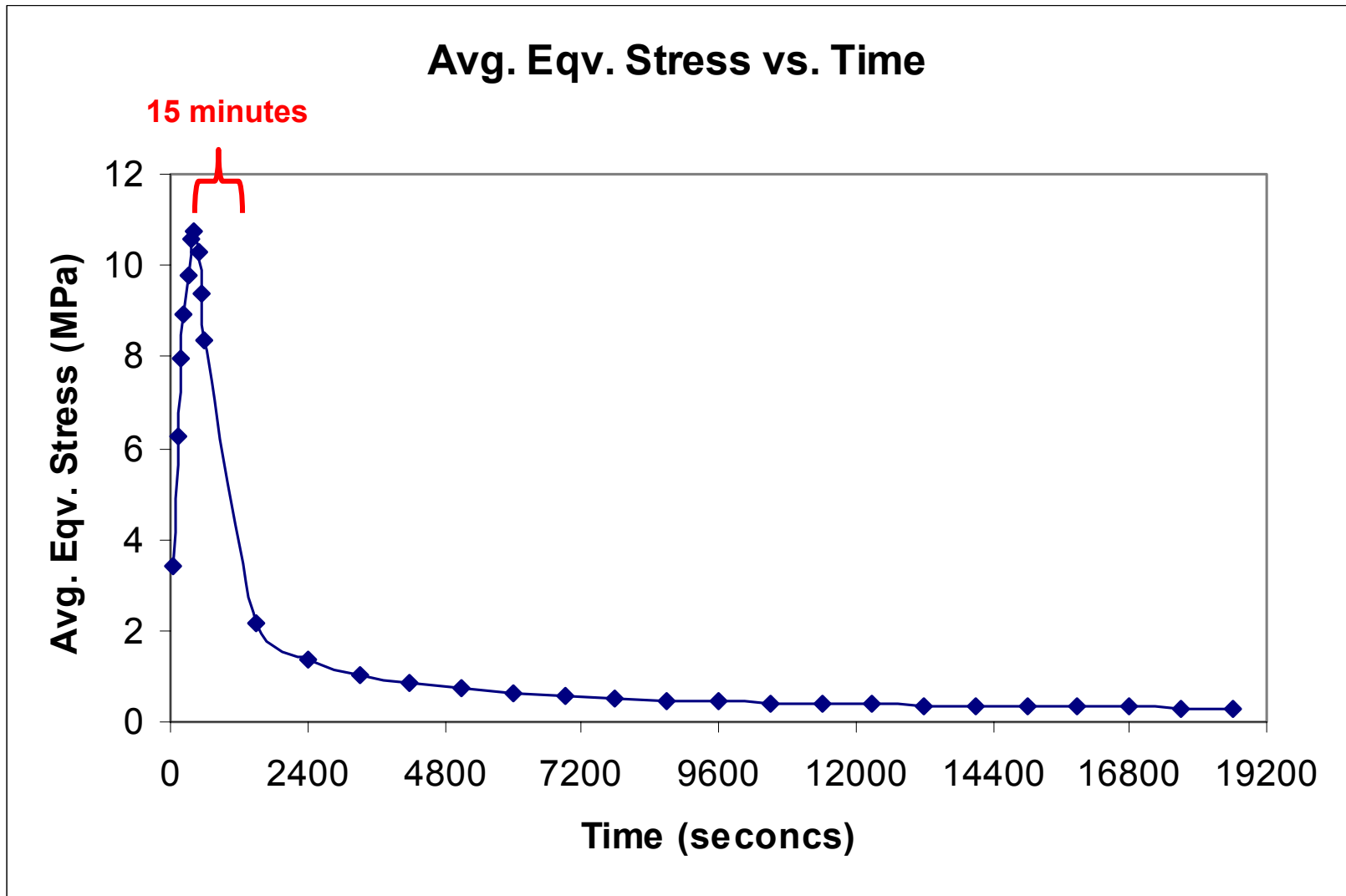
625 I/O CBGA 32x32x0.8mm
-40° to 125°C; 240 min Cycle Results
107 min. Dwells



- A validated model is needed in order to convert any thermal cycle data to a field lifetime

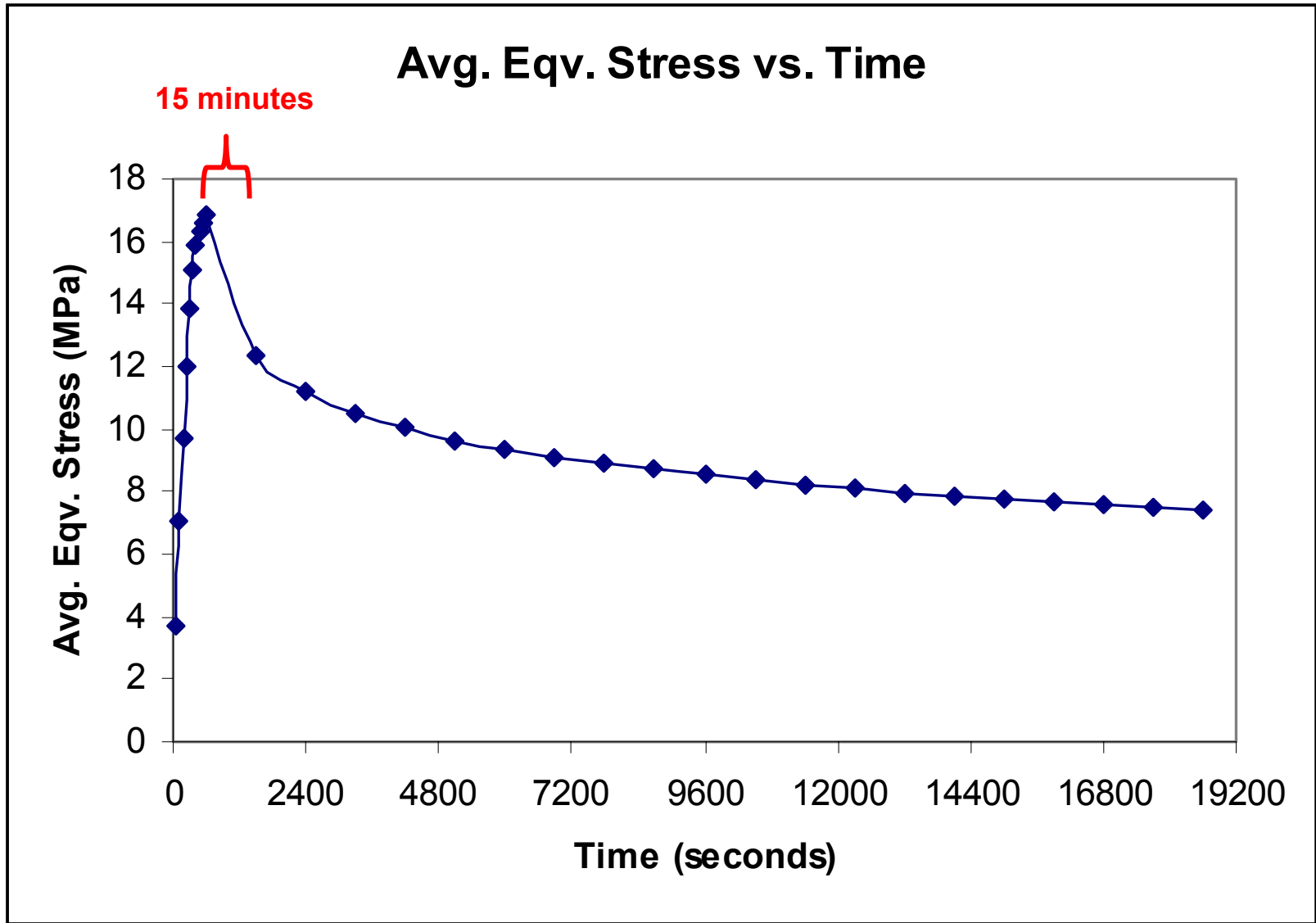
Creep of SnPb vs. SAC

SnPb, 25 to 125°C, 10°C/min (LCCC68)



Source: CALCE

SAC, 25 to 125°C, 10°C/min (LCCC68)



Source: CALCE