Solid State
COOLING SYSTEMS
*Temperature Control...***Precisely.**

Chillers for Laboratory and Laser Use
Advanced LSO Workshop 2011

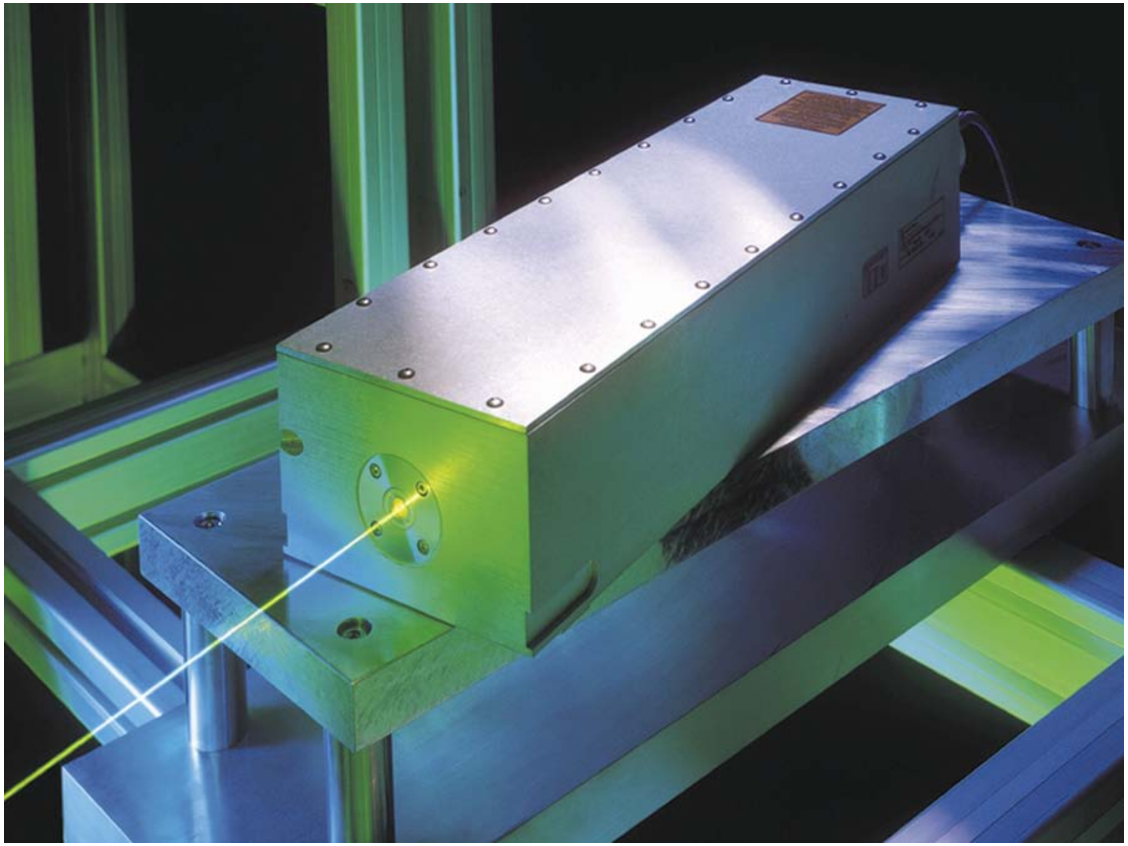
Laser Cooling

Why Do Lasers Require Temperature Control?

Avoid Overheating

Wavelength Stability

Beam shape improvement



Beam pointing

Average Power

Pulse width stability

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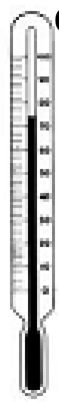
History of Chillers

Early History: Ice used as chiller

1714: Thermometer/ temperature scale

1756: First artificial cooling experiment

1834: Peltier effect



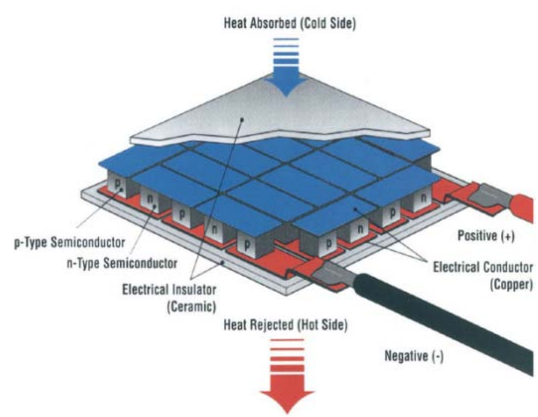
1858: Absorption refrigeration

1870's: First compression chiller

1950's: First Freon compression chiller

1960: Thermoelectric modules introduced

Today: Thermoelectric chillers used in precise temperature control



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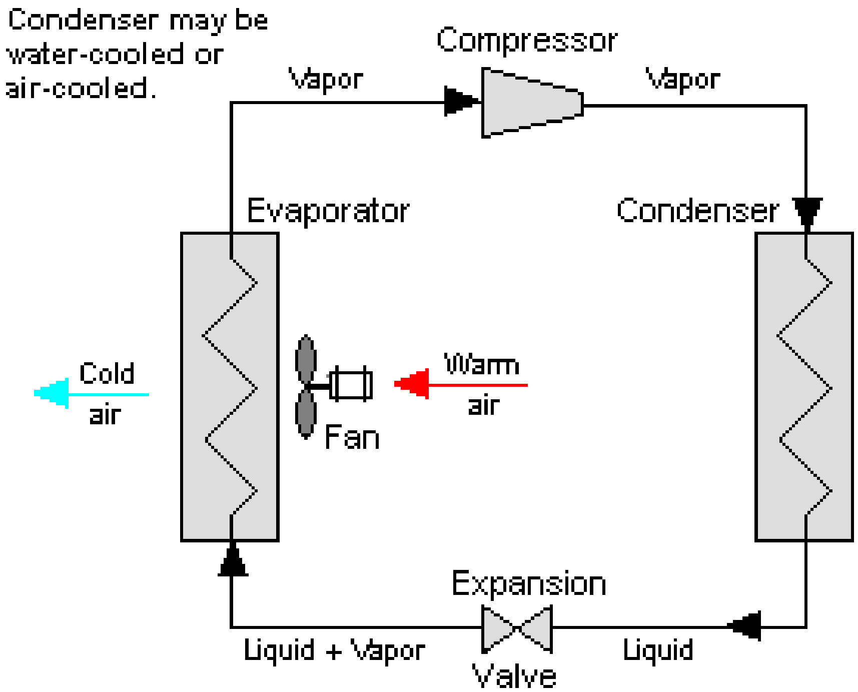
Chiller Technologies

- Vapor Compression
- Thermoelectric
- Absorption Chambers

How Different Chillers Work: Compressor Chillers



TYPICAL SINGLE-STAGE VAPOR COMPRESSION REFRIGERATION

- Concept: Freon-type refrigerant removes heat from a space and rejects that heat elsewhere.
- Systems contain at least 3 moving parts: compressor, pump, and fan.
- Temp control using: Pulse-heating systems or hot gas bypass valve.

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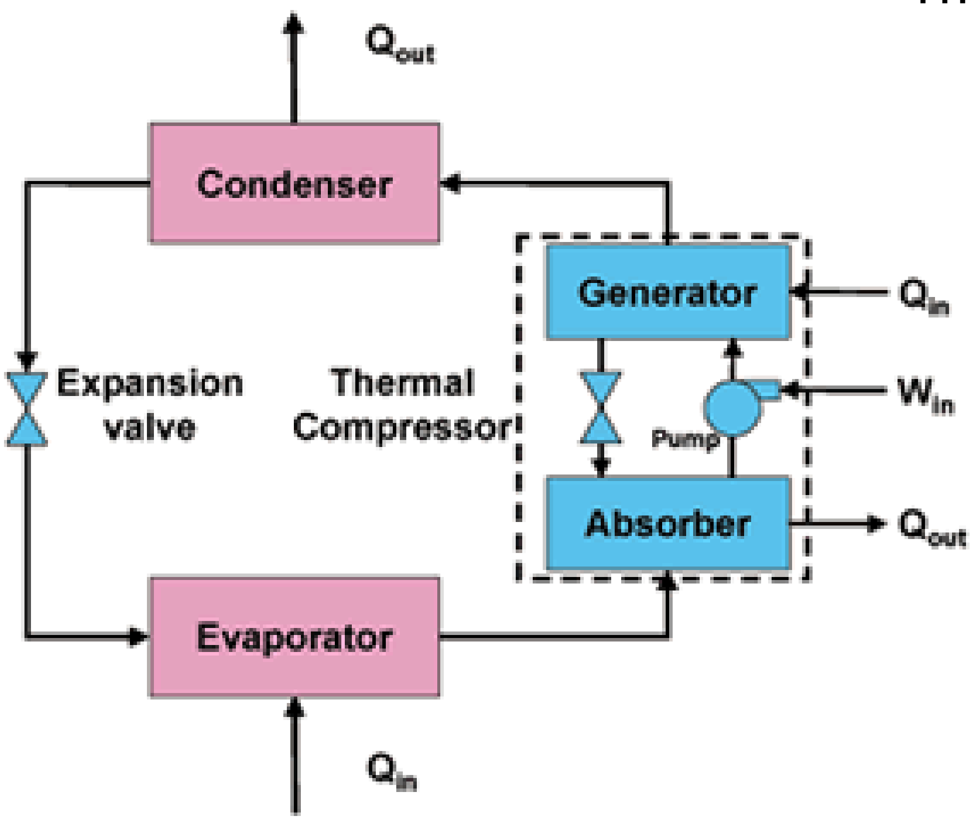
Compressor Chillers: Applications

- Semiconductors: PVD, Plasma Etch, Lithography
- Lasers: Gas, Diode, Semiconductor
- Food and Beverage: Displays, Transportation
- Lab: Vacuum systems, Analytical Equipment
- Home/Office: Air conditioning

How Different Chiller Work: Absorption Chillers



Three stages:

- Evaporation: Liquid refrigerant evaporates.
- Absorption: Gaseous refrigerant is dissolved into absorbate.
- Regeneration: Combined liquid is heated. Refrigerant evaporates out and is condensed, then returned to the evaporator.

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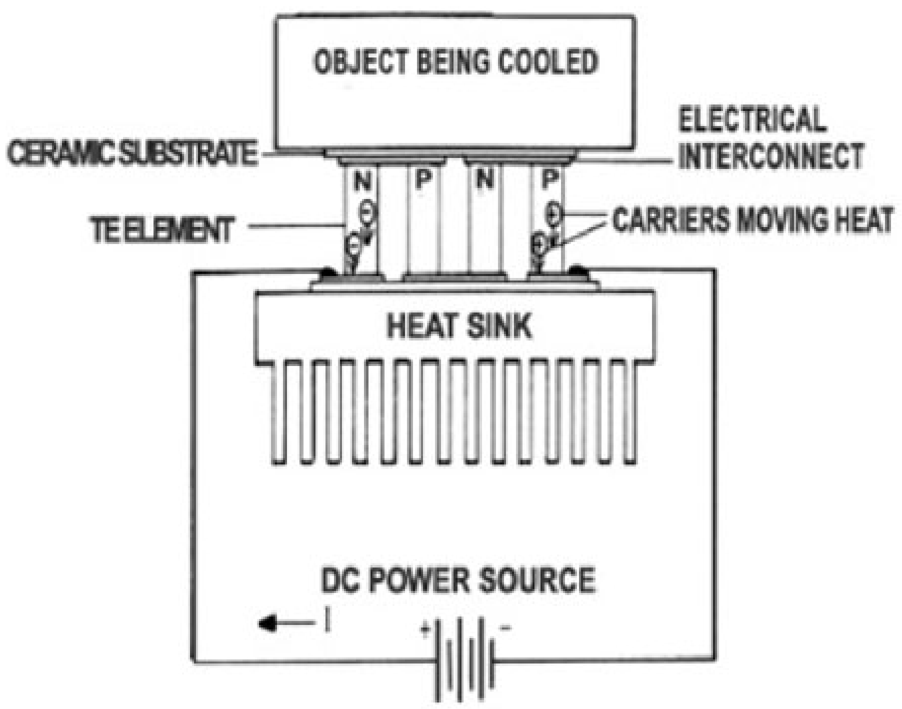
Absorption Chillers - Applications

- Where waste heat is available (from turbine exhausts or industrial processes or from solar plants)
- Printing and pulp mills
- Solar air conditioning
- Petroleum and chemical industry
- Breweries

How Different Chillers Work: Thermoelectrics



- Thermoelectric modules are sandwiched between two surfaces. When DC current is applied, heat is transferred from one surface to the other.
- The "cold side" of the heat exchanger is designed to maximize cooling within the customer’s equipment. The "hot side" of the heat exchanger is designed to efficiently move heat into another medium.
- Total heat rejected from the heat exchanger is the sum of the heat removed plus the power supplied to the modules themselves.

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Thermoelectric Chillers - Applications

- Medical: Laser surgery, Hypothermia therapy, Cryoliposis
- Portable coolers
- Cooling electronic components, point of use
- Satellites and spacecraft
- Semiconductor: Lithography, Plasma Etch, Metrology

Cooling Capacities and Controls

Thermoelectric Chillers:

- Low to moderate cooling capacity
- Variable cooling power
- Continuously variable PID

Refrigerant Chillers:

- Moderate to high cooling capacity
- Hot gas bypass and/or pulse on heater temperature control
- On/Off PID

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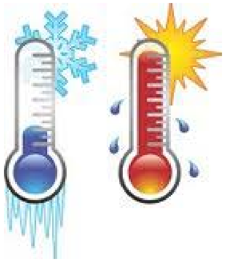
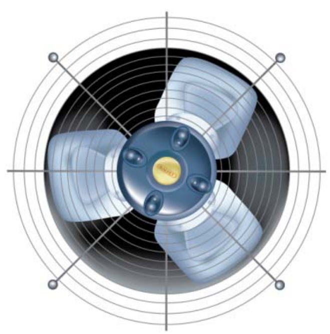


Precision

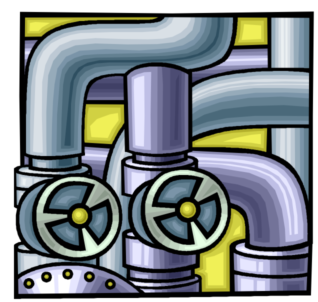
Thermoelectric:

- Precise small load temperature control
- Temp cycling capability
- Infinitely variable control method
- Limited moving parts: fan and pump



Refrigerant:

- Marginal small load temperature control
- On/Off control method
- Moving parts: compressor, fan, pump and hot gas bypass valve



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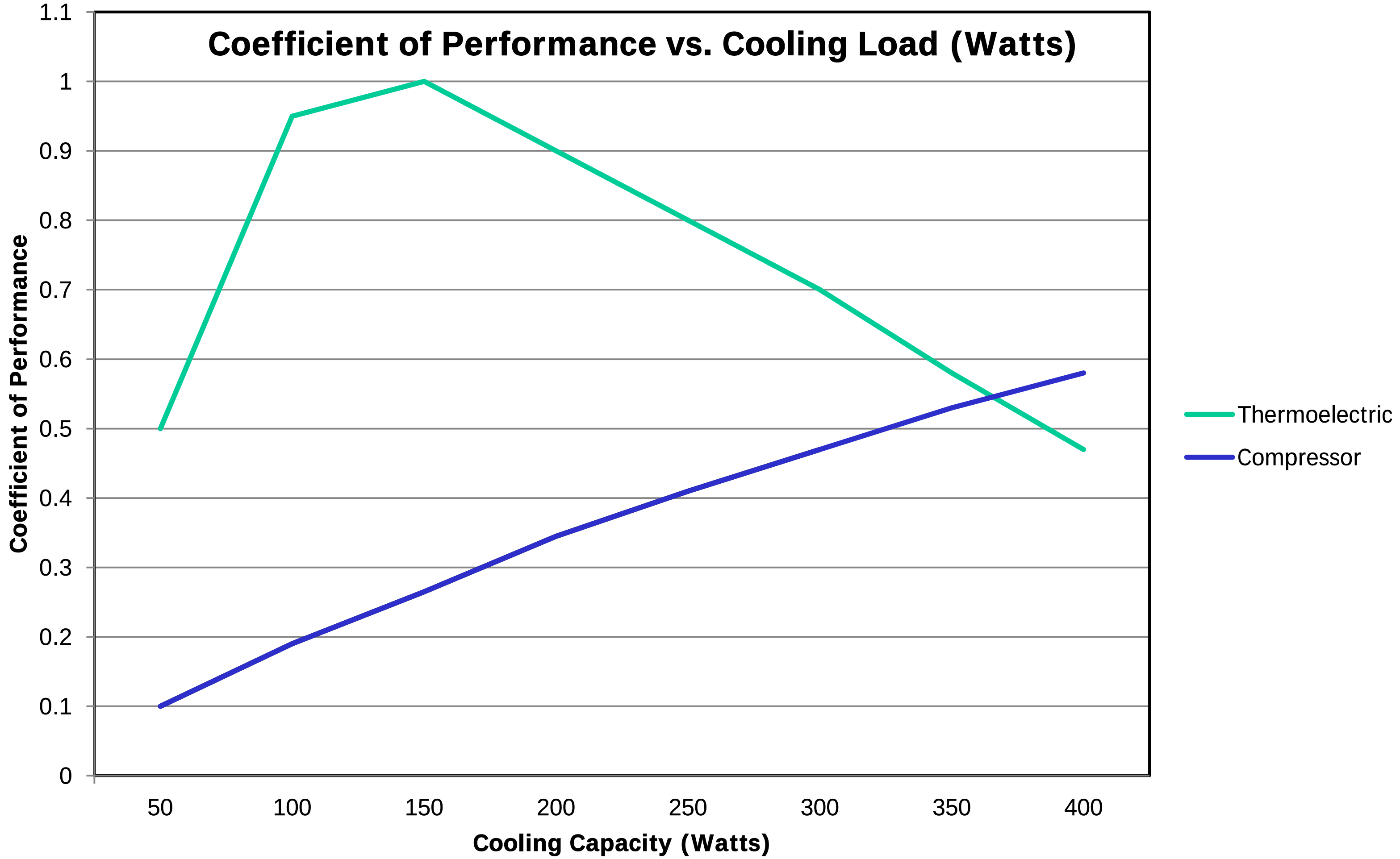
Energy Consumption

Thermoelectrics

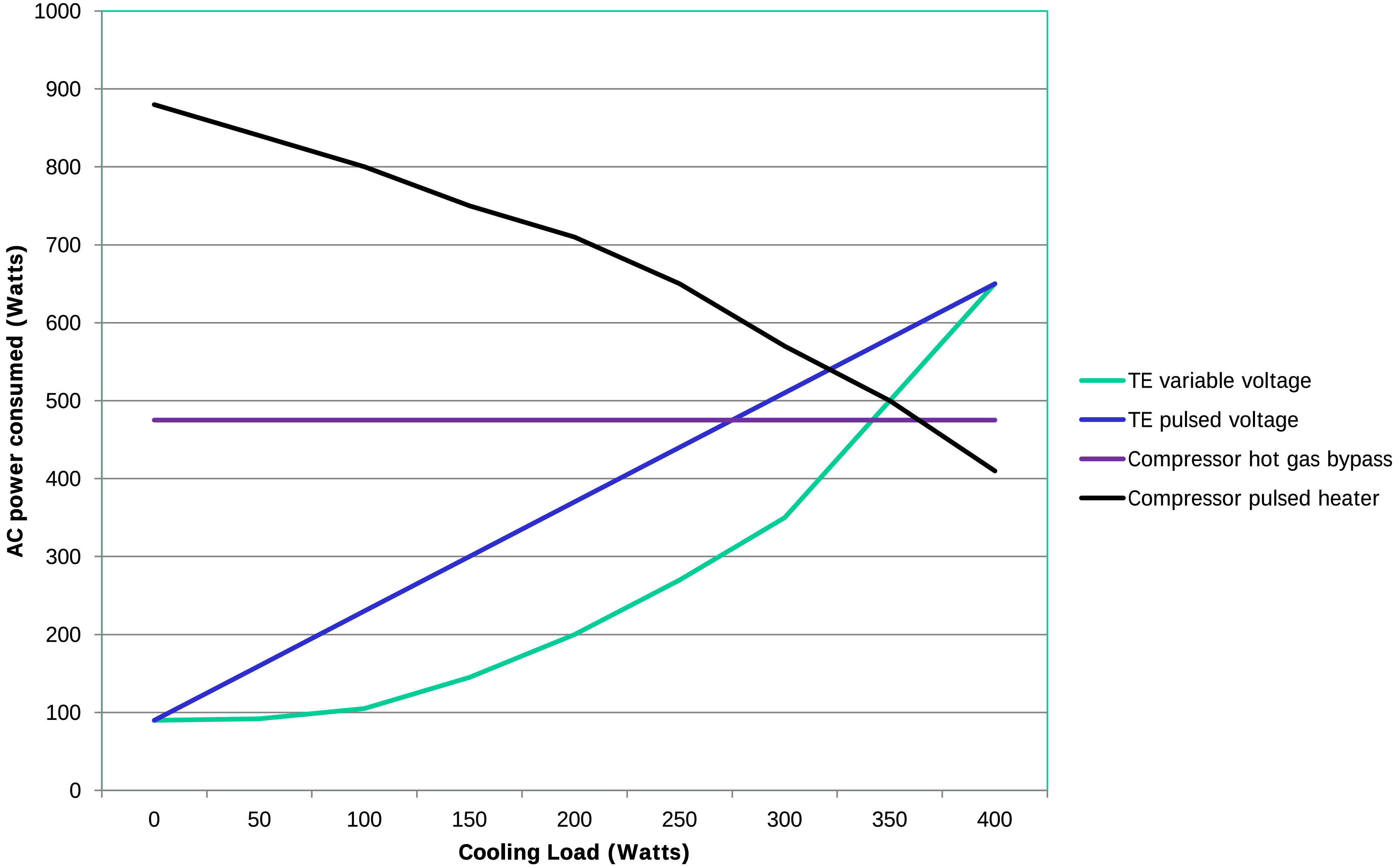
Energy consumption near ambient is minimal

Compressor chillers

Energy consumption is high



Chiller Power Consumption Comparison



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Conclusion

- TE cooling is best suited to precise temperature control with low to modest loads.
- Compression cooling is best suited to modest to high loads where precision is not critical.
- For every kW saved, thermoelectric cooling saves $1,000 per year @12 cents/kWh.