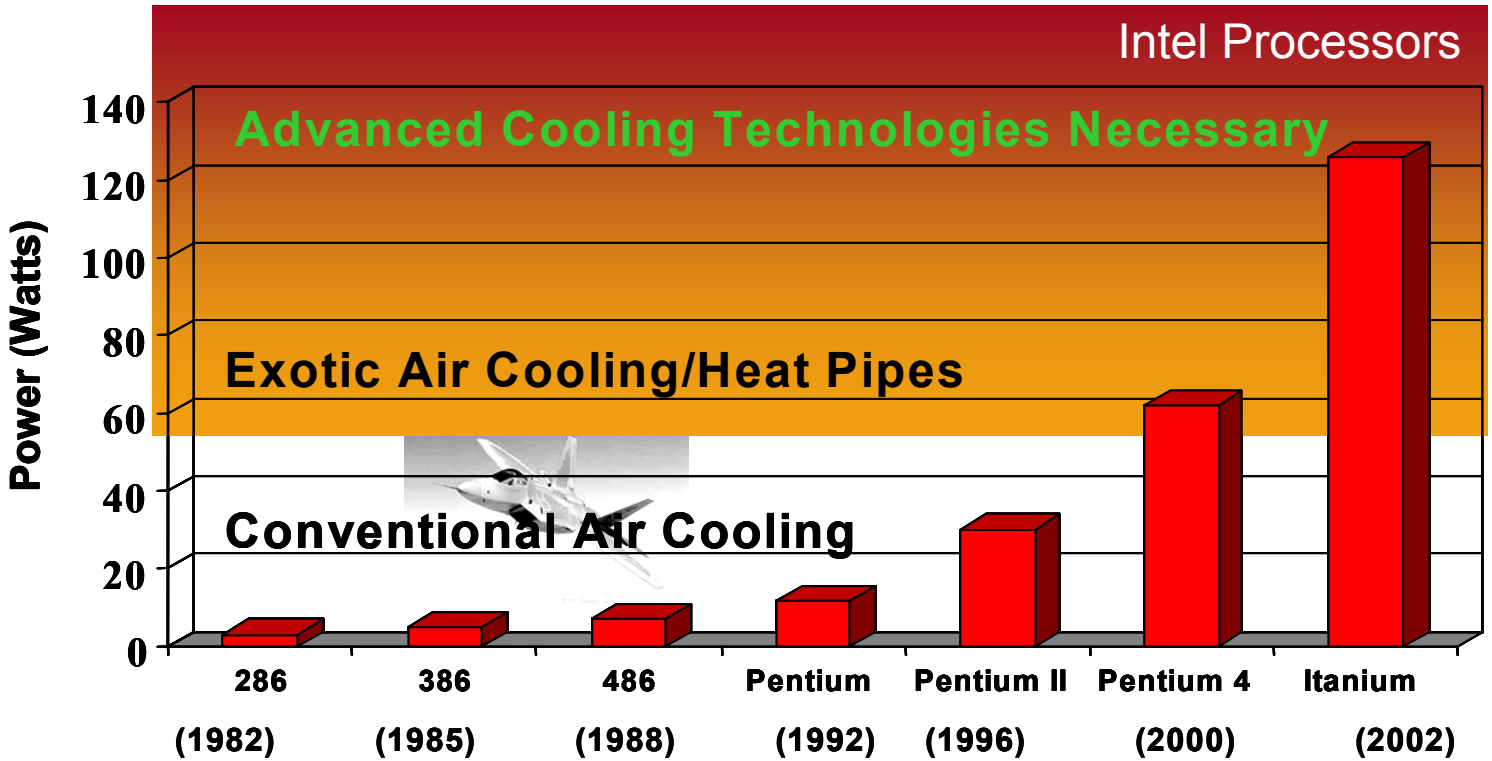
Spray Cooling for High Performance Microprocessors

ISR

August 9, 2004

A Fundamental Problem

- **Processor Technology is Surpassing Conventional Cooling**
  - Industry is moving towards Advanced Cooling
  - Commercial Solutions Designed for Benign Environments

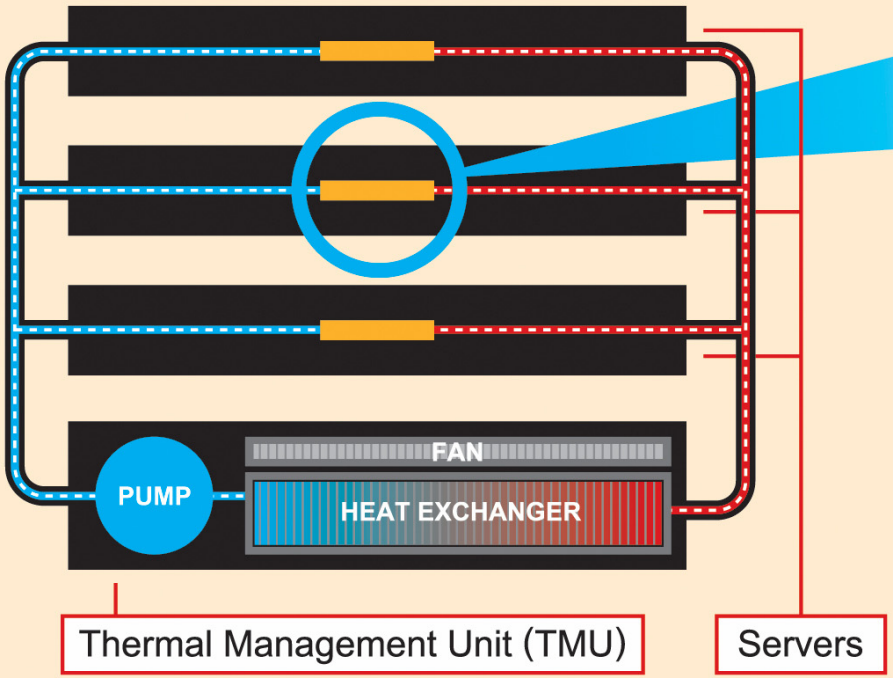


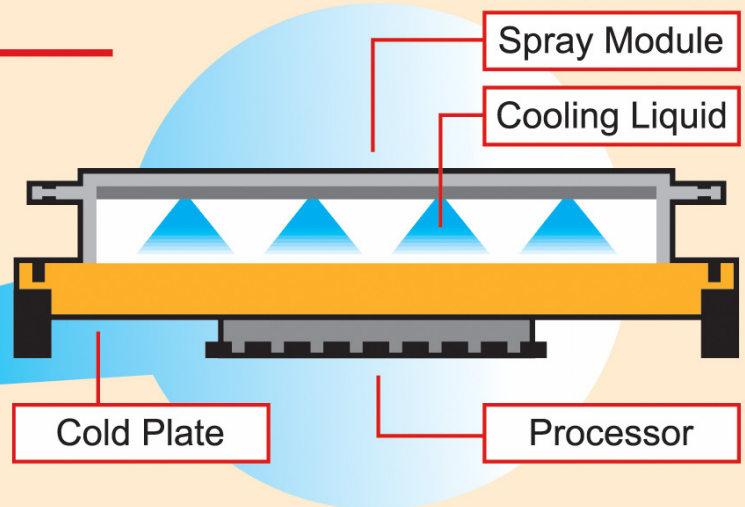
Current Electronics are Running Up Against the "Brick Wall"

Hot Spot & System Cooling Solutions

How SprayCool™ Technology Works

Spray modules are located on the chip inside the server. Thermal Management Unit is located in a separate enclosure, in the same rack.



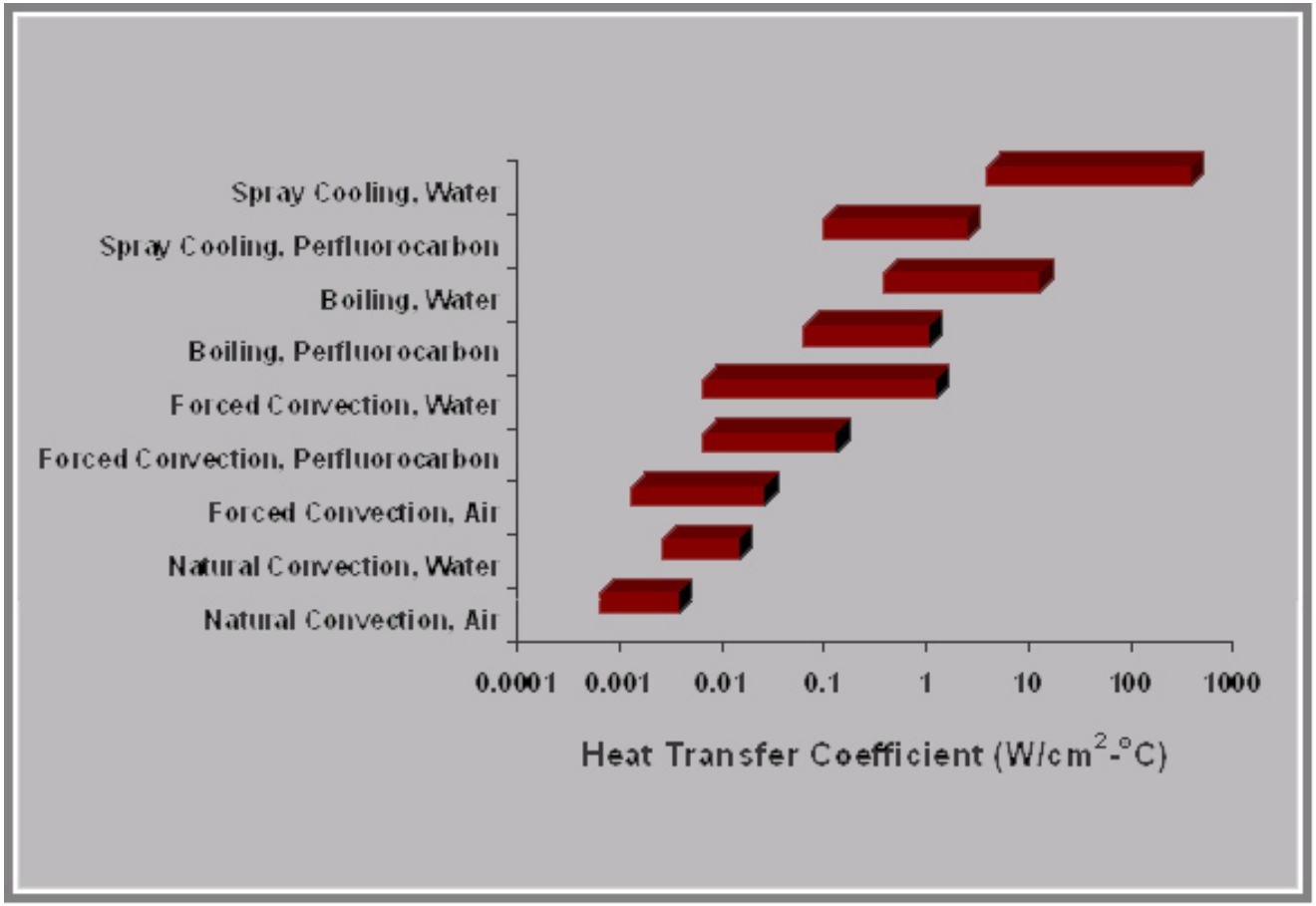


1. Fluid enters the spray module
2. Fluid is sprayed on the cold plate and evaporates
3. Vapor exits the spray module and is recondensed in the heat exchanger

Flexible Process for Cooling High Heat Flux Electronics

Cooling Options

- **Cooling performance comparisons**

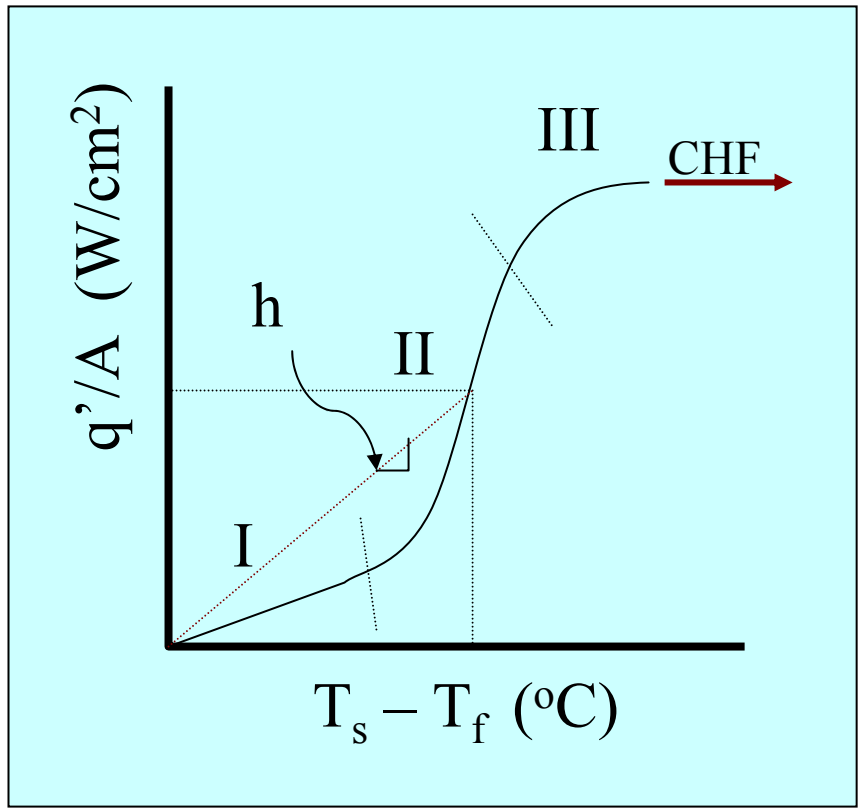


Heat transfer coefficients can vary by six orders of magnitude

Spray Cooling Behavior

- **Performance Range**
- **I. Low Superheat**
  - Predominately Forced Convection
- **II. High Temperature**
  - High-Efficiency Evaporative Cooling
- **III. Near CHF**
  - Reaching partial dry out, danger of burnout

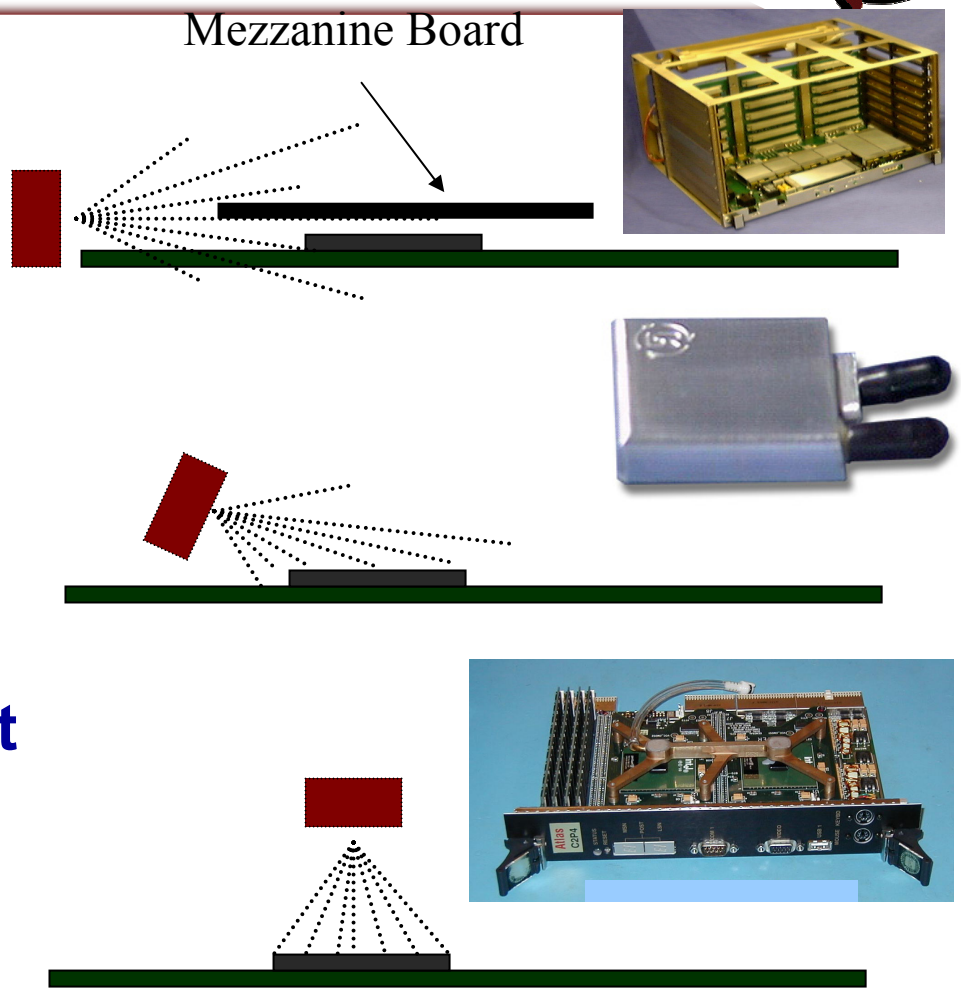
$$q' = h\ A\ DT$$



Wide Performance Range, Most Applications Today are on the Flat Portion of the Curve (I – Low Superheat)

Spray Cooling: Configurations

- **SprayCool Configurations**
- **I. Transverse Spray**
  - h ~ 0.1 to 1.0
  - Gaps ~ 0.05” to 0.8”
- **II. Angled Spray**
  - h ~ 0.2 to 1.5
  - Gaps ~ 0.25” to 0.8”
- **III. Normal Impingement**
  - h ~ 0.3 to 3.5
  - Gaps ~ 0.5” to 0.8”



ISR Uses Flexible Spray Cooling Configurations

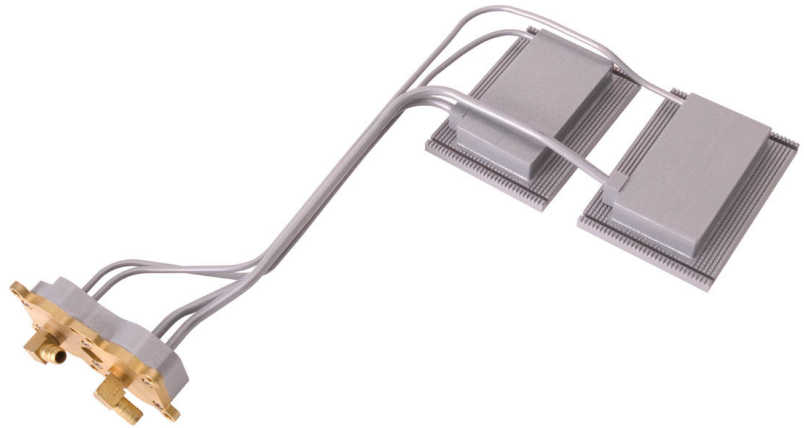
Benchmark Program

Thermal Performance/Benchmark Testing

- Two Servers used for Baseline Testing
  - 1 standard Air Cooled Product
  - 1 to convert to SprayCool
- Servers are Fully Instrumented and Tested
  - Component Temperatures
  - Audible Noise, Air Flow, Power Consumption, etc.
  - Performance Benchmark
    - Software Load - Six Instances of CPU Burn, N Bench Performance Benchmarking Program run on top, with Servers under full load

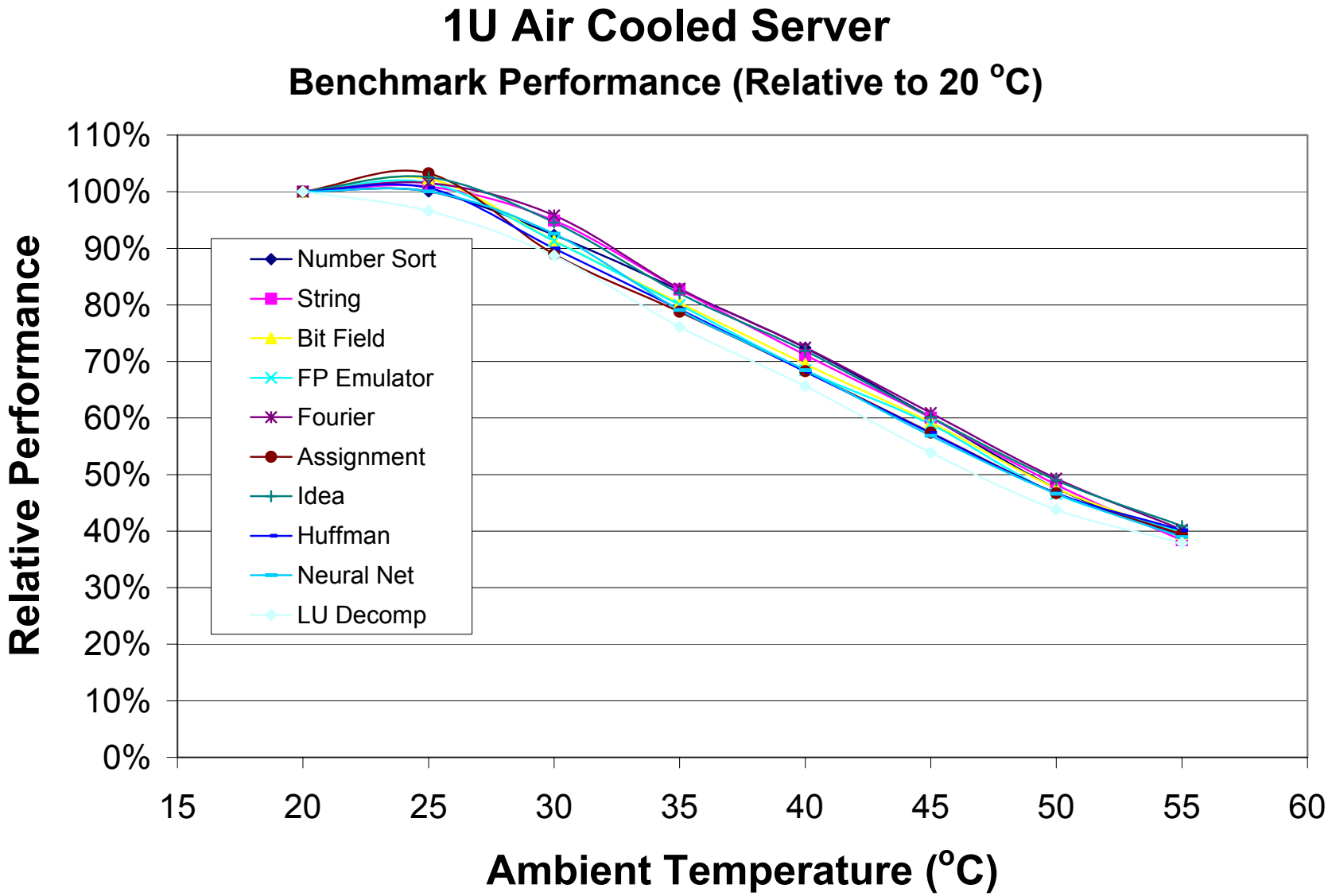
Server Conversion

- Replace Heat Sinks with a Spray Module Kit



- Reject Heat to Remote Thermal Management Unit

1U Server, nBench Performance



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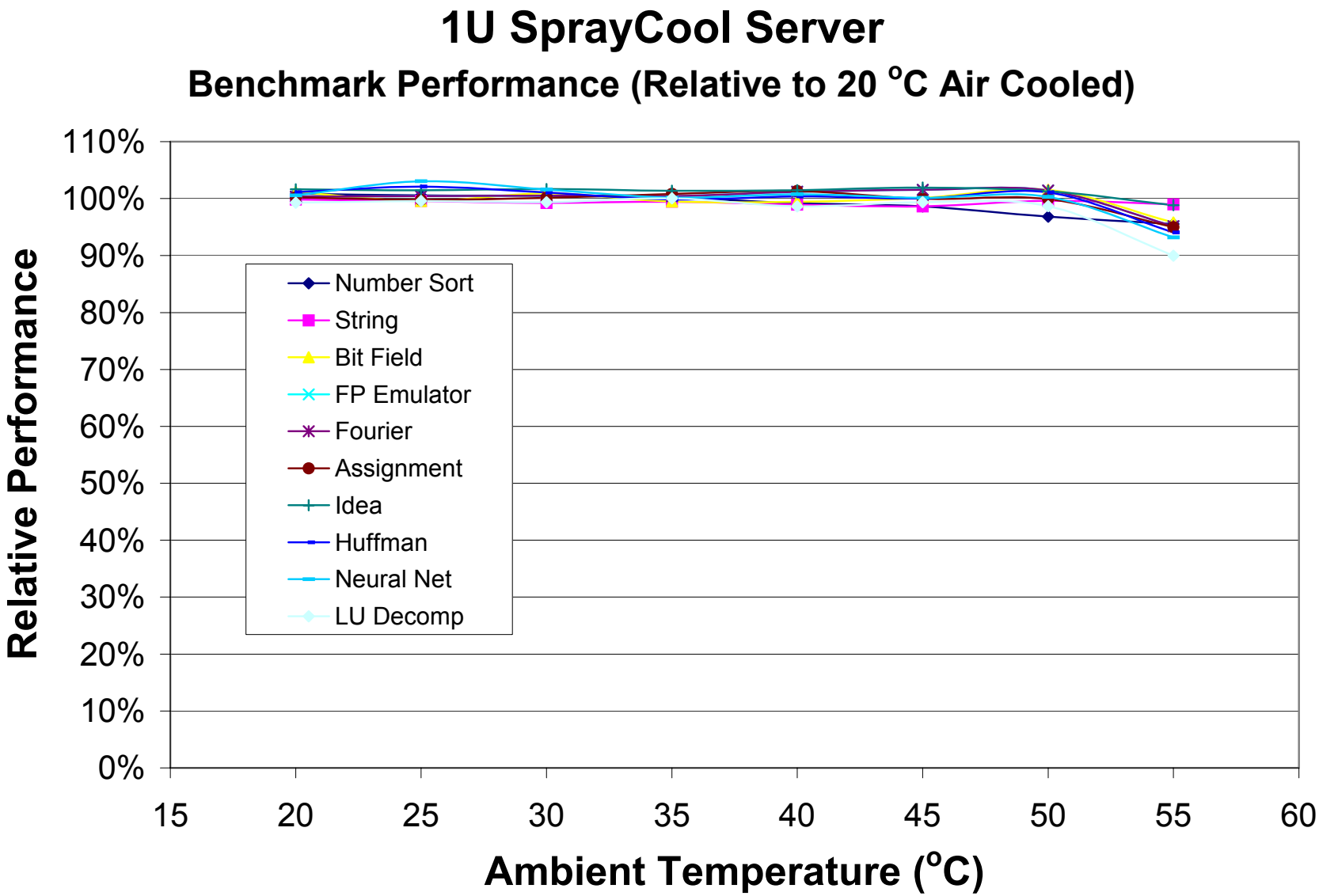
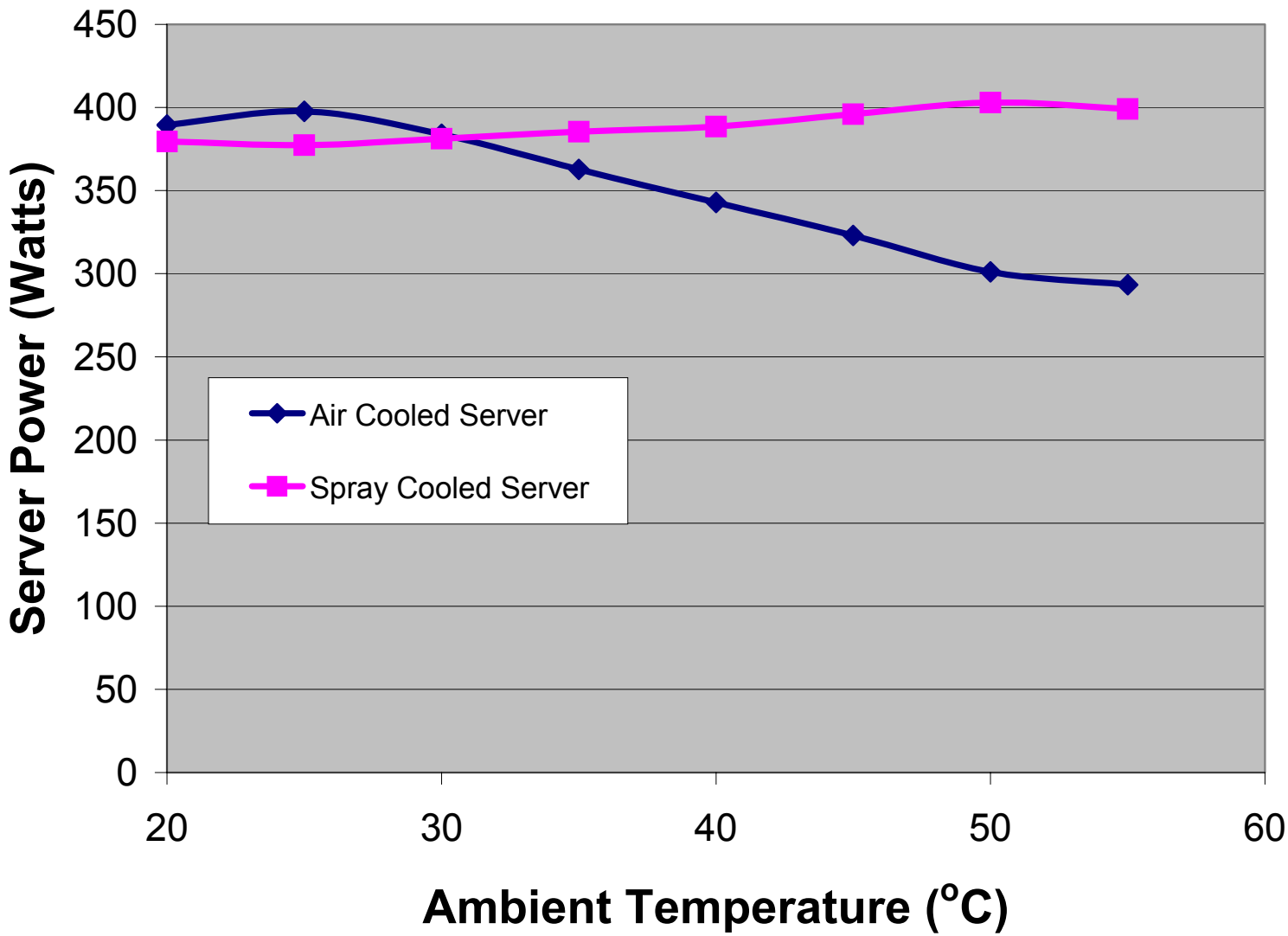


Power Comparison



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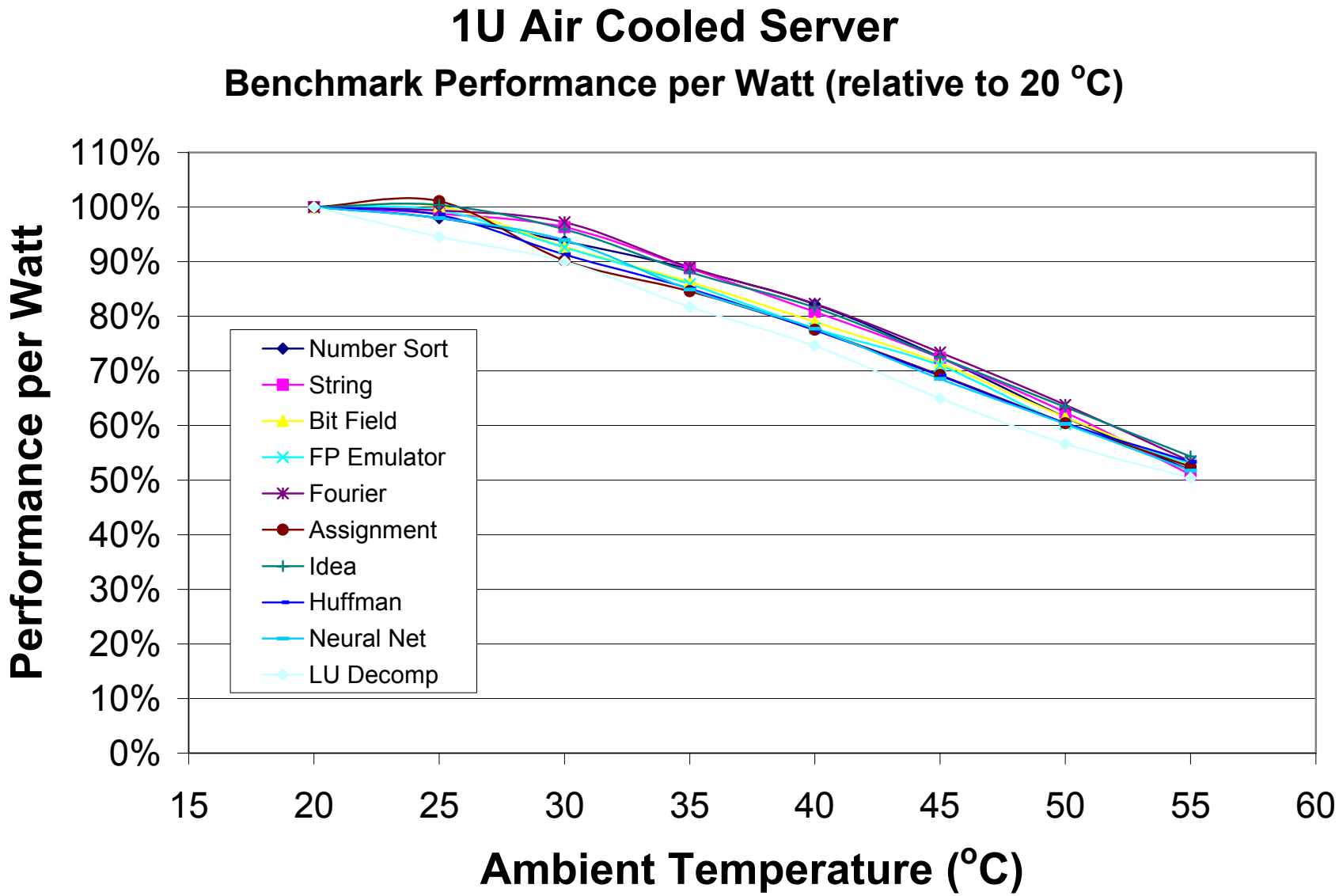

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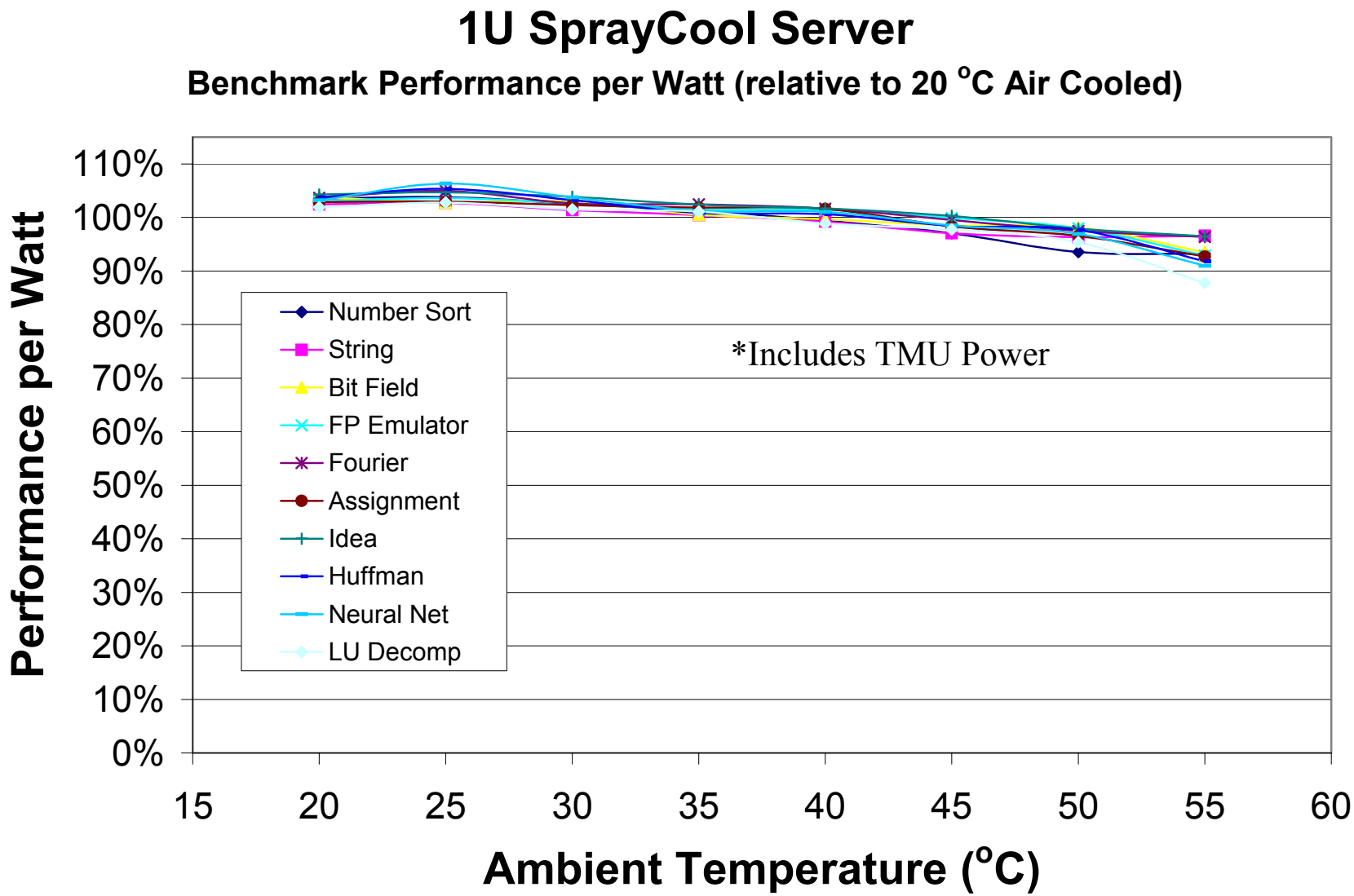

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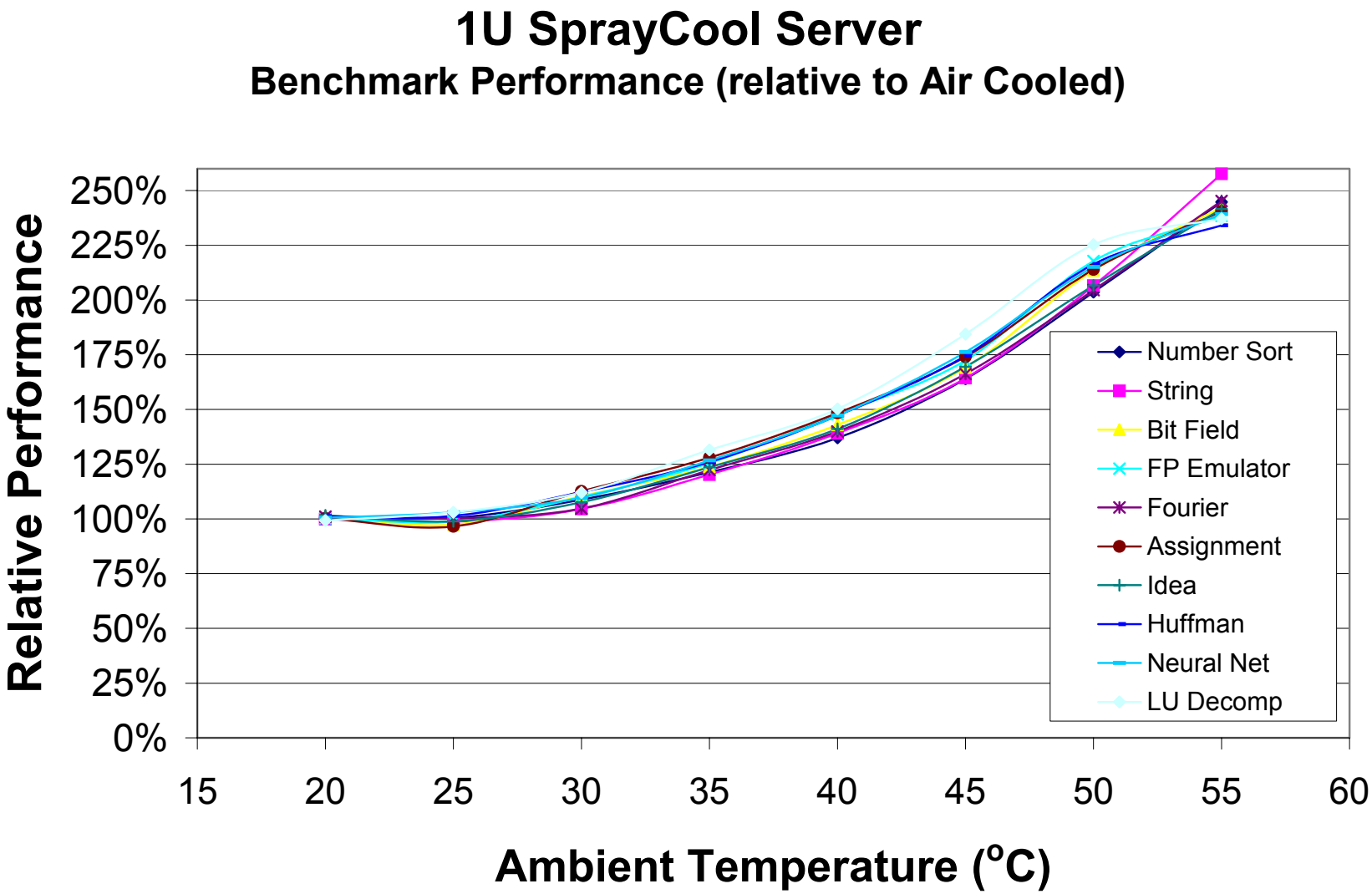

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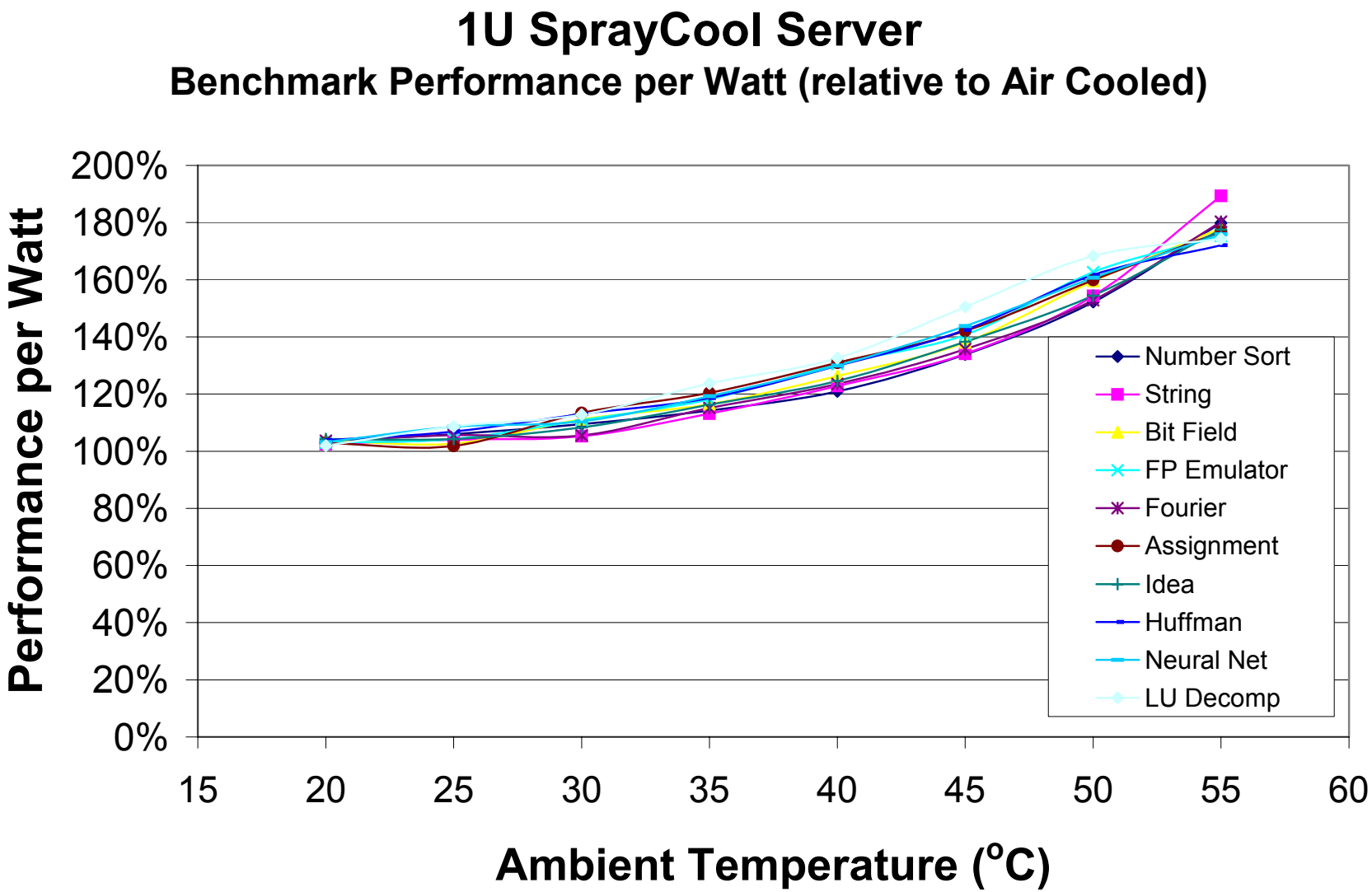
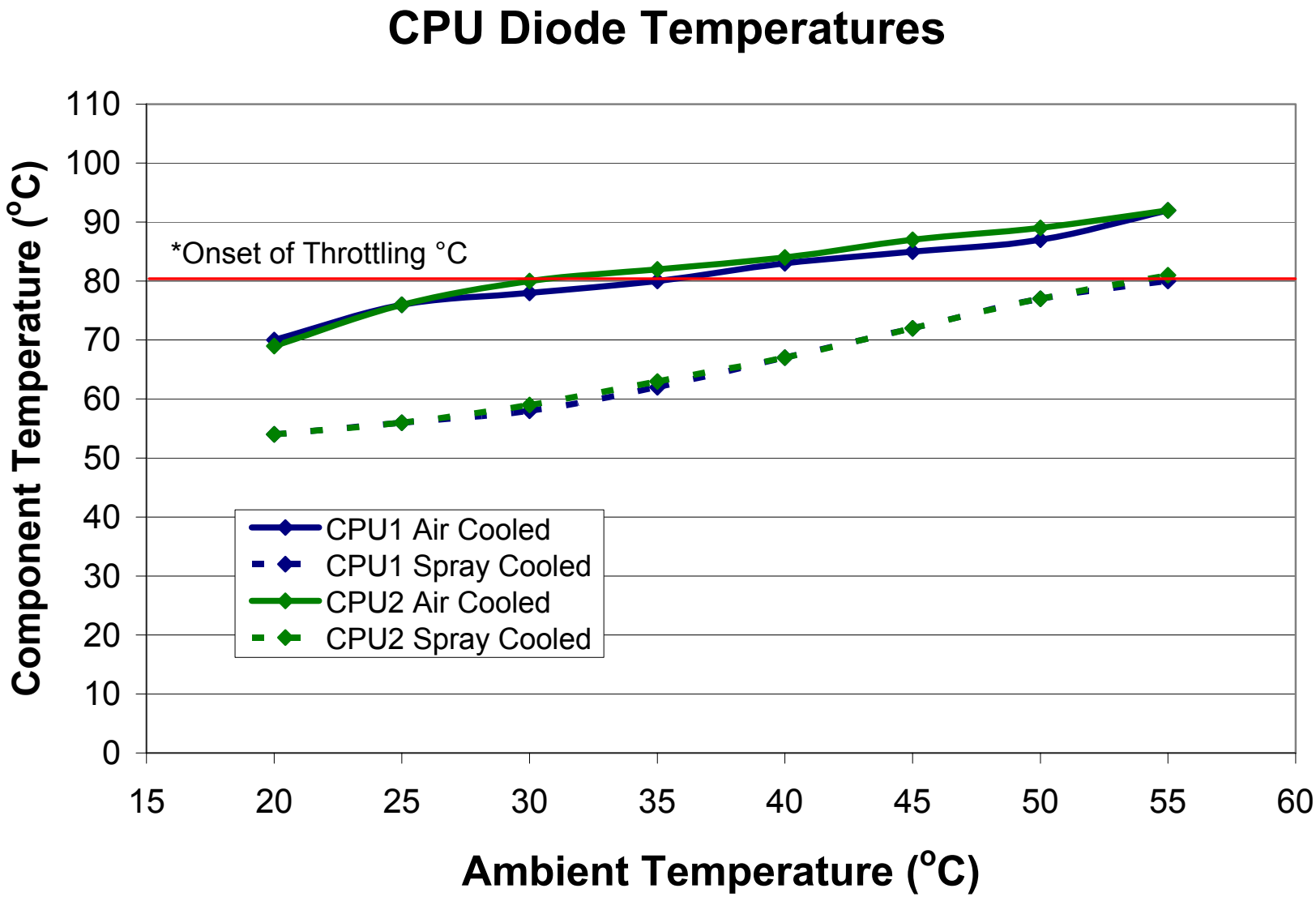


1U Server, Thermal Performance



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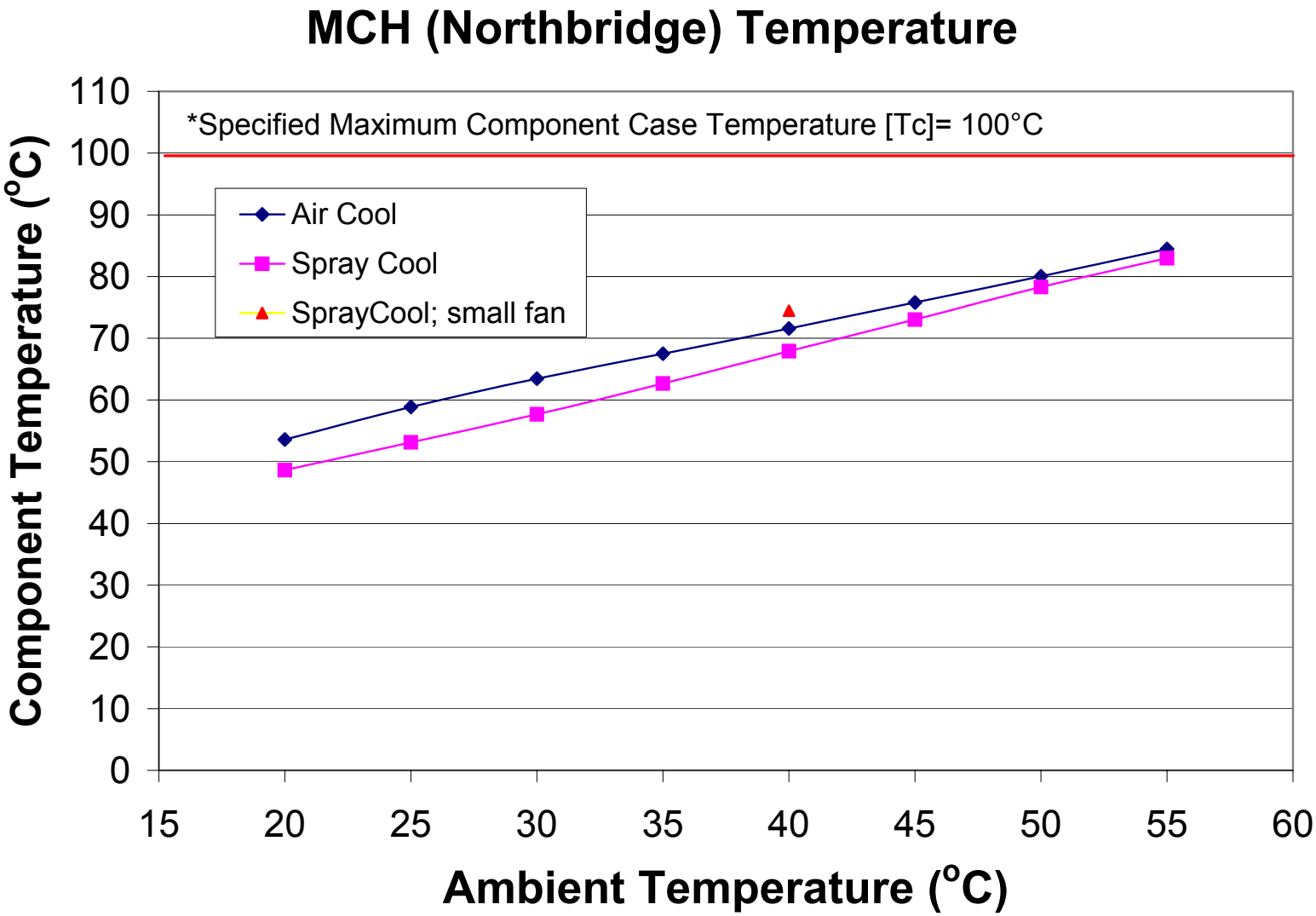

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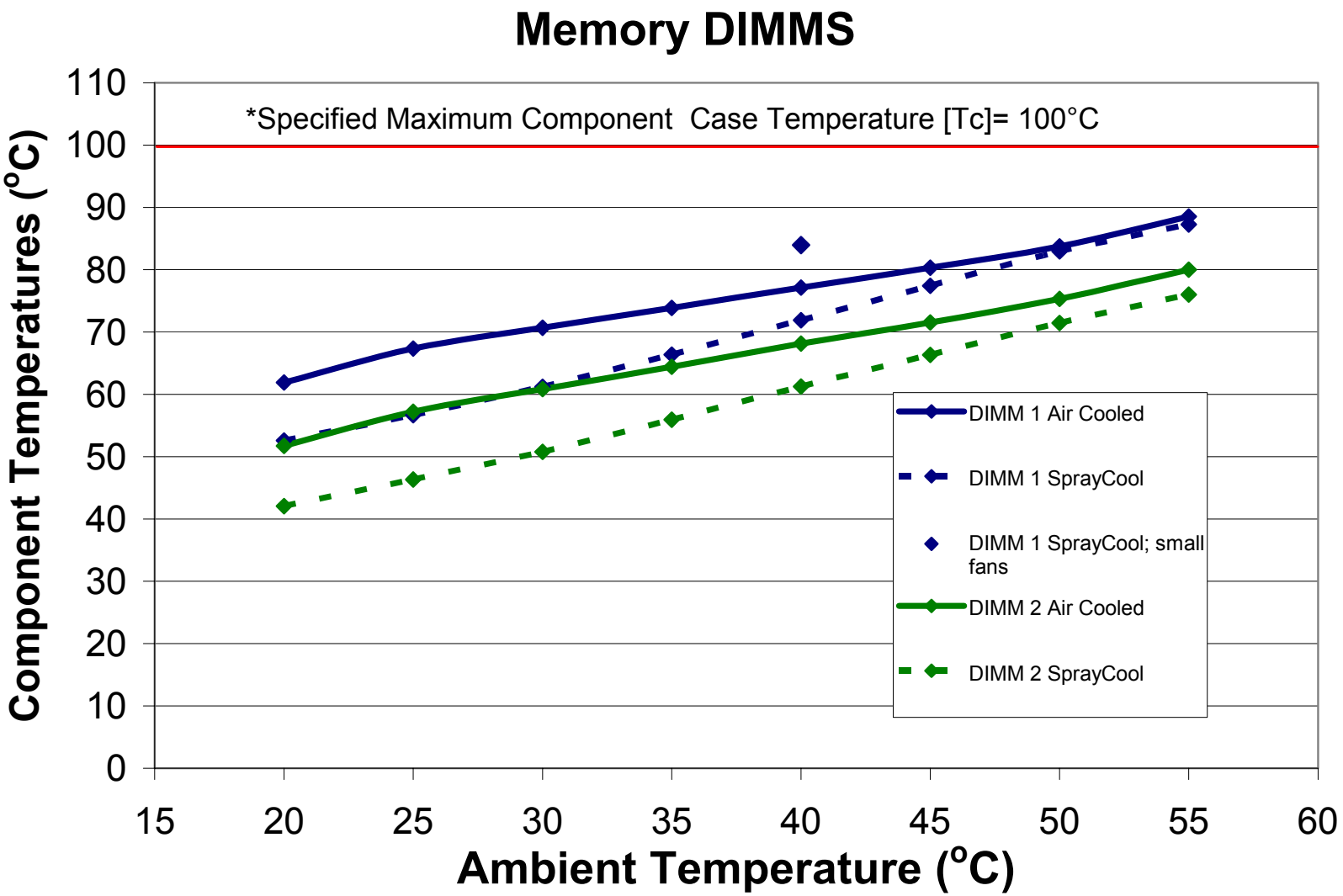

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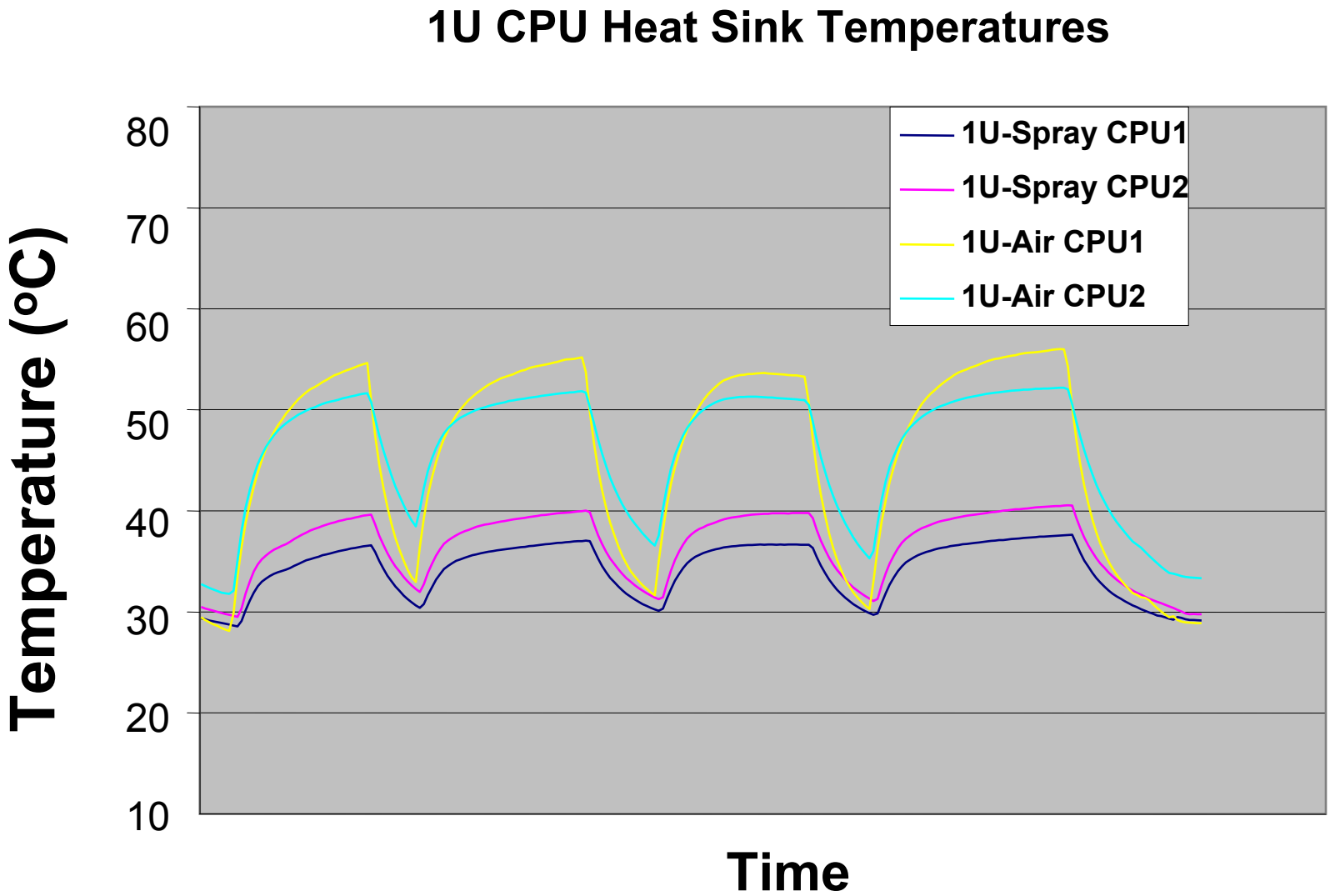

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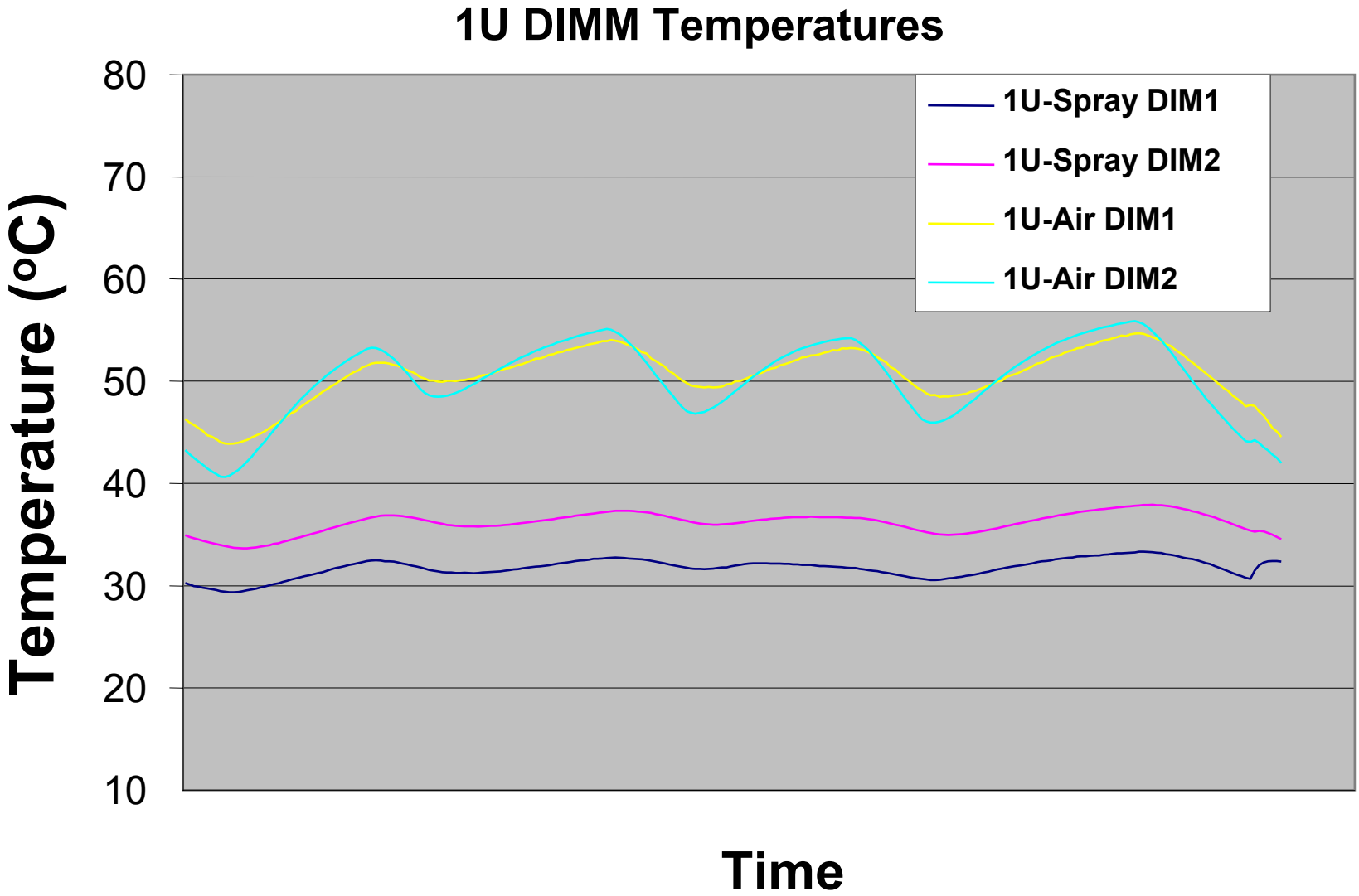
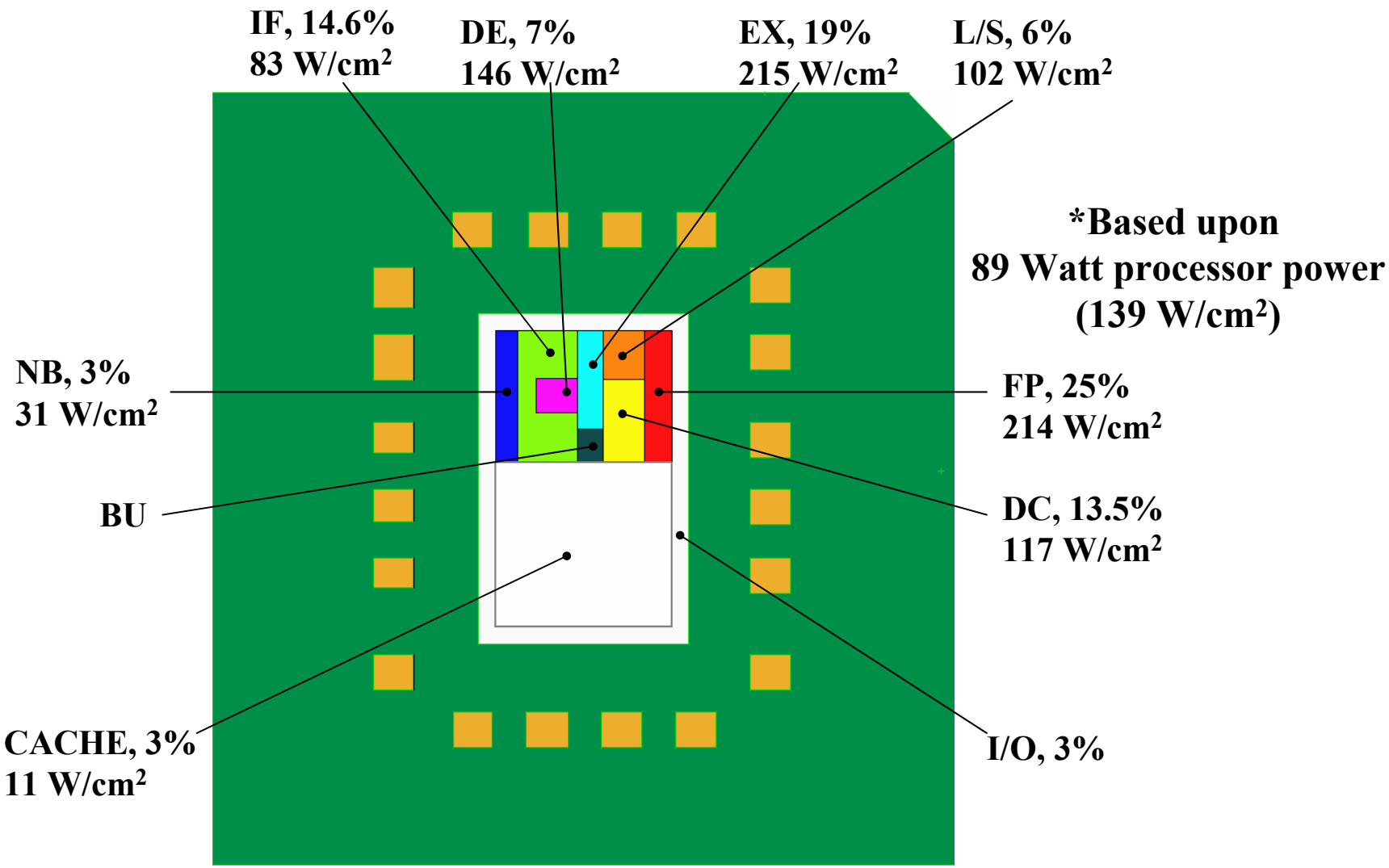
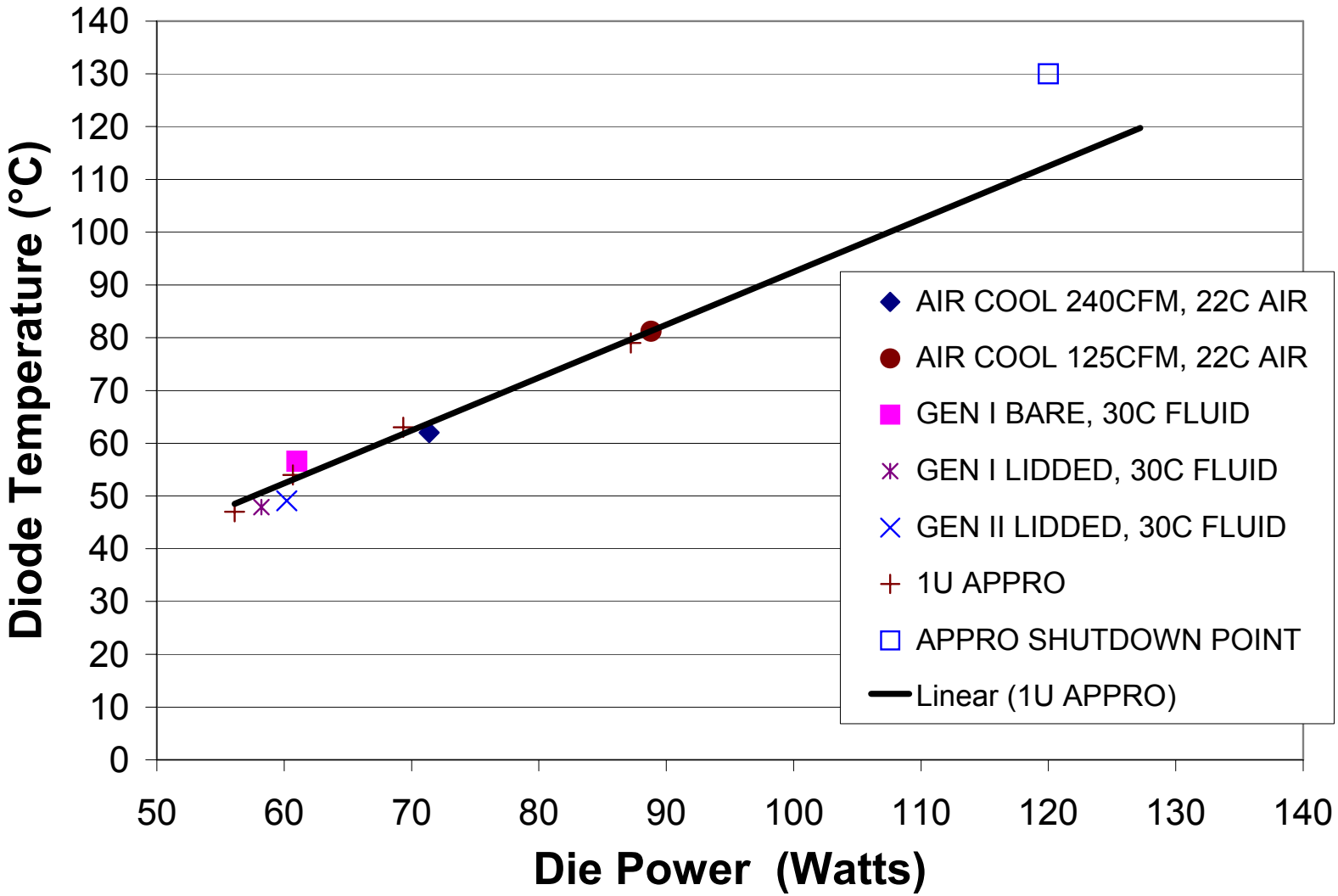


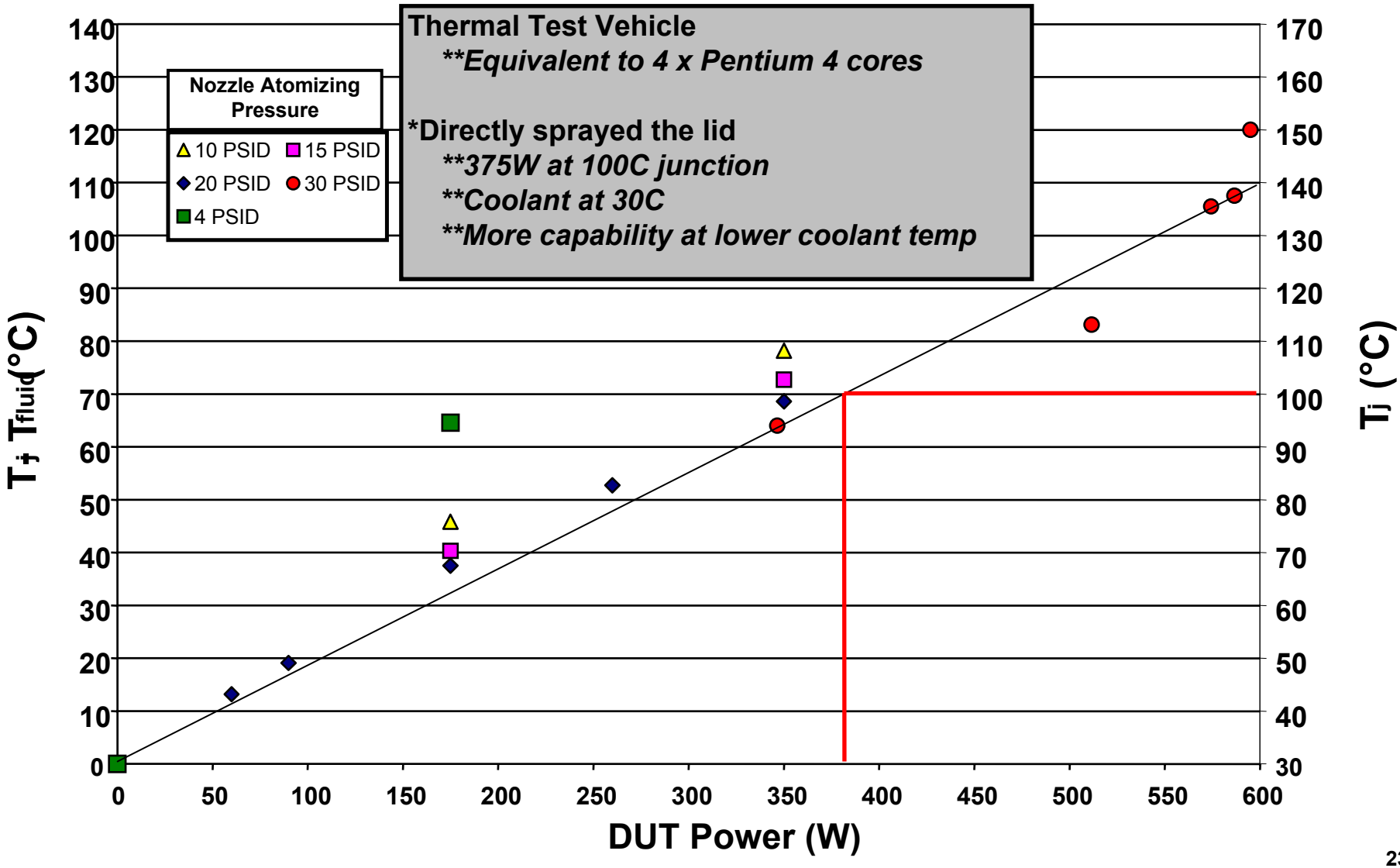
Typical Processor *Thermal Map*



Leakage Current Effects



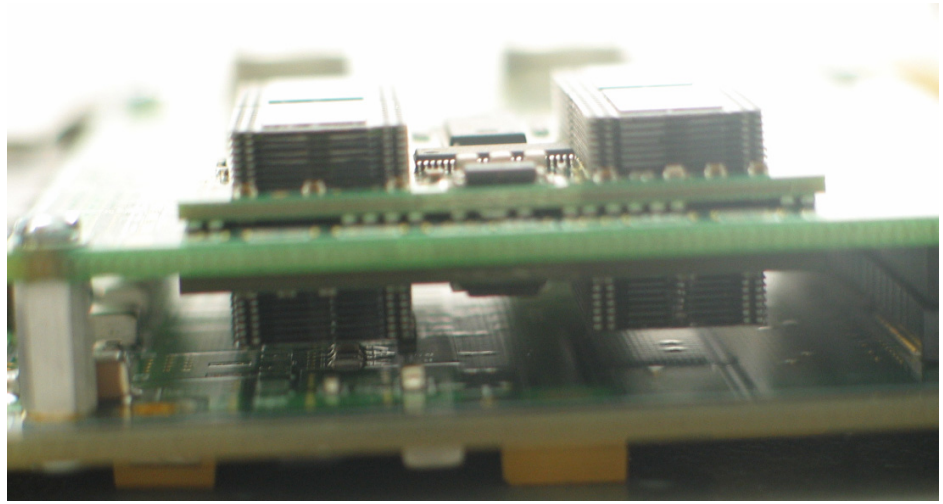
Multi-Core Server TTV

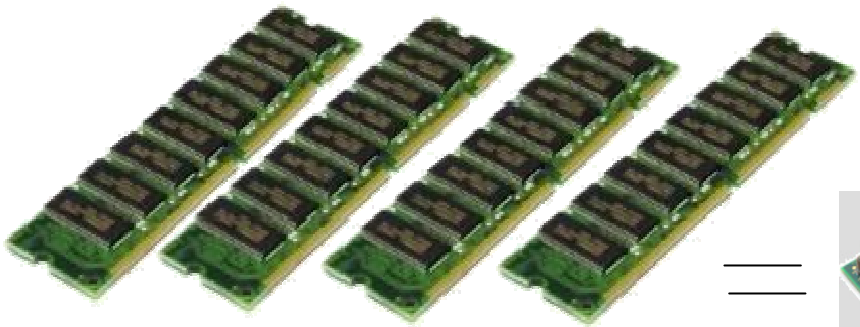


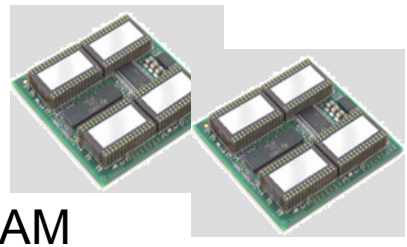
Dense Server Blade Development

Tessera 3D Chip-Scale Packaging

- **Ball Stacked memory**







8GB of RAM

TESSERA
We make it possible

Dense Server Blade Development

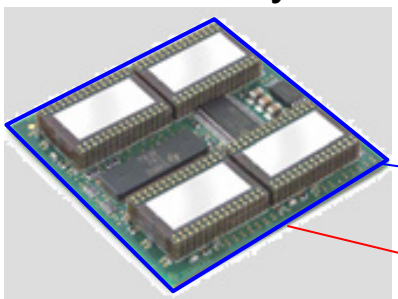
Develop & demonstrate Spray Cooled Blade Server

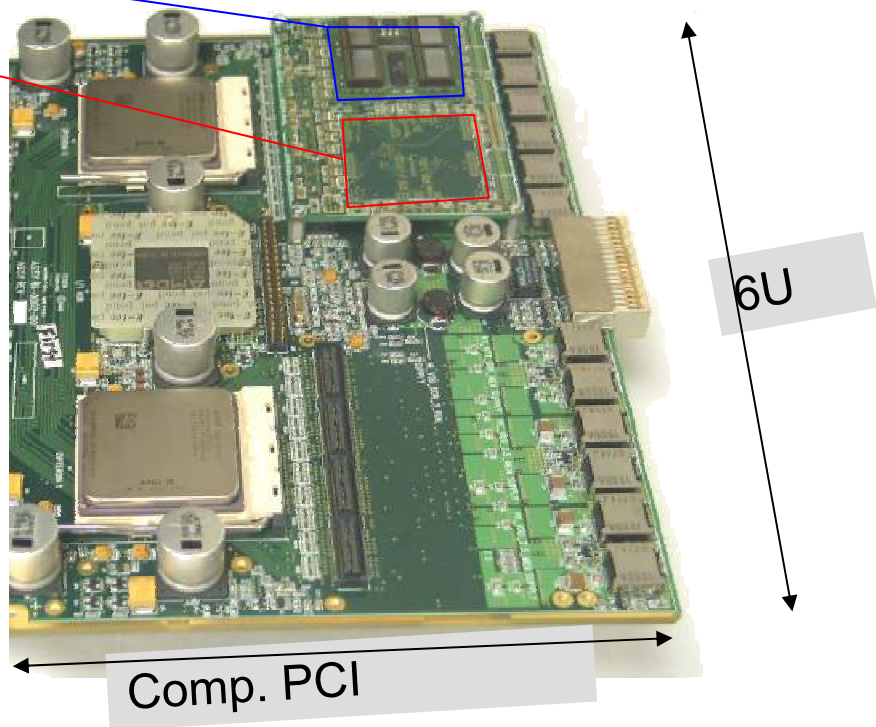
Dual socket, dense memory (8GB)

CompactPCI Form Factor Blade (6U x 160mm)

- **IBM 970 Version**
- **AMD Opteron Version**
- **Researching interconnect**

High Density Memory





Conclusions

Spray Cooling Benefits

- Eliminate throttling across a broader band of ambient temperature operation
- Reduce component temperatures
- Eliminate “Hot Spots”
- Reduce Thermal Cycling
- Opportunity for optimization of Noise, Power Consumption
- Ability to environmentally isolate (sealed servers)
- Flexible, cost effective approach
- Highest Density Packaging