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Sandia National Laboratories

The Sandia Cooler: A fundamentally new approach to air cooled heat exchangers

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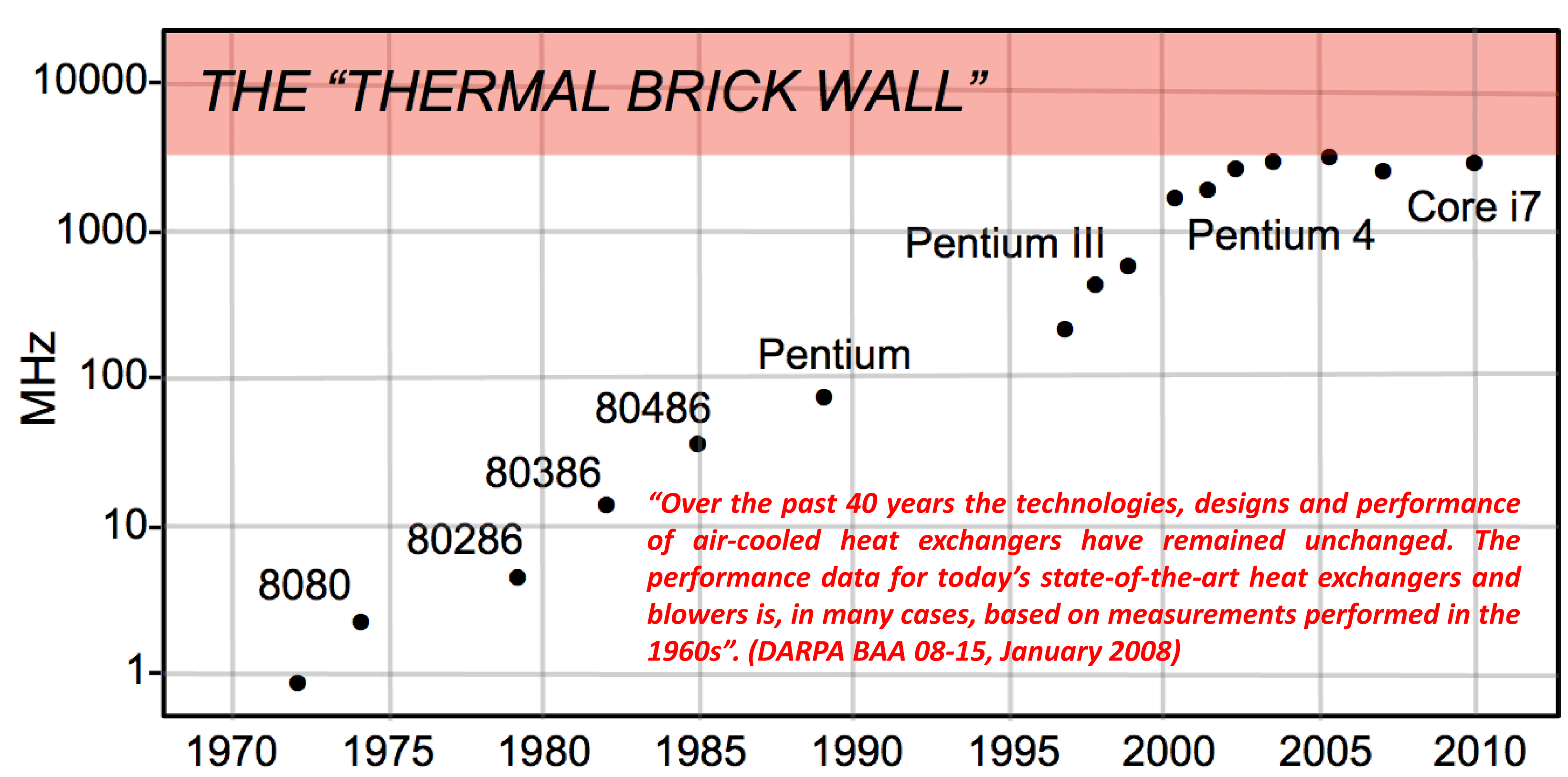
What is the challenge?

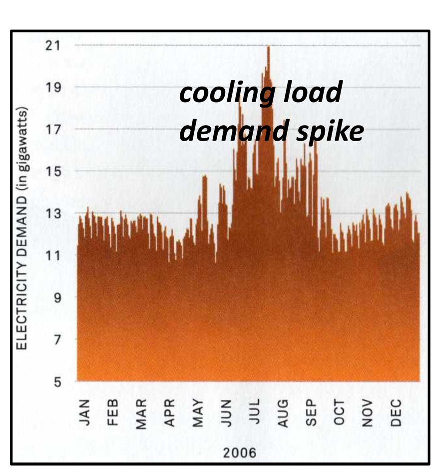
Air-cooled heat exchanger performance is of great importance to numerous applications in the Energy and Information Technology Sectors. But the basic "fan-on-finned-heat-sink" device architecture hasn't changed much since the 1960's, and only modest improvements in heat rejection performance have been achieved. The fundamental problem is the thermally insulating boundary layer of motionless air that envelops the fins of such structures, which is largely undisturbed by impinging air flow from the fan. The are two other important problems as well. Fan noise currently imposes an upper limit on cooler performance, and over time, fouling of the heat exchanger fins (e.g. dust, pollen, condensation) causes a drastic reduction cooling performance.



Intel processor clock speed time line

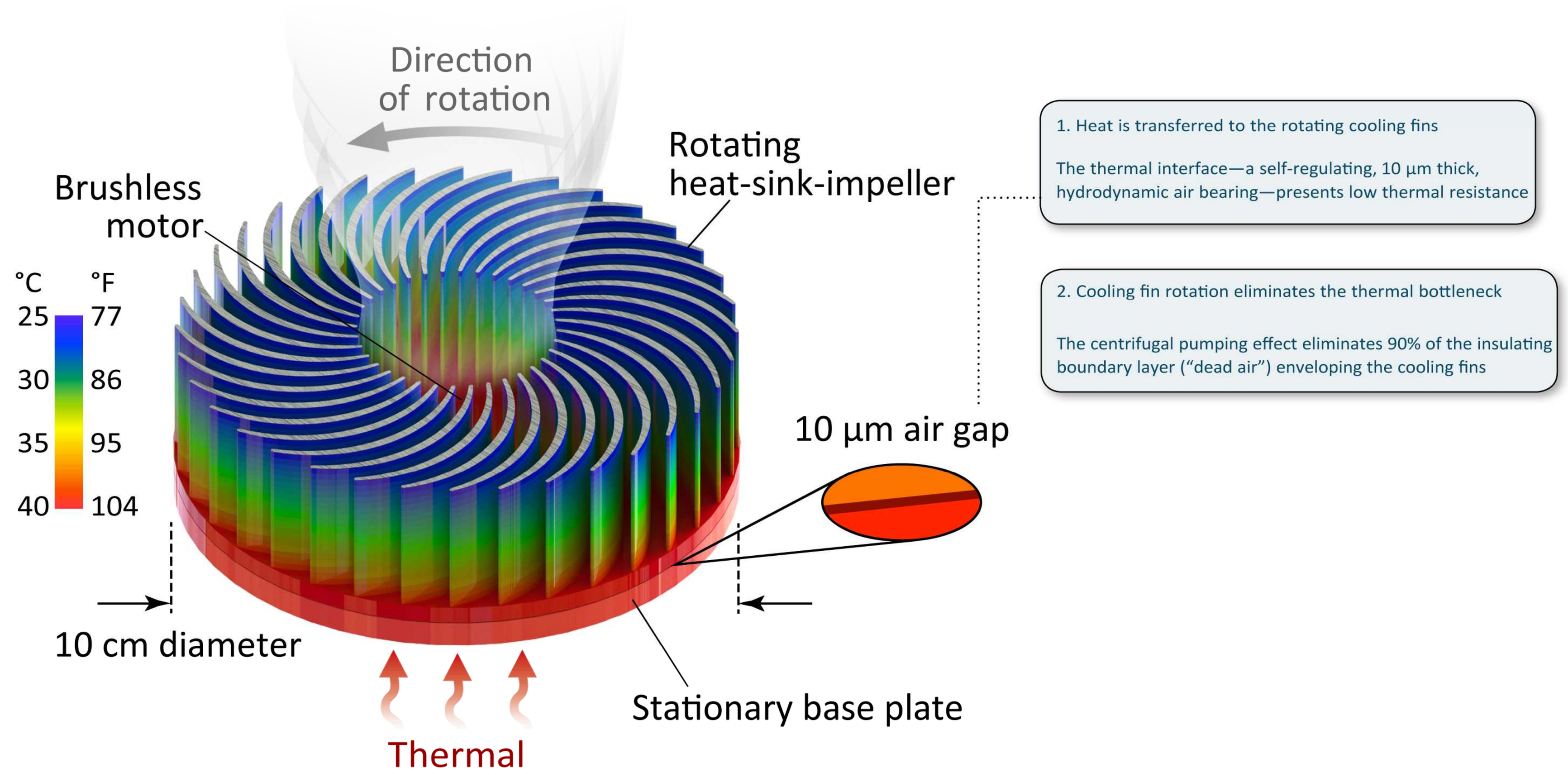
CPU clock speeds followed Moore's Law for 40 years, driven by advances in transistor size reduction (lithography). But this progress came to a halt a decade ago when transistor density surpassed the limitations of CPU cooler technology.

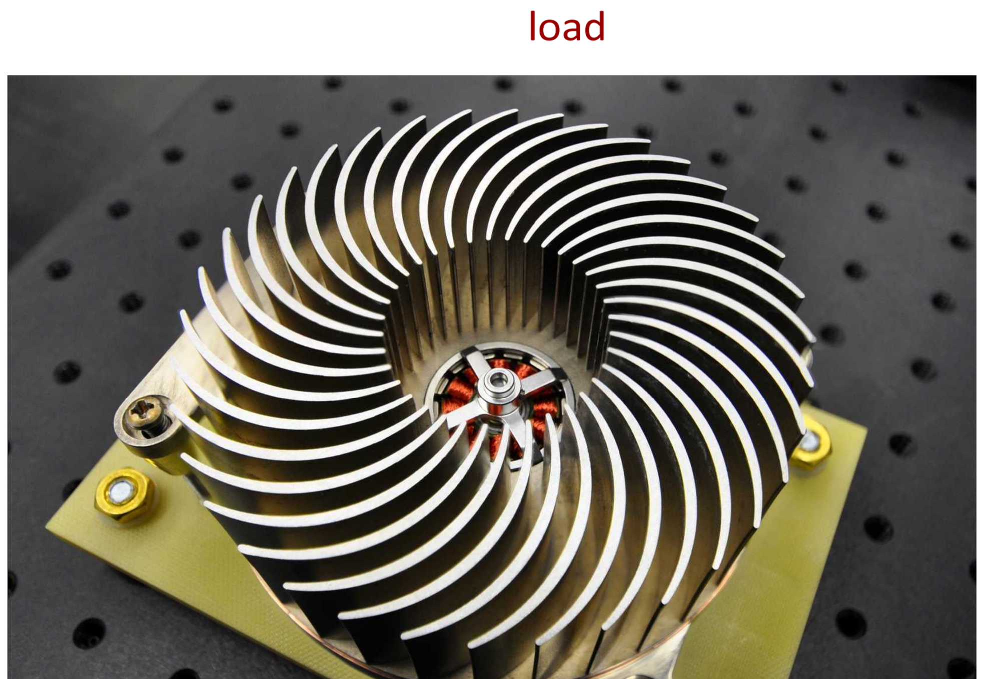
The end result of heat exchanger fouling. Cooling fins are buried in a thick layer of dust, choking off air flow.



The stability of the electrical power grid depends in large part on grid operating margin. During cooling load demand spikes grid operating margin can drop to zero. Increasing the efficiency of air conditioners and refrigeration equipment is vital to grid surety.

What is our innovation?

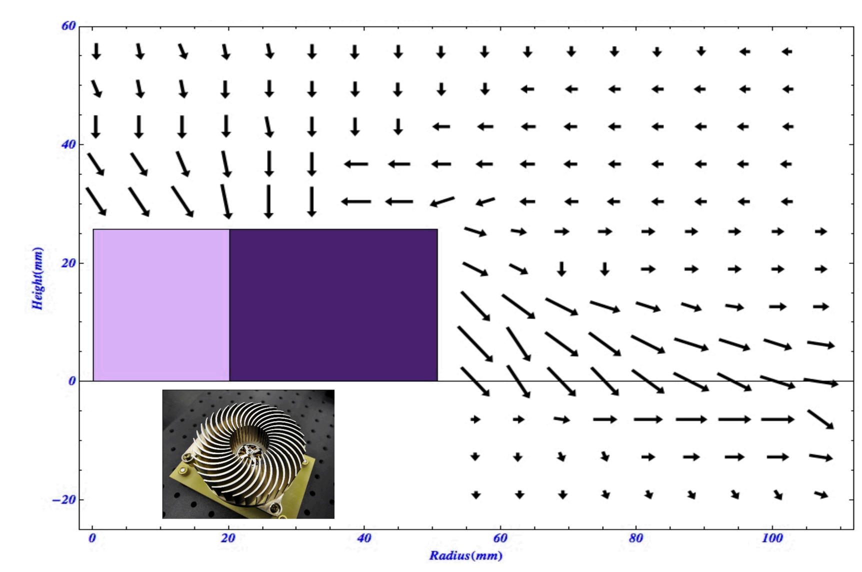


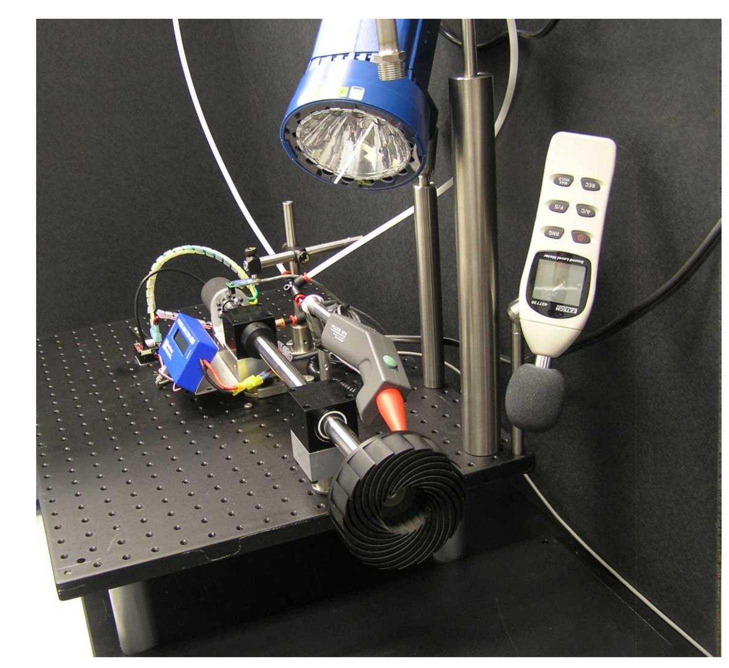


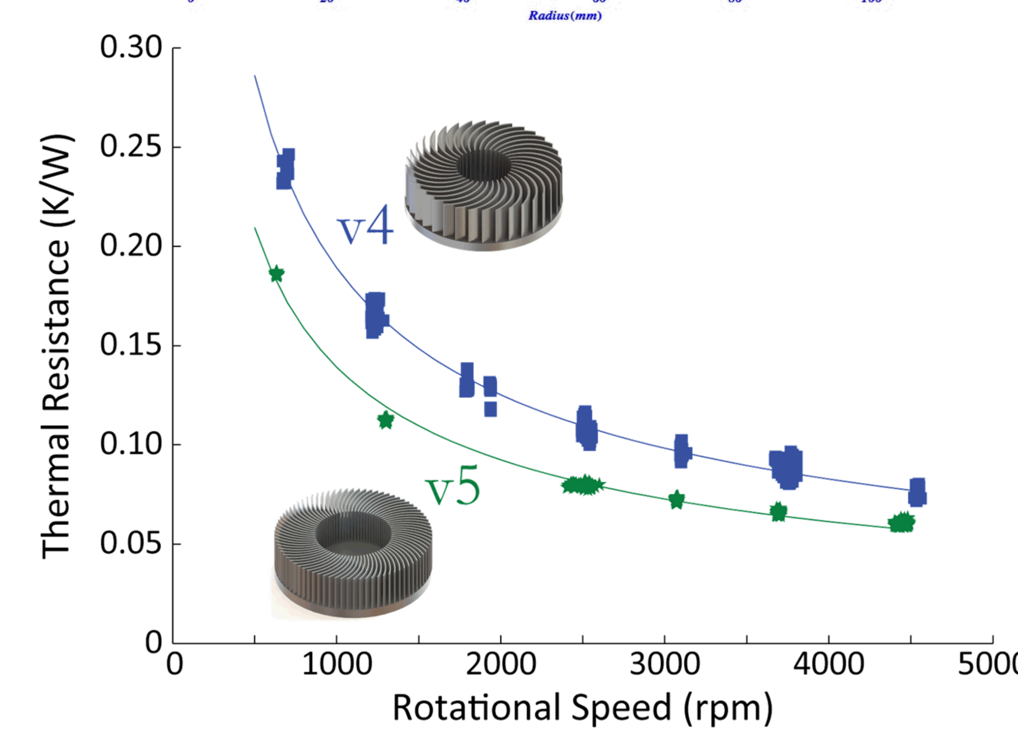
The version 4 Air Bearing Heat Exchanger

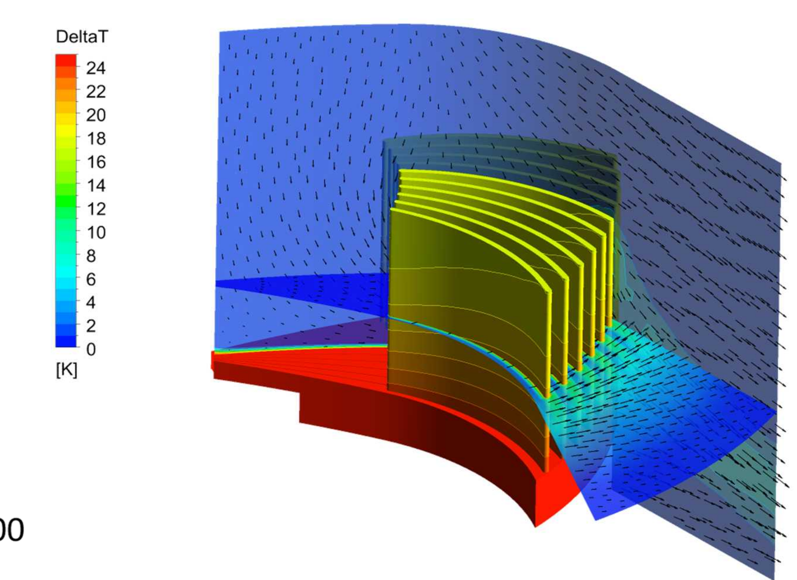
- A practical solution to the boundary layer problem has finally been devised.
- High-speed rotation prevents fouling of heat exchanger fins (see fan blade above).
- Unlike a traditional vane axial fan, this new device architecture provides a wide range of flexibility with regard to fin shape. This allows us to achieve very low noise operation.

What have we learned so far?

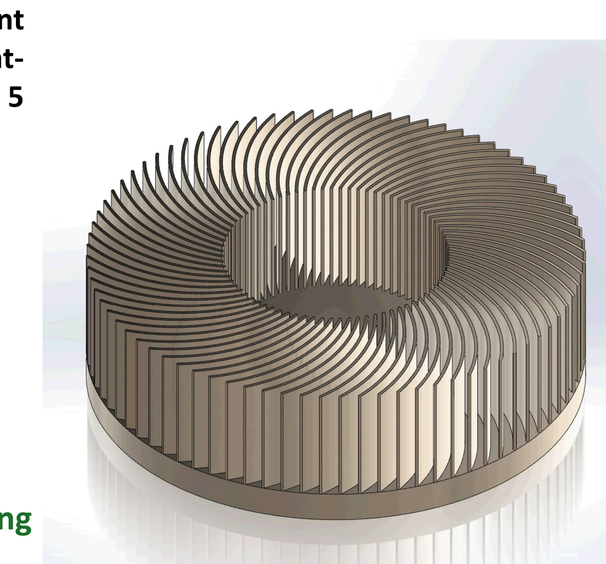








Heat-sink-impeller optimization is an extremely complex problem. A combination of laboratory flow field measurements, heat transfer measurements, and computational fluid dynamic (CFD) modeling of fluid low with conjugate heat transfer are required to tackle device optimization. Upper left: flow field measurement data. Upper right: test bed used to make laboratory measurements on candidate heat-sink-impeller geometries. Middle left: thermal resistance data from heat-sink-impeller to ambient air as a function of angular velocity. Middle right: CFD model results of version 5 heat-sink-impeller (velocity vectors and temperature contours). Lower right: version 5 heat-sink-impeller design based on insights from optimization analysis.



Lessons learned to date:

- Fin aspect ratio can be safely reduced to generate more fin area
- Flaring of diffuser region should be increased substantially
- Diameter of central inlet should be increased by ~30%
- Brushless motor noise eliminated by integrating motor into platen
- Motor integration also solves rotor mechanical tolerance problems
- Self-starting/stopping hydrodynamic air bearing implemented
- Incorporated dry ceramic anti-friction coating into hydrodynamic air bearing

Why is this important for our nation?

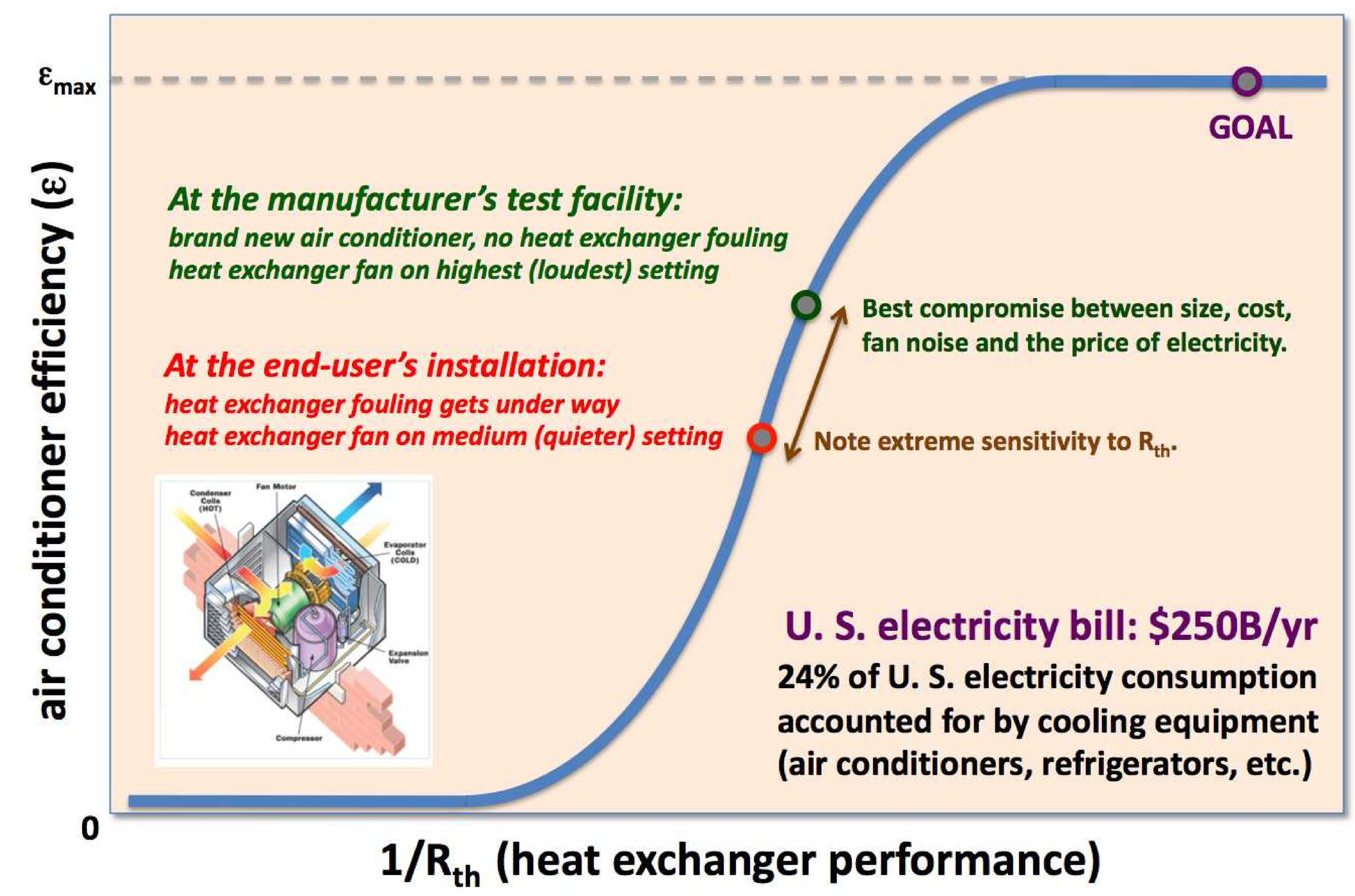
Information technology sector:

- Existing CPU/GPU clock speeds could be immediately doubled if adequate air cooling was available
- Electricity demand for data center cooling is now 1% of electricity consumption and ramping up fast

Energy sector:

- Cooling and refrigeration equipment account for 30% of total electricity consumption
- Improved heat exchangers could put a big dent in this number (see below)
- Cooling load demand spikes are particularly of concern with regard to power grid stability
- Lighting accounts for 14% of building energy consumption
- Proliferation of LED lighting could more than cut this number in half
- The last remaining obstacle to proliferation of LED lighting is the thermal management problem

The unrealized opportunity for energy savings in air conditioning



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