**Cooling of Electronic Equipment**

**Introduction**

Why should we worry about the thermal behavior of electronic equipment?

- A standard Intel Pentium 4 chip is:
  - $10.4 \, mm \times 10.4 \, mm$
  - contains millions of electronic components
  - dissipates approximately 75 watts of power
  - is restricted to a maximum temperature of $85 \, ^\circ C$

This does not seem like a big deal. A 100 W light bulb dissipates more power than this.

**Power vs. Heat Flux**

**100 W light bulb**

- Power = 100 W
- Area = 100 cm$^2$
- Flux = 1.0 W/cm$^2$

**Pentium 4 Processor**

- Power = 75.3 W
- Area = 1.08 cm$^2$
- Flux = 69.7 W/cm$^2$

\textit{70 times larger!}

- the heat flux at the surface on a chip is exceedingly high
• this is primarily because of the miniaturization of electronic devices in order to maximize signal processing speed

• if we track the evolution of Intel processors over the course of the past several decades we see a pattern which is expected to continue for the next several years

• the following figure puts the magnitude of this heat flux into perspective

• the problem is further compounded by the fact that a maximum operating temperature of approximately 85 − 100 °C is necessary in order to ensure long term reliable operation

• failure rate increases dramatically as operating temperatures rise above 100 °C
• electronic cooling presents a significant challenge to design engineers

• is the problem expected to get better anytime soon? not likely. By 2007, Intel expects to have 1 billion transistors/chip! with power dissipation of more that 100 W and heat fluxes of order 1000 W/m².

Therefore we must deal with the problem with engineering solutions that necessitate a good understanding of all forms of heat transfer.