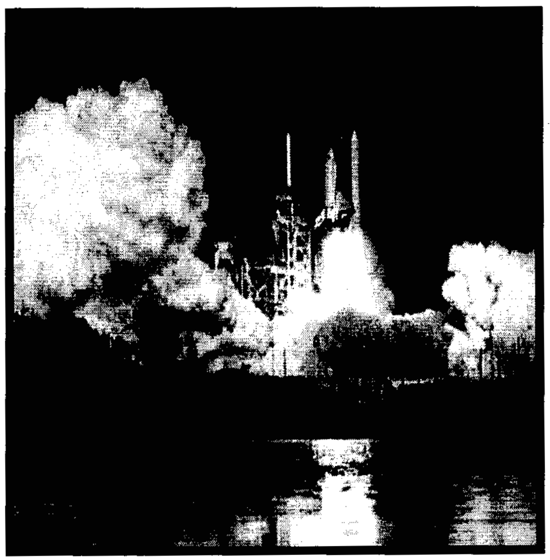
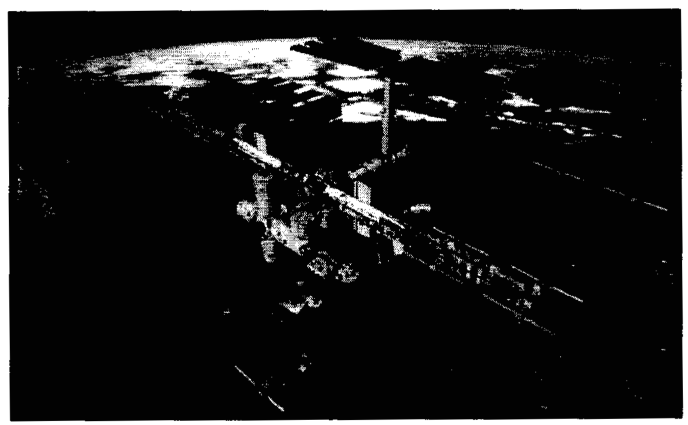
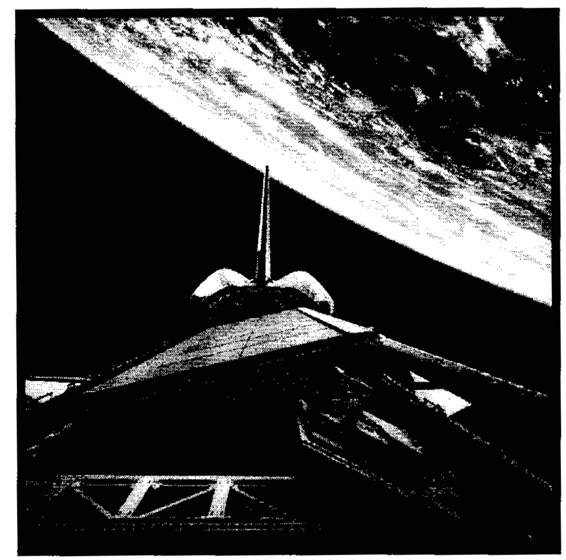
Military & Space Electronics Conference

Investigation of Low Glass Transition Temperature on COTS PEMs Reliability for Space Applications







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Agenda

- Introduction
- Glass Transition Temperature (Tg) Measurement Methods
- Definition of Glass Transition Temperature
- Coefficient of Thermal Expansion (CTE)
- Failure Modes of Exceeding Tg
- Tg Measurements Data
- PEMs Issues vs Tg
- Burn-In/Reliability Investigations
- Advanced Reliability Data
- Observations/Summary

The work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract to the National Aeronautics and Space Administration

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Introduction

Many factors influence PEM component reliability.

Some of the factors that can affect PEM performance and reliability are the glass transition temperature (Tg) and the coefficient of thermal expansion (CTE) of the encapsulant or underfill.

JPL/NASA is investigating how the Tg and CTE for PEMs affect device reliability under different temperature and aging conditions. Other issues with Tg are also being investigated.

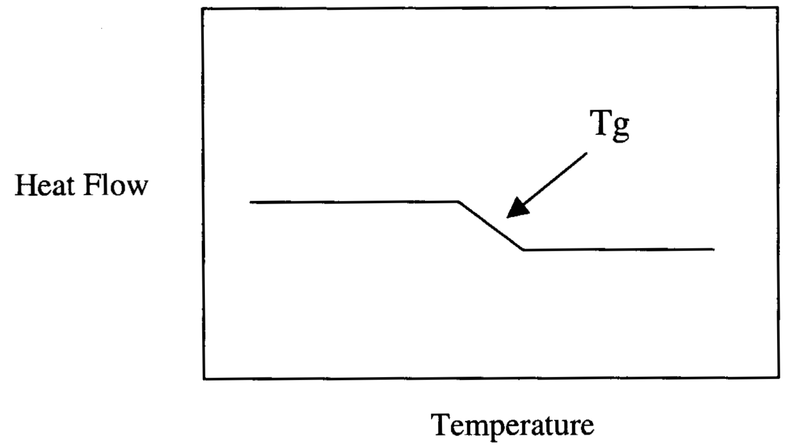
Data will be presented on glass transition temperature test results and reliability tests conducted at JPL.

Tg Measurement Methods Available

	Typical Time	Sample prep	Repeatability	Dependability	Comments
Differential Scanning Calorimetry	20 minutes	Easy	Good	Marginal	Many materials do not exhibit clear transitions
Thermo Mechanical Analysis	40 minutes	Medium	Fair	Good	Very dependant on sample preparation
Dynamic Mechanical Analysis	120 minutes	Difficult	Excellent	Excellent	Tg can be defined several different ways

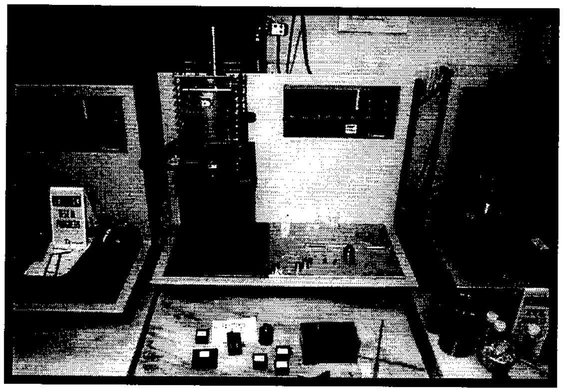
Differential Scanning Calorimetry (DSC)

- Quick and simple test
- No special preparation needed
- Method consists of heating the sample in a closely calibrated thermocel where the temperature of the sample is compared to the temperature of a blank reference point within the same cell
- The change in heat capacity at the Tg is seen as a shift in the baseline for the cured encapsulant

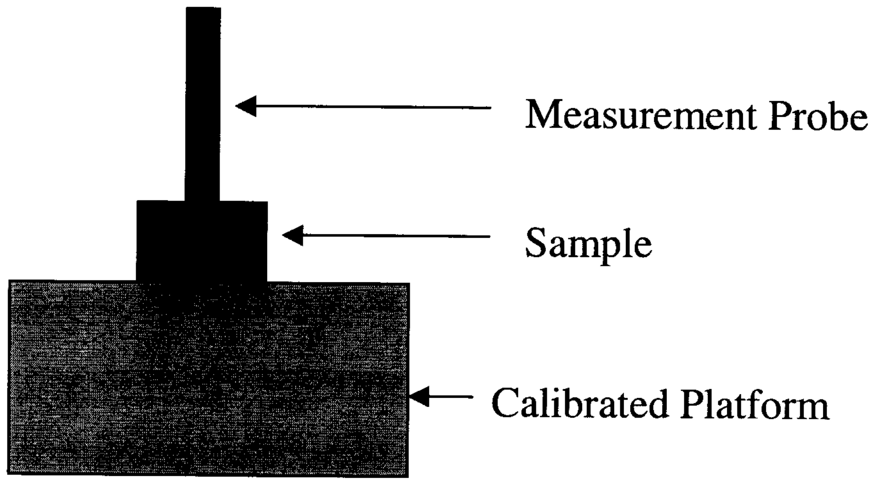


JPL DSC Tester

Thermal Mechanical Analysis (TMA)



JPL TMA Tester



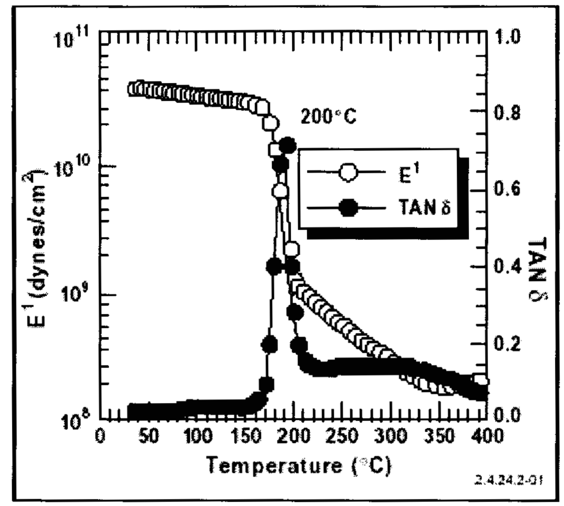
The method consists of heating the sample upon a expansion-calibrated platform and measuring the dimensional change of the sample with an instrumented probe. Probe placement can alter reading.

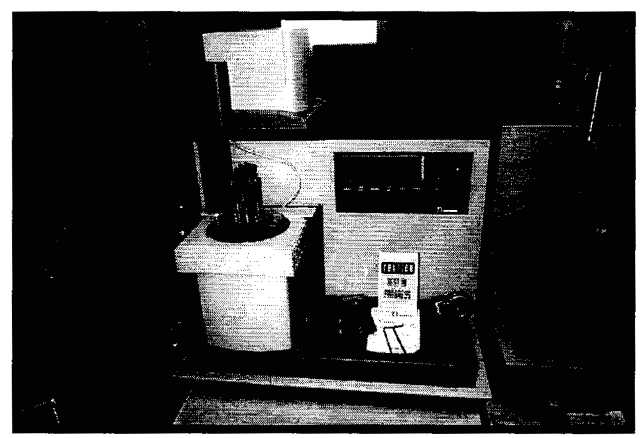
- ISO 11359-1:1999
  Plastics -- Thermomechanical analysis (TMA) -- Part 1: General principles

- ISO 11359-2:1999
  Plastics -- Thermomechanical analysis (TMA) -- Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature

Dynamic Mechanical Analysis (DMA)

- Measures changes in dynamic characteristics of materials
- e.g. Modulus (stiffness)
- e.g. Damping (energy dissipation)
- e.g. Creep
- e.g. Stress Relaxation

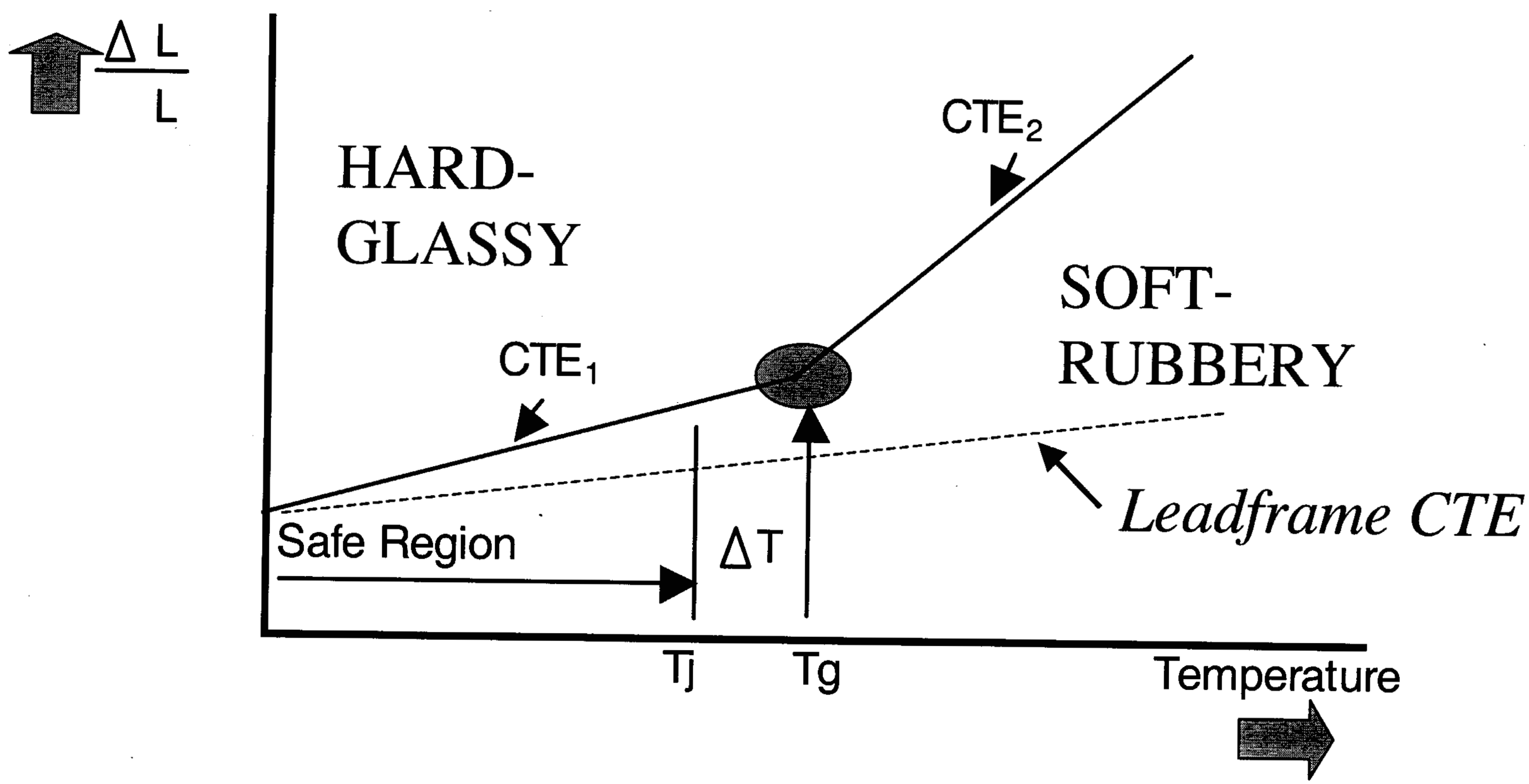




JPL DMA Tester

Glass Transition Temperature (Tg) - Amorphous Polymer

PEM Tg is calculated as the midpoint of the temperature range at which a dramatic change in CTE occurs.



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Coefficient of Thermal Expansion (CTE)

CTE is a measure of the fractional change in dimension (usually thickness) per degree rise in temperature. For microelectronics encapsulants, it is often quoted in "ppm/°C" (value x 10-6/°C).

CTE is highly dependent on the chemistry composition, filler loading, and cure cycles of the encapsulant.

It is desirable to have both a high Tg and a low CTE that closely matches the package assembly components (which include the die, wires, and leadframe).

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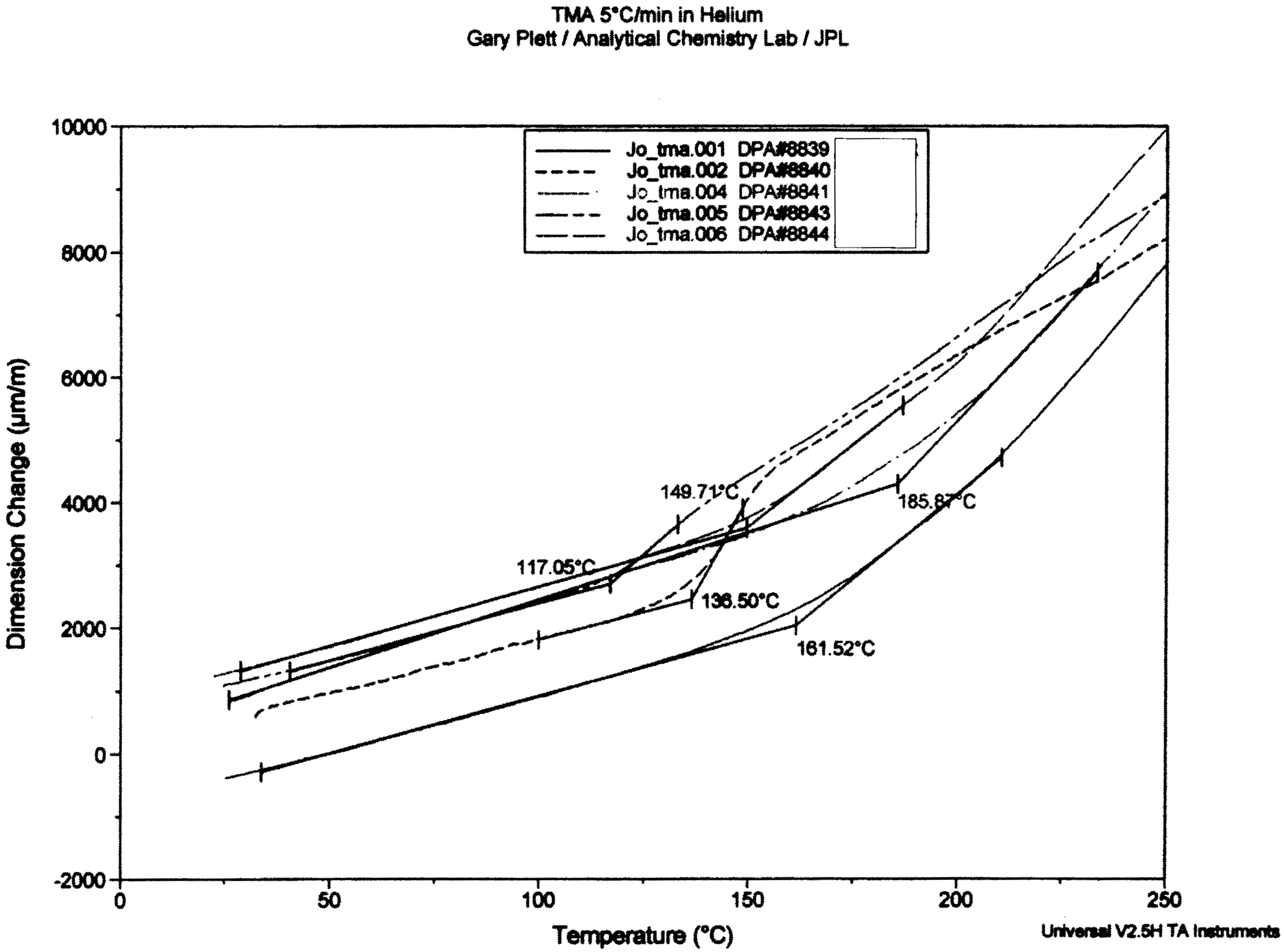
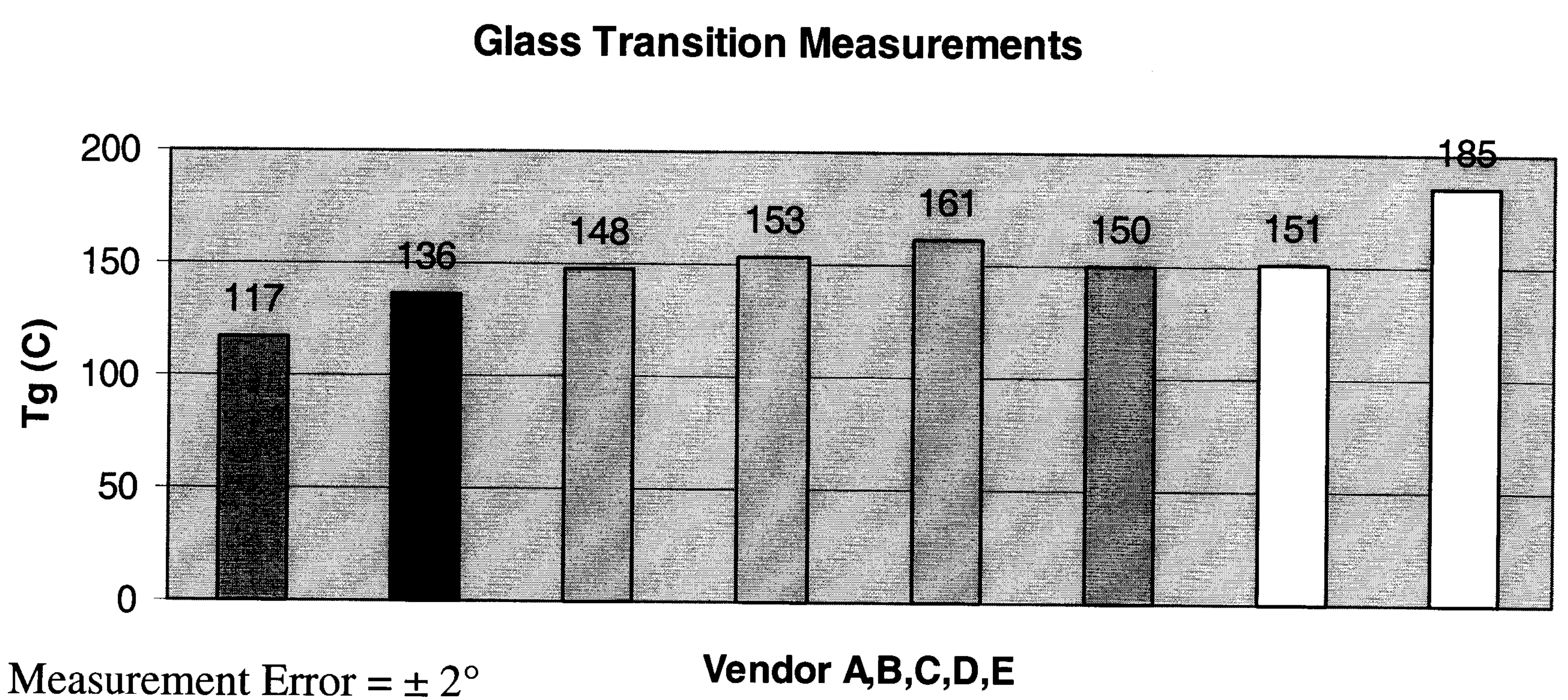
Failure Modes Reported When Tg is Exceeded

- CTE of epoxy encapsulant will permanently change (breakdown of chemical cross-linking of polymers); this could cause displacement of wire bonds resulting in a premature wear-out and breakage of wires
- Premature aging (e.g. storage)
- Induced stresses between materials internal/external) because of CTE mismatch; reduces temp. cycling capability
- Adhesion degradation
- Corrosion and lifted bonds due to release of Bromine, Red Phosphorous (flame retardants) and or other ionics
- Device performance degradation

Examples of Tg Measurement Results for PEMs with No Preconditioning



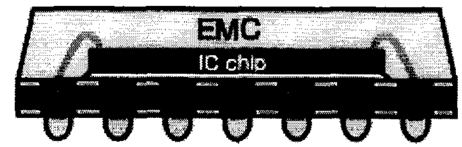
PEMs Tg Measurement Results with No Preconditioning



Measurement Error = ± 2°

Tg varies among different vendors and sublots from the same vendor.

Example of Semiconductor Vendor's Epoxy Molding Compound Properties Specified



General Properties					
Item	Unit	Condition	Newly Developed		Conventional
			CEL-300*	CEL-310*	CEL9200*
Spiral Flow	cm	EMMI-1-66	100	90	90
Gelation Time	sec	175°C	40	30	28
Tg	°C	TMA	120	110	120
CTE(α1)	ppm/°C	TMA	7	8	8
Flexural Modulus	GPa	JIS-K-6911	28.0	26.0	26.0
Water Absorption	wt%	PCT 20h	0.28	0.31	0.30
Flammability	-	UL-94	V-0	V-0	V-0

PEMs Issues Relative to Tg

- **Maximum allowable burn-in temperatures vs Tg (now under investigation)**
- Derating required vs Tg (future)
- Reliability vs low and high Tg (future)
- Review of ASTM E595-93 methodology (future) (performing outgassing) when Tg <125°C

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Allowable Burn-In/Reliability Investigations

Objective: Determine how devices fail or degrade when the BI temperature is at or above the part Tg as measured.

- #1) Device Type A/D, Tg = 117C (30 parts split into three groups)

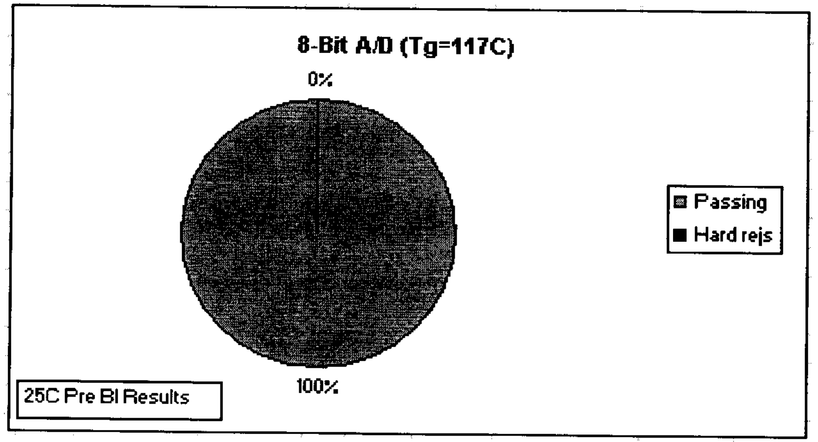
  Pre & Post Performance testing over temperature with +85C/+115C/+145C Burn-In for 240 hours

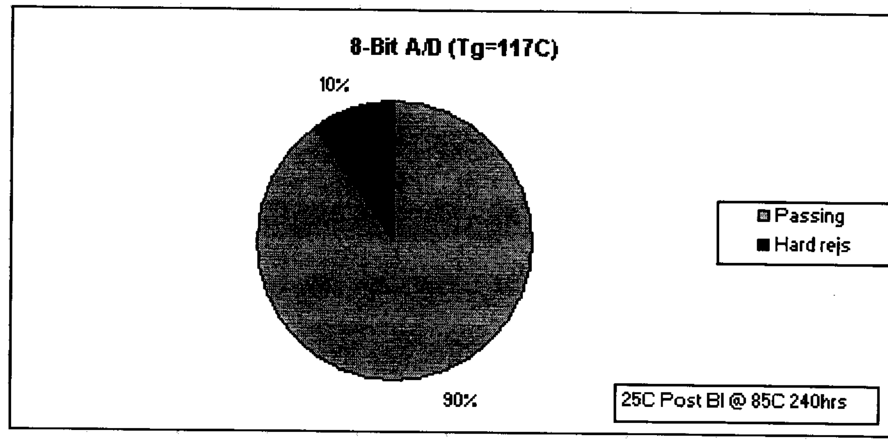
- #2) Device Type Op Amp, Tg = 136C (30 parts split into three groups)

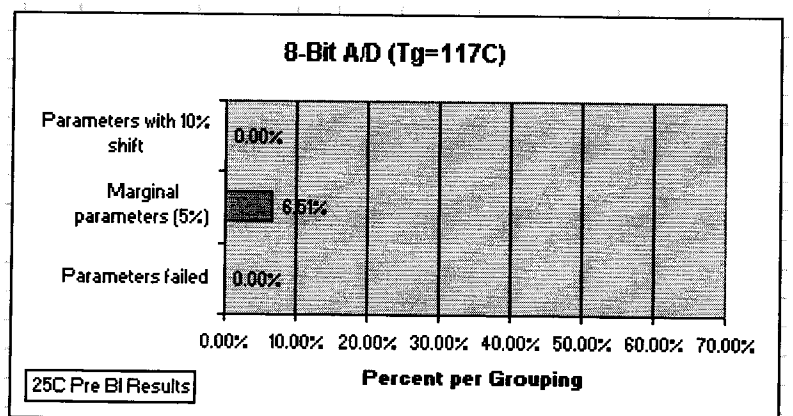
  Pre & Post Performance testing over temperature with +85C/+130C/+150C Burn-In for 240 hours

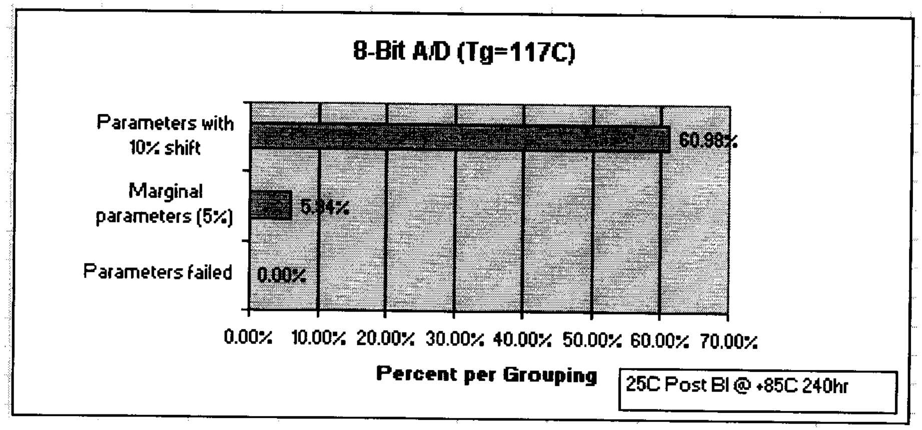
SS=10

COTS A/D Reliability Data Set 1A





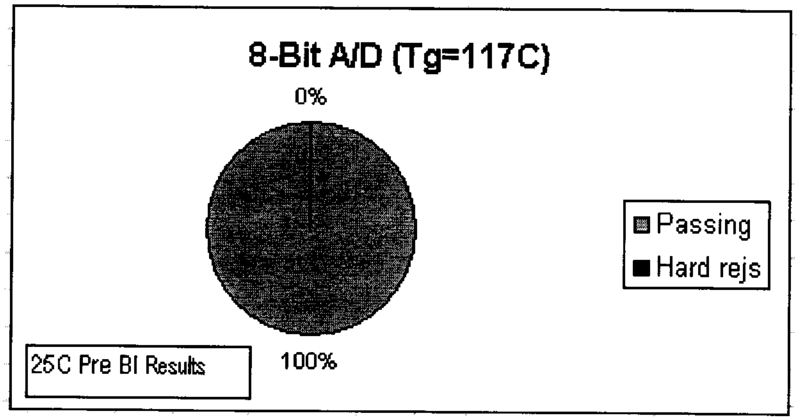


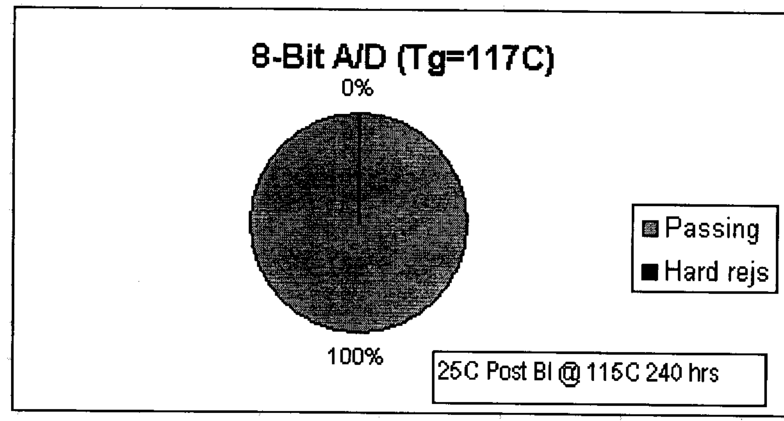


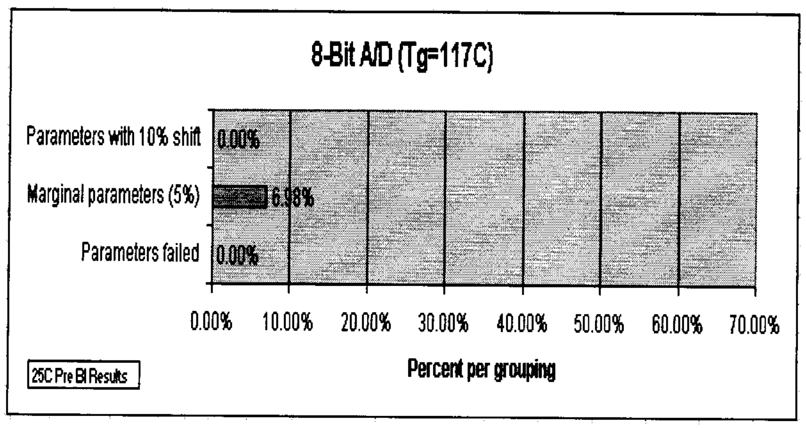
Note: Hard rejects include opens, shorts, and failing data sheet parametric limit.

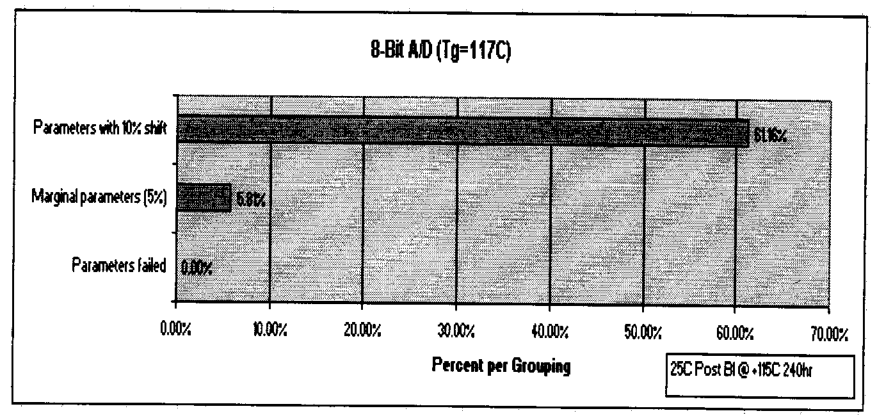
COTS A/D Reliability Data Set 1B

SS=10



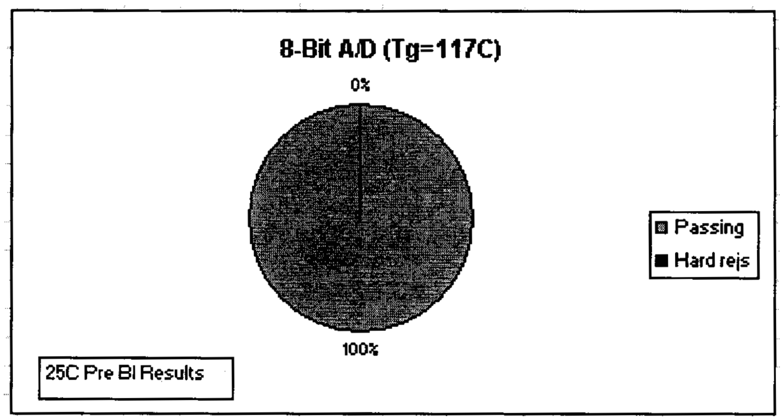


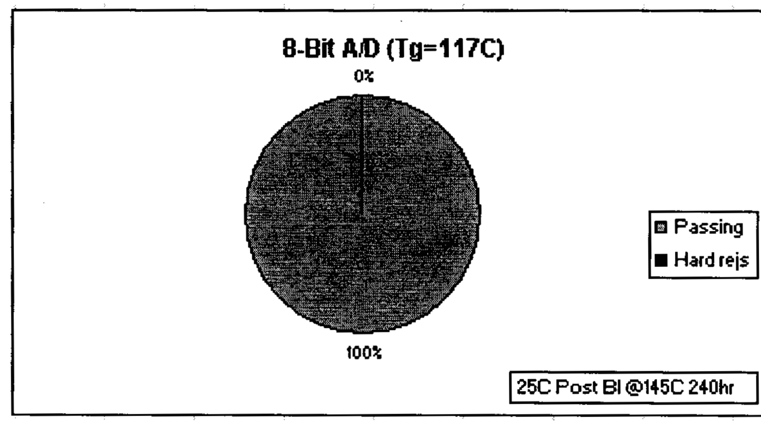


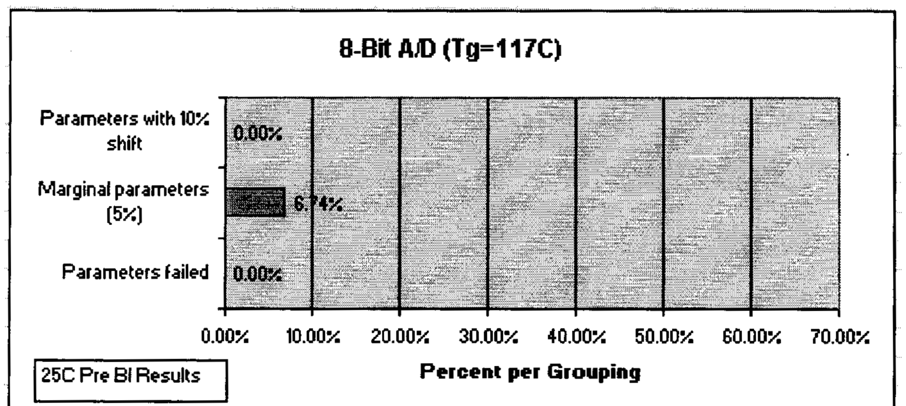


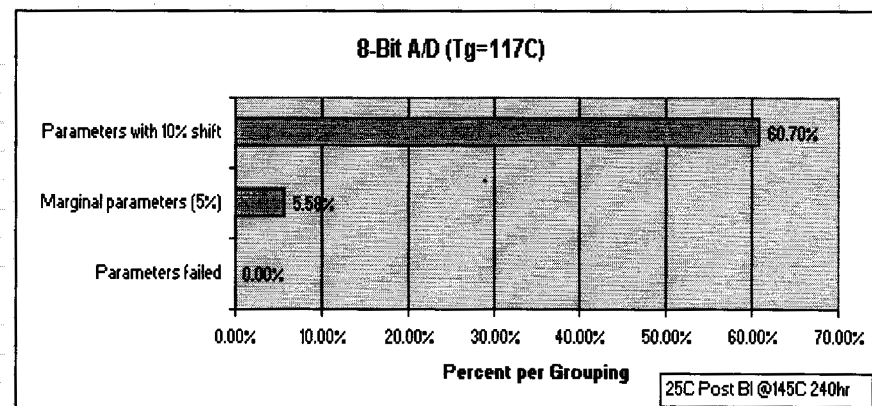
COTS A/D Reliability Data Set 1C

SS=10



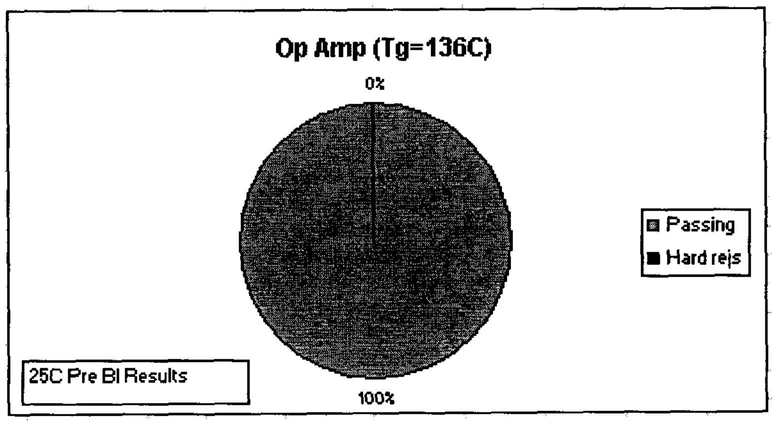


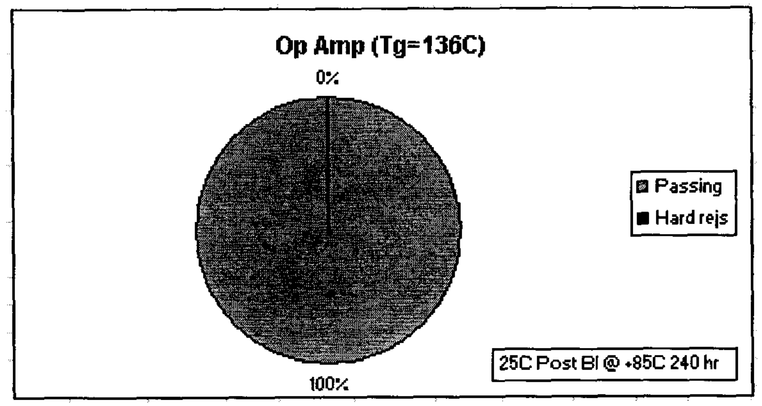


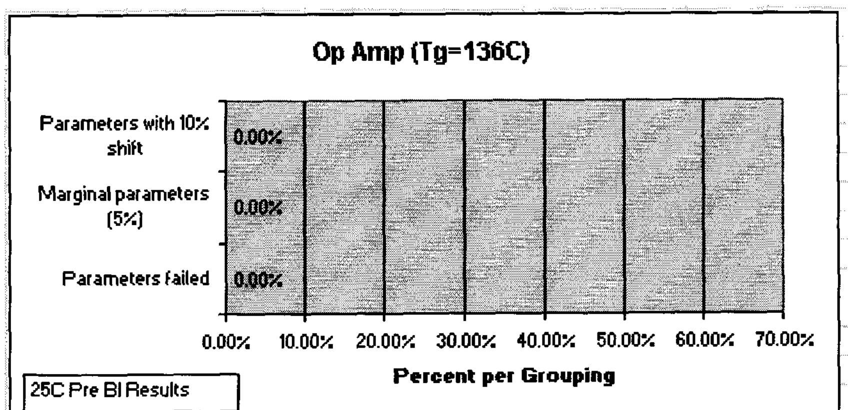


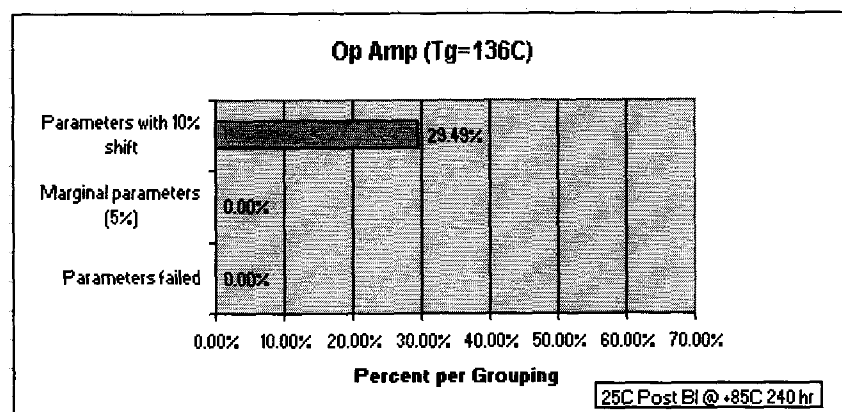
COTS Op Amp Reliability Data Set 2A

SS=10



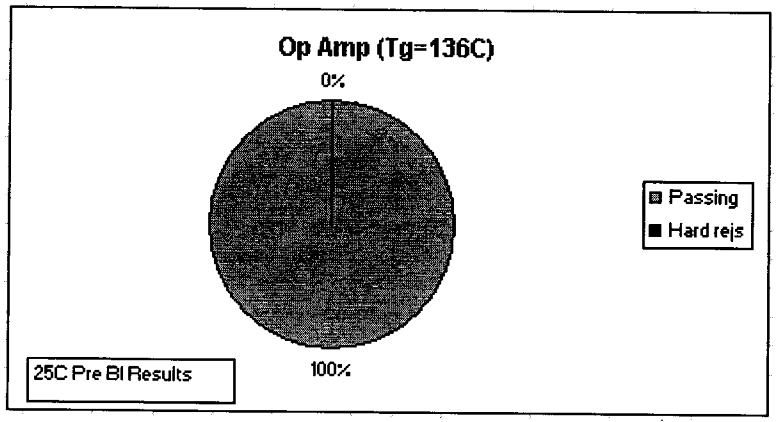


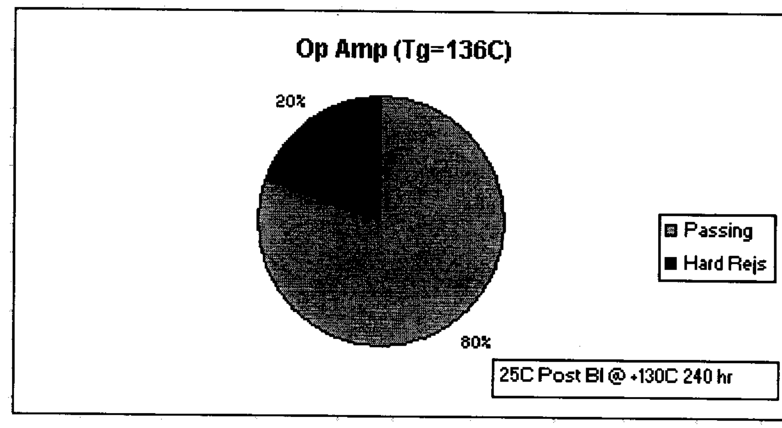


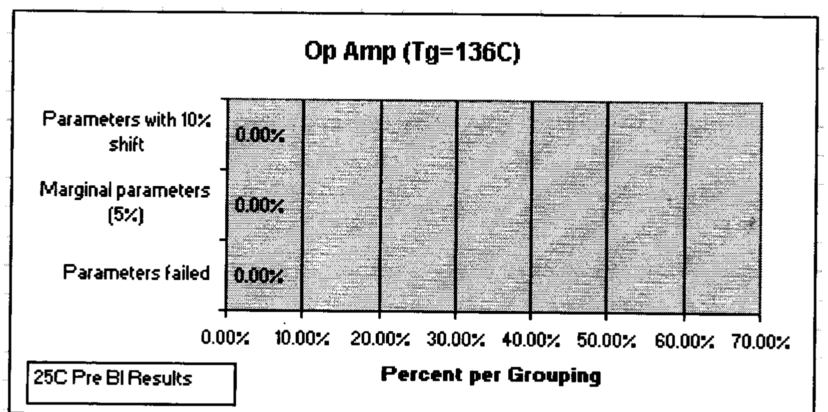


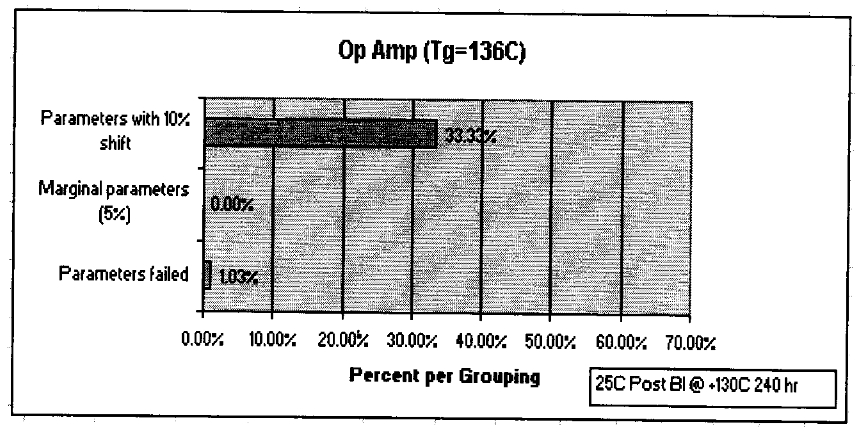
COTS Op Amp Reliability Data Set 2B

SS=10









COTS Op Amp Reliability Data Set 2C

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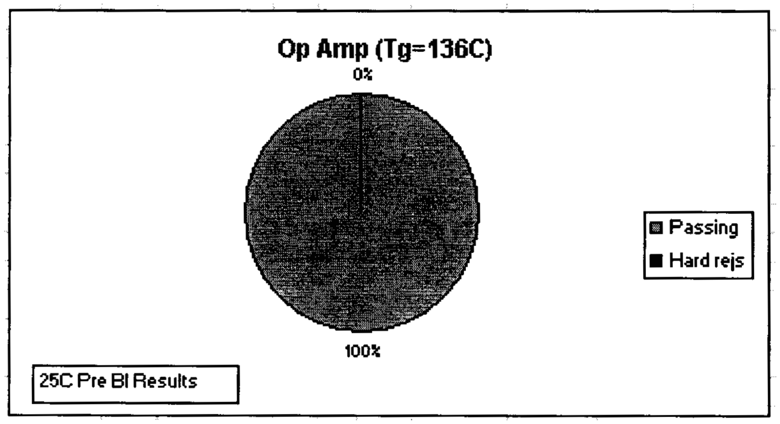

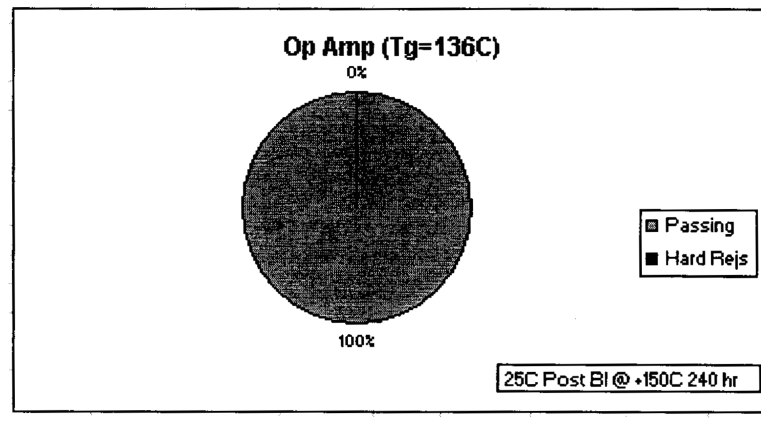

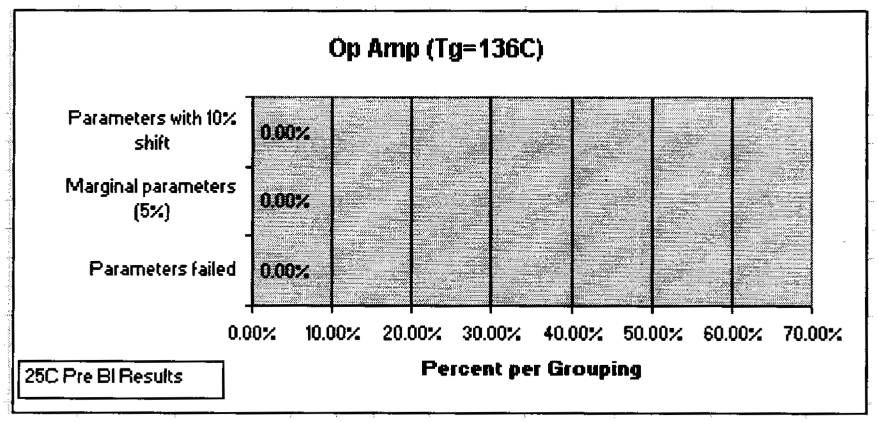

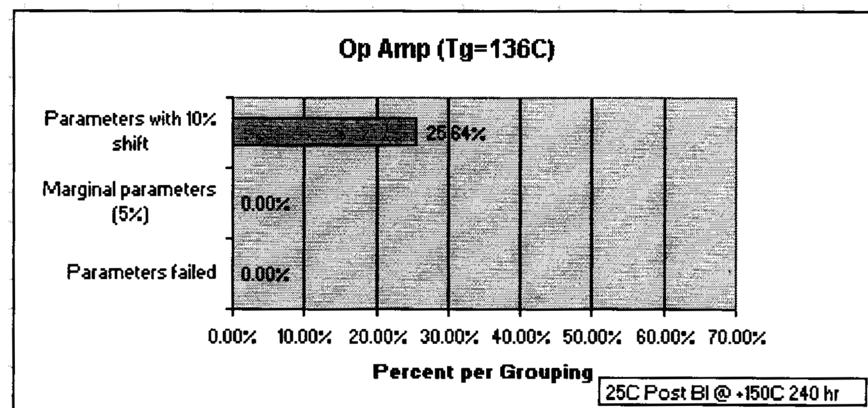

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Observations/Summary

- Based on room temperature measurements of the two device types, burned in at three different temperatures, it does not appear there is correlation between BI temperature and Tg. Because of the small sample size, additional investigation is needed to be more conclusive e.g longer burn-in/life test duration and higher temperatures and review of the high and low test data results.

- Three burn-in failures (functional & parametric) occurred. Further analysis is underway to determine if the Tg had a role in the failures.

- Consistent parametric shifts are apparent with all burn-in conditions used. For the A to D the predominant parameters exhibiting >10% shift were input leakage and high output current. For the Op Amp the predominant parameters exhibiting >10% shift were input offset voltage/current, input bias, and large-signal voltage gain. Further study is needed to establish if Tg has an affect.

- Changes in vendor's material properties, for PEMS, are continually occurring, and necessitate user vigilance.

Follow-up Work

- Investigation of Tg changes after burn-in (correlations?)
- Review of cold and high temperature electrical read & record data taken on the test samples
- Perform failure analysis on the three burn-in rejects
- Perform post burn-in measurements for any ionics extracted