# BiTS

# Burn-in & Test Socket Workshop

**March 3-6 , 2002**
**Hilton Phoenix East/Mesa Hotel**
**Mesa, Arizona**

IEEE

IEEE COMPUTER SOCIETY

**Sponsored By The IEEE Computer Society Test Technology Technical Council**

**Burn-in & Test Socket Workshop**

# Technical Program

## Session 1
## Monday 3/04/02 8:30AM

## Socket Design Investigations

**"Effect Of High Temperature Heating On Music Wire Spring Performance"**

**Jiachun (Frank) Zhou** - Kulicke & Soffa Interconnect, Inc.
**January Kister** - Kulicke & Soffa Interconnect, Inc.
**Alberto M. Campos** - Kulicke & Soffa Interconnect, Inc.

**"Low Cost Burn-in Socket Design For Area Array Package (BGA)"**

**Ichiro Fujishiro -** Yamaichi Electronics, USA Inc.

**"Force and Resistance Probing Automation for Contactors"**

**Valts Treibergs** - Everett Charles Technologies
**Jason Mroczkowski** - Everett Charles Technologies

# Effect of High Temperature Heating on Music Wire Spring Performance


**Jiachun Zhou (Frank), presenter**
**January Kister**
**Alberto M. Campos**

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BURN-IN & TEST SOCKET WORKSHOP

# Introduction

| Material Name and Specification | Max Service Temp. | |
|---|---|---|
| | F | C |
| Music Wire, ASTMA228 | 250 | 121 |
| Austenitic Stainless Steel AISI 302 | 600 | 316 |
| Beryllium Copper, ASTM B197 | 400 | 204 |

Data from reference.

May not be suitable for small spring with < 0.1mm diameter wire.

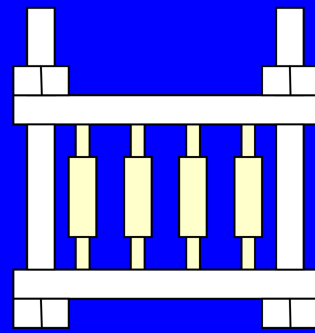
# Objectives

Investigate the effects of high temperature heating on spring performance.

Verify suitable temperature range of music wire spring application (<0.1mm wire diameter).

Analyze the root-cause of spring failure in high temperature environment.

# Test Methods



**Compressed spring in parallel plates;**

**Heating compressed springs in high temperature oven for a period of time;**

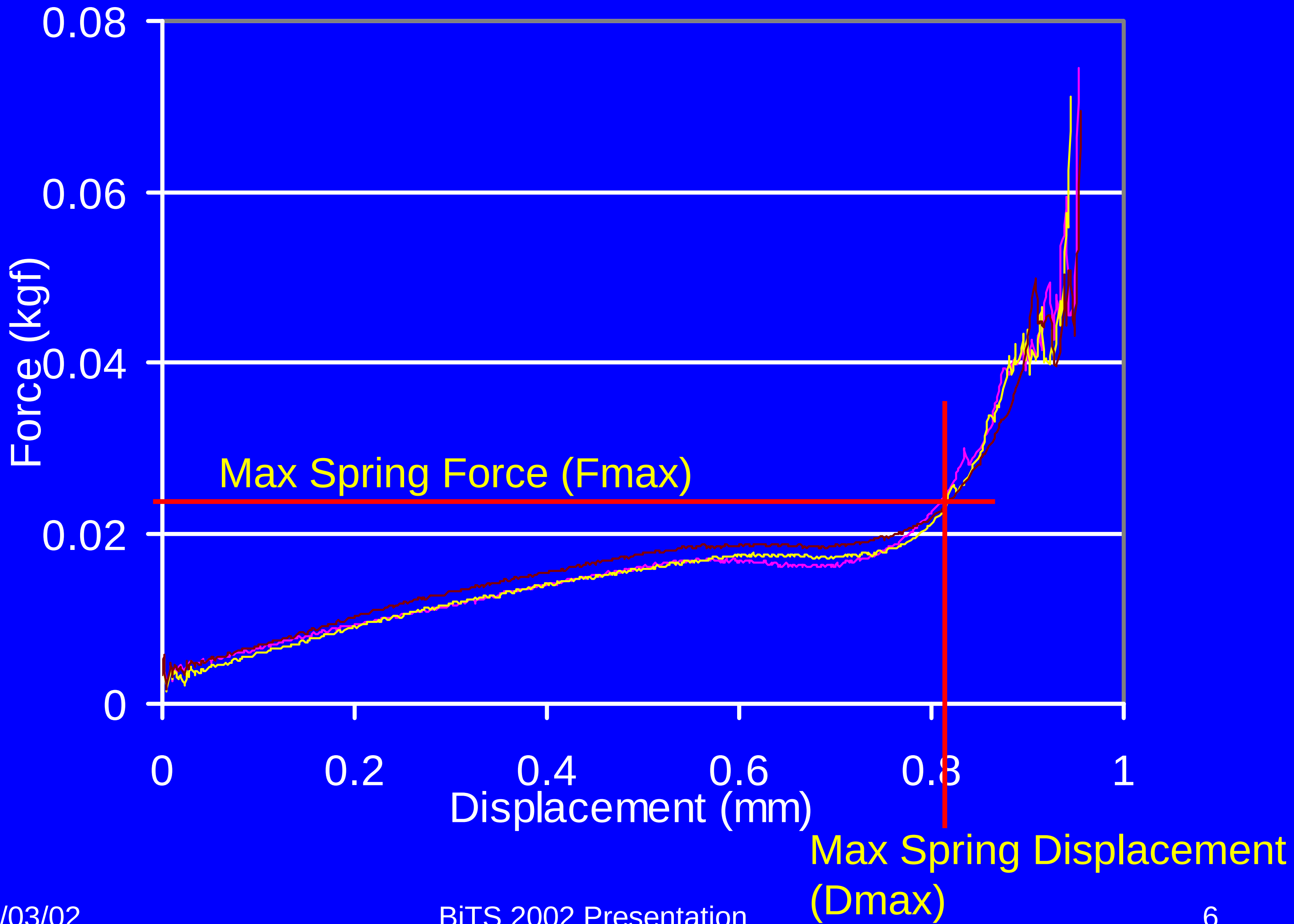
**Force-deflection measurements (at room temperature) after taking the springs out of oven.**

# Spring Sample

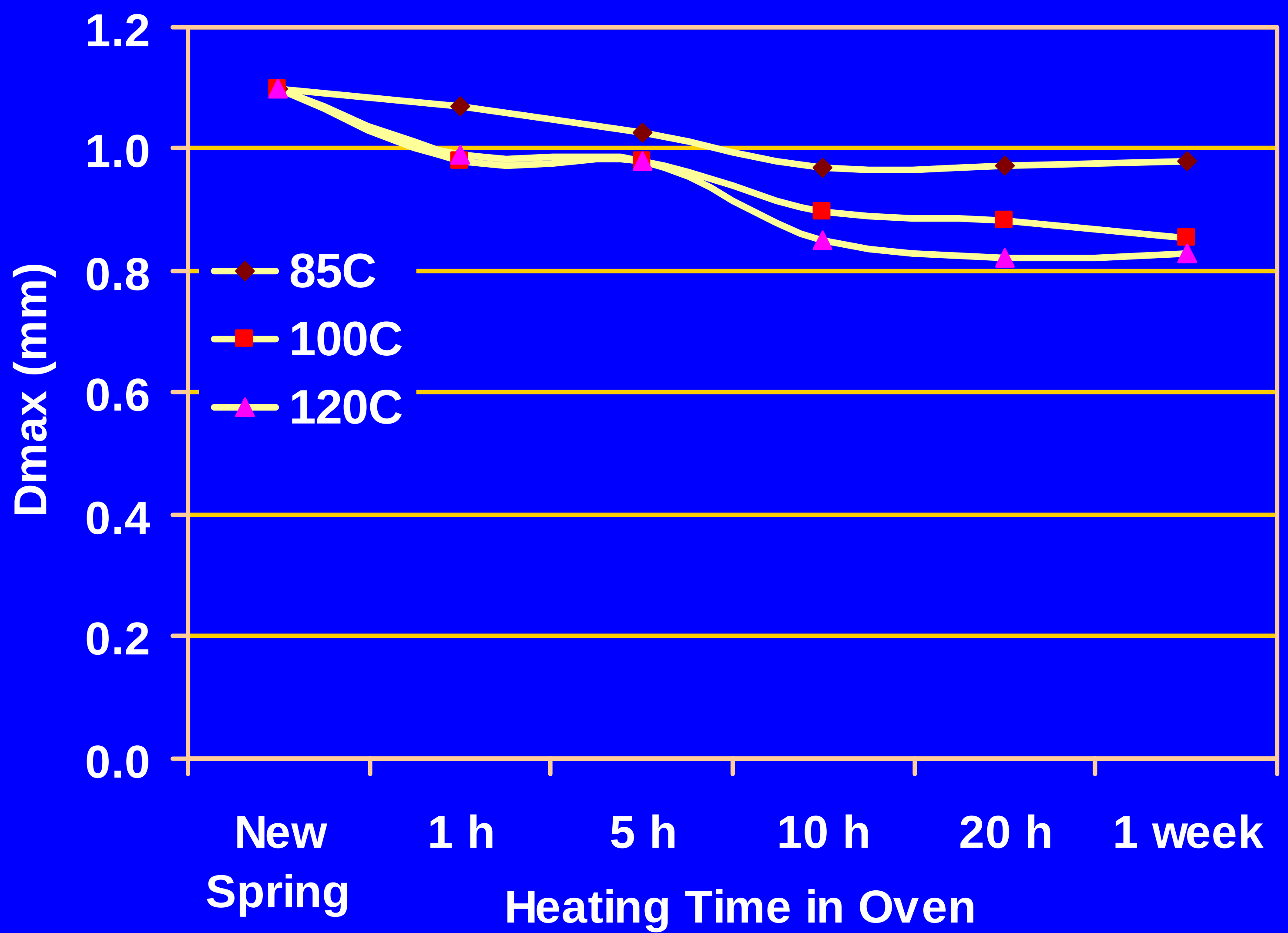
| Sample | OD (mm) | Free Length (mm) | Wire Diameter (mm) |
|---|---|---|---|
| S1 | 0.49 | 1.70 | 0.06 |
| S2 | 0.65 | 3.80 | 0.08 |
| S3 | 0.38 | 5.20 | 0.065 |

**Material: Music wire, carbon steel (~0.8% C)**

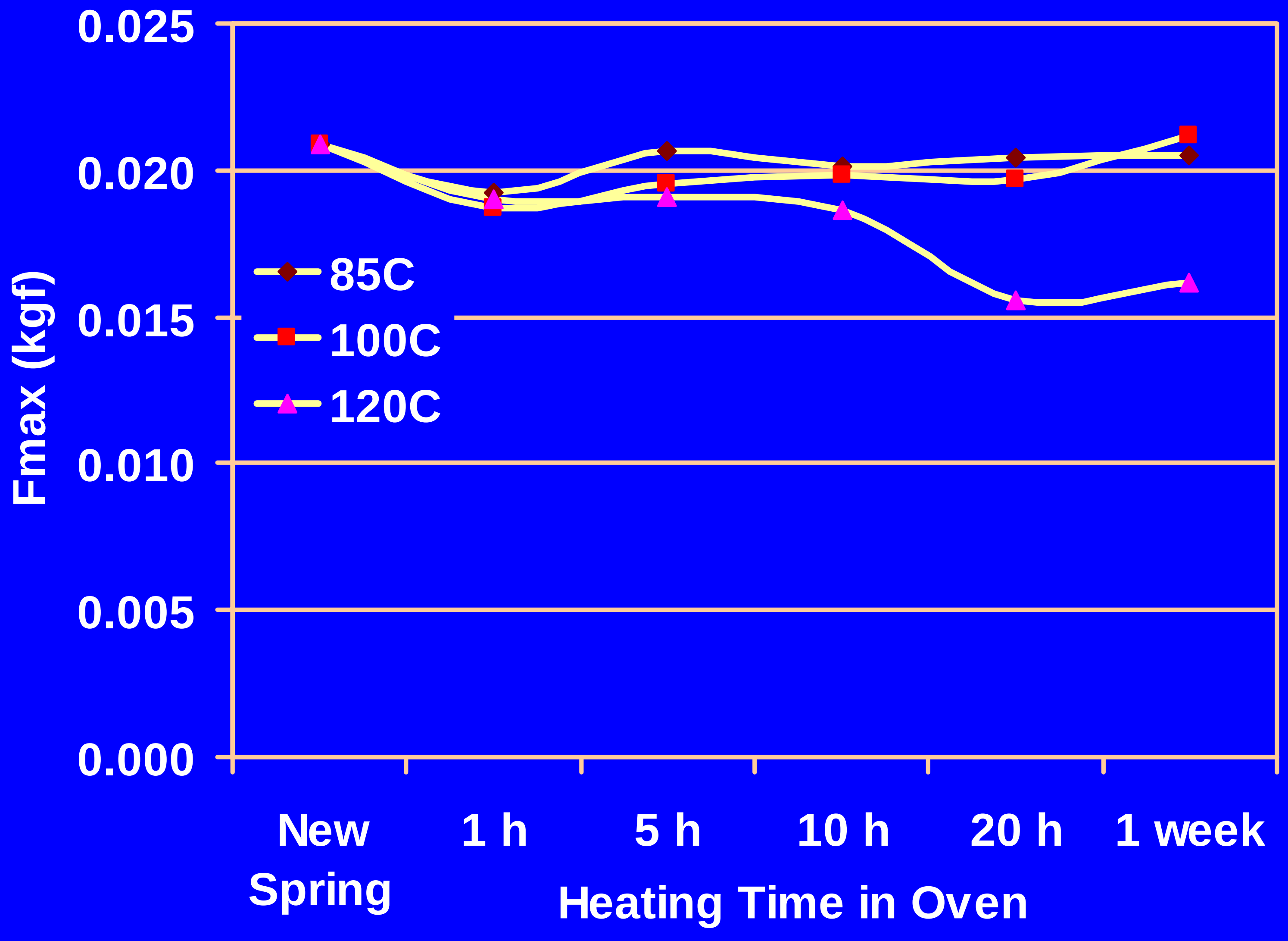
# Criteria of Performance Evaluation



# Max Displacement vs H.T. vs Temp. (S1)



# Max Force vs. H.T. vs Temp. (S1)

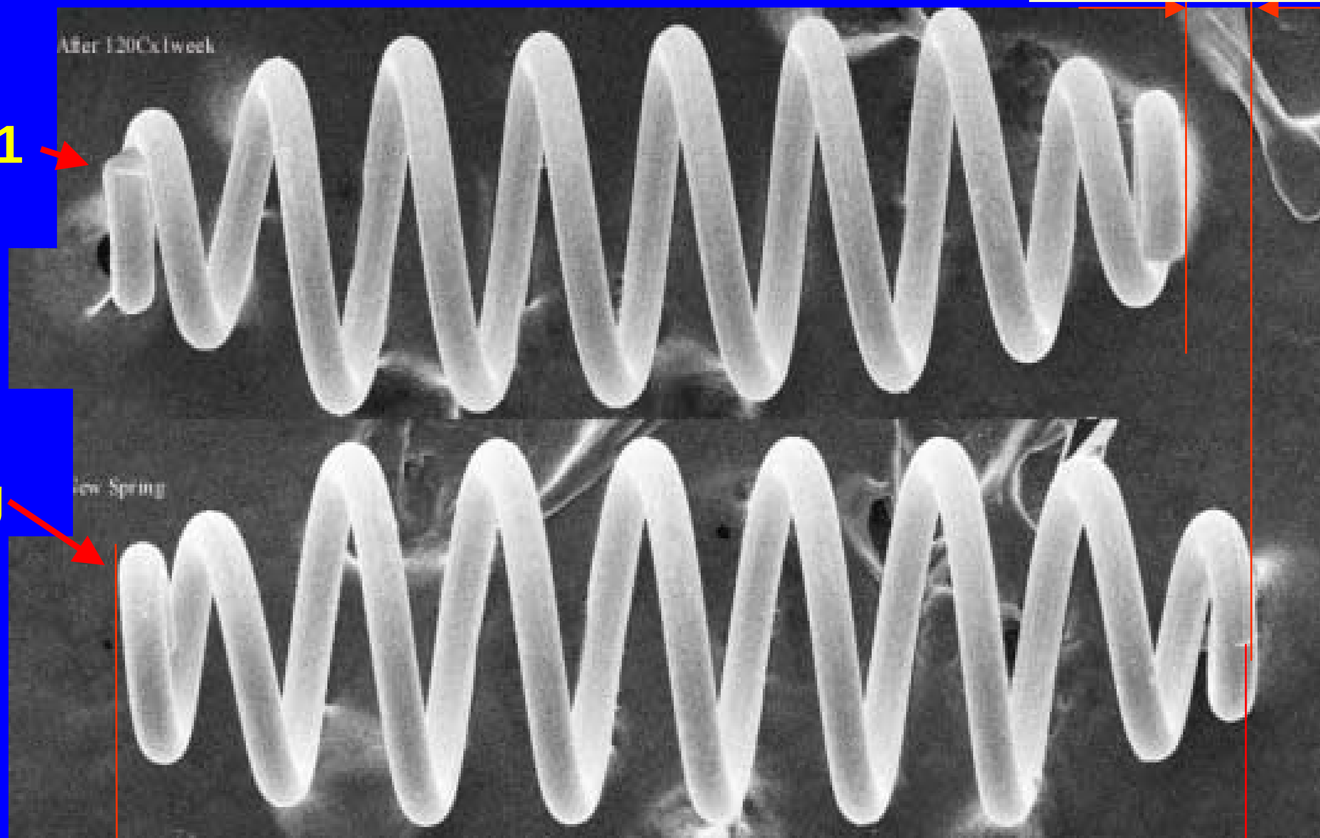


# Comparison: New Spring vs after 120°C x 1 week (S1)

0.08 mm

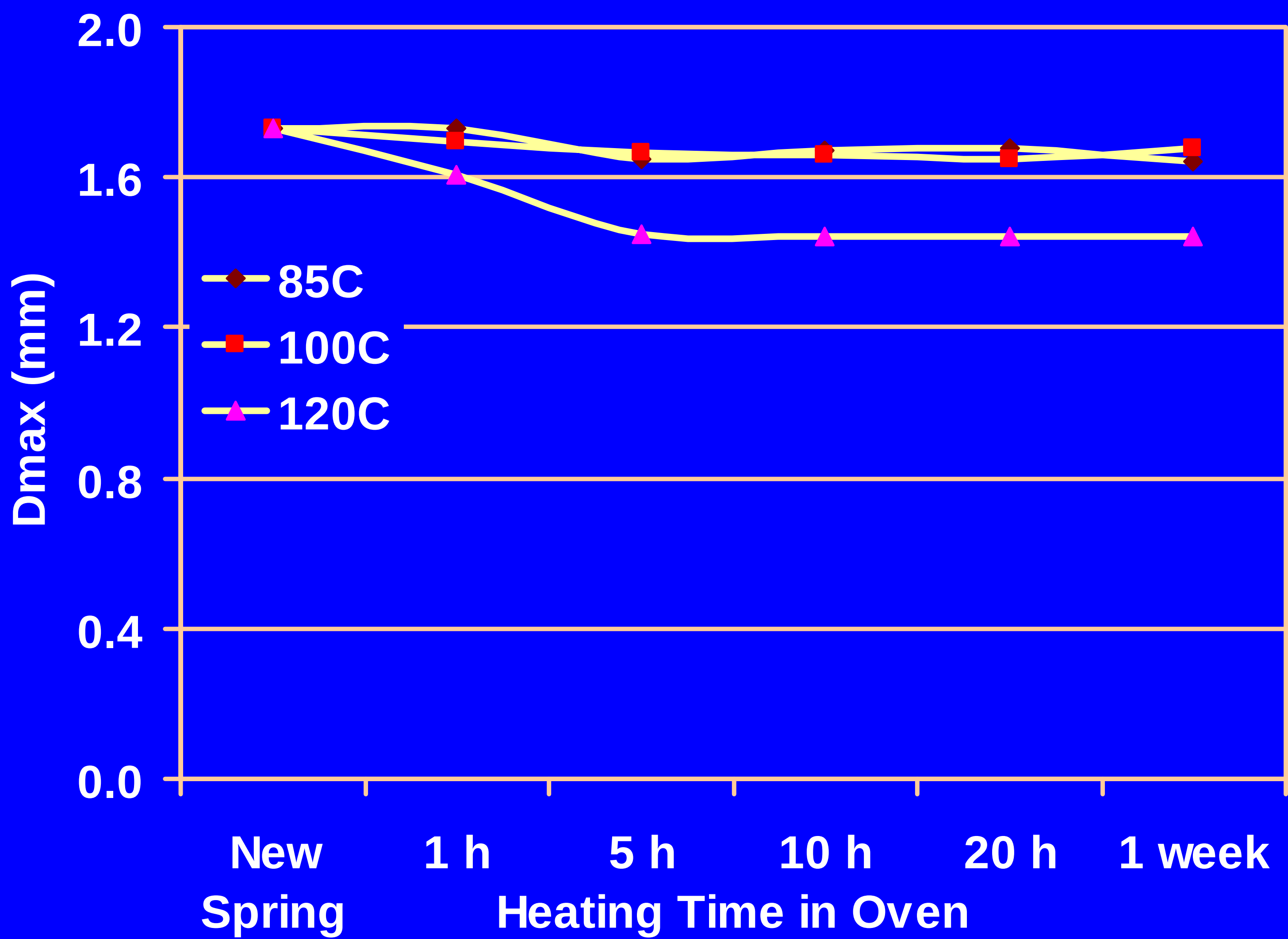
Spring after 120°C x 1 week

New Spring

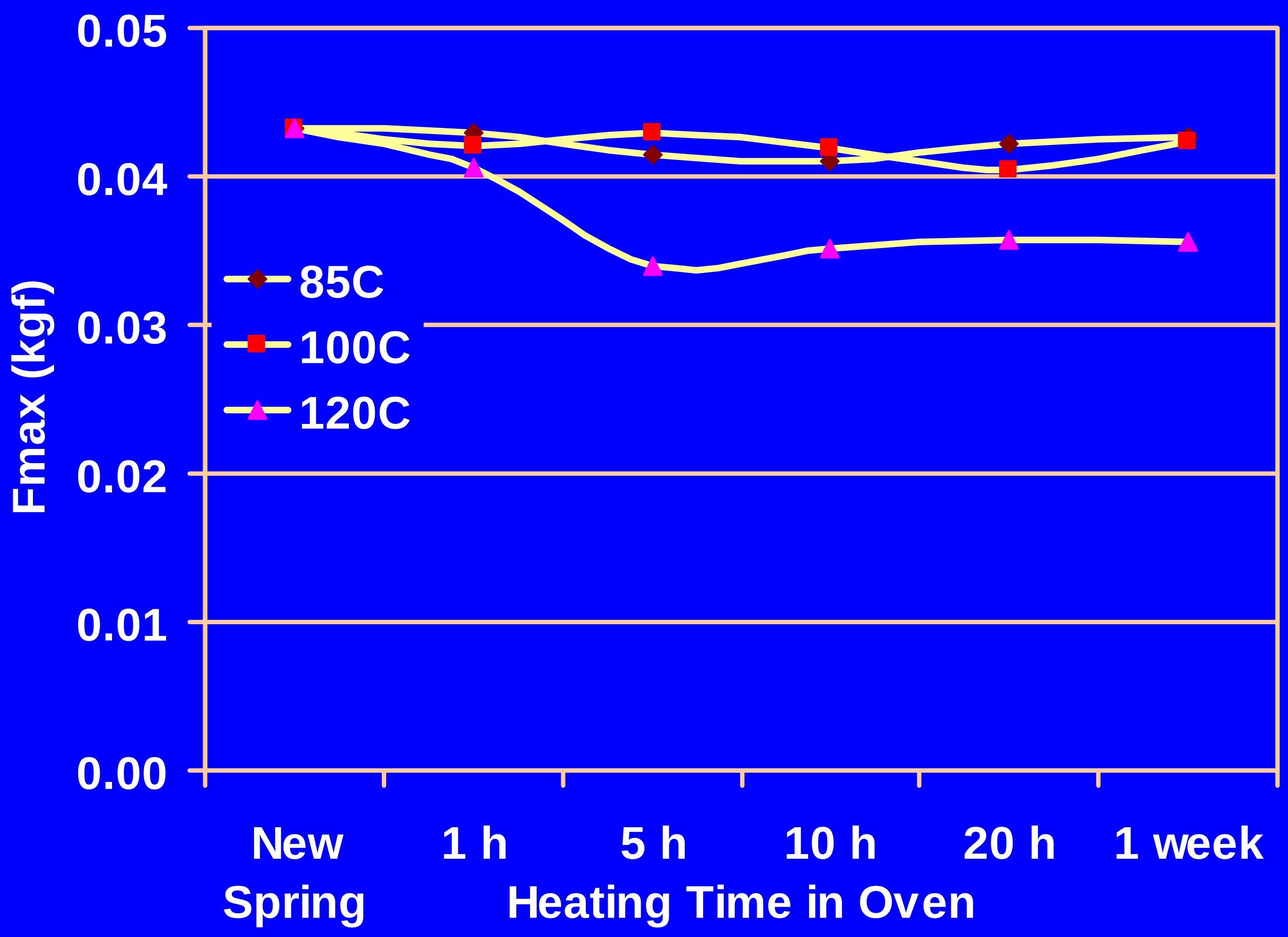



1.75 mm

# Max Displacement vs H.T. vs Temp. (S2)



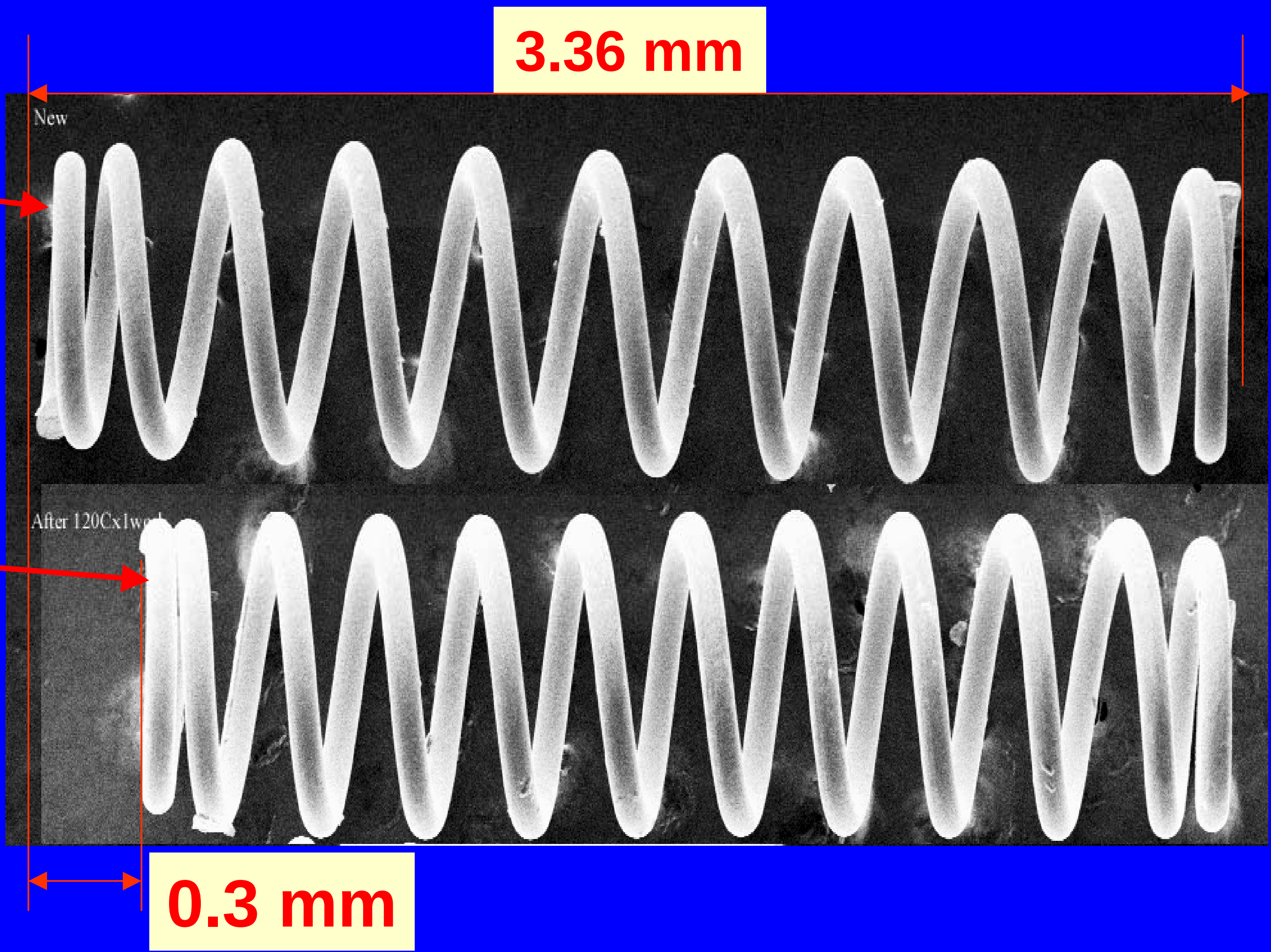
# Max Force vs. H.T. vs Temp. (S2)



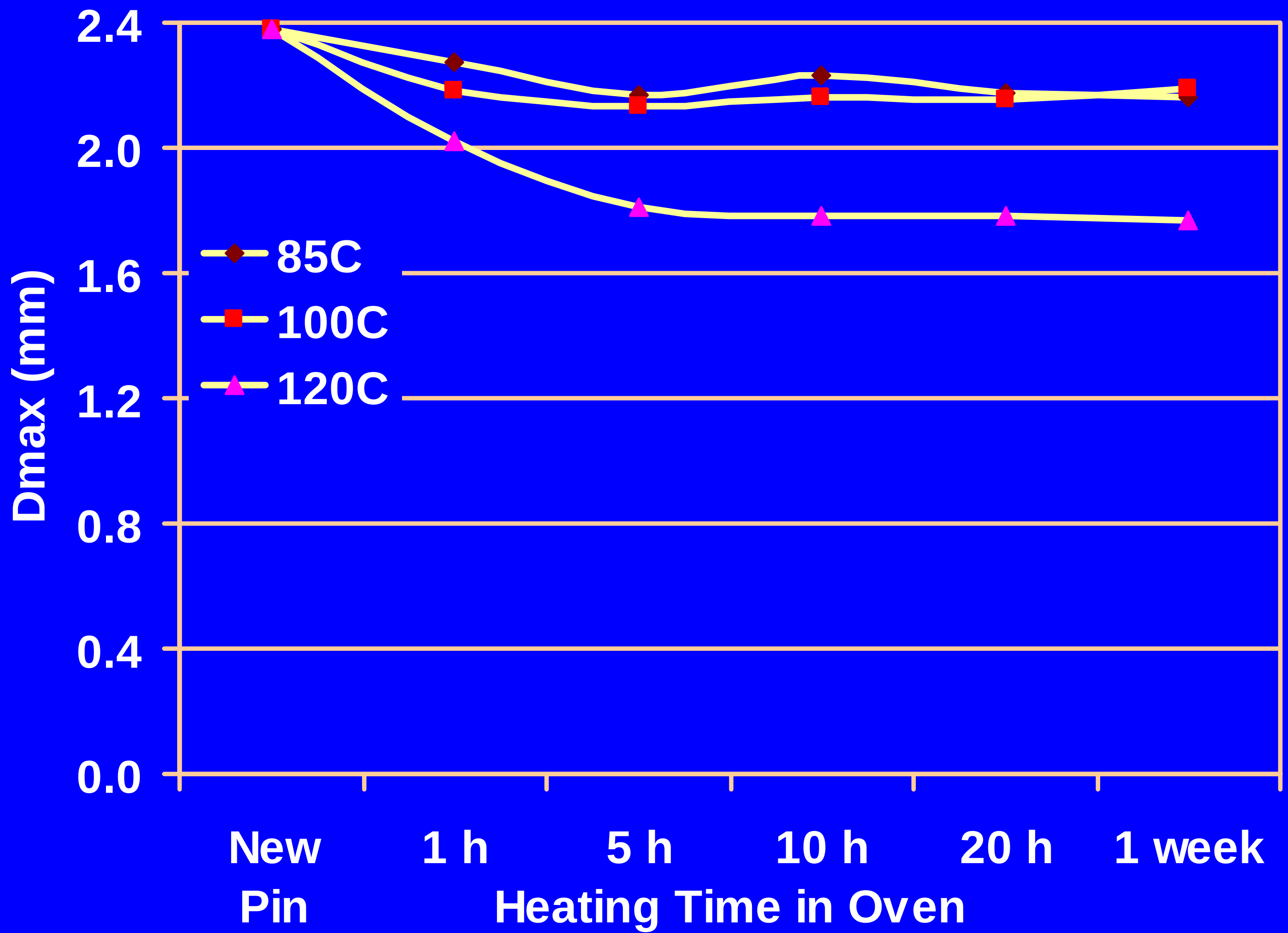
# Comparison: New Spring vs after 120°C x 1 week (S2)

New Spring

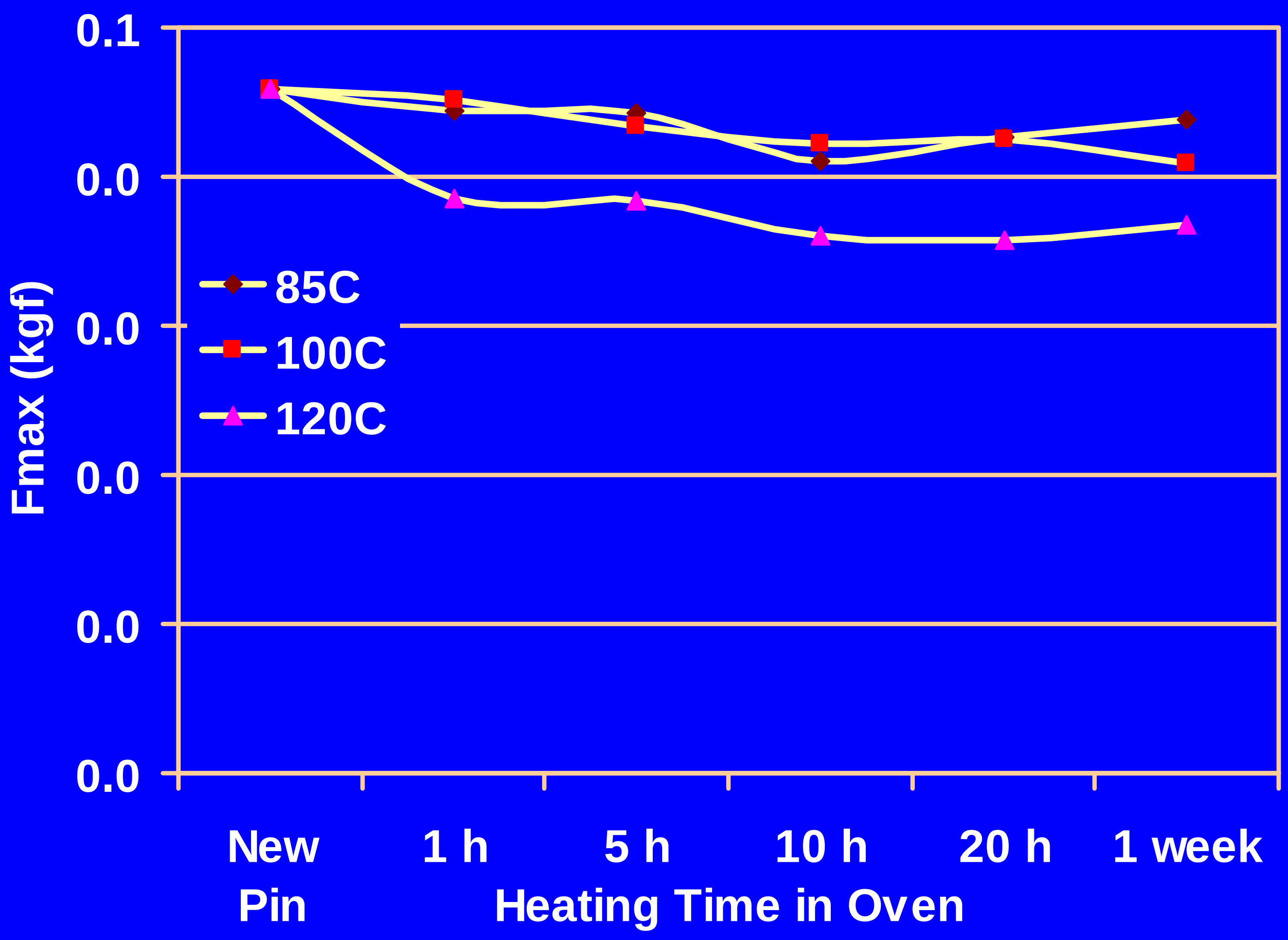
Spring after 120°C x 1 week



# Max Displacement vs H.T. vs Temp. (S3)

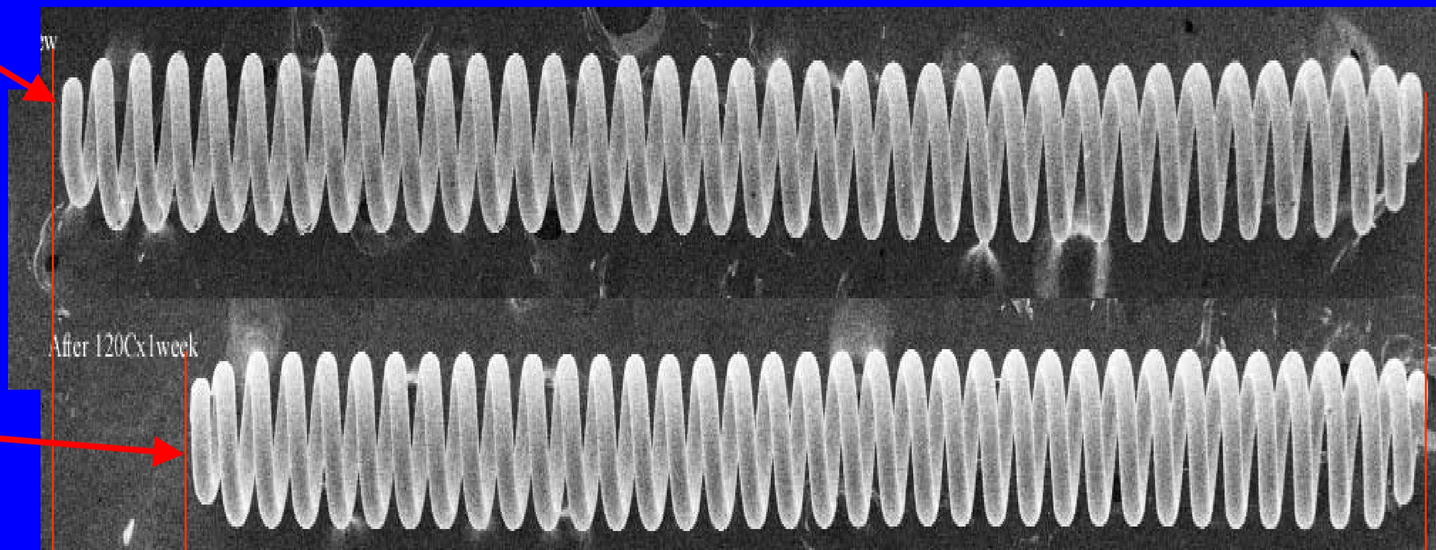


# Max Force vs. H.T. vs Temp. (S3)



# Comparison: New Spring vs after 120°C x 1 week (S3)

New Spring




Spring after 120°C x 1 week

0.47 mm

5.3 mm

# Summary - 1

<100ºC heating has little effects on small music wire spring (<0.1mm wire diameter).

>120°C heating, maximum displacement of spring decrease significantly after about 20 hours. Less than 20 hours, the spring can maintain normal performance.

# Summary – 2

Permanent deformation (length shortage) of spring during heating causes the reduction of maximum displacement of spring.

The length shortage due to heating at 120°C for one week ranges 5~10% for music wire spring. But spring keeps good elasticity and displacement range with linear F-D relation even though spring is short.

# About Authors

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# Low cost Burn-in Socket Design for Area Array Package (BGA)

2002 Burn-in and Test Socket Workshop

March 3 - 6, 2002

By: Ichiro Fujishiro

# Contents

# 1. Market Trend

Source : Semiconductor Assembly Council

## Worldwide IC Shipments by Package Family

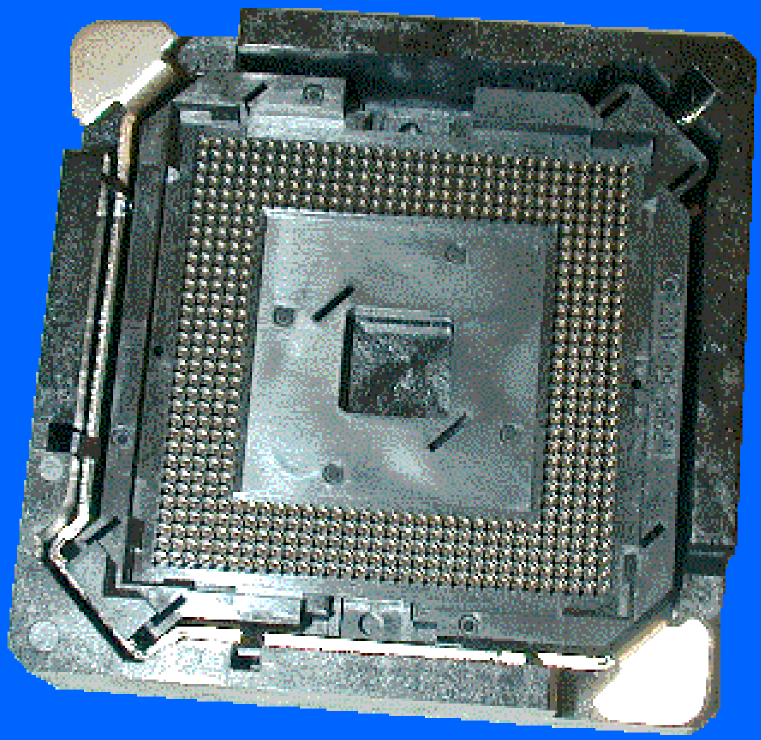
| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | CAGR (%) |
|---|---|---|---|---|---|---|---|
| | | | Package Units (M) | | | | |
| DIP | 10,098 | 7,492 | 7,426 | 7,192 | 7,286 | 7,459 | –5.9 |
| SO | 53,090 | 49,010 | 55,428 | 60,139 | 67,549 | 76,911 | 7.7 |
| CC | 2,422 | 2,150 | 2,188 | 2,215 | 2,331 | 2,477 | 0.4 |
| QFP | 9,078 | 8,355 | 9,399 | 9,848 | 11,141 | 12,828 | 7.2 |
| PGA | 286 | 261 | 307 | 351 | 383 | 441 | 9.1 |
| BGA | 2,418 | 2,660 | 3,456 | 4,029 | 4,871 | 5,748 | 18.9 |
| CSP | 2,366 | 3,417 | 5,295 | 7,324 | 9,891 | 12,168 | 38.8 |
| DCA | 6,755 | 6,378 | 7,483 | 8,154 | 9,354 | 10,757 | 9.8 |
| Total | 86,513 | 79,725 | 90,983 | 99,253 | 112,806 | 128,789 | 8.3% |

# 2. Considerations in the Development of Low Cost Burn-In Socket for BGA

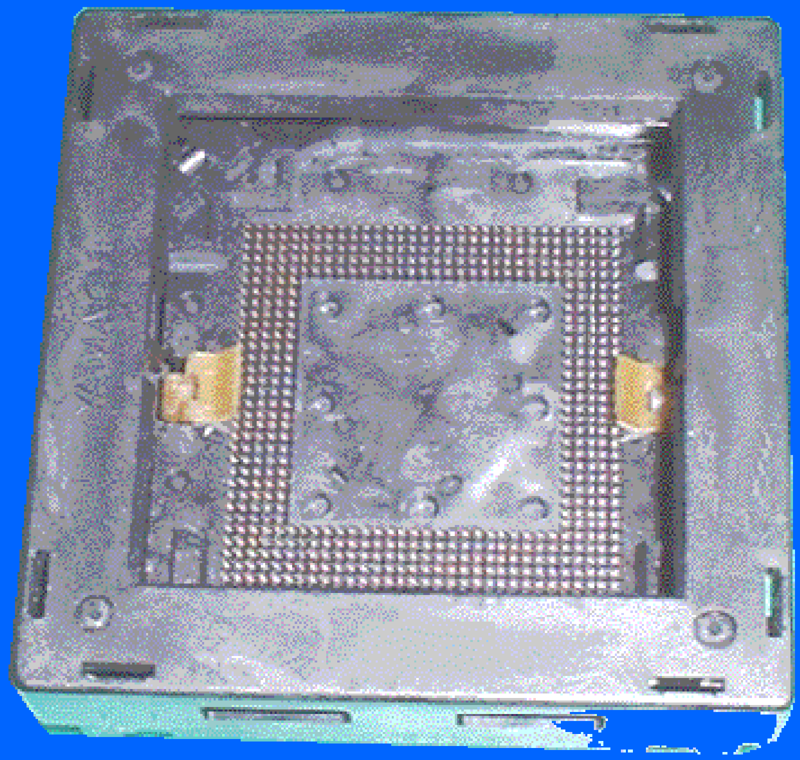
- Lower Cost with Reduced Component Count.
- Keep High Reliability with Existing Tweezers Type Contact.
- Smaller Size for High Density Assembly.
- Lower Height for Better Wind Flow.
- Easy Matching with Existing Loader/Un-loader.

# 3. Appearance of Low Cost Burn-In Socket for BGA

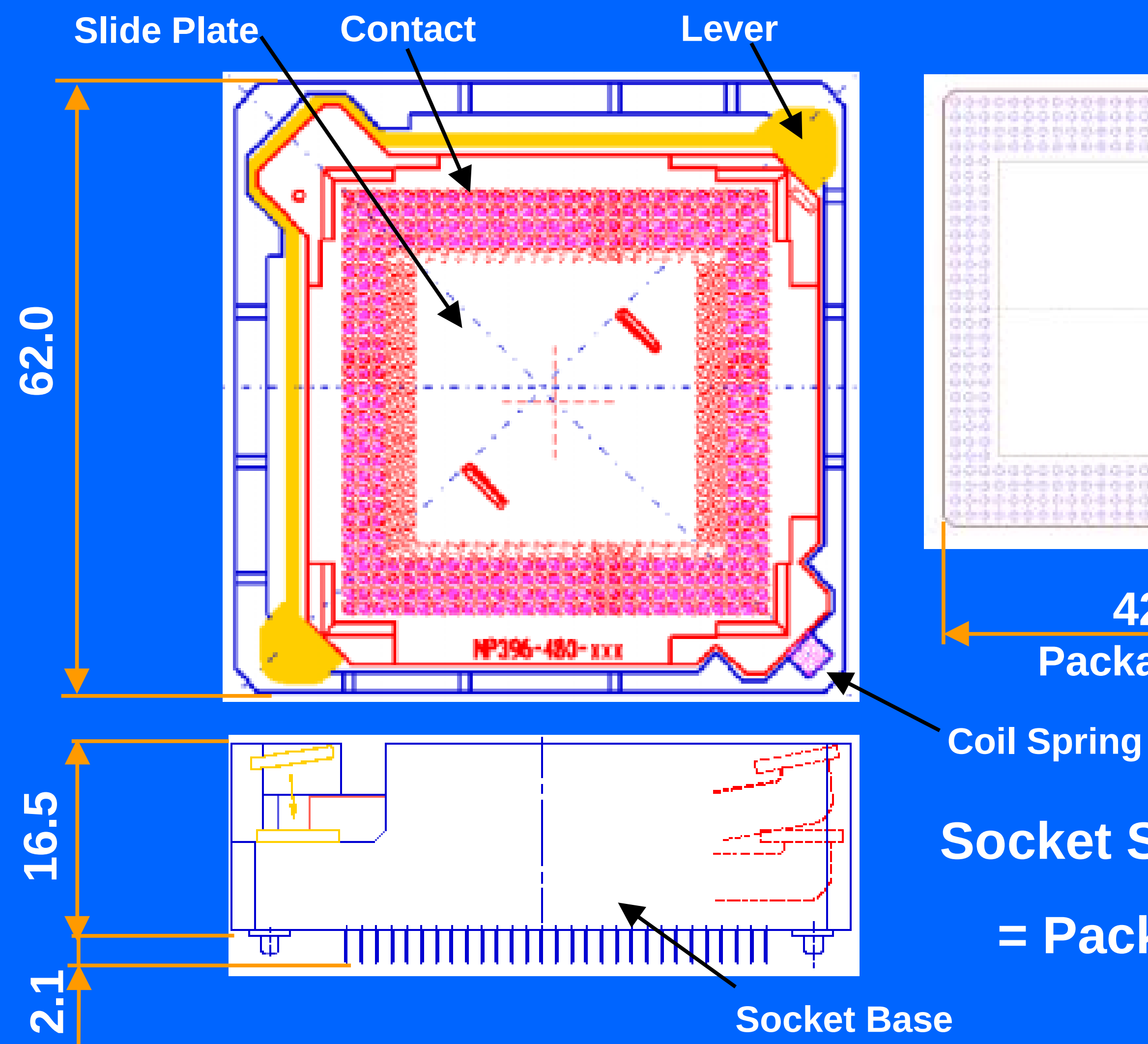
Low Cost Socket

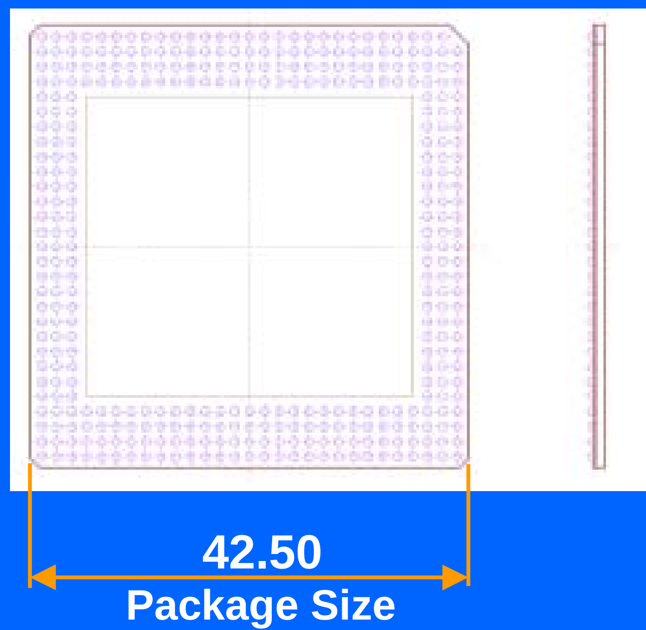


Existing Socket



# 3. Appearance of Low Cost Burn-In Socket for BGA



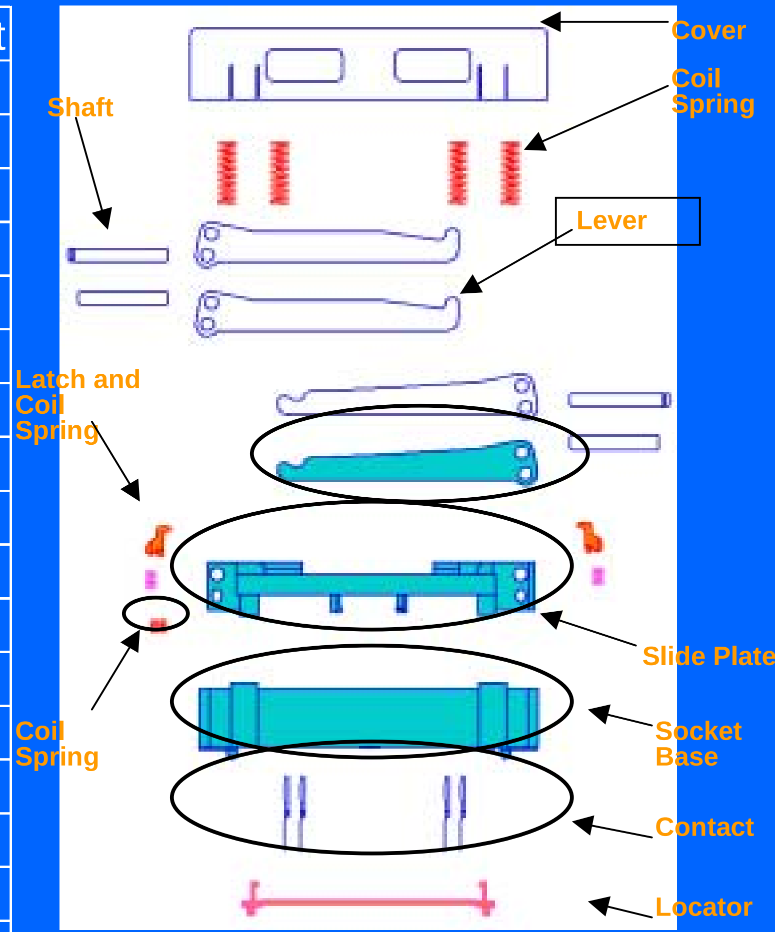




**Socket Size**

**= Package Size + 19.5mm**

# 4. Socket Components Comparison

| | | New Socket | Existing Socket |
|---|---|---|---|
| 1 | Socket Base | 1 | 1 |
| 2 | Slide Plate | 1 | 1 |
| 3 | Contact | 500 | 500 |
| 4 | Lever A | 1 | 1 |
| 5 | Coil Spring A | 1 | 1 |
| 6 | Locator | none | 1 |
| 7 | Latch | none | 2 |
| 8 | Coil Spring B | none | 2 |
| 9 | Cover | none | 1 |
| 10 | Lever B | none | 1 |
| 11 | Lever C | none | 1 |
| 12 | Lever D | none | 1 |
| 13 | Coil Spring C | none | 4 |
| 14 | Shaft A | none | 2 |
| 15 | Shaft B | none | 2 |
| 16 | Retaining Ring | none | 2 |
| | **Total** | **504** | **523** |
| | **Total (w/o Contact)** | **4** | **23** |




**Parts of Existing Socket**

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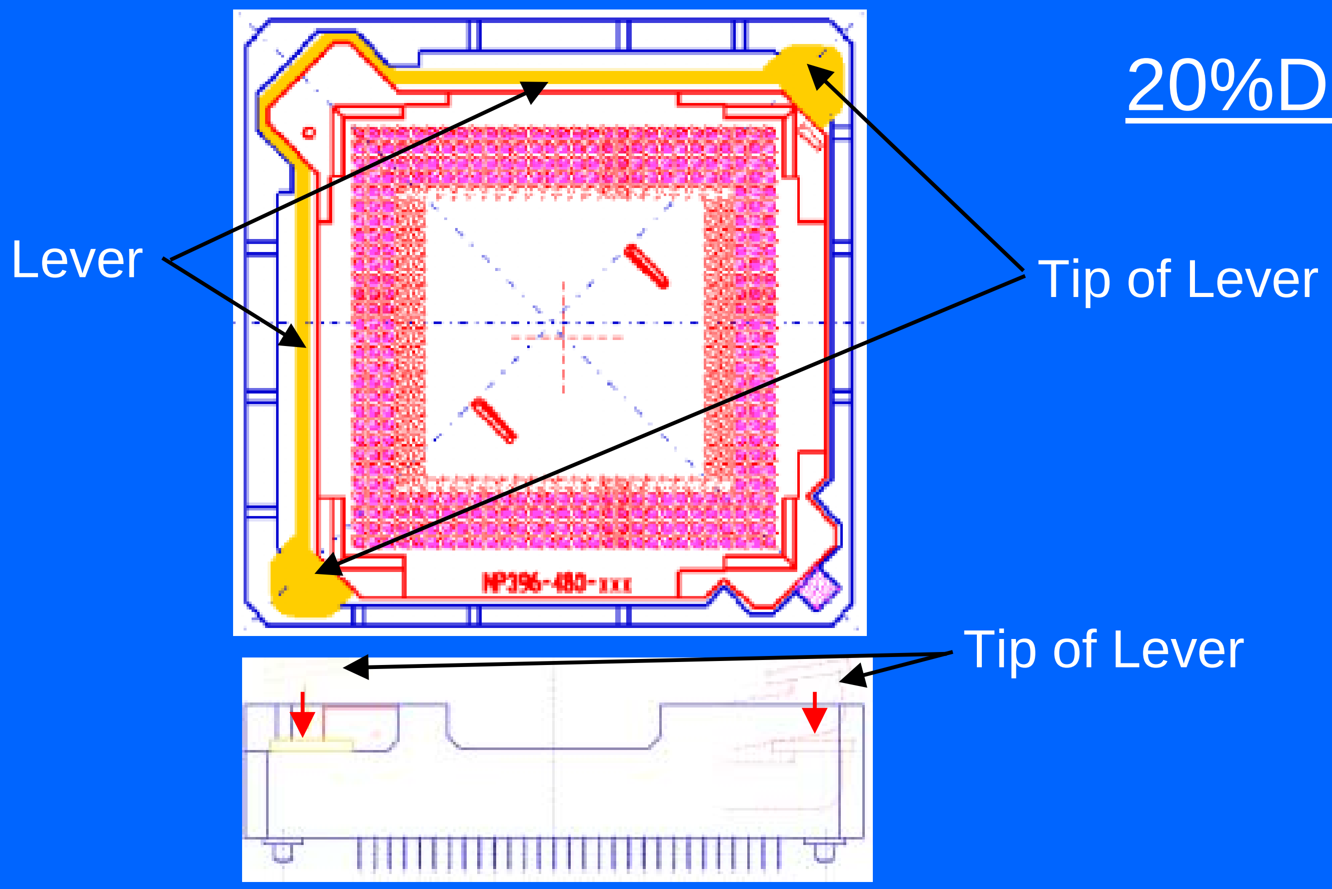
# 5. Operation of Low Cost BGA Socket

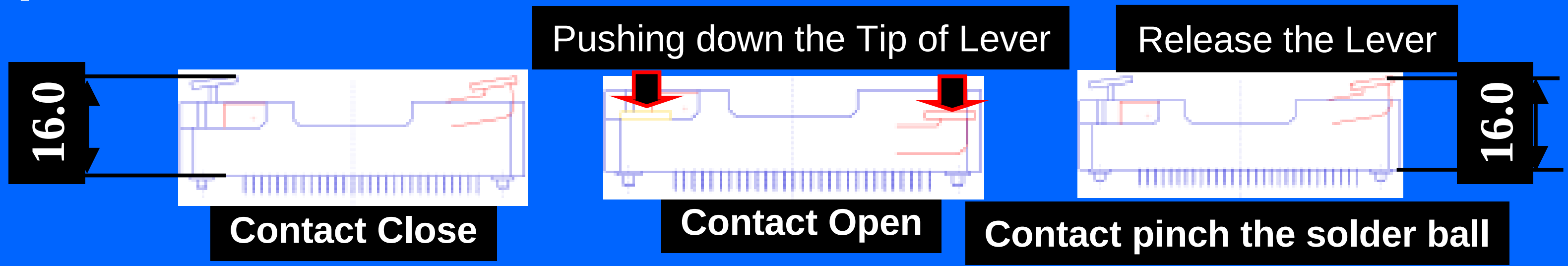
## Lower Operation Force

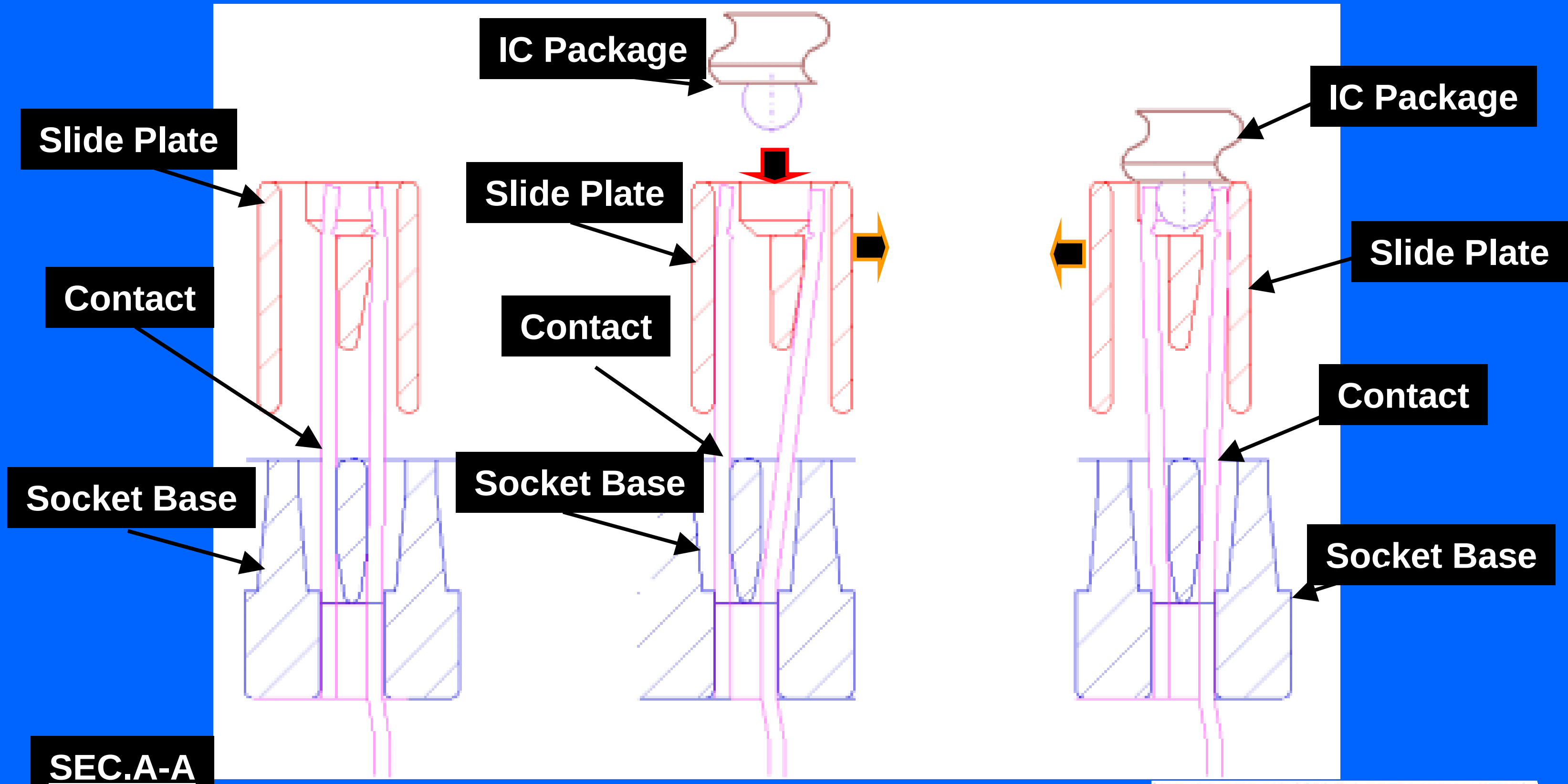
(Existing Socket = 4.0Kg)

<u>20%Decreased</u>



# 5. Operation of Low Cost BGA Socket




SEC.A-A

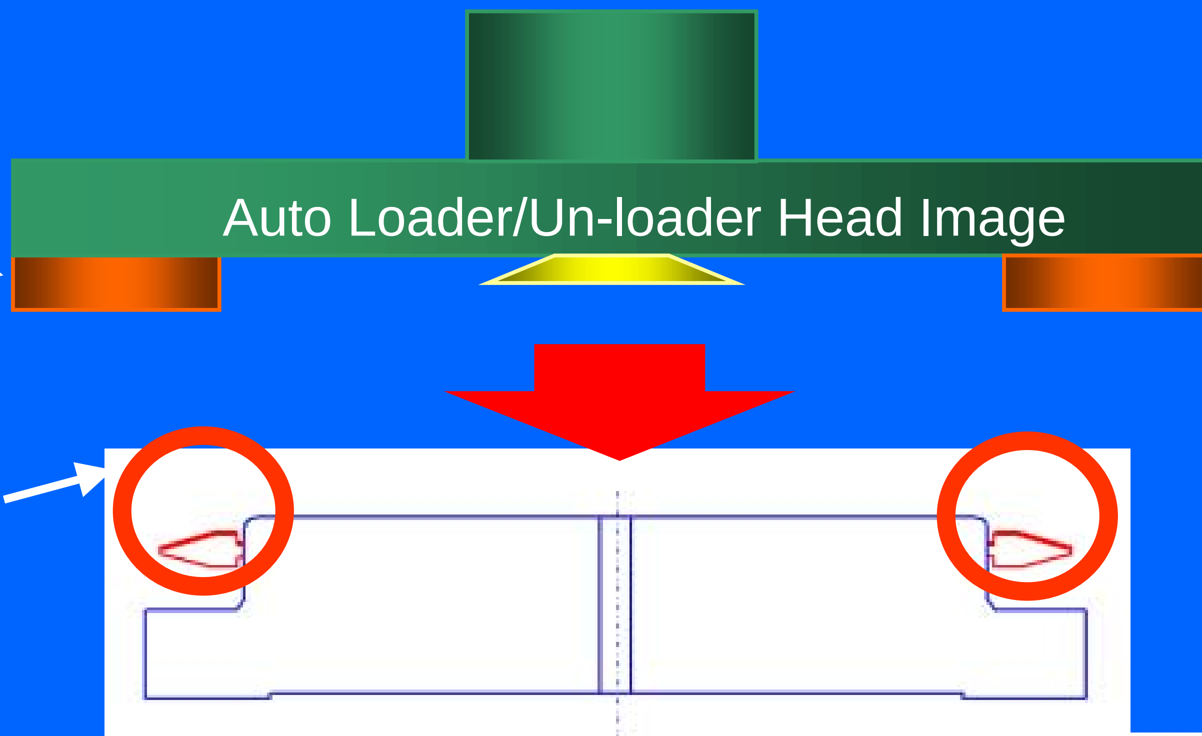
# 5. Operation of Low Cost BGA Socket

## Simplified Actuation Mechanism

Low cost socket requires a minor change of auto loader/un-loader head

Minor Change

Tip of Lever

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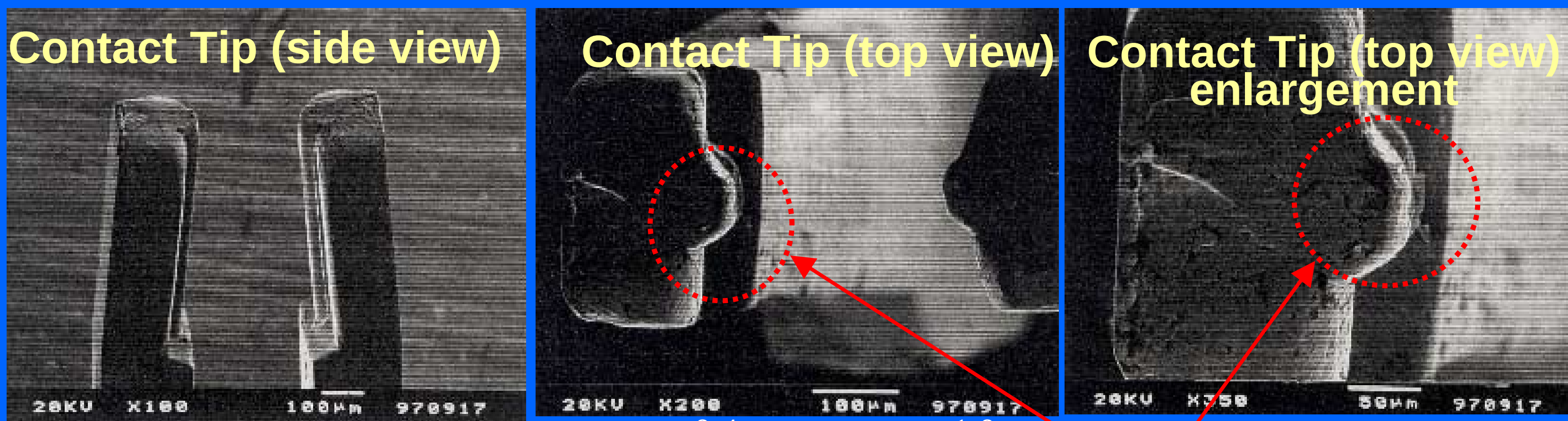
# 6. Features of Low Cost BGA Socket

## High Reliability

Utilize previous high reliable contact

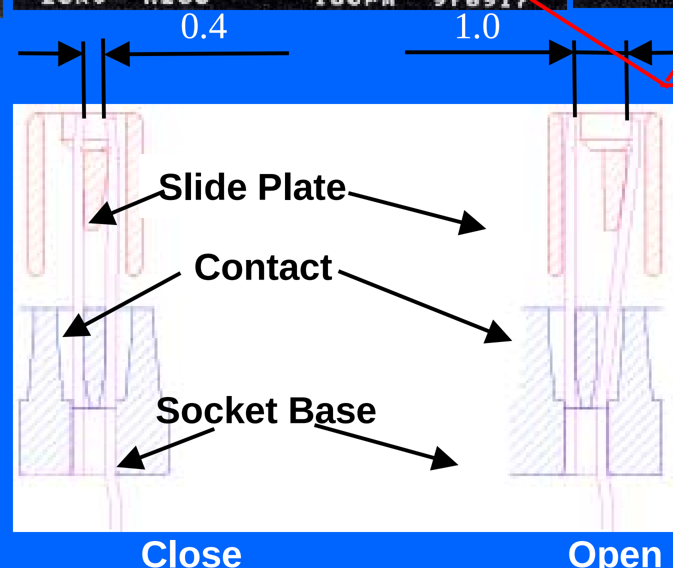



**Each Contacts are divided by socket base and slide plate.**

**No short circuit**

**Precision contact position**

**No damage to contact**



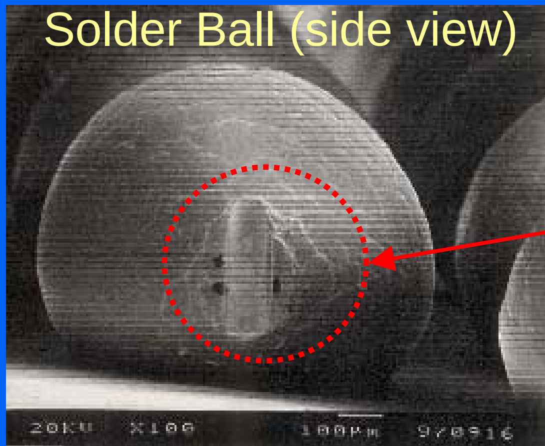

**Contact Point**

**Applicable Solder ball diameter**

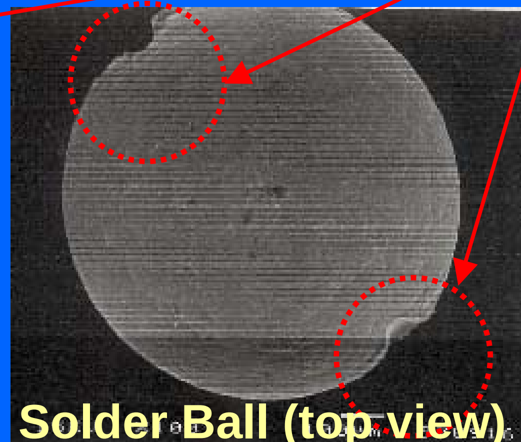
**=0.75mm**

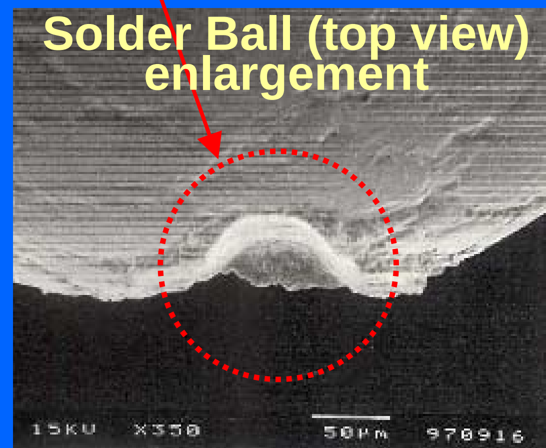
# 6. Features of Low Cost BGA Socket

## High Reliability




Contact Mark




Small contact mark

No contact mark at the top of solder ball

No sticking problem

# 6. Features of Low Cost BGA Socket

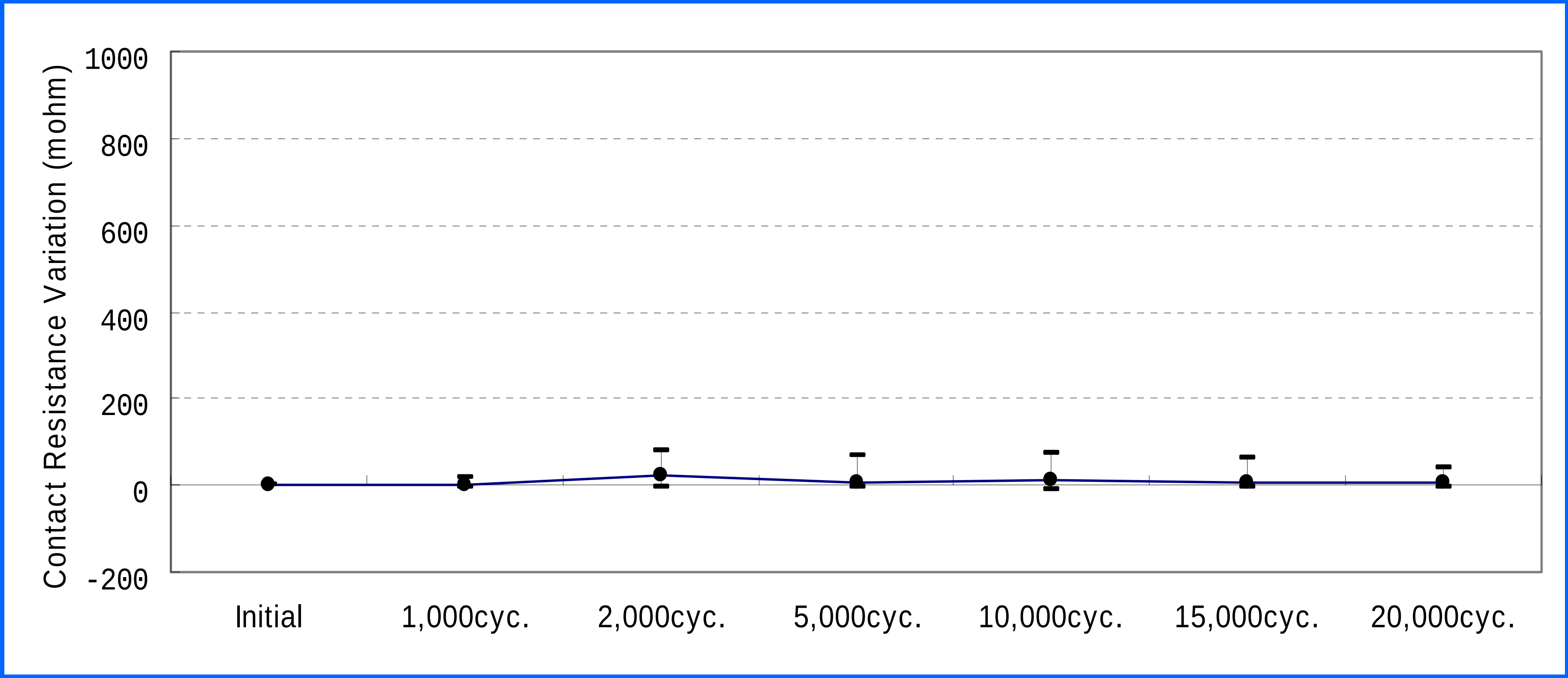
## High Reliability

Cycle test (room temperature)

Contact resistance variation

N=2 sockets, 160points  (80points/socket)

Data is for loop resistance




**Initial = 24.0mohm**

# 6. Features of Low Cost BGA Socket

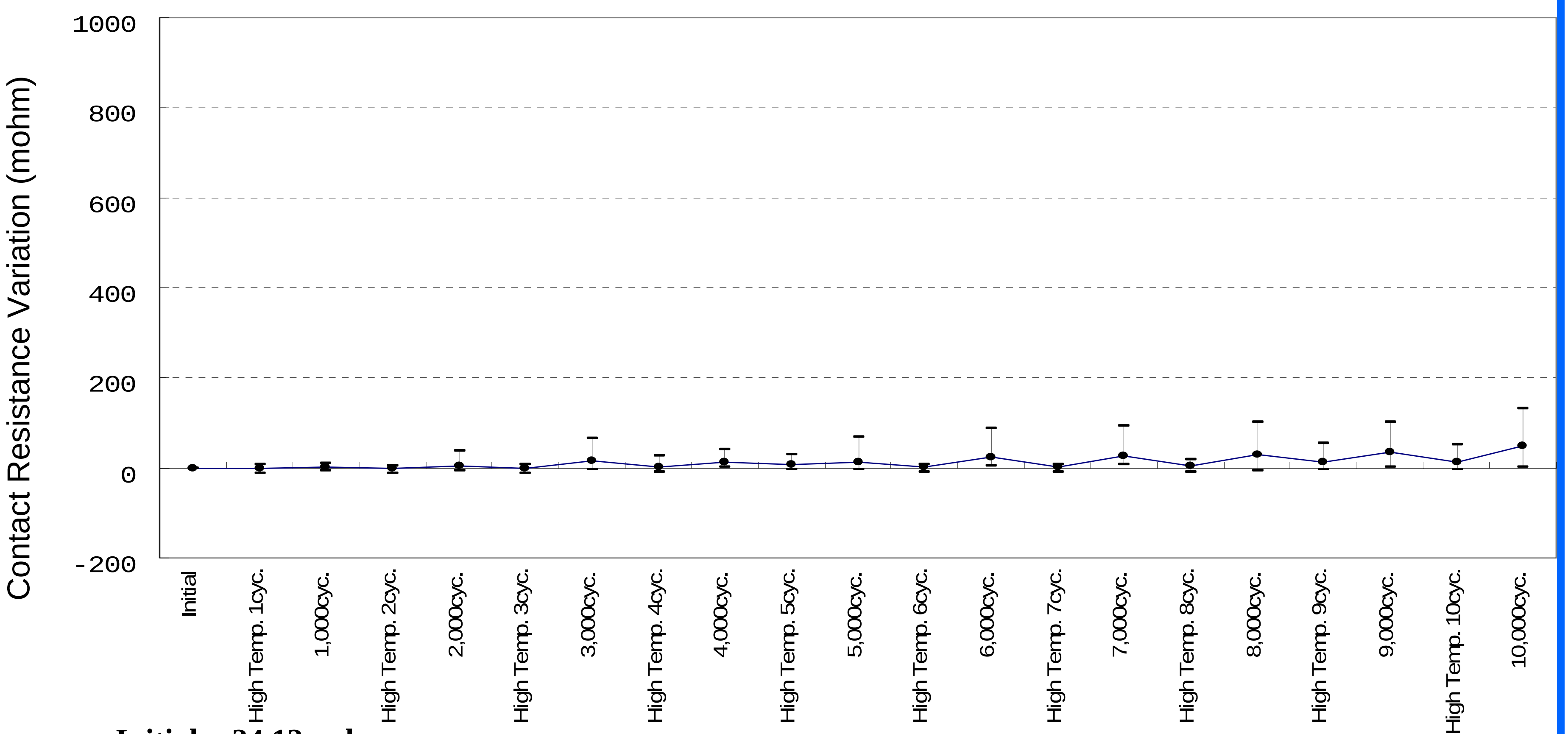
## High Reliability

Cycle test (high temperature, 125 degree C / 48h)

Contact resistance variation

N=2 sockets, 160points (80points/socket)

Data is for loop resistance




**Initial = 24.12mohm**

# 6. Features of Low Cost BGA Socket

## High Density

Reduced Socket Body Size

Low Cost : 62mm sq.

Existing: 74mm sq.

-12mm

Reduced Socket Area

Low Cost : 3,844mm$^2$

Existing: 5,476mm$^2$

-1632mm$^2$

30%DOWN

Reduced Socket Weight

Low Cost : 46g

Existing: 75g

-29g

Easy handling with light weight

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# 6. Features of Low Cost BGA Socket

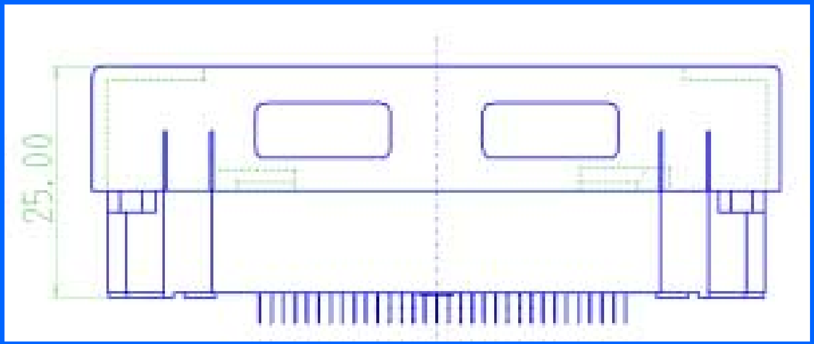
## Better Air Flow

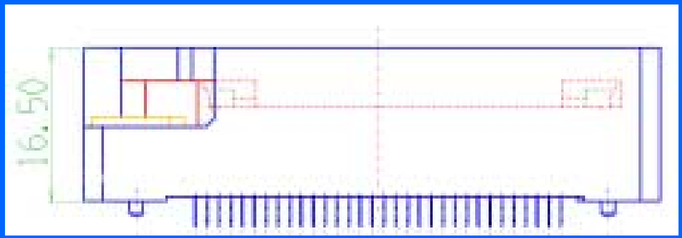
Reduced Socket Height

Low Cost : 16.5mm

Existing: 25mm

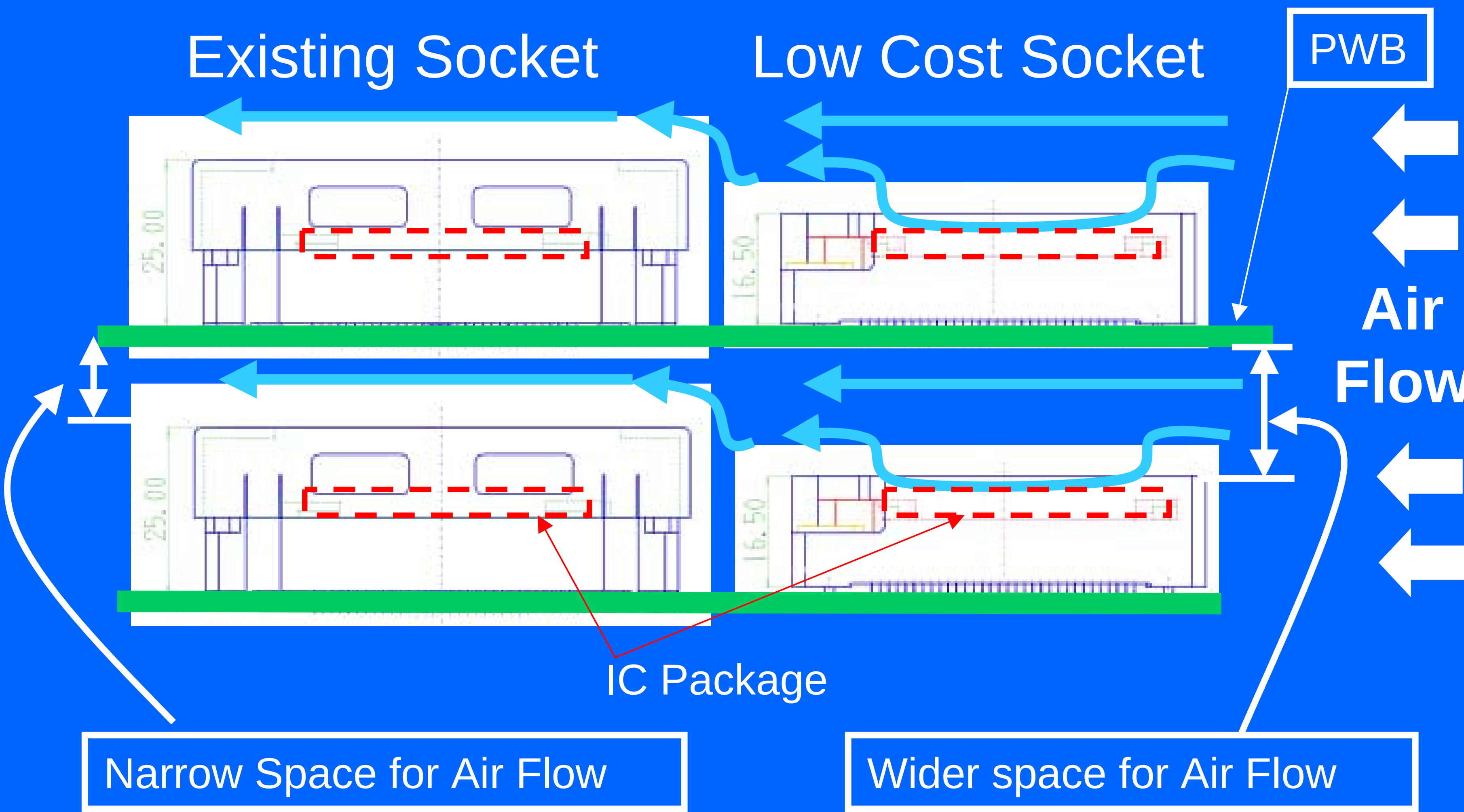
8.5mm



# 6. Features of Low Cost BGA Socket

## Better Air Flow



# 7. Conclusion

Development of low cost BGA socket
- Reduced Component Count
- Cover-less
- Shaft-less

High reliability
- Utilize previous high reliable contact

High Density and light weight - Smaller size

Better Air Flow - Lower height

| | Existing Socket | New Socket | Difference |
|---|---|---|---|
| Socket Size | 74.0mm | 62.0mm | 12.0mm 16“ off |
| Socket Height | 25.0mm | 16.5mm | 8.5mm 34“ off |
| Socket Area | 5,476$mm^2$ | 3,844$mm^2$ | 1,632$mm^2$ 30“ off |
| Socket Weight | 75g | 46g | 29g 38% off |
| Component Count (W/O Contact) | 23 parts | 4 parts | 19 parts 82% off |
| Operation Force | 4.0Kg | 3.2Kg | 0.8Kg 20% off |
| Loader/Un-Loader Interface | on Cover | on Lever | Coverless |

# *Force and Resistance Probing Automation for Contactors*

**Jason Mroczkowski, Valts Treibergs**
**Everett Charles Technologies**
**March, 2002**

EVERETT CHARLES TECHNOLOGIES
Testing the Limits

BiTS BURN-IN & TEST SOCKET WORKSHOP

# *Presentation Topics*

- STG's Need
- Our Goal
- The Problem
- Our Solution
  - Hardware
  - Software
  - Probe considerations
- Some Data
  - FReD plots, etc. of various contact technologies
- The Future
- Summary and Conclusion

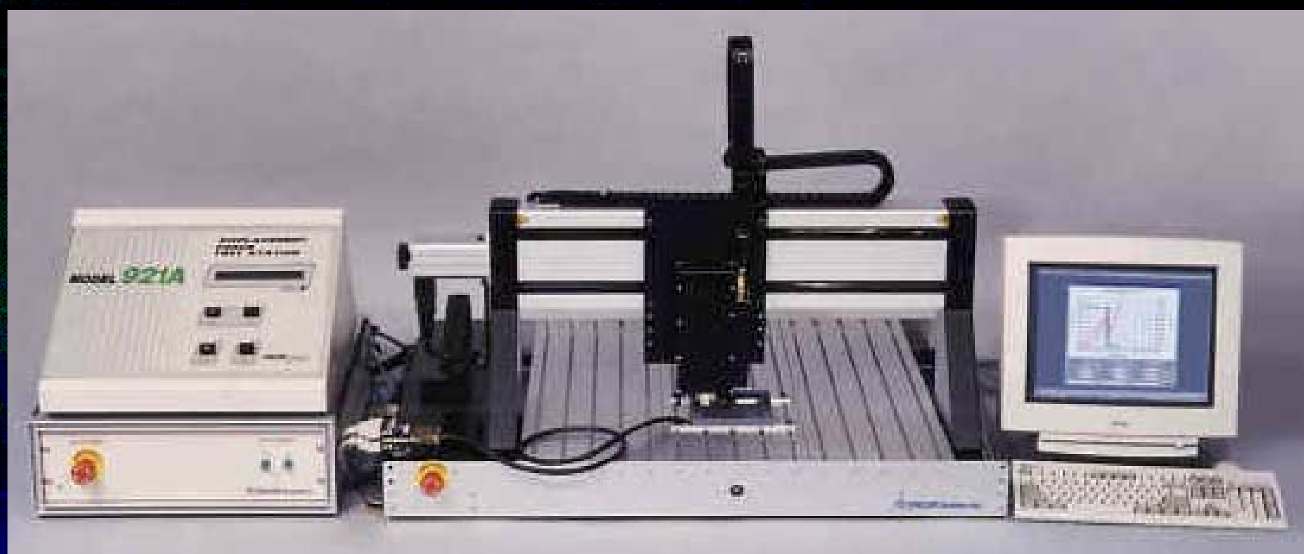
## *Our Need*

- ECT-STG needed to automate force and resistance measurements for new contactor technology qualification and production validation
  - Precise force and resistance measurements are very tedious and time consuming
  - Measurement sample sizes tend to be too small - statistically significant data sometimes was missed
  - The ‘human element’ in data taking sometimes ended in biased or unreliable results
  - Manual testing was not practical for production inspection or for rapid field failure analysis

# *Our Goal*

- A programmable X-Y robot with m$\Omega$ resistance and gram force sensors with full data acquisition capability
- A unit 'off the shelf' was found - Tricor Systems 921 X-Y DFR system

***NO PROBLEM!!!***



## *The Problem*

- **921 DFR** X-Y robot DFR system cost: $49,775.00
- Our allocated budget:

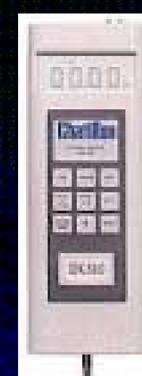
# ZERO

## *The Solution*

- Build it yourself!!!
- Hmmmm - where to start…
- SCROUNGE, SCROUNGE, SCROUNGE

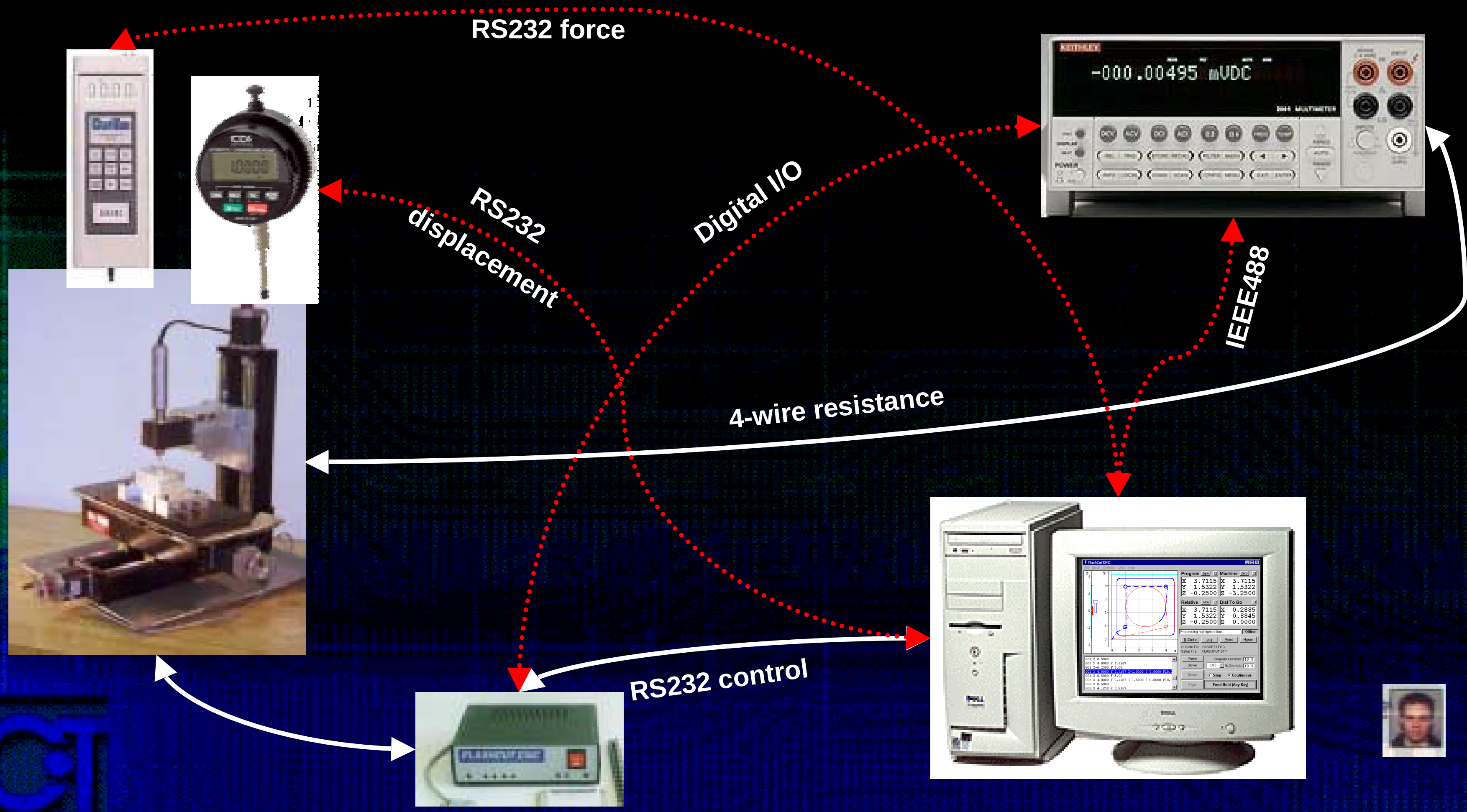
Existing equipment:





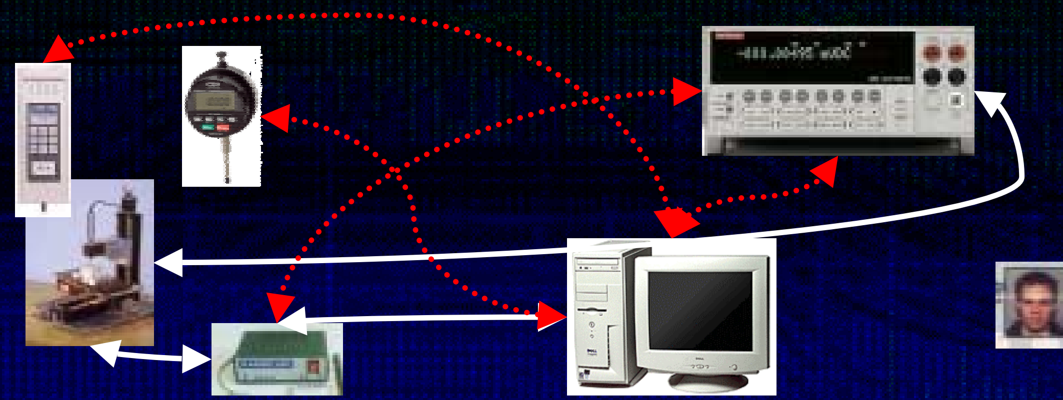
# *The Solution (Hardware)*

- The **F**orce **R**esistance and **D**isplacement System
  ( FReD - for short )



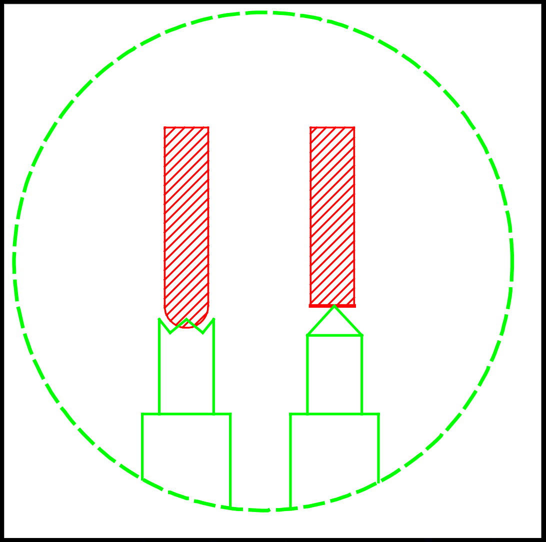
# *The Solution (Hardware)*

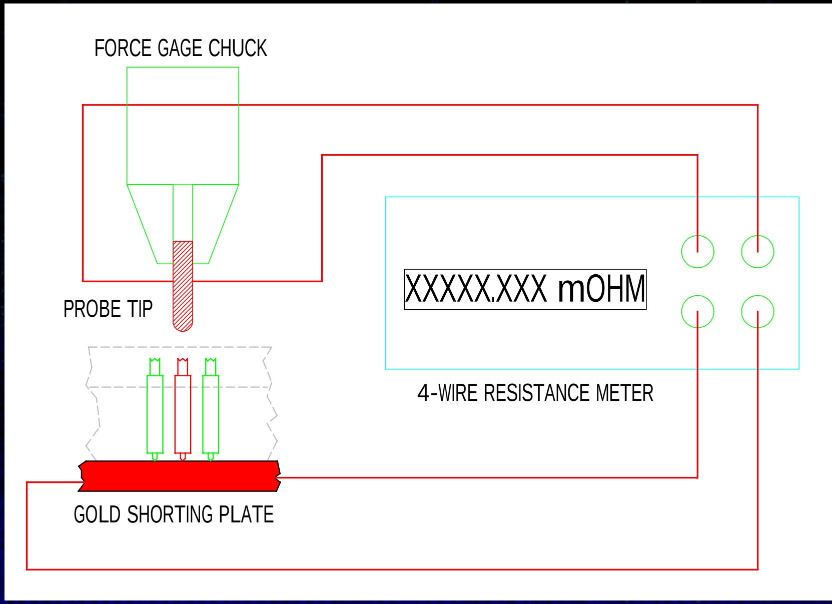
- FReD's missing *BiTS:*
  - Indicator serial cable: new $72
  - Force gage serial cable: new connector $3, stolen mouse cable $0
  - Additional serial port card on PC: $26
  - Digital I/O wiring: another stolen mouse $0
  - Roll of duct tape:  $2.59
  - IEEE 488 adapter board: $12
  - IEEE 488 cable: $26
- Bolt it all together…



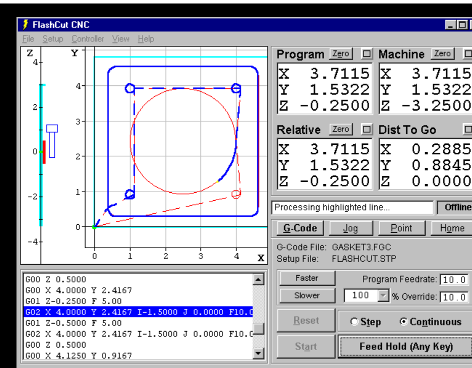
# *The Solution: Probe Considerations*

- Probe size should simulate DUT ball/pad geometry
- Wires must be soldered near tip to minimize bulk resistance
- Probe should be replaced often
- Nickel/Gold plating is recommended on tip
- Contactor must be firmly mounted to shorting plate
- Wires must be affixed to shorting plate on opposite ends to minimize bulk resistance





# *The Solution (Software)*




- Use existing NC G-Code software to drive robot
- Data Acquisition software: $2100 ***yea-right..***
- MS Excel macros/extensions - ***way too slow***
- Visual Basic dumping into Excel - ***OK*** ***(but a second PC was needed - not enough system resources to run VB and NC controller on one machine- oh well…)***

The birth of ECT *AUTODATA*

# *The Solution - Features*

- XYZ motion to .0002” precision
- Programmable in G-CODE or probe position imported from CAD data
- G-CODE triggered data gathering event with system feedback
- 1 gram force resolution
- 4-wire resistance to .01 milliohm resolution
- Data output into standard Excel spreadsheet
- Output formats: FReD curves, resistance maps, force maps, force and resistance histograms, monitored cycle testing, resistance/force statistics per contactor/lot, wear testing, etc…………………..

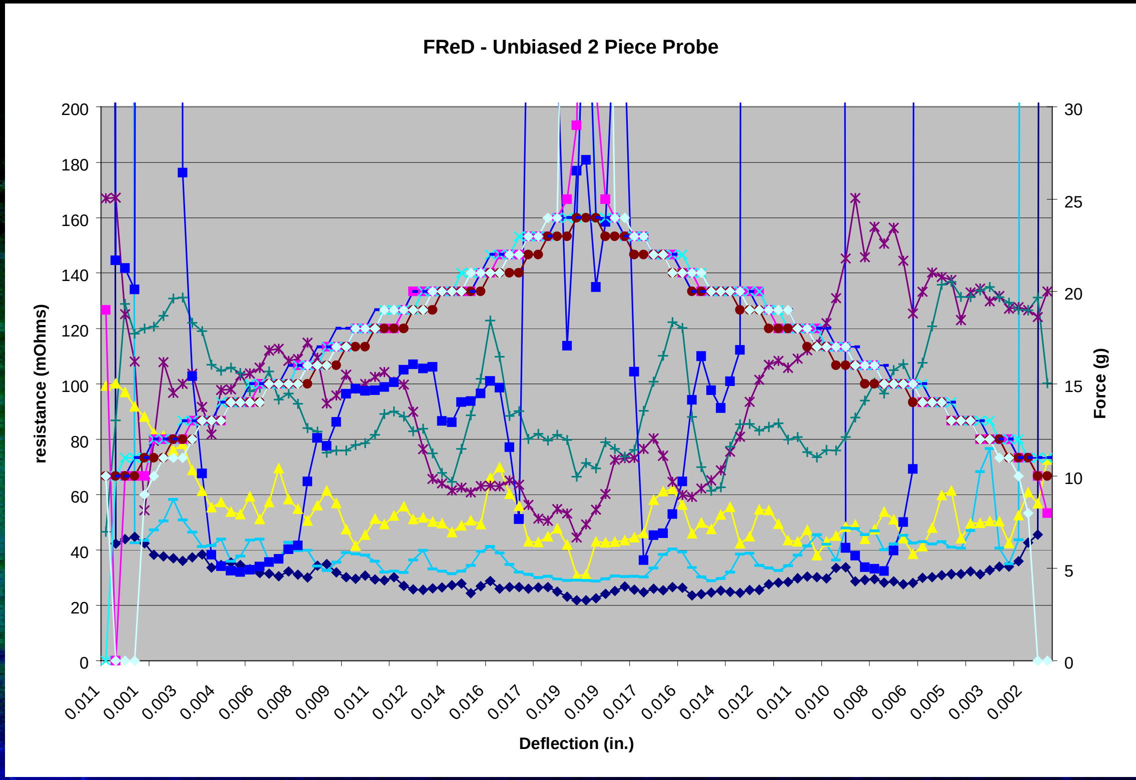
Total cost to integrate system: *$142.59*

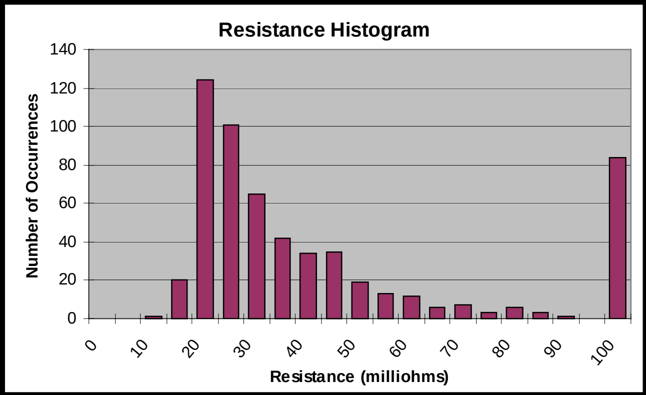
# *Results - The Good, The Bad, The Ugly*

- Resistance maps show patterns of resistance failure
- FReD plots analyze a contact system's reliability over the entire actuation
- Resistance histograms and statistics (mean, standard deviation, skew, etc.) are good tools to evaluate improvements
- Force contours show mechanical failures

<u>All of the tools above show inherent differences in contact technologies</u>

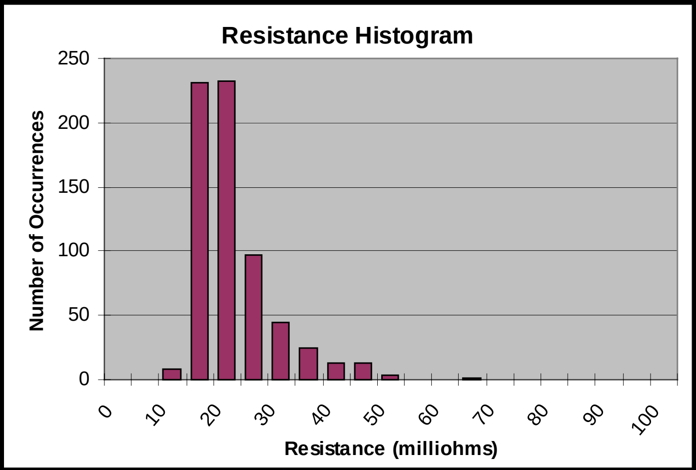
# Results: FReD Unbiased 2 Piece Probe

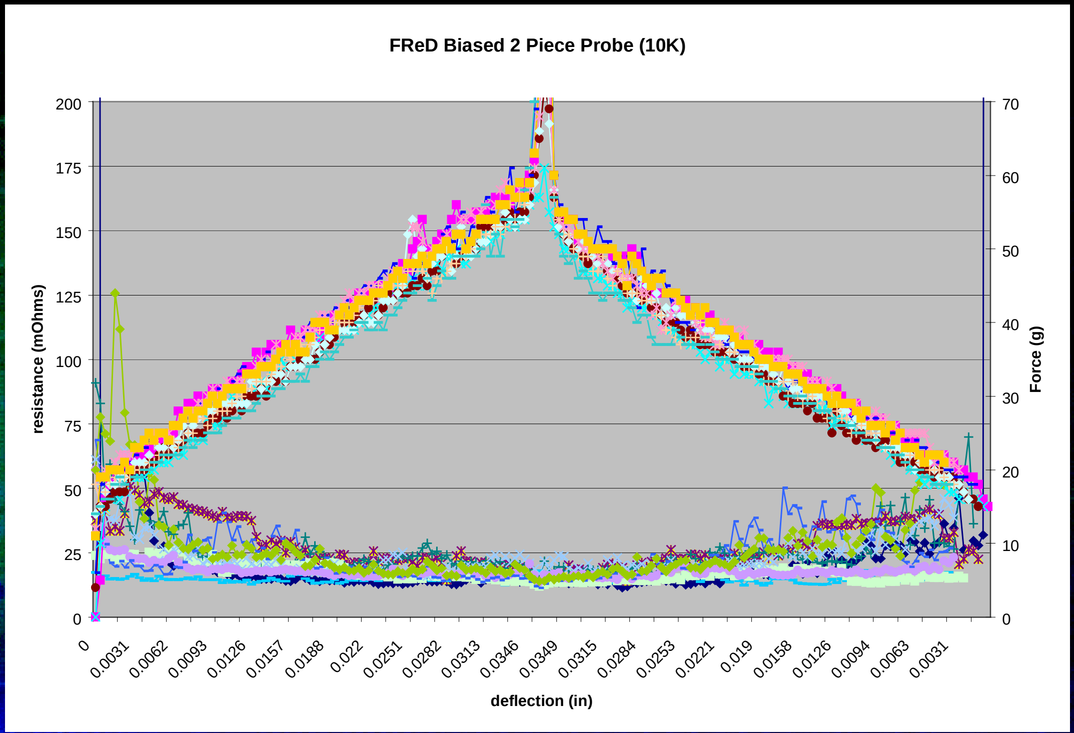



- Very smooth and predictable force
- Erratic and unreliable resistance - opens

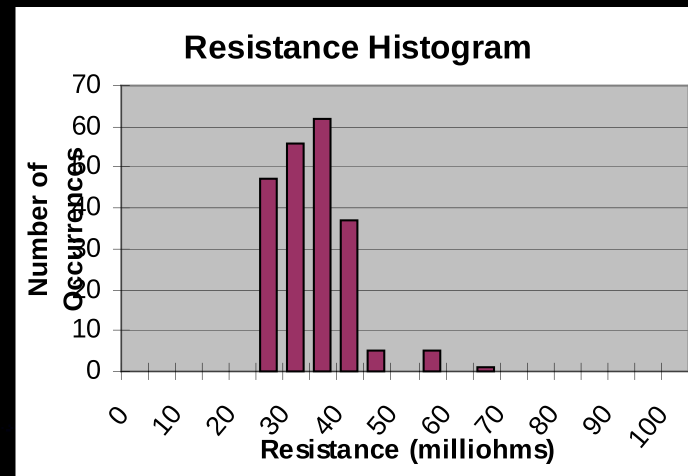
# Results: FReD Biased 2 Piece Spring Probe

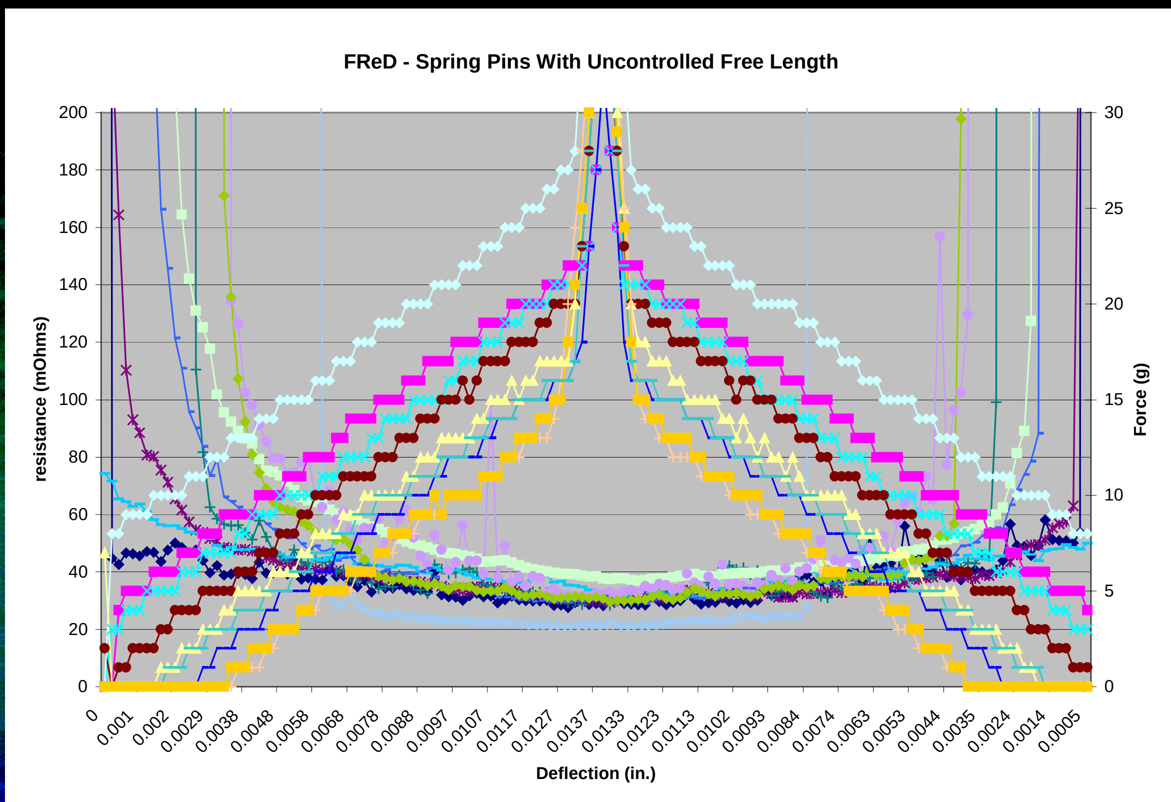



- Force in stroke can have 'grindy' feel
- Slight force differences for 'inward' and 'outward' stroke
- Very reliable and consistent resistance in working zone

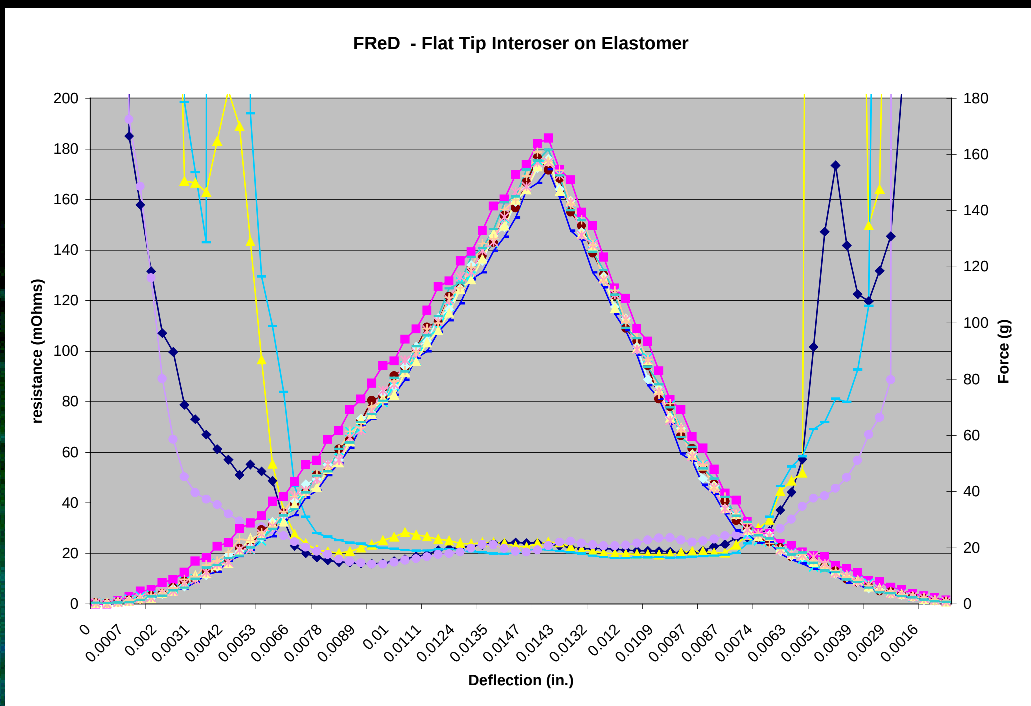
# *Results: FReD - Probe With Uncontrolled Free Length*

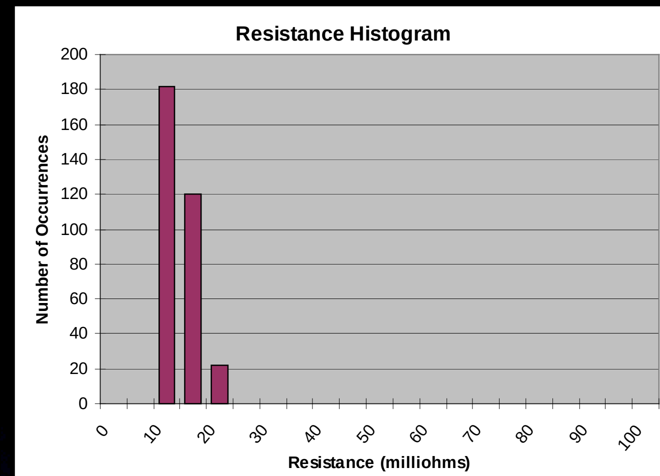



- Overlaid force traces have wide separation
- Wide variance in preload evident

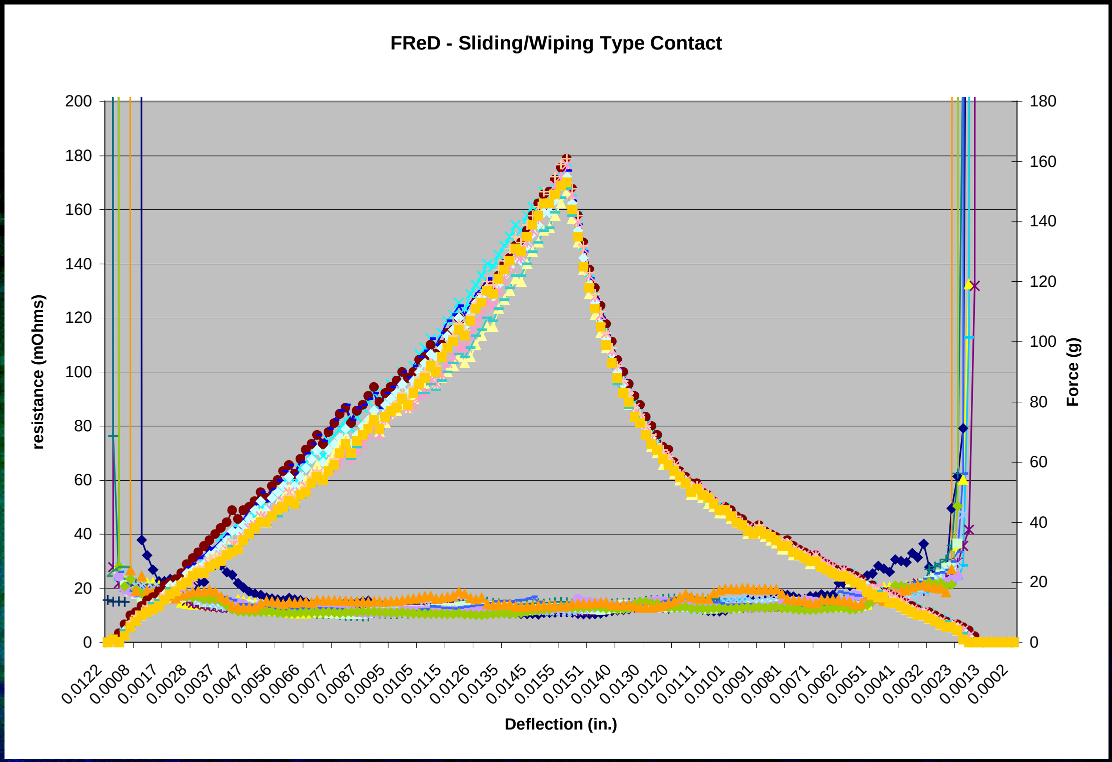
# *Results: FReD - Elastomer/ Flat Interposer*

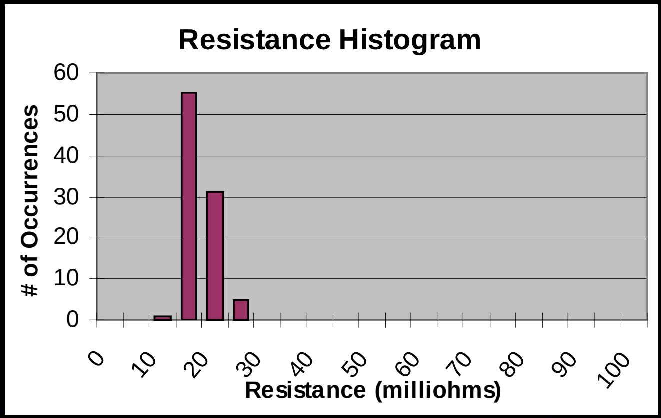



- High force system
- Resistance at beginning of stroke very unstable
- Uniform force
- Uniform working resistance

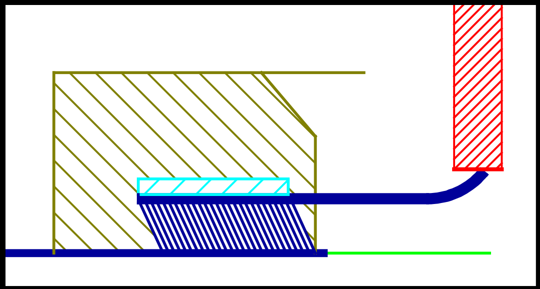
# Results: FReD - Sliding/Wiping Contact for QFP

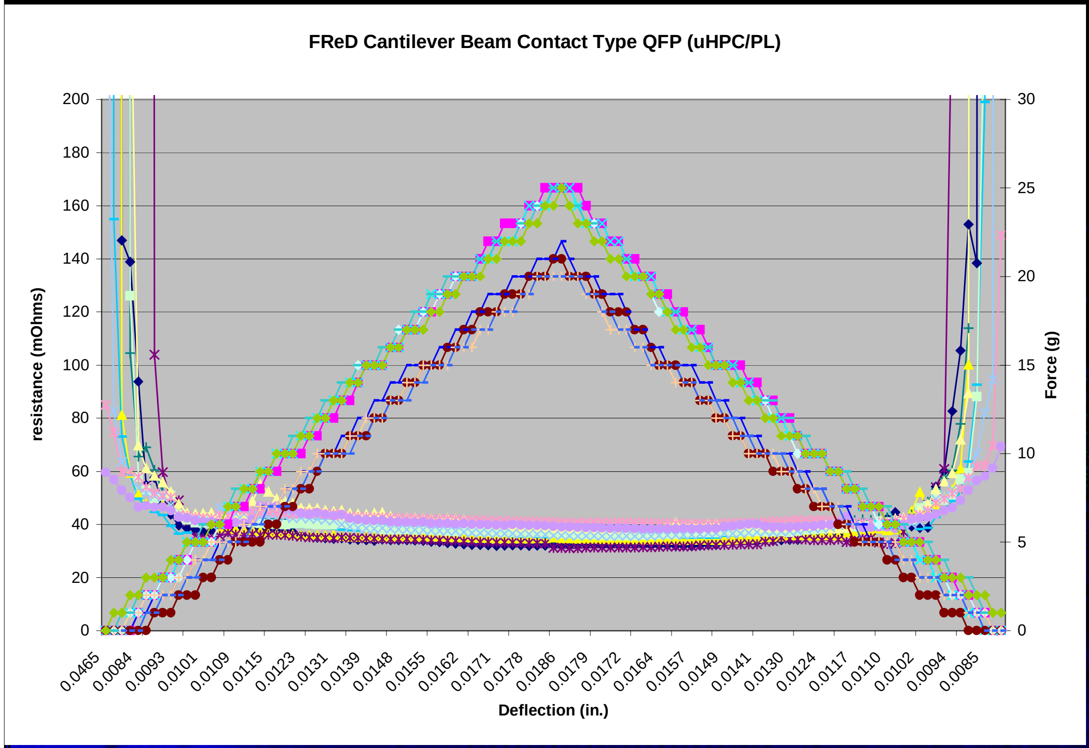


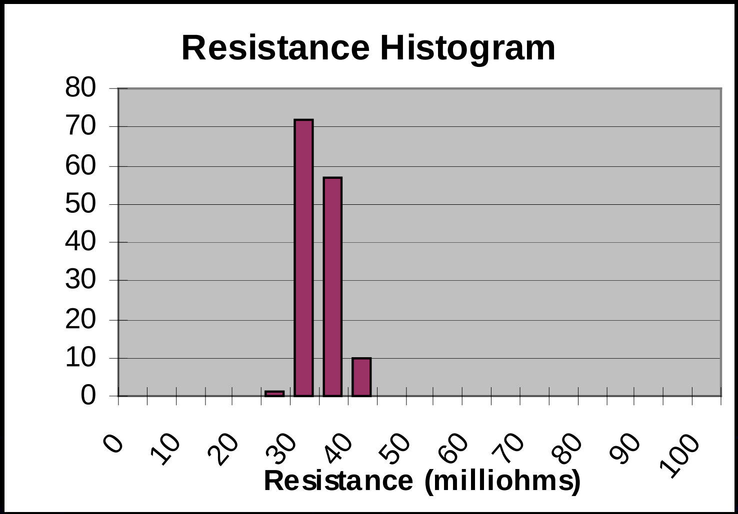




- Frictional 'stiction' effects during inward stroke can be seen in force curve
- Reliable and consistent resistance in working zone

# Results: FReD - ECT μHPC/PL



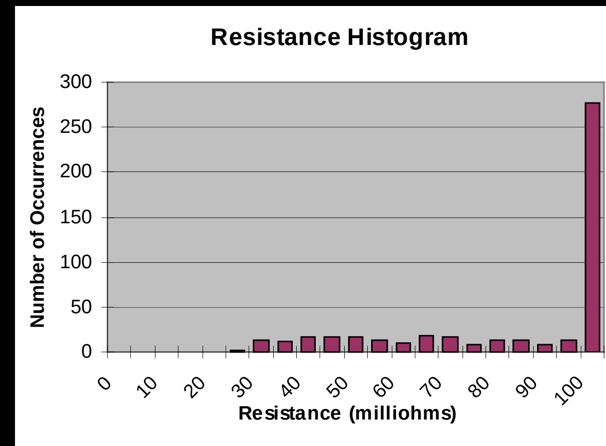


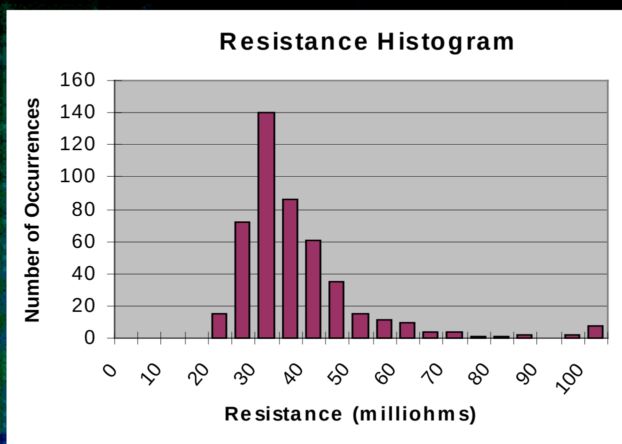




- Force in stroke very smooth
- Very reliable and consistent resistance in working zone

# Results: Resistance Map Before and After Cleaning

| position | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 66.2 | 87.1 | 26.8 | 86.3 | 112 | 96.6 | 828 | 1490 | 491 | 149 | 67.9 | 422 | 89.5 | 68.1 | 67 | 46.9 | 1152 | 937 | 135 | 236 | 407 | 140 | 277 | 161 | 221 | 89.6 |
| 2 | 125 | 289 | 56.4 | 655 | 51.6 | 213 | 160 | 103 | 59.2 | 82.8 | 93.4 | 233 | 102 | 79.4 | 55.3 | 499 | 393 | 109 | 67.2 | 435 | 954 | 92.8 | 423 | 370 | 249 | 136 |
| 3 | 97.9 | 54.7 | 34.9 | 134 | 134 | 53 | 48.6 | 154 | 33.7 | 56.5 | 105 | 40 | 875 | 553 | 114 | 529 | 81.8 | 92.3 | 563 | 2570 | 104 | 59.2 | 184 | 230 | 110 | 113 |
| 4 | 64.7 | 46.6 | 47.8 | 135 | 57.2 | 119 | 70.3 | 149 | 769 | 182 | 209 | 366 | 86.5 | 127 | 154 | 432 | 120 | 958 | 861 | 44.7 | 116 | 642 | 309 | 43.6 | 422 | 585 |
| 5 | 82.4 | 43.2 | 503 | 170 | | | | 378 | 84.4 | 756 | 35.9 | 96.6 | 62.5 | 34.6 | 117 | 46.7 | 208 | 48.4 | 149 | | | | 74.7 | 222 | 216 | 183 |
| 6 | 70.7 | 62.5 | 35.7 | 312 | | | | | | | | | | | | | | | | | | | 206 | 113 | 1044 | 648 |
| 7 | 44.1 | 52 | 282 | 61.6 | | | | | | | | | | | | | | | | | | | 1061 | 7194 | 121 | 89.3 |
| 8 | 72.1 | 95.4 | 59.3 | 151 | 88.4 | | | | | | | | | | | | | | | | | 72.6 | 170 | 399 | 626 | 136 |
| 9 | 53.8 | 84.5 | 86.1 | 273 | 83.7 | | | | | | | | | | | | | | | | | 291 | 2064 | 268 | 198 | 75.5 |
| 10 | 168 | 59.6 | 430 | 49.1 | 97.1 | | | | | 33.5 | 150 | 114 | 67.3 | 113 | 59.6 | 32.5 | 38.7 | | | | | 69.7 | 2862 | 91.6 | 68.6 | 220 |
| 11 | 65.1 | 574 | 111 | 201 | 70.9 | | | | | 80.3 | 41.8 | 494 | 113 | 93.7 | 124 | 297 | 44.9 | | | | | 102 | 53.4 | 309 | 47.8 | 277 |
| 12 | 177 | 664 | 390 | 947 | 84.2 | | | | | 36.3 | 67.1 | 81.4 | 43.4 | 982 | 141 | 52.3 | 42.4 | | | | | 250 | 48.9 | 129 | 1510 | 442 |
| 13 | 807 | 678 | 210 | 91.1 | 105 | | | | | 62.7 | 46.7 | 38 | 53.4 | 77 | 48.7 | 54.8 | 92.3 | | | | | 78.6 | 1761 | 73.6 | 129 | 38.7 |
| 14 | 190 | 122 | 97.7 | 206 | 81.6 | | | | | 106 | 116 | 78.1 | 95 | 35.2 | 50.9 | 51.5 | 32 | | | | | 48.3 | 37.1 | 194 | 52.6 | 306 |
| 15 | 56 | 34.6 | 457 | 205 | 171 | | | | | 52.6 | 97.3 | 87.1 | 153 | 41.7 | 49.9 | 43.3 | 33.7 | | | | | 178 | 77.3 | 260 | 611 | 51.1 |
| 16 | 70.2 | 95.9 | 84.1 | 116 | 45.7 | | | | | 47 | 74.2 | 73.2 | 31.1 | 68.9 | 42 | 52.6 | 64.1 | | | | | 1232 | 65 | 40.4 | 134 | 179 |
| 17 | 127 | 146 | 446 | 105 | 134 | | | | | 50.9 | 103 | 172 | 41 | 66.1 | 39.3 | 52.3 | 33 | | | | | 3326 | 2549 | 112 | 146 | 849 |
| 18 | 420 | 565 | 49.6 | 66.6 | 659 | | | | | | | | | | | | | | | | | 266 | 58 | 265 | 107 | 282 |
| 19 | 61.2 | 232 | 808 | 134 | 229 | | | | | | | | | | | | | | | | | 65.7 | 155 | 135 | 122 | 138 |
| 20 | 32.9 | 144 | 151 | 200 | | | | | | | | | | | | | | | | | | | 104 | 43.1 | 69.8 | 404 |
| 21 | 67.3 | 219 | 91.7 | 185 | | | | | | | | | | | | | | | | | | | 85.3 | 37.2 | 83.5 | 72.6 |
| 22 | 1115 | 71.6 | 253 | 157 | | | 62.2 | 485 | 187 | 146 | 138 | 137 | 84.6 | 77.1 | 253 | 89 | 203 | 4503 | 215 | 2941 | | | 323 | 194 | 1382 | 280 |
| 23 | 1235 | 139 | 117 | 384 | 101 | 102 | 222 | 316 | 87.4 | 416 | 153 | 975 | 43.9 | 818 | 169 | 129 | 155 | 3690 | 133 | 4701 | 75 | 372 | 85.7 | 865 | 487 | 56 |
| 24 | 1734 | 1140 | 109 | 748 | 110 | 666 | 152 | 31.3 | 285 | 619 | 202 | 175 | 39.3 | 710 | 60 | 157 | 72.2 | 517 | #### | 63.1 | 1762 | 98 | 302 | 8936 | 214 | 1046 |
| 25 | 910 | 1556 | 131 | 311 | 306 | 101 | 1028 | 1465 | 782 | 1088 | 1390 | 68.3 | 71.5 | 620 | 49 | 122 | 148 | 301 | 60.2 | 758 | 66.7 | 33 | 70.5 | 108 | 140 | 120 |
| 26 | 192 | 267 | 178 | 382 | 340 | 517 | 141 | 79.6 | 156 | 392 | 99.4 | 95.5 | 57 | 2228 | 147 | 113 | 1003 | 166 | 668 | 182 | 169 | 95.5 | 530 | 43.2 | 259 | 364 |



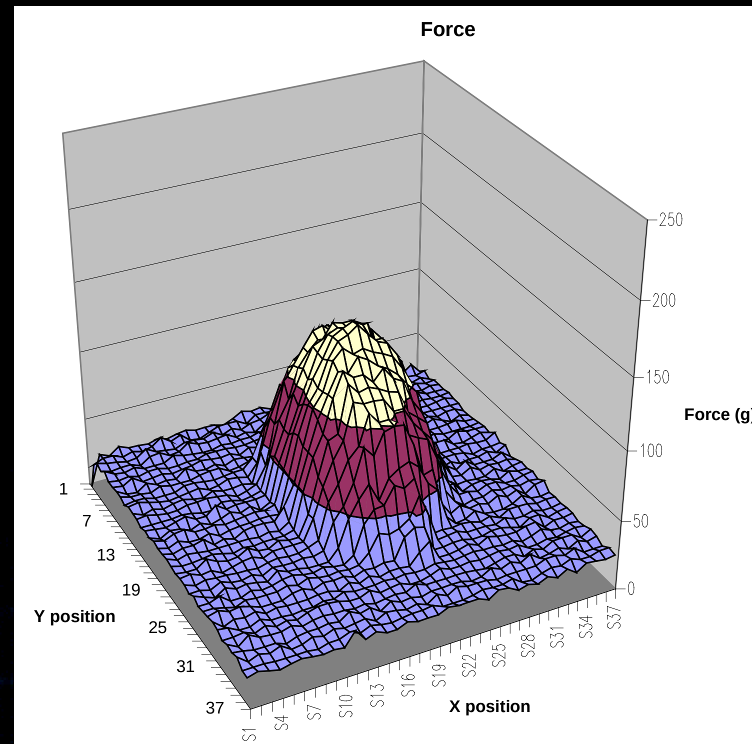

| position | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 23.6 | 38.1 | 36 | 30.1 | 38.9 | 33.3 | 33.4 | 35.4 | 31.1 | 32.5 | 38.8 | 72.7 | 43.7 | 33.8 | 30.2 | 44.6 | 49.4 | 30.2 | 55.5 | 38.7 | 29.2 | 87.5 | 30.3 | 29.4 | 42.8 | 33.6 |
| 2 | 47 | 27.8 | 22.1 | 28.9 | 776 | 26.3 | 48.1 | 36.9 | 42.4 | 37.3 | 57.3 | 40.7 | 56.9 | 29 | 35.4 | 32.7 | 35.3 | 55.3 | 31.6 | 50.9 | 47.2 | 31.3 | 56.7 | 28.4 | 39.7 | 31.2 |
| 3 | 98 | 22.8 | 42.6 | 25.5 | 35.6 | 40.6 | 26.8 | 55.3 | 32.3 | 524 | 36.2 | 33.9 | 54.5 | 35.1 | 29.2 | 33.7 | 38.3 | 41.8 | 61.9 | 30.7 | 32.3 | 46.5 | 54.2 | 30.7 | 36 | 26.6 |
| 4 | 46.1 | 42.9 | 28.8 | 25.2 | 41.9 | 36.4 | 26 | 85.2 | 33.2 | 42.4 | 29.9 | 39.9 | 32.4 | 28.4 | 57.7 | 47.7 | 39.9 | 73.1 | 33.4 | 52.2 | 34.4 | 34.6 | 32 | 56.2 | 224 | 30.2 |
| 5 | 38.5 | 35.9 | 25.1 | 24.6 | | | | 44 | 30.5 | 47.2 | 48.8 | 27.3 | 38.9 | 29.7 | 44.7 | 28.8 | 25.4 | 41.6 | 32 | | | | 27.6 | 35.9 | 43.2 | 32.1 |
| 6 | 38.1 | 32.4 | 42.9 | 30.3 | | | | | | | | | | | | | | | | | | | 42.9 | 33.9 | 35.1 | 33.5 |
| 7 | 22.5 | 33.6 | 37.3 | 25.6 | | | | | | | | | | | | | | | | | | | 33.9 | 47.2 | 31.7 | 32.9 |
| 8 | 43.4 | 27.1 | 32.7 | 26.3 | 36.1 | | | | | | | | | | | | | | | | | 35 | 33.2 | 38.3 | 33.1 | 44.4 |
| 9 | 28.4 | 32.4 | 23.7 | 35.8 | 27.9 | | | | | | | | | | | | | | | | | 33 | 39.5 | 31.3 | 31.7 | 28.2 |
| 10 | 35.7 | 27.3 | 33.2 | 35.1 | 28 | | | | | 49.4 | 31 | 44.8 | 28.7 | 31.8 | 26 | 34.5 | 29.3 | | | | | 34.3 | 41.1 | 32 | 32 | 36.8 |
| 11 | 33.8 | 34.3 | 34.1 | 83.6 | 34.5 | | | | | 30.5 | 33.8 | 40.4 | 40.4 | 37.5 | 54.8 | 22.9 | 33.4 | | | | | 40 | 29.6 | 39.2 | 45.9 | 43.2 |
| 12 | 32.6 | 34.8 | 31.3 | 27.2 | 24.5 | | | | | 36.2 | 29.3 | 38.2 | 49.3 | 46.7 | 33.5 | 41.3 | 32.4 | | | | | 46.7 | 36.5 | 29.2 | 43.5 | 38.2 |
| 13 | 39.2 | 38.3 | 27.5 | 43.1 | 30 | | | | | 41.5 | 33.7 | 27.1 | 34.3 | 46.1 | 47.3 | 31.4 | 41.9 | | | | | 34.8 | 102 | 42.8 | 57.9 | 39.5 |
| 14 | 49.1 | 31.6 | 25.5 | 38.4 | 25.5 | | | | | 60.9 | 37.7 | 35 | 30.3 | 96.4 | 24.7 | 32.8 | 24.3 | | | | | 31.2 | 48.1 | 29.1 | 48.8 | 38.3 |
| 15 | 30.5 | 29.4 | 30.2 | 33.1 | 28.3 | | | | | 41.9 | 31.7 | 37.3 | 28.6 | 51.5 | 43.9 | 32.6 | 53.2 | | | | | 63.1 | 45.8 | 41.9 | 46.2 | 65.1 |
| 16 | 61.2 | 34.3 | 135 | 34.8 | 30.4 | | | | | 101 | 70.1 | 39 | 32.3 | 40.9 | 38.7 | 33.8 | 52 | | | | | 31.7 | 54.8 | 33.2 | 42.3 | 45.3 |
| 17 | 36.9 | 50.4 | 26.4 | 38.1 | 34 | | | | | 20.6 | 44.8 | 39.5 | 36.3 | 41.9 | 41.9 | 27.9 | 156 | | | | | 32.9 | 46.2 | 34.3 | 31.1 | 48.1 |
| 18 | 29.8 | 31.7 | 39.7 | 39.4 | 31.4 | | | | | | | | | | | | | | | | | 37.5 | 33.9 | 58.3 | 46.6 | 42.2 |
| 19 | 30.2 | 37.2 | 31.1 | 31.9 | 34.9 | | | | | | | | | | | | | | | | | 44.6 | 32.3 | 35 | 58.7 | 48.6 |
| 20 | 46.7 | 43.3 | 37.5 | 34 | | | | | | | | | | | | | | | | | | | 32.6 | 31.3 | 72.3 | 51.1 |
| 21 | 34.1 | 33.4 | 35.8 | 27.7 | | | | | | | | | | | | | | | | | | | 34.4 | 24.2 | 39 | 49.9 |
| 22 | 37.6 | 29.9 | 28 | 22.4 | | | 39.9 | 27.1 | 25.4 | 39.3 | 35.7 | 24 | 29.7 | 28.3 | 36.8 | 31.3 | 38.8 | 63.7 | 34.1 | 38.1 | | | 27.4 | 46.8 | 43.9 | 38.8 |
| 23 | 28.9 | 38.2 | 51.4 | 25.4 | 33.7 | 30.6 | 33.1 | 36.1 | 29.8 | 33.1 | 29.2 | 29.8 | 29 | 30.6 | 41.3 | 31 | 60.1 | 36.1 | 33.9 | 30.4 | 30.2 | 44.1 | 37.2 | 35.3 | 45 | 38.1 |
| 24 | 78.1 | 35.3 | 67.5 | 65.9 | 32.2 | 41.9 | 28.6 | 31.2 | 31 | 45.4 | 42.6 | 32.7 | 26.5 | 35 | 43.5 | 36.7 | 52.9 | 29.6 | 31.3 | 40.3 | 40.3 | 32 | 32.4 | 38.7 | 32.4 | 38 |
| 25 | 30.4 | 33.9 | 44.7 | 34.5 | 31.9 | 51.3 | 26.4 | 42.3 | 43.2 | 32.6 | 27.1 | 41.8 | 42.2 | 213 | 40.1 | 49.7 | 27.5 | 47 | 32 | 29.3 | 64.9 | 38.2 | 39.8 | 33.4 | 27.5 | 65.6 |
| 26 | 24 | 33.1 | 41.4 | 61.4 | 37 | 32.9 | 38.3 | 44.8 | 32.2 | 60.4 | 49.5 | 26 | 31.2 | 37 | 32.6 | 31.3 | 38.5 | 40.9 | 41.4 | 27.2 | 48.8 | 33.8 | 44.4 | 30.2 | 51.3 | 35.7 |

➤After standard maintenance cleaning process done, heavily used contactor nearly returns to usable condition

# Results: Resistance/Force Map - Mechanical Failure

| position | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 80.6 | 42.4 | 26.3 | 48.2 | 22.4 | 36.8 | 50.1 | 50.3 | 41.3 | 21.4 | 13.2 | 62.5 | 65.1 | 44.7 | 13.1 | 25.6 | 14.8 | 14.7 | 28.2 |
| 2 | 37.6 | 24.4 | 108 | 40.6 | 49.6 | 67.2 | 28.8 | 55.4 | 52 | 24 | 15.5 | 18.2 | 18.7 | 14.8 | 13.4 | 18.8 | 29.7 | 15.4 | 25.6 |
| 3 | 31 | 77.1 | 36.4 | 31.8 | 28.2 | 104 | 68.5 | 18.7 | 89.7 | 38.9 | 39.5 | 15.8 | 35.7 | 14.5 | 15.7 | 50.6 | 10.4 | 13.3 | 21.1 |
| 4 | 272 | 66.3 | 144 | 113 | 28.4 | 29.1 | 30.8 | 31.1 | 36.3 | 15.4 | 36.9 | 33.6 | 44.6 | 105 | 20.6 | 30.2 | 15.9 | 22.9 | 15.2 |
| 5 | 53.3 | 60 | 21.3 | 20.2 | 141 | 52.9 | 130 | 292 | 41.7 | 135 | 158 | 17.5 | 14.8 | 31 | 227 | 40.2 | 16.2 | 27.3 | 121 |
| 6 | 82.1 | 71.7 | 31.6 | 36.6 | 41.7 | 26.3 | 46.7 | 611 | 23.9 | 31.8 | 21 | 478 | 19.9 | 55.2 | 13.9 | 18.3 | 11.6 | 34.1 | 17.3 |
| 7 | 65.4 | 174 | 44.7 | 65 | 25 | 71.9 | 61.8 | 20 | 47.5 | 31.1 | 28.7 | 36.3 | 25.5 | 31.3 | 11.1 | 20.4 | 53 | 17.2 | 59.5 |
| 8 | 62.6 | 40.9 | 86.1 | 30.7 | 32.5 | 28.3 | 83 | 23.9 | 35 | 33.5 | 43.7 | 47.9 | 24.9 | 24.2 | 34.1 | 13.8 | 225 | 72.3 | 85.1 |
| 9 | 113 | 42.2 | 428 | 17.9 | 47.8 | 28.6 | 45.1 | 81.2 | 57.4 | 43.5 | 164 | 35 | 80.2 | 33.6 | 44.1 | 77.9 | 27.5 | 55.2 | 27.4 |
| 10 | 184 | 62.1 | 33.2 | 49.3 | 40.2 | 40.1 | 36.7 | 25.8 | 25.6 | 40.2 | 29.9 | 36.5 | 90.4 | 26.7 | 14.8 | 41.1 | 230 | 55.6 | 36.6 |
| 11 | 211 | 39.8 | 53.8 | 42.5 | 31 | 25.2 | 51.7 | 42.6 | 49.1 | 41.6 | 25.7 | 88 | 71 | 457 | 31.6 | 41.3 | 59.5 | 58.5 | 47.6 |
| 12 | 195 | 49.4 | 73 | 40.4 | 29.3 | 27.9 | 39.7 | 37.4 | 42 | 46.6 | 26.2 | 33.5 | 41.9 | 26 | 23.4 | 27.9 | 35 | 35.7 | 45.5 |
| 13 | 55.8 | 49.5 | 28.7 | 54.5 | 26 | 39.9 | 122 | 27 | 31.4 | 21.1 | 53.3 | 24.9 | 24.5 | 41.3 | 35.8 | 38.2 | 45.3 | 21.1 | 65.3 |
| 14 | 97 | 42.3 | 224 | 36.7 | 36 | 28.6 | 59.6 | 30.1 | 36.3 | 119 | 30.2 | 360 | 45 | 29.9 | 26.7 | 45.4 | 31.6 | 68.9 | 166 |
| 15 | 101 | 29 | 29.5 | 37.5 | 36.2 | 47.6 | 35.6 | 582 | 113 | 39.9 | 28.3 | 53.1 | 182 | 32.2 | 51.6 | 63.8 | 51.6 | #### | 33.4 |
| 16 | 45 | 37.5 | 45.1 | 48.1 | 31.9 | 29.9 | 65.2 | 35.6 | #### | 53.1 | #### | 132 | #### | 22 | 50.1 | 223 | 120 | 44.9 | 54.8 |
| 17 | 70 | 42.5 | 28.6 | 122 | 38.4 | 48.4 | 37.1 | #### | #### | 101 | 126 | #### | #### | #### | #### | 57 | #### | 91.1 | 86.3 |
| 18 | 466 | 60.6 | 19.5 | 30.5 | 44.1 | 62.3 | #### | 74.2 | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### |
| 19 | 50.6 | 86.8 | 35.3 | 28.1 | 39.5 | 45.8 | 81.3 | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### |
| 20 | 46.7 | 45.1 | 43.8 | 44.8 | 52.4 | 72.4 | 39.1 | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### |
| 21 | 47.8 | 31.7 | 567 | 27.9 | 48.5 | 59 | 883 | #### | #### | #### | #### | #### | #### | #### | #### | #### | 137 | #### | 33.9 |
| 22 | 309 | 44.8 | 29.9 | 98.7 | 74.1 | 17.3 | 49.4 | #### | 1071 | #### | #### | #### | #### | #### | #### | #### | #### | #### | 22.2 |
| 23 | 39.9 | 34 | 32.1 | 113 | 53.8 | 79.5 | 45.7 | 67.4 | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### |
| 24 | 54.9 | 47.7 | 78.6 | 51.9 | 56 | 34 | 56.3 | 45.6 | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### |
| 25 | 44.6 | 31.8 | 29.3 | 59.3 | 53 | 50.5 | 94.4 | 2643 | 30.6 | #### | #### | #### | #### | #### | #### | #### | #### | #### | #### |
| 26 | 133 | 29 | 144 | 29.7 | 52.8 | 86.1 | 30.6 | 49.8 | 33.9 | #### | 45.7 | #### | #### | #### | #### | #### | #### | #### | #### |
| 27 | 666 | 37.6 | 36.5 | 46.3 | 34.4 | 25.2 | 659 | 72.6 | 57.1 | 34 | 2865 | #### | #### | #### | #### | #### | #### | #### | #### |
| 28 | 31.5 | 39.1 | 25.9 | 31.4 | 35.4 | 36.2 | 24.8 | 49.9 | 56.3 | 136 | 54.1 | 73.7 | #### | 158 | 79.4 | #### | #### | #### | #### |
| 29 | 60.9 | 42.2 | 37.4 | 40.3 | 32.3 | 30.8 | 39.7 | 41.7 | 30.7 | 36.8 | 127 | #### | 50.5 | 76.3 | 458 | #### | #### | #### | #### |
| 30 | 43.5 | 37.9 | 65.2 | 67.9 | 26.9 | 27.7 | 34.1 | 32.3 | 36 | 78.2 | 63.4 | 28.4 | 83.4 | 38.4 | 18.5 | 84.1 | #### | #### | #### |
| 31 | 57.5 | 62.5 | 31.7 | 24.3 | 146 | 46.8 | 31.6 | 30.7 | 35.8 | 26.9 | 25 | 37.2 | 32 | #### | 37.1 | 44.1 | 32.2 | 65.5 | 39.8 |
| 32 | 57.4 | 40.4 | 50.7 | 31.2 | 136 | 30.6 | 38.3 | 34.1 | 25.2 | 73.1 | 45.9 | 35.3 | 27.4 | 76.9 | 37.3 | 42.9 | 519 | 30.5 | 31.1 |
| 33 | 47 | 27.2 | 65.6 | 77.5 | 46.4 | 28.6 | 30.4 | 30.4 | 38.9 | 24.9 | 27.2 | 26.2 | 47 | 25.4 | 29.3 | 41.7 | 31.1 | 30 | 37.7 |
| 34 | 67 | 39.2 | 33.8 | 36.3 | 36.1 | 29.2 | 28.3 | 55.6 | 32.8 | 30.2 | 32.7 | 1018 | 40 | 24.9 | 30.5 | 32.8 | 25.5 | 27.3 | 26.5 |
| 35 | 31 | 34.7 | 32.8 | 45.2 | 47.6 | 29.9 | 31.7 | 39.2 | 30 | 30.5 | 39.3 | 32.2 | 27.5 | 79.5 | 39.8 | 23.5 | 32.7 | 30 | 44.7 |
| 36 | 51.8 | 33.7 | 35.4 | 27.5 | 31.7 | 26.2 | 43.1 | 27.9 | 31.1 | 34.9 | 50.5 | 26.2 | 34.9 | 57.7 | 28.3 | 36.8 | 132 | 38.2 | 39.9 |
| 37 | 295 | 32.8 | 29.6 | 28.2 | 31.5 | 27.5 | 51.8 | 858 | 28.2 | 26.9 | 41.2 | 33.4 | 35.7 | 43.4 | 44.6 | 30.5 | 40.1 | 52.5 | 22.7 |

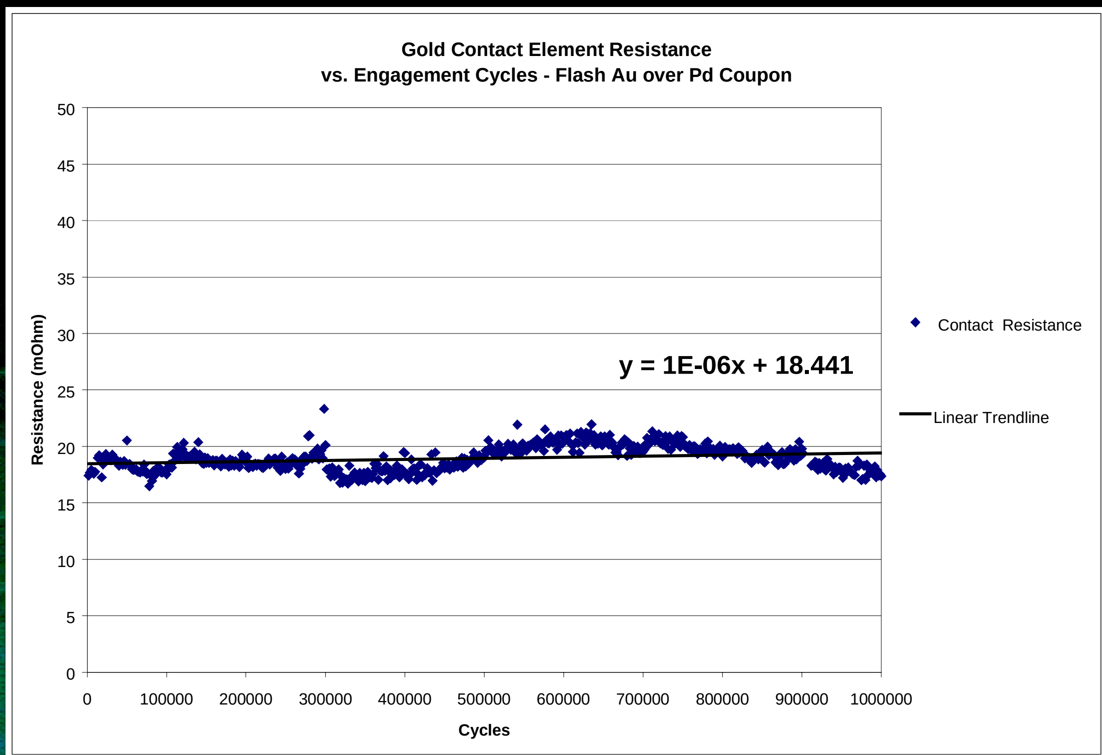
| position | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11.9 | 18.9 | 11.7 | 10.6 | 13.2 | 11.4 | 10.5 | 11.8 | 11.7 | 9.87 | 20.1 | 13.6 | 18.4 | 16.8 | 15.8 | 16.1 | 18.8 | 15.6 |
| 2 | 16 | 21.2 | 13.4 | 18 | 11.7 | 14 | 112 | 12 | 28.4 | 22.3 | 25.6 | 20.2 | 14.6 | 12.9 | 17.5 | 14.8 | 15.3 | 17.9 |
| 3 | 14.8 | 14.3 | 12.6 | 12.7 | 10.8 | 15.1 | 15.1 | 48.4 | 17.9 | 14.7 | 62.3 | 13.2 | 20.3 | 18.8 | 14.9 | 15.9 | 14.5 | 38.8 |
| 4 | 13.2 | 11.3 | 11.1 | 15.7 | 14.4 | 14.1 | 12.5 | 16.2 | 79.3 | 17.3 | 13.8 | 20.4 | 33.8 | 43.4 | 17.7 | 23.1 | 30.7 | 22.6 |
| 5 | 13.9 | 20.1 | 15.8 | 13.3 | 55.2 | 63.8 | 19.1 | 15.8 | 29.9 | 13.5 | 29.7 | 17.3 | 21.9 | 16.1 | 21.5 | 19.8 | 35 | 19.8 |
| 6 | 14 | 43.2 | 17.9 | 12.7 | 14.1 | 16.9 | 13.2 | 18.6 | 21.9 | 18.8 | 14.9 | 15.2 | 24 | 17.7 | 22 | 16.7 | 35.6 | 16.3 |
| 7 | 14.9 | 16.9 | 25.6 | 42.8 | 15.7 | 26.8 | 12.3 | 17.8 | 23.1 | 20.2 | 15.2 | 37.5 | 48.8 | 104 | 19.8 | 19.3 | 20.4 | 32.2 |
| 8 | 31.8 | 57.5 | 54.2 | 35.4 | 48.4 | 16.9 | 15.3 | 35.2 | 38.2 | 170 | 22.6 | 75.2 | 117 | 28.6 | 51.7 | 34 | 38.3 | 22.7 |
| 9 | 34.7 | 60 | 44.8 | 33.2 | 22.1 | 14.5 | 34.7 | 33.9 | 20.9 | 31.2 | 24 | 71.9 | 15.4 | 31.8 | 41.2 | 31.1 | 58.8 | 27.1 |
| 10 | 22.6 | 65.4 | 36.2 | 19.3 | 47.3 | 21.9 | 39.7 | 140 | 18 | 25.5 | 57.6 | 145 | 17 | 51 | 41.8 | 180 | 24 | 187 |
| 11 | 109 | 87.2 | 25.7 | 13.7 | 72.6 | 31 | 31.9 | 106 | 51.8 | 35.9 | 131 | 222 | 15.5 | 29 | 22.6 | 41.7 | 36.6 | 20.7 |
| 12 | 32.8 | 35.2 | 31.5 | 49.3 | 25.4 | 29.1 | 31.3 | 36.7 | 35.3 | 29.4 | 36.8 | #### | 57.1 | 30.6 | 28.1 | 32.6 | 66.1 | 27.6 |
| 13 | 33 | 27.2 | 28.6 | 26.3 | 37.5 | 40.8 | 80.4 | 53.8 | 35.4 | 25.1 | 16.6 | #### | 29.8 | 35.1 | 44 | 27.1 | 36.4 | 64.2 |
| 14 | 40.1 | 60.9 | 23.4 | 19 | 33.7 | 40.3 | 32.5 | 53.7 | 41.1 | 39.2 | 65.7 | #### | #### | 31.1 | 30.7 | 20.8 | 45.2 | 35.8 |
| 15 | 134 | #### | 35.6 | 160 | 46.7 | 32.1 | 41.1 | 68 | 228 | 30.3 | 28 | 27.1 | #### | 88.9 | 36 | 58.5 | 145 | 35.1 |
| 16 | #### | 42.7 | 44.4 | 23.9 | 29.1 | 70.3 | 68.5 | 31.9 | 28.6 | 42.5 | 40.3 | #### | #### | 25.5 | 27 | #### | 62.6 | 20 |
| 17 | #### | 52.7 | 2985 | #### | 1041 | 49.9 | #### | 36.4 | 32.6 | 30 | 30.7 | #### | #### | 36.1 | 49.5 | 37.6 | #### | 36.1 |
| 18 | #### | 53.9 | #### | 273 | 82.4 | 104 | 1307 | 215 | 38.1 | 21 | 26 | #### | #### | 27.7 | 30.7 | #### | 30.9 | #### |
| 19 | #### | #### | #### | #### | #### | 77.6 | 78 | 16.5 | 35.3 | 74.5 | 28.5 | #### | #### | 36 | 29.3 | 40.3 | 111 | 25.3 |
| 20 | #### | #### | 119 | #### | #### | 10.3 | 37.1 | #### | 36.6 | 30.1 | 21.5 | #### | #### | 38 | 30.7 | #### | 34.3 | 148 |
| 21 | 104 | 126 | #### | #### | #### | #### | 116 | #### | 29.9 | 29.2 | 112 | #### | #### | 31.5 | 43 | 21 | 30.5 | 27.4 |
| 22 | #### | #### | #### | #### | #### | 24.3 | 75.2 | #### | 29.3 | 38.2 | 35.2 | 24.1 | #### | 42.7 | 41 | 25.8 | 35.1 | 38.4 |
| 23 | #### | #### | #### | #### | #### | 172 | 114 | #### | 122 | 100 | 28.8 | #### | #### | 41.7 | 55.7 | 31.5 | 42.7 | 34.6 |
| 24 | #### | #### | #### | #### | 27.7 | #### | 70.3 | #### | 29.6 | 33.5 | 26.4 | #### | #### | 34.2 | 29.3 | 30.5 | 42.6 | 34.9 |
| 25 | #### | #### | 65.5 | #### | #### | 106 | 38.3 | 37 | 29.9 | 49.9 | 56.4 | 36.3 | 24.6 | 34.7 | 25.8 | 29.5 | 49.2 | 266 |
| 26 | #### | #### | #### | #### | #### | #### | #### | 48.8 | 39.1 | 30.3 | 136 | 37.7 | 23.5 | 30.4 | 25.7 | 22 | 49.4 | 30.9 |
| 27 | #### | #### | #### | 60.9 | 31.2 | #### | 31.8 | 64 | 37.1 | 39.7 | 38.2 | 29.9 | 29.6 | 38.2 | 28.1 | 34.1 | 36.7 | 36.3 |
| 28 | #### | 46.1 | #### | 192 | #### | 156 | #### | 28.9 | 44.3 | 38.2 | 26.9 | 31.4 | 18.9 | 29.5 | 57.3 | 34.1 | 45.1 | 37.9 |
| 29 | #### | #### | #### | 31.5 | 37.3 | 37.3 | 32.9 | 33.7 | 34.5 | 25.6 | 33.4 | 27.8 | 50.8 | 41.8 | 18.7 | 33.9 | 42.9 | 39.3 |
| 30 | 103 | #### | 71.5 | 22 | 30.2 | 121 | 28.8 | 28.1 | 42.5 | 25.8 | 25.7 | 29.2 | 45.5 | 40.5 | 27.8 | 28.9 | 51.1 | 48.5 |
| 31 | 51.2 | #### | 35.9 | 93.1 | 40.8 | 37 | 40.8 | 83.1 | 31.3 | 44.7 | 31.7 | 47.9 | 32.7 | 34.8 | 35.1 | 20 | 56.2 | 28.5 |
| 32 | 44.2 | 49.7 | 25.8 | 100 | 49.9 | 33.6 | 40.7 | 24.3 | 31.4 | 27 | 41.4 | 24.1 | 44.3 | 26.2 | 35.7 | 25.5 | 93 | 31.4 |
| 33 | 28.8 | 26.7 | 34.3 | 28.6 | 24 | 99.4 | 59.9 | 43.8 | 46.3 | 67.1 | 68 | 30 | 633 | 87.3 | 26 | 39.8 | 35.2 | 32.5 |
| 34 | 23.3 | 42.5 | 25.5 | 26.7 | 52.7 | 32.2 | 45.2 | 30 | 38.3 | 27.5 | 56.5 | 33.9 | 43.2 | 31.3 | 27.2 | 40.4 | 33.3 | 39.3 |
| 35 | 30.1 | 28 | 24.6 | 29.2 | 34.5 | 16.4 | 31.3 | 34.1 | 40.8 | 49.2 | 32.2 | 34.8 | 38.8 | 26.5 | 78.7 | 27.3 | 39.1 | 45.1 |
| 36 | 41.9 | 19 | 134 | 35.3 | 34.2 | 26.7 | 26.5 | 41.8 | 34.6 | 46.7 | 25.4 | 35.1 | 27.8 | 30.7 | 895 | 54.6 | 50.6 | 32 |
| 37 | 29.8 | 35.5 | 49.3 | 28.7 | 29.6 | 38.6 | 32.4 | 27.3 | 33.8 | 32.7 | 28.1 | 31 | 33.5 | 30.4 | 34 | 28 | 29.5 | 47.6 |




➤Very large LGA contactor exhibited ‘opens’ in a large patch in the center

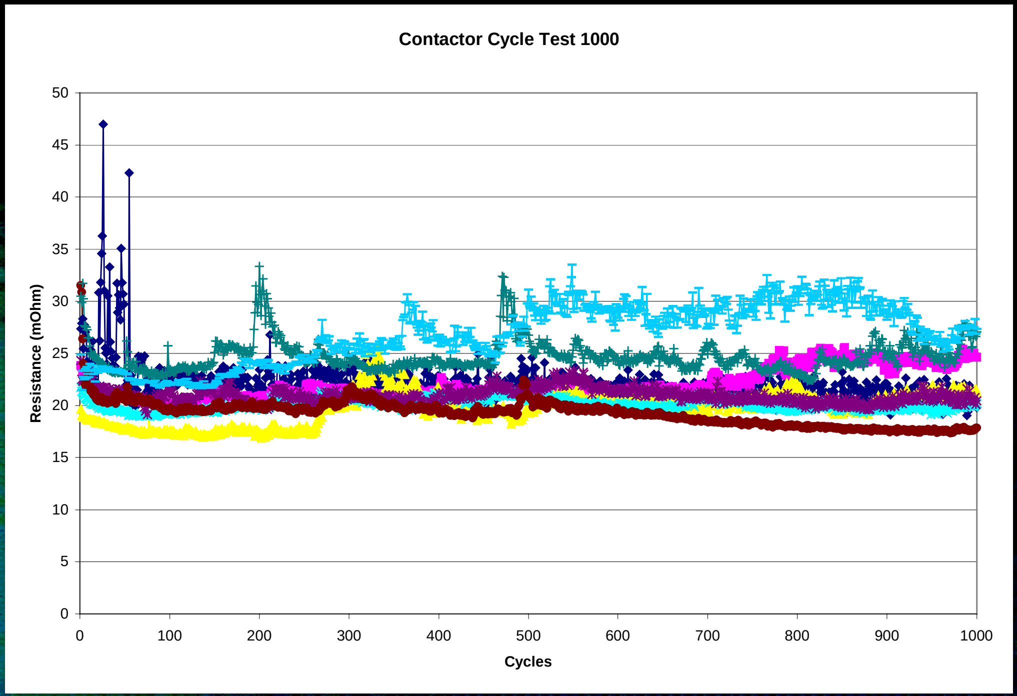
➤Contactor guideplate suffered from extreme expansion due to hydroscopic effects. Center was ‘domed’, resulting in probe hitting contactor floor too early

# *Results: Wear Analysis - Au Contact Wear Against Pd-Au*




- ➤Robot was set up with µHPC/PL leadframe element
- ➤Machine stroked element over Au flash over Pd coupon to simulate 1M actuations
- ➤Resistance was recorded every 1K cycles

# *Results: Monitored Cycle Testing*




- Robot continuously cycled 25 pogo pin array until each pin was tested 1000 times
- Some early 'break-in' is seen

# *The Future of FReD*

- FReD is always getting smarter
  - ➤ Working on improved software for simpler control and more powerful measurement
    - – Faster data gathering
    - – Automatic G-Code generation
    - – Easier user interface
  - ➤ Resistance probe can easily be replaced with VNA or TDR for signal integrity verification of interfaces, POGO blocks, and contactors
  - ➤ New tests being proposed: spring pin pointing accuracy, spring pin bias reliability validation, BGA solder transfer investigation, Lead-free BGA contact study, …..

## *Conclusion*

- FReD has proven to be an invaluable evaluation and characterization tool
- All contact systems have their own features and benefits - FReD is a tool to identify the pros and cons
- FReD is flexible and user friendly.  Many different tests can be performed
- And of course……………..
  - ➤FReD is *CHEAP……..*