



# Burn-in & Test Socket Workshop

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

**IEEE**

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SOCIETY**

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**Burn-in & Test Socket  
Workshop**

## **Technical Program**

**Session 6**

**Tuesday 3/05/02 4:00PM**

### **Burn-in Systems**

**“A Large Capacity And High Performance Burn-in And Test System For High Power Dissipating Components”**

**Dr. Jerry Tustaniwskyj - Unisys Corporation**

**Dr. James W. Babcock - Unisys Corporation**

**Jim V. Rhodes - Unisys Corporation**

**“Burn-in Oven With Chilled Water Heat Exchanger”**

**Chyi Feng Leow - Trio-Tech International**

**“The Challenges In Fine Pitch Burn-in Tooling”**

**Hwan Ming Wang - Intel Corporation**

**Anthony Wong Yeh Chiing - Intel Corporation**

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# A Large Capacity and High- Performance Burn-In and Test System for High-Power Dissipating Components

Dr. Jerry Tustaniwskyj, Dr. James W. Babcock,  
James V. Rhodes

**Unisys Corporation**

**March 3-6, 2002**

# Semiconductor Burn-in



- Accelerate early life failures (infant mortality) for devices under test (DUTs)
  - Higher voltages
  - Higher temperatures
- Maximize voltage and temperature without damage to DUT
  - Today's DUTs require lower operating voltages and have dense geometries, requiring precise control of both voltage and temperature during burn-in



# Limitations of “Air” Systems

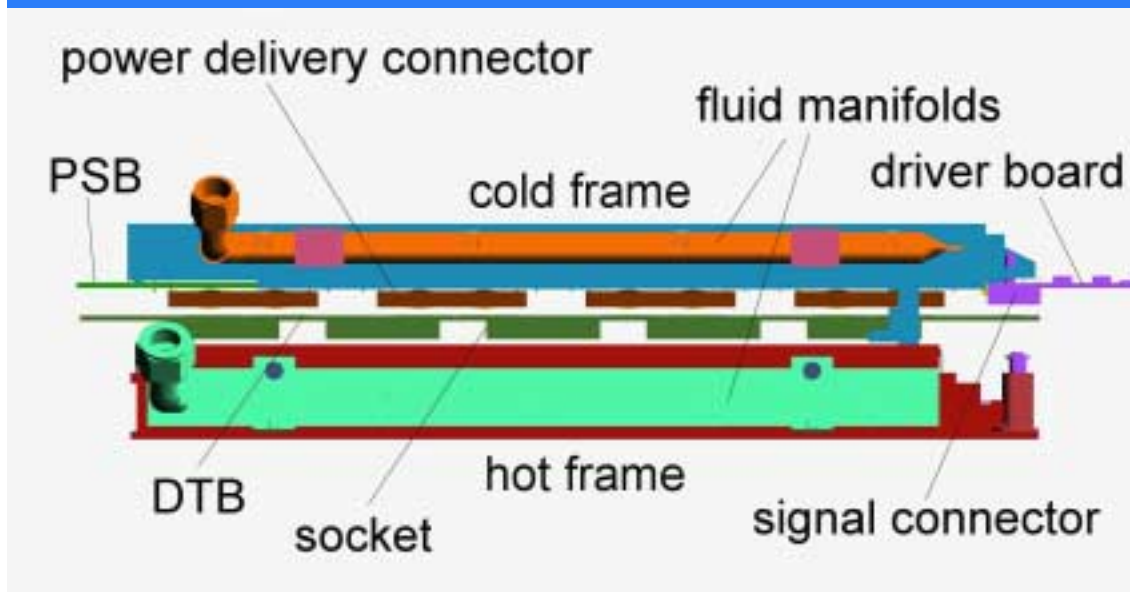
- • • • •
- Thermal delivery sub-system
  - Only capable of managing  $<\sim 15$  watt DUT power
  - Wide distribution of temperatures at that power level
- Electrical signal delivery sub-system
  - Limited signal quality and frequency performance due to burn-in board connection mechanism
- DC power delivery sub-system with bulk or even slot-level power supplies
  - Wide distribution of voltages, either between slots or even on burn-in board
  - Individual DUT control and monitoring not easy

# Unisys STS 3000

- Burn-in of high-power electronic devices
- Functional test of DUTs utilizing JTAG
- Individual DUT DC power delivery
- Advanced electrical signal delivery system
- System architecture upgrades allow higher performance



# Mechanical System



- Up to 1,680 DUTs/system
  - 28 slots/system
  - Two burn-in boards (BIBs) per slot
  - Up to 30 DUTs/BIB
- Zero BIB insertion force
- Final alignment managed by chamber

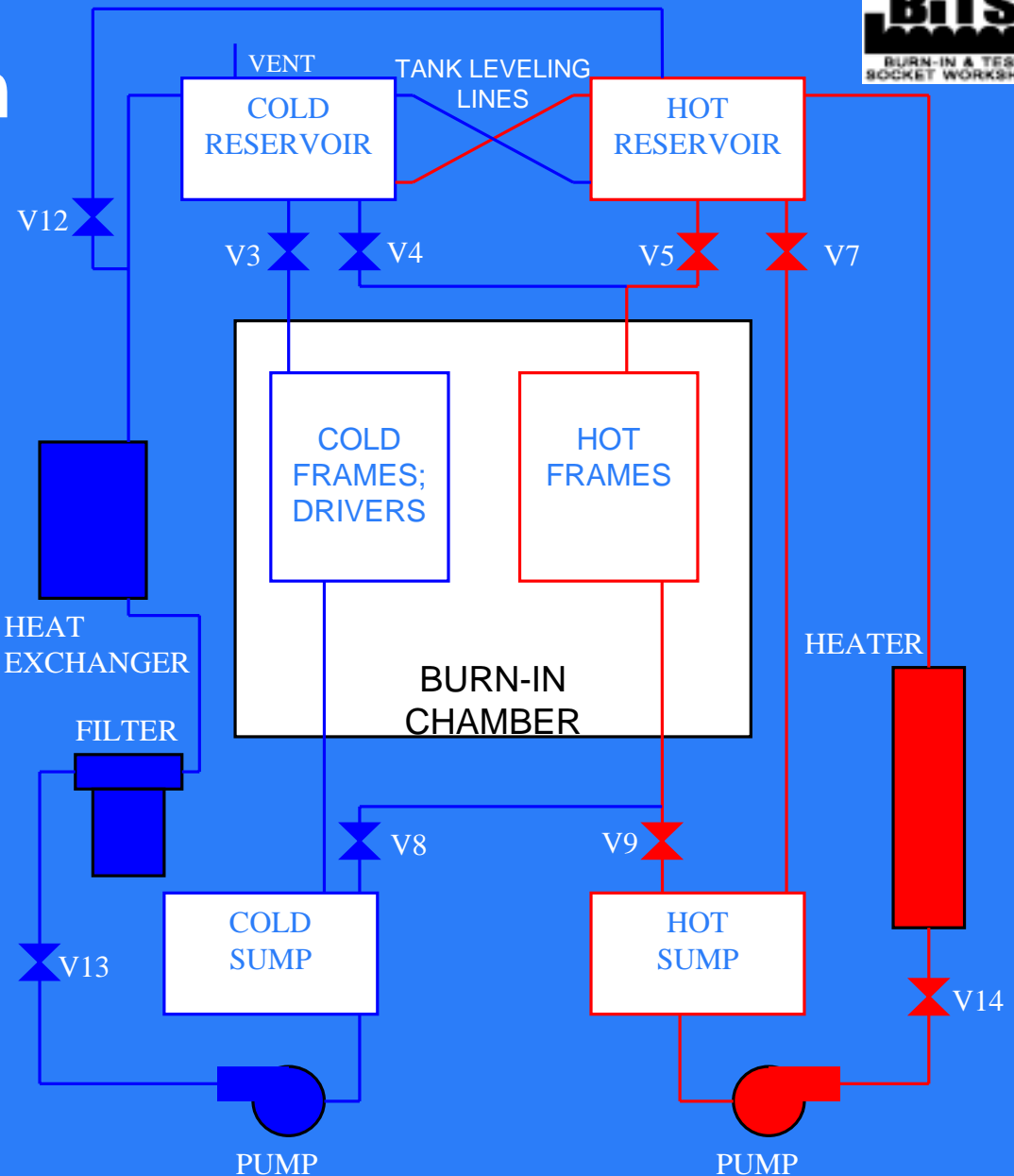




# Fluidics System



- Single fluid, two flow loops with two separate temperatures
- Leak tolerant, negative pressure operation
- Tight temperature control



# Fluid Temperature Control

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- Closed loop temperature control
  - Raise temperature by means of an in-line heater
  - Lower temperature with cold fluid injection
- Two sensor input to master temperature controller
- Very responsive to step changes in load
- Control within +/- 0.5 degrees C

# Thermal Interface



- Low melting temperature “alloy”
- Alloy remains on heat sink during disengagement
- Good for 1000+ cycles
- Alloy is easily replenished with no degradation to heat sink
- Typical resistivity equal to  $0.14^{\circ}\text{Ccm}^2/\text{W}$



# Heat Sink Assembly



- Gimbal assembly
  - self aligning, very low force at initial contact

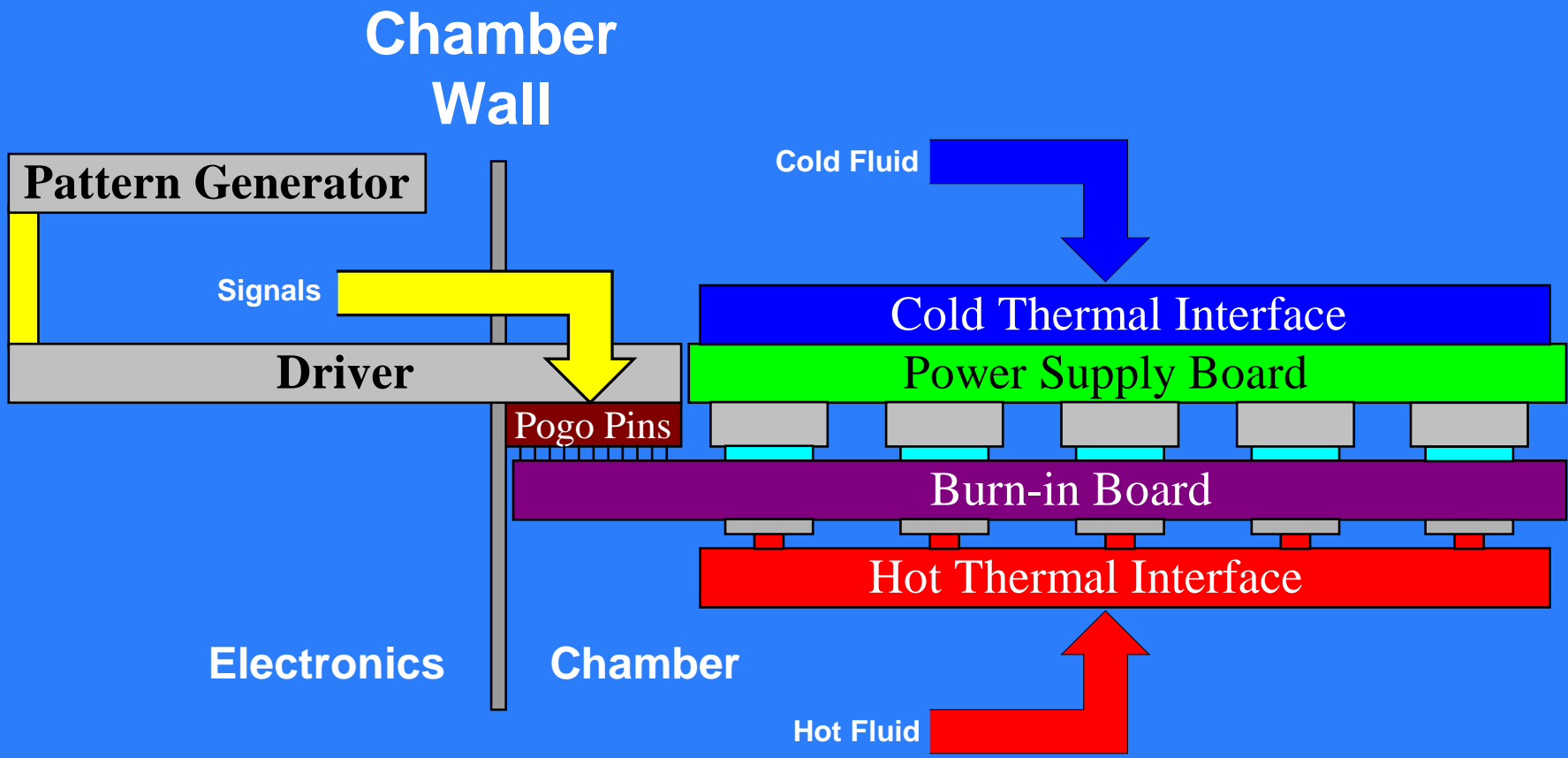
# STS 3000 Electrical

- • • • •
- JTAG based test delivery and test
  - Virtually unlimited SCAN pattern depths
  - 75 MHz data, 150 MHz clock
  - 48 parallel vectors
- DC power delivery
  - 0.50V to 2.50V
  - Up to 60Amps per DUT
  - +/- 25mV regulation at DUT
  - Each DUT power supply is continuously monitored, both voltage and current

# Burn-In Boards

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- 
- Do not have to exist in a high-temperature ambient condition
  - Lower cost
- Single DUT pin electronic zones
  - Each DUT has its own set of pin drivers, allowing for high-quality signals
  - Pogo pin interface
- Power connection from the bottom of the burn-in board
  - Short, direct power path to the DC generation source

# Single Slot – Side View



# STS 3000 Thermal Performance



- Present system optimized for (not limited to) 30W average, with 75W peak!
- Factors contributing to DUT junction temperature variation
  - Hot fluid temperature control
  - DUT-to-heat exchanger thermal resistance
- “Stack” rise a factor for higher power distributions





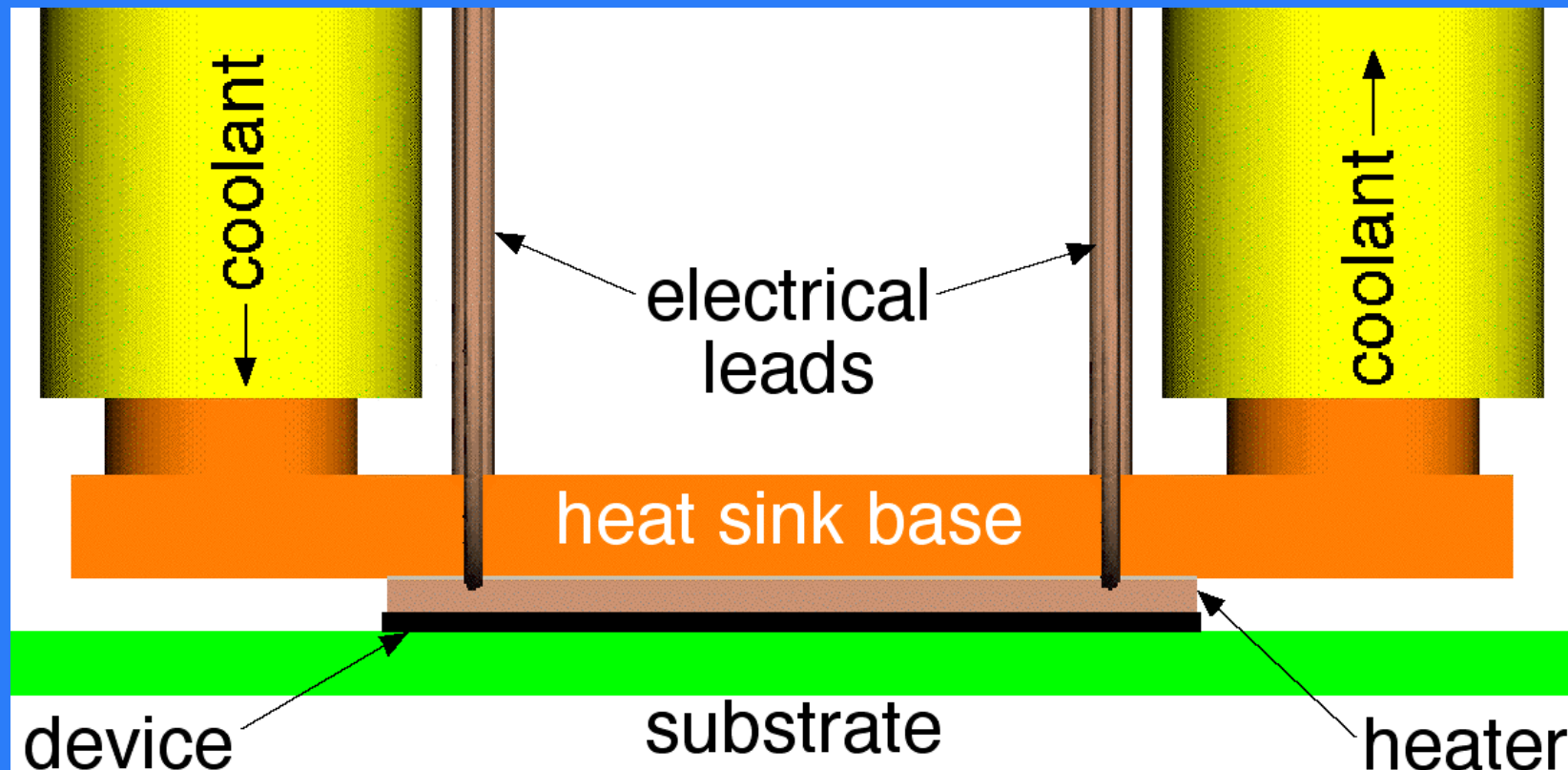
# STS 4000 – A Higher Power

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- Next generation up from the STS 3000
- Up to 840 DUTs/system
  - 28 slots/system
  - Two burn-in boards (BIBs) per slot
  - Up to 15 DUTs/BIB
- 100W maximum *and* average DUT power capable, 60Amps of current per DUT
- 200W per DUT capable with a reduction to 448 DUTs per system, 120Amps of current per DUT

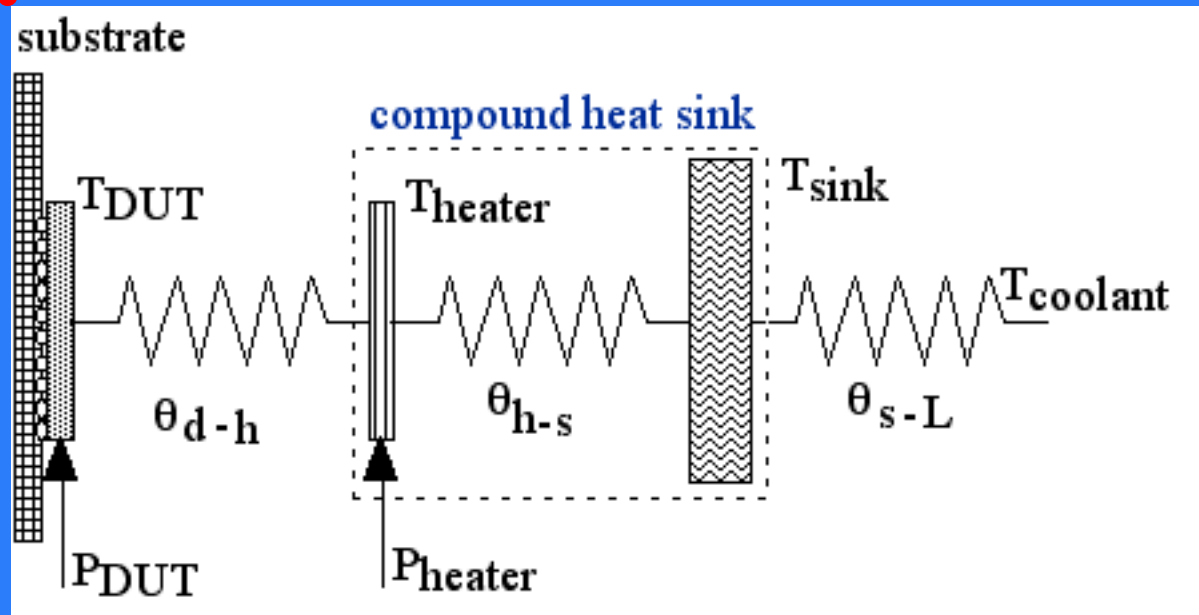
# STS 5000 - Going for the Gold!

- Average burn-in power levels to 400W @ 448 DUTs, or 200W @ 840 DUTs
- Per DUT current delivery of 160Amps, with +/- 10mV regulation at the DUT
- Tight temperature control: - +/-2 degrees C at DUT
- Individual DUT control factors
  - Very responsive thermal system
  - On-DUT sensor not always available
    - When on-DUT sensor is available, system will perform calibration automatically
  - Compact, fits in hot frame envelope

# STS 5000 - Simplified Heat Sink



# STS 5000 Thermal Schematic

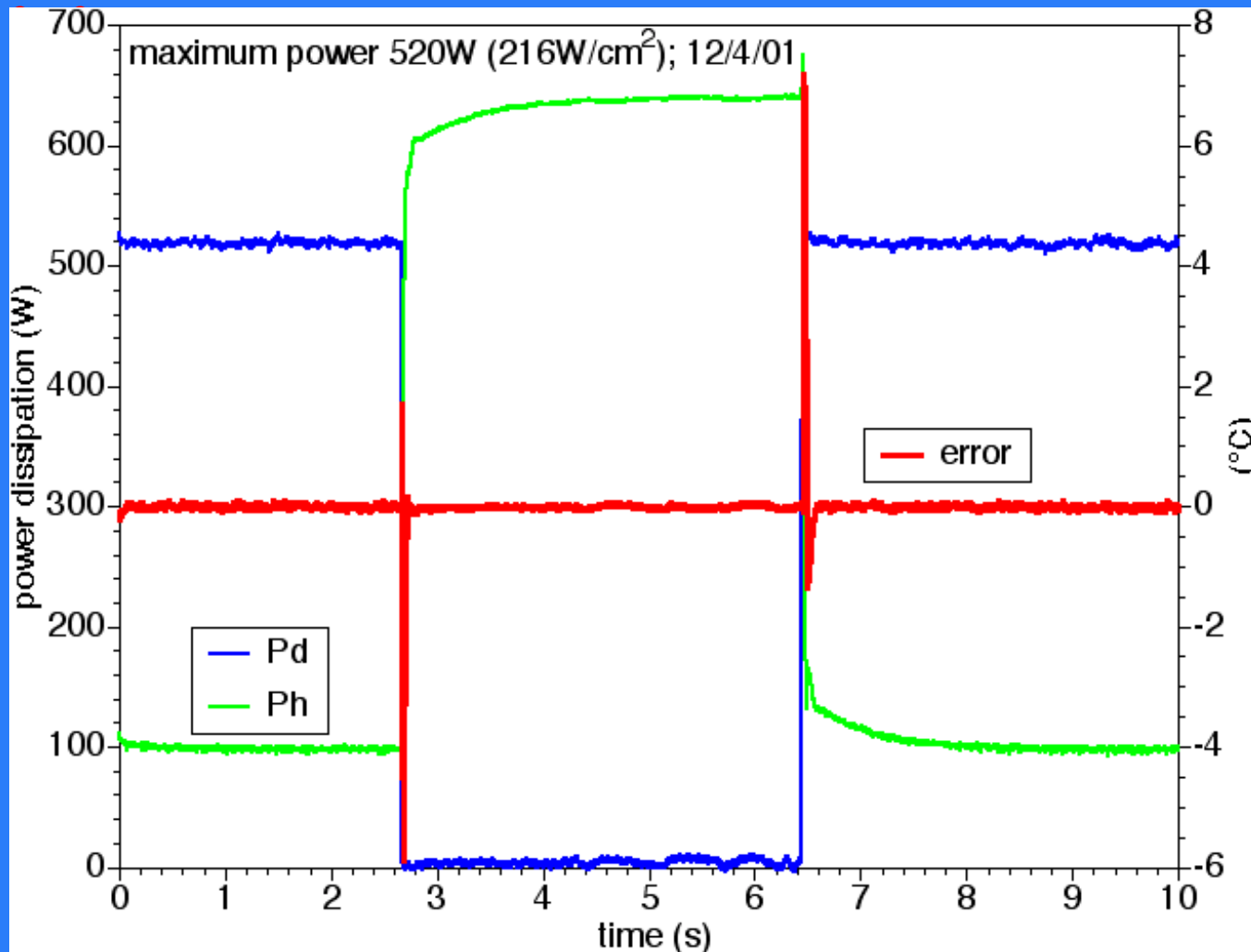


$$T_{DUT} = T_{heater} + \theta_{d-h} \left( M_h T'_{heater} - P_{heater} + \frac{T_{heater} - T_{sink}}{\theta_{h-s}} \right)$$

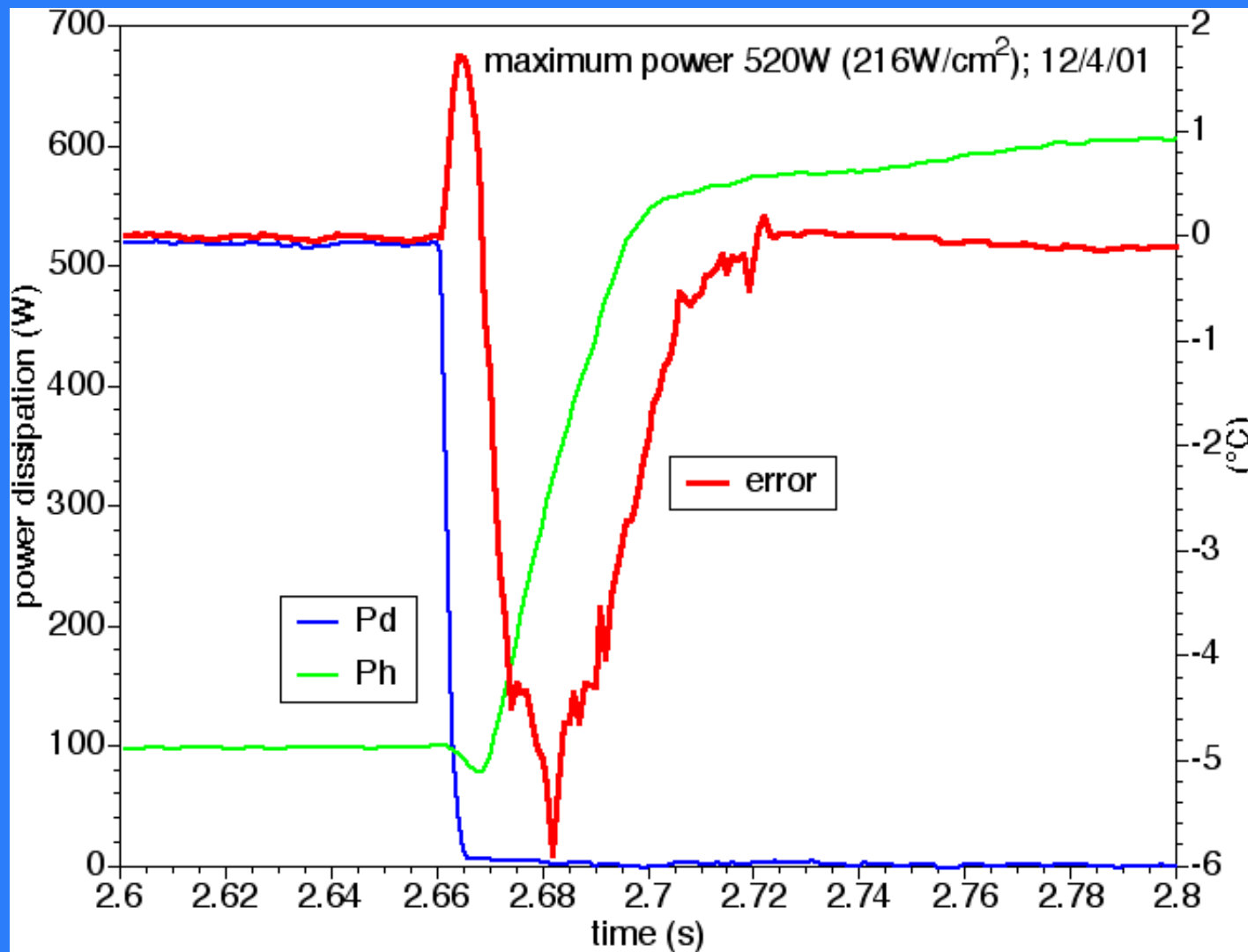
# STS 5000 Heat Sink Assembly



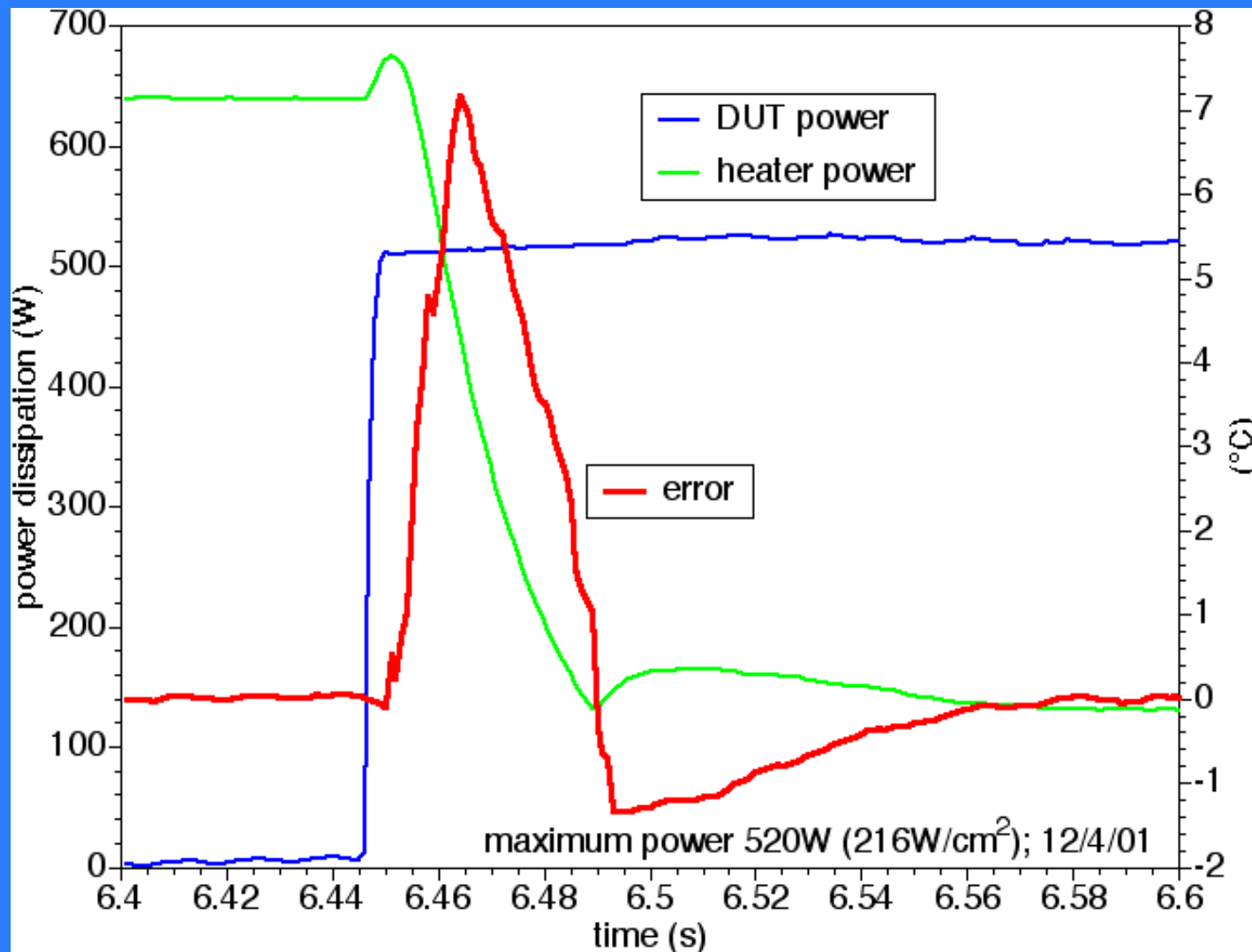
# STS 5000 Step Power Response



# STS 5000 Step Power Response



# STS 5000 Step Power Response





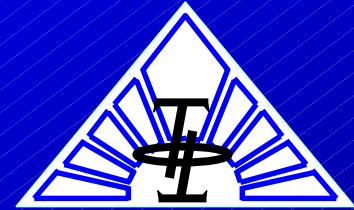
# Conclusion



- Unisys IS in this business!
- STS 4000 handles up to 200W DUTs
- STS 5000 handles up to 400W DUTs
- Both systems are large capacity (840 DUTs)
  - Use non-complex burn-in boards
- Both systems offer tight temperature and voltage control at the DUT
- Flexible SCAN test pattern generation



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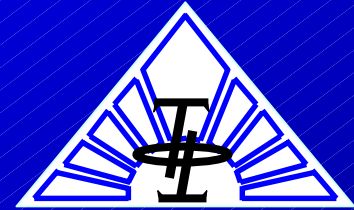


# 2002 Burn-In & Test Socket Workshop

Burn-In Oven With Chilled Water  
Heat Exchanger

CF Leow (Engineering Manager)

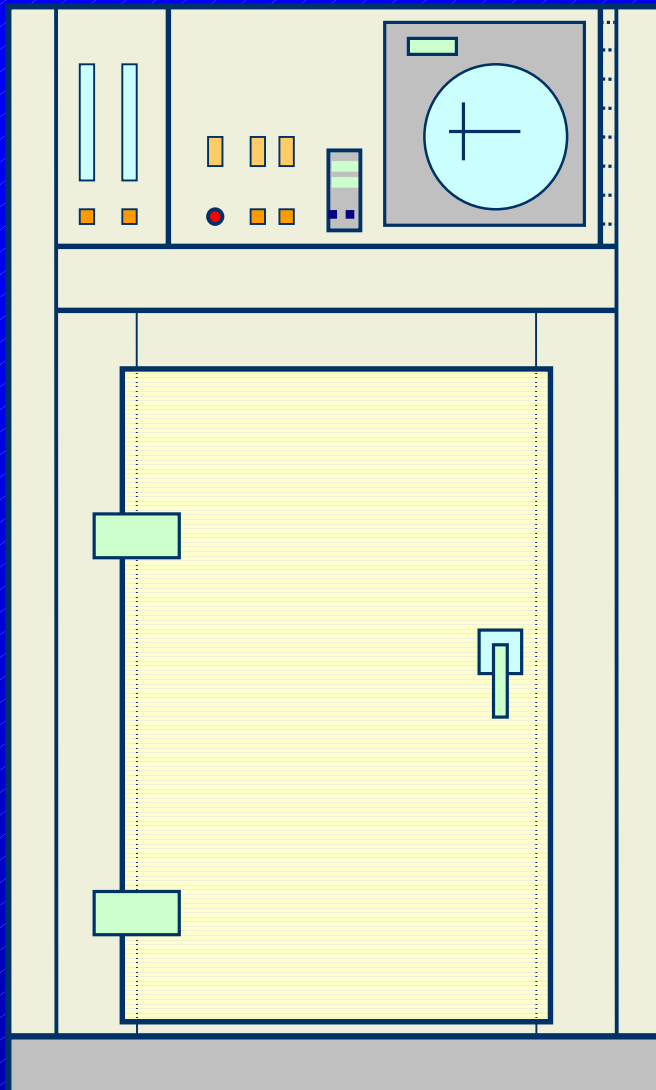
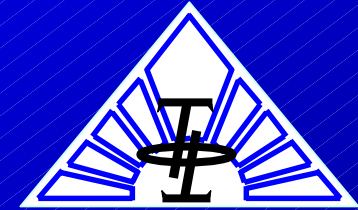




Outline :

- **Objective**
- **Advantages**
- **Specifications**
- **Upgrading Design I**
- **Data Collection I**
- **Upgrading Design II**
- **Data Collection II**
- **Oven Airflow Rate**
- **Cooling Power of Heat Exchanger**
- **Ramp Rate**
- **Summary**



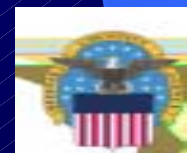


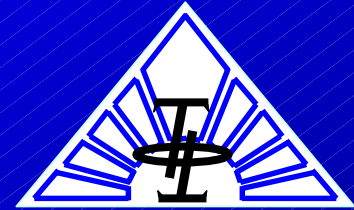
## 1) Objective :

To retrofit existing traditional burn-in oven with chilled water (air to liquid) heat exchanger capability to cater for devices with high heat dissipation.



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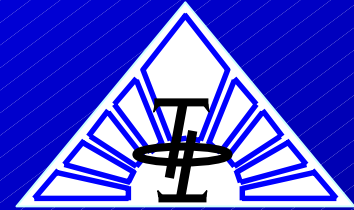




## 2) Advantages :

- **Increase the heat dissipation capability of existing traditional burn-in ovens.**
- **To allow low temperature burn-in with high heat dissipation capability.**
- c) **To prevent oven thermal run-away during the burn-in of high power devices.**
- d) **To reduce the cost of new equipment investment needed for the advance burn-in (with thermal control at DUT level) of high power devices.**
- e) **To maintain the existing floor space or footprint required by the oven.**





3) Specifications :

**Existing standard heat dissipation capacity :**

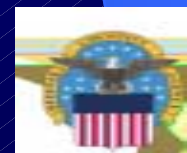
**7.5 KW @ 125°C operating temperature.**

**New heat dissipation capacity :**

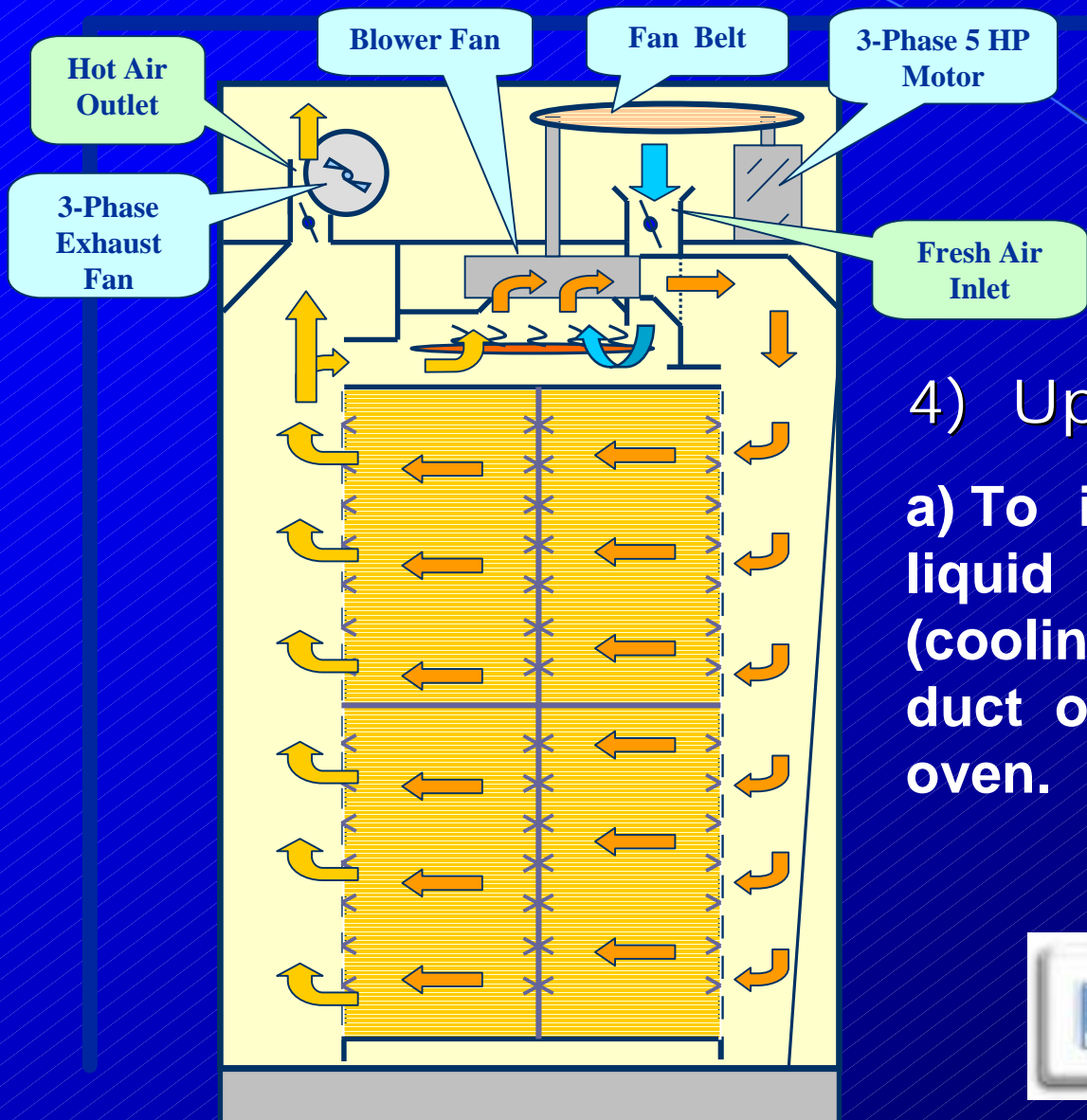
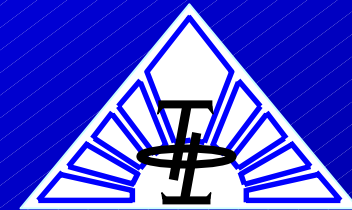
**19 KW @ 84°C operating temperature.**

**Or**

**33.4 KW @ 125°C operating temperature.**



# TRIO-TECH INTERNATIONAL



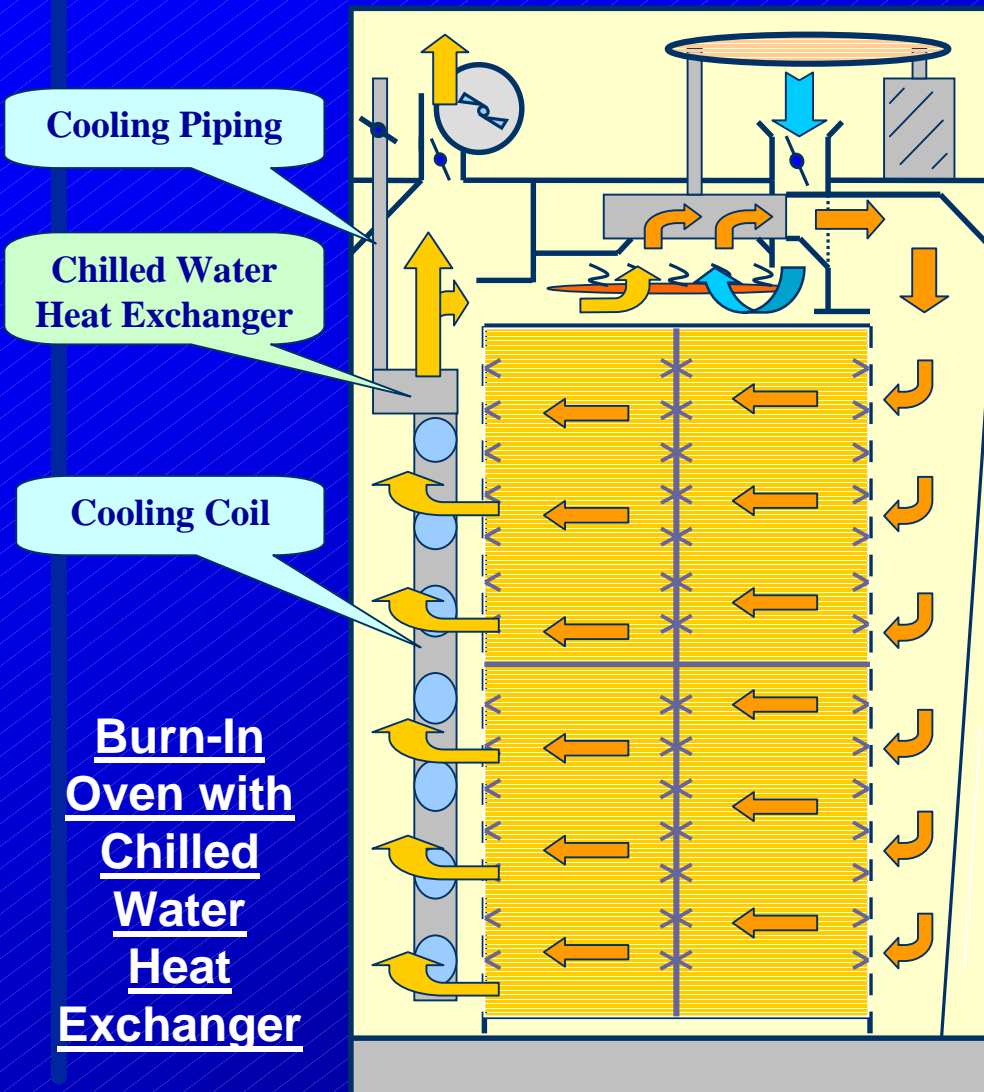
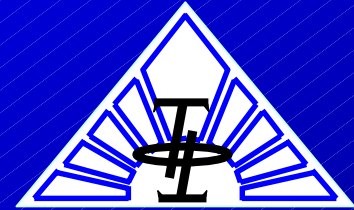
Existing Burn-In Oven  
(4 zones,  
16 slots / zone)

- 4) Upgrading Design I :
- a) To incorporate an air to liquid heat exchanger (cooling coil) at the return air duct of the existing burn-in oven.



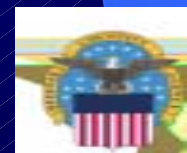
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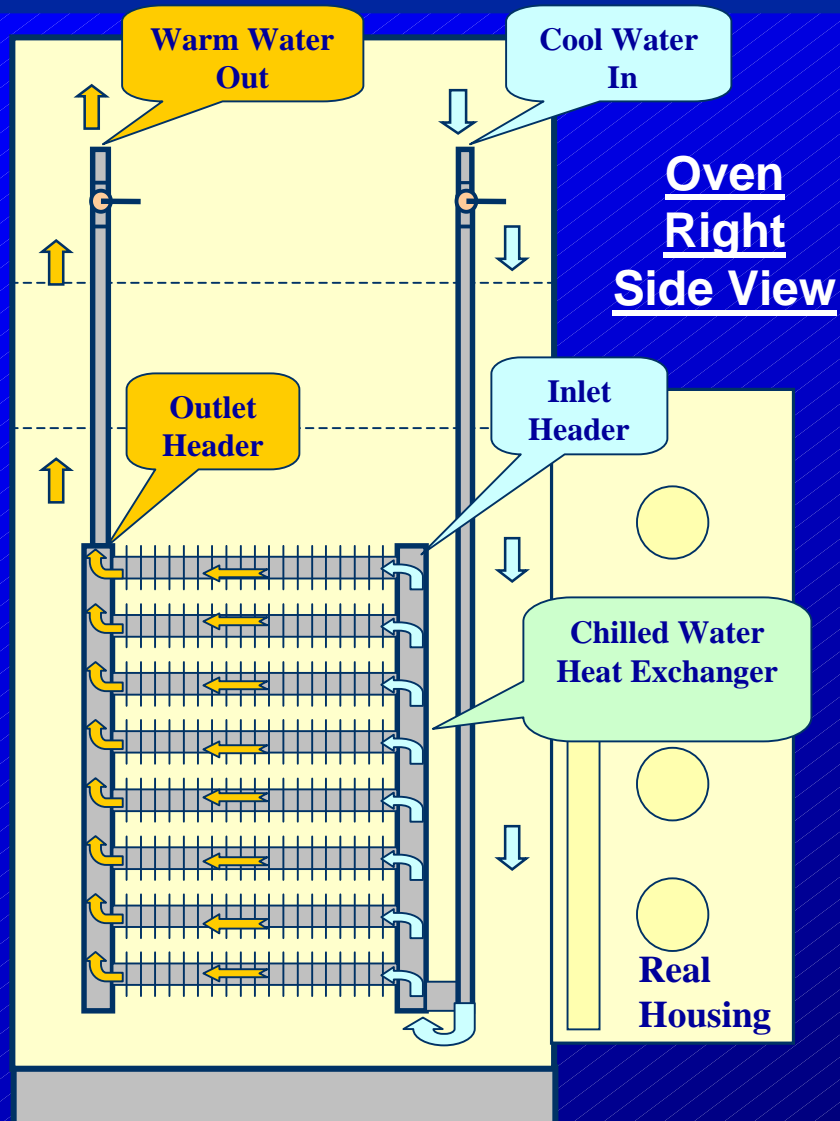


b) Chilled water from external facility air-cooled chiller will flow through the air to liquid heat exchanger in the burn-in oven and back to the chiller.

c) Control circuitry is incorporated to cater for both chilled water flow control and air heater control.





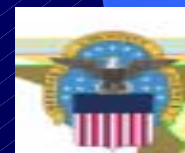


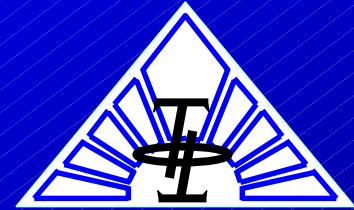
d) Heat from DUTs are removed through the circulating air and then by the chilled water circulating through the heat exchanger. This heat is transferred to the external facility chiller.

e) Cooling coil size is restricted by the space available at the return air duct of the existing burn-in oven.



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## 5) Data Collection I :

Heater coil dissipating heat in term of True AC power is used to simulate the amount of heat or DC power generated by DUTs during normal burn-in conditions.

Heat load per segment of heater coil =  $V_{rms} \times I_{rms} = 230VAC \times 16.5A = 3.8 KW$

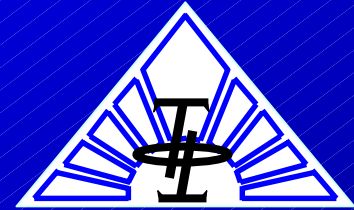
For the facility chilled water supply, temperature is maintained at approx.  $14^{\circ}C$  with a tolerance of  $\pm 2^{\circ}C$ ; water pressure is maintained at approx. 70 psi.

All tests conducted under normal air-conditional environment of approx.  $25^{\circ}C$ .

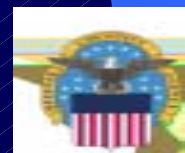


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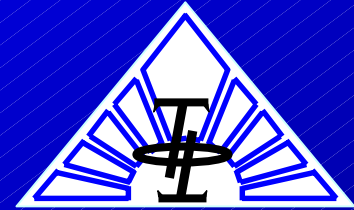




- a) Without heat load, without chilled water, min. oven operating temperature =  $49^{\circ}\text{C}$  with a temp. profile of  $\pm 0.5^{\circ}\text{C}$ .
- b) With no heat load, but with chilled water, min. oven operating temperature =  $34^{\circ}\text{C}$  with a temp. profile of  $\pm 0.5^{\circ}\text{C}$ .
- c) With 7.5KW heat load and chilled water, min. oven operating temperature =  $65^{\circ}\text{C}$  with a temp. profile of  $\pm 4^{\circ}\text{C}$ .
- d) With 11.4KW heat load and chilled water, min. oven operating temperature =  $85^{\circ}\text{C}$  with a temp. profile of  $\pm 6^{\circ}\text{C}$ .
- e) With 15.2KW heat load and chilled water, min. oven operating temperature =  $92^{\circ}\text{C}$  with a temp. profile of  $\pm 8^{\circ}\text{C}$ .
- f) With 19KW heat load and chilled water, min. oven operating temperature =  $116^{\circ}\text{C}$  with a temp. profile of  $\pm 8^{\circ}\text{C}$ .

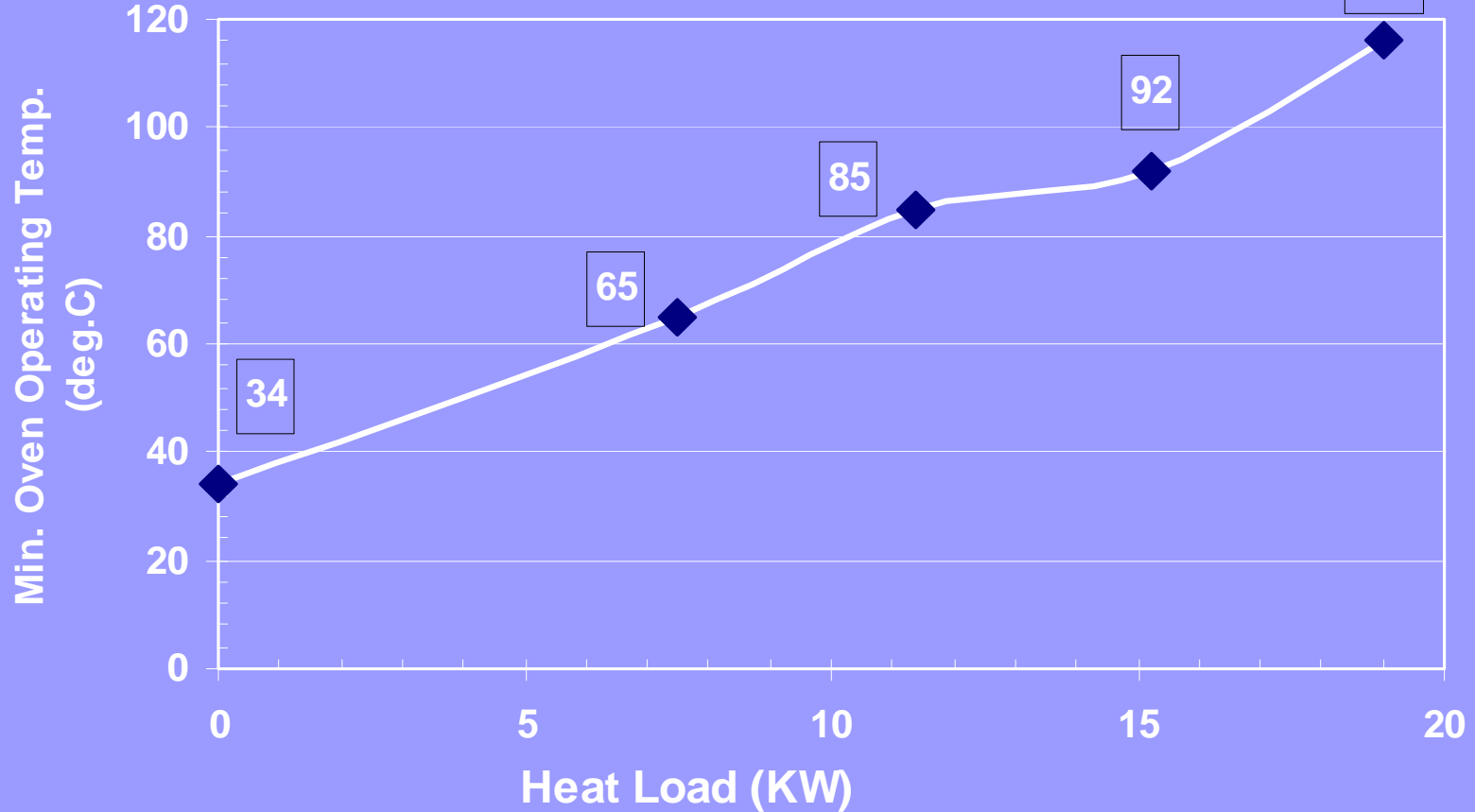


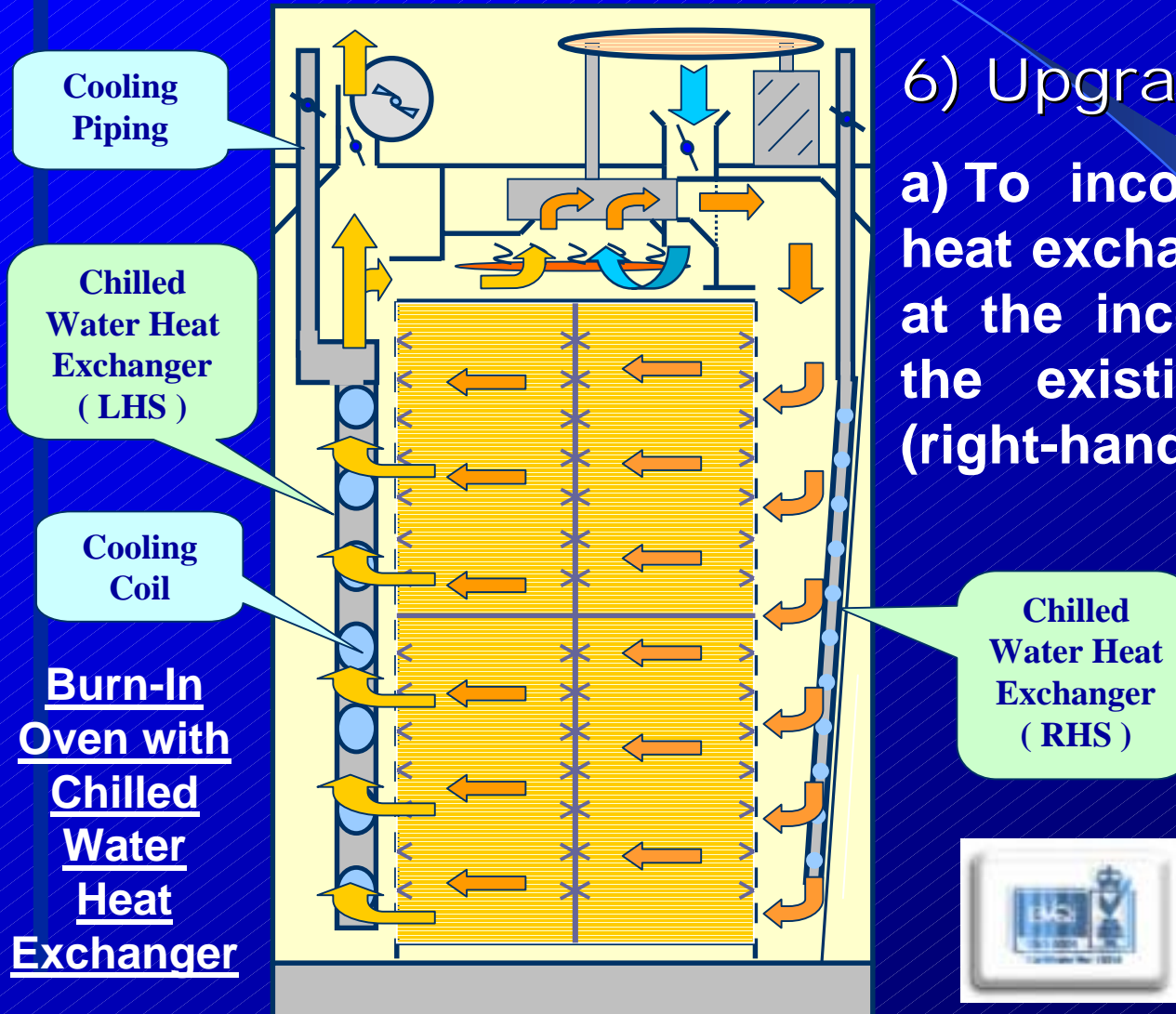
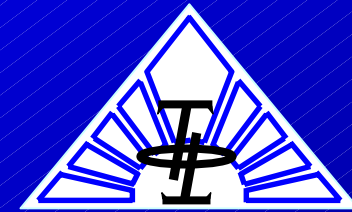
# TRIO-TECH INTERNATIONAL



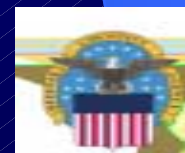
Heat Load (KW)	0	7.5	11.4	15.2	19
Min. Operating Temp. (deg.C)	34	65	85	92	116

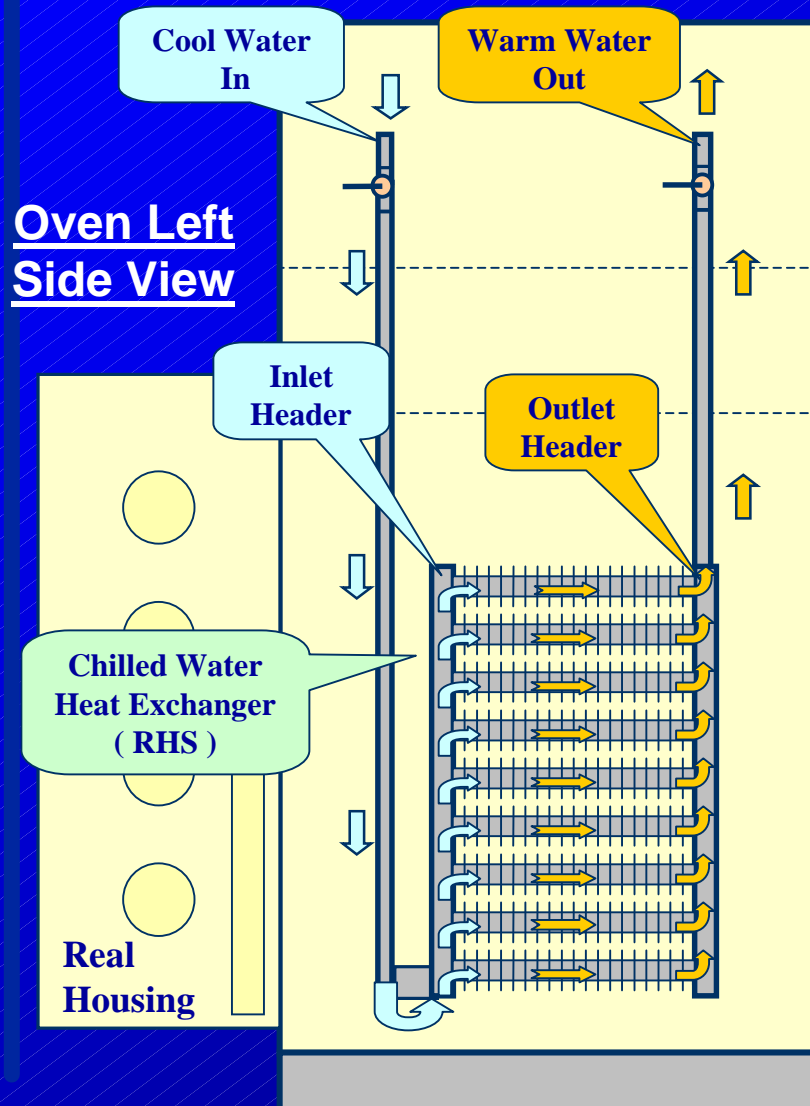
Min. Oven Operating Temperature vs Heat Load (Design I)





6) Upgrading Design II :  
a) To incorporate a smaller heat exchanger (cooling coil) at the incoming air duct of the existing burn-in oven (right-hand side of oven).



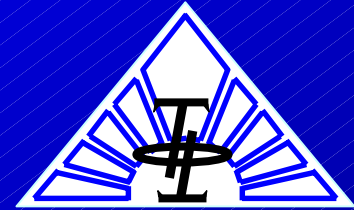


b) The additional small heat exchanger is connected in parallel with the first set of heat exchanger. It improves the overall oven heat dissipation capability.



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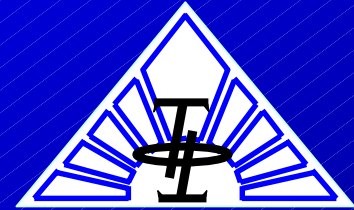


## 7) Data Collection II :

- a) With no heat load, but with chilled water, min. oven operating temperature = 30°C with a temp. profile of  $\pm 0.5^{\circ}\text{C}$ .
- b) With 3.8KW heat load and chilled water, min. oven operating temperature = 38°C with a temp. profile of  $\pm 3^{\circ}\text{C}$ .
- c) With 7.5KW heat load and chilled water, min. oven operating temperature = 50°C with a temp. profile of  $\pm 4^{\circ}\text{C}$ .
- d) With 11.4KW heat load and chilled water, min. oven operating temperature = 60°C with a temp. profile of  $\pm 6^{\circ}\text{C}$ .
- e) With 15.2KW heat load and chilled water, min. oven operating temperature = 72°C with a temp. profile of  $\pm 8^{\circ}\text{C}$ .
- f) With 19KW heat load and chilled water, min. oven operating temperature = 84°C with a temp. profile of  $\pm 9^{\circ}\text{C}$ .

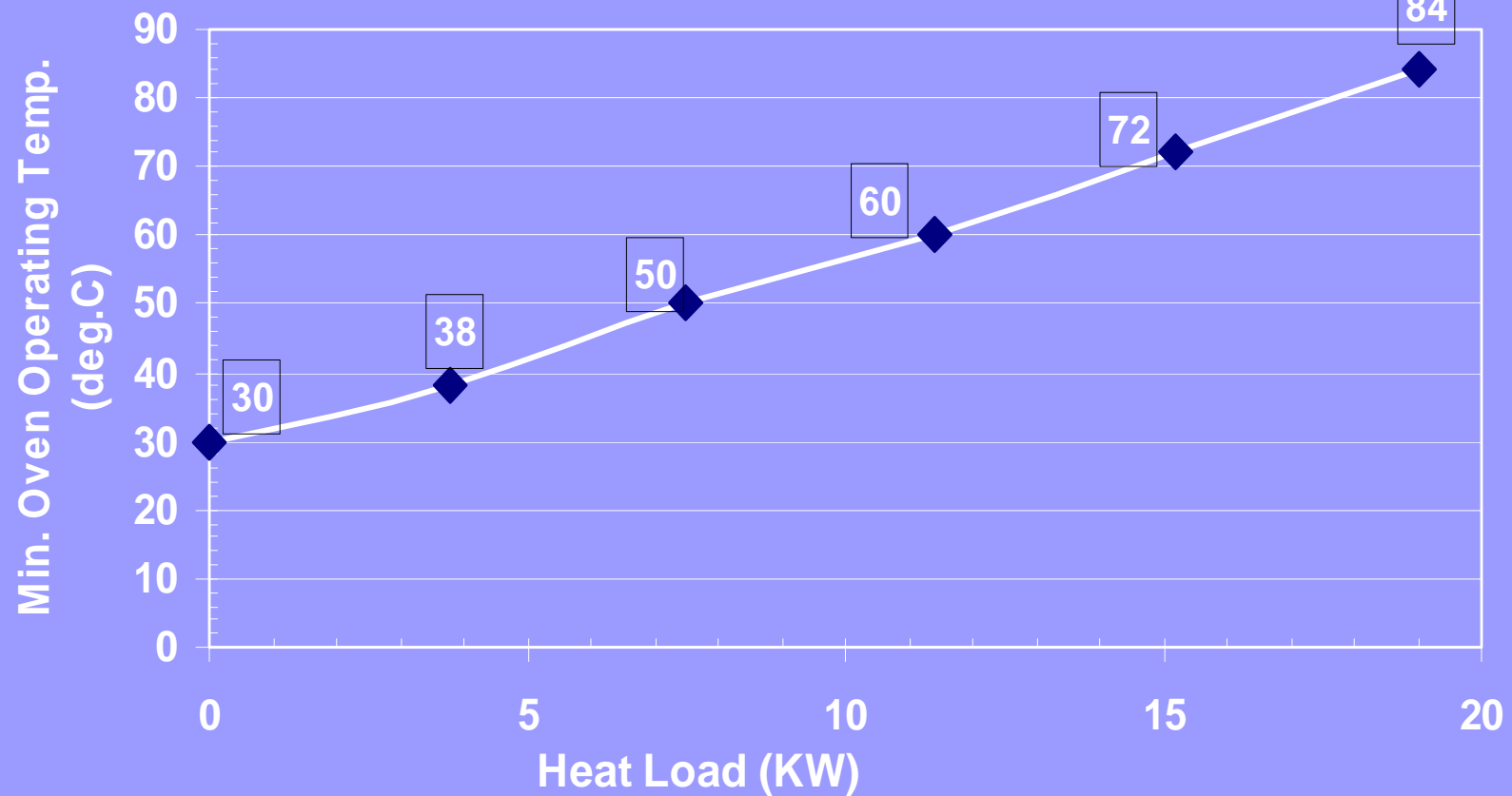


# TRIO-TECH INTERNATIONAL

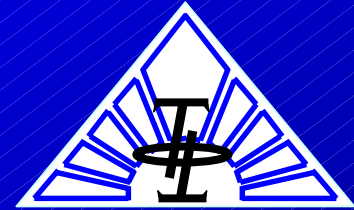


Heat Load (KW)	0	3.8	7.5	11.4	15.2	19
Min. Operating Temp. (deg.C)	30	38	50	60	72	84

Min. Oven Operating Temperature vs Heat Load (Design II)





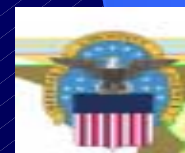


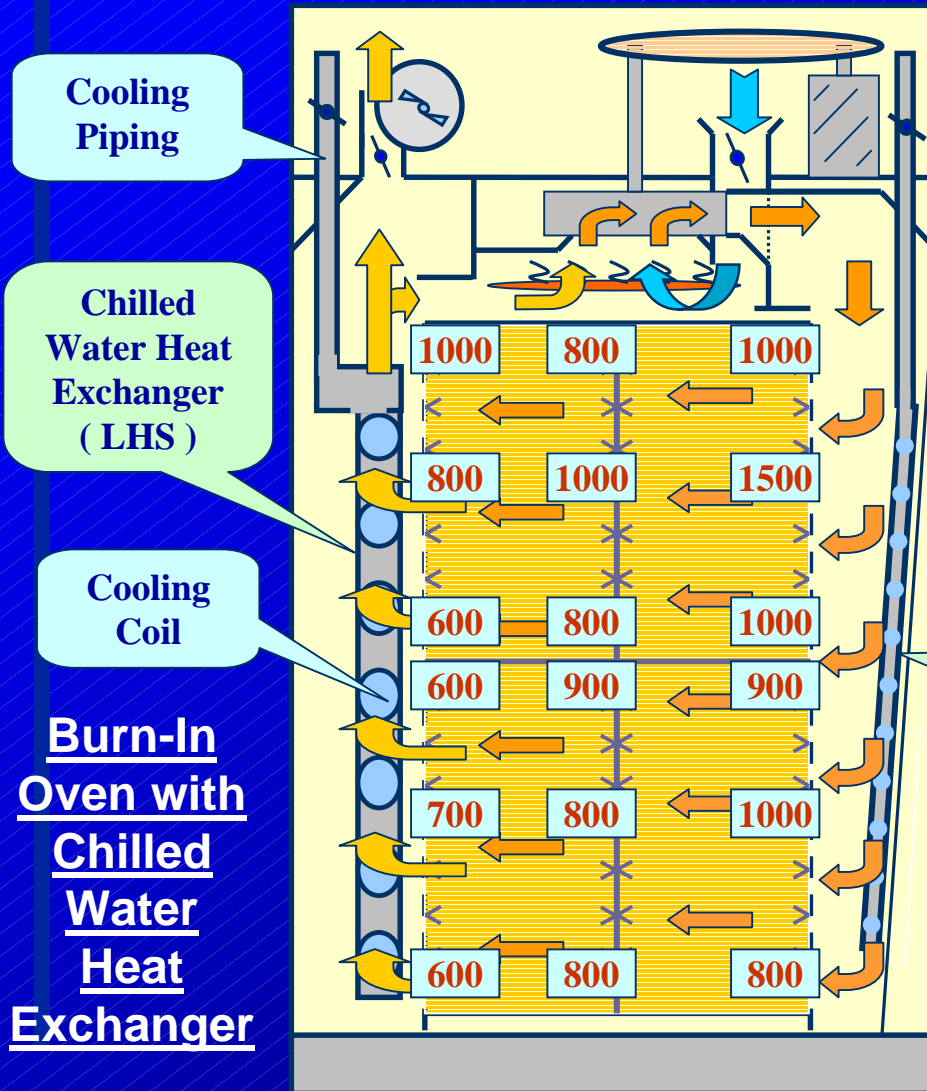
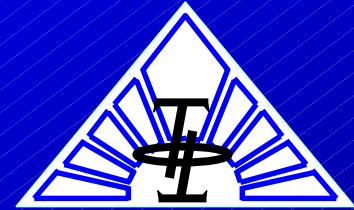
With above collected data, a Minimum Operating Temperature (°C) vs Heat Load (KW) equation can be derived as below.

$$Y = 2.85 X + 30$$

where Y = Minimum Operating Temperature (°C)  
& X = Heat Load (KW)

Therefore, at 125°C operating temperature, the amount of heat load the oven is able to dissipate is calculated to be 33.4KW.





8) Airflow Rate :

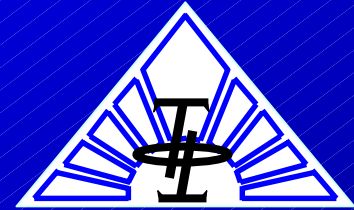
The actual airflow rate within the oven is measured (in lfm) with BIB fully loaded.

Max. airflow : 1500 lfm

Min. airflow : 600 lfm

Average airflow rate : 866 lfm





## 9) Cooling Power of Heat Exchanger :

All tests have been conducted with simulated heat load.

Actual heat being dissipated by the heat exchanger (cooling coil) can be calculated based on the chilled water inlet and outlet temperature different and chilled water flowrate using below formula.

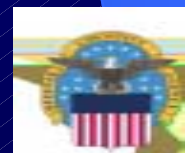
**Cooling Power (KW) = Water specific heat capacity x Inlet/Outlet Temperature different x Water density x Flowrate**

**= 4.187 kJ/Kg.K x (Tout – Tin) x 988 Kg/m<sup>3</sup> x Flowrate m<sup>3</sup>/sec**

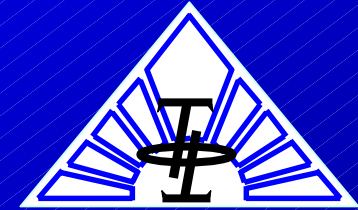
**Flowrate = 11 litres/min. = 0.11 m<sup>3</sup>/min**



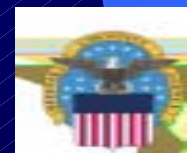
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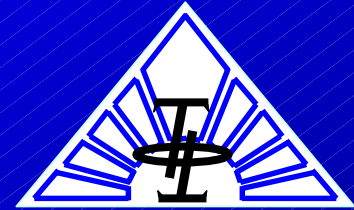


# TRIO-TECH INTERNATIONAL



Test #	Heat Load (KW)	In Temp. (deg.C)	Out Temp. (deg.C)	Delta T (deg.C)	Heat Dissipated (KW)
1	3.8	14.7	20.0	5.3	4.1
2	7.5	14.6	24.4	9.8	7.5
3	11.4	14.2	28.3	14.1	10.8
4	15.2	14.6	33.8	19.2	14.7
5	19.0	14.2	38.4	24.2	18.5



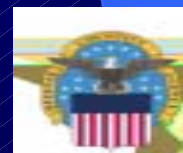


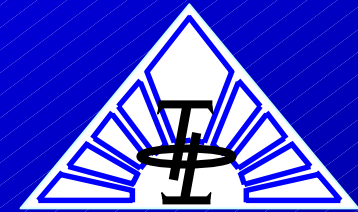
## 10) Ramp Rate :

For different heat loads, the oven will ramp up to the set burn-in temperature with different durations.

Below table shows the the amount of time needed to ramp up the oven from 45°C to 125°C set temperature at different heat loads.

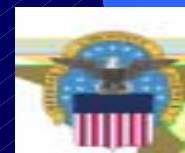
Heat Load (KW)	Ramp Up Time (mins)	Ramp Down Time (mins)
3.8	20	16
7.5	15	16
11.4	12	16
15.2	10	16
19	8	16





## 11) Summary :

- In conclusion, with our upgrading design, we have achieved a heat dissipation capacity of 19KW @ 84°C operating temperature with an average airflow of 866 lfm.
- We will be continuously improving and testing our oven with chilled water heat exchanger.
- It is the policy of Trio-Tech to provide quality products and services that conform to the requirements of all our customers.



# **BiTS 2002**

## **The Challenges in Fine Pitch Burn-In Tooling**

**Anthony Wong Yeh Chiing**  
**Hwan Ming Wang**  
**Intel Test Tooling Operation**



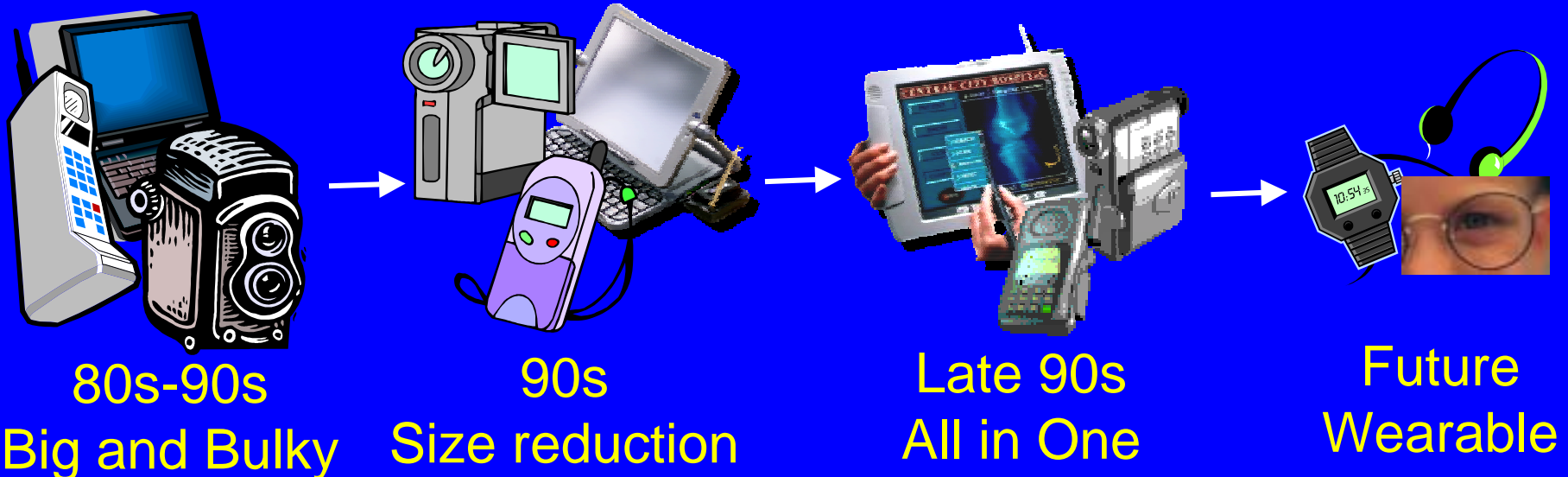
# Agenda

- Introduction
- Tooling design constraint & consideration
- Equipment capability and manufacturing processes stability
- Tooling assembly & repair difficulty
- High Volume Manufacturing handling
- Fine pitch burn in tooling cost and investment
- Solutions / standardization needed for cost-effective, stable and capable processes enabling



# Introduction

- Millions of people around the world use electronic gadgets such as cell phone, pager, personal digital assistant, digital camera, digital video camcorder, global positioning systems & computer in their daily life
- These products have continuously shrinking in size because of consumers' needs on smaller, light weight, powerful, and best of all – Wearable

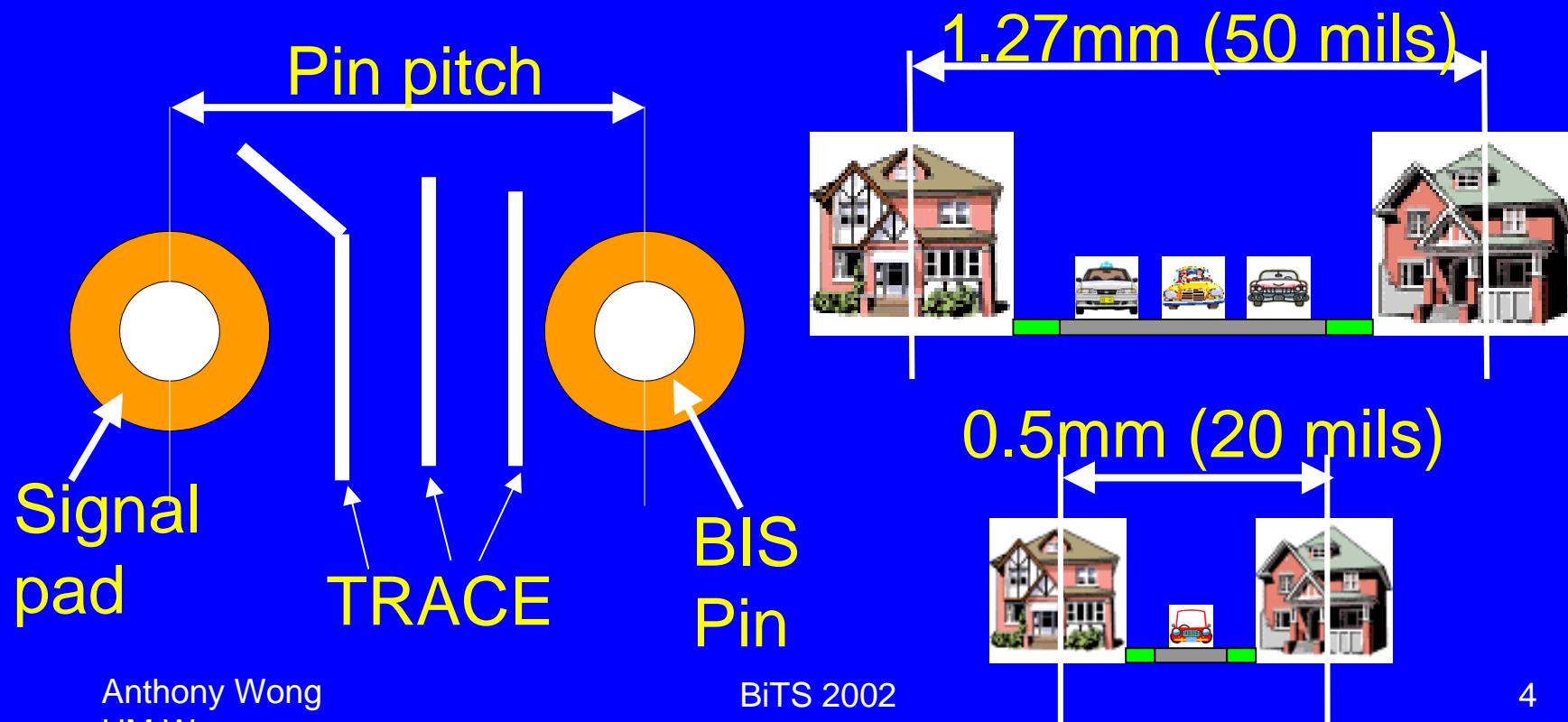


Anthony Wong  
HM Wang

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# Introduction

- Technology companies are pursuing smaller and better products to meet consumers' needs
- Available spaces for devices are shrinking
- Required smaller package, finer pitch device (<0.5mm), to optimize space utilization



# Introduction

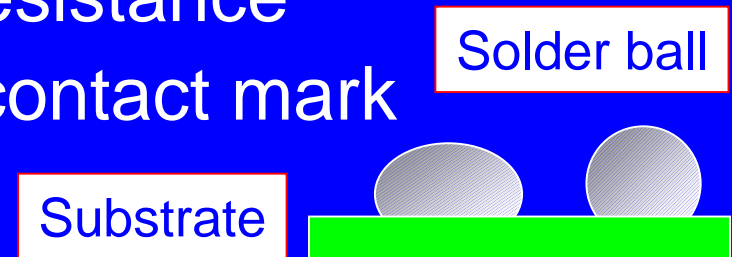
- Two types of fine pitch BI Tooling are available
  - Compression Mount Style (CMT)
    - Stamped/ etched pin / Pogo pin / Micro-coil spring
    - Burn In Socket (BIS) is direct mounted to the Burn In Board (BIB)
  - Through Hole Style (TH)
    - Stamped pin type
    - BIS is mounted on the BIB with contacts soldered to the PCB pads and pin holes

# Introduction

- TH type has been commonly used in all package platforms & larger pin pitch (>0.5mm) packages.
- CMT type are more widely used in test than in burn-in
- In fine pitch BI tooling, both types of BI Tooling have their own tooling design and manufacturing challenges.
- The goal is to have a cost effective integrated BI solution:
  - BIS + BIB

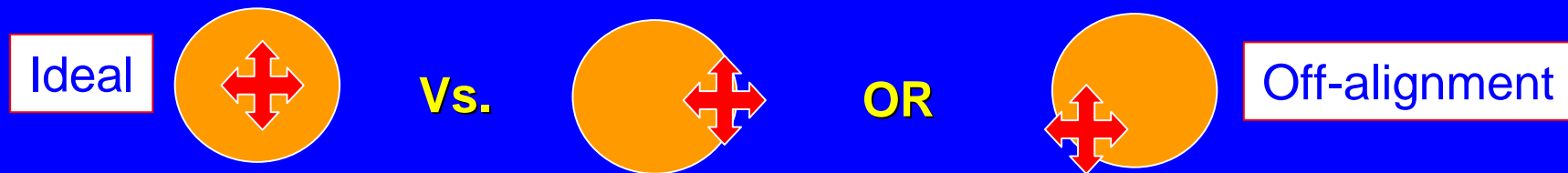
# Tooling Design Constraint & Consideration

- Package to BIS interface
  - Alignment guide (package body / solder ball)
  - Contact force and contact resistance
    - Solder ball deformation, contact mark
    - Electrical connection
  - BIS Contact contamination (oxidation / foreign material)
- BIS to BIB interface
  - Guide pin and contact alignment
  - CMT: BIS Alignment pin to PCB pad alignment
  - BIS Contact contamination
  - CMT: Contact force and contact resistance

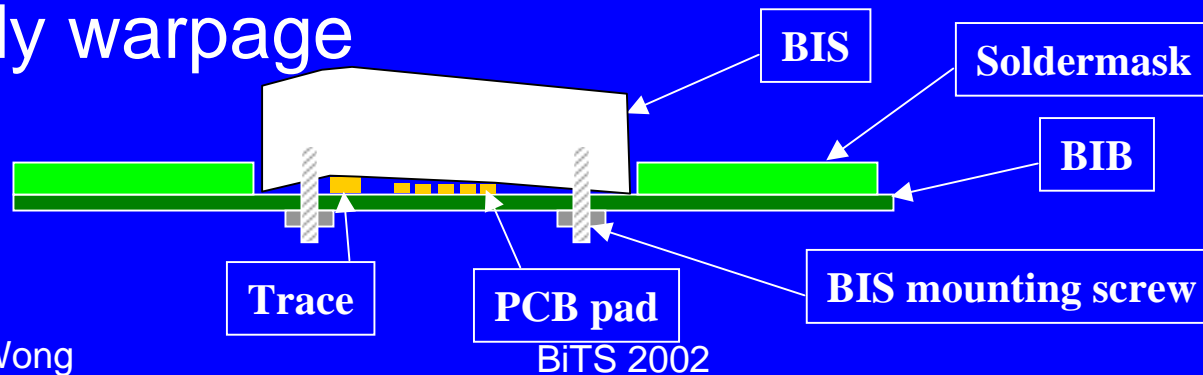


# Tooling Design Constraint & Consideration

- Alignment is extremely critical as pin pitch reaches 0.5mm or smaller, the dimension tolerance also reduced dramatically

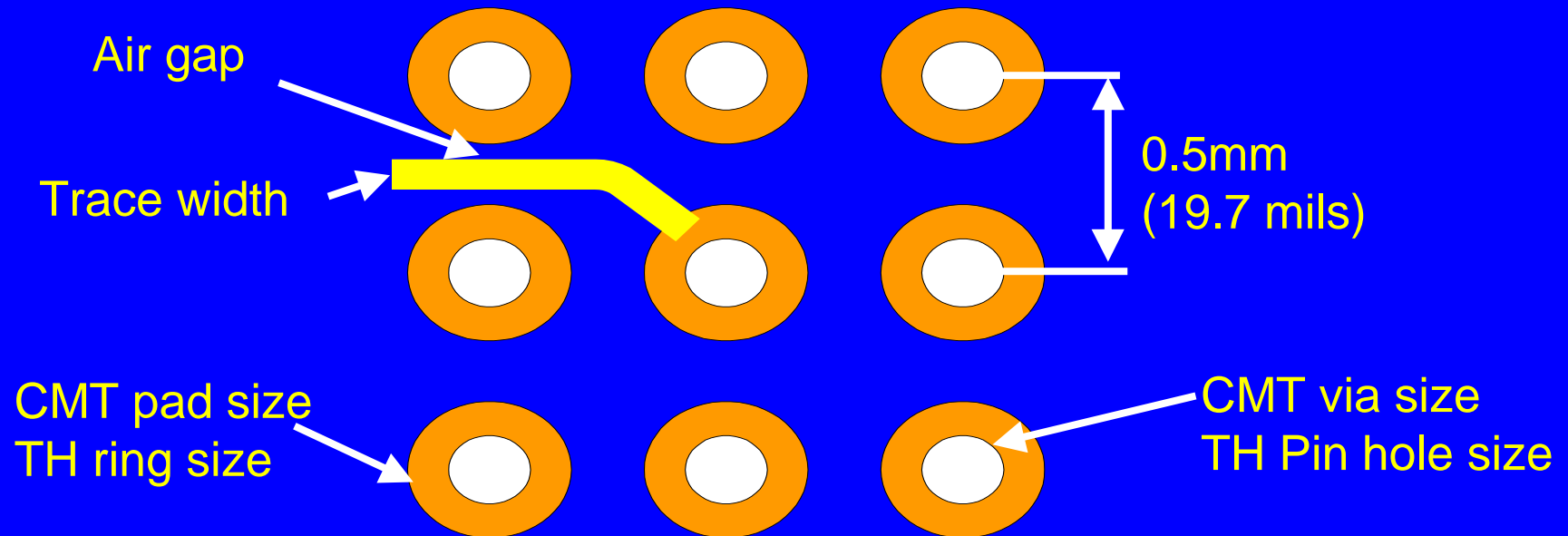


- CMT BIS Body Flatness on BIB
  - Caused uneven compression force
  - Contributors: PCB pad height, trace height, solder-mask thickness, PCB warpage, BIS body warpage



# Tooling Design Constraint & Consideration

- BIB Real estate availability for signal trace routing
  - PCB pad size, Annular ring size
  - PCB trace width < 2 mils
  - Air gap between trace and pad < 2 mils
  - TH: BIB pin hole size < 8 mils
- Fan out design?



# Equipment Capability and Manufacturing Processes Stability

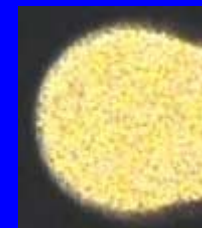
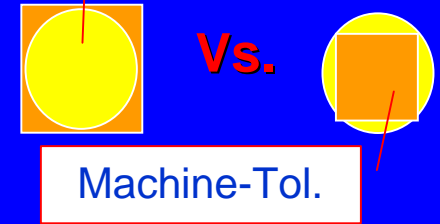
- BIS Molding on fine pitch critical features
  - Pin hole pitch, diameter, and its true position to guiding features; package solder ball / body
  - To avoid defects like : flash & void
- Limited space for socket mechanism
- TH : stamped pin reliability and durability
  - Pin life spans / pin fatigue
- Need stringent dimensional control of controlling features on socket
  - Guiding, contact pin hole & contact
  - High yield loss



# Equipment Capability and Manufacturing Processes Stability

- BIB Drilling machine true position accuracy
  - Socket Designers like TPR, machine manufactures quote x & y tolerance
- Drilling pattern / dimension repeatability across a large BIB with high BIS density on the boards.
- How are we going to make the vias?
  - Drilling / laser? What is the best cost solution?
- Signal CMT pad / annular ring / trace width – what is the accuracy of etching needed?
- Copper trace thickness / Pad height
- Gold plating thickness & reliable measurements?

Alignment TP



CMT pad

# Tooling Assembly & Repair Difficulty

- BIS Assembly Risks
  - Handling on miniature and highly delicate contacts and compact housing e.g. contact pin
  - High yield loss on human induced error if assembly process not properly controlled
- BIS Repair Concerns
  - Hard to repair any damaged miniature part on BIS
  - Socket component replacement
  - Repair is not preferable - high labor cost

# Tooling Assembly & Repair Difficulty

- CMT BIB
  - Special BIS mounting procedure is needed
  - Easy damage to CMT contact pin during BIS mounting on BIB
  - Mounting screw torque must be tightly controlled to ensure even pin compression during BIS mounting on BIB
  - Debris / oxidation on PCB contact pad, which is difficult to be cleaned
  - Difficult to repair broken fine width traces and touch up on over-etched/ under-etched signal pads



Over-etched pad

# Tooling Assembly & Repair Difficulty

- TH BIB
  - Special BIS insertion procedure is needed
  - Easy damages to the through hole pins during BIS mounting on BIB
    - susceptible to bend / twist
  - Difficult to repair broken fine width traces and over-etched/ under-etched annular ring
  - Difficult to remove and clean up the fine pin hole on BIB to enable new BIS mounting

# High Volume Manufacturing Handling

- BIS wear out
  - Change in socket feature physical dimension
    - Non-genuine failure induced
- High maintenance cost – Low yield on socket replacement for TH BIS
- Contamination in BI environment
- CMT BIS easily knock loose
  - Intermittent electrical connection / higher contact resistance
- TH BIS pin crack / damage
  - Intermittent electrical connection / higher contact resistance

# High Volume Manufacturing Handling

- BIB
  - Broken fine width signal trace
  - Warpage of board at elevated temperature
  - Handling of bare PCB: no excessive bend allow
  - Need cleaning on the bare PCB
    - foreign material / oxidation

# Fine Pitch Tooling Cost and Investment

- BIS needed for enabling
  - Contact technology tooling
  - Assembly and lead time
  - Quality control
- BIB
  - PCB Pad Etching and Gold plating
  - Fine pitch PCB via / alignment hole drilling
    - Drilling Machine upgrade
      - Finer and more accurate drilling
    - Laser Drilling option
  - Assembly, maintenance and lead time
  - Quality verification: dim. check, plating check

# Solution/Standardization needed for cost-effective, stable and capable processes enabling

- **Packaging Standardization**
  - **Contact grid and pattern**
    - **Depopulated pin map – alternative row**
  - **Package thickness – Standardize BIS latch**
  - **Solder ball material – lead free**
- **BIB Drilling machine & verification equipment**
  - **Mechanical accuracy & repeatability**
  - **Be able to verified it**
- **Collaboration between BIS & BIB and roadmap sharing between the end users and suppliers**
- **A neutral forum for technical info sharing and standardization recommendation: packaging & tooling**