THE UNIVERSITY OF TEXAS AT DALLAS

Thermal Management of Electronics and Data Centers

MECH 6V49.002 Manufacturing and Characterization of Functional Materials

Term Project Presentation

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Significance of Thermal Management of Electronics and Data Centers



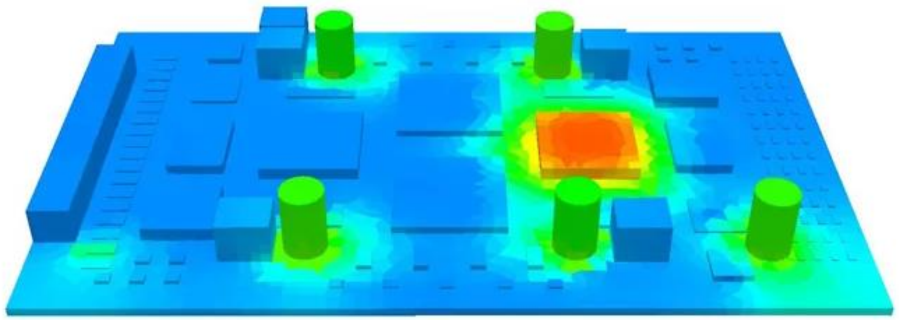
How is this relevant to thermal management of electronics and data centers?

First Law of Thermodynamics: The change in internal energy of a system is equal to the heat added to the system minus the work done by the system.

$$\Delta U = Q - W$$

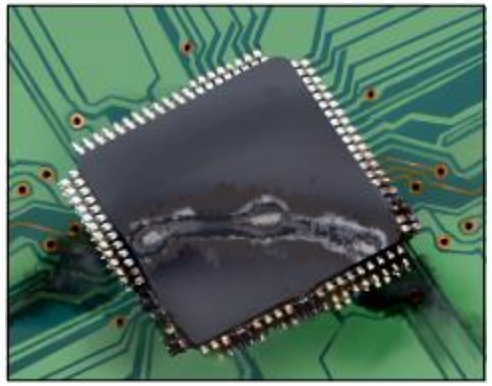
Change in internal energy | Heat added to the system | Work done by the system

Electronics generate heat as they operate, due to high power density.



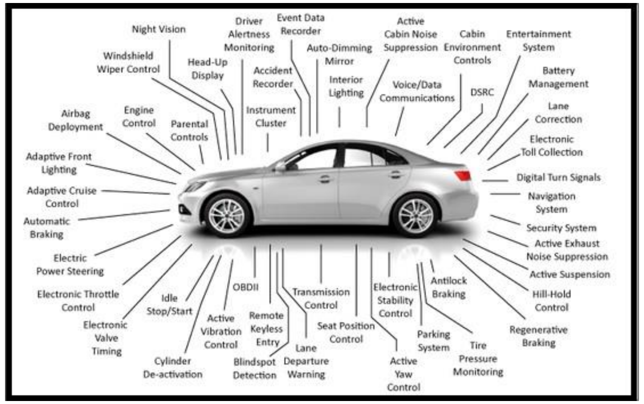
Lack of efficient heat dissipation can cause:

- Reduced performance
- Increased operating costs
- Component failures
- Safety Hazards



The alarm clock has a circuit board and LEDs

Your phone has a processor and a bunch of other electronic components



Your car has automotive electronics and battery.

UTD has a data center, and so does Instagram (Meta)!

What is a thermal management system?

‘Thermal Management’?

Heat Dissipation

…but that’s not all!

List of operating temperature ranges for various electronic components:

Component	Operating Temperature Range	Reference
Diodes	-65°C to +175°C	Vishay General Semiconductor datasheet
Resistors	-55°C to +155°C	Yageo datasheet
Capacitors	-55°C to +125°C	KEMET datasheet
Transistors	-55°C to +150°C	ON Semiconductor datasheet
Integrated Circuits	-40°C to +85°C	Texas Instruments datasheet
LEDs	-40°C to +100°C	OSRAM datasheet
Crystals	-20°C to +70°C	TXC Corporation datasheet
Switches	-20°C to +70°C	Omron Electronic Components datasheet
Relays	-40°C to +85°C	TE Connectivity datasheet (for general relays)

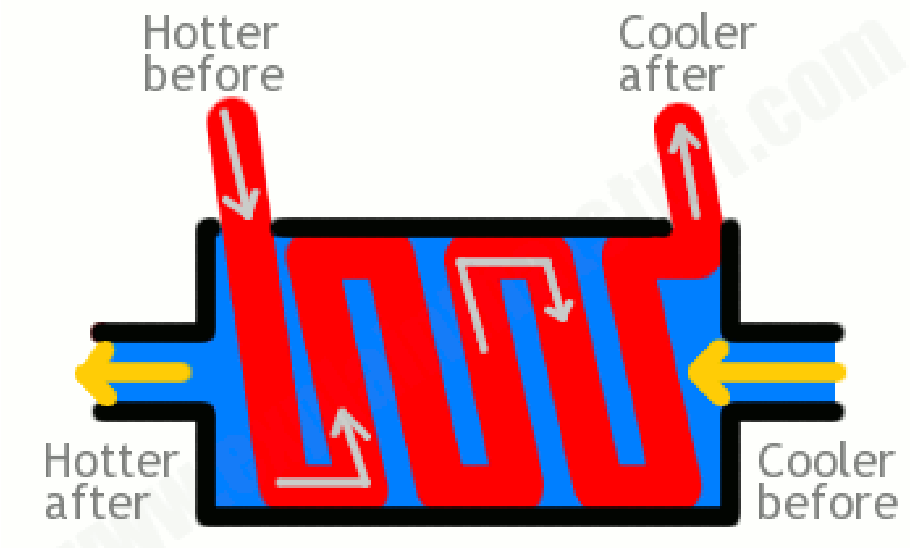
List of maximum air temperature ranges for various electronic devices in a data center:

Device	Maximum Recommended Air Temperatures for Operation	Cautionary Notes
Variable Frequency Drives	40°C [104°F]	Operation above this temperature typically requires de-rating a larger drive or risking premature failure.
Variable Frequency Drives with External Heat Sinks	50°C [122°F]	Operating above this temperature typically requires de-rating a larger drive or risking premature failure.
Human Machine Interface (HMI), Touch Screens & Flat Screen Displays	50°-60°C [122°-140°F]	Manufacturers of HMI specify a maximum operating temperature for their products. A few smaller devices are available that operate as high as 70°C (158°F).
HD Televisions	40°-50°C [104°-122°F]	32°C (90°F) is recommended for normal life expectancy.
Programmable Logic Controls (PLC)	50°-80°C [122°-176°F]	Most devices are not certified to function properly beyond their maximum operating temperatures.
Computers & server racks	Internal air temperature 40°C [104°F] With cooling fans 55°C [130°F]	In a loaded PC with standard cooling, operating temperatures can easily exceed the limits. The result can be memory errors, hard disk read-write errors, faulty video, and other problems not typically recognized as heat related. Nearly all server racks require cooling.

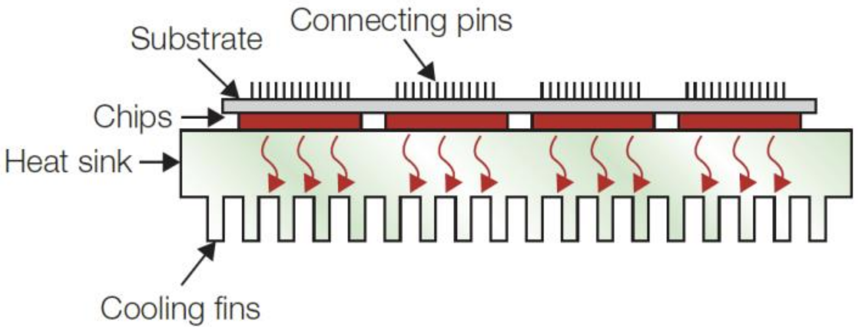
TEMPERATURE
CONTROL

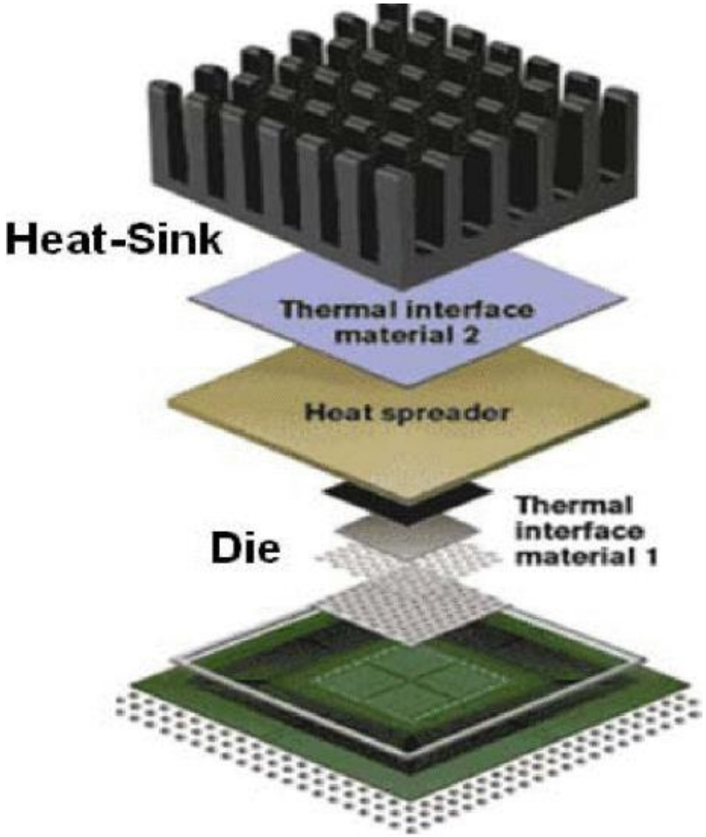
Heat Flux = The flow rate of heat per unit area

Thermal Management of Electronics



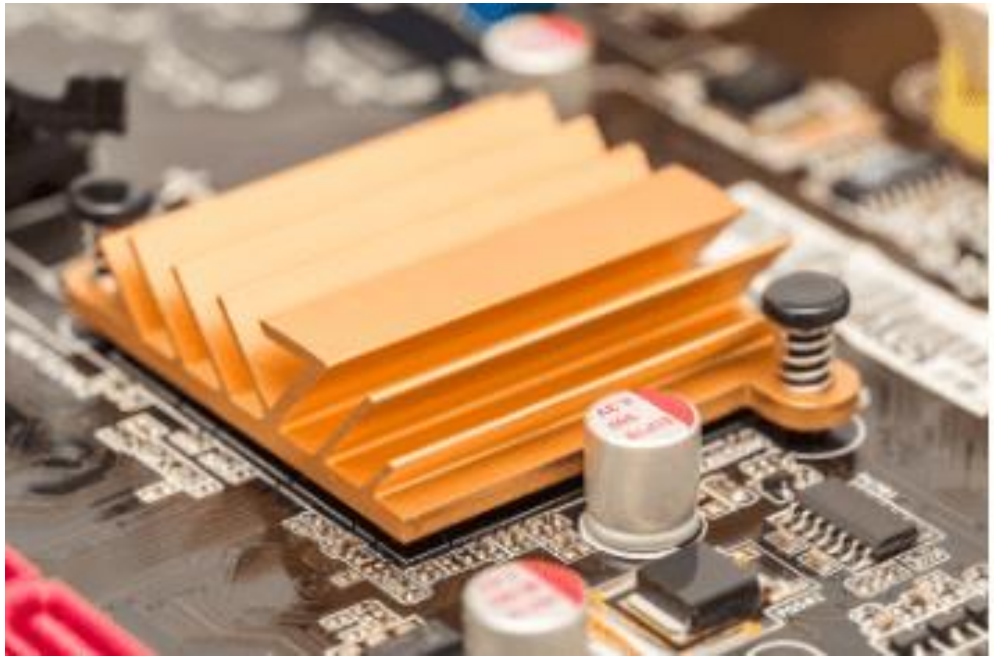
General Heat Exchanger working principle

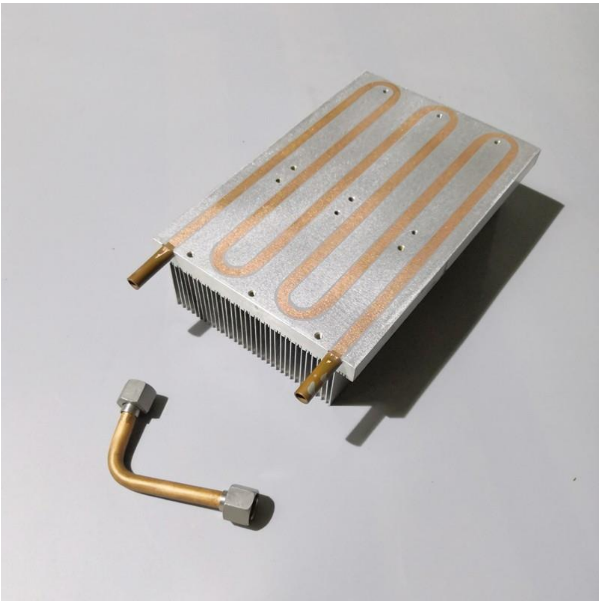




Heat Sink with TIM and Heat Spreader for heat exchange in electronics

Types of Heat Sinks





Passive Heat Sink

Free convection through fins

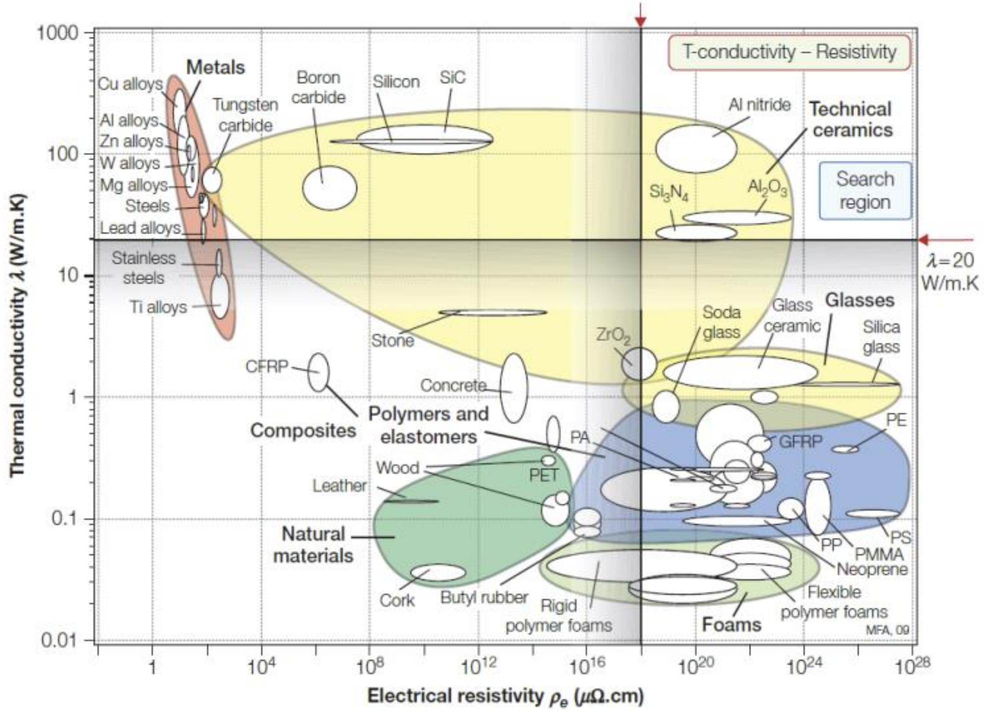
Active Heat Sinks

Forced convection or liquid cooling

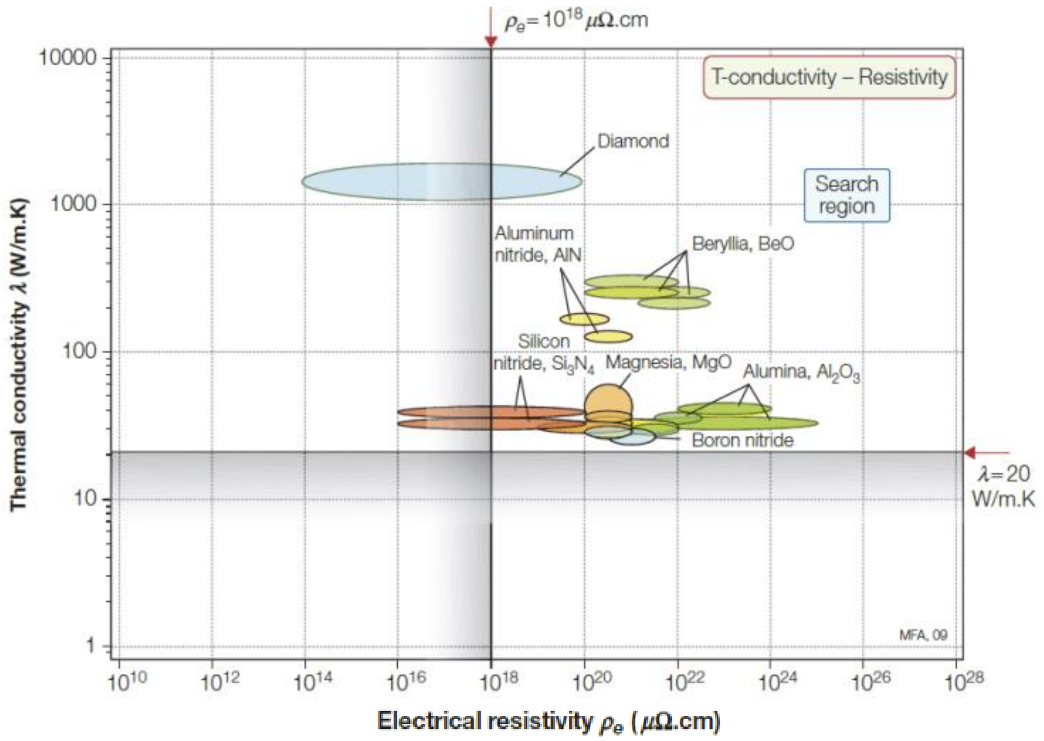
How is this relevant to my functional materials class?

Table 6.33 Design Requirements for Heat Sinks	
Function	Heat sink
Constraints	Material must be "good insulator," or $\rho_e > 10^{18}$ $\mu\Omega$.cm Maximum service temperature > 150°C All dimensions are specified
Objective	Maximize thermal conductivity, λ

Ashby plot for thermal conductivity vs. electrical resistivity

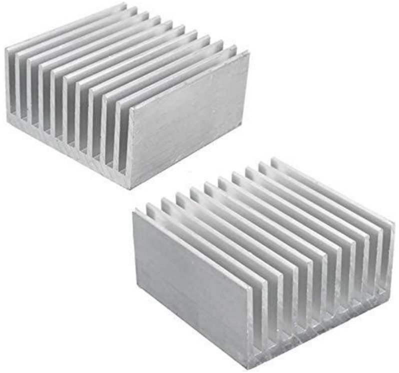


Ashby plot for thermal conductivity vs. electrical resistivity (magnified region of interest)

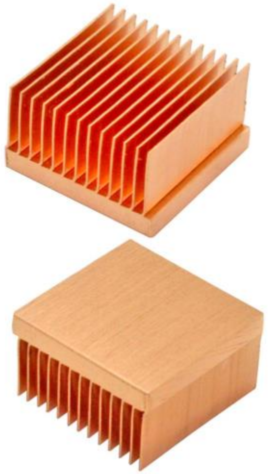


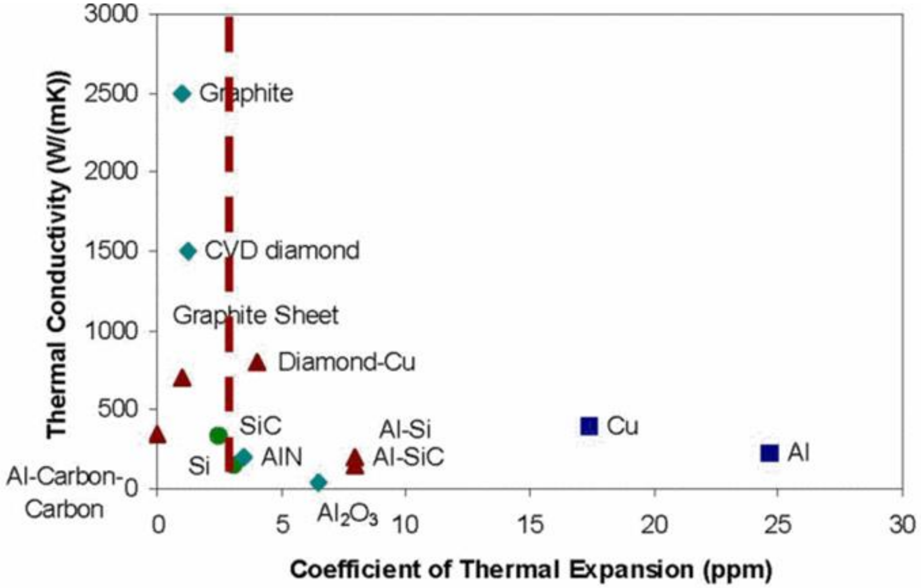
Most common materials used for heat exchangers:

- Aluminum



- Copper



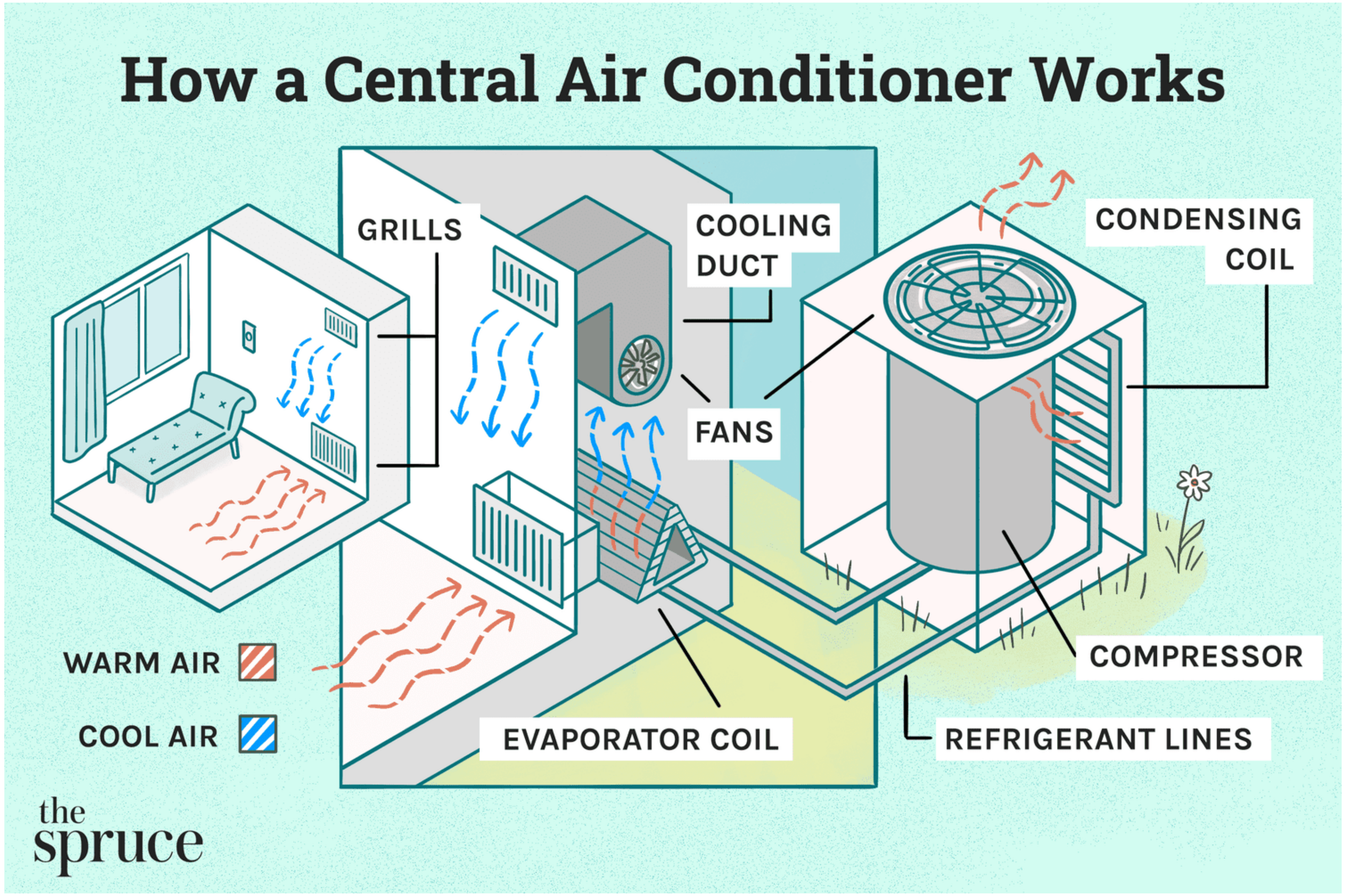


Material	Thermal conductivity	CTE 10^{-6}/K	Price/
CVD diamond	>1300	2.0	High
Aluminium Nitride	260	4.0	Medium
Cubic boron nitride	200-250	1	High
Silicon Carbide	200	2.8	Medium
Alumina	30	5	Low
Copper	400	16	Low
Aluminium	200	23	Low
Molybdenum	138	5.1	Low
Copper Molybdenum	165-215	6.8-9.5	Medium
Copper Tungsten	175-235	6.5-9	Medium

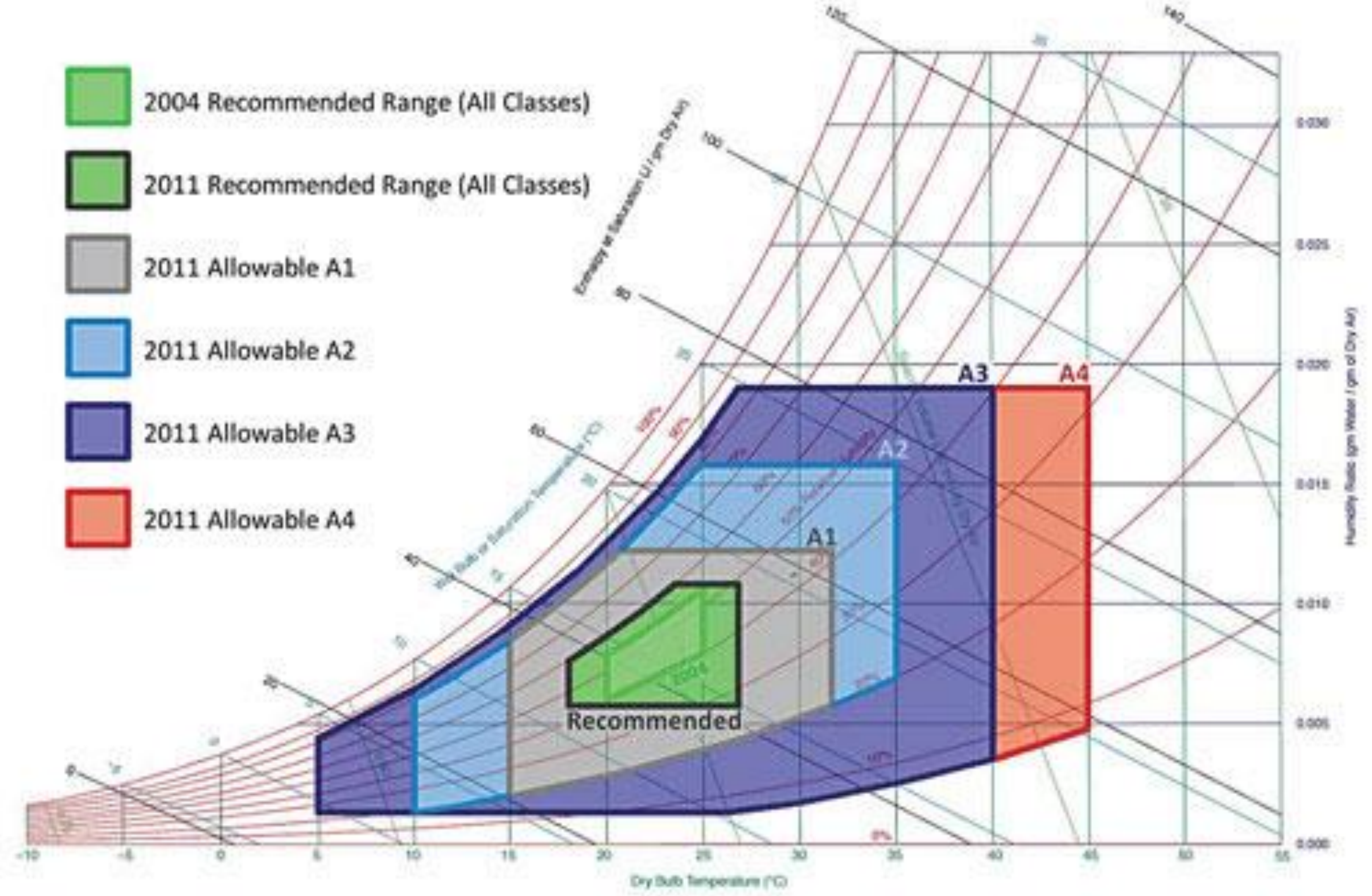
Thermal Management of Data Centers

What is a Data Center?

A data center is a facility of one or more buildings that house a centralized computing infrastructure, typically servers, storage, and networking equipment in a confined space.



- Room Temperature
- Relative Humidity

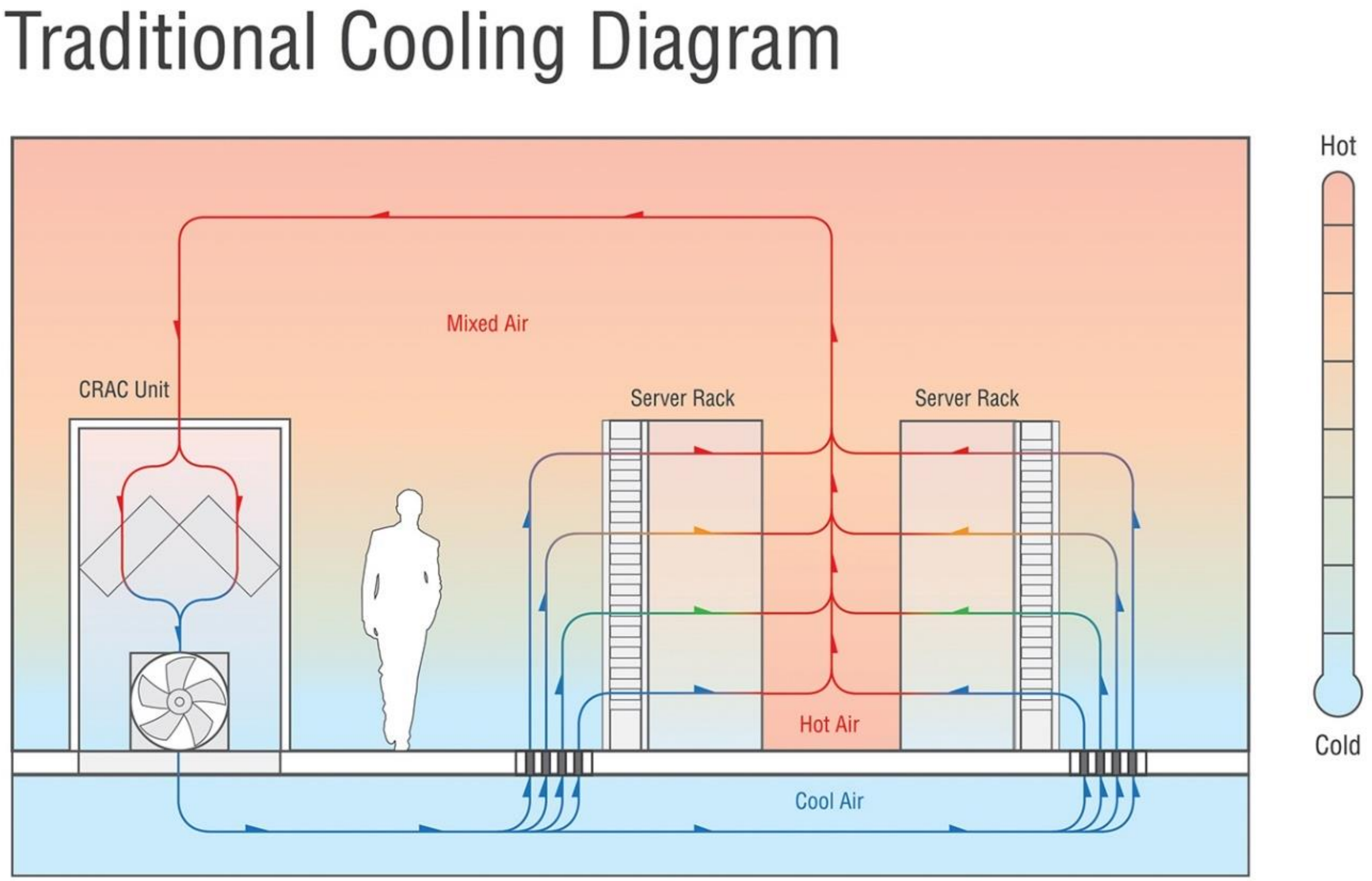


ASHRAE – The American Society of Heating, Refrigerating and Air-Conditioning Engineers

Cooling Process for Data Centers

- Server Cooling
- Space Cooling
- Heat Rejection
- Fluid Conditioning

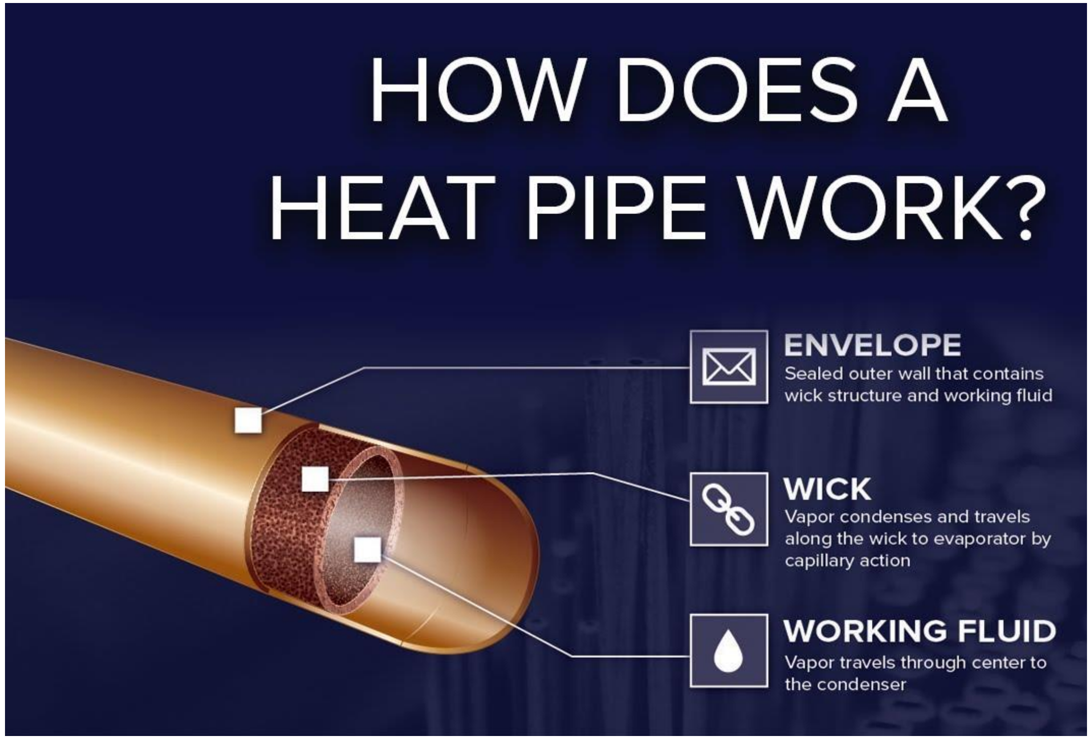
- Raised Floor
- Hot Aisle Enclosure
  (Ceiling)
- Economizer

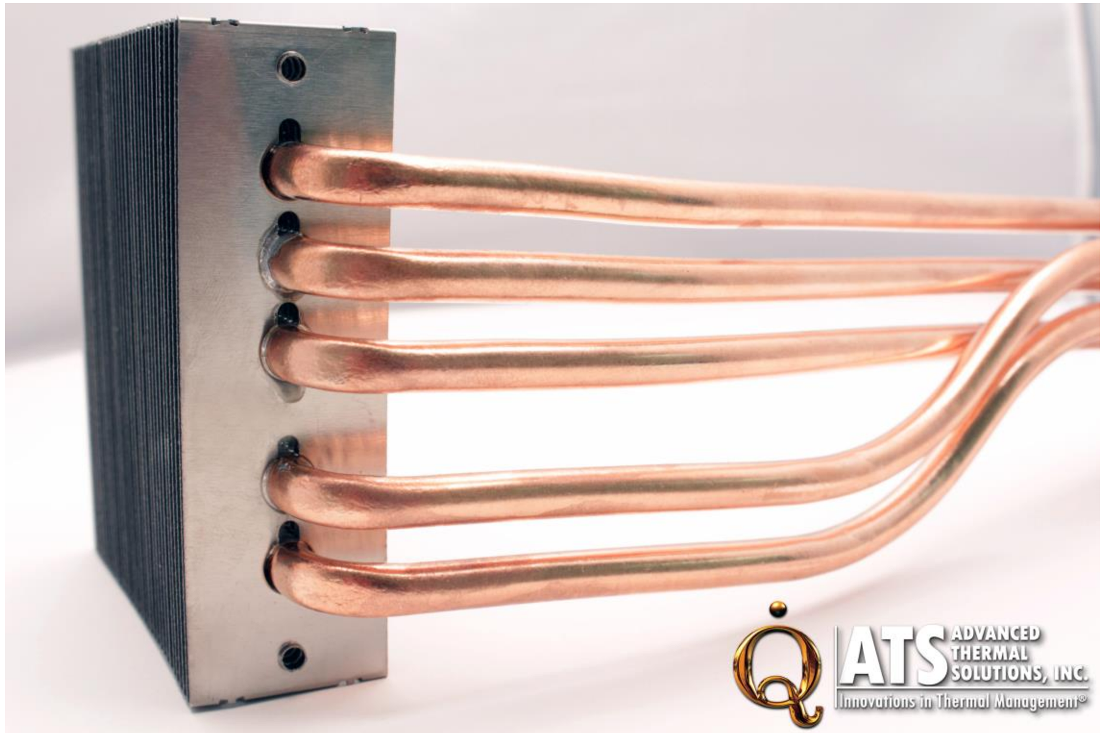


Advanced Cooling Technologies

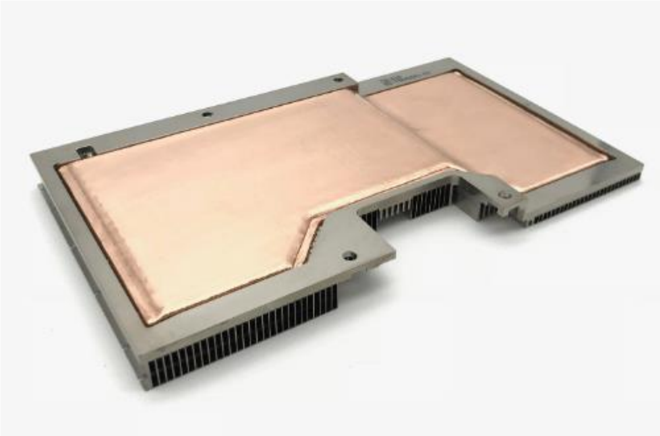
For space constrained devices, high heat flux applications, rugged environments, and situations where heat needs to be moved long distances.

- Heat Pipes: Heat source to remote fin array.

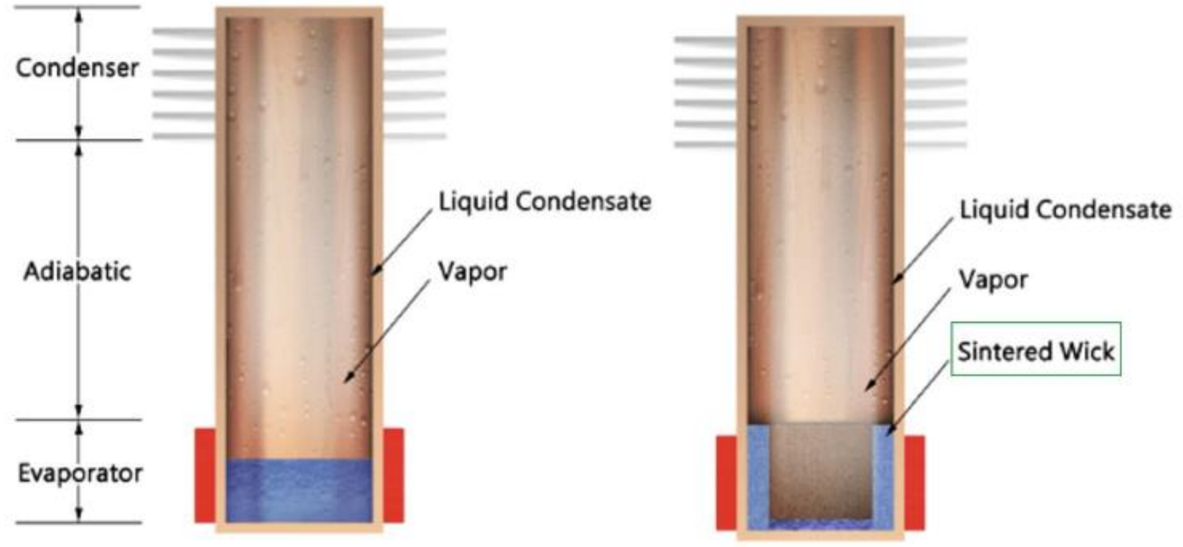




- <u>Vapor Chambers:</u> Spread heat across the base of a local fin array.



- <u>Thermosiphons:</u> Carry more heat than heat pipes over longer distance.



Wickless (L) and Partial Wick (R) Thermosyphons

Thank You

Any Questions?

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