BiTS™

# Burn-in & Test Socket Workshop

**March 7 - 10, 2004**
**Hilton Phoenix East / Mesa Hotel**
**Mesa, Arizona**

# ARCHIVE

Burn-in & Test Socket Workshop ™

# COPYRIGHT NOTICE

Burn-in & Test Socket Workshop

# Technical Program

## Session 2
## Monday 3/08/04 10:30AM

## THERMAL ANALYSIS

### "FEA Analysis Of A Burn-in Socket Contact - Beware The Use Of Simple Models"

**Dr. James A. Forster** – Texas Instruments
**Prasanth Ambady** – Texas Instruments **Ray Mandeville** – Texas Instruments

### "Chips On Fire, New Approach To Thermal Management"

**Kevin Moody** – Kulicke & Soffa

### "Heat Sink Modeling And Design For Dissipating High Heat"

**S. Kumaran** – Trio-Tech International

# FEA Analysis of a Burn-in Socket Contact
## - Beware the use of Simple Models.

**Prasanth Ambady, Ray Mandeville and <u>James Forster</u>**

**Texas Instruments,**
**Sensors & Controls, Attleboro, MA**

**2004 Burn-in Test Socket Workshop - March 7-10, 2004**
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**Mesa, Arizona**

TEXAS INSTRUMENTS

BiTS
BURN-IN & TEST SOCKET WORKSHOP

# Outline

- Introduction
- Brief introduction to the history and process of design
- What is FEA
- Examples of the analysis of some contacts
- Concluding remarks

# Introduction/Objective

- A personal perspective of how we got here – the design process
- Share some information about the use of FEA in the analysis of contacts
- Not a detailed introduction to FEA
- Educate/inform
- This is not a recommendation of any specific software package
- BUT MOST OF ALL
  - my objective is to be interesting and to stimulate you to think about the design process, and to have some fun

# BiTS and FEA

- A review of the BiTS archives shows only one paper on FEA - from 2001 titled:.

  "A Finite Element Analysis of Solder Balls on BGA Package in Sockets During Burn-in"

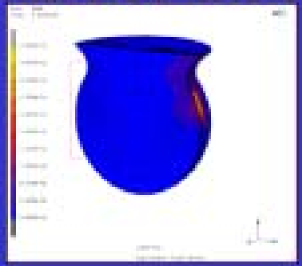
  by Al Sugarman and Ariane Loranger

- The presentation examined the complex interactions between contacts and solder balls at burn-in temperatures.

# BiTS and FEA

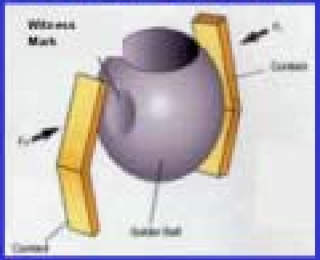
- **Result from Sugarman and Loranger**

## FEA OF DOUBLE ARM TWEEZERS STYLE CONTACTS



Two arm tweezers design. Total Strain after 42 days (1/2 Model)

Two arm tweezers design. Model used for FEA of double tweezers design



Schematic of two arm tweezers style contact.

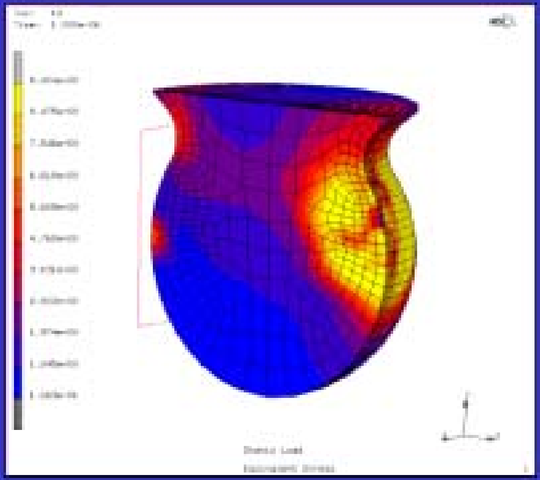


Figure 7. Two arm tweezers design (1/2 Model). Equivalent Stress Static Load at 0 hours and 125°C.

Slide 12

# But First ......
# Let’s take a Few Steps Back

- **What is Design - and how do we “Do it”?**
- **Man has always strived to leave his impact on the “landscape”.**

  **“Man is a singular creature... he is not a figure in the landscape - he is a shaper of the landscape. In body and mind his is the explorer of nature, the ubiquitous animal who did not find but has made his home in every continent." - Jacob Bronowski**
- **Lets examine a few examples ........**

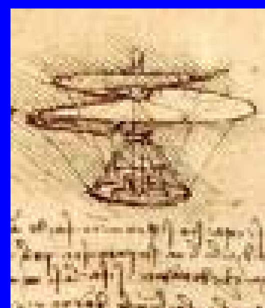
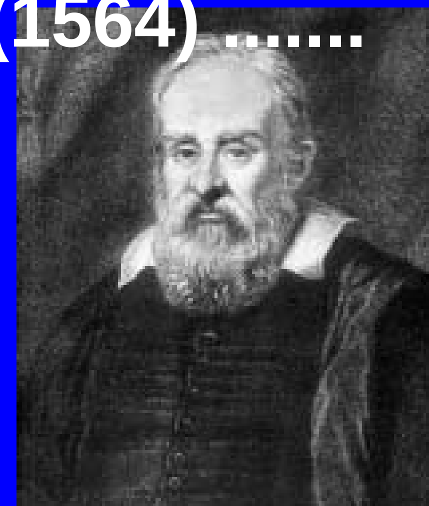
# Early Attempts

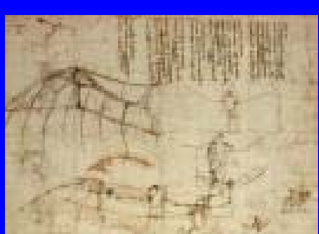
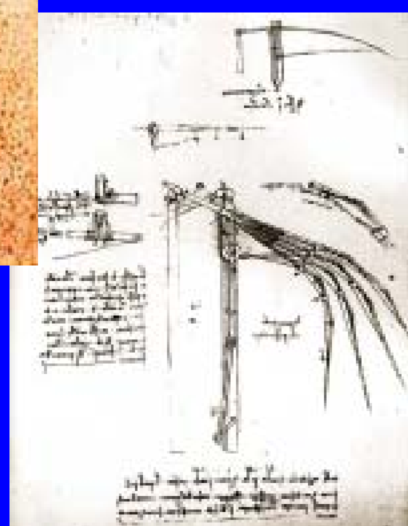
- Man's earliest designs focused on monuments, housing and weapons – This was survival




# Development of Science
# - an Understanding of Materials

- **The beginnings of science and understanding Da Vinci (1452), Galileo (1564) …….**

# An Understanding of Materials


- **1676 - Robert Hooke**

  **The birth of "elasticity" and the understanding of material properties.**

  **Proposes the relationship between force and extension of a spring.**

$$e = f.(F)$$

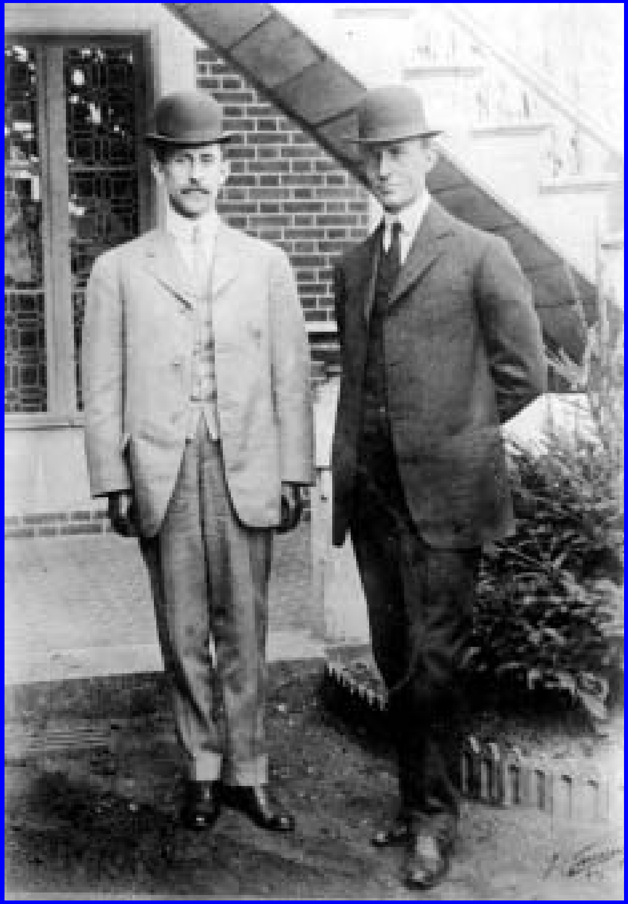
- **1804 - Thomas Young**

  **Extended Hooke's law into the universal realtionship between stress and strain**

$$\sigma = E.\varepsilon$$

# The Development Process
# - Correlating Experiments and Theory

- 1896 to 1903 The Wright brothers



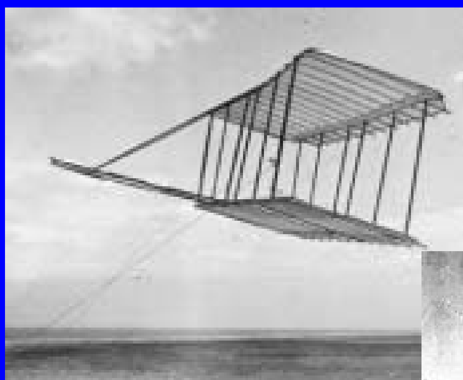
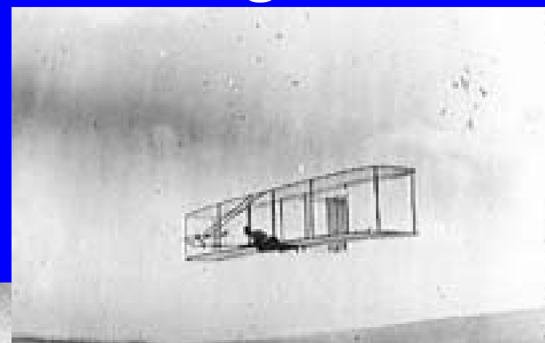
Developed a formal approach to understanding the relationship between science and engineering.

Perhaps the first "Research and Development program"

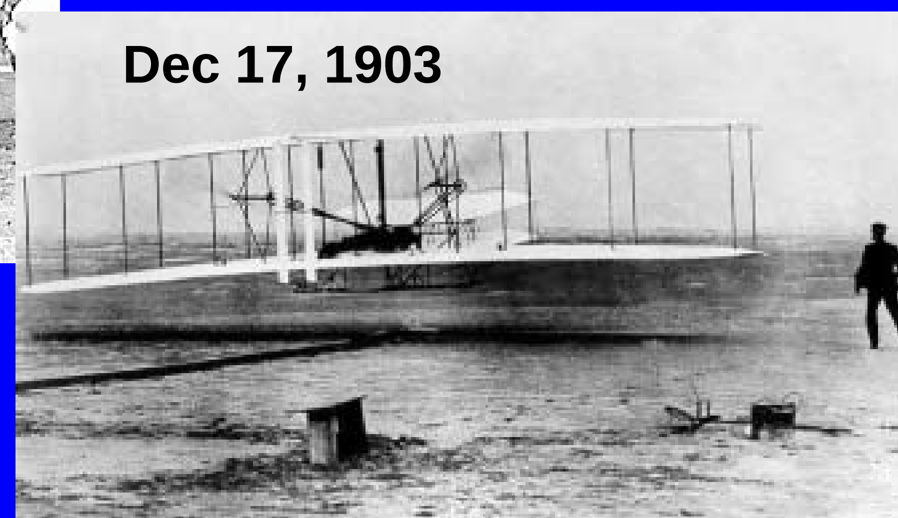
Built 3 gliders to understand "flight".

# The Development Process
# - Correlating Experiments and Theory

- **1896 to 1903 The Wright brothers development**



# The Impact of Education

- **Post World War era.**
- **Formal education of many people in sciences and math enabled the creation of the "Design Engineer"**

# The Impact of Analysis on Design

- **Kelly Johnson and the Lockheed Skunk Works**

**Intuitive but the broad understanding of design and strength of materials led to "analysis" of designs before parts were made.**

**The engineers tools were still simple**

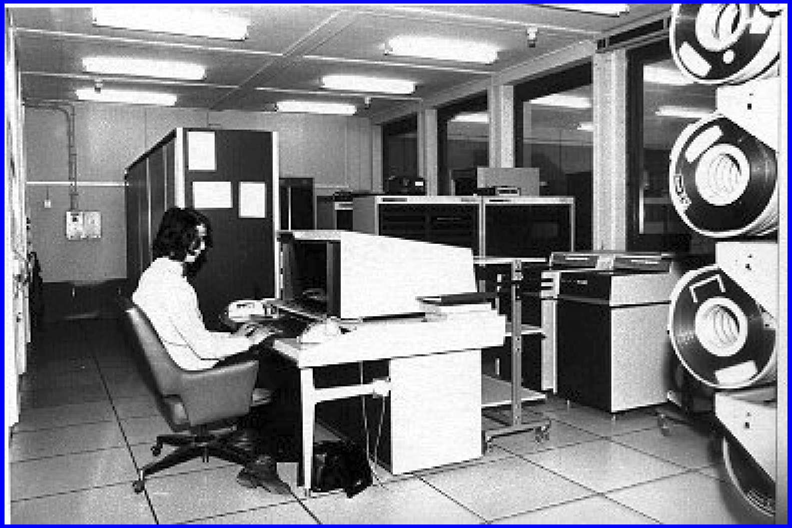
# The Design Engineer

- The 1950's
- Rooms of design engineers –
- Tools - slide rules and log tables - laborious hand calculations of stress and strain

# The Design Engineer’s Tool


# The Impact of Computers

- Development of powerful mainframe computers allowed thousands of “calculations”.
- Some design engineers used this new tool to analyze complex problems.
- The Finite Element Method is developed
- But computers are expensive and difficult to use



# The Analyst is Born .......

- The analyst
  - Often a math or engineering graduate
  - Capable of integrating the complex interface between problem definition, the mathematics of a classical solution and the computer language
  - Punched cards for input
  - A stack of pages and pages of “green bi-fold” – The output with rows and columns of numbers.

# The Personal Computer

- Put massive computing power and analytical capability on every desktop.
- Development of GUI (Graphical User Interfaces - Windows) and analytical software removed the last barriers between complex mathematics and easy to use software and  graphical representations of the solution.
- 3D Design software and FEA programs enable users to perform complex calculations without a detailed understanding of the “code” behind the user interface.

# The cost of FEA in the 1970's

- "In inflation adjusted dollars, a PC capable of FEA can be purchased for the commercial price of ONE run of an FEA analysis on a scientific mainframe in the late 1970's.

  ……….

  That doesn't even begin to discuss the difficulty of the output of results. You almost needed a hard hat to wear around the stacks of printout that could accumulate"

  - Peter Budgell – FEA Consultant

# The cost of FEA in the 1970's

- In 1968 a typical UNIVAC 1108 - a 1.3 MHz CPU with half a megabyte of RAM and 100 megabyte hard drive cost $1.6 million.
- Oh, and you want a printer too...?

- Shipments of the IBM's new 3031 processors begin in the first quarter of 1978.
- The new 3031 processor complex with two million characters of main memory, can be leased for $25,000 monthly.

  Purchase prices are $1,000,000, .... to .... $1,345,000

# What is FEA? – (Conceptually)

- FEA is a numerical analysis technique used to solve engineering problems for structural and field applications.
- The objective of FEA is to break a complicated structure into small, easy to analyze segments, called finite elements.
- Each element is formulated to obey the governing physics using numerical computational techniques.
- The elements are assembled into a matrix of algebraic equations. This matrix is solved computationally.

# What is FEA? – (Practically)

Typically - FEA software consists of three steps:

- Pre Processing,
- Analysis,
- Post Processing.

# What is FEA? – Pre Processing

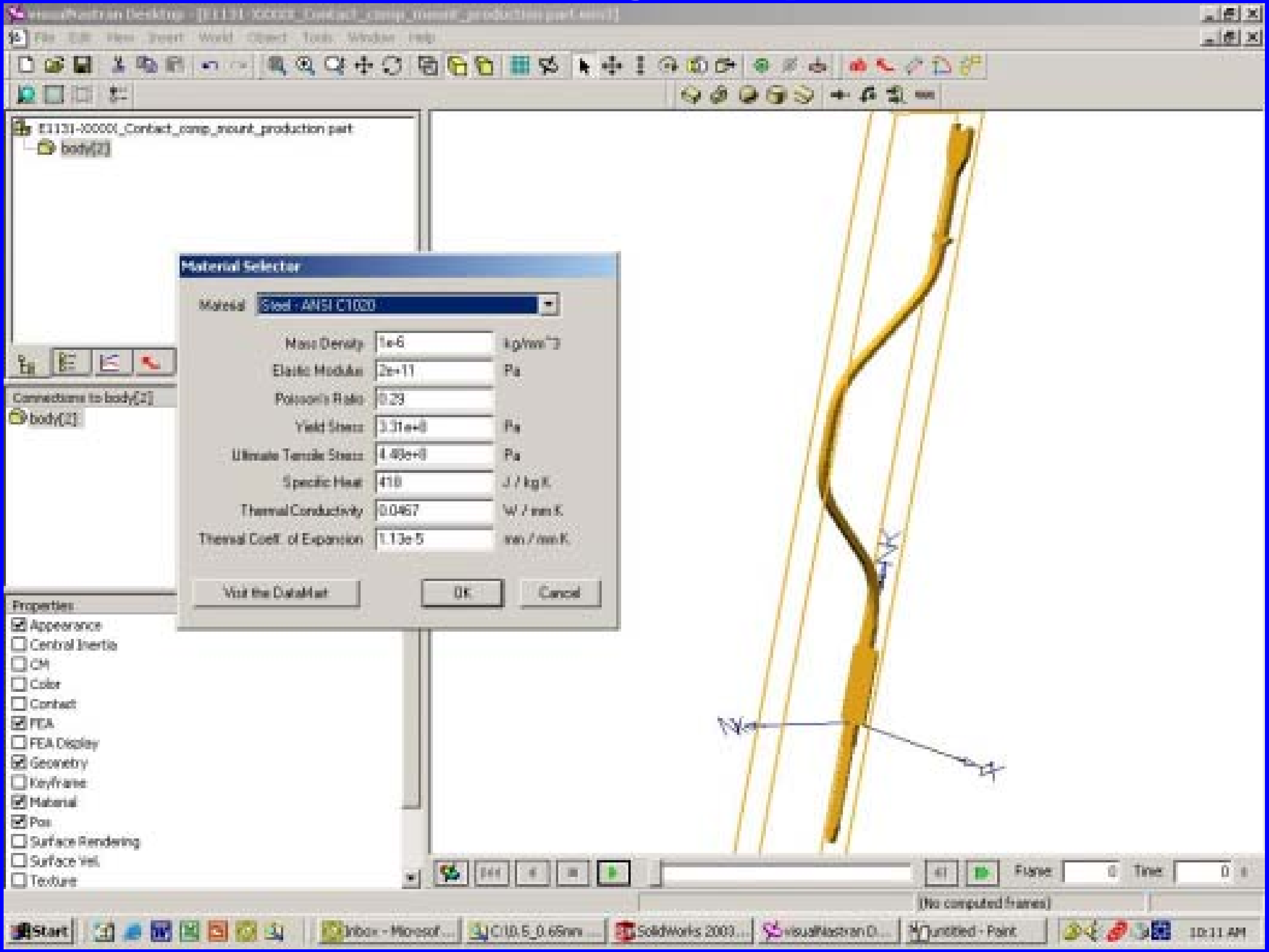
## Pre Processing includes

- Geometric modeling, mesh generation –
- Application of the boundary conditions and the load
- Assigning material and geometric properties.

| Material | BeCu C17200HT | |
|---|---|---|
| Yield strength | 1200 Mpa | 174 ksi |
| Tensile strength | 1300 Mpa | 200 ksi |
| Modulus of Elasticity | 130 GPA | 17 msi |

# Pre Processing
# – Assigning Material Properties

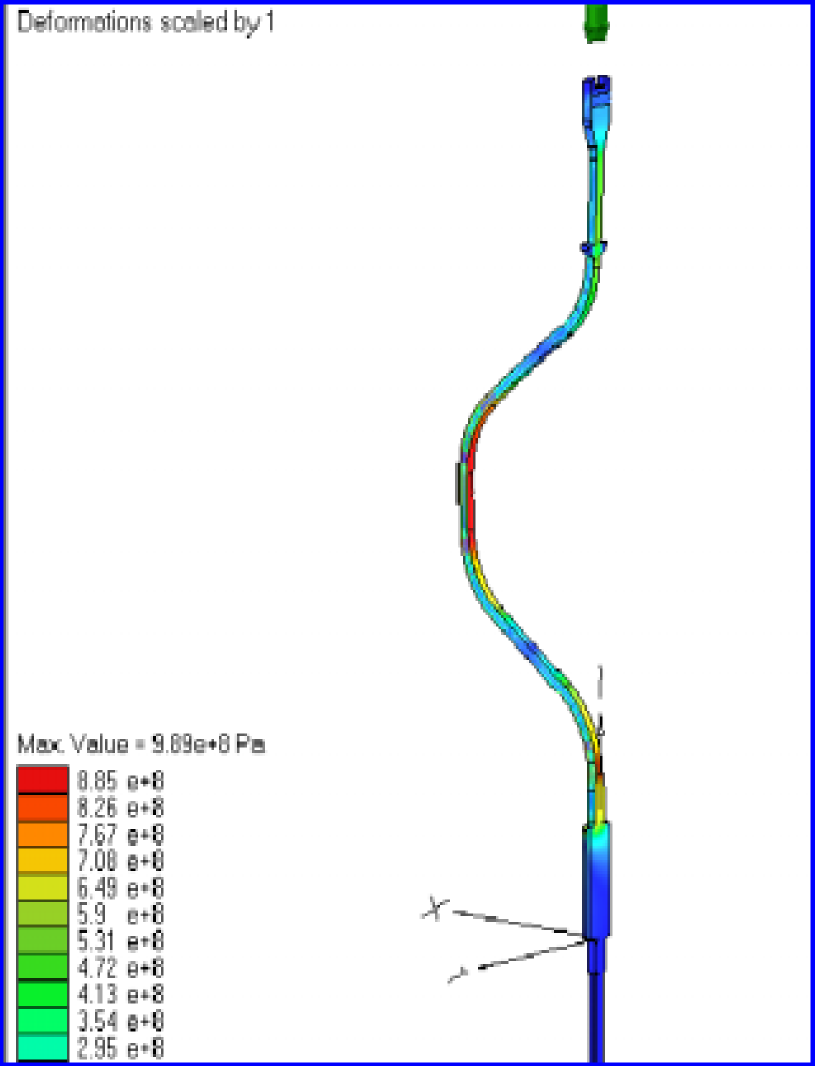
**Image of screen as designer performs analysis.**



# What is FEA? – (Analysis)

- Analysis portion of the FEA process is the most complex with applications such as:
  - Structural
  - Thermal
  - Electrical
  - Magnetics
  - Fluids

# What is FEA? – (Post Processing)




- <u>Post Processing</u> Displays the results in graphical form such as
  - contour plots,
  - animated “movies”,
  - XY - data plots, etc..
- This improves communication of the results with customers, suppliers, other engineers and management

# The Language of FEA

- **Those "experienced" in FEA understand the meaning and significance of**

| | | |
|---|---|---|
| **plane strain** | **lagrangian** | **criteria** |
| **total lagrangian** | **yield criterion** | **Plasticity** |
| **stress strain** | **convergence** | **von mises** |
| **elastic modulus** | **eigenvalue** | **damping** |
| **symmetry** | **linear vs non-linear** | |
| **cyclic symmetry** | **element** | **Eigenvector** |
| **plane stress** | **axisymmetric** | **structural** |
| **tangent modulus** | **lagrangian** | **updated** |

**tetrahedral vs hexahedral element**

**and ...........**

# What Do I Need to Know to do FEA?

- Do I know my product - what it's designed to do, and the environment in which it performs?
- Do I know what tools are applicable to simulate my product and its environment?
- Do I know the extent to which the tools I've chosen can simulate the "real world"? (Linear, nonlinear, coupled physics ??)
- Have I correlated the computer simulation with testing to validate my tools and modeling procedures? (Are the results any good??)

# Why FEA?
## Product Development – Prototyping

- What you see is what you get.
- Easy to move from prototype to production.
- Time consuming.
- Expensive.
- Difficult to optimize a design or manufacturing process.
- Usually the outcome is a “pass” or “fail”.
- Not much insight in the “reasons” that lead to failure.

# Why FEA?

## Product Development – FEA Simulation

- Results depend on quality of input data and user expertise. What you see may, or may not be what you get.
- Faster than prototyping.
- Less expensive than prototyping.
- Enables the engineering (hence optimization) of a design or process.
- Gives insight into why it “passes” or “fails”
- Allows for numerous “what if” studies.
- Helps in the understanding of the physics involved in the particular application.
- Can be fine-tuned with prototype/testing results.

# FEA at the Click of a Button

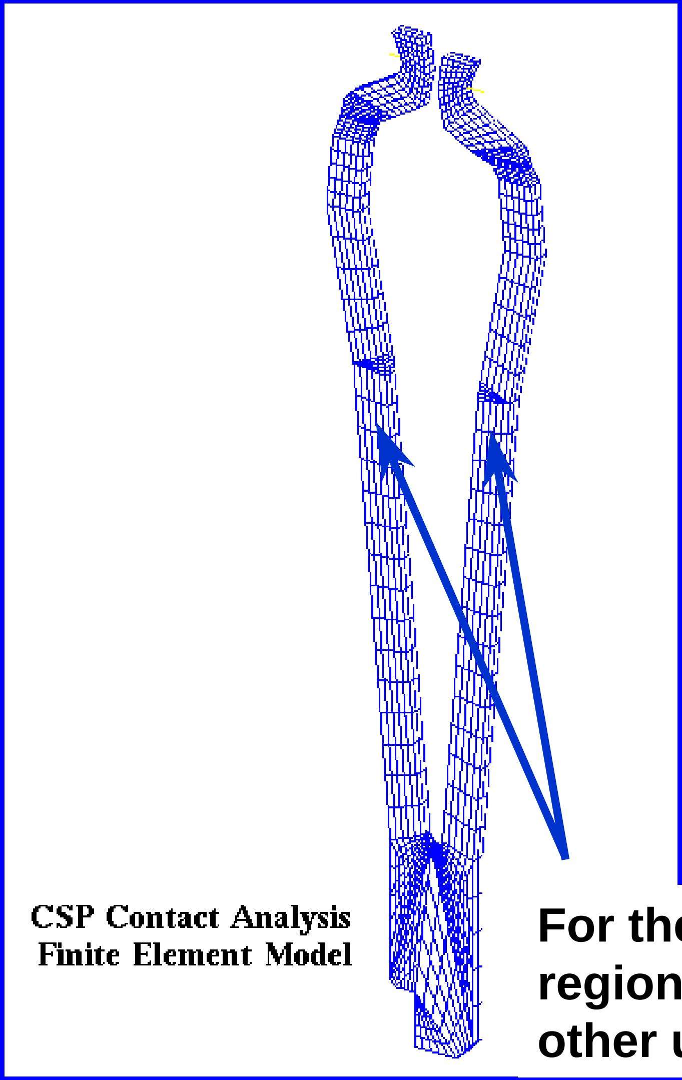
- **Recall - FEA is an approximation and consists of three steps:**
  - **Pre Processing,**
  - **Analysis,**
  - **Post Processing.**
- **Originally these were distinct separate steps with different software packages to help the analyst.**
- **Today with software packages such as Nastran, CosmosWorks, which can be "linked" to 3-D design software, this is done at the click of a button**

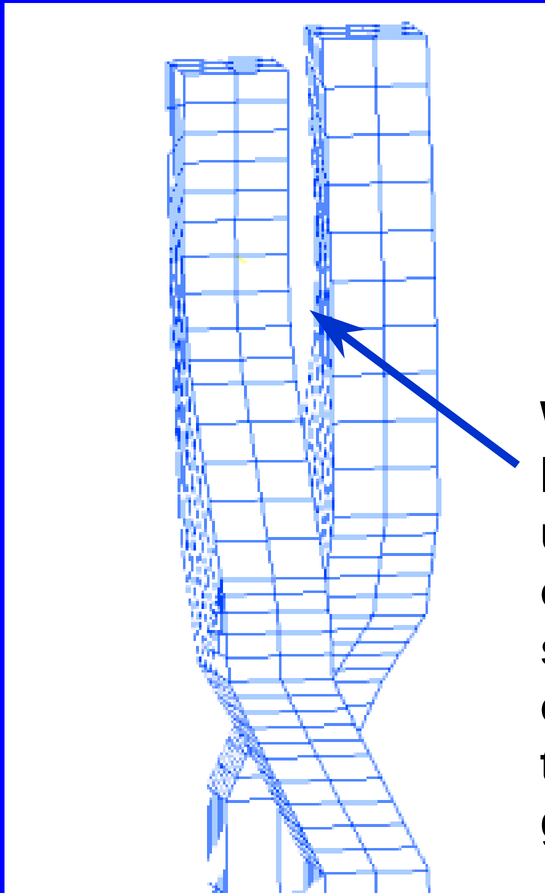
# What Can Go Wrong?

- FEA is an approximation
- Important to understand and select an appropriate analysis - Linear or non-linear.
- The software does not make this decision
- For example if:
  - Material properties are not constant (Non linear behaviour or part yields)
  - The force/load orientation changes
  - Physical movement (contact moves)
- Then the analysis must be Non-Linear or significant errors will be introduced
- The FEA expert or analyst <u>MUST</u> be consulted on these problems.

# Some Examples

## CSP Dual Pinch Contact – The Model



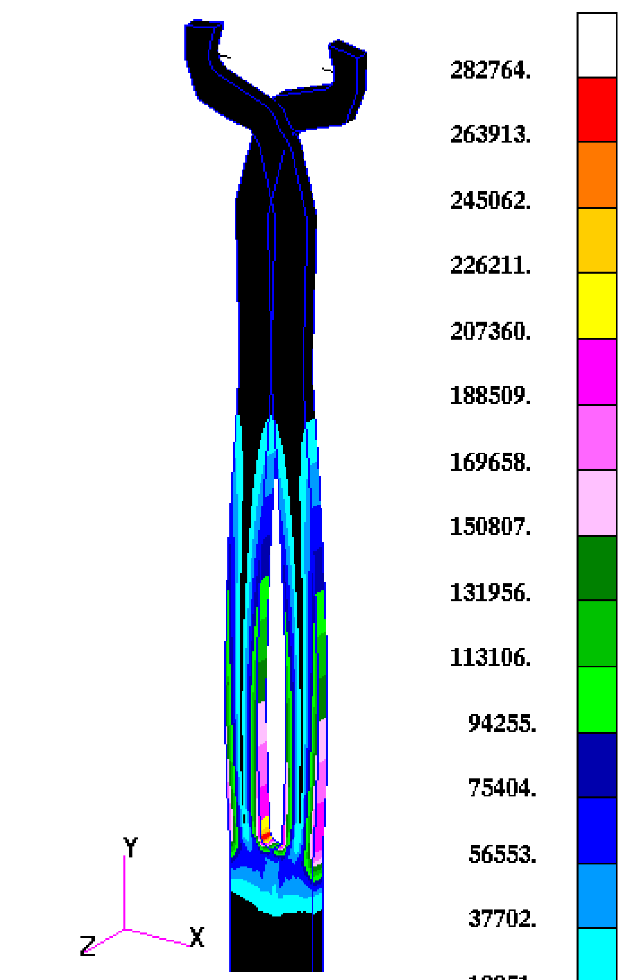



When fully loaded, the upper portions of the contact slide past each other due to the offset geometry.

For the "Maximum Stress Case", these regions are displaced towards each other until self contact develops.

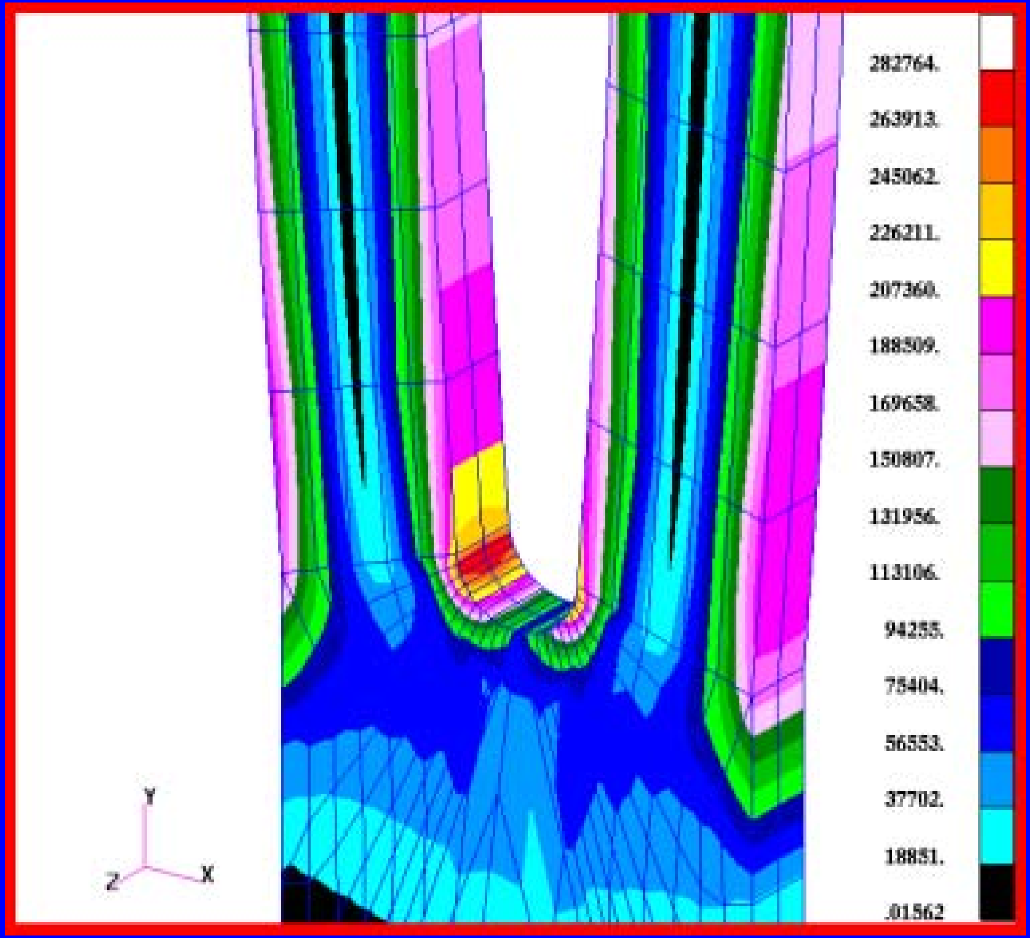
# Some Examples

## CSP Dual Pinch Contact – Linear Analysis



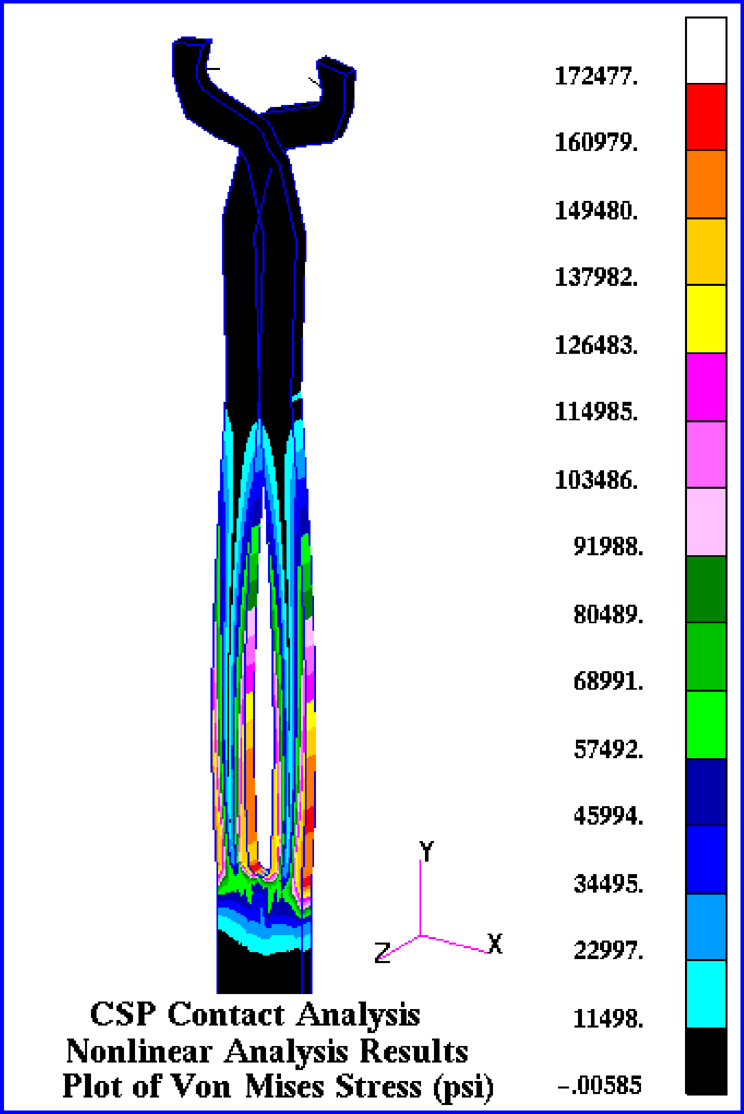

CSP Contact Analysis
Plot of Von Mises Stress (psi)

**Max. stress 282,764 psi**

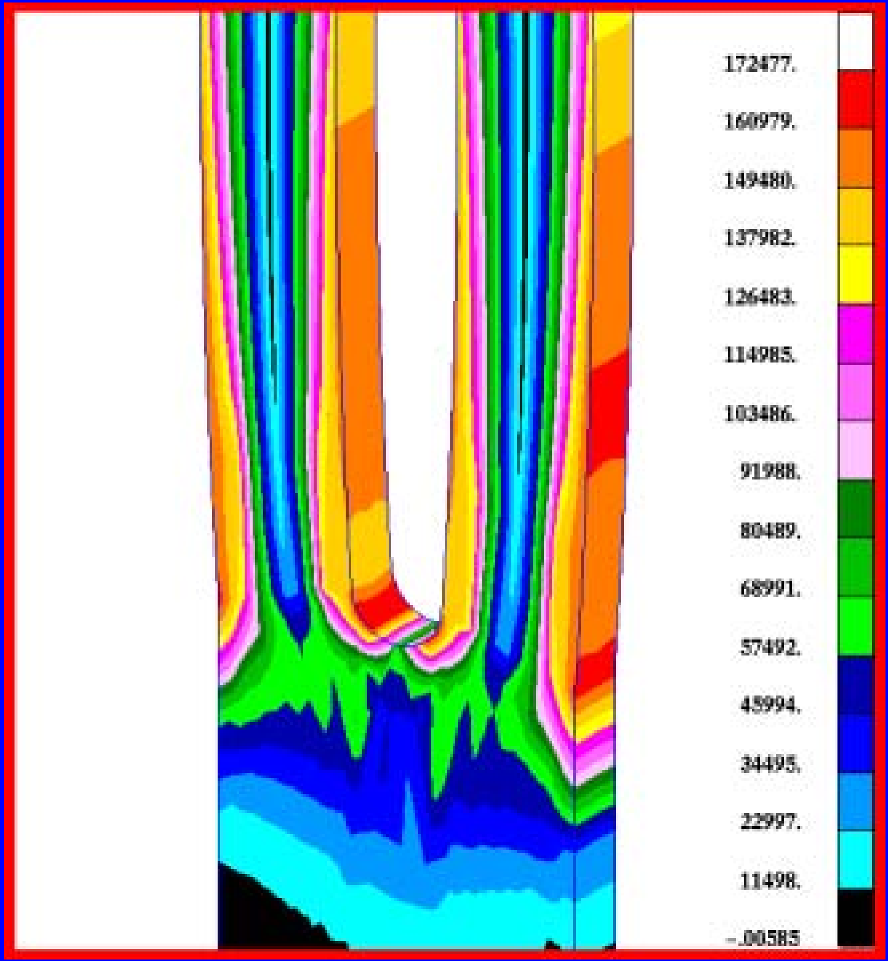


# Some Examples

## CSP Dual Pinch Contact - Non Linear Analysis



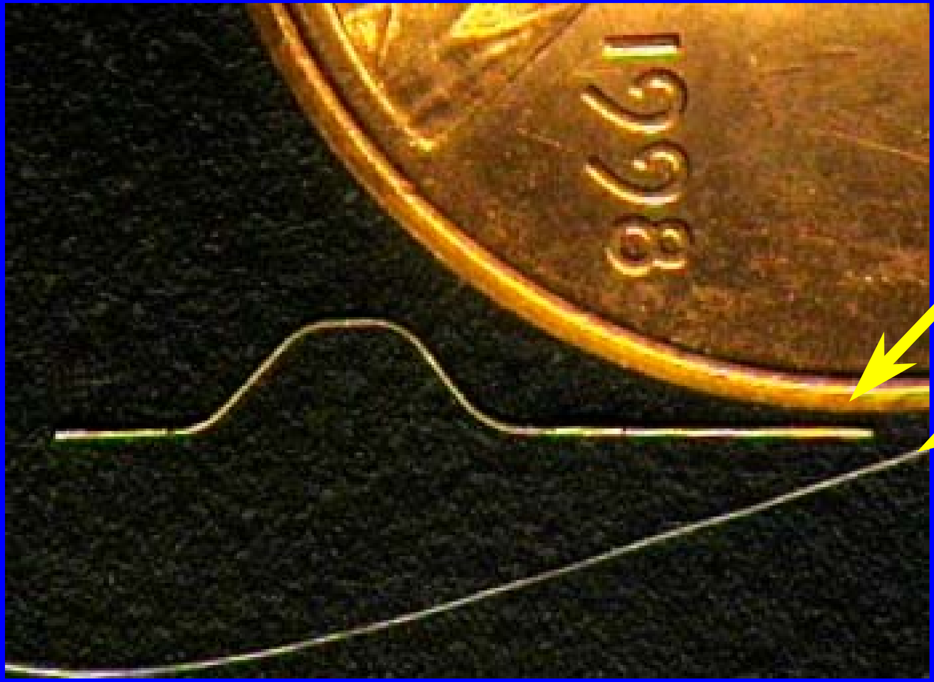

**Max. stress 172,477 psi**



# Some Examples

## 0.5 mm Pitch CSP Buckling Beam Contact

- FEA Allows analysis of “difficult-to-handle” micro-miniature parts
- Prototyping development virtually impossible.

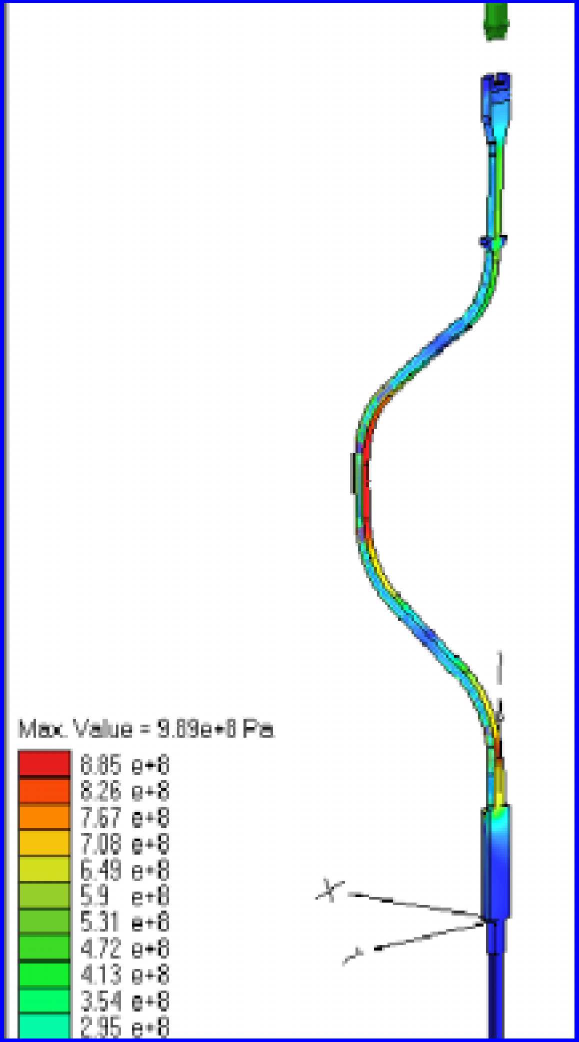



Contact

Human hair

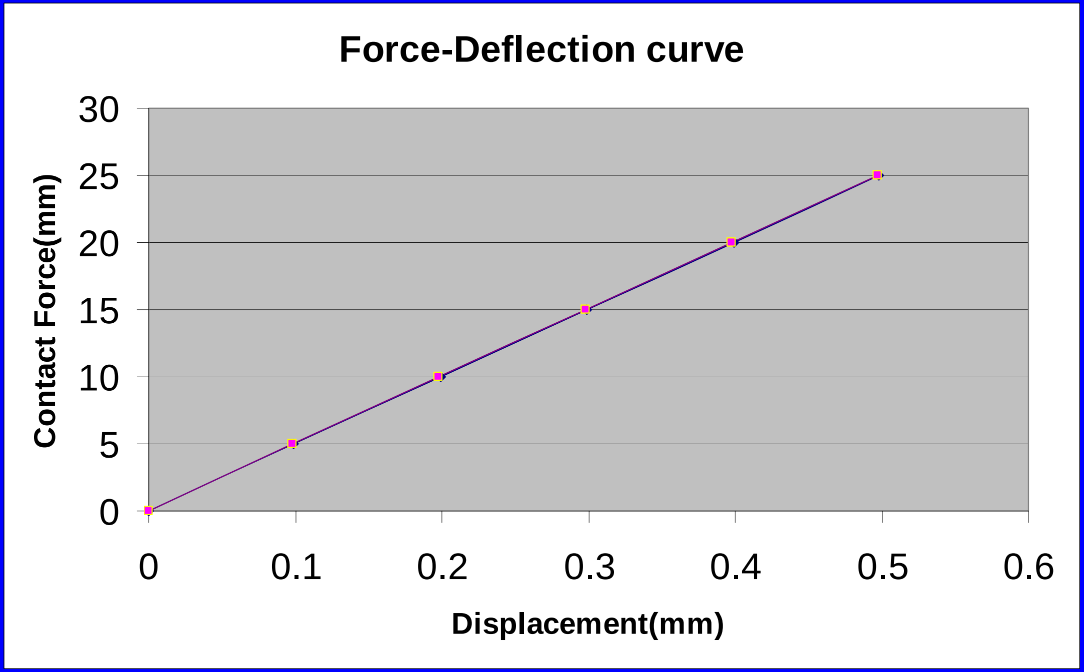
# Some Examples

## 0.5 mm CSP Buckling Beam Contact – Linear

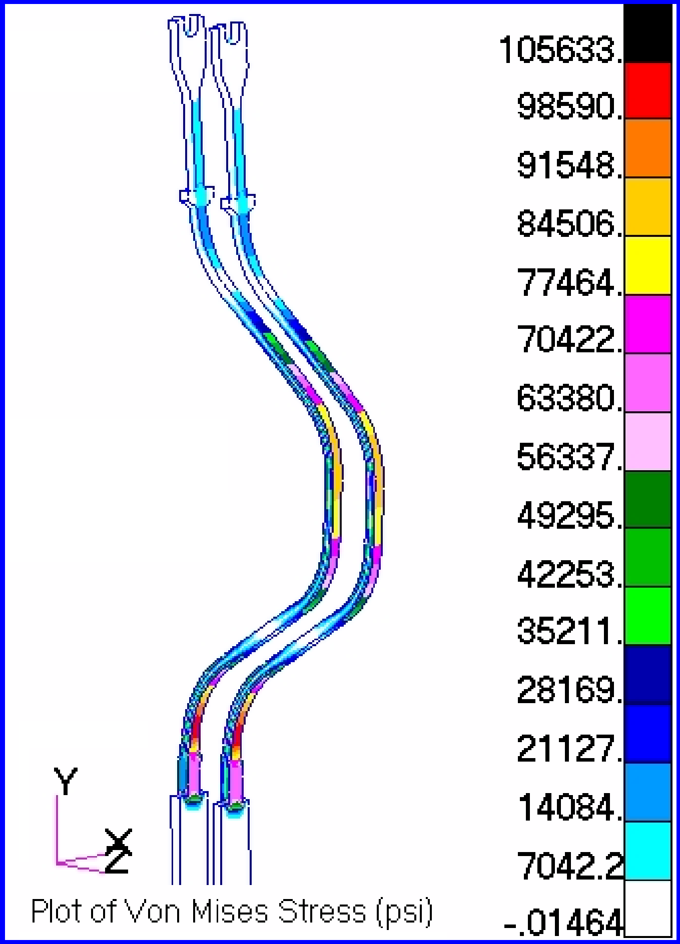



# Results

- **Maximum stress 143,000 psi**
- **Force /deflection curve**

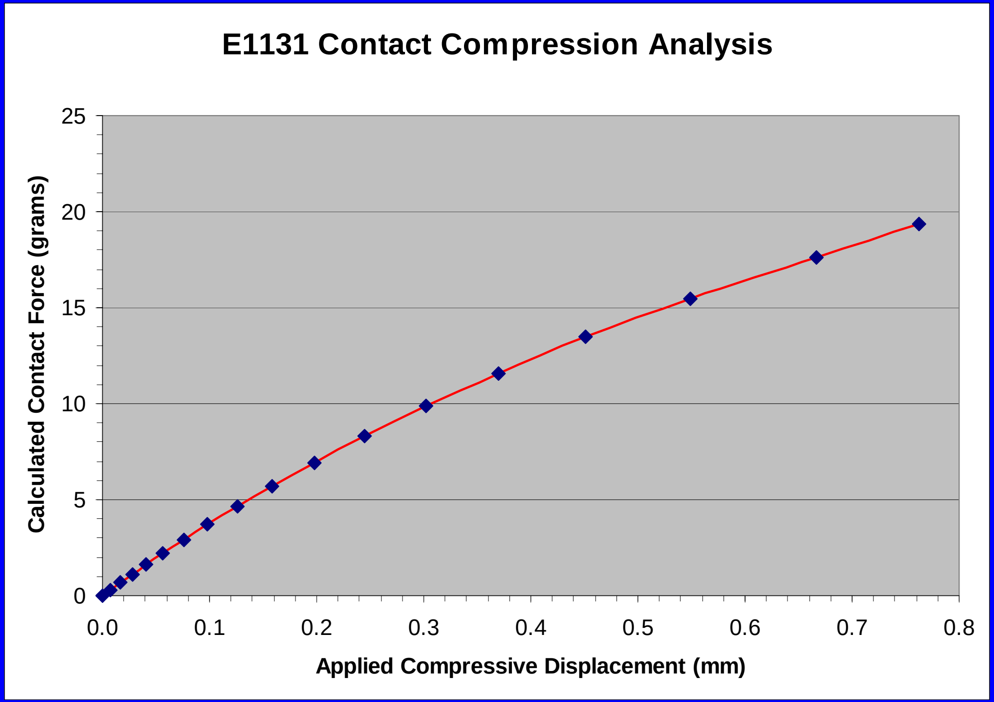


# Some Examples
## 0.5 mm CSP Contact - Non Linear




# Results

- Maximum stress 106,000 psi
- Force /deflection curve



# Some Examples

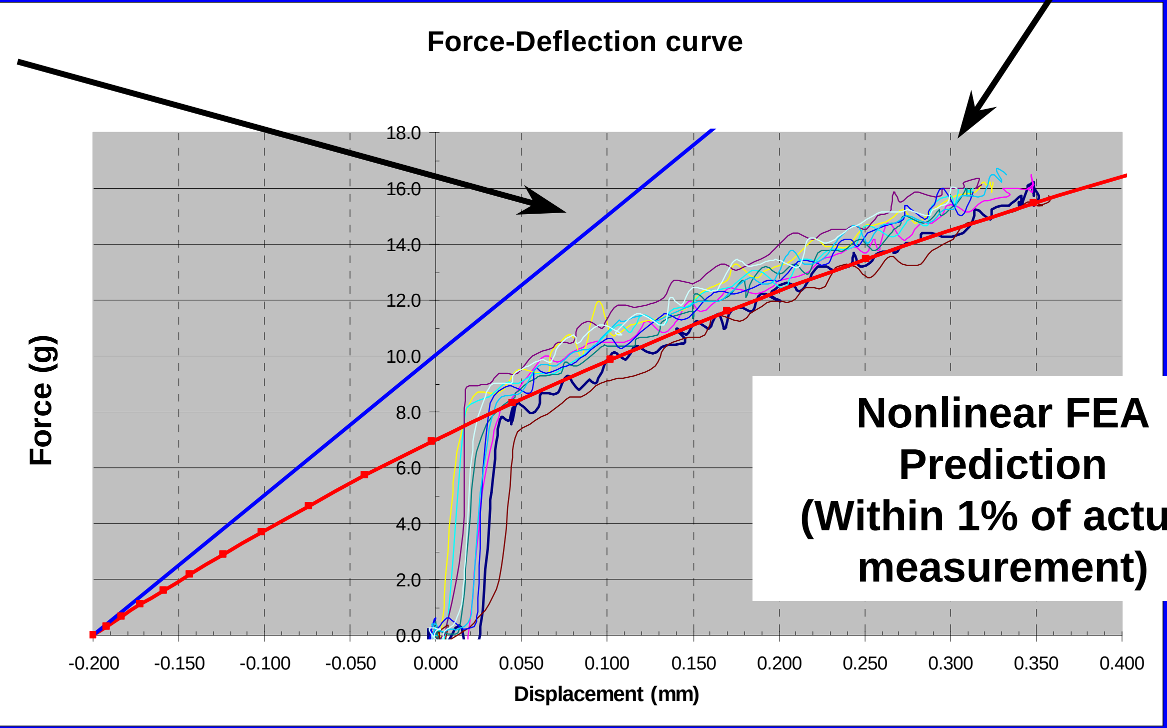
## Comparison Linear/Non Linear/experimental

### Results

- Maximum stress linear 143,000 psi
- Maximum stress non linear 106,000 psi
- Force /deflection

Linear Analysis prediction results in erroneous first pass approximation. Further Iterations would likely not converge to optimal design.

Test Data




Nonlinear FEA Prediction (Within 1% of actual measurement)

# Closing Comments

- FEA is a tool which has revolutionized the world of design
- Care must be exercised to ensure that the results are meaningful
- Garbage in – Garbage out.
- Our understanding is imperfect - mistakes will still happen.
- Attempt to verify predications whenever possible.
- "It is difficult for outsiders to assess whether FEA work is being done effectively".

  - Peter Budgell (FEA Consultant)

# Chips on Fire, New Approach to Thermal Management

**Kevin Moody,** presenter

**Kulicke & Soffa**
**3191 Corporate Place**
**Hayward, CA 94545**
**Ph: (510)259-5050**

BURN-IN & TEST SOCKET WORKSHOP

# Overview

**Introduction**

**Thermal Management System**

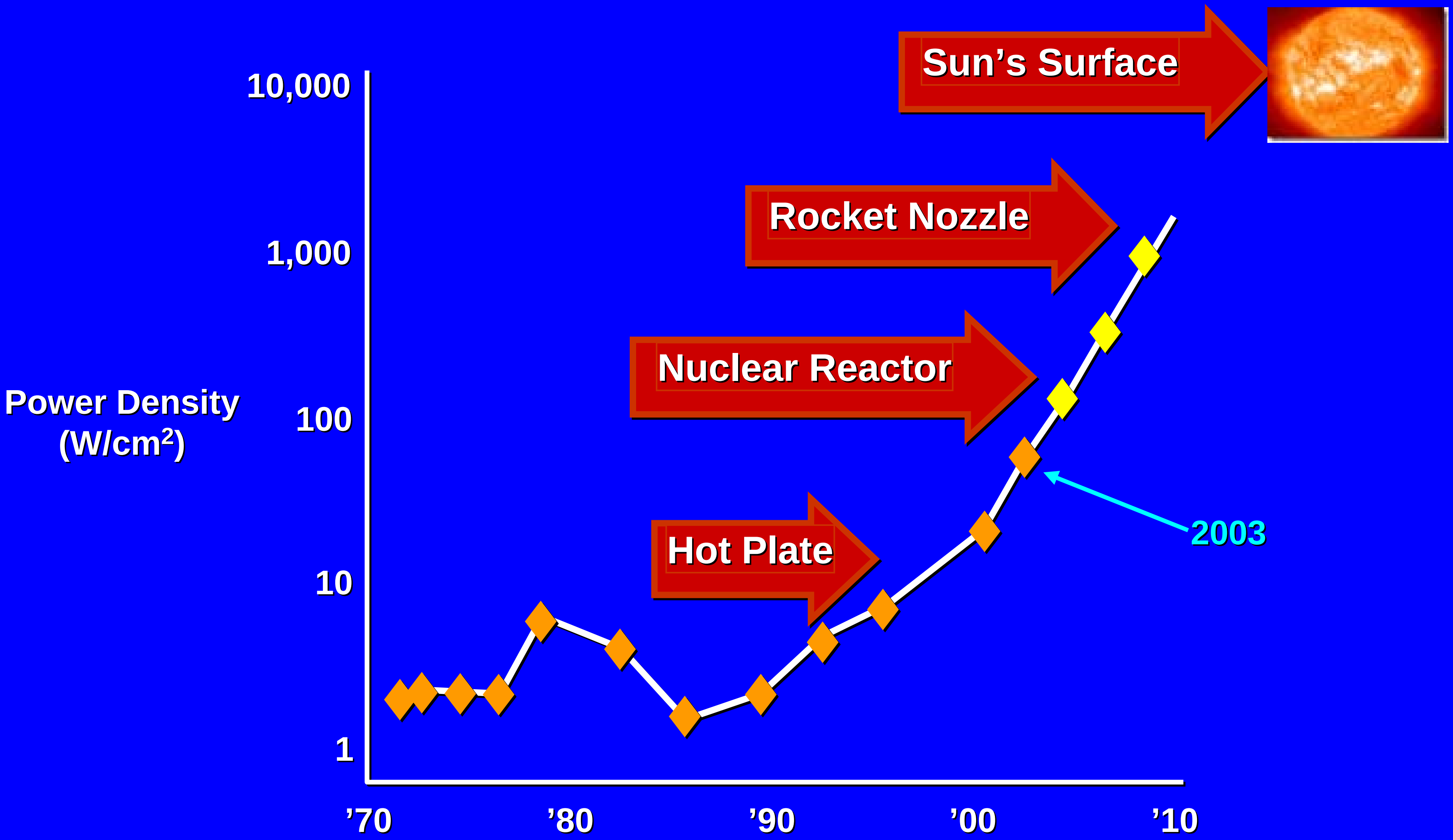
**Test Results and Discussions**

**Summary**

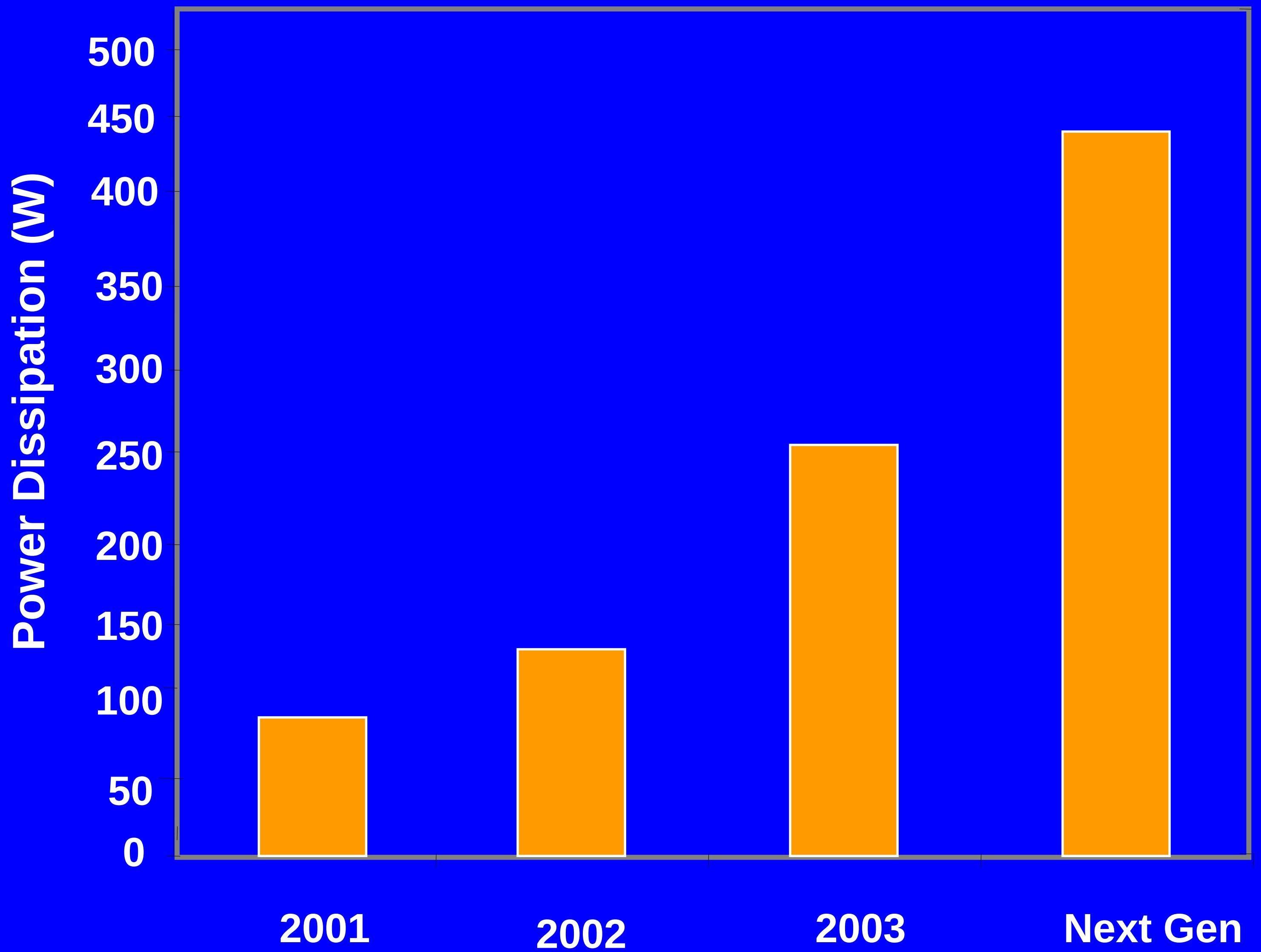
# Introduction

- Two Die Sizes
  - Large Die: Integrated Heat Spreader (IHS)
  - Small Die: Bare die
- Large Die Challenges
  - Power is increasing
  - Die size is increasing (spreading resistance issues)
- Small Die Challenges
  - Power is increasing
  - Die size is decreasing (power density issues)

# Power Density Trend



# Power Dissipation



# System Integration

- The K&S thermal control system features compact size and small footprint that makes it easy to integrate with system level testers and handlers, and provides straightforward maintenance

**K&S Thermal Management System**

***System Level Tester***

***Automated Handlers***

***Lab Testing & Debug***

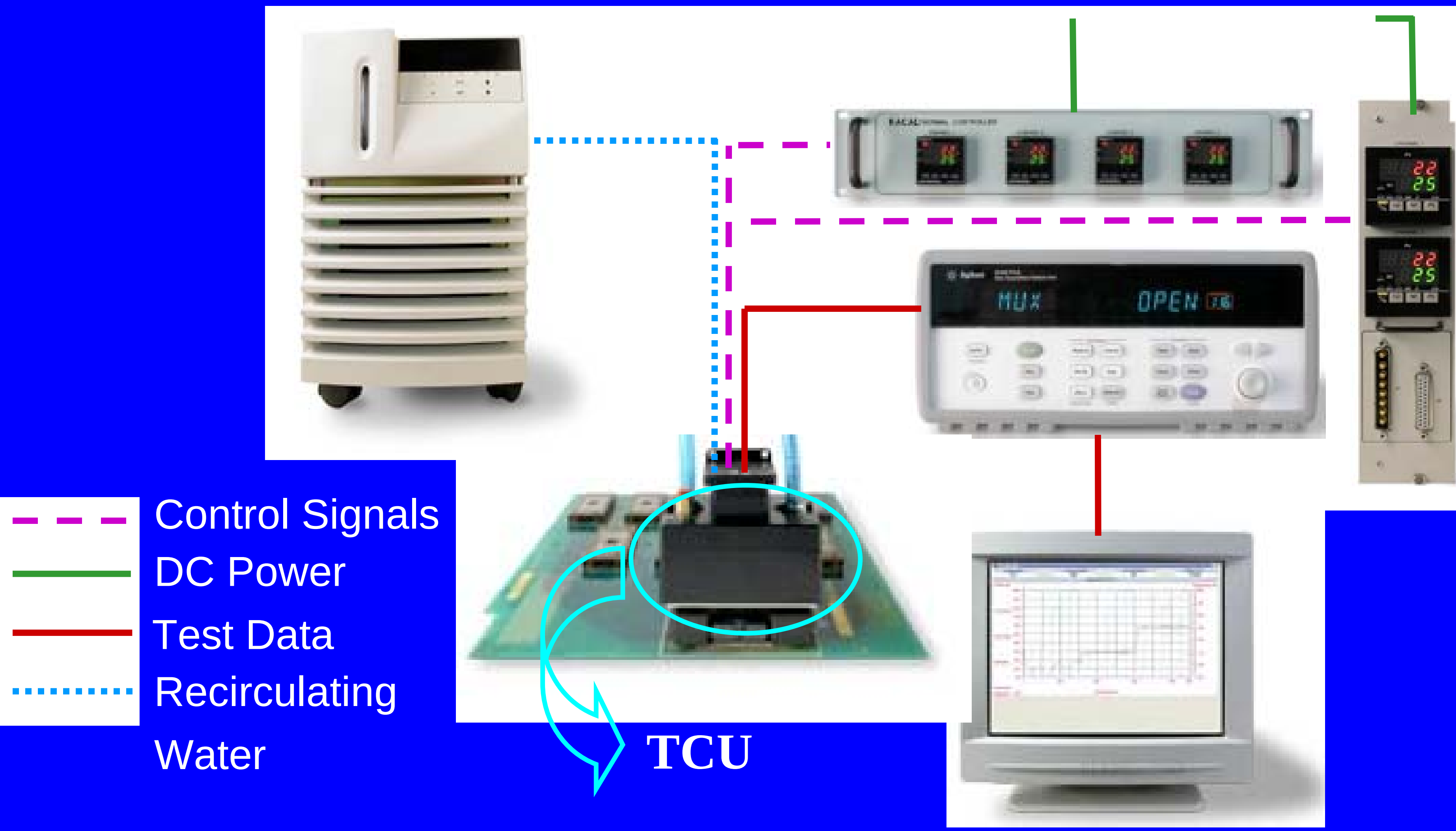
# Thermal Management Options

| THERMAL MANAGEMENT METHOD | ACCURACY & STABILITY | TEMP RANGE | THERMAL EFFICIENCY | DYNAMIC RESPONSE | COST | ENVIRONMENTAL & ERGONOMIC ISSUES |
|---|---|---|---|---|---|---|
| *Refrigeration* | Very High | Wide (Cool) | Very High | Very Fast | Very High | Yes |
| *TCE w/Liquid* | High | Wide (Cool & Heat) | Moderate-High | Fast | Moderate | Condensation (can be insulated) |
| *Liquid* | Low | Narrow (Cool) | High | Slow | Low | Condensation (can be insulated) |
| *Active Heat Sink* | Low | Narrow (Cool) | Moderate | Slow | Very Low | Noise & Vibration |
| *Passive Heat Sink* | Low | Narrow (Cool) | Low | Slow | Very Low | No |

# Thermal Management System

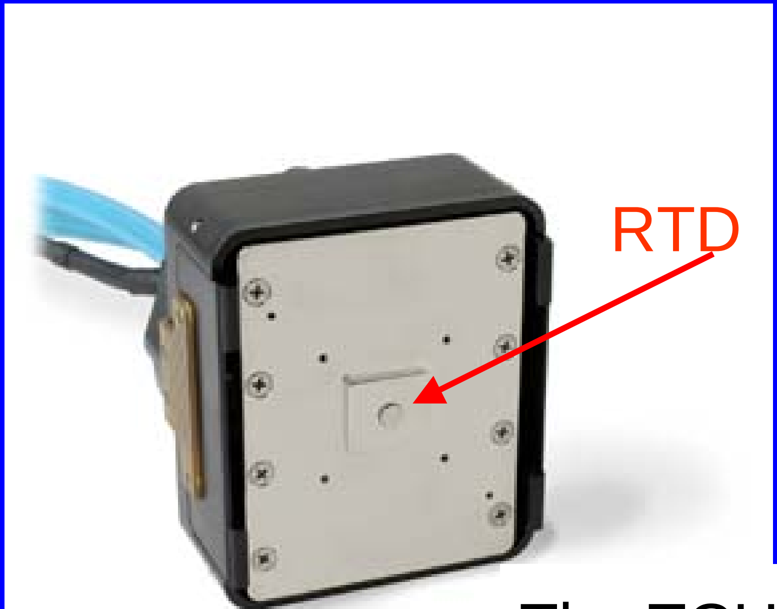
- The K&S Thermal Management System utilizes **Thermoelectric technology** in conjunction with active **liquid cooling** for rapid thermal cycling (heating/cooling mode) or to regulate a steady temperature during testing.

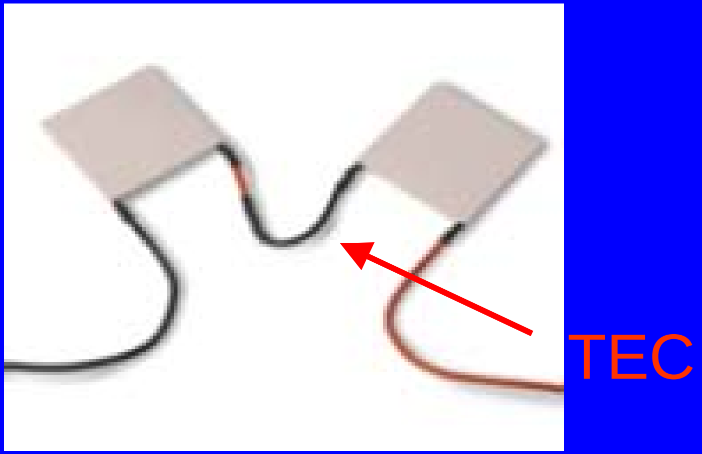
# Complete Thermal Management System




The heart of the K&S Thermal Management System is a Thermal Control Unit

# Thermal Control Unit

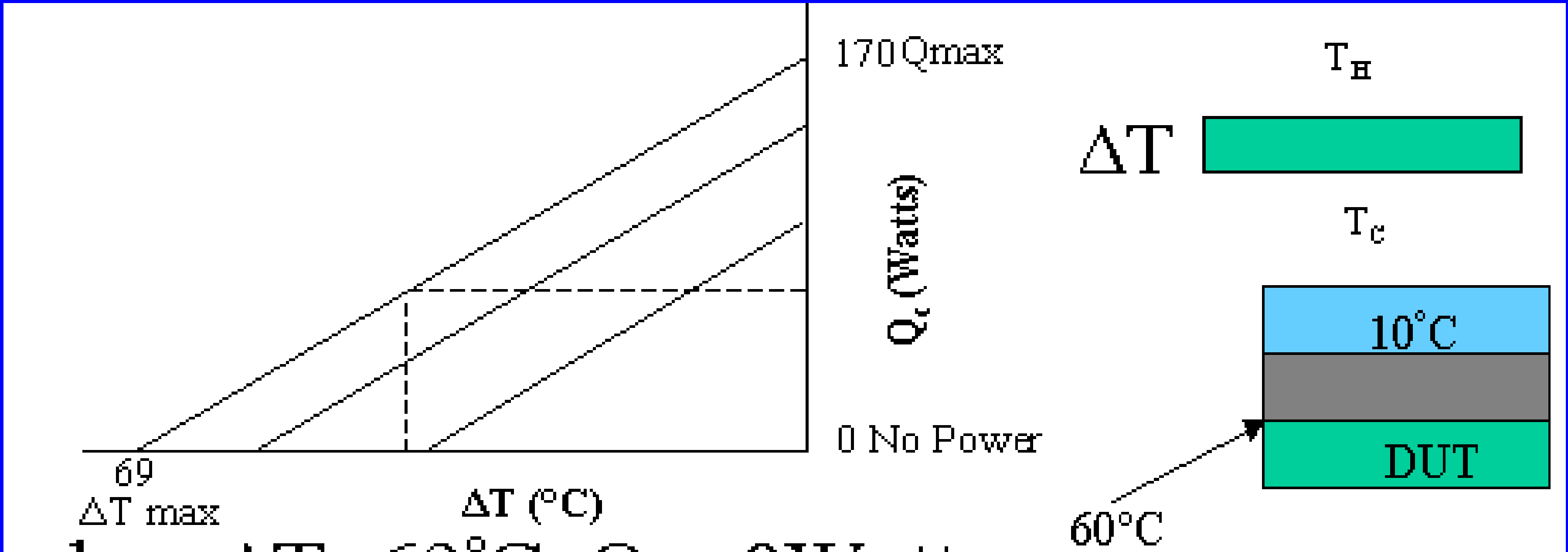



The TCU houses a Thermoelectric Cooler

Thermoelectric Cooling (TEC) employs Peltier Effect (cooling) and Joulian Effect (heating/$I^2R$) to convert electricity to temperature differential. Using the TEC in the heating mode is very efficient because net heat (Joulian plus DUT) is pumped to the hot side.

# Characteristic Curve Of a Thermo-electric Cooling (TEC)

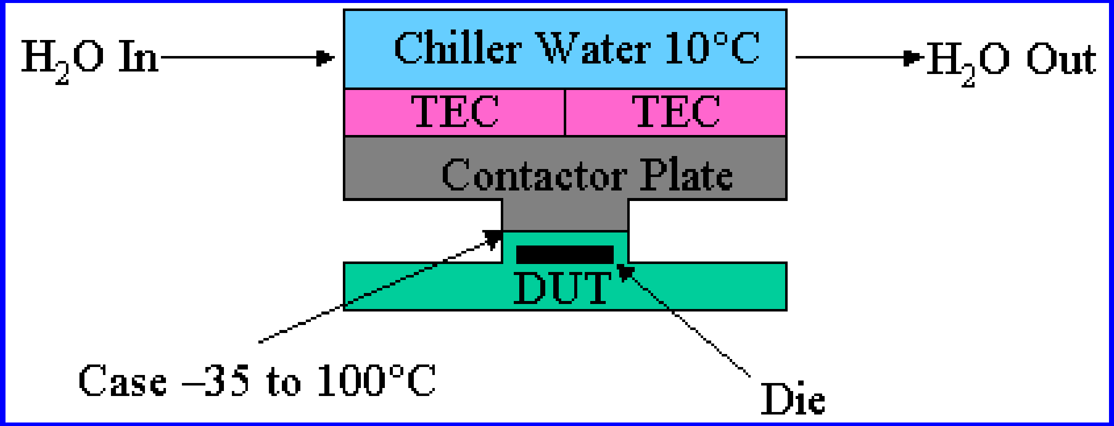



when $\Delta T = 69^\circ C$, $Q_c = 0$ Watts

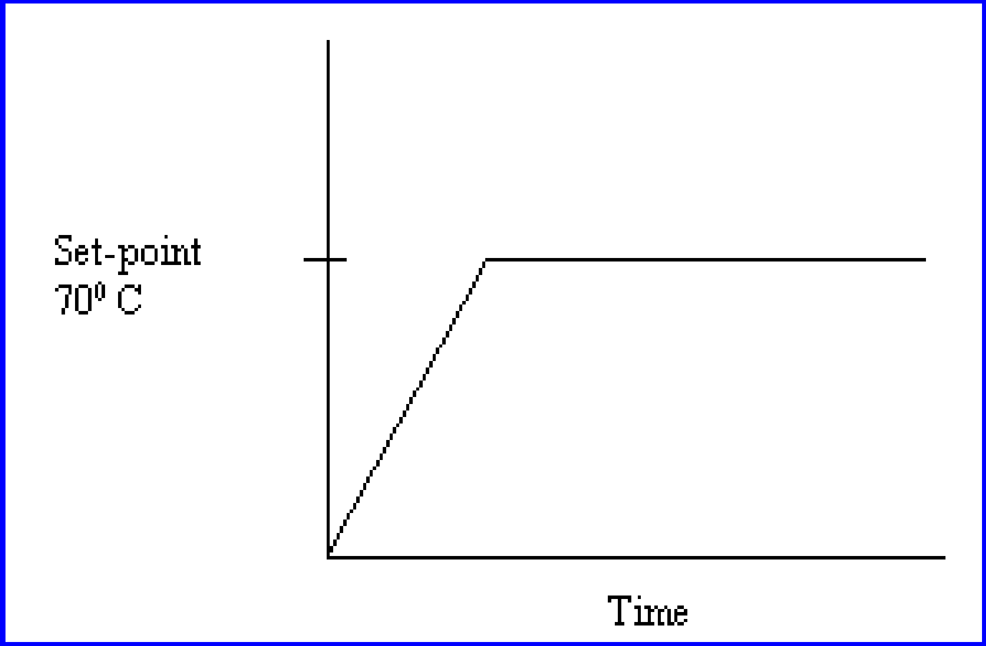
$\Delta T = 0^\circ C$, $Q_c = 170$ Watts

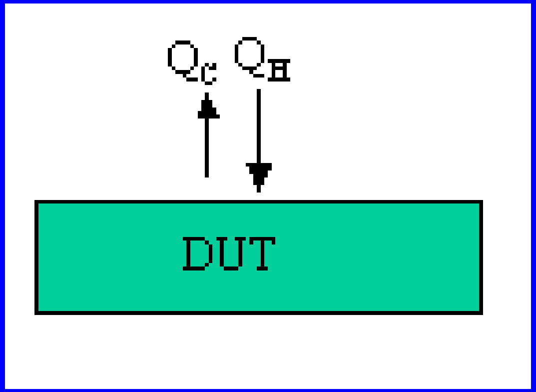
$\Delta T = 50^\circ C$, $Q_c = ?$

# TCU Function

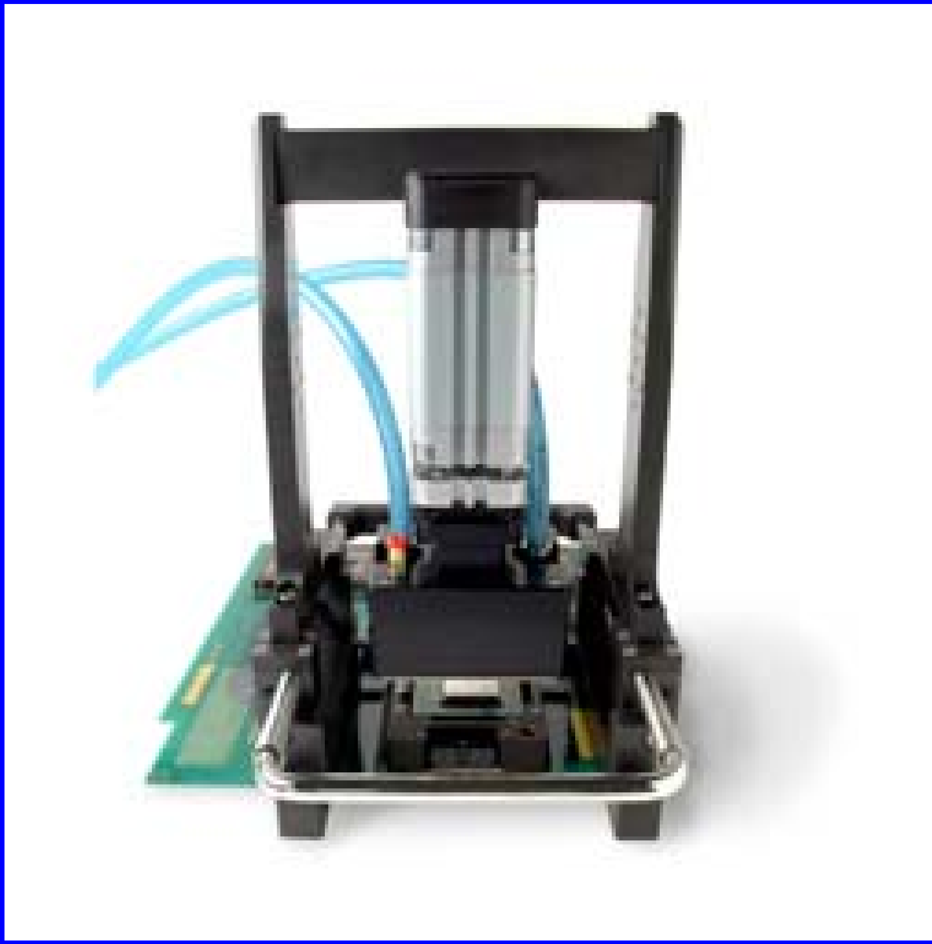



TECs **Extract Heat** from DUT in the **Cold Mode** operation and **Pump Heat** into the DUT in a **Hot Mode** operation



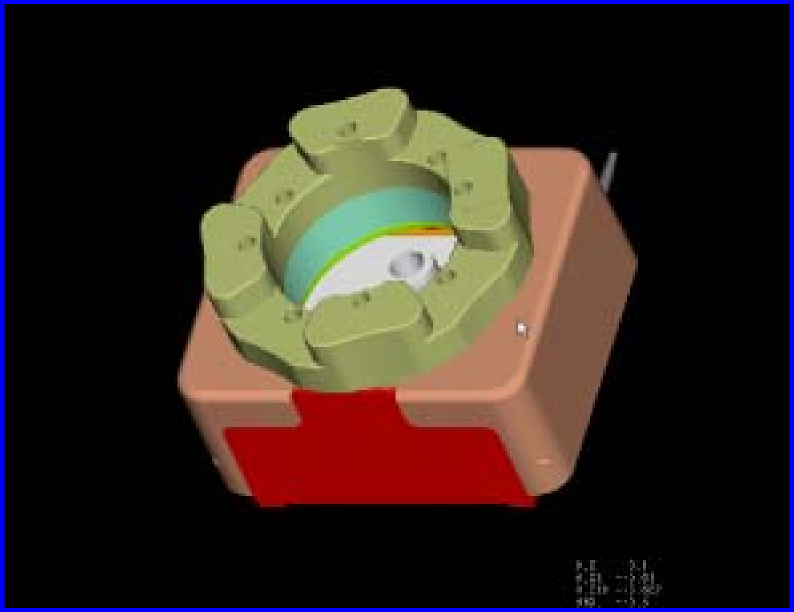



# TCU with Mounting Configuration



The TCU is also available in a mounting configuration for connection to an optional pneumatic actuator that provides automated application for higher throughput.

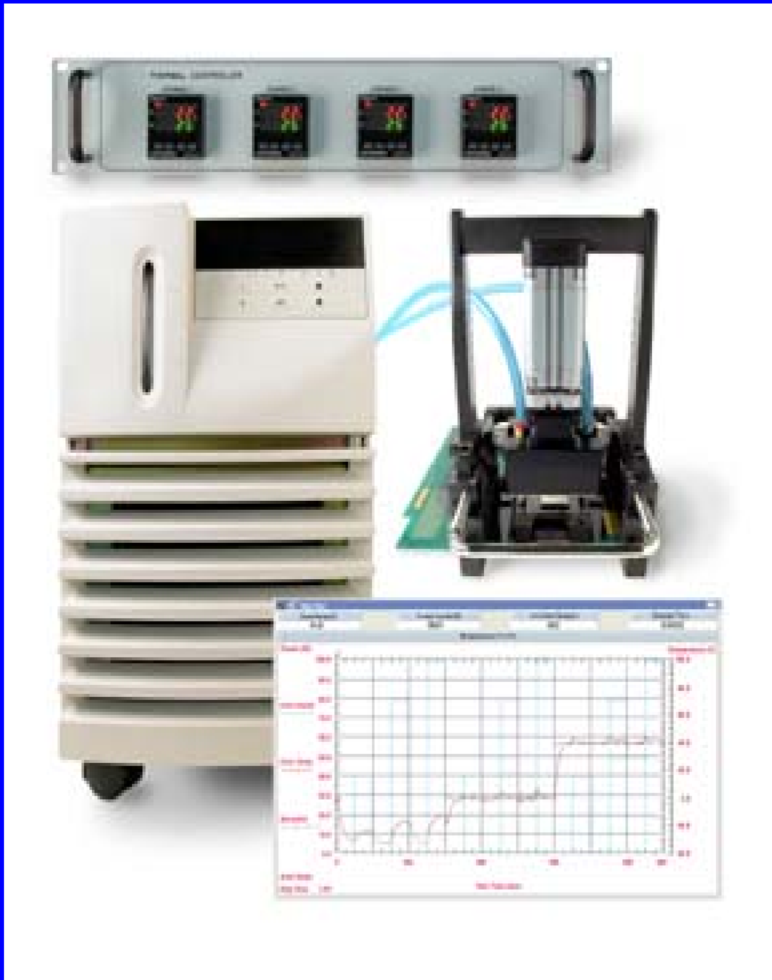
# TCU with Hand latching Mechanism



The TCU is available with a hand latching mechanism for manual interface to an OZ TEK® test socket.

# Applications

- High Power Simulation
- Temperature Characterization
- High Volume Production Testing



# Applications

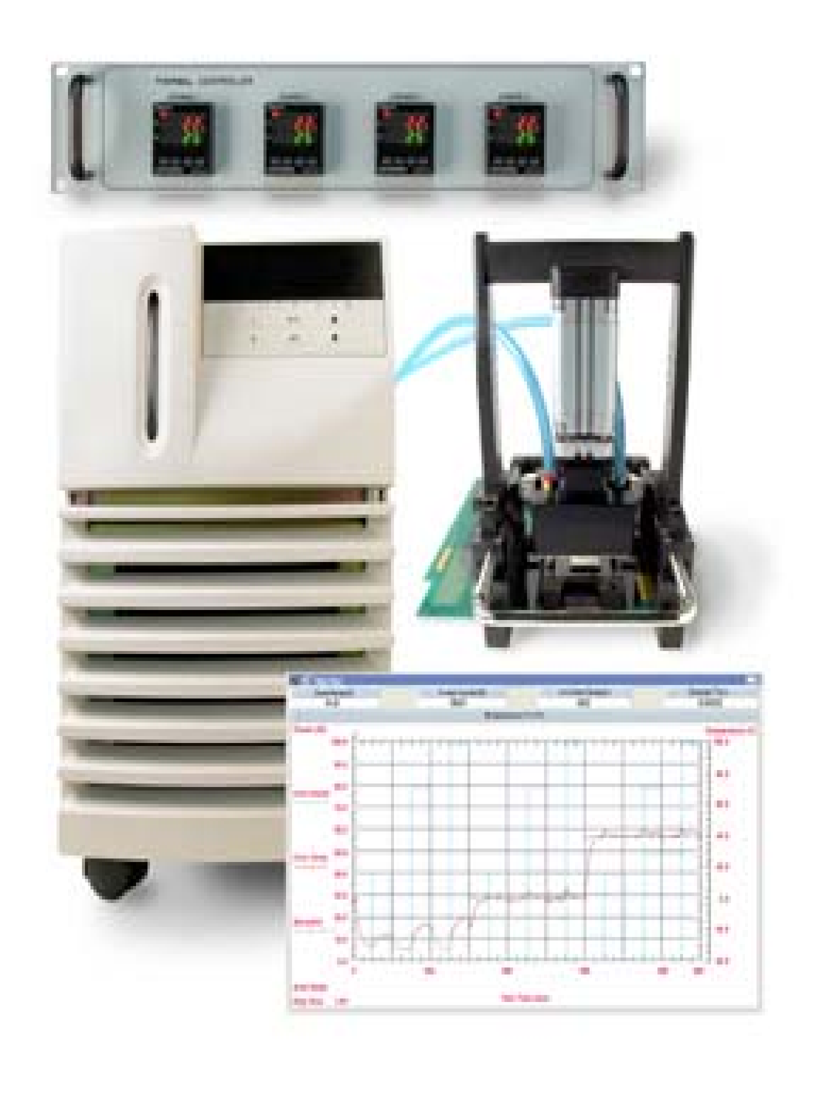
## High Power Simulation

A new generation of high power IC devices dissipate significant heat flux that must be controlled during testing in order to produce accurate results. The K&S Thermal Management System can regulate a steady temperature (within ***±2°C*** deviation at ***100 W*** thermal load) between a set point temperature of ***–35° to +100°C*** during testing. This allows precise simulation of high power operation at a specific temperature or over a specific temperature range. The result is effective heat removal for higher quality data and improved production yields.

# Applications

## Temperature Characterization

The K&S Thermal Management System can control thermal cycling over a ***-35° to +100°C*** temperature range from at an average ***ramp rate of 5°C/sec*** with data acquisition as fast as ***50 readings/sec*** . This allows for rapid dynamic response to the level of heat dissipation and more accurate power characterization of a device under test (DUT). The K&S Thermal Management System delivers better performance than thermal streams and is less expensive than refrigeration systems.



# Applications

## High Volume Production Testing

The K&S Thermal Management System is an effective alternative to conventional heat sink-fan cooling systems for high volume testing of production ICs. An optional ***pneumatic actuator*** provides automated application of the Thermal Control Unit (TCU) for higher throughput.  The ***over-temperature protection*** feature gives safer ergonomic test procedure.

# System Characteristics

***Cooling Capacity*: 120 W standard (higher capacity available)**

***Range***: –35° to +100°C (0 to 100 W)

***Offset Precision***: ±2°C (100 W)

***Ramp Rate***: 5°C/sec (higher rate available)

***TCU Mount***: Manual – latching mechanism for manual interface to OZ TEK® socket
Automatic – Pneumatic actuation

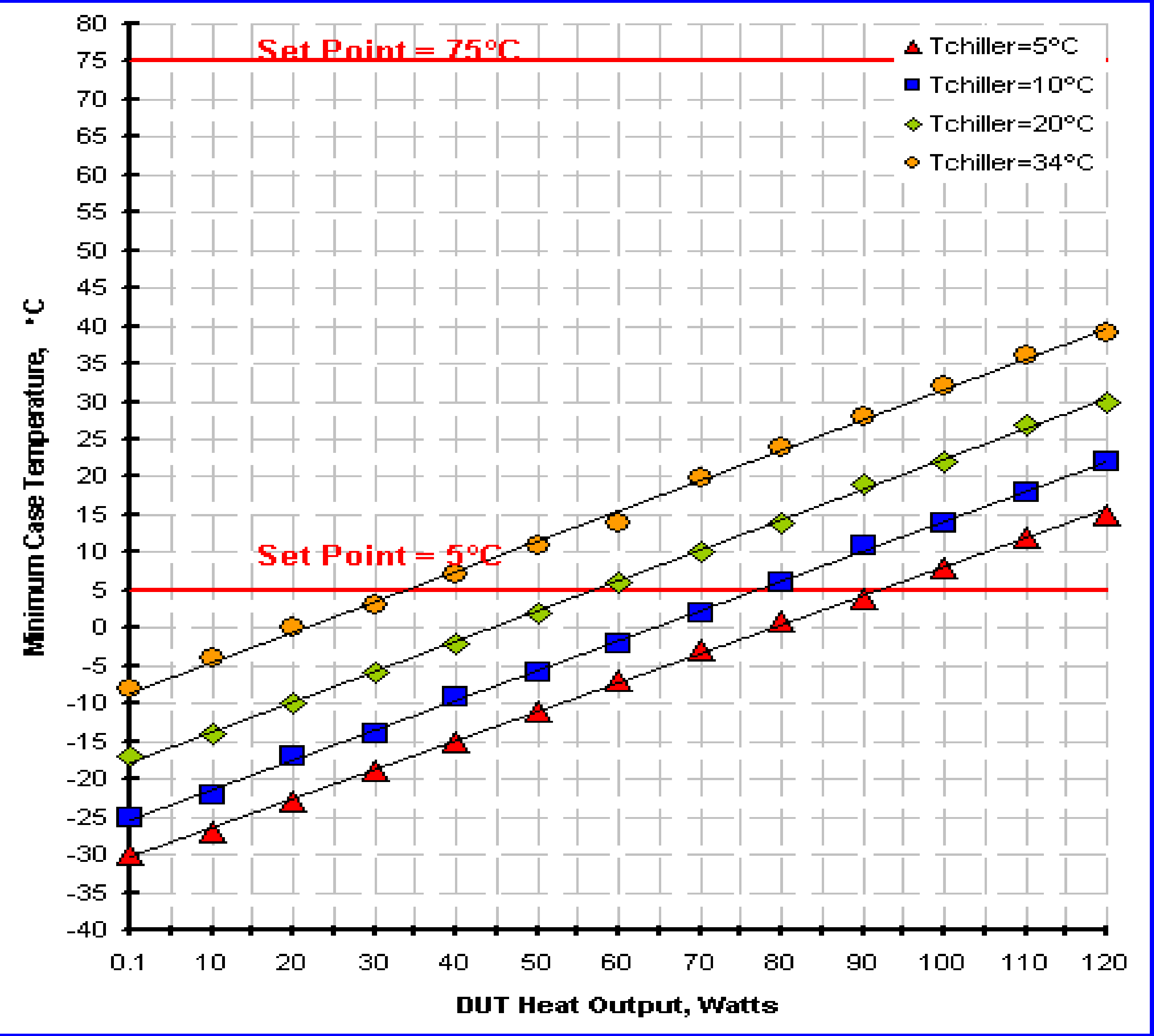
***Test Capacity***: 1 or 2 packages with 2-channel thermal controller
Up to 4 packages with 4-channel thermal controller

***Safety***: Thermal Control Unit– Thermostat (set 35°C)for liquid over-temp protection
Thermal Controller– LED indicates over-temp, and fuses provide protection

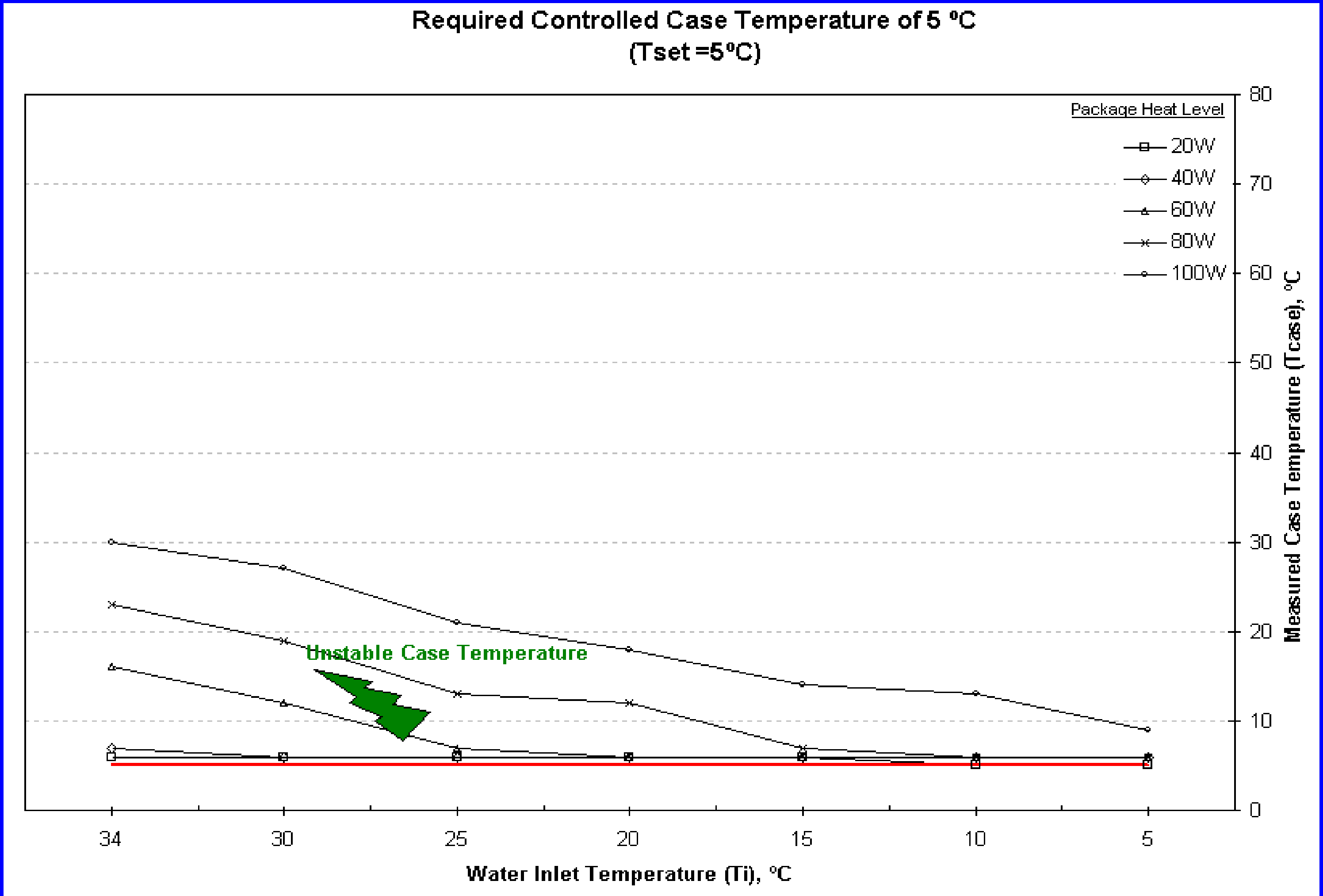
***Environmental***: No freon, unlike refrigeration systems
Quieter than conventional heat sink and fan systems
No condensation

***Other Features***: EMI Shield for the RTD sensor
Isolated water lines
With Elastomer washer for self leveling

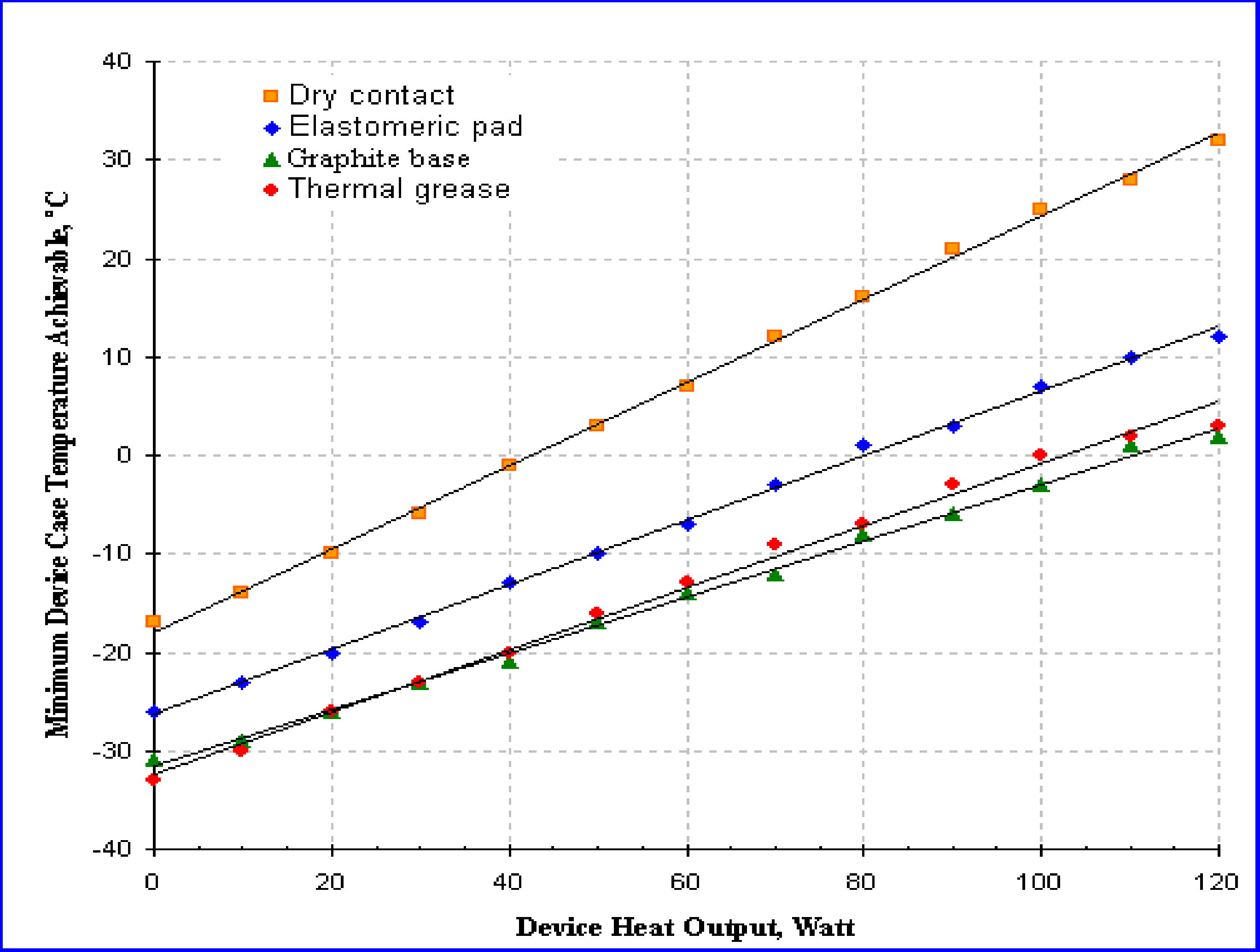
# TCU Thermal Performance



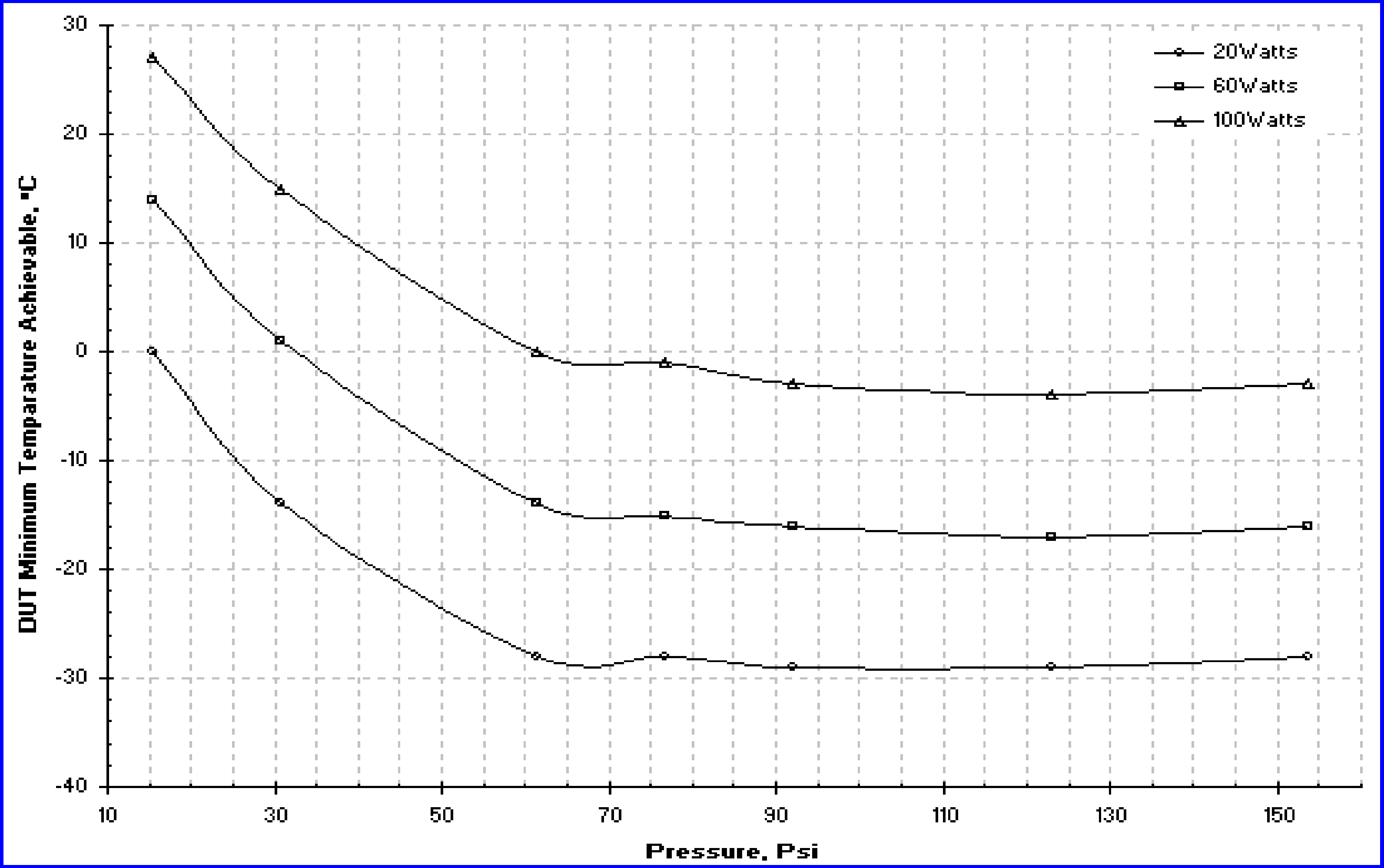
# Case Temperature vs. Water Inlet Temperature



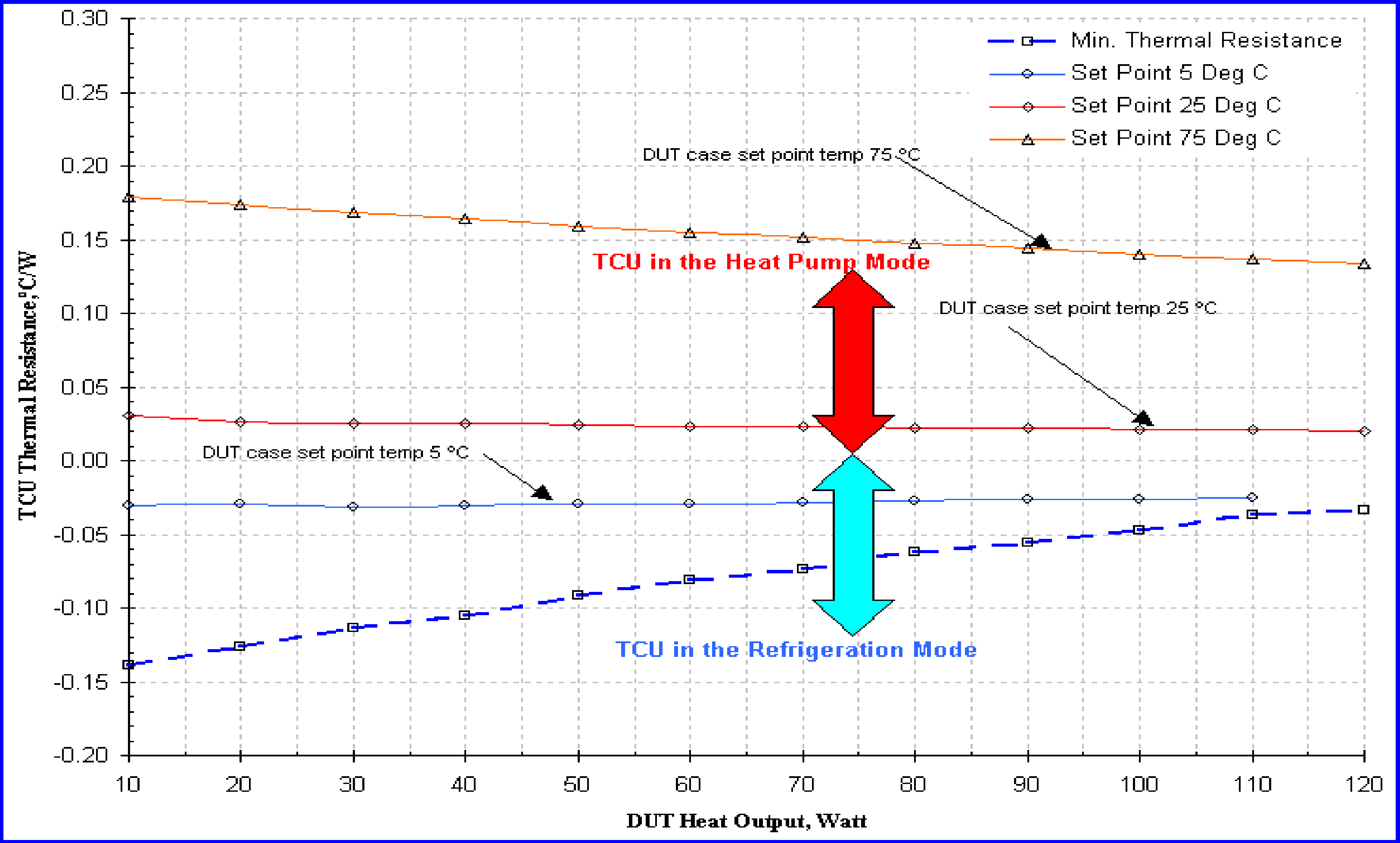
# Device Case Temperature at various DUT Heat Output



# Device Case Temperature at various Contract Pressure



# TCU Thermal Resistance using Graphite base interface Material



# Summary

• High power IC devices dissipate significant heat flux that must be controlled during testing.

•Thermoelectric technology with active liquid cooling  provides optimized thermal cycling (heating/cooling mode) or regulate a steady temperature during testing

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TRIO-TECH INTERNATIONAL

# 2004 Burn-In & Test Socket Workshop

# Heat Sink Modeling and Design

# For Dissipating High Heat

S. Kumaran (Engineering Manager)

BURN-IN & TEST SOCKET WORKSHOP

# Outline

1) Objective
- ✓ Thermal Challenges
- ✓ Heat Sink Fundamental
- ✓ Heat Sink Technology
- ✓ Finned Heat Sink Model
- ✓ Design Considerations & High Power Thermal Solution
- ✓ Technology & Cost Comparison
- ✓ Summary
- ✓ References

# 1) Objective

- To present technology available
- Thermal solution that can dissipate high heat & to find the optimum heat sink
- Finned Heat Sink Model

# 2) Thermal Challenges

- Nowadays, heat has become a major concern in the electronics industry.
- Excessive heat is a major threat to device reliability.
- Following are the major challenges:-
  - Heat loads of components increase exponentially.
  - Space available for dissipation decreased.
  - Cost Pressure.
  - Prevent thermal Runaway.

# 3) Heat Sink Fundamental

- Heat sink is an integral part of a device cooling system and its importance must be emphasized.
- Heat generated in the component is due to the power lost $I^2R$.
- This heat must be carried away by any means in order to keep device temperature within operating range, thus avoiding malfunction.
- Heat sink performance usually is specified in terms of thermal resistance:-

$$T s = \frac{Ts - Ta}{Q}$$

where

?s=Thermal Resistance

Ts=Heat Sink Temp.

Ta=Ambient Temp.

Q=Heat input to heat sink

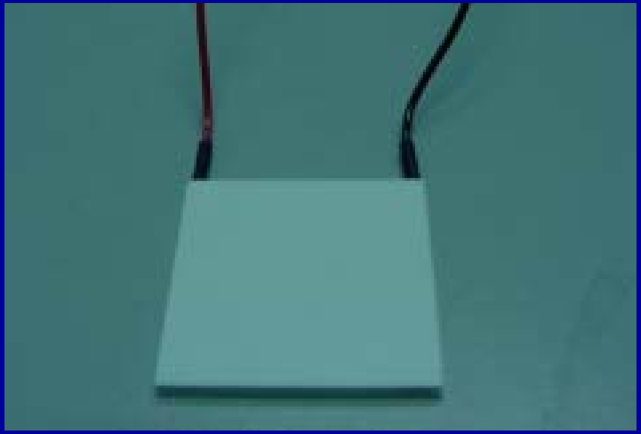
# 4) Heat Sink Technology

- Several types of heat sinks are available including:-
  - Heat-Pipe
  - Liquid Cooled Heat Sink
  - Forced Air Cooled Heat Sink
  - Natural Convection Heat Sink
  - Thermo Electric Cooler
- Natural Convection heat sink is satisfactory especially for device less than 5 watt.
- For majority applications, natural convection heat sink unable to remove the required amount of heat from the system.

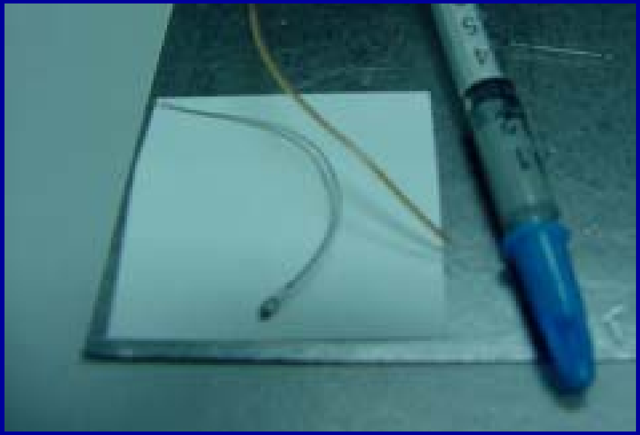
# 4) Heat Sink Technology

Passive Heat Sink

Forced Air Cooled Heat Sink



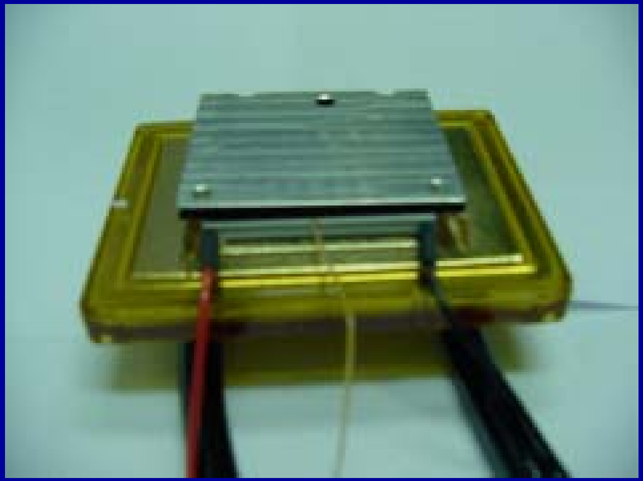
ThermoElectric Cooler



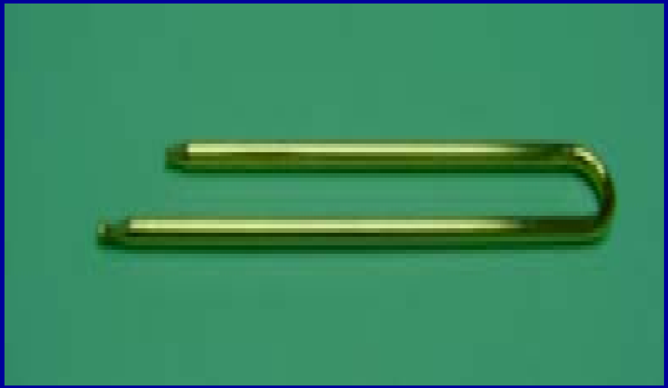
Heat Sink Accessories

# 4) Heat Sink Technology

Liquid Cooled Heat Sink



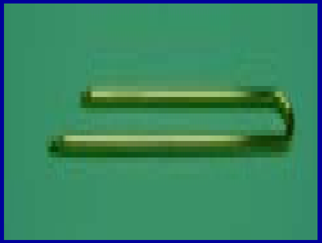
TEC with Liquid  Cooled Heat S



Heat Pipe

Heat Pipe with fan cooled Heat

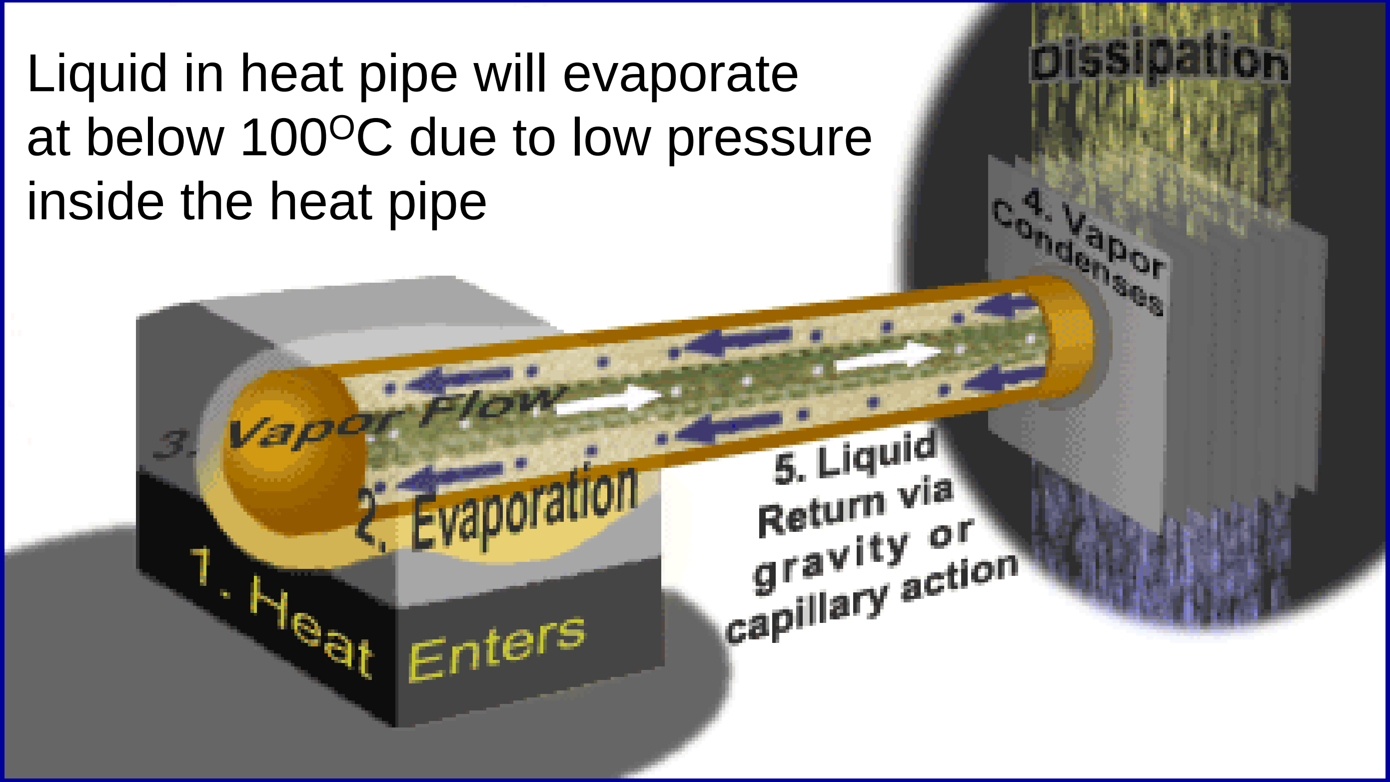
# 4) Heat Sink Technology (Cont')



- ***Heat Pipe***
  - **Often referred to as heat superconductor, heat pipe can quickly transfer heat from one point to another.**
- **Very promising and increasingly popular because:-**
  - **Uses effective evaporation and condensation cycles (latent heat) to extend surfaces available for dissipation.**
  - **More packaging flexibility for heatsinks.**
  - **Does not require mechanical pumps, valves or power hence more quiet and reliable.**
- **State of the art heat pipes can provide passive cooling for heat fluxes of over 200 W/cm$^2$.**

# 4) Heat Sink Technology (Cont')

Liquid in heat pipe will evaporate at below 100$^{O}$C due to low pressure inside the heat pipe



# 4) Heat Sink Technology (Cont')

- ***Liquid-Cooling***
  - Typically, mixture of water and glycol can eliminate audible noise.
  - Thus move heat away easily from the user area.
  - Significantly increased system reliability.
- **Though yet to gain general market acceptance, as heat fluxes exceed 200 watts per square cm, heat pipe and liquid cooling are the only alternatives.**

# 4) Heat Sink Technology (Cont')

- ***Fan-Cooled Heat sink Coolers***
  - **Efficient method of removing heat**
  - **Impingement cooling of heat sink by fan**
  - **Result in low thermal resistance to cool almost any type of low heat generating device.**
- ***Air Cooling***
  - **Is the conventional preference due to low system cost.**
  - **Proven reliability and has been used for decades.**
  - **Wide ranges of air cooled heat sinks are available to meet the needs.**
  - **Air cooling is most effective for lower power & lower power density semiconductor components and a limiting factor in many high density system packages.**

# 4) Heat Sink Technology (Cont')

## ➢ *Thermoelectric Cooler*

- **Unlike a simple heatsink, a thermoelectric cooler permits lowering the temperature of an object below ambient.**
- **Stabilizing the temperature of temperature sensitive device which are subject to widely varying ambient condition.**

# 5) Finned Heat Sink Model

- Heat sinks are used to control the heat loads to its required level.
- Adding fins to the heat sink increases surface area, it also increase pressure drop.
- As a consequence it reduces the volumetric airflow, which also reduces the heat transfer coefficient.
- There surely exists a point at which the number of fins in a given area can be optimized to attain the highest performance operating under a given fan.
- A heat sink model is developed to find the optimum point for the heat sink design.

# 5) Finned Heat Sink Model (Cont')

- **Thermal Resistance R**
  - **The thermal resistance is obtained from :-**

    **$T.R = 1/\eta f A f H$**
    **where $\eta f$ = fin efficiency**
    **$Af$ = fin profile area**
    **$H$ = heat transfer coefficient**

- **'H' varies due to the varying flow velocity in the channel with changing channel width, the optimized channel width can be obtained.**
- **Heat transfer coefficient H is obtained from:-**
  **$H = NuKair/L$**

# 5) Finned Heat Sink Model (Con’t)

- **Average Nusselt number**
  - **Teertsra[2] proposed a composite model to calculate the average Nusselt number in a channel for fully developed and developing flow:-**

$$Nug = [\ (Re^*aPr/2)-3 + (0.664(\sqrt{Re^*a})Pr1/3(\sqrt{(1+3.65/\sqrt{Re^*a})}))-3]-1/3$$

- **Approach Velocity Reynolds Number:-**
  - **It is evaluated by taking the aspect ratio of the channel width to length and it is defined as**

$$Re^*a = (\ Vag/v\ )\ (\ g/L\ )$$

**where v : viscosity of fluid**
**Va: approach velocity**
**g: Channel width**
**L: Channel Length**

# 6) High Power Thermal Solution & Consideration

- Perfect heat sink is capable of absorbing an unlimited quantity of heat without exhibiting any increases in temperature.

- Practically it is impossible, following must be taken into consideration when designing heat sink:-

  - Maximum power dissipation
  - Heat dissipation area
  - Maximum ambient temperature
  - Maximum case temperature
  - Maximum junction temperature
  - Minimum air flow if applicable
  - Maximum weight and size

# 6) High Power Thermal Solution & Consideration

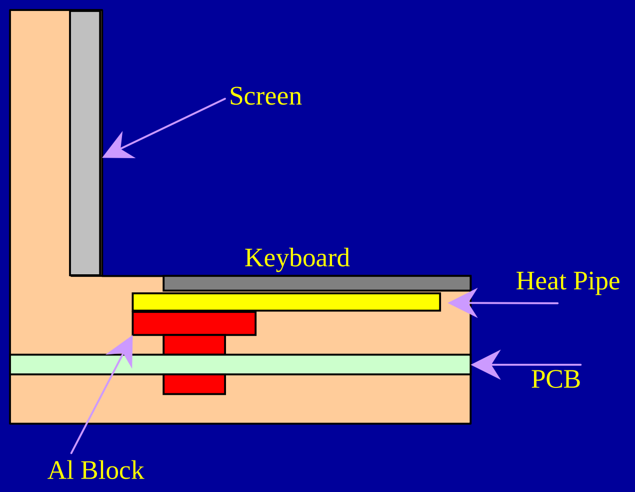
- Consumer application
  - Heat pipe technology in notebook etc.

ii) Burn-In Solution

  - Individual DUT Thermal Control in Burn-In System.

# 6) High Power Thermal Solution & Consideration

- ***Consumer application ( Heat Pipe)***




➢ **Diagram illustrate the use of heat pipe technology in the cooling of processor base notebooks.**

➢ **Advantages of using heat pipe:-**

- **Can eliminate the use of liquid pump & fan.**
- **Reliable and no power required.**
- **Can be formed to meet space availability.**
- **Low delta T hence can provide maximum surface area.**
- **Minimize volume and weight.**

# 6) High Power Thermal Solution & Consideration

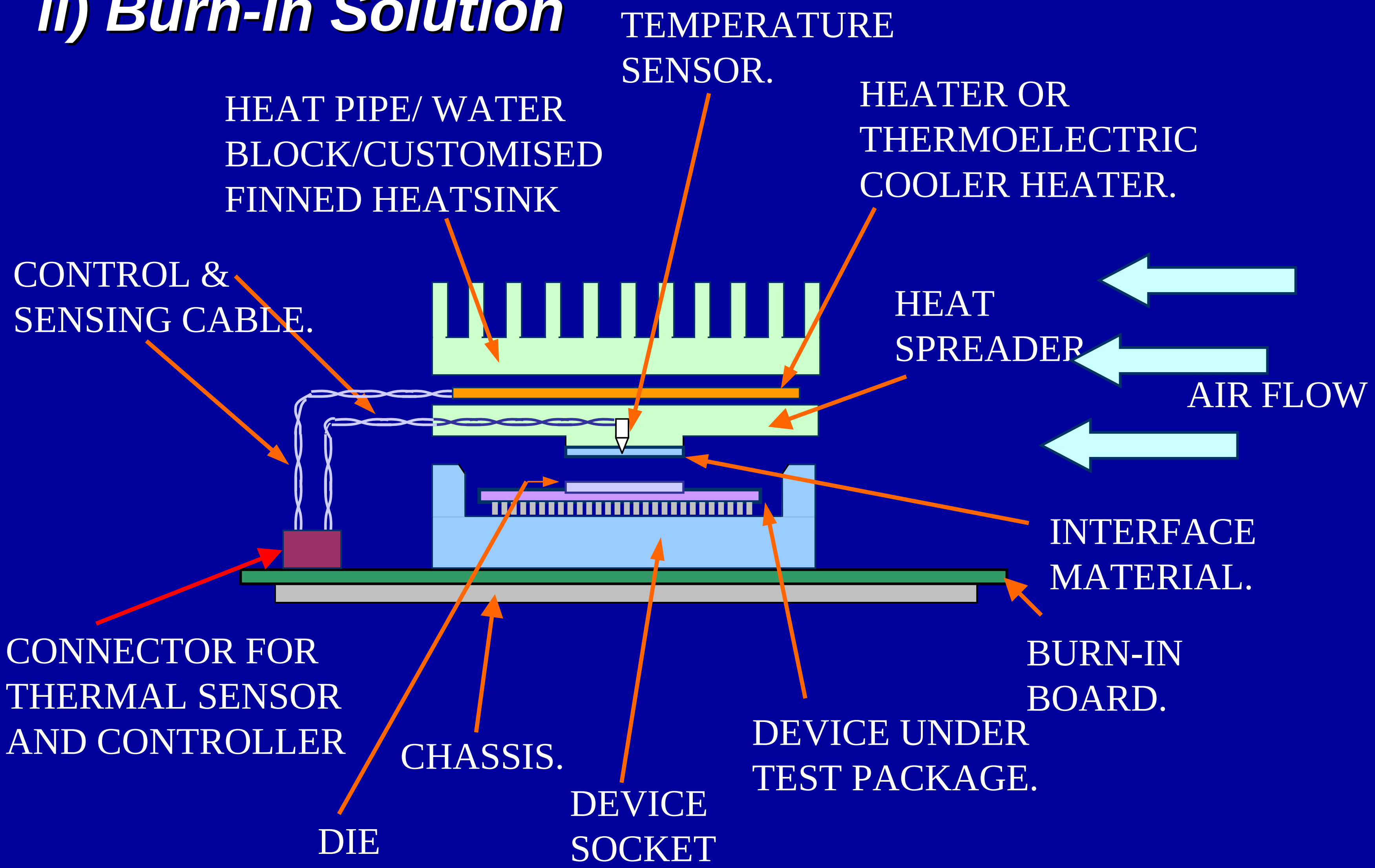
- **Heat Pipe potential and application**
- **The table below illustrates the potential of heat pipe technology in cooling processor with heat flux in excess of 200 w/cm$^{2}$.**

**Summary of prototype heat pipe test result**
**Shows the potential of the emerging technology**
**(Combined Pulsating and Capillary Transport Mechanism)**

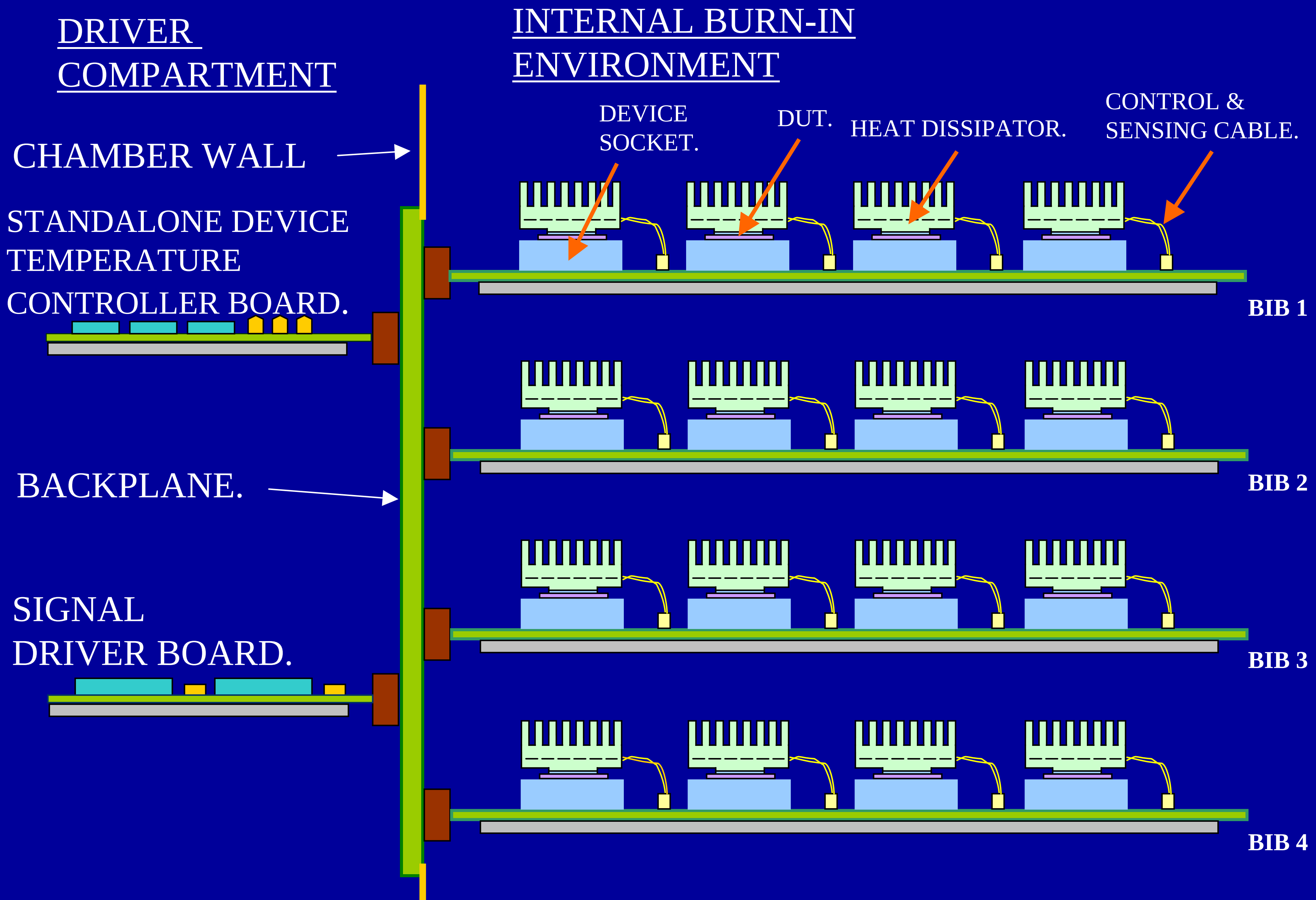
| Heat Pipe Mechanism | Heat Pipe Fill Ratio | Heat Flux | Thermal Resistance |
|---|---|---|---|
| CPCT | 50% | 160W/cm$^{2}$ | 0.60$^{0}$C/W |
| CPCT | 55% | 175W/cm$^{2}$ | 0.38$^{0}$C/W |
| CPCT | 60% | 175W/cm$^{2}$ | 0.27$^{0}$C/W |
| CPCT | 70% | 220W/cm$^{2}$ | 0.16$^{0}$C/W |
| CPCT | 80% | 185W/cm$^{2}$ | 0.20$^{0}$C/W |

# 6. THERMAL DESIGN AND SOLUTION (Con't)

## *ii) Burn-In Solution*



# 6. THERMAL DESIGN & SOLUTION (Con't)



# 6. THERMAL DESIGN & SOLUTION (Con't)

- Customised heat sink (passive, active, liquid cool, heatpipe) with heater/TEC will be used for the individual DUT thermal control.
- Temperature sensor mounted at the heat sink baseplate as to monitor the device temperature.
- Temperature monitoring and controlling is controlled by the Temperature controller board.
- Thermal interface material to cushion die surface.
- Chamber airflow is used to cool DUTs.
- Device power variation is compensated by individual Heater or TEC.

# 7. Technology & Cost Comparison

| Thermal Technology | Thermal Efficiency | Heat Flux ($W/cm^2$) | Thermal Resistance $^oC/W$ | Cost (10 W Device) | Cost (50 W Device) | Cost (100W Device) | Cost (200W Device) |
|---|---|---|---|---|---|---|---|
| Heat Pipe | Very High | <220 | 0.16 | 55 | 60 | ~160 | ~260 |
| Liquid Cooling | High | <150 | 0.4 | 150 | 150 | 160 | Na |
| Forced Convection Cooling | Moderate | <50 | 0.8 | 10 | 20 | Na | Na |
| Passive HeatSink | Low | <10 | 3 | 5 | Na | Na | Na |

# 8. Summary

**In conclusion:**

- **Heat pipe Technology**
    - **The high heat flux heat pipe technology will advance the state-of-the-art and able to provide robust and efficient cooling for future hotter electronics.**
    - **Heat pipes are now being combined with other technologies (liquid cooled etc) as to meet these emerging requirements.**

# 9. Questions

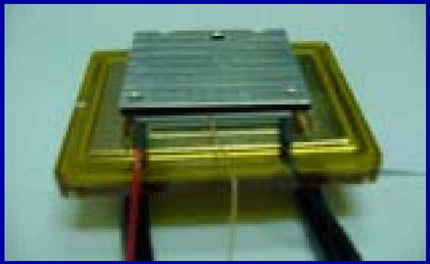
Passive Heat Sink

Forced Air cooled Heat Sink

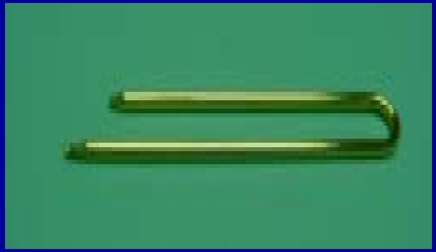
Thermocouple wire

ThermoElectric Cooler

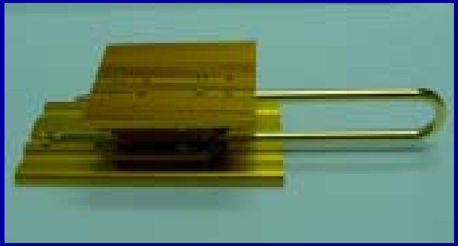
Liquid Cooled Heat Sink



TEC with Liquid Cool Heat Sink



Heat Pipe



Heat Pipe with Heat Sink

Heat Pipe with fan cooled Heat Sink

# 10. Main References


- H.Xie, M.Aghazadeh, “The use of heat Pipes in the cooling of portables with high power packages,” Proc. 45th Electronic Components and Technology Conference, May 1995, Las Vegas, Nevada

2) Teertstra P., Yovanovich M.M., Culham J.R., and Lemezyk T., ”Analytical Forced Convection Modelling of Plate Fin Heat Sinks”, Proceedings of 15th IEEE Semiconductor Thermal Measurement & Management Symposium, pp. 34-41, San Diego, CA, March 9-11, 1999.

3) White F.M., 1991, Heat and Mass Transfer, Addison-Wesley