BiTS™

Burn-in & Test Socket Workshop

March 6-9, 2005
Hilton Phoenix East / Mesa Hotel
Mesa, Arizona

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Burn-in & Test Socket Workshop

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Burn-in & Test Socket Workshop

Technical Program

Session 5

Tuesday 3/08/05 10:30AM

CHARACTERIZATION AND QUALIFICATION

"Qualifying A Supplier – What One Customer Does"

Tim Swettlen – Intel Corporation **Marc Berube** – Intel Corporation

Brett Grossman – Intel Corporation

"Reducing The Cost Of Test: High Speed Contactor Systems"

Gordon Vinther – Ardent Concepts, Inc. **Tom Goss** – M/A-Com / Tyco Electronics

"Verification Of The Predictive Capability Of A New Stress Relaxation Test Apparatus And FEA Technique For Predicting The Stress Relaxation Of Electro-Mechanical Spring Contacts Made Using CuBe Strip"

Mike Gedeon – Brush Wellman, Inc. **Hideo Matsushima** – Brush Wellman Japan LTD

Qualifying a supplier,
what one customer does

Marc Berube	Intel Corp.
Brett Grossman	Intel Corp.
Tim Swettlen	Intel Corp.

March 2005

BURN–IN & TEST
SOCKET WORKSHOP

Agenda

- Conversion of product requirements into socket requirements
- Methodology for evaluating socket technologies against requirements
- Process for short listing suppliers
- Impact of the lack of standardized test methods

Socket Electrical Parameters

- As with any evaluation, one has to define criteria
  - ✓ Measurable across all samples
- Includes Commercial, Mechanical, Thermal & Electrical parameters
  - ✓ Sample list of some of the electrical parameters
- Where do these parameters come from?

Sample Electrical parameters

Parameter	Target	Unit
Contact Resist (Cres)	30	mohm
Loop Inductance	2	nH
MTBF	100000	cycles
PM Interval	15000	cycles
ESD	10^6 - 10^9	Ohms
Pin Current Rating	2.3	Amp
Contact pin to package land/pin alignment	1.33	Cpk
Max IO pin count	200	pins
Min pin pitch	1.1	mm
Max Datarate	20	Gbps
Max Frequency	20	GHz
Return Loss	-13	dB
Insertion Loss	-1.5	dB
Xtalk (isolation)	-30	dB
Impedance	100 +/-10%	Ohms

**Targets shown are for illustrative purposes only*

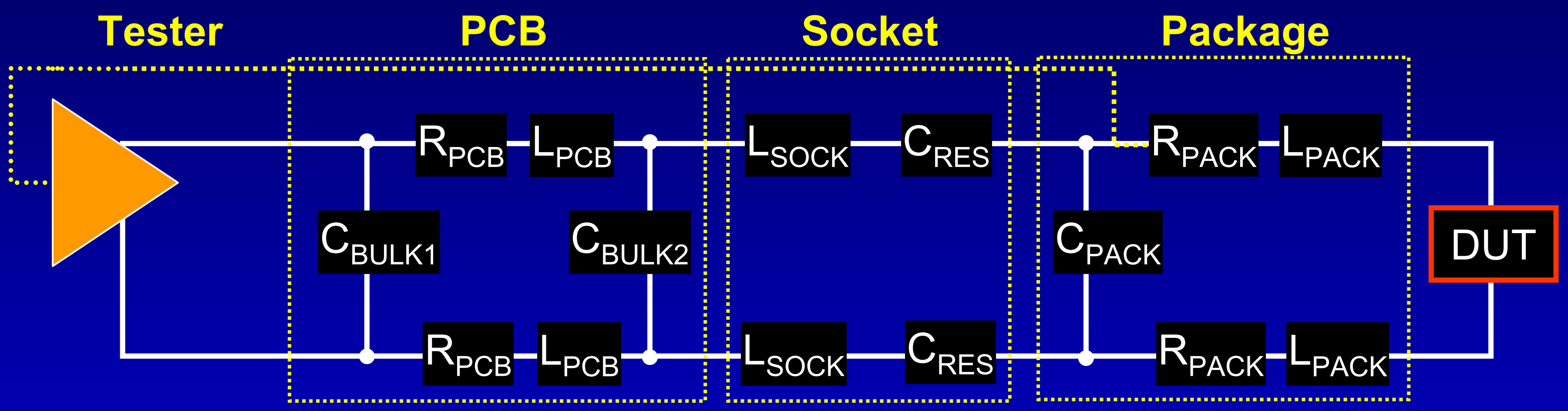
Target transition flow

e.g. 63 GHz Processor or New Chipset

Product	Module	Socket
1. Die Size 2. Power	BI capacity	Vcc/Vss Depopulation
2. Power 3. Vcc 4. I(t)	Power budget	Res. & Induct. targets
5. Bus architecture	Structural test w/ loop thru	Bandwidth targets
6. Test costs	Lifetime & MTBF	$/TD MTBF

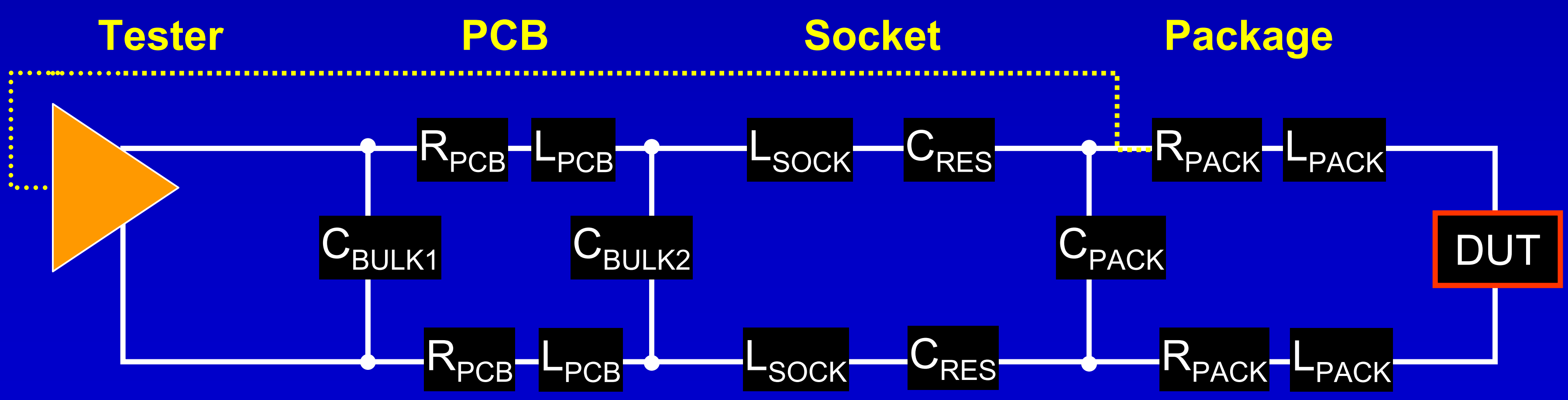
Drive down example

Definitions



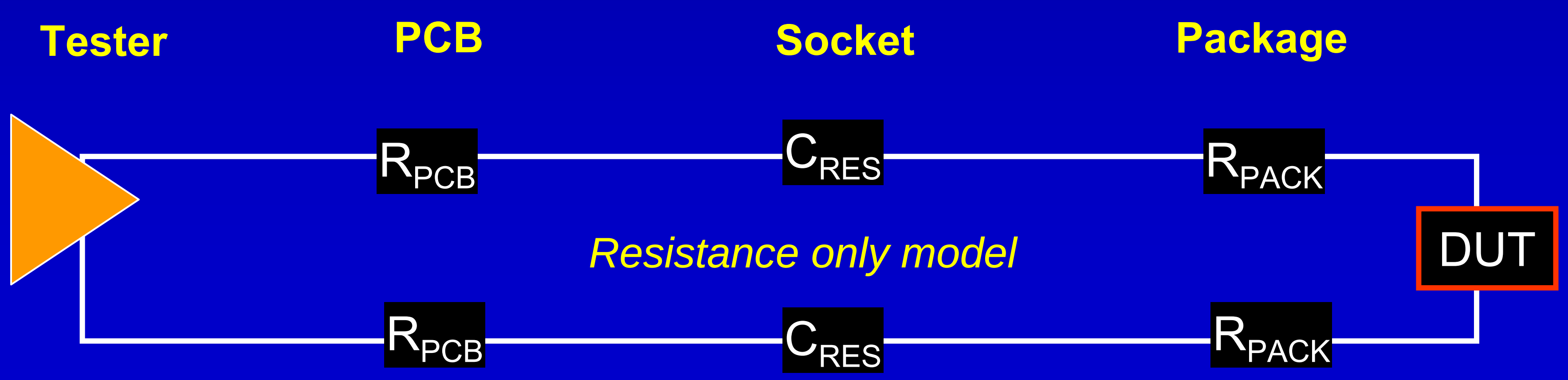
Drive down example

- Contact Resistance (C_{RES}) example
- 100 Watt DUT running at 1 V
  - ➢P= V * I → I = 100 Amp (max)
  - ➢*Assume* 80% max swing → 0.80 * 100 A = 80 Amps
- ✓*Assume* a 10% Voltage window
  - ➢0.9-1.1 V maintained at DUT for normal operation



Drive down example

- Resistance budget, *assume* 60% of total path
  - ✓ 0.60 * 100 mV = 60 mV
  - ✓ *Assume*
    - ➢ 50% loss in PCB/package & 50% loss in socket
    - ➢ 0.5 * 60 mV = 30 mV just from socket
- Total voltage drop due to the socket of 30 mV
  - ✓ For 2 Cres elements



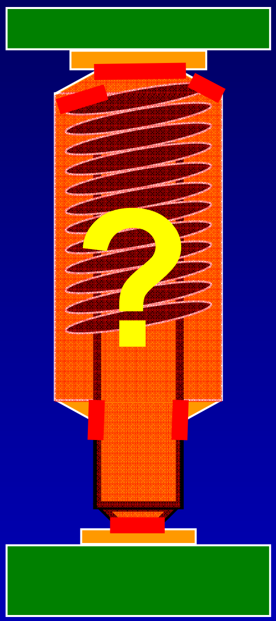
Drive down example

- *(continued)* R total = 0.300 mΩ
  - ✓ V=IR 30 mV / 100 Amps
- ***Assume***
  - ✓ 200 Vcc & 200 Vss
  - ✓ C_{RES} = 0.150 mΩ * 200
- $\underbrace{C_{RES} = 30\ m\Omega}$

What does this mean?

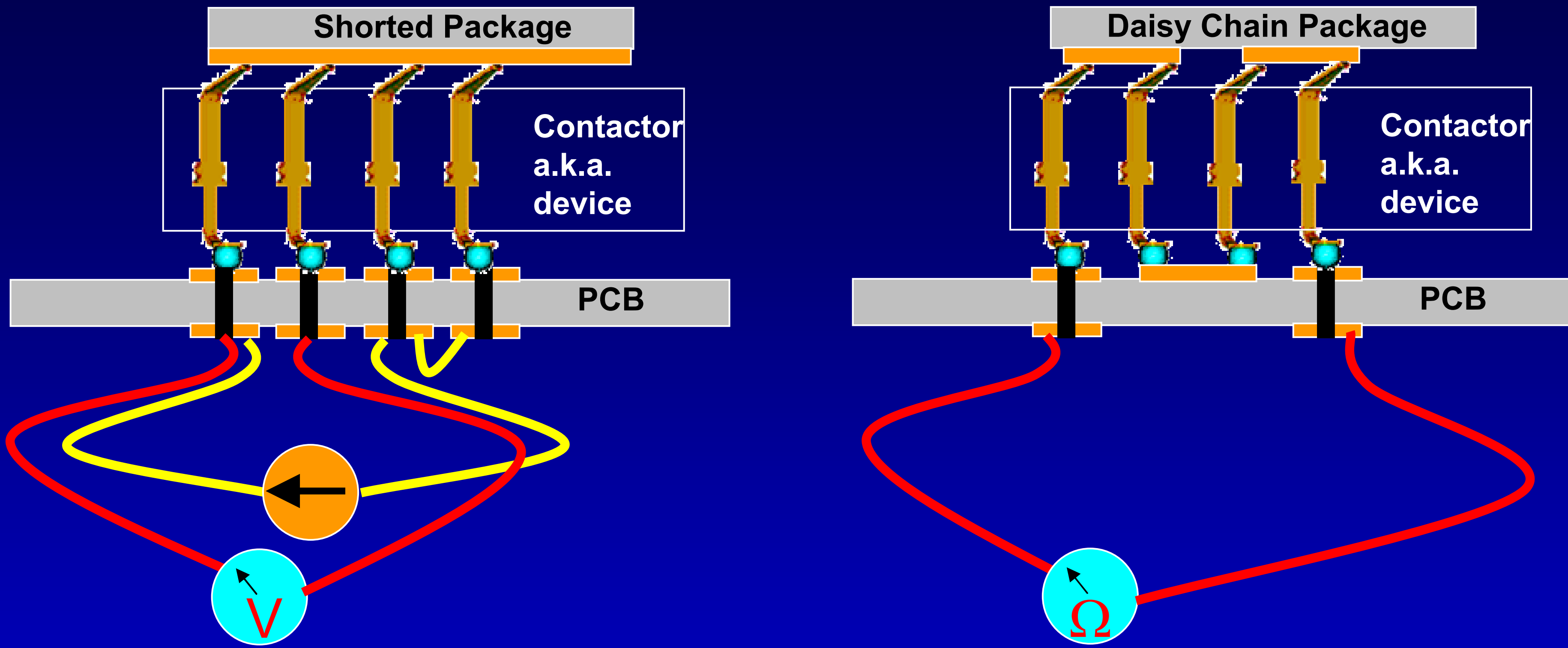
Contact Resistance

- What is it ?
  - ✓ The cumulative interfacial resistance of all mating contacts of the contactor pin
  - ✓ Or, is it the sum of the interfacial resistances and the bulk resistance of the pin?
  - ✓ Or, something else?



- Why do we care:
  - ✓ The resistance of the pin and its mating surfaces sets the first order limit on power delivery performance
- How is it measured:
  - ✓ **<u>By as many different methods as there are people measuring</u>**

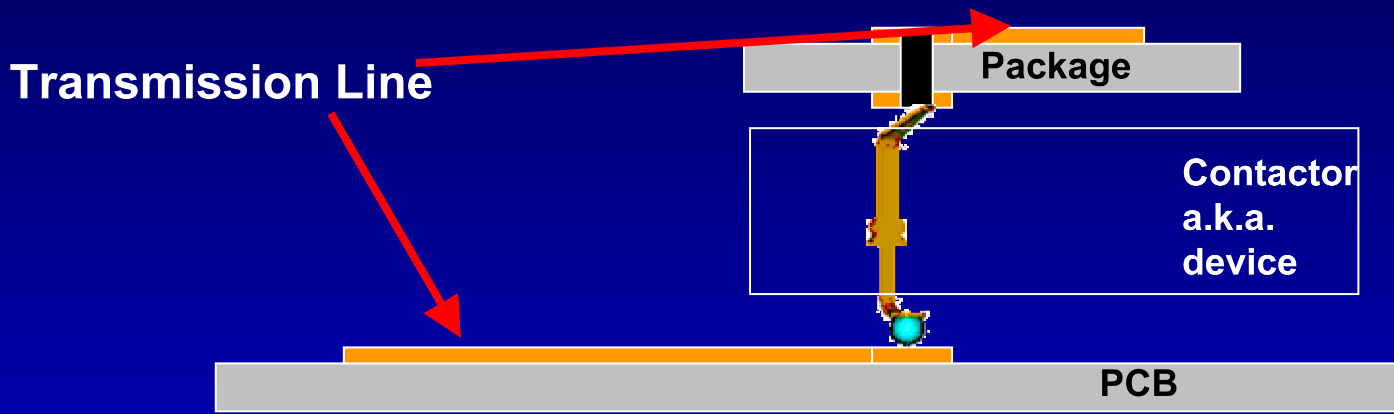
Cres Methodology



- 4-wire Measurements
  - ✓ Source on 1 pin
  - ✓ Sink on all remaining pins
  - ✓ Cres = Measured Value
- 2-wire Measurements
  - ✓ Source through daisy chain of 10-15 pins
  - ✓ Cres = Average of Measured Value

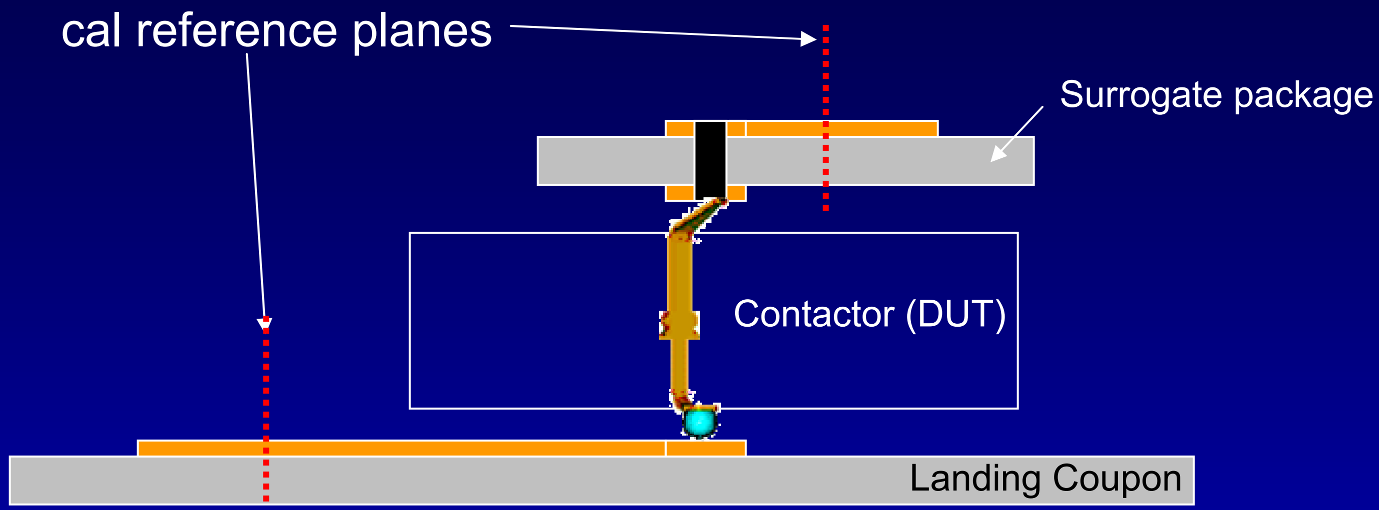
Insertion Loss

- What is it?
  - ✓ The loss resulting from the insertion of a device in a transmission line



- Why do we care:
  - ✓ Total loss in a channel "from pogo-pin to bond-pad" must be controlled to achieve proper bus operation
  - ✓ The contactor is one piece of this channel
- How is it measured:
  - ✓ **By as many different methods as there are people measuring**

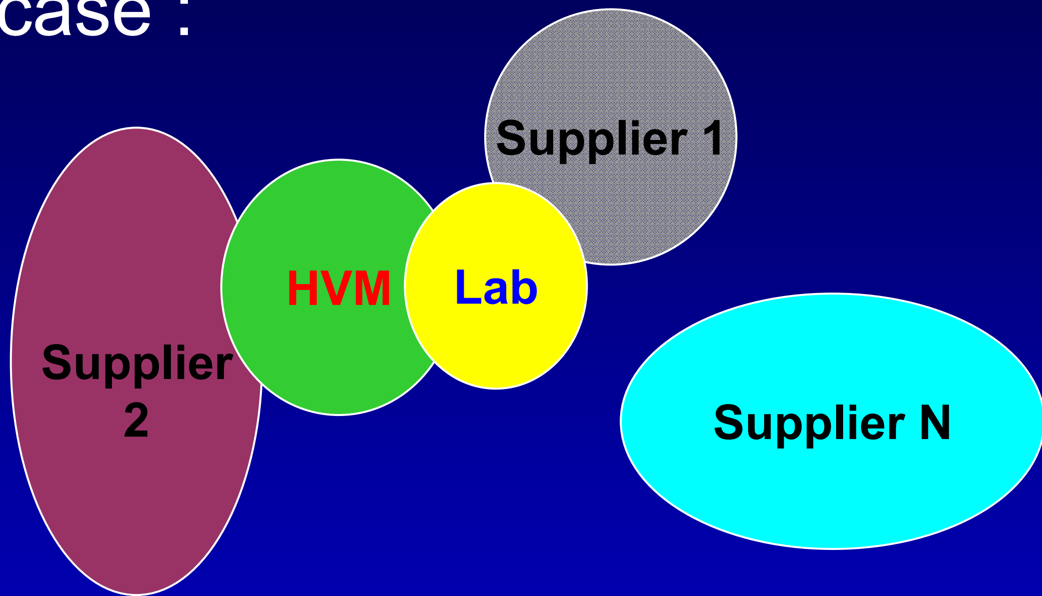
Insertion Loss



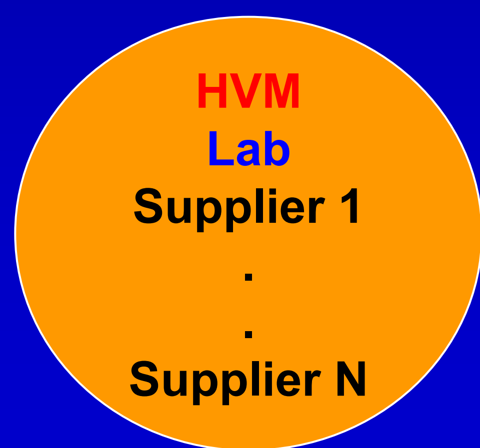
- DUT is fixtured between precision ceramic coupons
- 2 port & **4 port** Thru measurements are made
  - ✓ [Measured] = [LC][DUT][SP]
- NEXT & FEXT measurements are made
- Coupons are de-embedded
  - ✓ $[DUT] = [LC]^{-1}[Measured][SP]^{-1}$
- Datasets are combined to generate causal 8 & 12 port models

Supplier data vs. Lab data vs. HVM data

- Actual case :



- Ideal case:



Socket Evaluation Highlights

- Pathfinding
  - ✓ Several years ahead of production
  - ✓ Targets are speculative
  - ✓ Lab Environment
  - ✓ Screening Experiments
    - ➢ Sample sizes are small
  - ✓ Focus is on developing test methods and narrowing solution space
- Development
  - ✓ Closer to production
  - ✓ Higher confidence targets
  - ✓ HVM Environment
  - ✓ Full DOE's conducted
    - ➢ Statistically significant samples
  - ✓ Focus is on demonstrating HVM capability and selection

Ultimate goal is successful operation in HVM.
Lab evaluations are used as the filter.

Introduction Opportunities

Pathfinding	Development	HVM
Time → Well in advance of any specific product intercept.	Time → Test tooling decisions made early in the development phase.	Time → If pursued, the result of a problem w/ existing solution or introduction of a "Me Too" tech. solution.
Who → Open to all technologies; especially novel solutions. Technology options receive preference over similar (me too) technical solutions.	Who → Usually limited to incumbent technology solutions and one or two promising potential solutions coming out of Pathfinding.	Who → Likelihood of introducing a solution outside of what was evaluated and qualified during the development phase of the technology is low.

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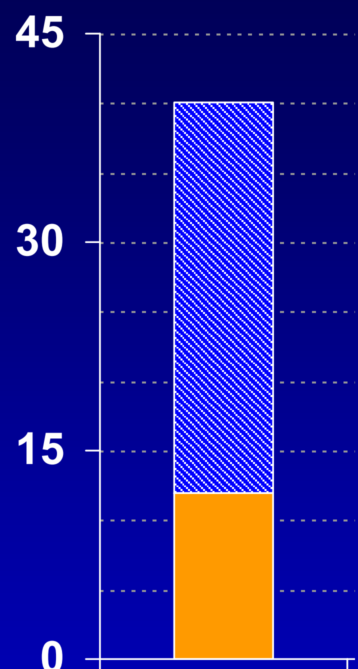
Suppliers Considered vs. Time



Step 1 =
Industry Survey

Key message:
Any and all options considered in Step 1!

HVM

Selection Timeline

A fishnet of the industry using the anticipated requirements as the filter criteria, hopefully identifying a handful of potentially capable candidates. Normally limited to paper studies & supplier data. Selection includes just a small handful of candidates.

Lack of standards: Impact

Cres

- Technical
  - ✓ Inconsistent Definitions
  - ✓ Inconsistent Methods

  = Inconsistent Results
- Financial
  - ✓ ROI: Cost of generating Cres data vs. customer ignoring the data

Insertion Loss

- Technical
  - ✓ Inconsistent Reference planes
  - ✓ Inconsistent Fixturing
  - ✓ Inconsistent Calibration

  = Inconsistent Results
- Financial
  - ✓ Cost of developing the methodology
    - ➢ i.e. going it alone
    - ➢ i.e. re-inventing the wheel
  - ✓ Cost of outsourcing measurements
  - ✓ ROI: Producing data that's not used

Measurement Standards

- Why:
  - ✓ Ensuring your methods match <u>a</u> customers methods is not sufficient
  - ✓ Resources to evaluate potential solutions at Intel are either people limited or equipment time limited
- Supporting Arguments:
  - ✓ EIA/JEDEC has several socket standards already
  - ✓ EIA/JEDEC, IPC, ARFTG have all demonstrated high frequency measurement standards are achievable
- Impact of driving standards:
  - ✓ Positioning your company as a technology leader
  - ✓ Producing data that adds value to all your customers

TODAY

- Supplier familiarity with Intel’s qualification procedures and production environment limits their success during selection

TOMORROW

- Supplier success will be based on the capability of their technology, service and price. Their development rate will be independent of Intel resources.

Summary

- Goal is successful HVM testing
  - ✓ Awareness of the whole path allows a vendor to leverage strengths and limit design impacts
  - ✓ Tooling requirements are based on product performance requirements
  - ✓ Performance measurement techniques vary

- **Supplier Data ≠ Intel Lab Data or HVM Data**

- Defined Standards help **<u>both</u>** the supplier & customer
  - ✓ Opens the number of suppliers for consideration
  - ✓ Improves the supplier info turns during development

ARDENT CONCEPTS, INC.
Innovative Interconnect Solutions

Reducing the Cost of Test: High Speed Contactor Systems

BiTS
Burn-in & Test Socket Workshop

Gordon Vinther, Ardent Concepts, Inc.
Tom Goss, M/A-Com/Tyco Electronics
March 7, 2005

Introduction – The Need

- **<u>Recessed Lead Package</u>**
  - Pure Z-Axis interconnect required
- **<u>Higher Speed</u>**
  - Exceptional AC performance required
  - Low Inductance contacts
- **<u>Faster Throughput Requirement</u>**
  - Increasing ATE UPH
  - Fixturing must be simple, easily refurbished
- **<u>Shortest Possible Contactor Change Downtime</u>**
- **<u>Cleaning/Repair/Maintenance Issues</u>**
- Cost of Test Reduction <u>must not negatively impact yield</u>

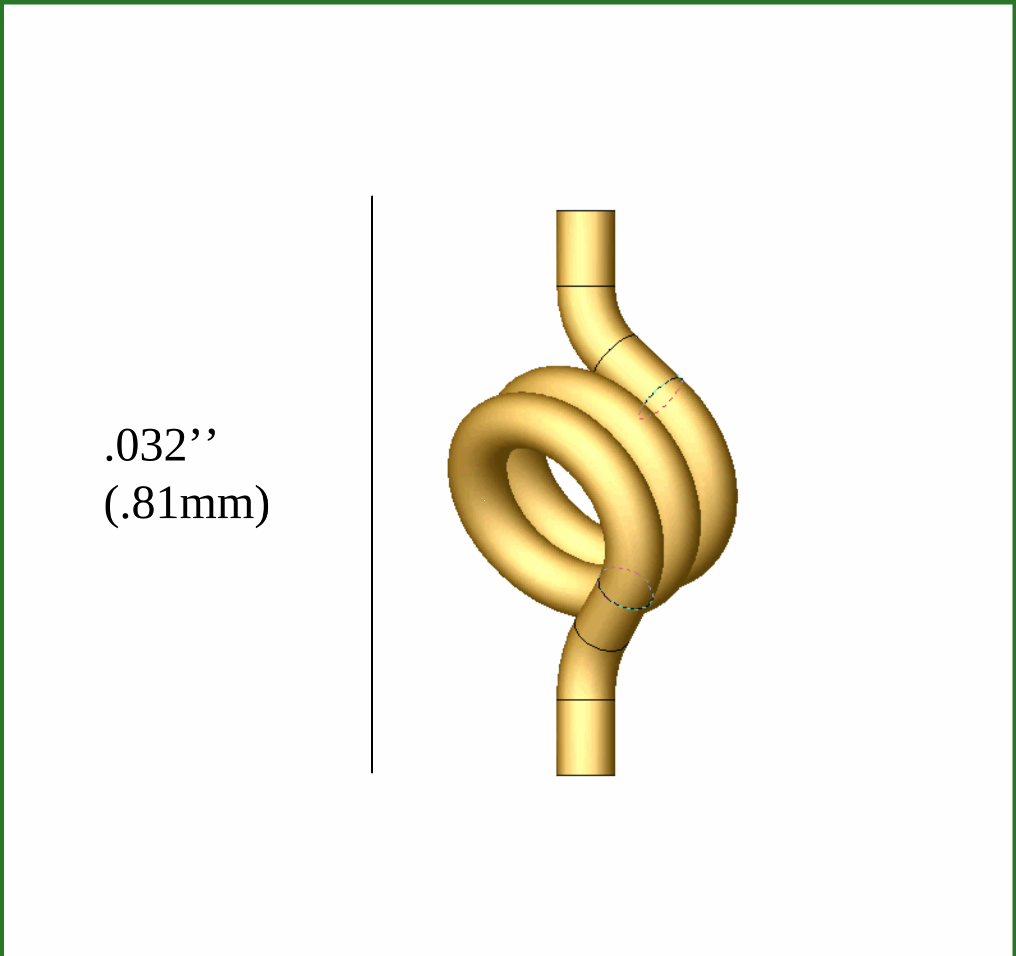
Introduction – The Analysis

- Test Setup
- Application Description
- AC Characterization Data
- Force vs. Deflection vs. Resistance Data
- Resistance vs. Contact Lifecycle Data
- Cost of Test Analysis
- Other Relevant Applications
- Conclusions

Introduction – The Solution

- **Small**, short, z-axis design
- **Consistent** RF performance characteristics
- **Consistent** Performance of System
- **Replaceable** and re-usable components
- **Lower cost** of components, no negative impact on yield

Redundant Contact™ Technology



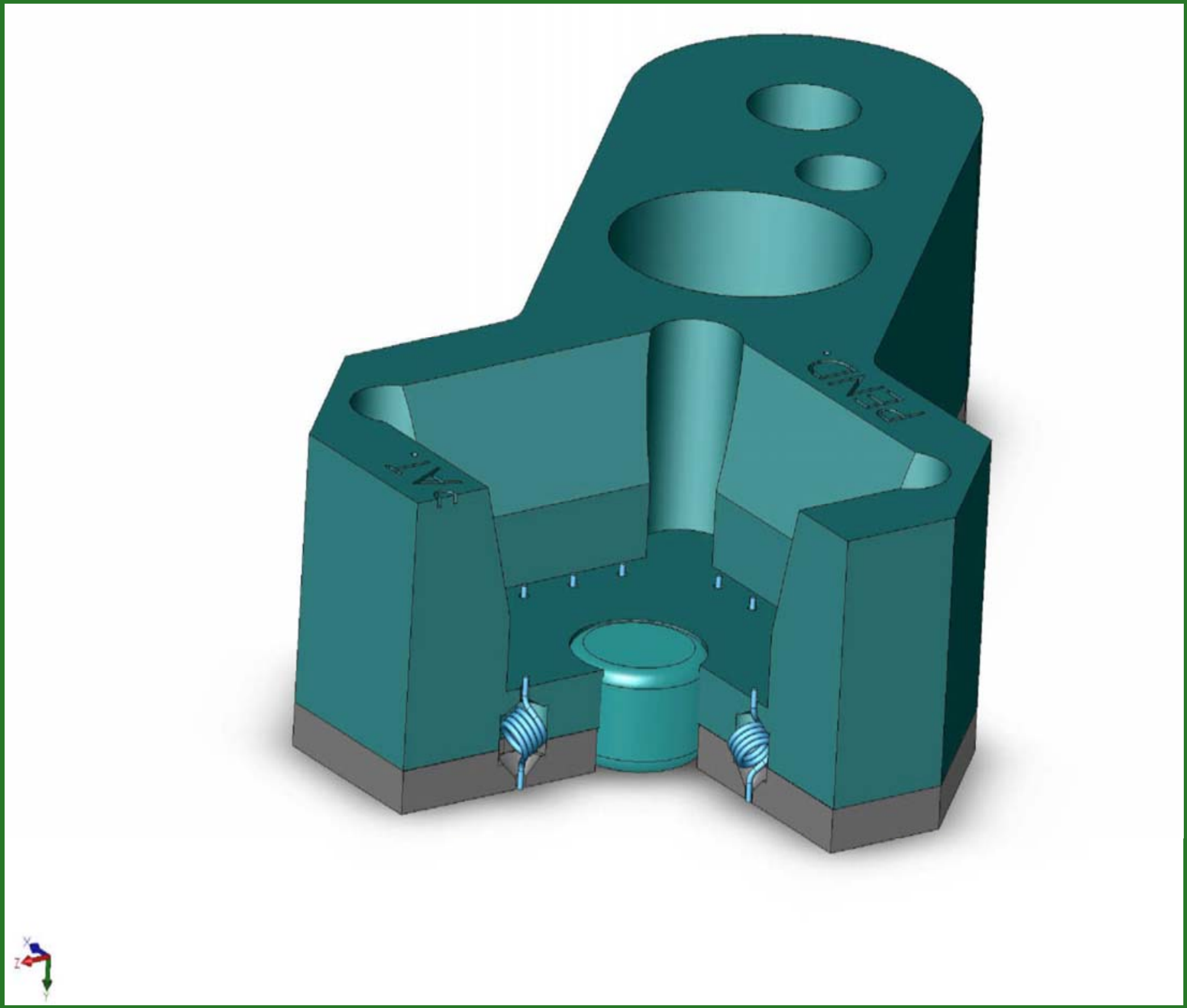
- Scalable Design
- Super Short Height
- Low Self Inductance
- Good Current Carrying Capacity
- Long Life
- High Bandwidth

US Patent # 6,787,709. Other US and Foreign Patents Apply.

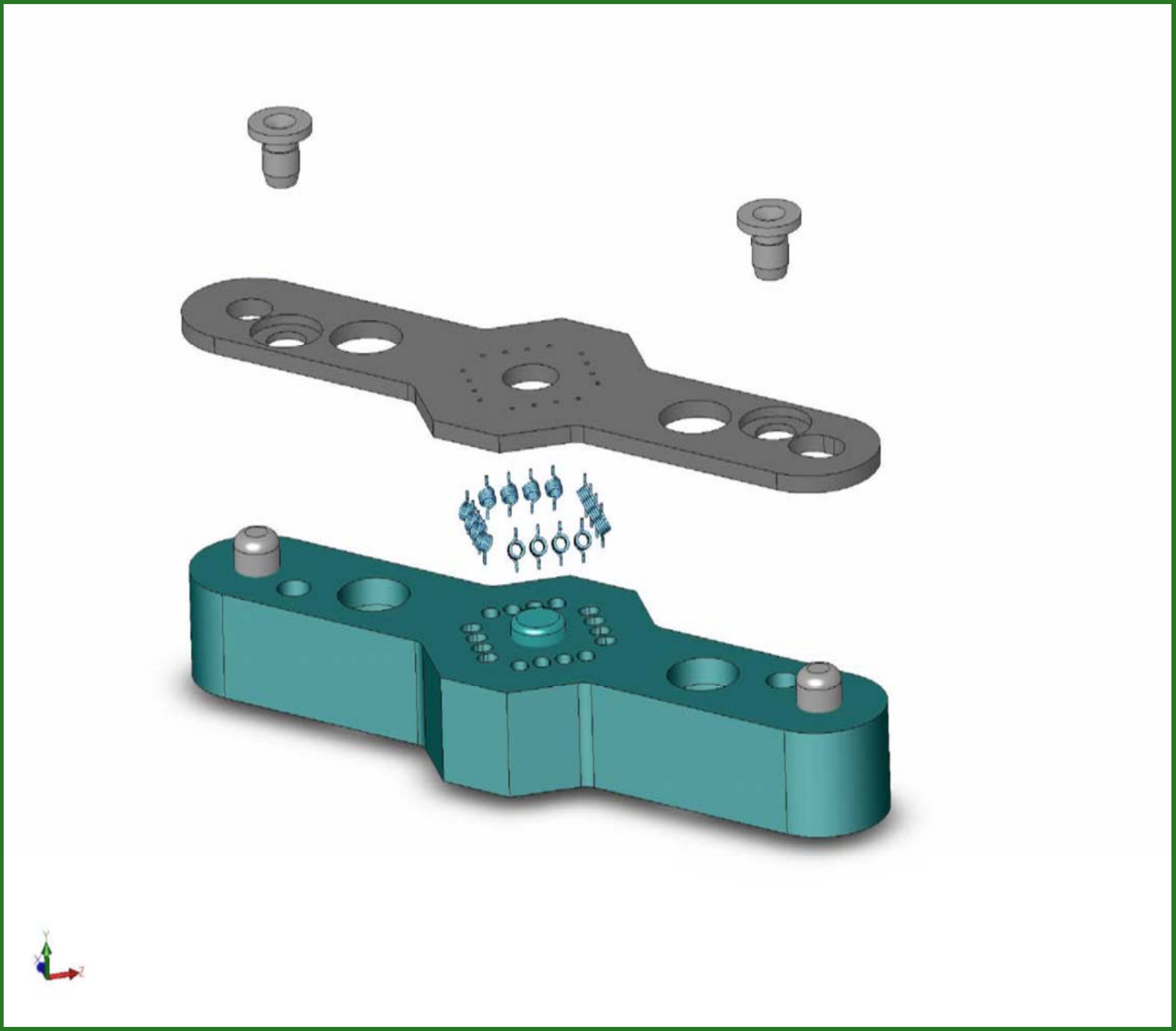
Redundant Contact™ Technology

US Patent # 6,787,709. Other US and Foreign Patents Apply.

Redundant Contact™ Technology



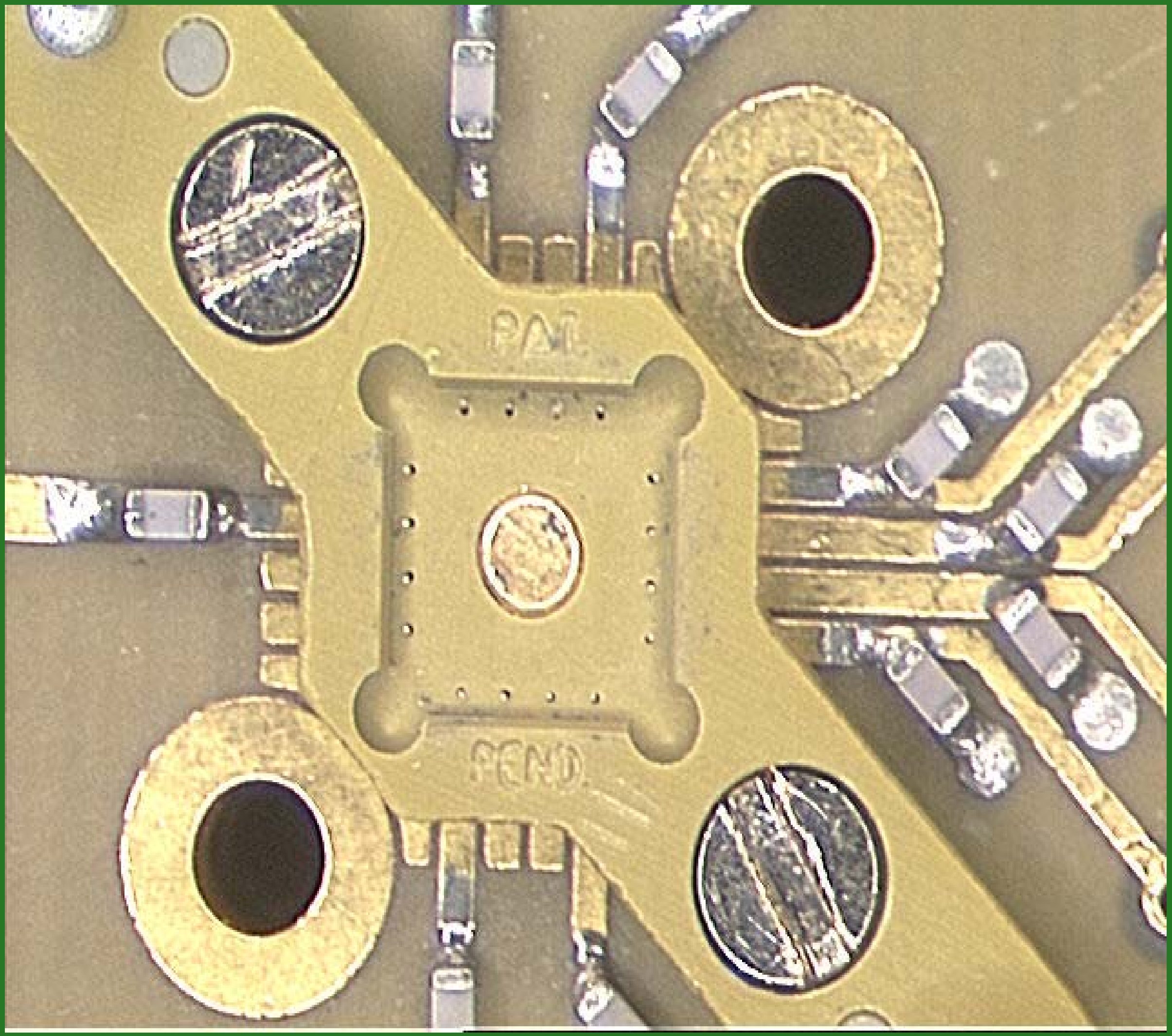
Redundant Contact™ System Assembly



Test Set-up/Fixturing

- Ismeca NT16 Turret Handler
- Custom Harmonic Detection Stand using:
  - HP 1173A Attenuator Switch Driver
  - Agilent E3318B Power Meter
  - Agilent 8753E5 S-Parameter Network Analyzer

Test Set-up/Fixturing

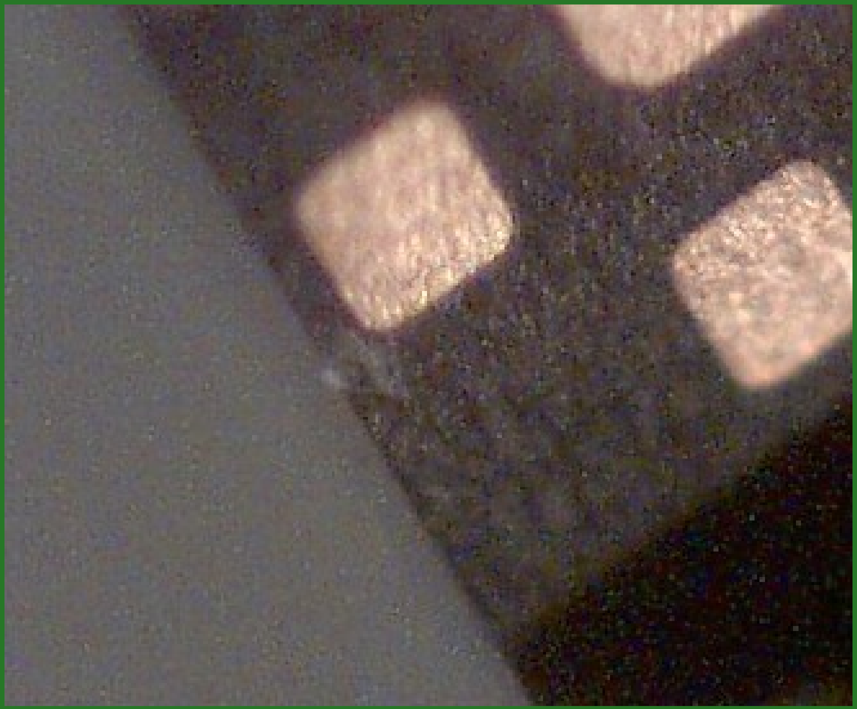


Application Description

- IEEE 802.11b/g, 2.4GHz
- 2W switch
- Packaged in a 3mm 16ld lead free QFN
- Used in Mobile Handsets

Application Description

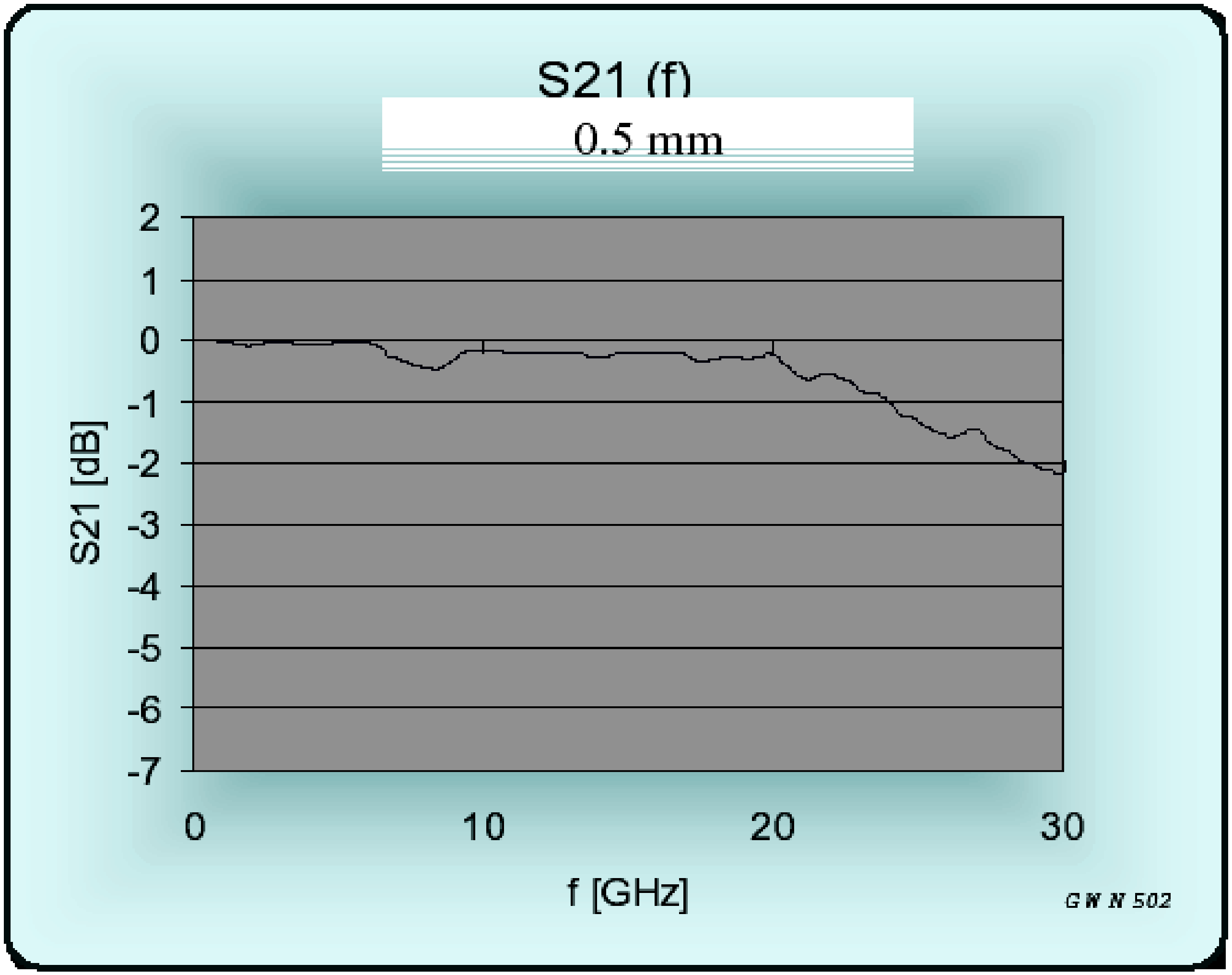
- **Problem**: Recessed Pads on Small Profile Package
- **Solution**: Z-axis contacts with small diameter tip geometry



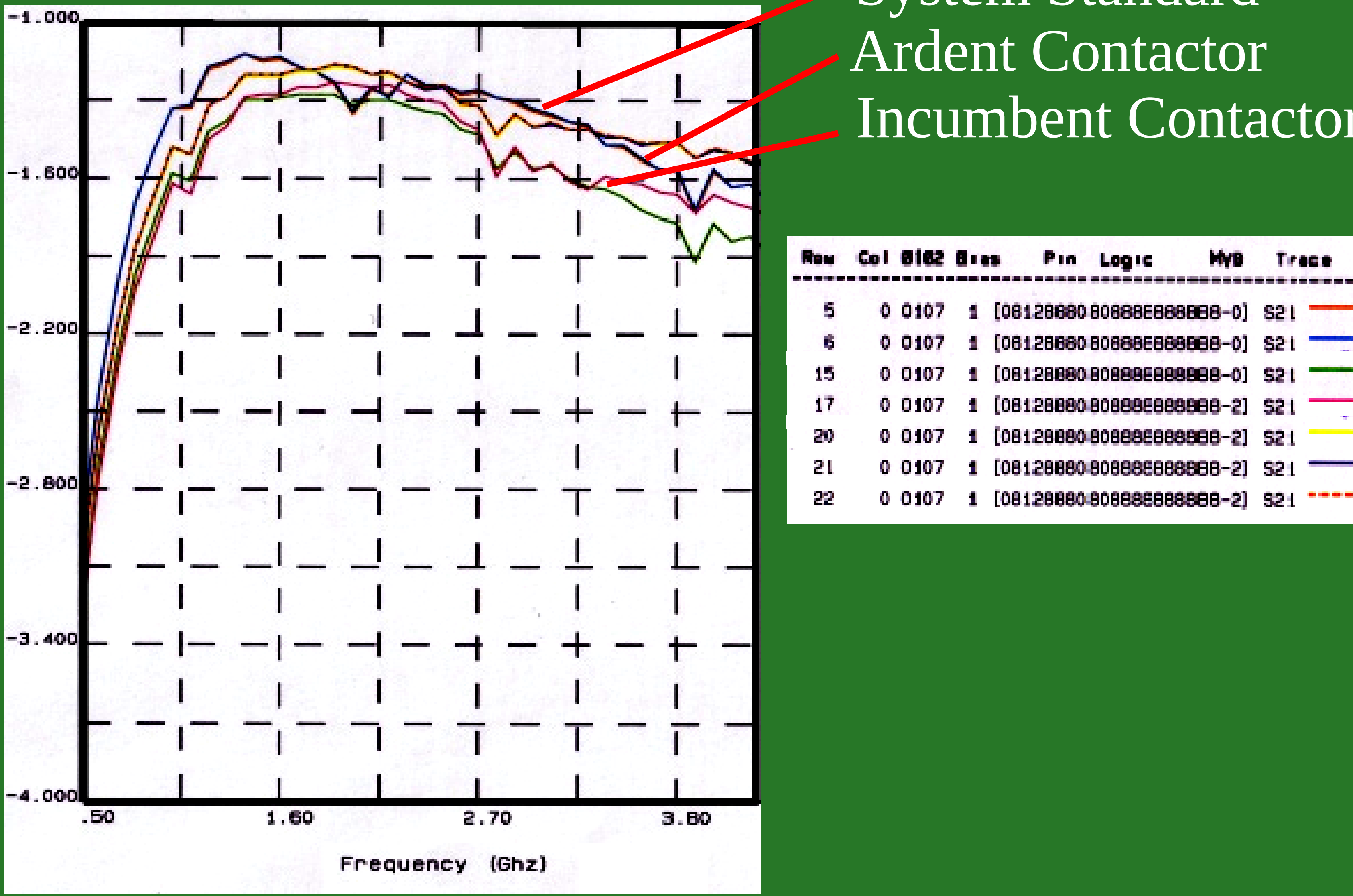
Overview of Data Analyzed

- AC Performance of Contactor
    - 4 Coil Version
    - 3 Coil Version
    - Ground Slug Version
- Yield Performance of Contactor
    - Insertion Loss 4 Ports
    - Isolation
    - 3rd Harmonic
- FvDvR Performance of Contactor

S21 Loop Thru Bandwidth Curve (.5mm)

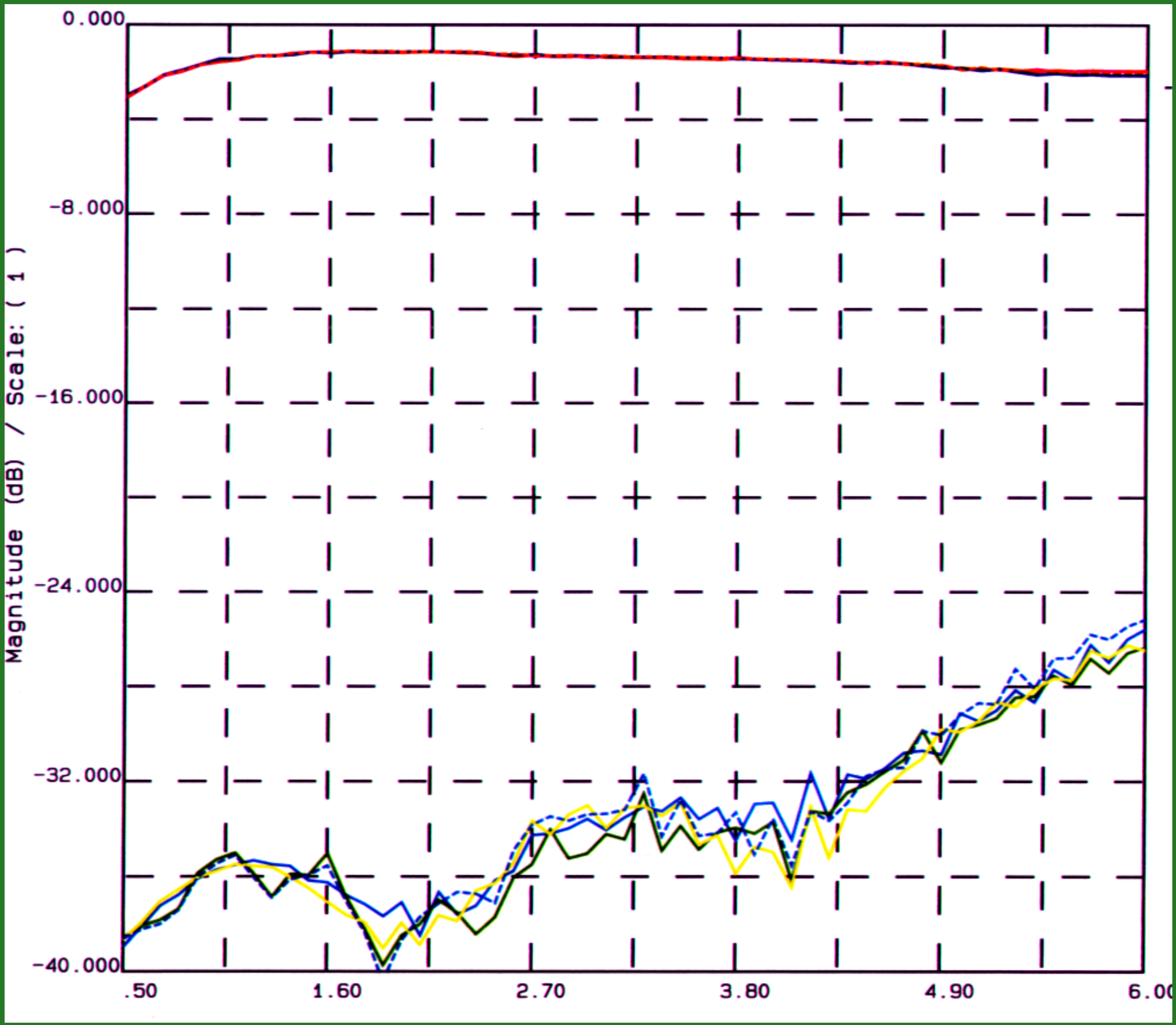


Contactor Test Data: Insertion Loss

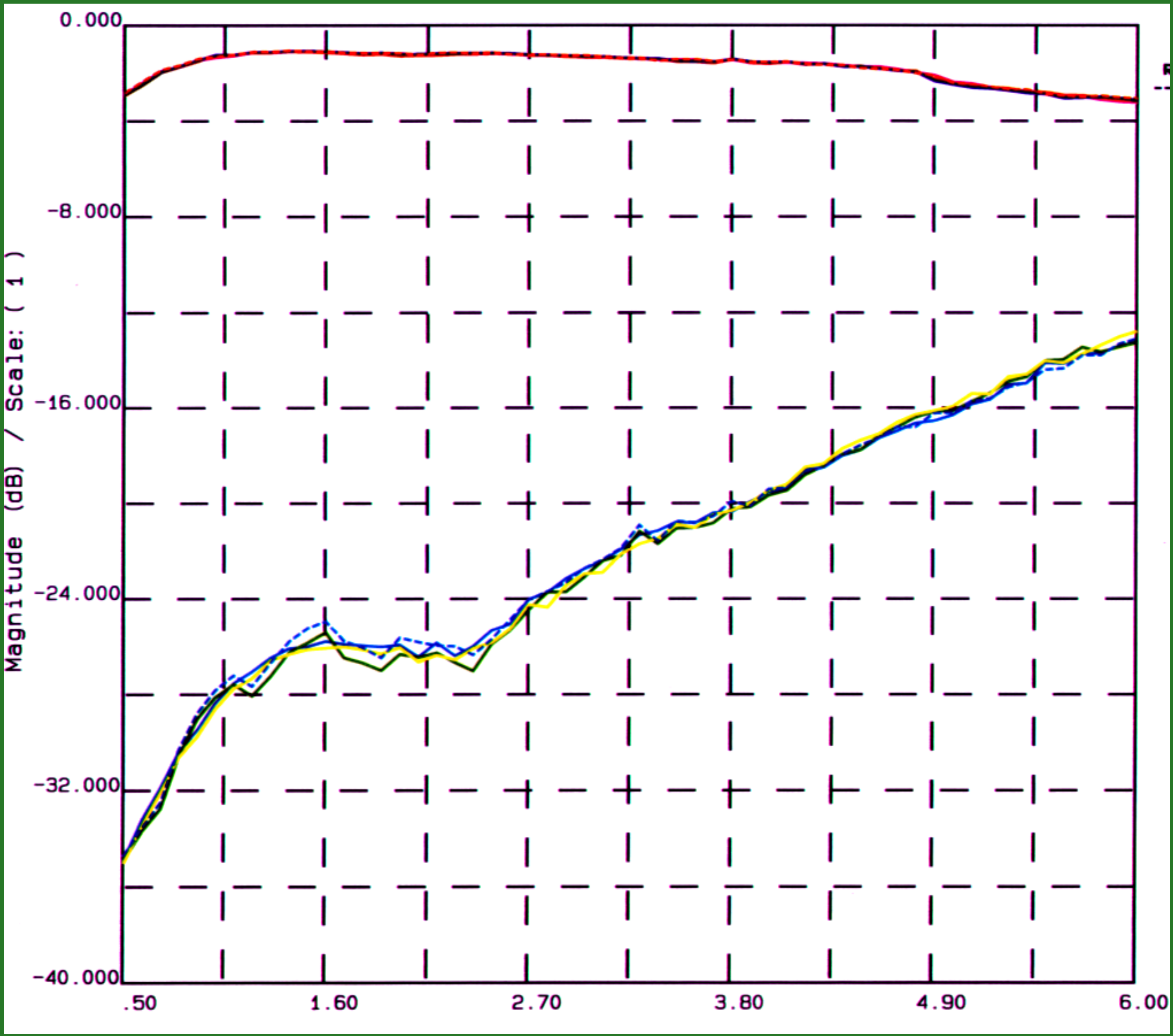


Row	Col	0102	Bias	Pin Logic	MVB	Trace
5	0	0107	1	[illegible]	S21	
6	0	0107	1	[illegible]	S21	
15	0	0107	1	[illegible]	S21	
17	0	0107	1	[illegible]	S21	
20	0	0107	1	[illegible]	S21	
21	0	0107	1	[illegible]	S21	
22	0	0107	1	[illegible]	S21	

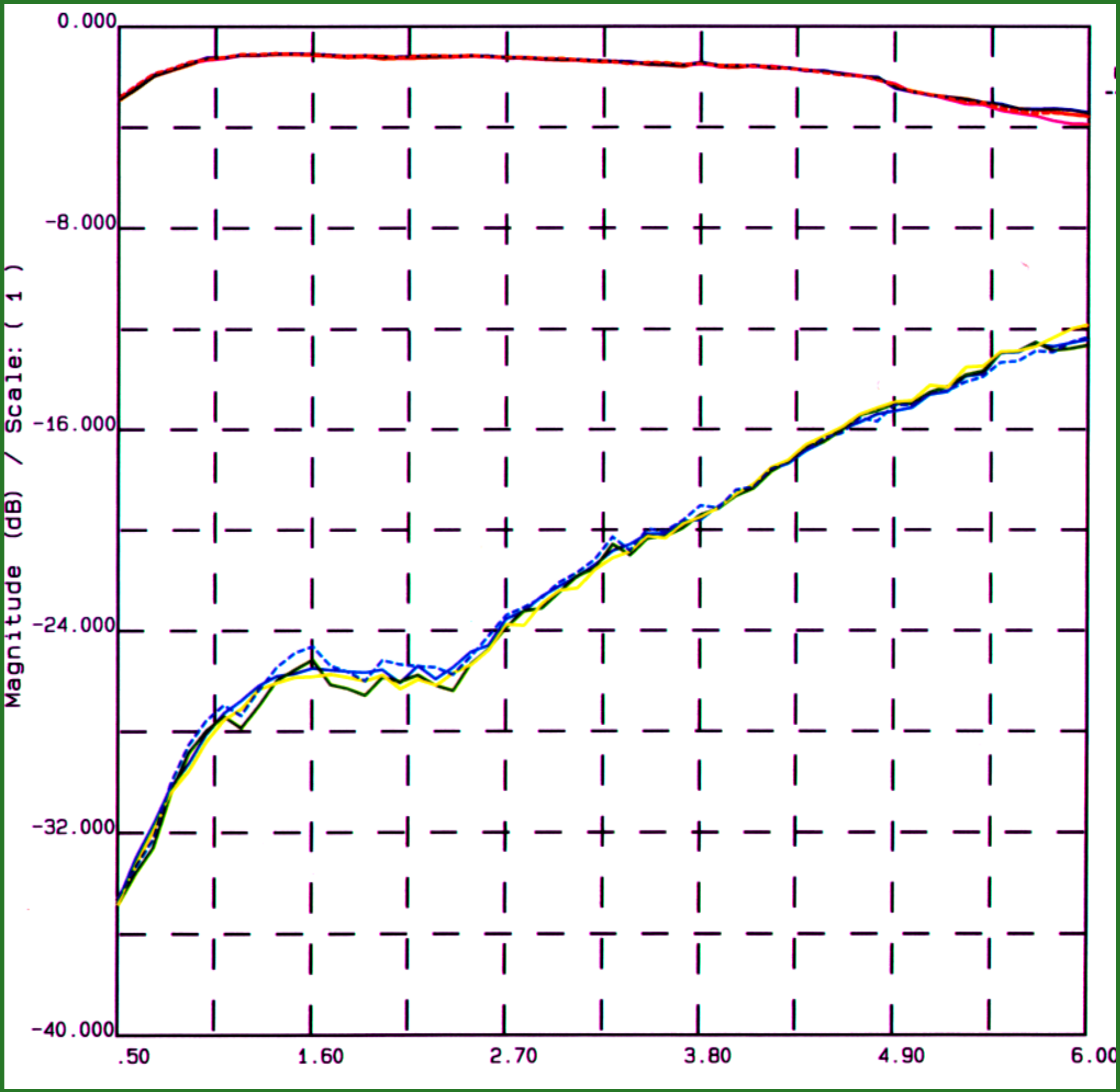
Contactor Test Data: System Standard



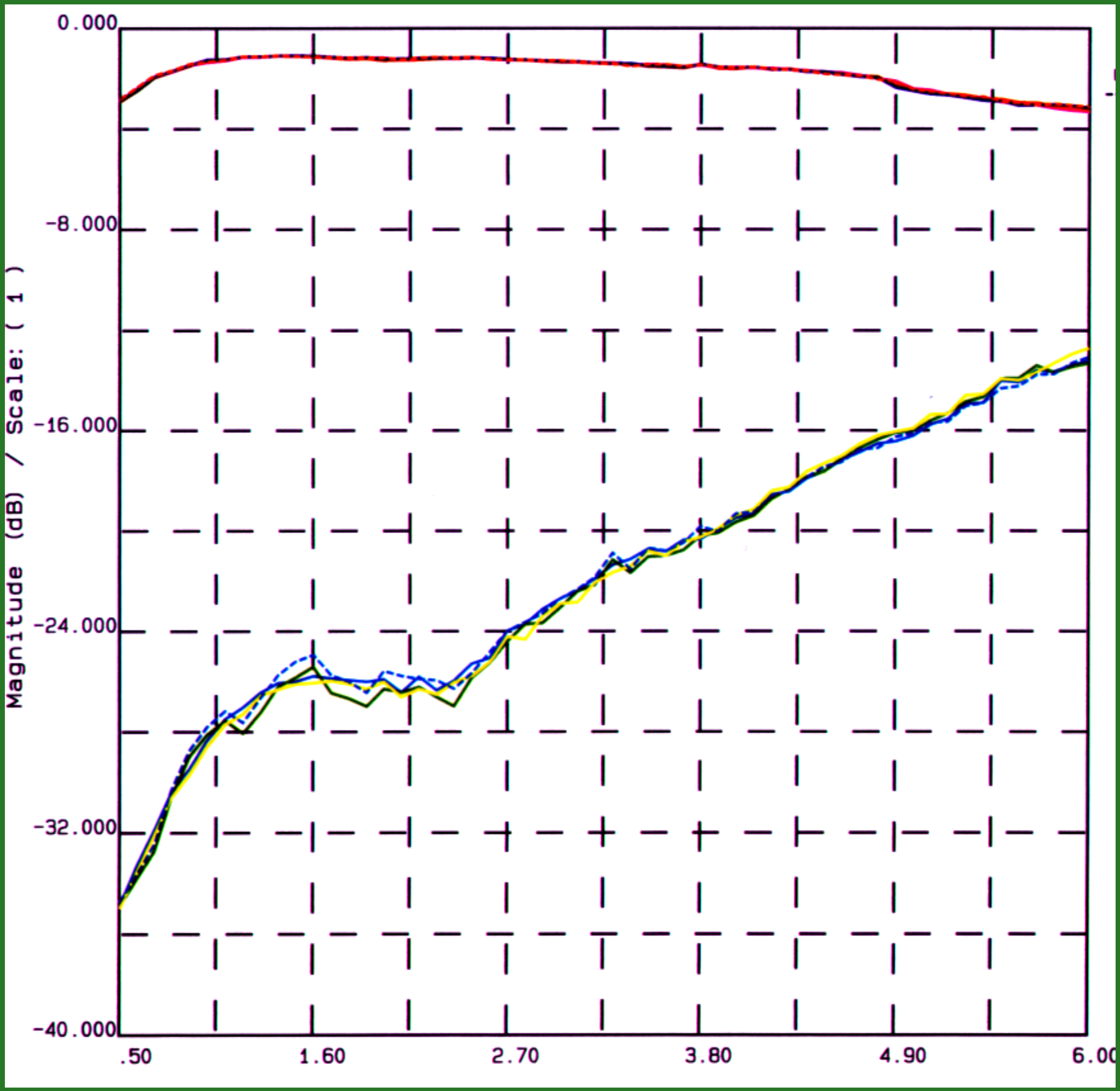
Contactor AC Test Data: 0°



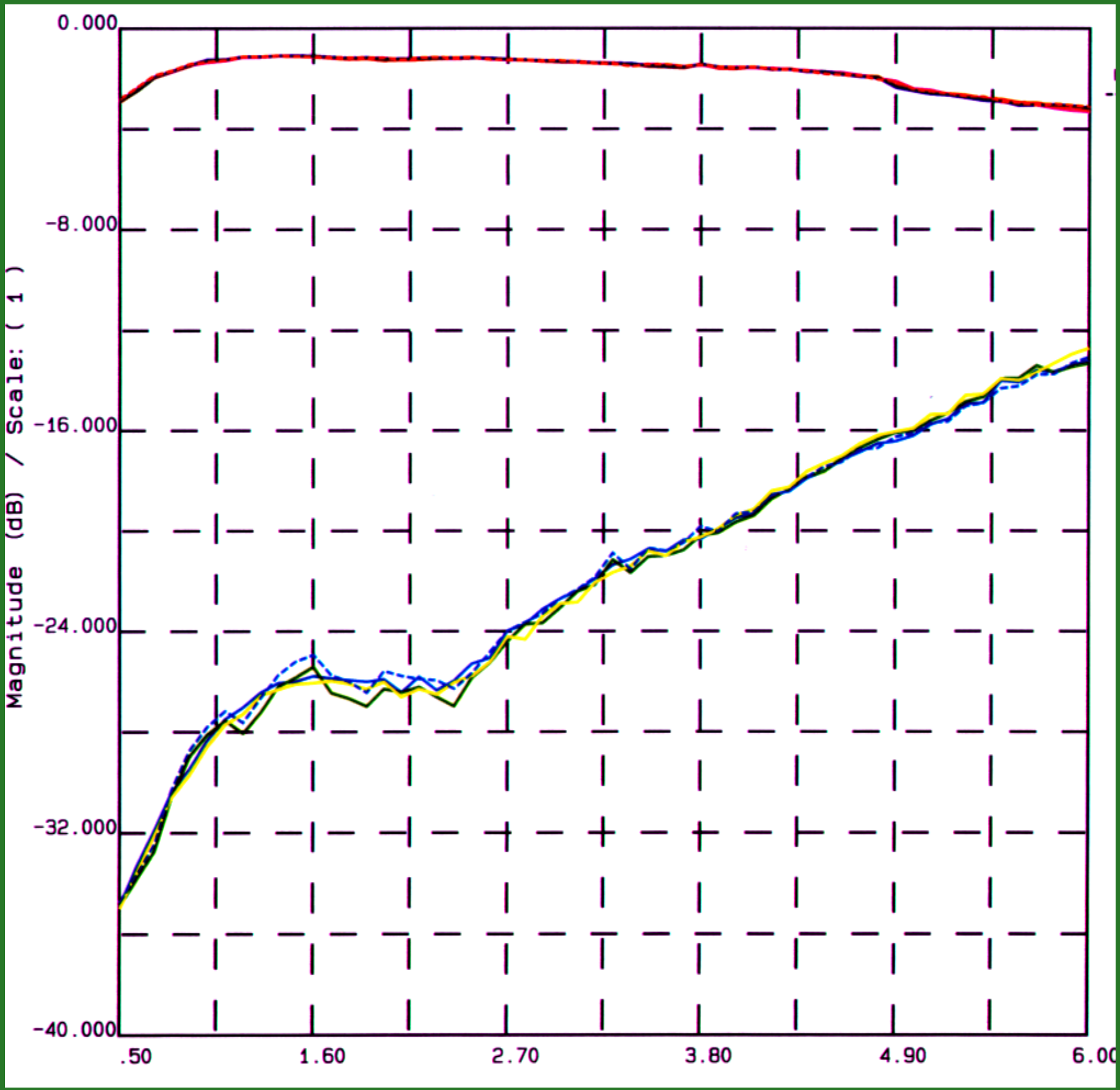
Contactor AC Test Data: 0° (25% more stroke)



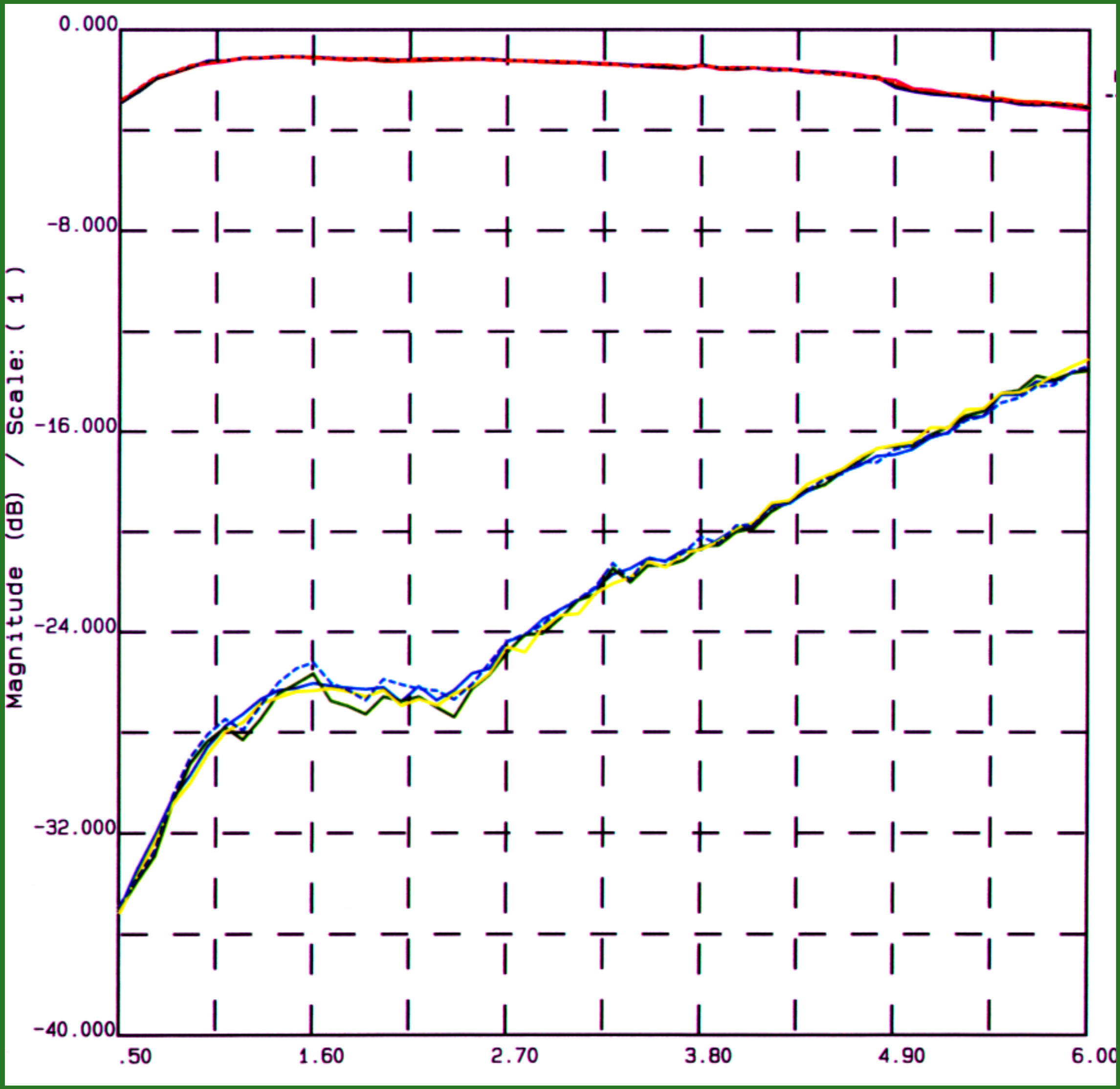
Contactor Test Data: 180°



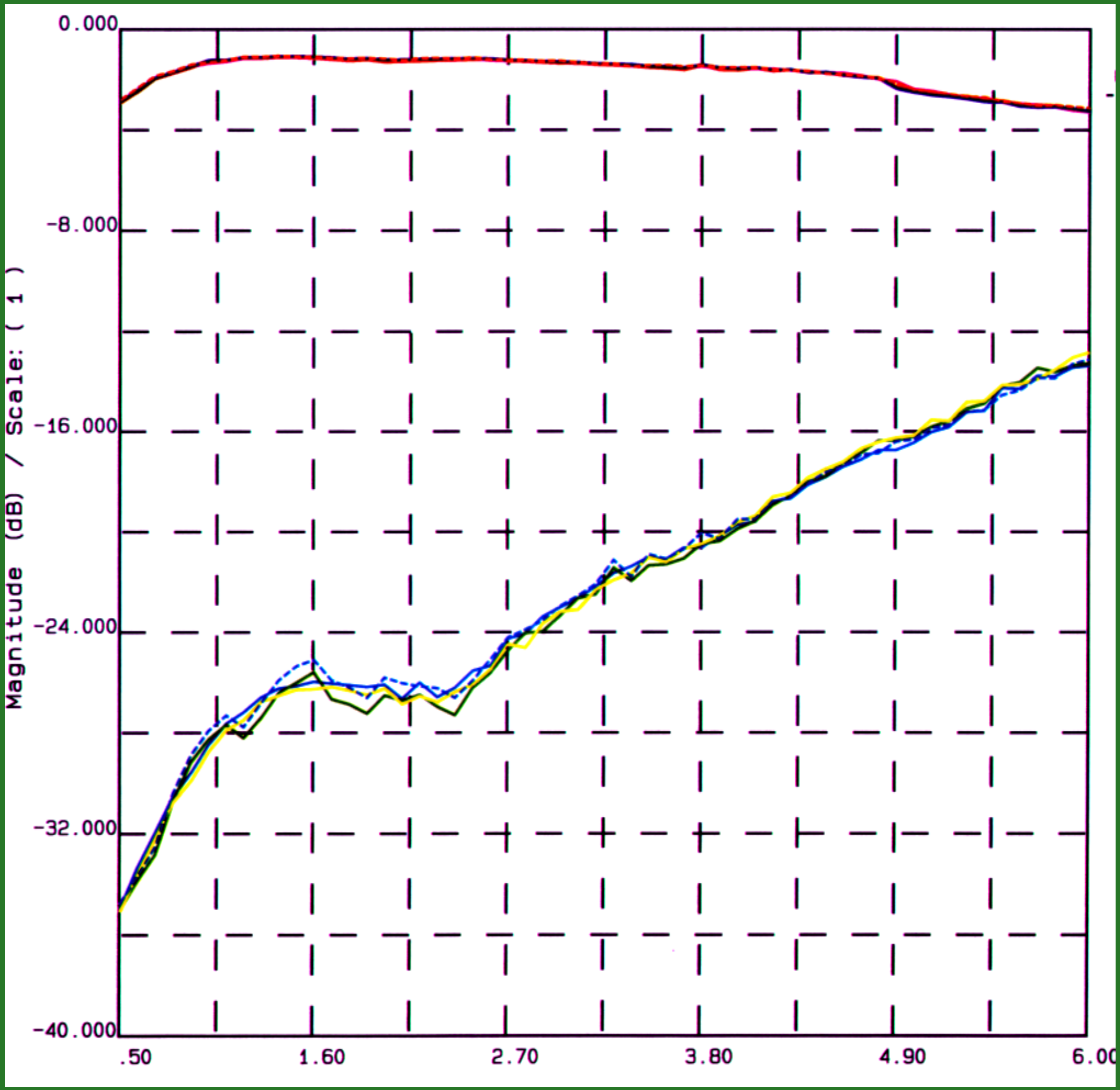
Contactor Test Data: 180° (25% More Stroke)



Contactor Test Data: 0° (3.5 coil version)

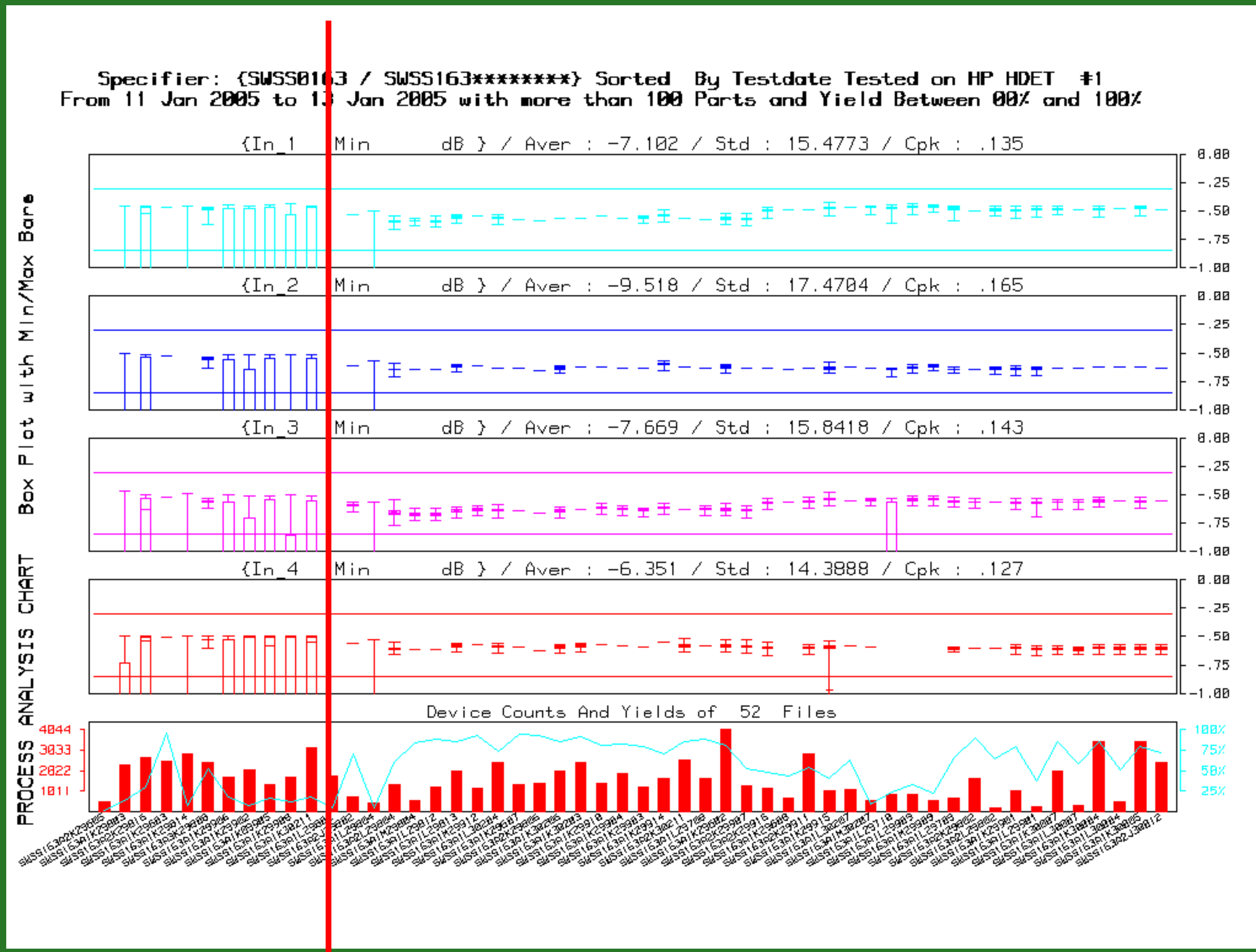


Contactor Test Data: 0° (w/ ground slug)

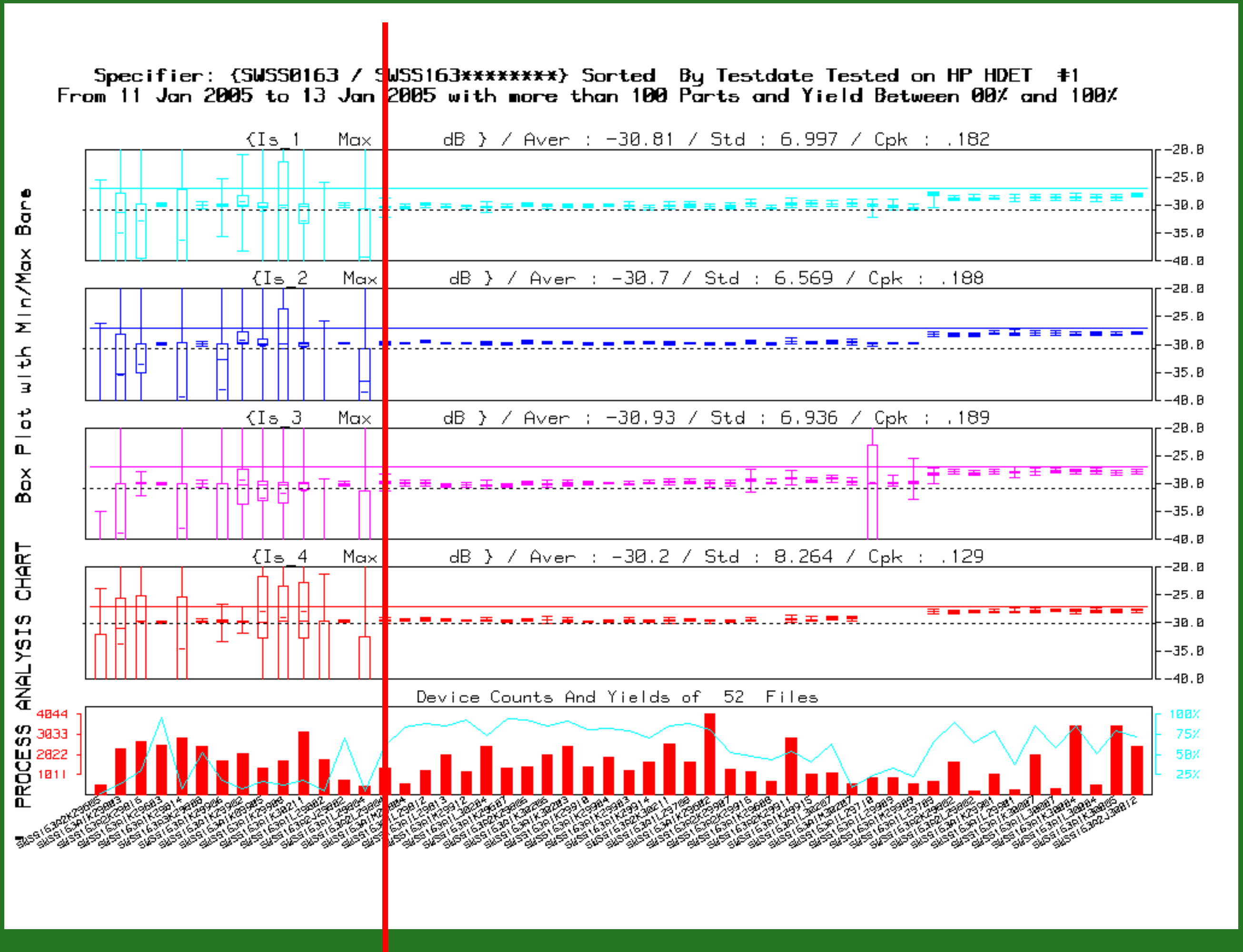


Contactor Test Data: Yield Loss

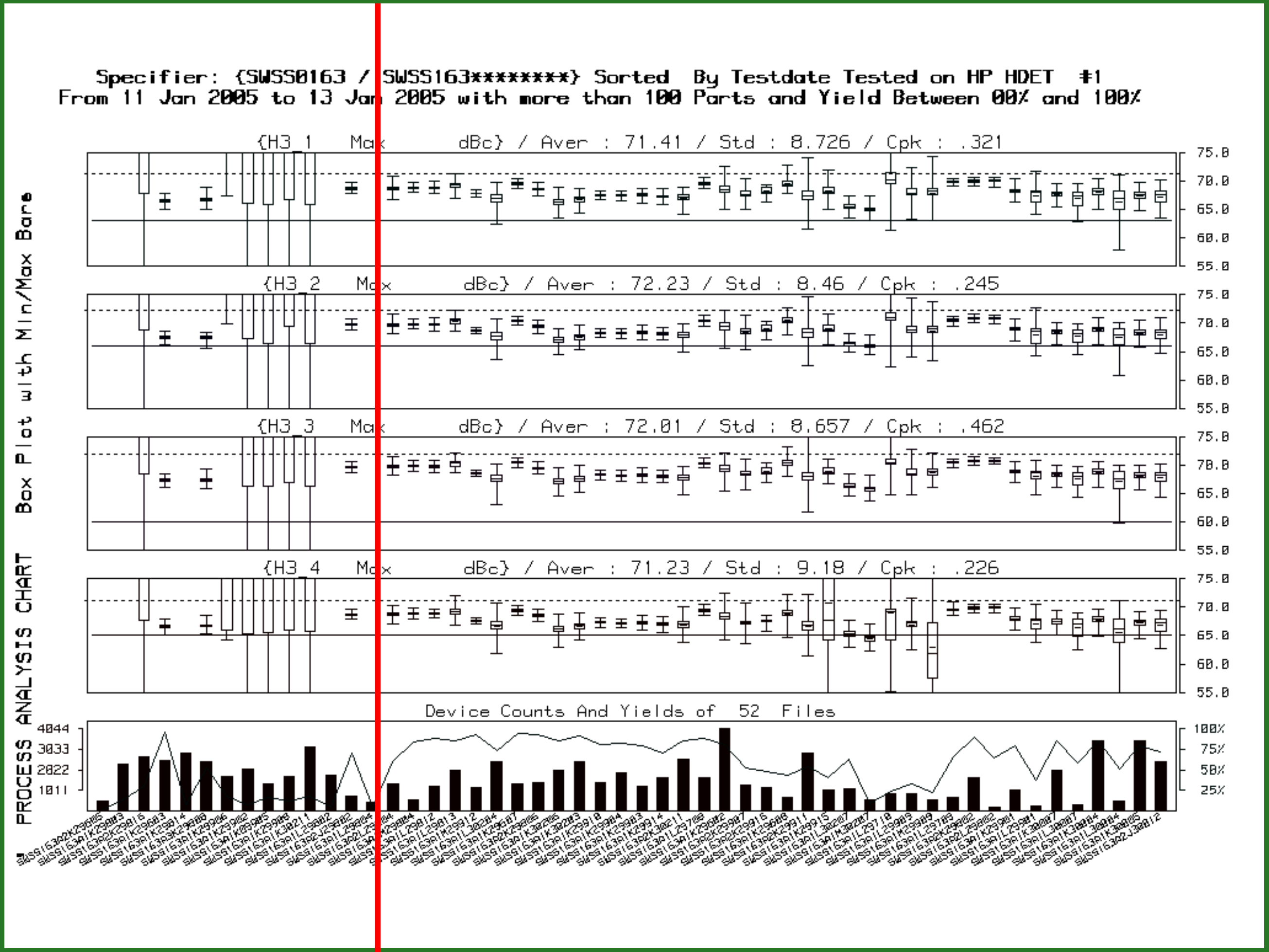
Incumbent Ardent



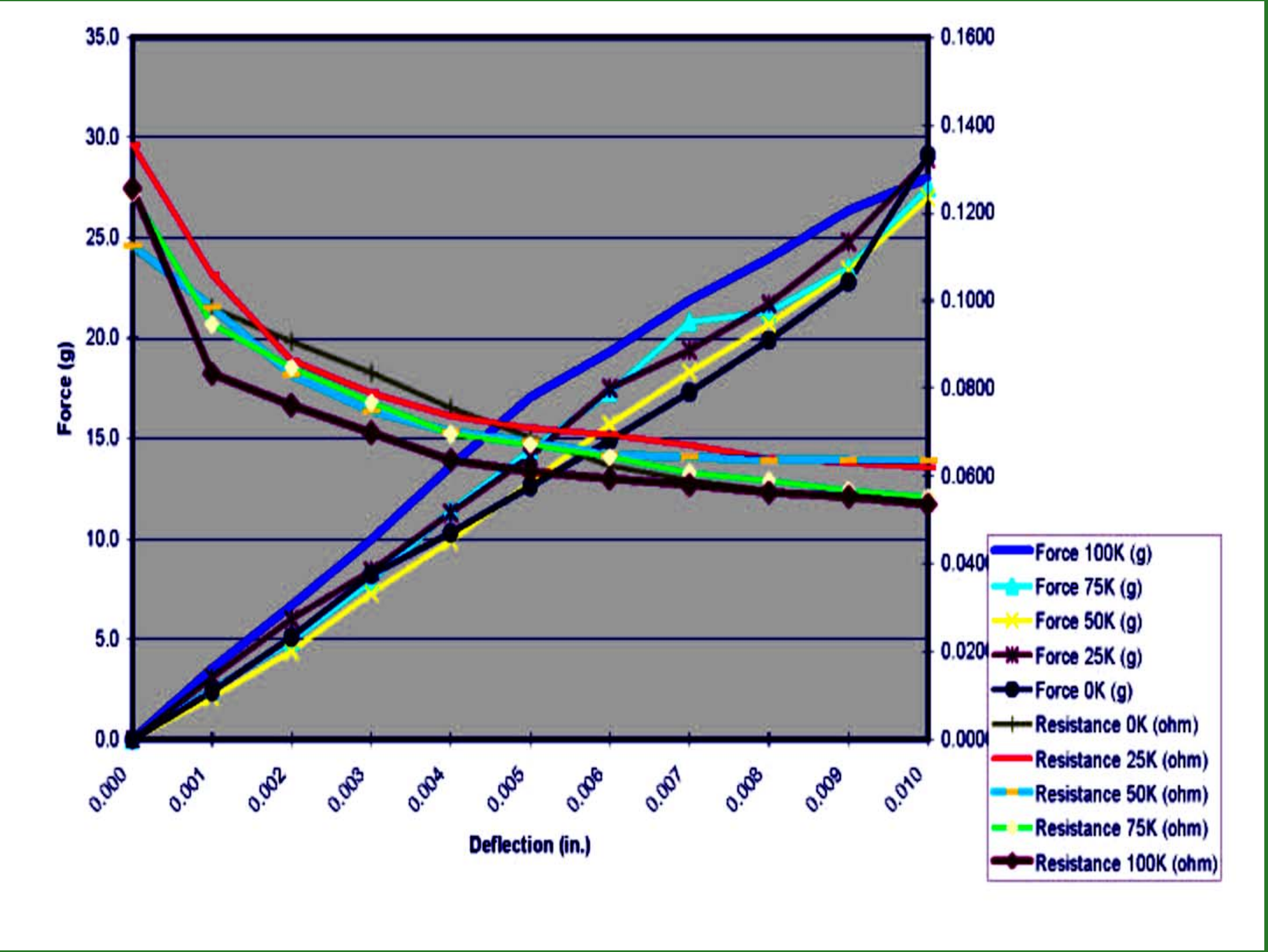
Contactor Test Data: Isolation



Contactor Test Data: 3rd Harmonic

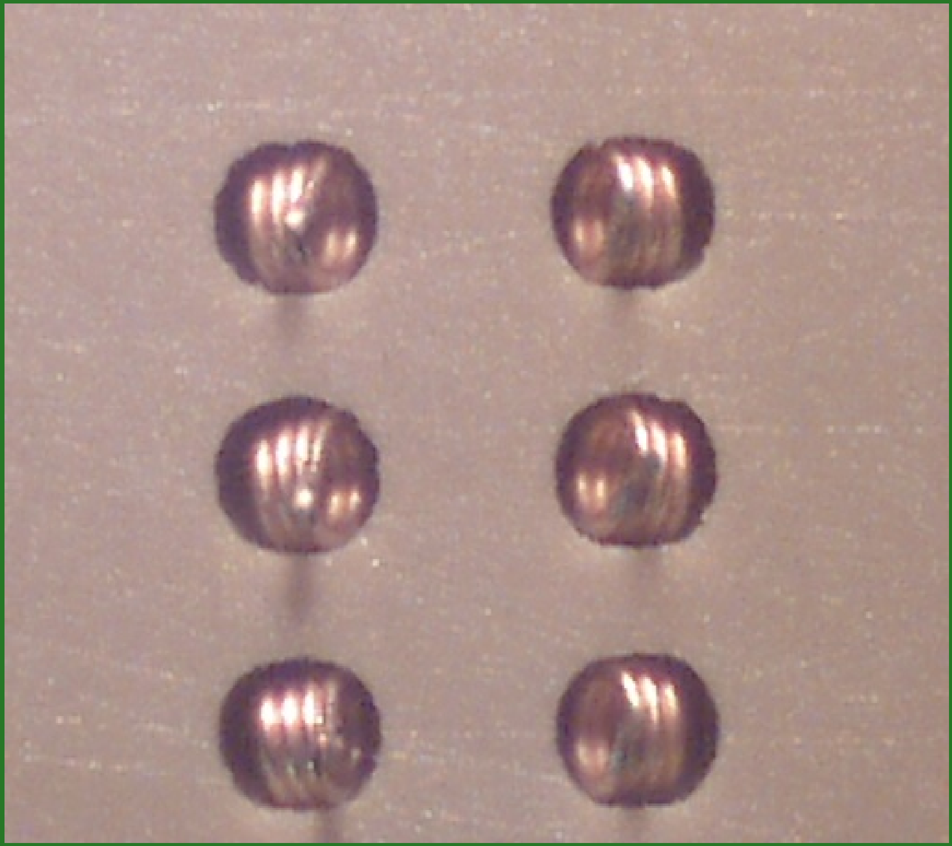


Contact Test Data: FvDvR to 100K Cycles



Machine Downtime and Refurb

- **Problem**: Part replacement during machine downtime is critical
- **Solution**:
  - Easy to replace contacts, rivet design contactor system
  - Contacts are affordable, one piece design

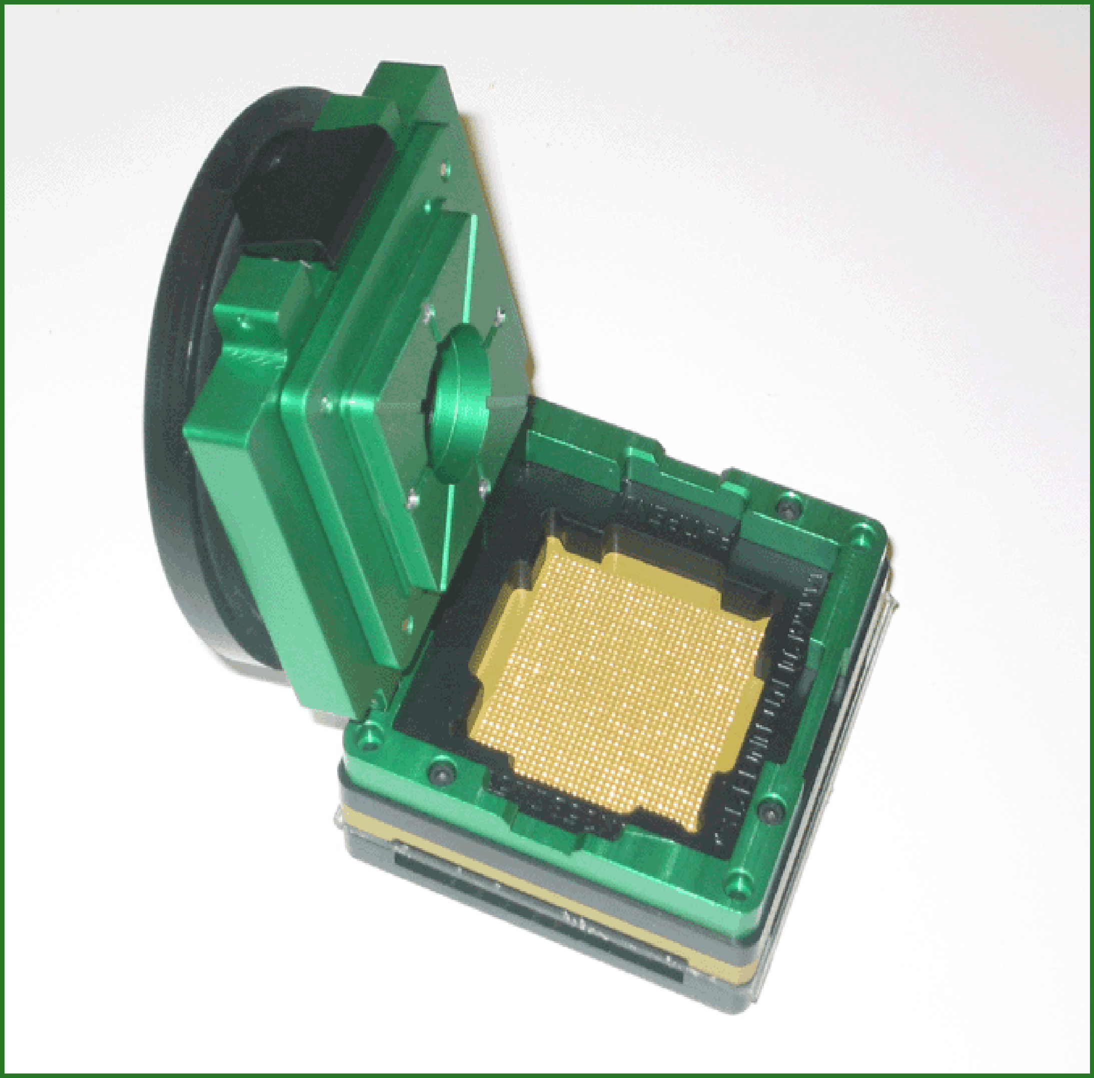


Machine Downtime and Refurb

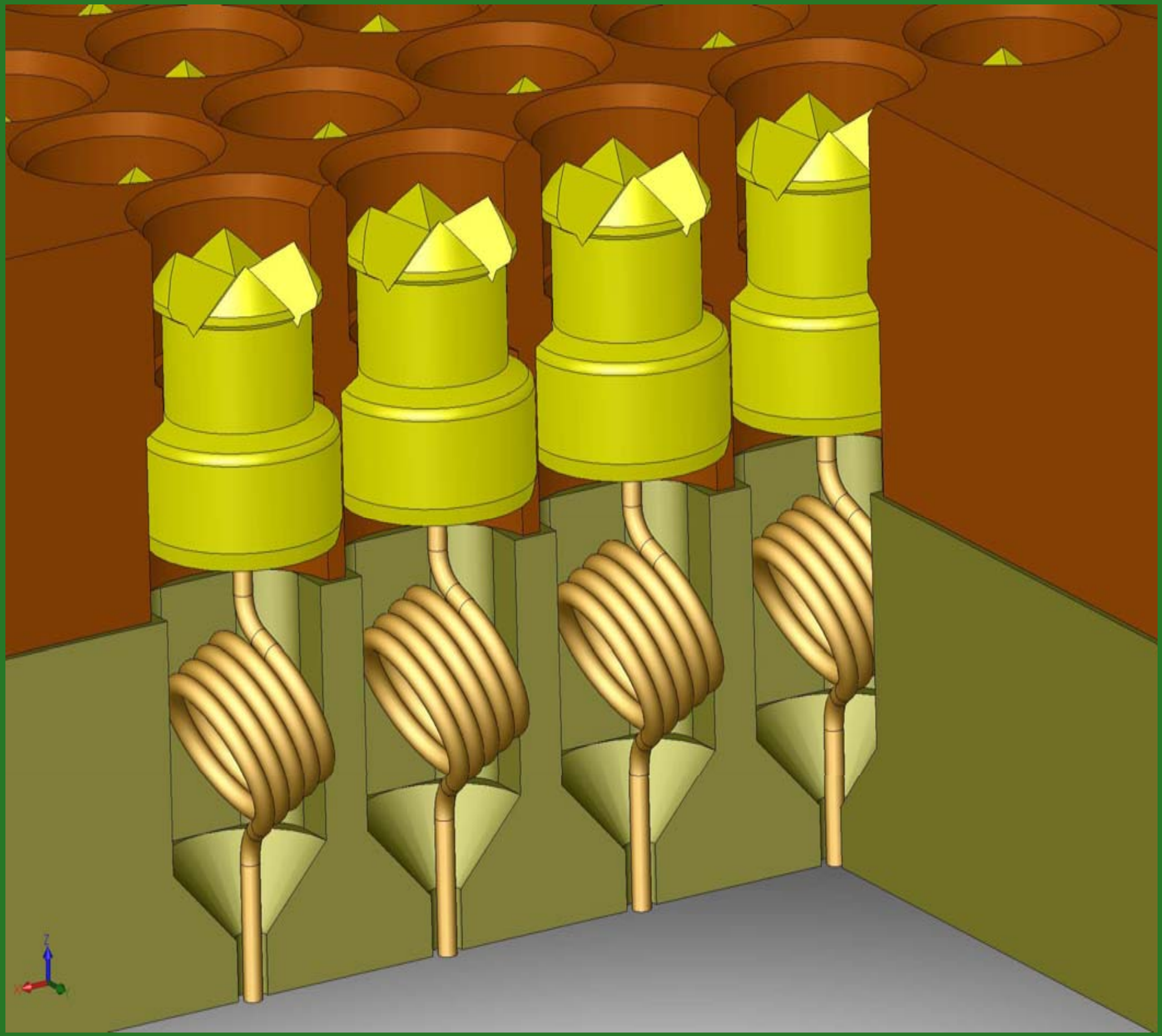
- Contactor Changeover Interval: 50K Cycles
- Contactor Changover Period: 1 per shift
- Machine Downtime: 5 minutes
- Contactor Refurbish Time: 10 minutes
- Cost Per Touchdown: $.0037

Other Applications

Test Contactors

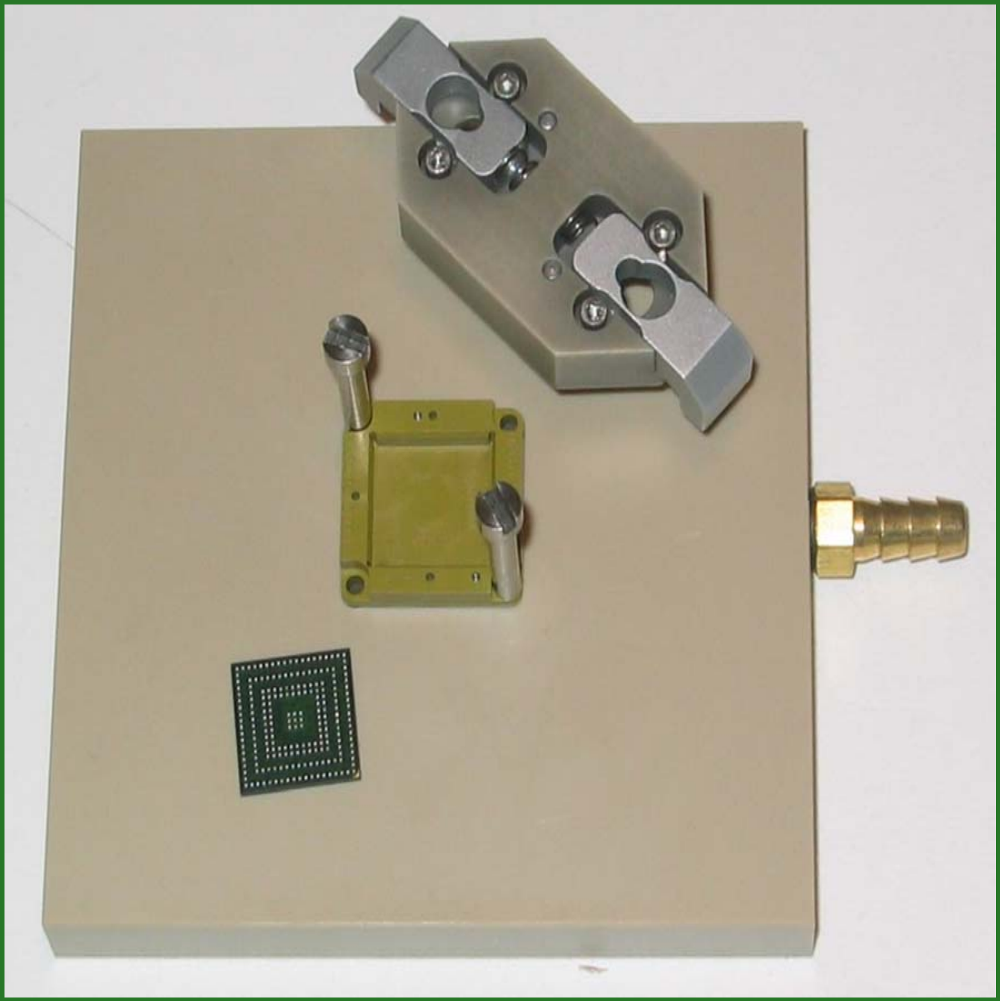


Redundant Contact™ Technology

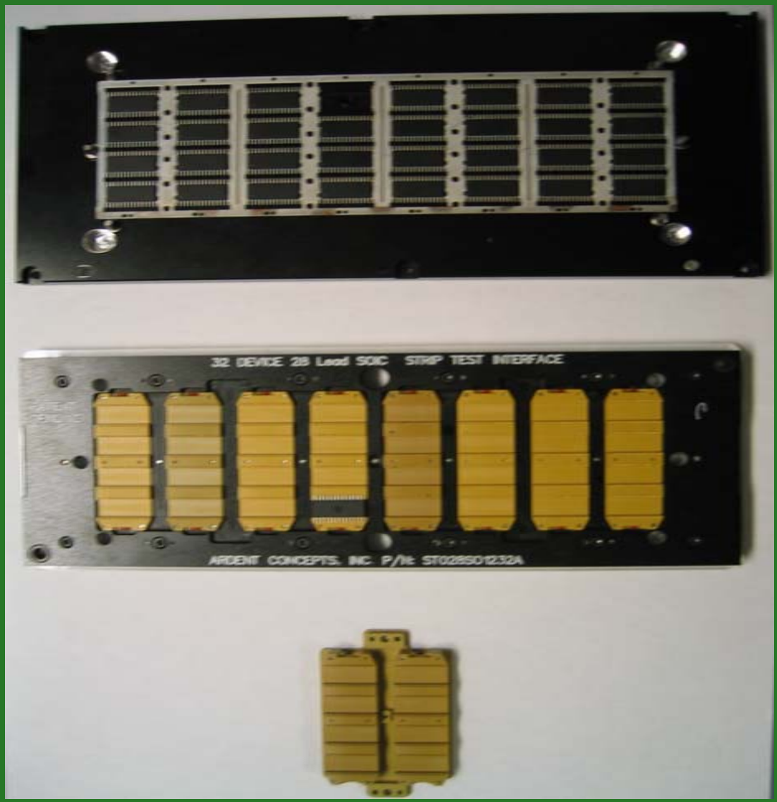


US Patent # 6,787,709. Other US and Foreign Patents Apply.

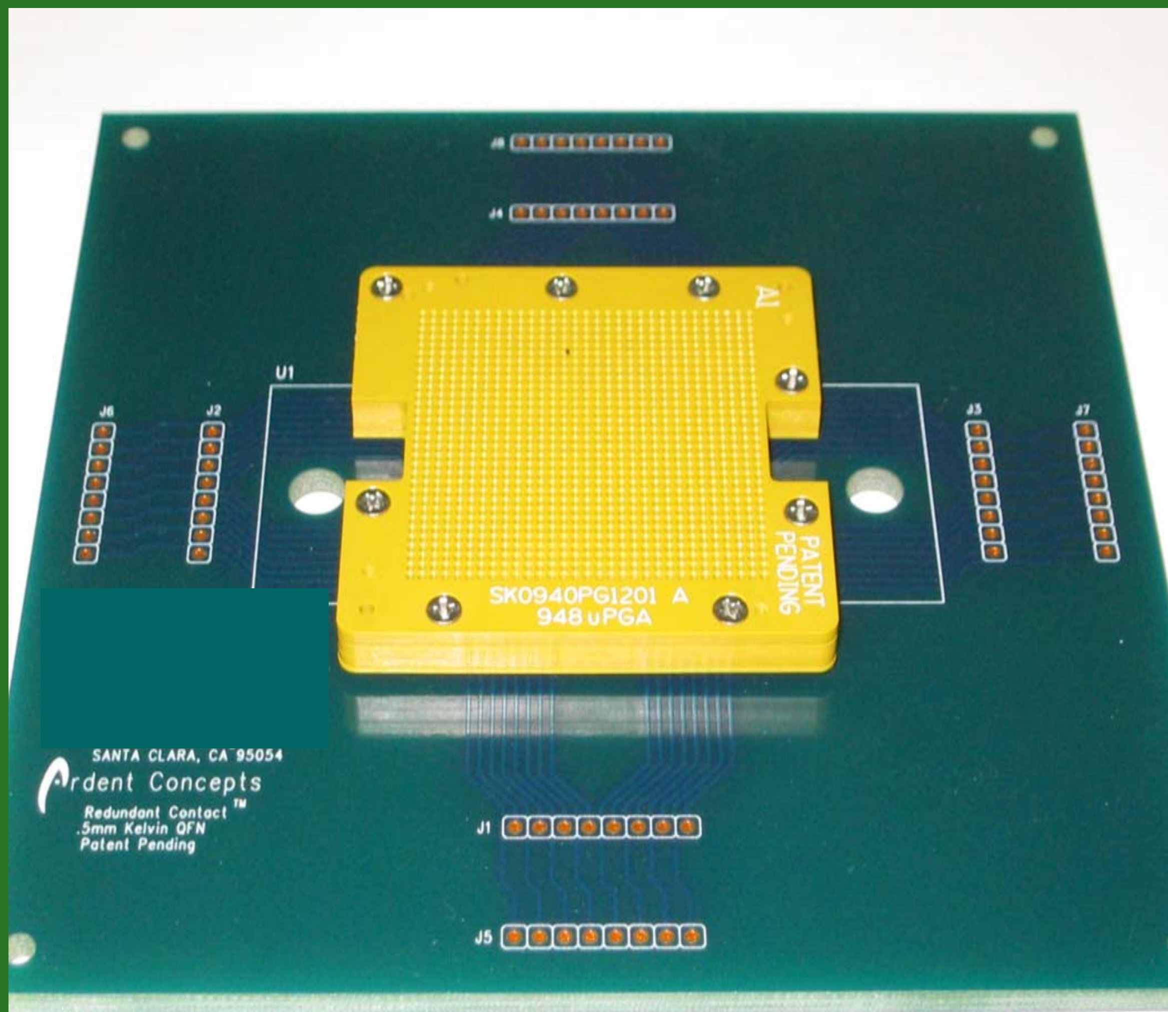
Characterization Contactors



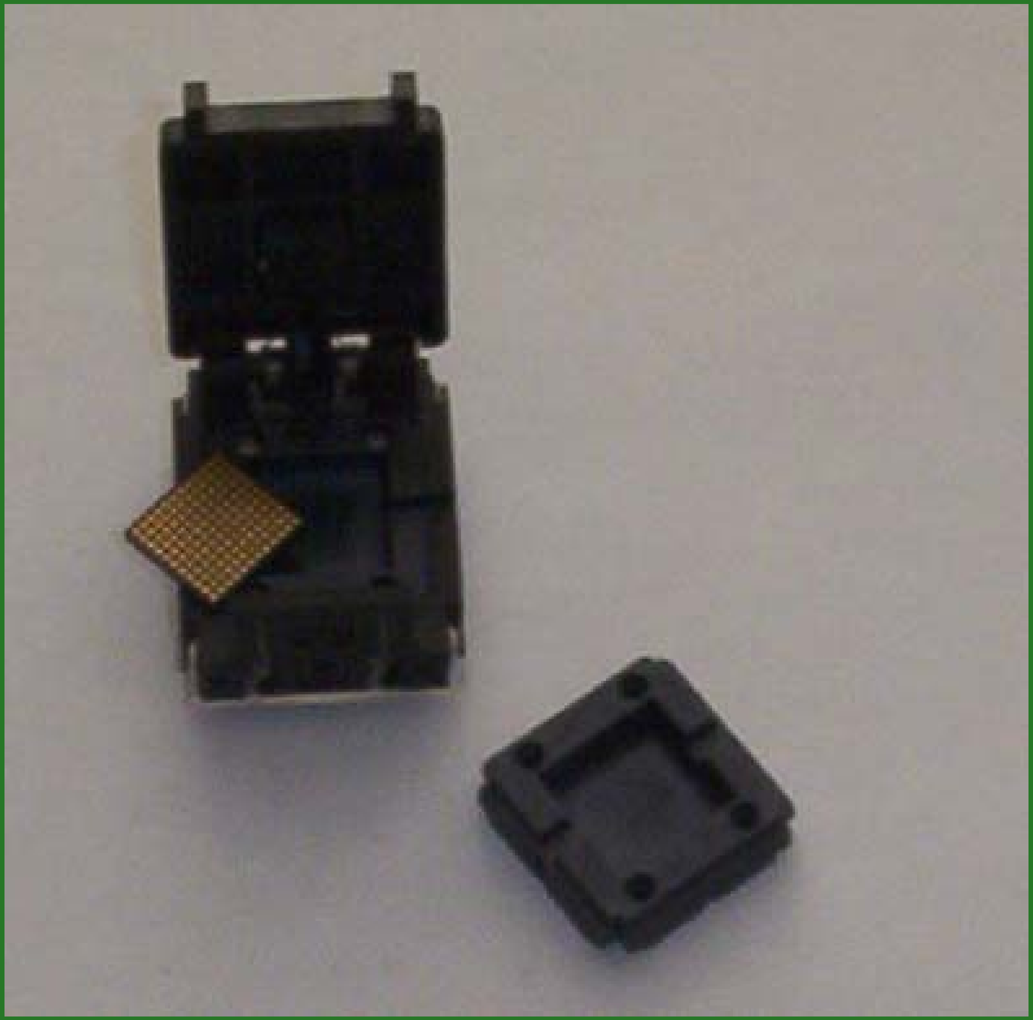
Strip Test Contactors



System Level Test Contactors



Burn-In Contactors



Board-to-Board Contactors

Conclusions

- **Z-axis** Contactor Solution key for recessed pad QFN applications
- **Consistent** AC performance essential to yield
- **Quick**, refurbishable contactors reduce machine downtime
- **Cost-effective** replacement pins reduce overall cost of test without sacrificing throughput

THANK YOU!

Verification of the Predictive Capability of a New Stress Relaxation Test Apparatus and FEA Technique for Predicting the Stress Relaxation of Electro-Mechanical Spring Contacts Made Using CuBe Strip

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Brush Wellman Inc.

Hideo Matsushima
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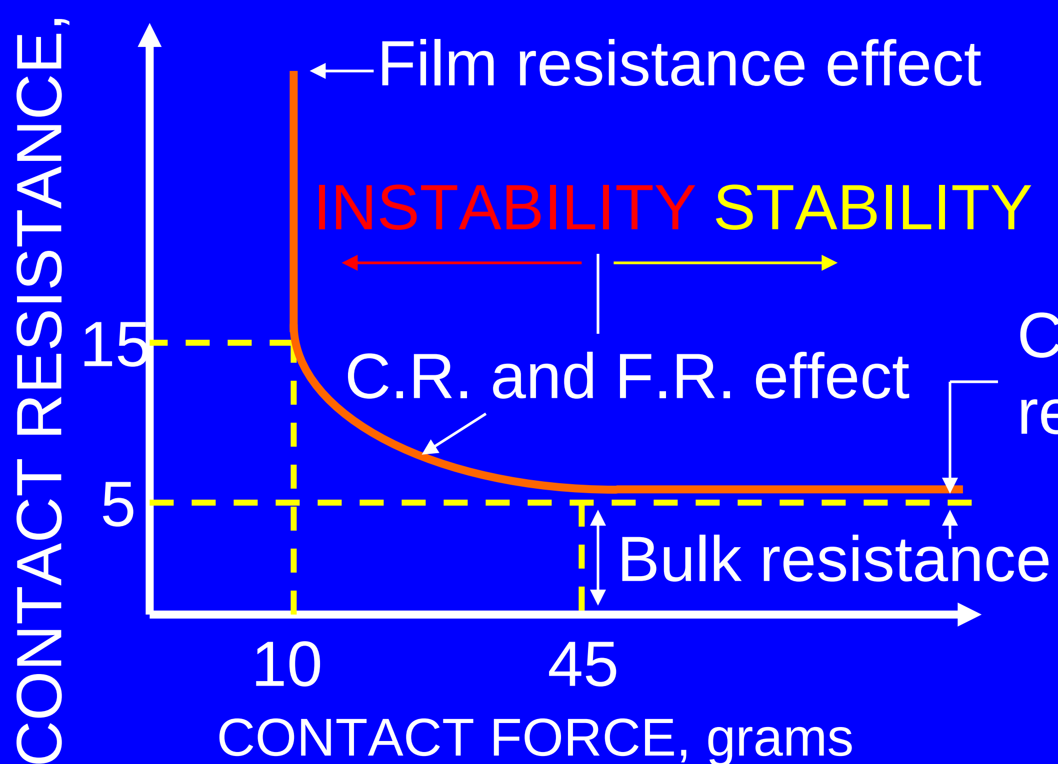
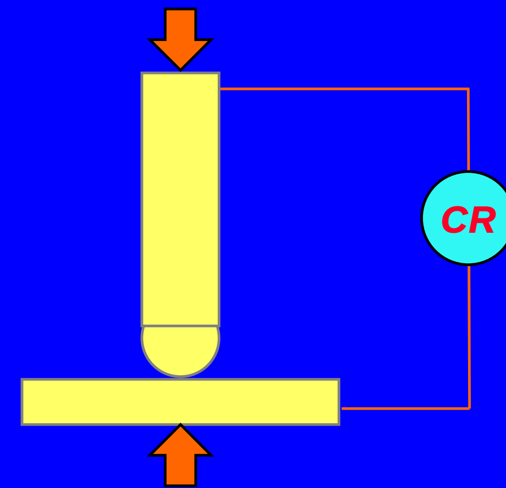
Socket Workshop

2005 Burn-in and Test
Socket Workshop
March 6 - 9, 2005

Contact Resistance

Spherical contact mated to flat circuit card pad without contact wipe (Au on Au system)

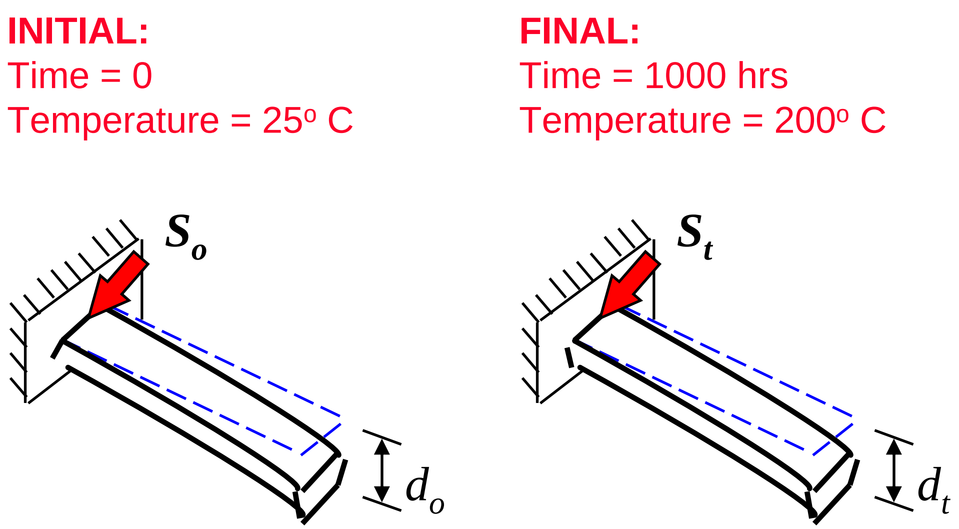




Contact resistance is a function of contact (normal) force

Stress Relaxation

- Gradual decay of stress at constant strain
- Temperature, stress, time, alloy & temper dependent



$$d_0 = d_t$$
$$S_0 \neq S_t$$

Stress Relaxation

- Normal force is related to max surface stress
- Therefore: loss of stress = loss of normal force

Max surface stress

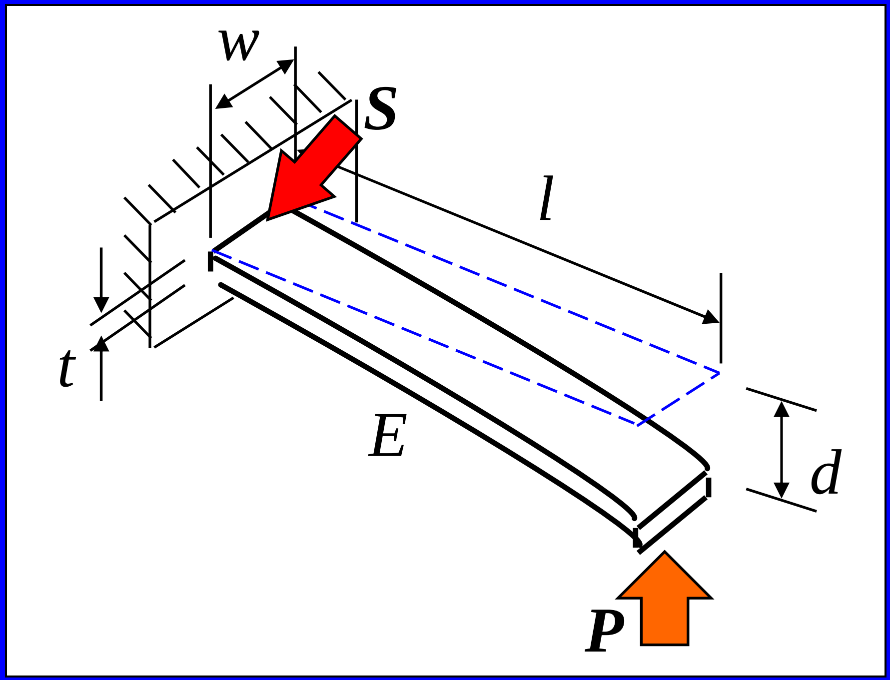
beam width

$$P = \frac{S_{\max} w t^2}{6l}$$

beam thickness

Normal Force

beam length

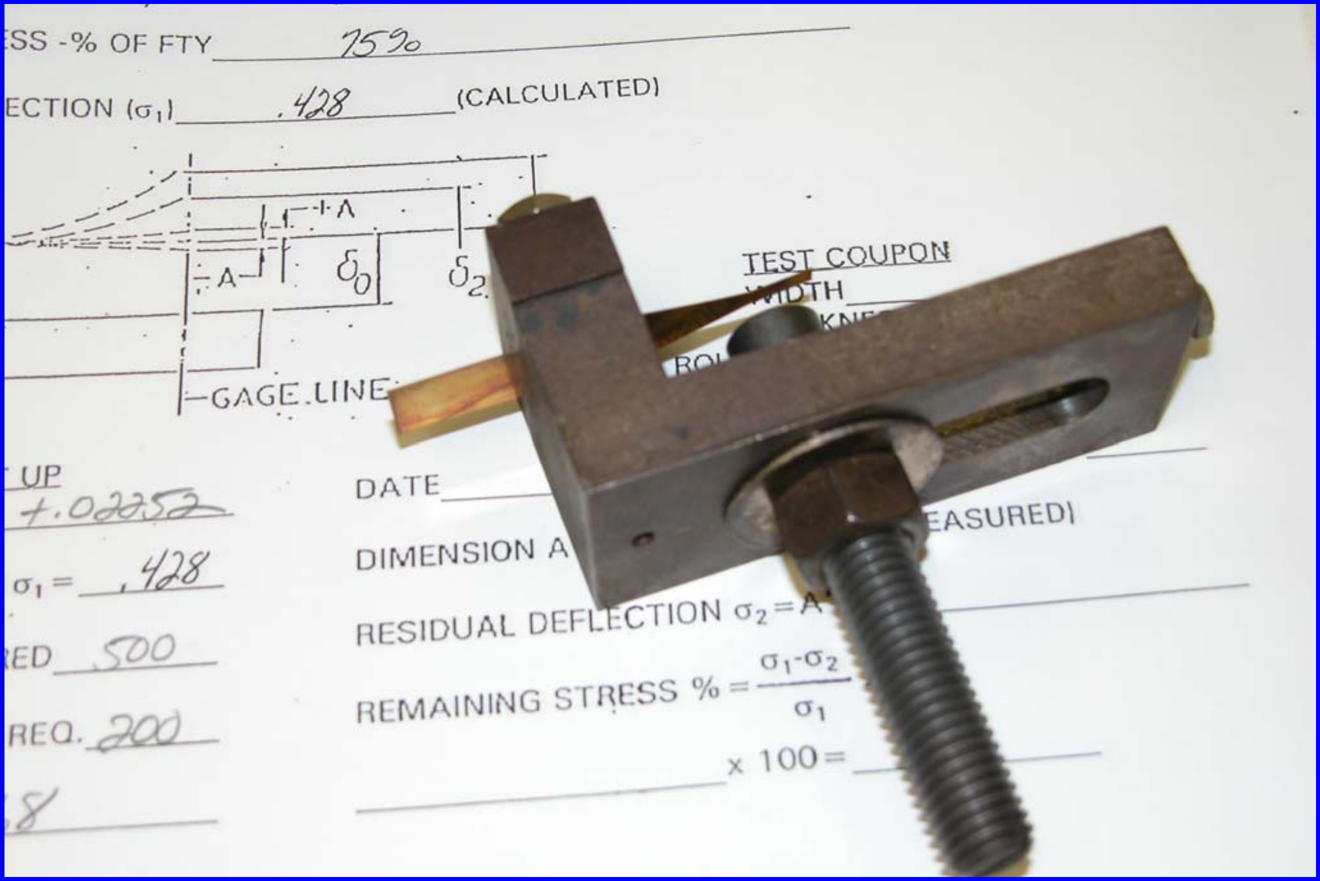


Implications of Stress Relaxation

- Increasing permanent set
- Decreasing contact force
- Increasing contact resistance
- Decreasing reliability

- Prediction of stress relaxation is as important as prediction force-deflection curves or permanent set

Traditional Bending Stress Relaxation Test Fixture

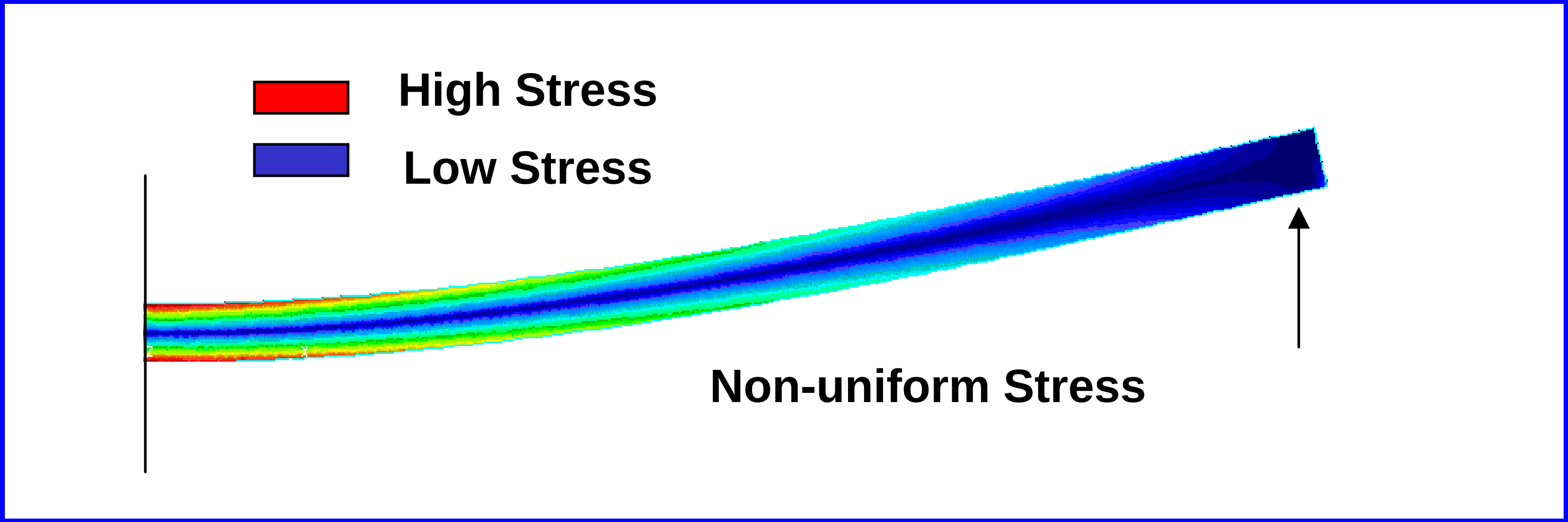


Traditional Procedure

- Deflect specimen to position (d_1) which creates desired stress in beam
- Place in oven at desired temperature
- Remove after desired time
- Measure permanent set at end of beam (d_2)
- Stress remaining = $\frac{d_1 - d_2}{d_2}$
- Note: 1 test specimen yields only 1 data point

Modeling Stress Relaxation

- For FEA purposes, need to correlate stress relaxation with absolute stress, time, and temperature within each element
- Traditional bending test samples = stress gradient



New Stress Relaxation Test Procedure

- Test samples with uniform x-section under uniaxial tension = uniform stress
- Load samples in tension
- Correlate natural frequency with tension
- Measure change in frequency over time
- Used successfully for wire

Test Set-up

Signal conditioner

Digital multimeter

Test fixture

Spectrum analyzer

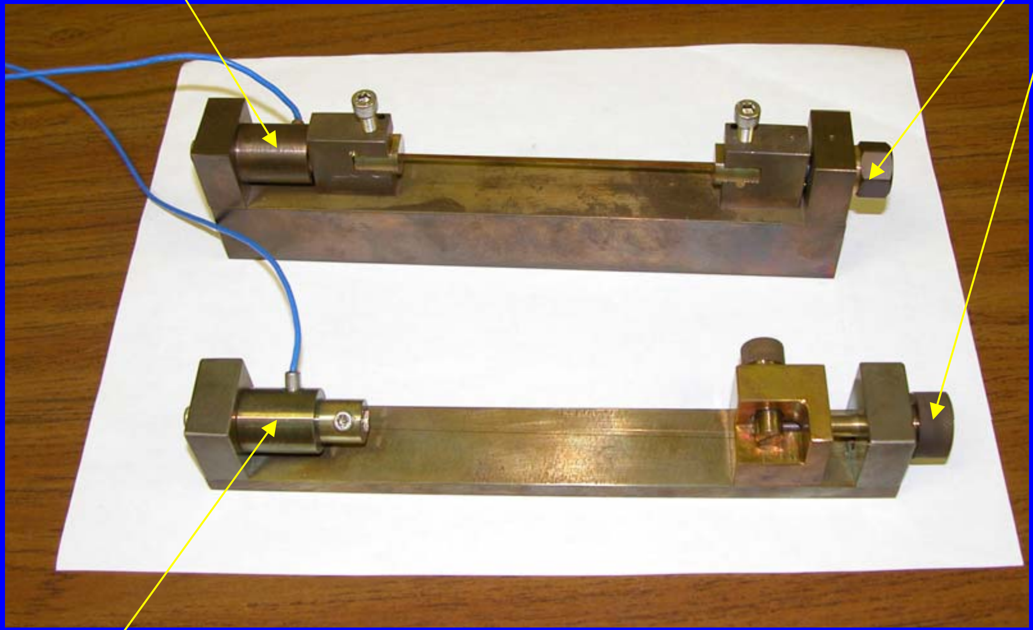
New Tensile Stress Relaxation Test Fixtures

Piezoelectric sensor & load cell

Tension adjustment knob

Strip fixture

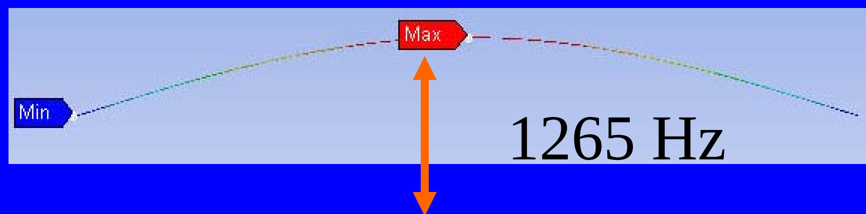
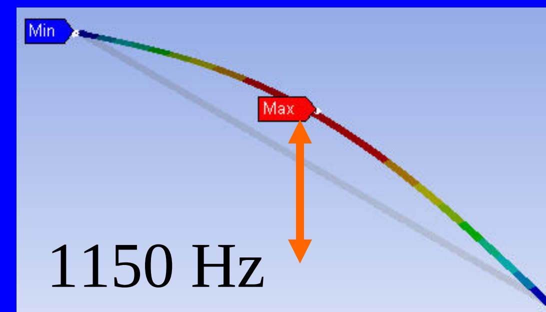
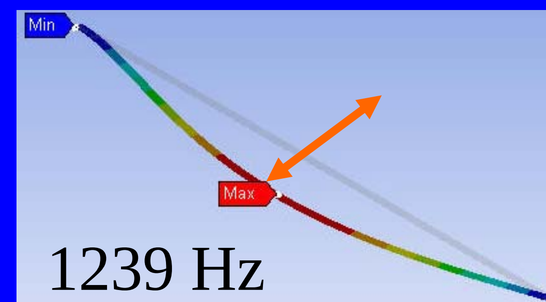
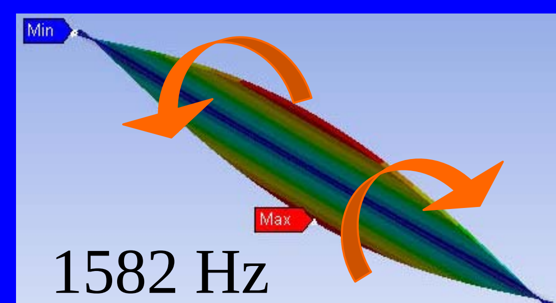
Wire fixture



Piezoelectric sensor

Fixtures made from CuBe to match CTE of test samples

Modal Analysis Using FEA

Mode	Wire	Strip
1		
2		
3		

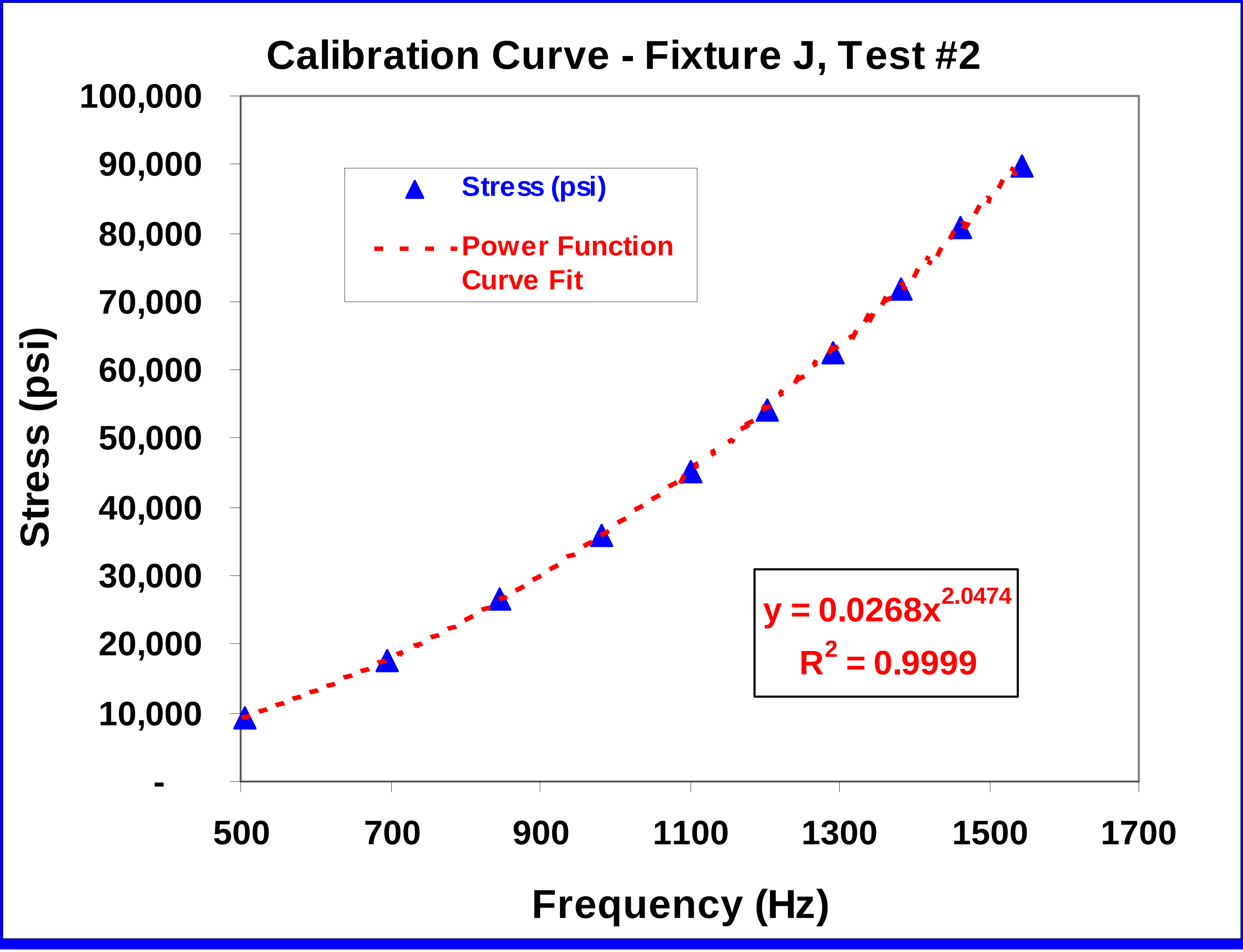
Measuring Natural Frequency

- Wire:
  - Length >> Area - 1-D wave equation applies
- Strip:
  - Planar vibration modes factor in
  - Stress not directly calculable from frequency
  - Requires calibration curve - stress vs. frequency
  - Photo-etched to control stress risers

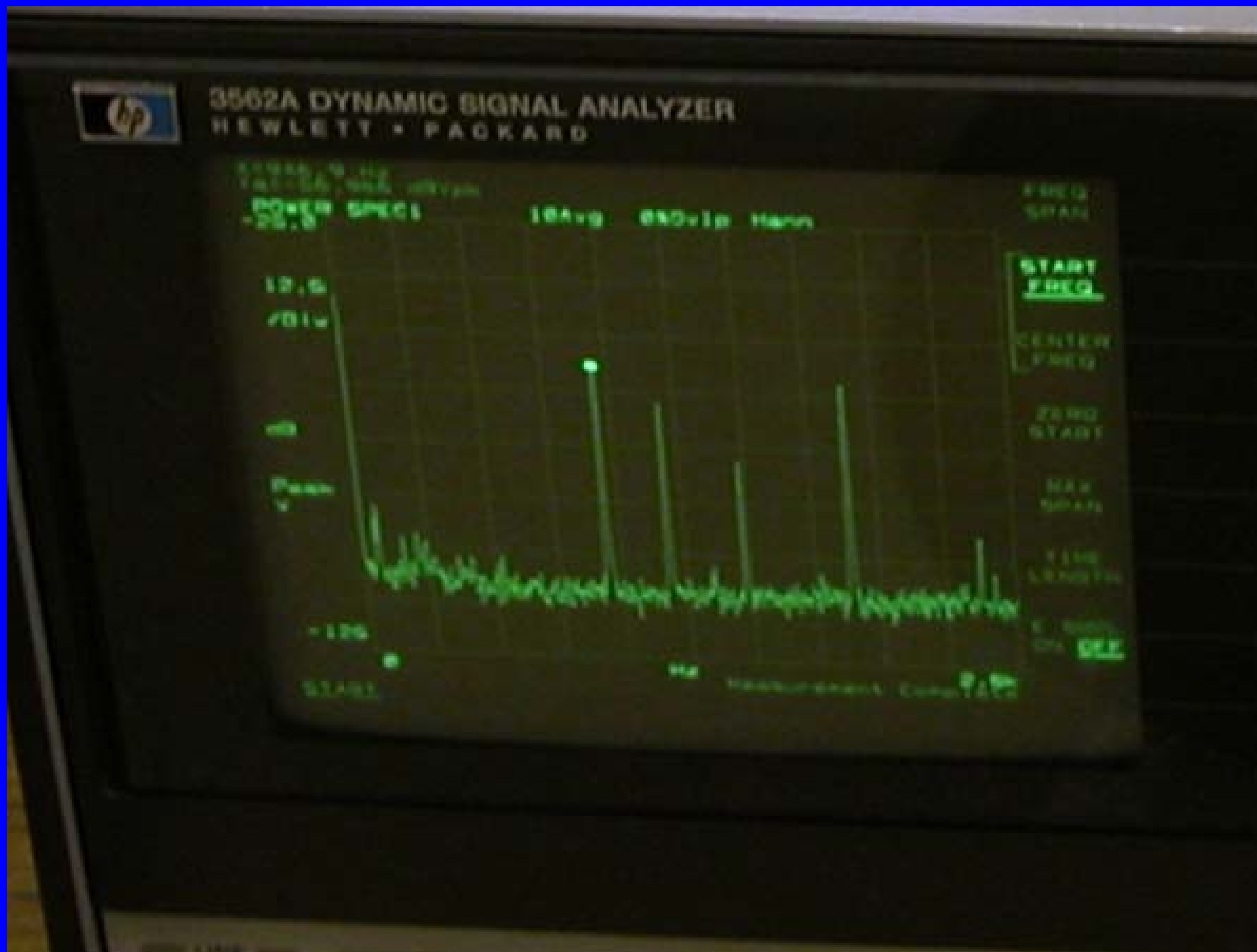
New Test Procedure

- Set signal conditioner to load
- Increase load to desired voltage level
- Set signal conditioner to resonance
- Measure & record frequency
- Repeat for all calibration frequencies
- Place fixture in furnace for desired time
- Cool to equilibrium
- Record change in frequency
- Return to furnace for additional soak time

Example Calibration Curve



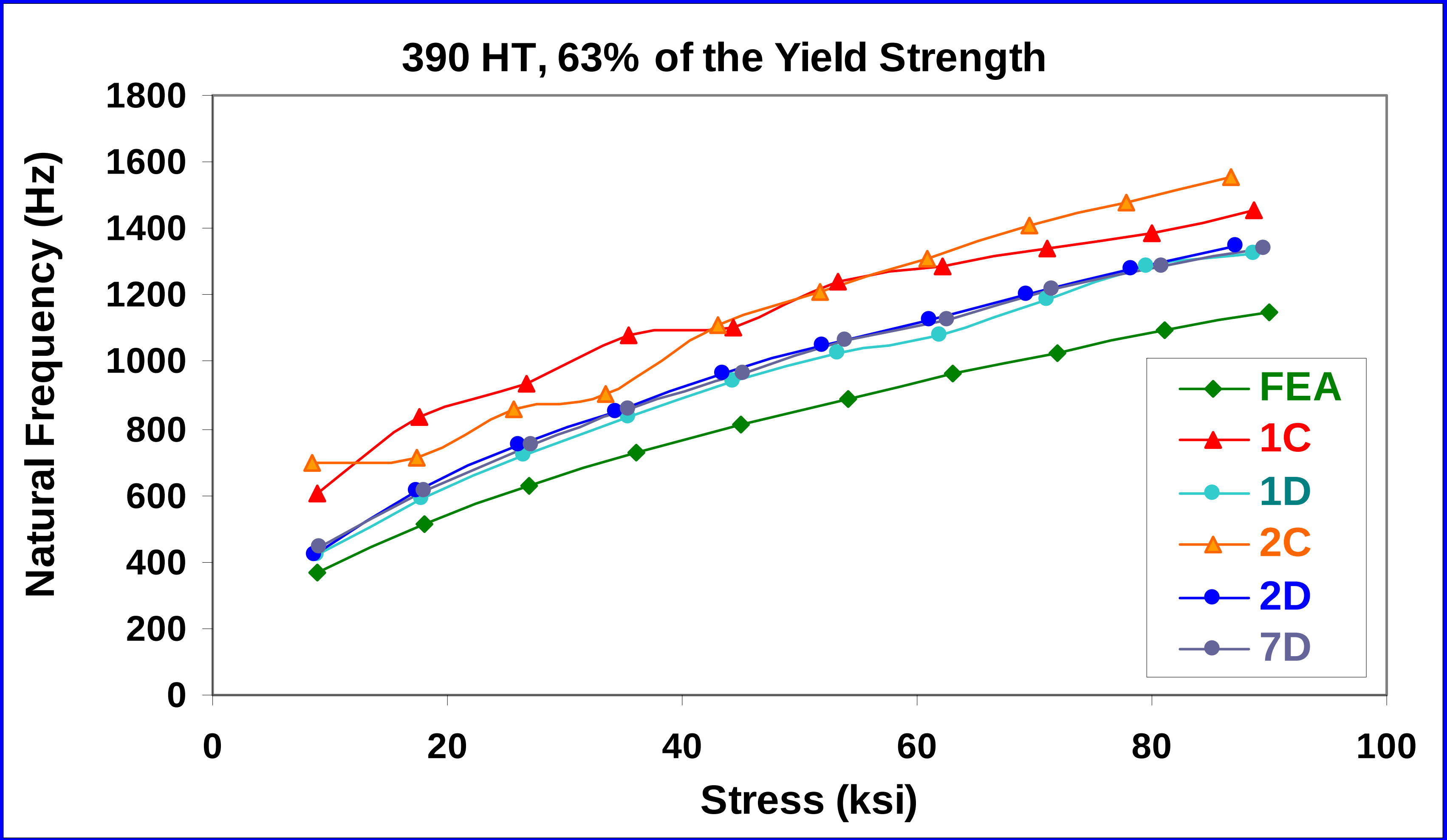
Frequency Response - Analyzer Output



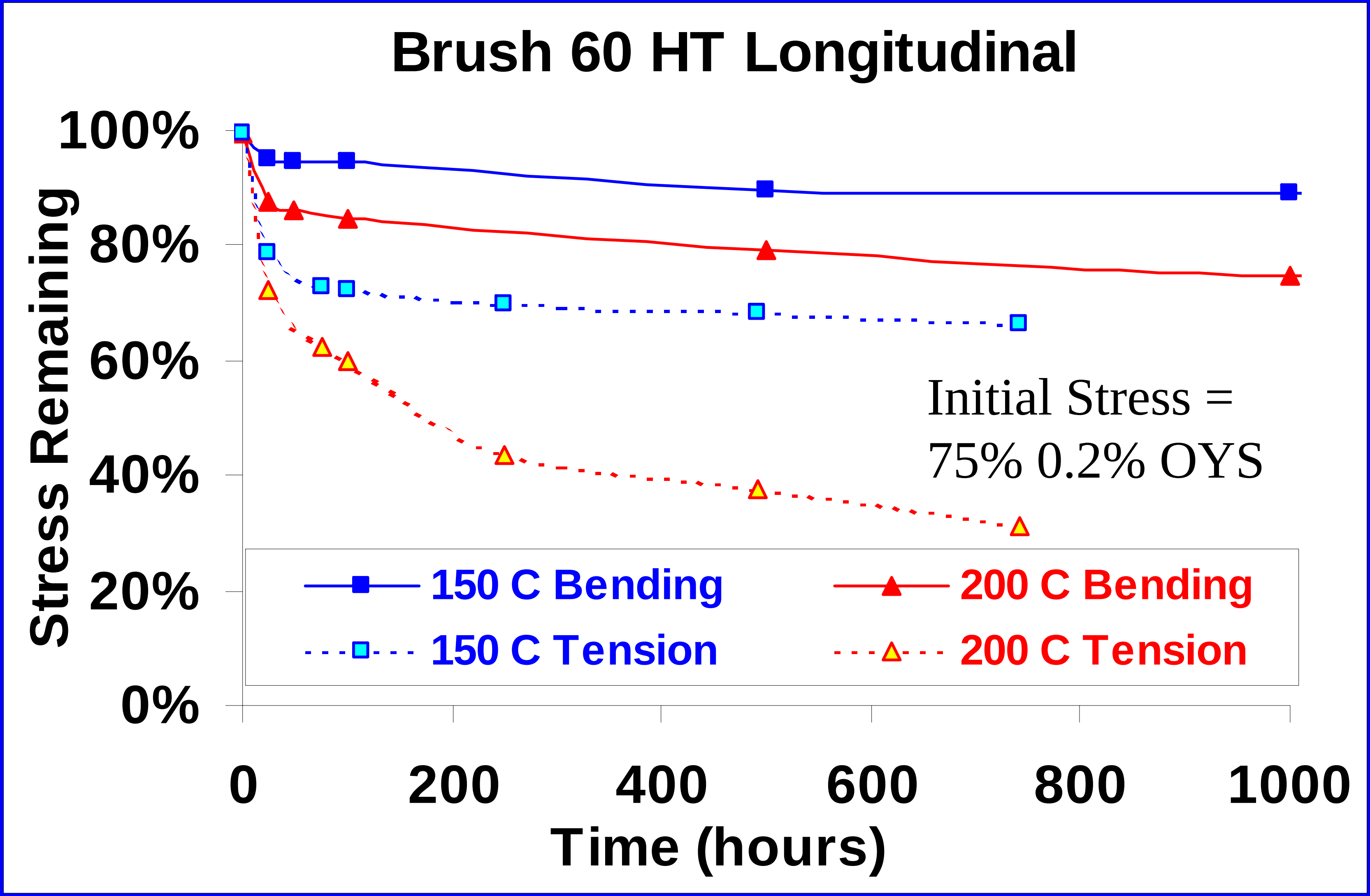
Strip Fixture Challenges Encountered

- Premature yielding/fracture
  – Clamping mechanism change
- Clamping force balance
  – Too little = slippage
  – Too much = yielding/fracture
- Load cell sensor drift
- Operator bias
- Departure of primary test operator

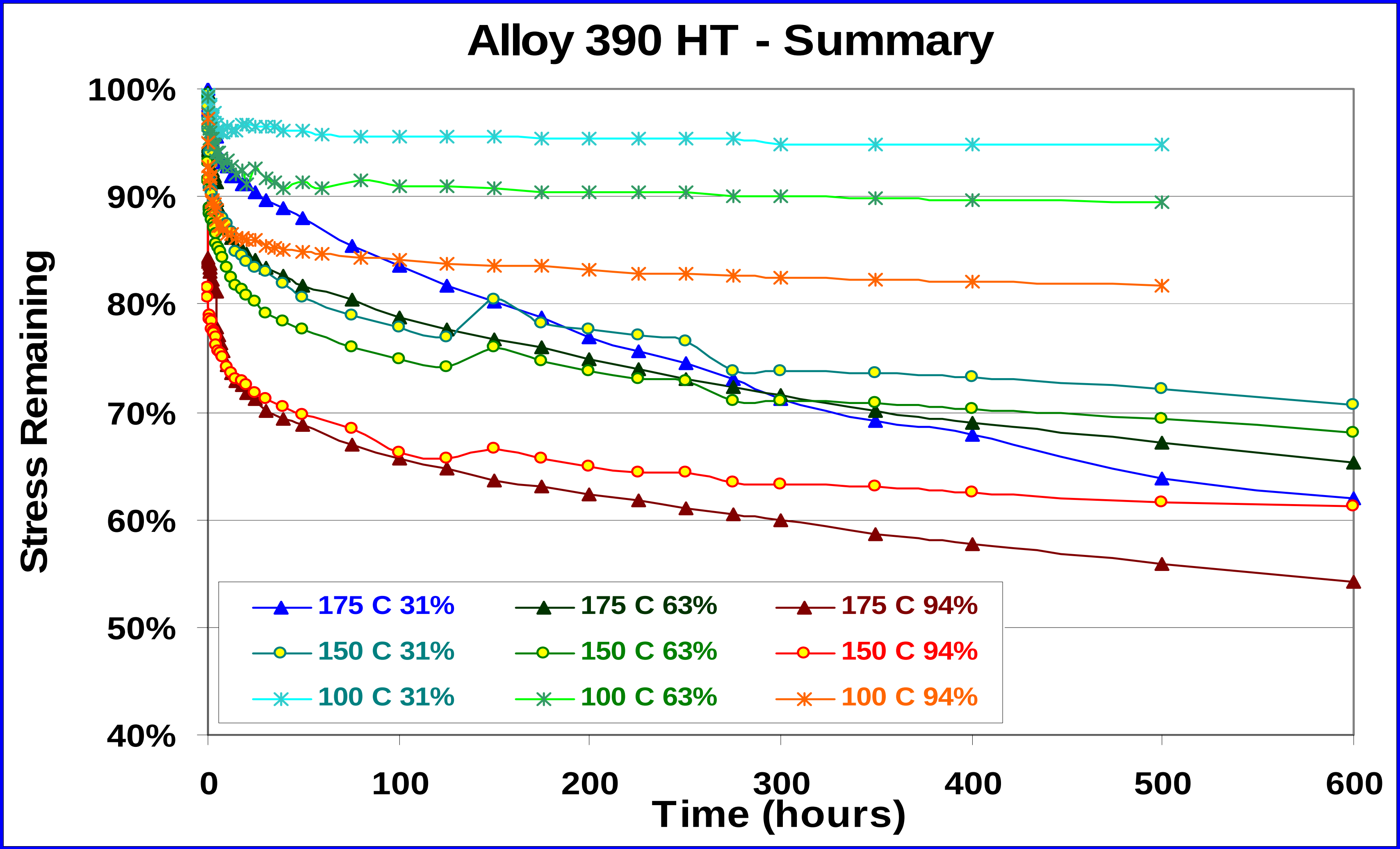
Predicted Curve vs. Reality



Direct Comparison of Methods



Initial Results

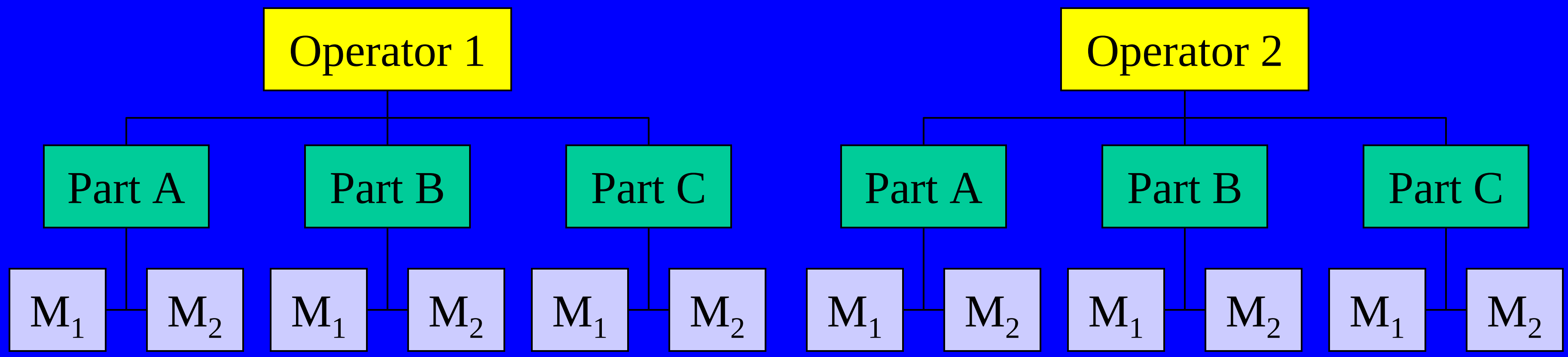


Initial Findings

- Relaxation rate in tension > relaxation rate in bending
- Relaxation rate increases with initial stress level as well as temperature and time

Test Reliability

- Components of Variation (COV) Study
  - Testing is destructive, so an Measurement System Evaluation (MSE) is not possible
  - Statistically driven evaluation of test capability
  - Designed sampling plan arranges sources of variation into a hierarchy of causes



COV Study

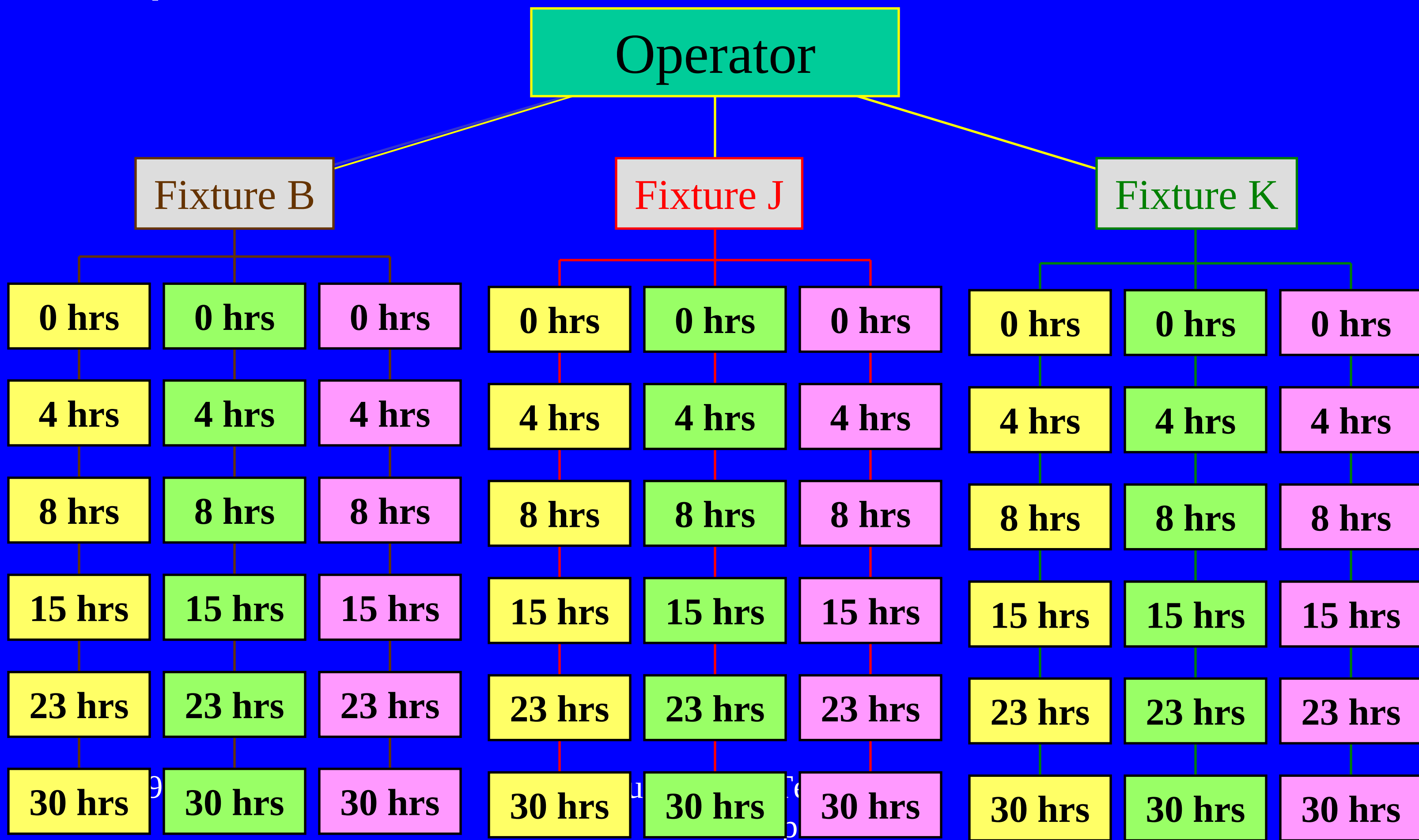
- Results subgrouped and control charted
- Amount of variation from each level in the hierarchy determined mathematically
- Identifies major sources of variation

$$\sigma^2_{\mathbf{Total}} = \sigma^2_{\mathbf{Operator}} + \sigma^2_{\mathbf{Part}} + \sigma^2_{\mathbf{Measurement}}$$

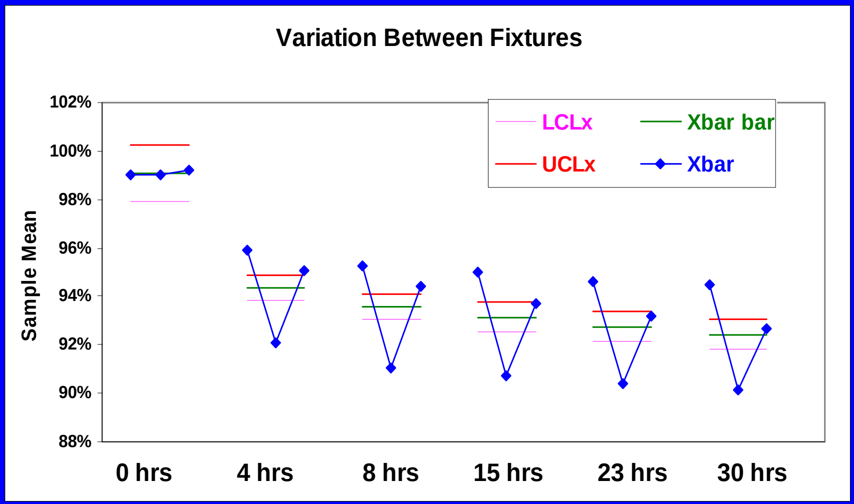
- Part to part variation <u>must be greater than</u> the measurement or operator variation for the measurement system to be considered capable

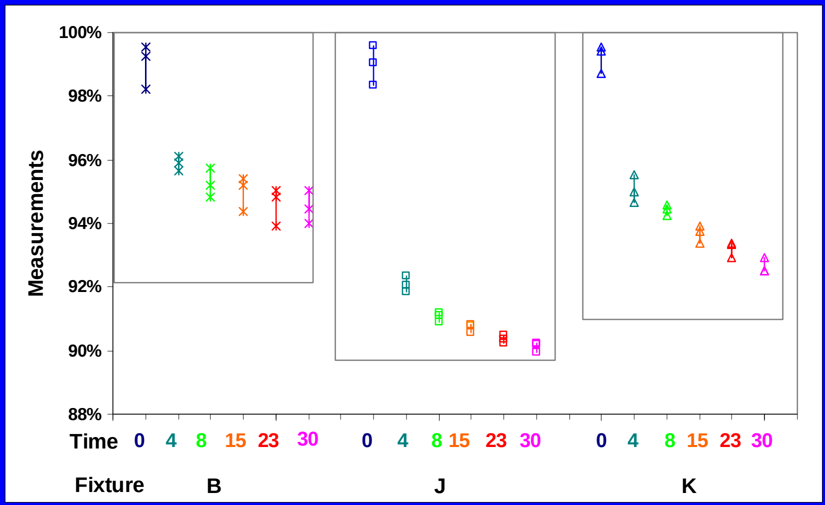
COV Study

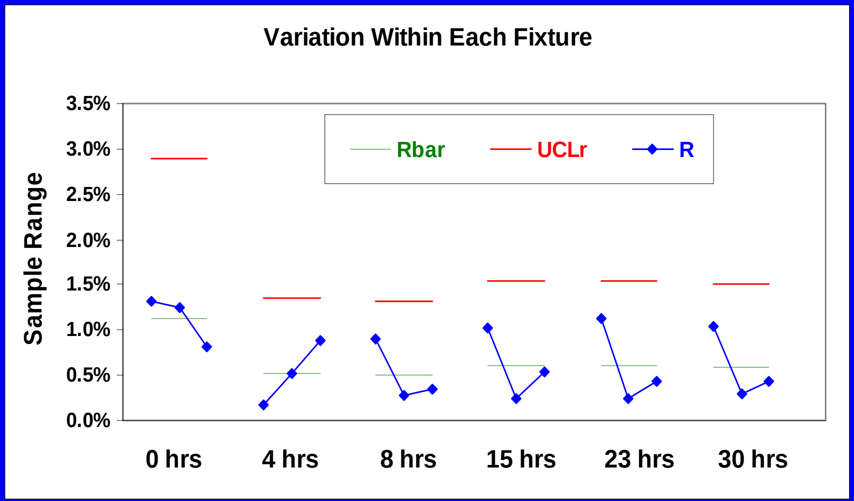
- One operator, 3 fixtures, one test condition
- Measurements at 6 time increments, 3X repetition

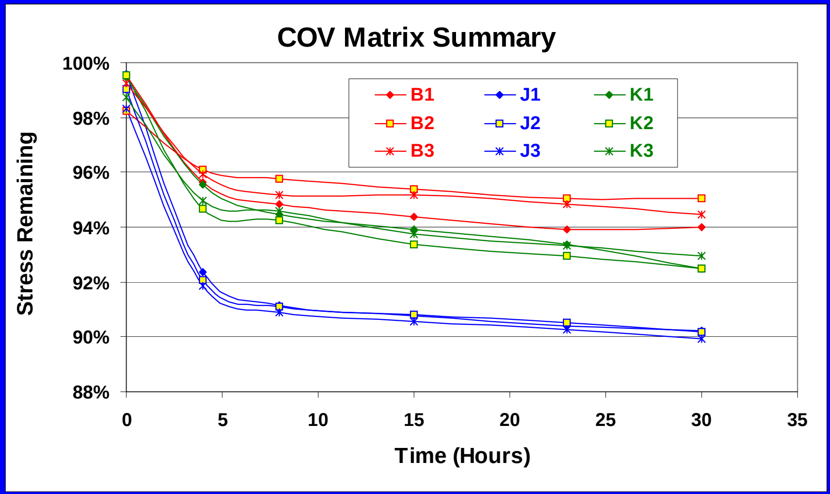


COV Study


Variation Between Fixtures
LCLx
UCLx
Xbar bar
Xbar
Sample Mean
102%
100%
98%
96%
94%
92%
90%
88%
0 hrs
4 hrs
8 hrs
15 hrs
23 hrs
30 hrs


Measurements
100%
98%
96%
94%
92%
90%
88%
Time 0 4 8 15 23 30 0 4 8 15 23 30 0 4 8 15 23 30
Fixture B J K


Variation Within Each Fixture
Rbar
UCLr
R
Sample Range
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0 hrs
4 hrs
8 hrs
15 hrs
23 hrs
30 hrs

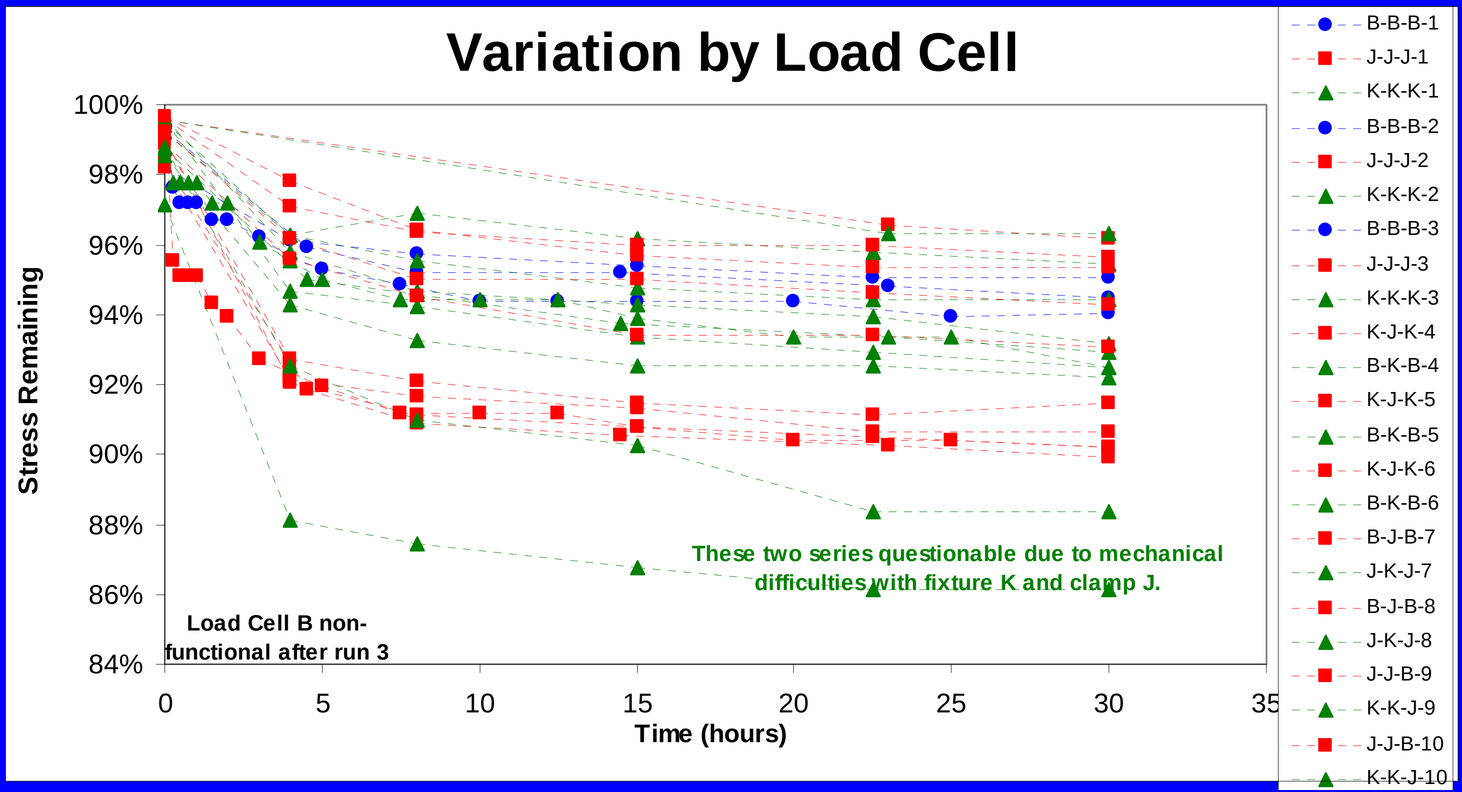

COV Matrix Summary
B1
B2
B3
J1
J2
J3
K1
K2
K3
Stress Remaining
100%
98%
96%
94%
92%
90%
88%
0
5
10
15
20
25
30
35
Time (Hours)

COV Study

- Summary of Initial COV
  - Results within each fixture are repeatable
  - 95% of the variation exists between fixtures
- Expanded COV Study
  - Repeated at shorter times and fewer intervals
  - Load cells, clamps, and frames were exchanged to see which components the variation followed

Expanded COV Study

- Problems appeared to accompany load cells
- Fully crossed study impossible due to failed sensors



Fixture Repair and Recalibration

- Operator bias traced to temperature dependence
  - Loading, testing in climate-controlled room
  - Sufficient time to reach equilibrium
- Sensor recalibration indicated that the sensitivities of the load cells changed by as much as 4.8% in the 9 remaining fixtures
  - May require recalibration after each test run to ensure sensor accuracy

Fixture Repair and Recalibration

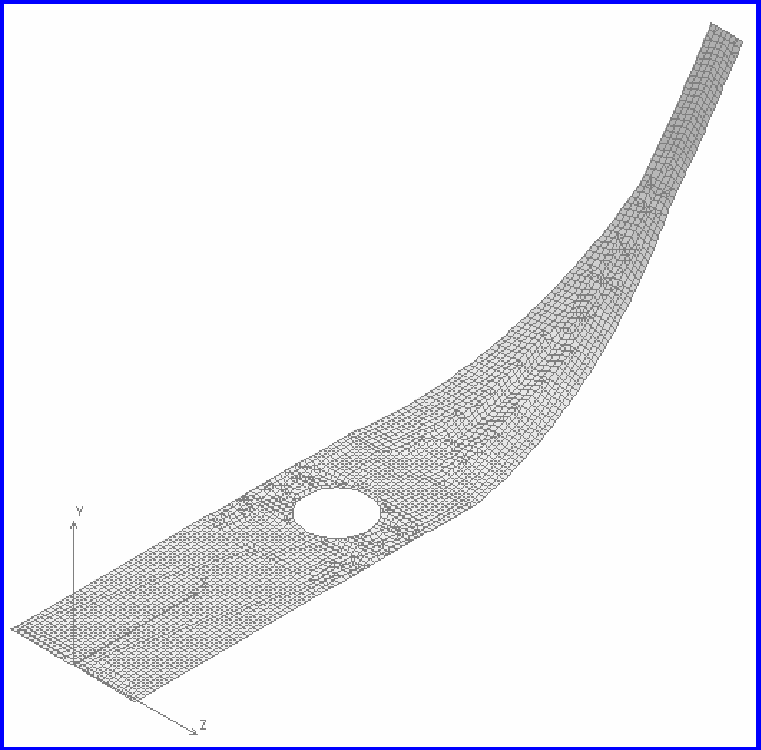
- 3 sensors inoperative, required repair and rebuilding
- Thermal expansion caused some sensors to contact test fixture frames
  - Transferred some load to frame from sensor
  - Load higher than recorded by sensor
  - Material removed from sensors to ensure this does not happen again

Next Steps

- Verify predictive capability of new method with validation study
- Re-run COV study to ensure that repairs worked and measurement system is capable
- Build databases with additional test runs
- Conduct additional validation studies with customers on BiTS models

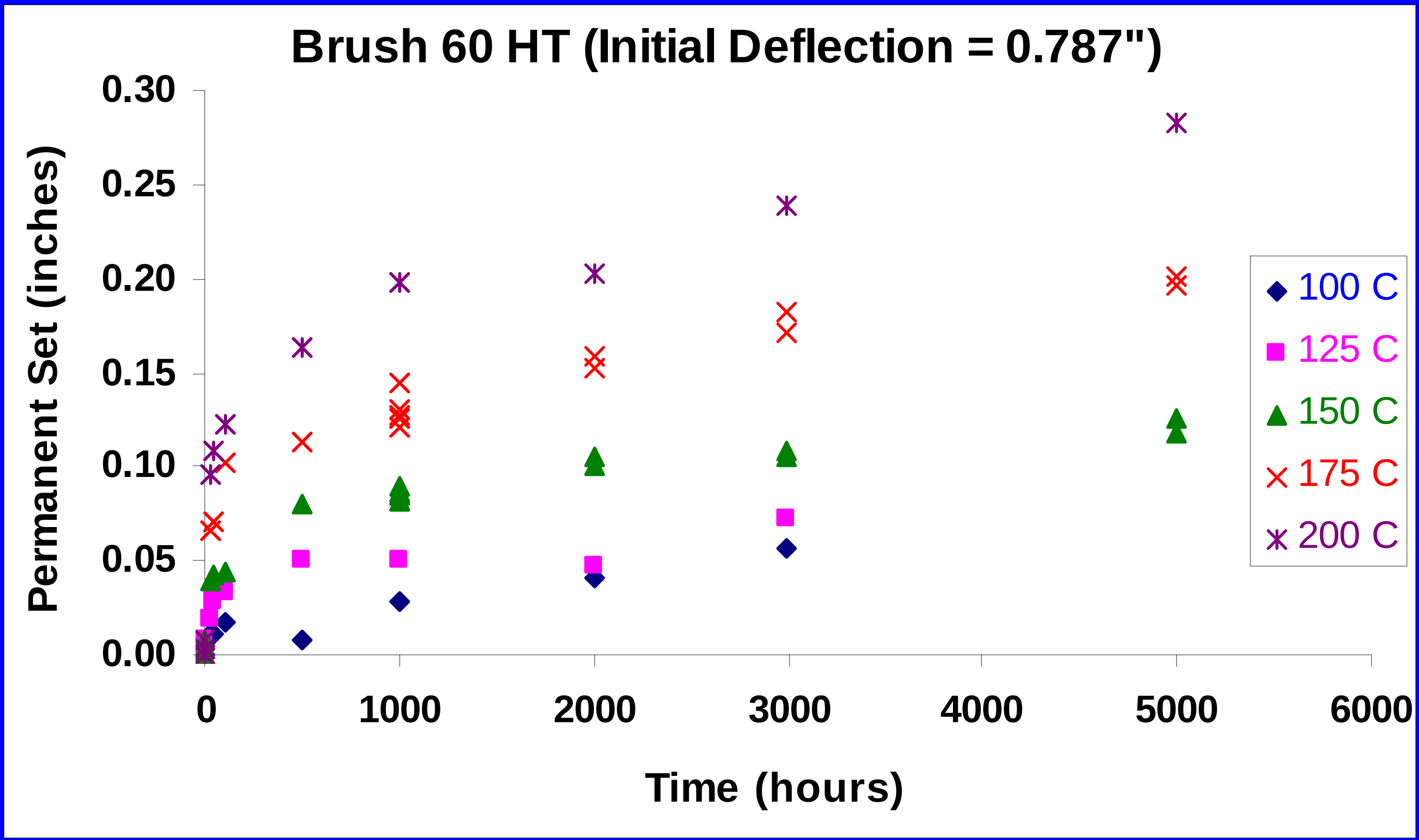
Validation Study

- Use data generated by new tensile technique to model the behavior of material in the traditional bending test



Experimental Results

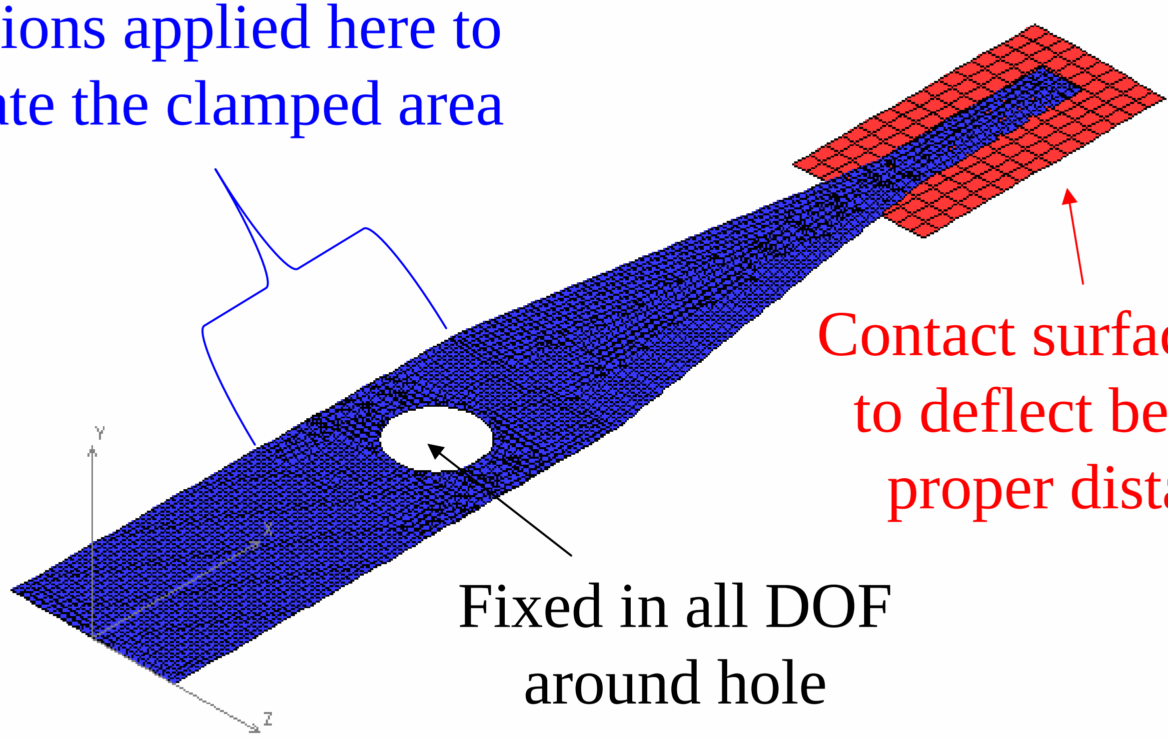
- Permanent set measured in lab by bending test



Finite Element Model Used in Analysis

4-node thick shell elements with Von Mises kinematic strain hardening

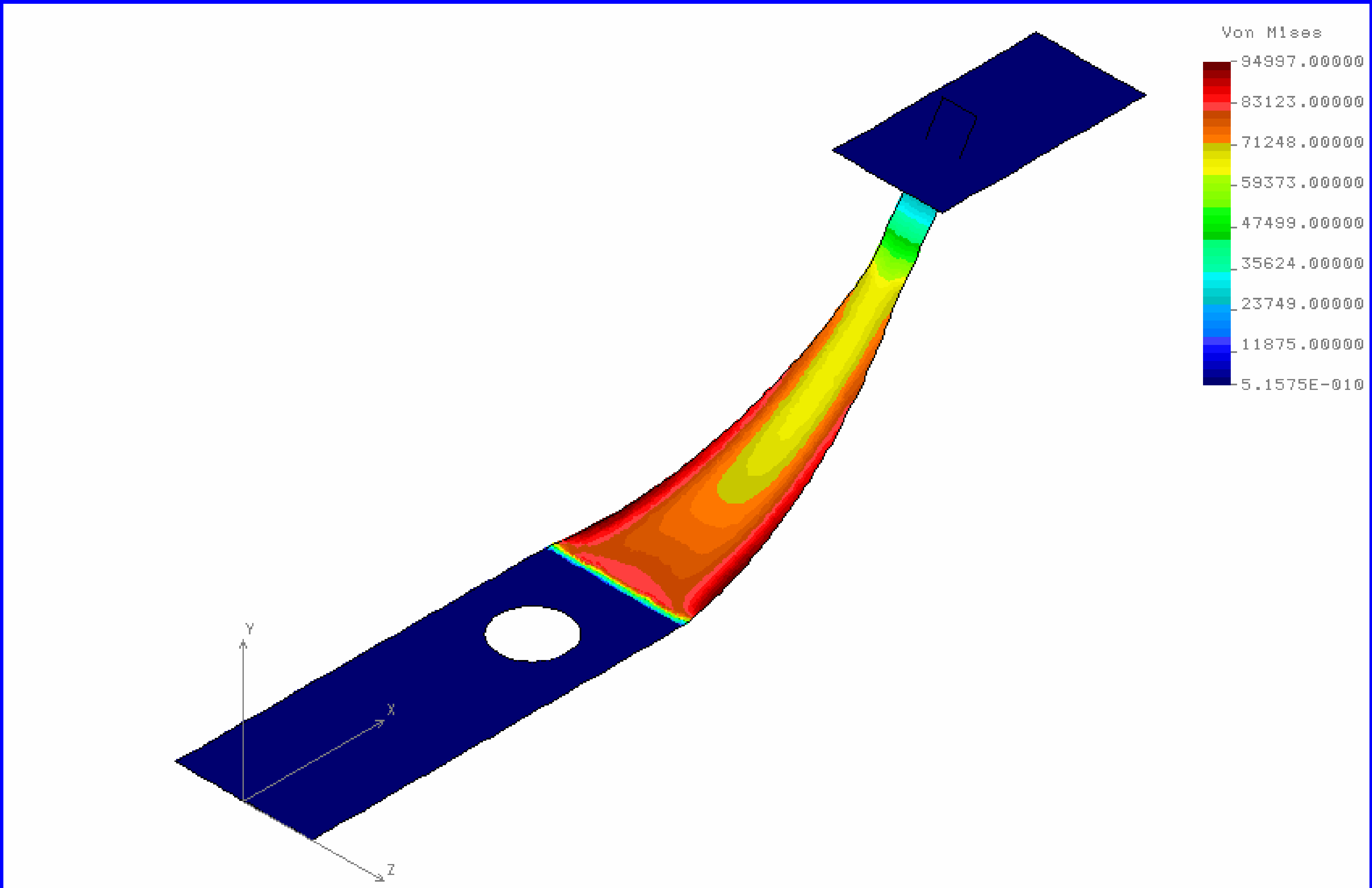
XZ symmetry boundary conditions applied here to simulate the clamped area



Contact surface used to deflect beam to proper distance

Fixed in all DOF around hole

Initial Stress at Peak Deflection



How Does FEA Compare?

- Results to be unveiled live at 2005 BiTS Workshop