HIGHLY ACCELERATED THERMAL SHOCK

Highly Accelerated Thermal Shock (HATS™) Testing for PCB Hole Reliability

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Outline

- Acknowledgements
- History of Thermal Shock
- MIL-STD and IPC Test Methods
- Experimental Background
- Delphi Standards
- HATS™ Test System
- Comparison Data
- Final Thoughts

Acknowledgements

Rick B. Snyder

Delphi Delco Electronics Systems, Inc.

Kokomo, IN

Timothy A. Estes

Conductor Analysis Technologies, Inc.

Albuquerque, NM

History of Thermal Shock

- Thermal shock testing has been around for a long time
- Thermal shock tests have been used to determine PCB & PCA reliability
- Air-to-air methods have longest history in thermal shock
- Significant disadvantages in cost and time
  - Costly to run dual-chamber and liquid systems (electricity or liquid nitrogen)
  - Air-to-air methods take a very long time

History of Thermal Shock

- Reliability models based upon coefficient of thermal expansion (CTE) of the device under test (DUT)
- Difference in thermal extremes (delta T) determines overall expansion of DUT
  - Example: -40 to +145C is an 185C delta T
- Dual-chamber air-to-air methods require difficult sample fixturing and wiring
- Monitoring typically infrequent
  - Finding glitches almost impossible

MIL-STD-202G, Method 107

- Originated in the late 1950's
  - Test method last updated in 1984
- Contains both air-to-air & liquid-to-liquid parameters
- Based upon two chamber model
  - Hot & cold for either air or liquid
- Dwell time based upon mass of samples tested
  - Time conservatively estimated for sample to reach equilibrium
- Most methods are built upon this standard

MIL-STD-202G, Method 107

- Transition time between chambers is less than 5 minutes
- Air-to-air methods
  - Lots of thermal mass in transfer cage used to move DUT between temperature zones
  - Low heat transfer rate to DUT
- Liquid-to-liquid methods
  - High heat transfer rate to DUT
  - Difficult to move samples between liquids
  - Liquids are volatile & very expensive

Method 107, Air-to-Air

Category	Lower Temperature (C)	Upper Temperature (C)
A	-55	85
B	-65	125
C	-65	200
D	-65	350
E	-65	500
F	-65	150

Air-to-Air Categories

Mass (g)	Dwell Time (minutes)
< 28	15
28 to 136	30
136 to 1,360	60
1,360 to 13,600	120
13,600 to 136,000	240
> 136,000	480

Air-to-Air Dwell Times

Method 107, Liquid to Liquid

Category	Lower Temperature (C)	Upper Temperature (C)
AA	0	100
BB	-65	125
CC	-65	150
DD	-65	200

Liquid-to-liquid Categories

Mass (g)	Dwell Time (minutes)
< 1.4	0.5
1.4 to 14	2
14 to 140	5

Liquid-to-liquid Dwell Times

IPC-TM-650, TM 2.6.7 Series

- 2.6.7A: Thermal Shock and Continuity - Printed Board
- 2.6.7.1: Thermal Shock - Polymer Solder Mask Coatings
- 2.6.7.1A: Thermal Shock - Conformal Coating
- 2.6.7.2A: Thermal Shock, Continuity and Microsection - Printed Board
- 2.6.7.3: Thermal Shock - Solder Mask

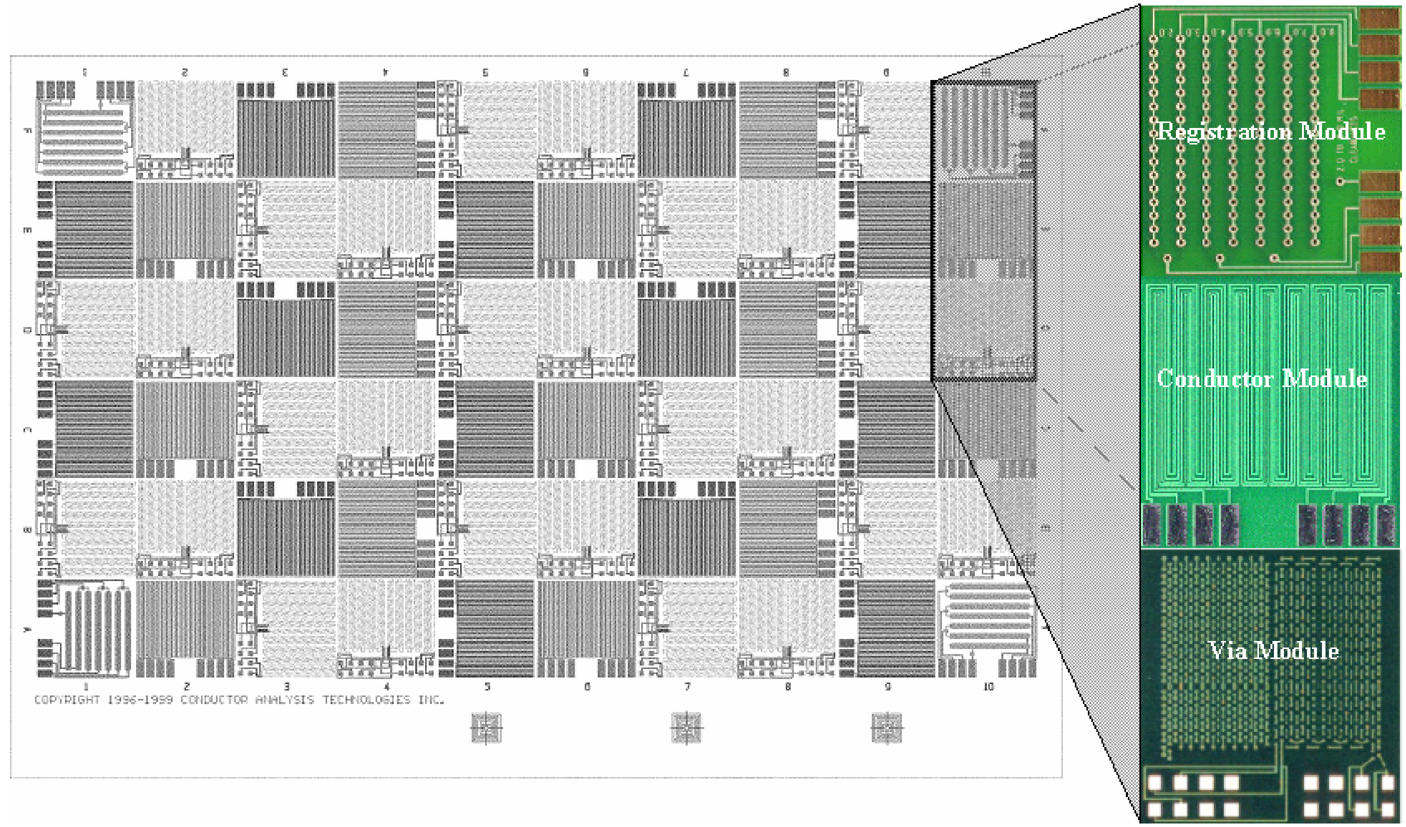
IPC-TM-650, TM 2.6.7 Series

- IPC methods are based upon the “MIL-STD” methods
- Small distinctions between methods for product technology
- Geared specifically to PCB’s and related materials
- Upper temperature is set to be below glass transition temperature (Tg) of laminate materials

Experimental Background

- Objective – compare different thermal shock test methodologies
- Delphi test panels fabricated by 3 different PCB manufacturers
- 6-layer 0.031-inch CAT process capability panels
  - CAT via formation modules (used for Delphi and HATS™ test)
  - IST coupons
- Comparison testing
  - Delphi air-to-air cycle (-40 to +145C)
  - Modified IST cycle (+25 to +170C)
  - HATS™ cycle (Delphi temperature cycle)

CAT Process Capability Panel



10.5 x 7.25 inch, 6-layer 0.031-inch thick panel

Test Panel Pre-Conditioning

- Panels subjected to 6 cycles of assembly pre-conditioning temperature profile
  - 2 minute preheat from +25 to +183C
  - 1 minute dwell between +183 to +215C
  - 3 minute cool-down
- Panels retested to determine any changes in coupon via net resistance
  - No significant changes were found

Delphi Standards

- 25 minute dwell at each temperature extreme
- Less than 5 minute transfer between extremes
- 1000 cycles $\rightarrow$ 41.7 days...(a long time)
- Temperature extremes and delta T based upon end product use
- Use of periodic resistance measurement to monitor reliability
  - Periodic monitoring misses actual failure point
- Delphi uses custom boards with different hole technologies

Delphi Application Specific Requirements

Class	Cycle	Operating Temperature	Typical Applications
A	-40 to 105C	85C	Passenger compartment
B	-40 to 125C	105C	Underhood Off-engine
C	-40 to 145C	125C	Underhood On-engine
D	-40 to 165C	145C	High performance/Chip-on-board/High dissipation components

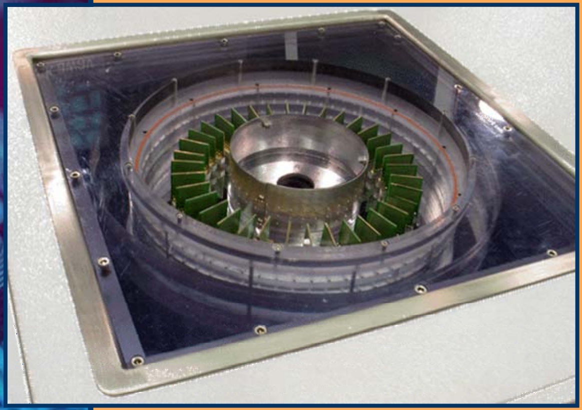
HATS™ Test System

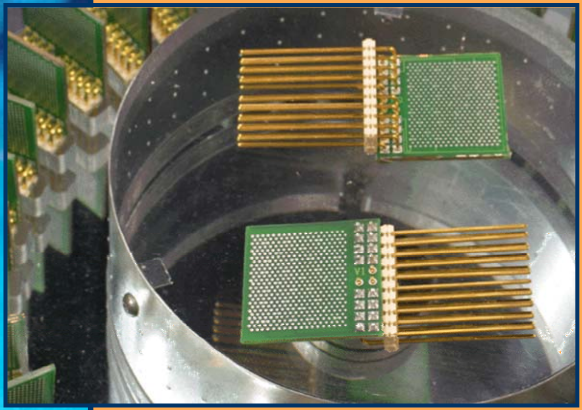
- **H**ighly **A**ccelerated **T**hermal **S**hock (HATS™)
- Partnership – Conductor Analysis Technologies & Microtek Labs
  - New company – Integrated Reliability Test Systems, Inc.
- Air-to-air methodology with stationary coupons
  - Single chamber, high volume airflow with large heat transfer capacity
  - 36 coupons (144 nets) per chamber load
- Thermal specifications
  - Temperature range: -60 to +160C
  - Air transition time: 30 seconds (-60 to +160C)
  - Air Stability: ± 2C
- Data acquisition
  - Mode: 4-wire resistance
  - Accuracy: 2% of resistance value
  - Precision: 2% resistance CoV
  - Speed: 10 readings per second

HATS™ Test System

- Sample sizes ranging from
  - 0.5 inch x 1.0 inch (smallest)
  - 1.0 inch x 2.0 inch (largest)
- Cycles times for a -40 to 145C cycle
  - 0.031” coupons approximately 7 minutes
    - 500 cycles in 2.5 days
  - 0.125” coupons approximately 10 minutes
    - 500 cycles in 3.5 days
- Capable of simulating test temperatures of current induced (CITC or IST) test methodologies

HATS™ System

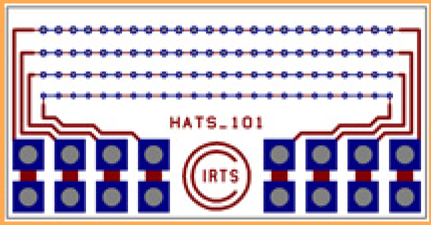




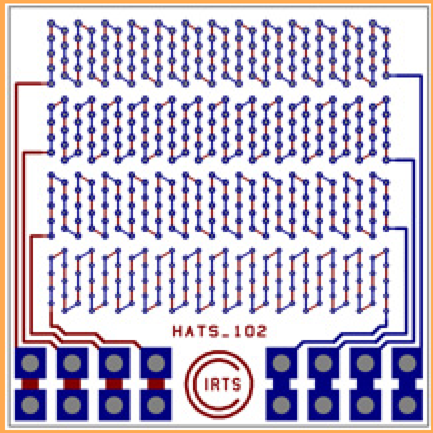
Online Coupon Generator

- www.HATS-Tester.com
- Gerber files immediately emailed
- 4 independent nets per coupon
- Nets can be “Through”, “Blind”, “Buried” or “Stacked”
- Parameters for each net
  - Hole size
  - Land size
  - Grid size
  - Interconnect sequences
  - Include/exclude teardrops
  - Include/exclude non-functional lands
  - Include/exclude soldermask coverage
  - Include/exclude ground planes

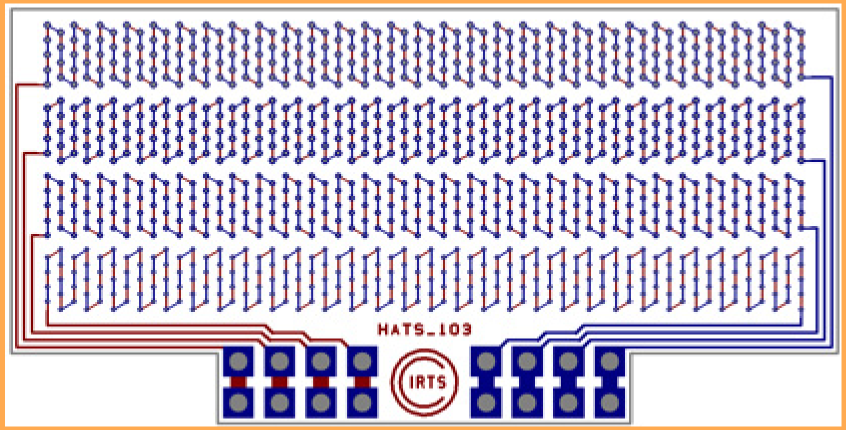
HATS™ Test Coupons



1.0 x 0.5 inch Coupon

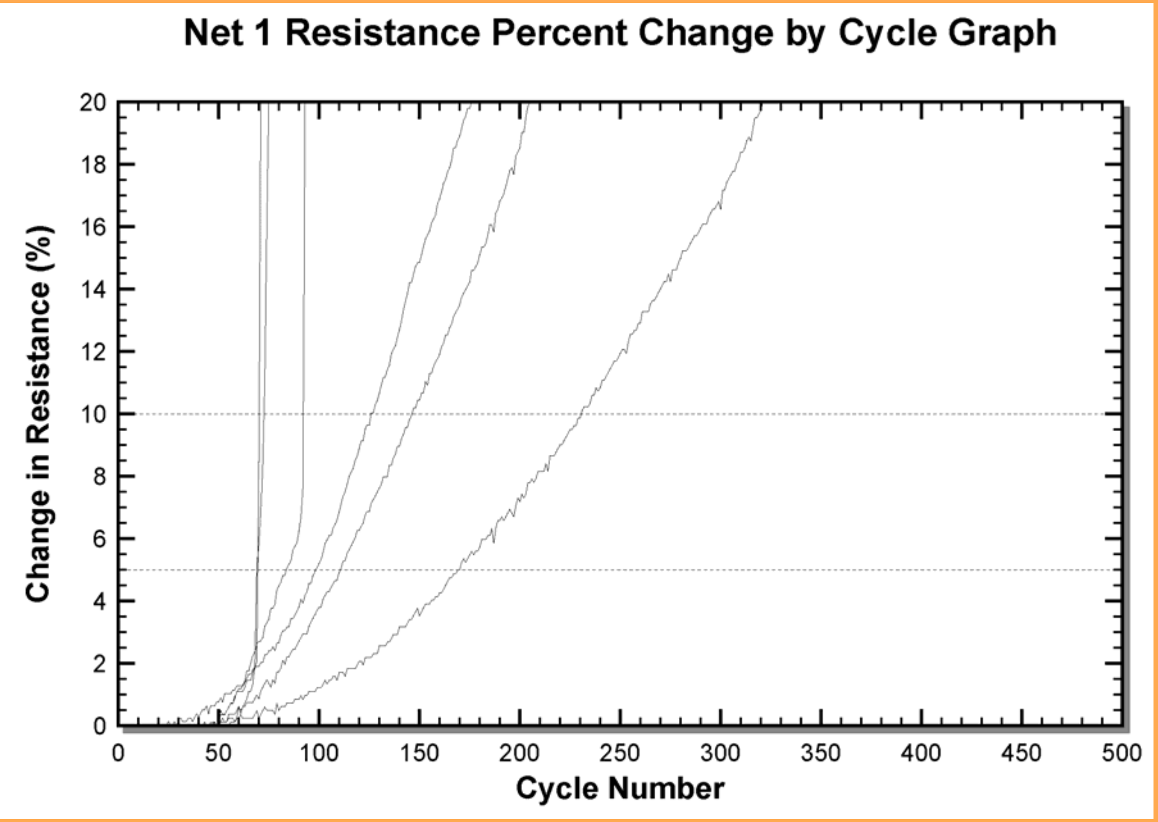


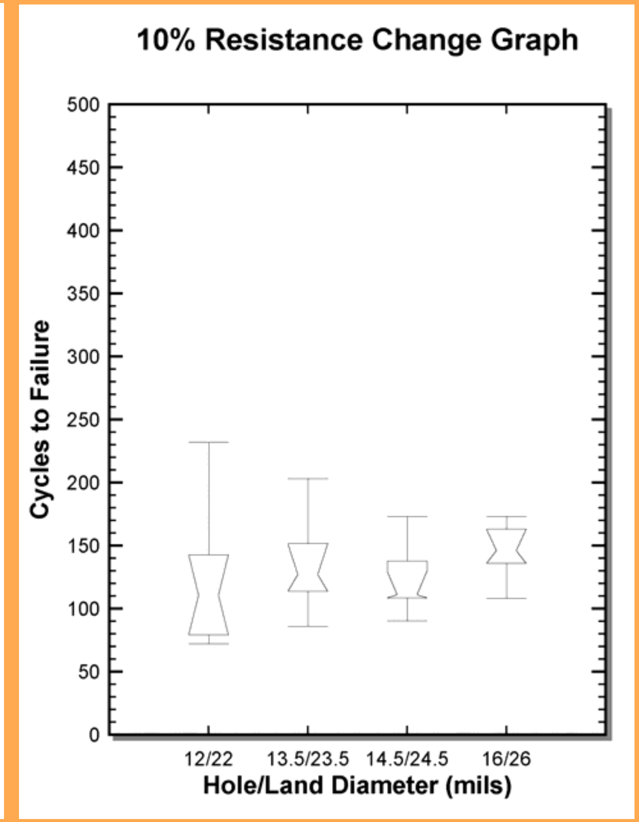
1.0 x 1.0 inch Coupon



2.0 x 1.0 inch Coupon

HATS™ Test Data

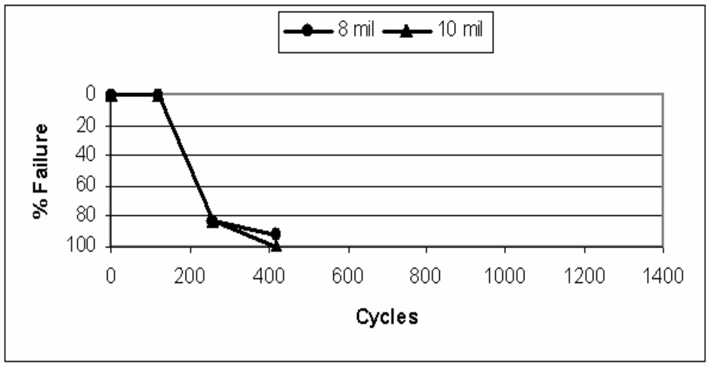




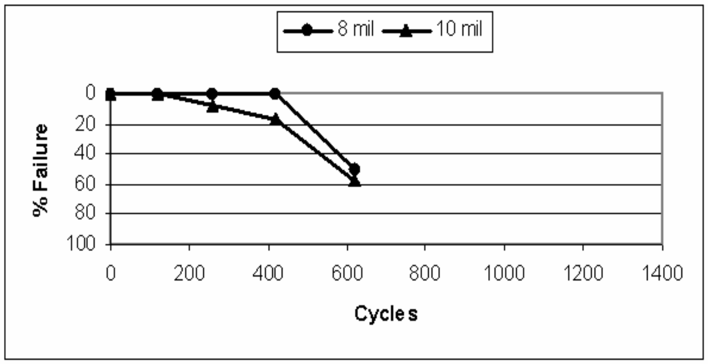
Delphi/PCQR^2 Reliability Study

Hole (mils)	Land (mils)	Annular Ring (mils)	Aspect Ratio	Interconnect Sequence
8	14	3	3.8:1	1-4-2-5-3-6
8	20	6	3.8:1	1-4-2-5-3-6
10	16	3	3.1:1	1-4-2-5-3-6
10	22	6	3.1:1	1-4-2-5-3-6

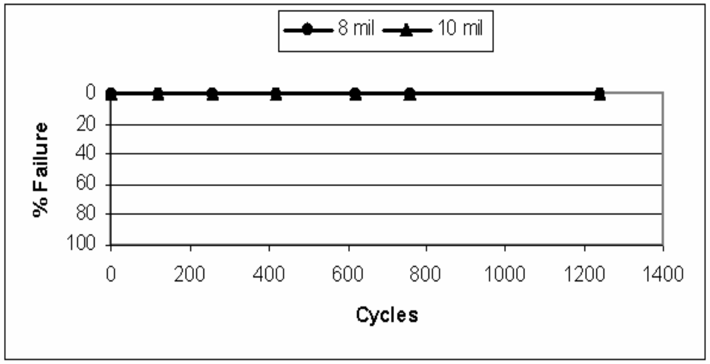
Delphi Data



Manufacturer A

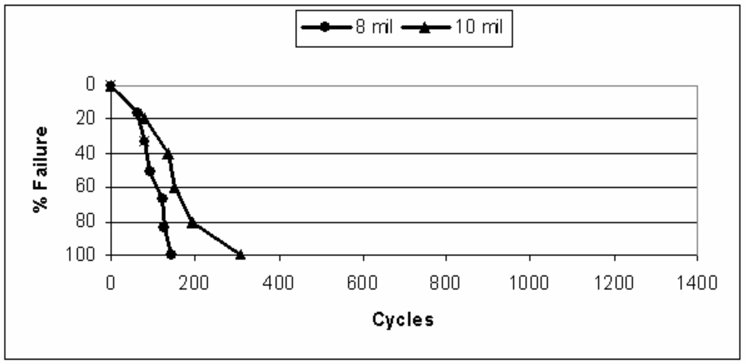


Manufacturer B

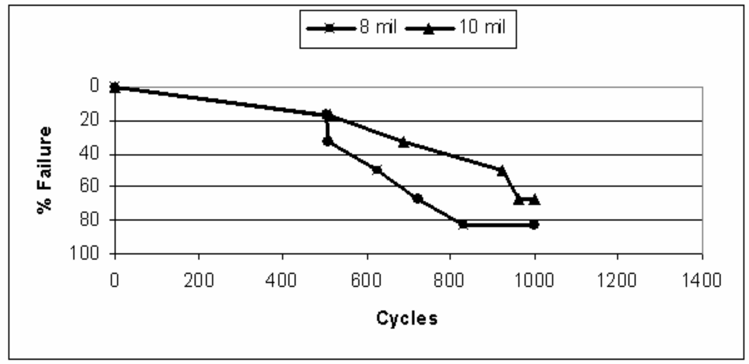


Manufacturer C

IST Data



Manufacturer A



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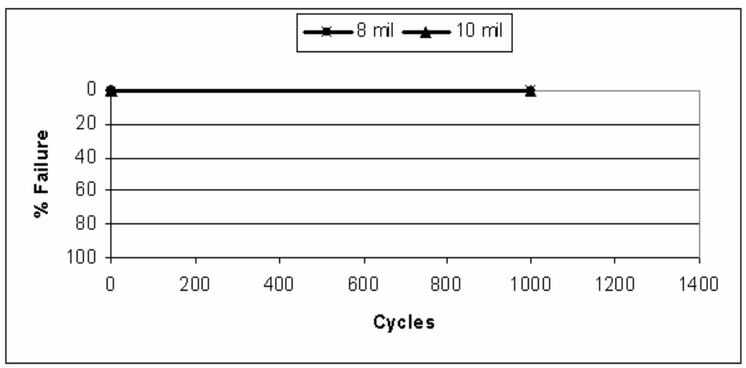
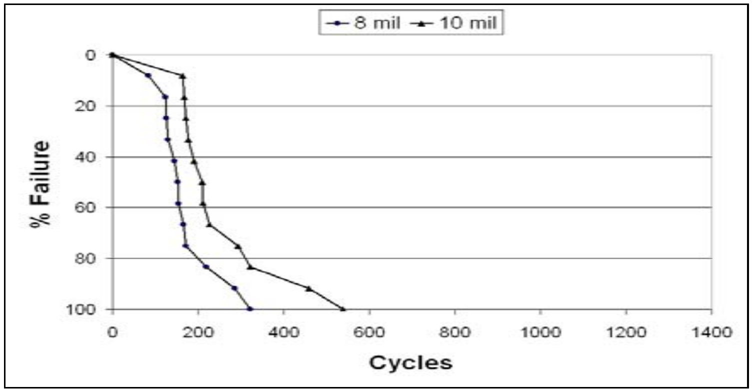
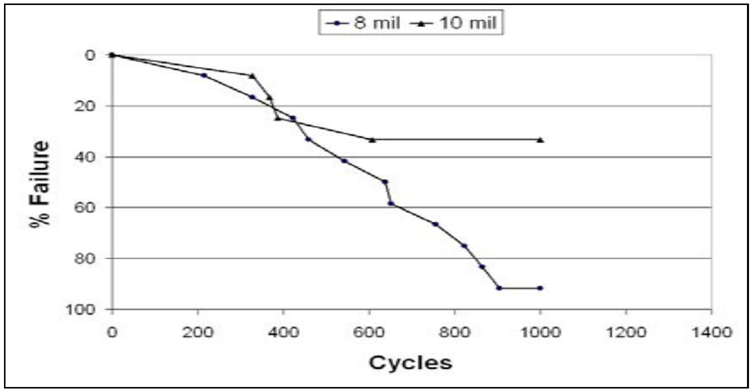


Manufacturer C

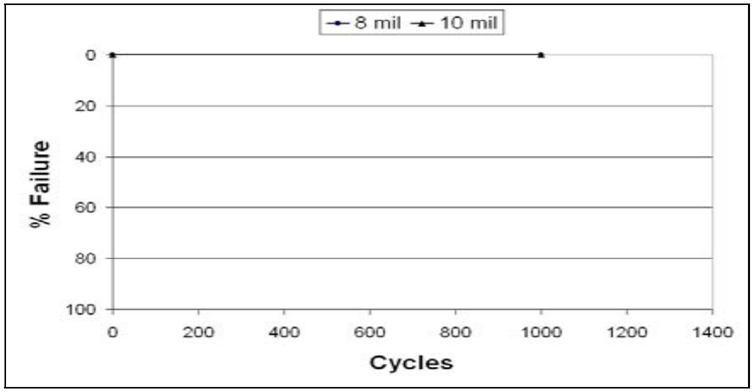
HATS™ Data



Manufacturer A

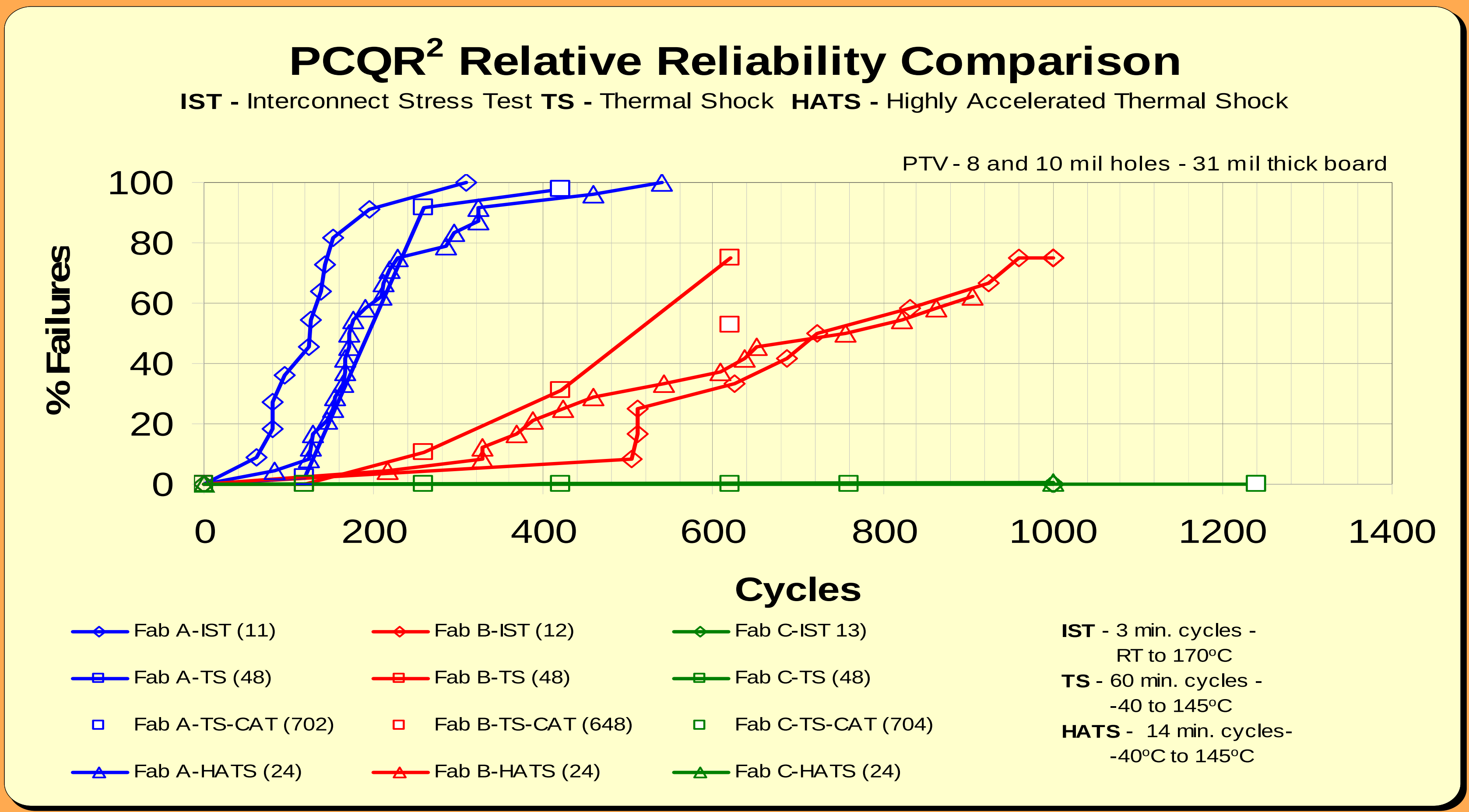


Manufacturer B



Manufacturer C

Delphi/PCQR^2 Reliability Study



IPC D-36 PCQR^2 Adoption of HATS™

- PCQR^2 committee adopted HATS™ test method for relative reliability data
  - Shortened Delphi Class "C" cycle time for under hood on-engine requirements
  - Uses standard CAT via formation modules from PCQR^2 test panels
- PCQR^2 Database relative reliability test cycle
  - 500 cycles or until 10% resistance change
  - -40C to +145C
- www.pcbquality.com

Test Methodology Differences

Attribute	HATS	IST	Dual-Chamber
Thermal exchange	Air-to-air	Current induced	Air-to-air
Number of coupons per load	36	6	Custom
Nets per coupon	4	2	Custom
Total number of nets per load	144	12	Custom
Typical temperature range (C)	-60 to +160	+25 to +150	-55 to +160
Delta T (C)	220	125	215
Typical cycle time (minutes)	14	5	60
Precision 4-wire resistance	Yes	Yes	Difficult

Test Methodology Differences

- HATS™ method provided 4.3 times shorter cycle time than Delphi dual-chamber method
  - Same temperature range and delta T as Delphi Class "C" cycle
  - Uses air as the transfer medium
- IST cycle time was shortest
  - Lowest temperature of IST cycle is 65C higher than Delphi Class "C" cycle
  - Lower delta T than Delphi method, +145C vs. +185C
  - Upper temperature of IST test method
    - Exceeds T_g of many laminate materials
    - 25C higher than Delphi method

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