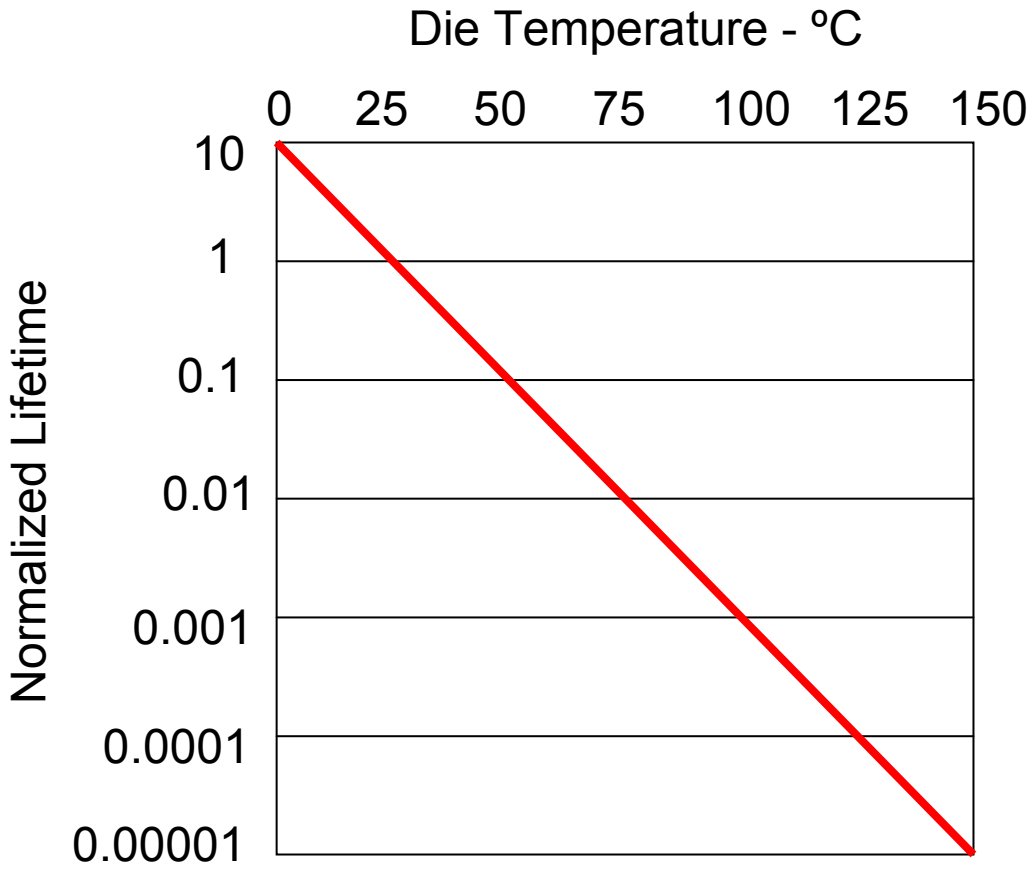
Rack Temperature

Semiconductor Cooling Issues

- Junction temperature is key to lifetime
  - Failure increases 10x for 25ºC rise
  - IBM shoots for 55 ºC junction with direct contact cooling
- 125 ºC manufacture data is max - shouldn’t use as design criteria
  - 100x lifetime reduction from 75 ºC

Semiconductor Lifetimes

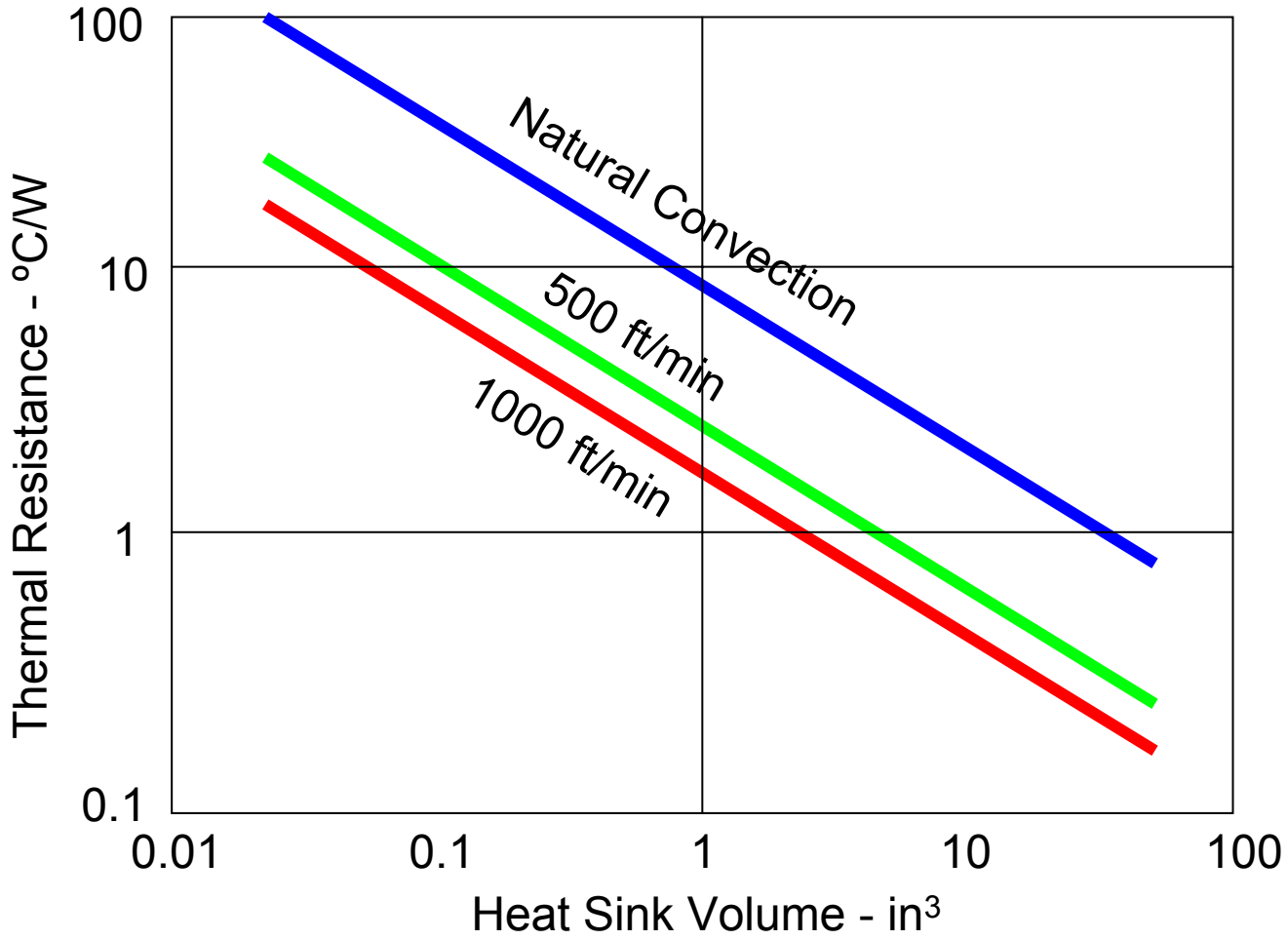
- Arrhenius Diagram - CMOS - 1eV



Junction Temperature

- Three major components
  - Junction to case temperature
    - Manufacturer package
    - Device power
  - Case to air temperature
    - Heat sink design
  - Air temperature
    - Cooling system

Air Cooled Heat Sinks



How to get to 85 ºC

- Junction to case usually 25 ºC - 35 ºC
  - The manufacturer designs the IC package based on device power to get into this range
- Heat sink 10 ºC - 20 ºC
  - User can control this somewhat by design
- Conclusion: air less than 30 ºC

Air-Water HE Issues

- Heat exchangers are low ΔT
- Inlet usually limited by condensation
  - At SLD this was 17 ºC
- Cooled air at 25 ºC
- Return heated air at 35 ºC max

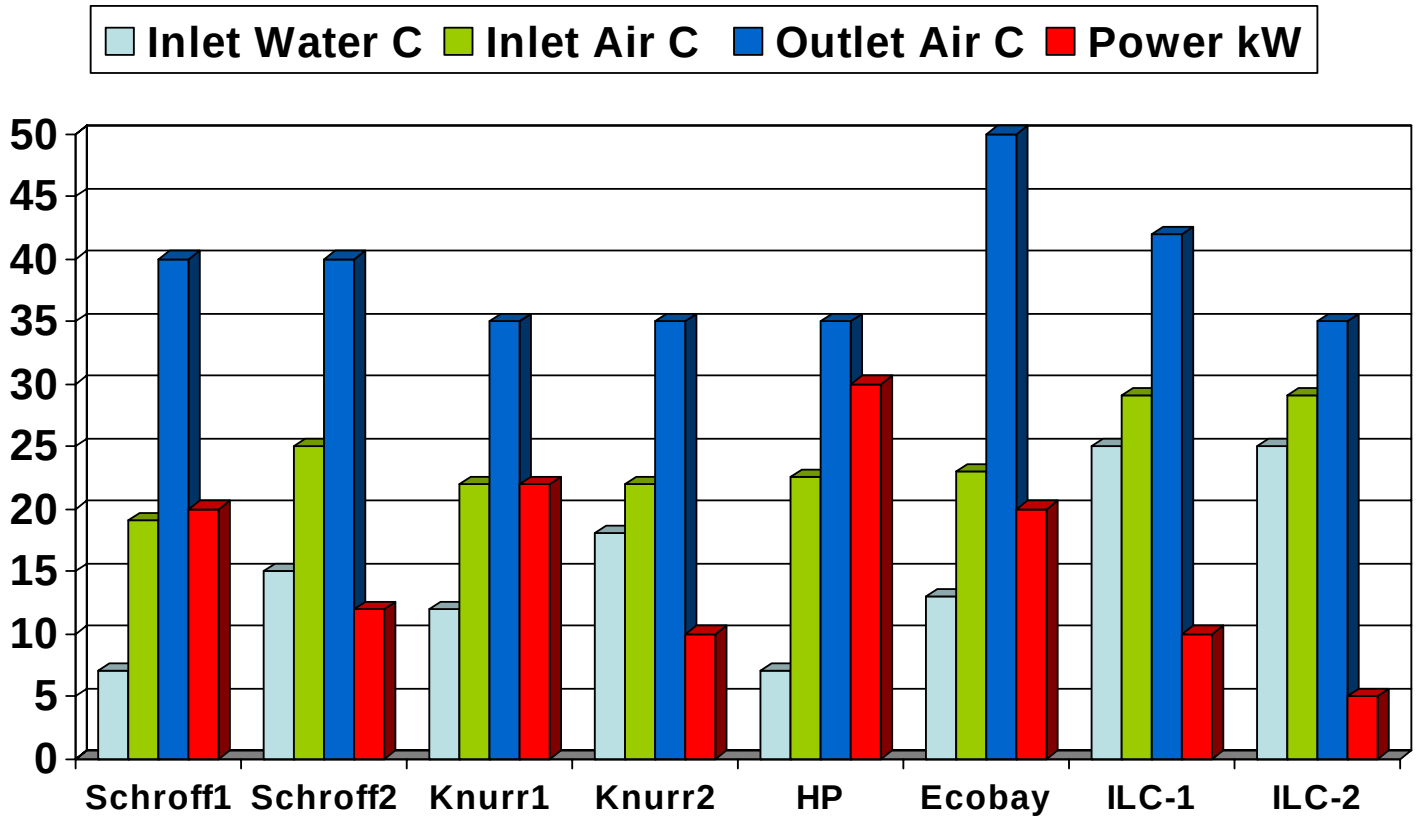
Excel Sheet 1

Rack Power and Temperature													
										calculated from manufacture's air and water flow (col G & H)			
Mnfg	**inlet water (deg C)**	**outlet water (deg C)**	**water delta T (deg C)**	**chilled air (deg C)**	**return air max (deg C)**	**air delta T (deg C)**	**power (kW)**	**flow rate (gpm)**	**air flow (cfm)**	**power in water at 10 deg C rise**	**implied delta T**	**power in air at 10 deg C rise**	**implied delta T**
Varistar (Schroff)	7			18	40	22	20	12.3	1765	33	6	10.1	19.8
	15			26	40	14	12	6.8	1765	18	7	10.1	11.9
Knurr	12	18	6	20	35	15	20	14	3240	38	5	18.5	10.8
	18			22	35	13	10	14	3240	38	3	18.5	5.4
HP	7			22.5	35	12.5	30	20	2750	54	6	15.7	19.1
Ecobay	13	20	7	23	50	27	20	12	1680	32	6	9.6	20.8
air: cfm/kW @ 10 deg C	175	Note: this is at sea level. See chart below for altitude corrections.											
water: gpm/kW @ 10 deg C	0.37												
Notes:													
1) Knurr runs a constant flow rate and bypasses to control the temperature. May account for apparent low flow in the 10kW case.													
2) all heat exchangers run a low delta T on the water loop - between 5 and 7 degrees.													
3) The SLD racks ran 5 degrees max. at 10 kW.													
4) air delta T comparisons off in some cases. Some could be due to fan speed controls. Not sure why HP is off so much.													

Excel Sheet 2

Assumptions	inlet water (deg C)	outlet water (deg C)	water delta T (deg C)	chilled air (deg C)	return air max (deg C)	air delta T (deg C)	water power (kW) see note 3	flow rate (gpm) see note 1	air flow (cfm) see note 2,3
type numbers in yellow cells	17	22	5	25	35	10	10	7.4	1750
clear cells are calculated									
Note 1: velocity in pipes limited to 5 ft/sec to minimize erosion. Table shows flow rare maximums vs. pipe diameter	**pipe dia (in)**	**flow max (gal/min)**							
	1/4	1							
	3/8	2							
	1/2	3							
	5/8	5							
	3/4	7	racks above fall in this range for water connection						
	1	12							
	1 1/4	19	heat exchangers in the racks constructed of smaller tubes (3/8 ?) in parallel						
Note 2: Because of back pressure and "reasonable" fans the practical limit for air flow is about 3000 cfm.									
Note 3: Altitude correction for air flow at 20 deg C	**Altitude (ft)**	**Correction Factor**		**Constant Power cfm**	**Water Flow gpm**	**Constant Air Flow kW**	**Water Flow gpm**		
ex: 1000 cfm @ sea level =	0	1		1750	7.4	10.0	7.4		
1120 cfm at 3000 ft for same	1000	1.04		1820	7.4	9.6	7.1		
delta T cooling	2000	1.08		1890	7.4	9.3	6.9		
If cfm is constant then power	3000	1.12		1960	7.4	8.9	6.6		
is reduced to 89% for same temp.	4000	1.16		2030	7.4	8.6	6.4		
	5000	1.22		2135	7.4	8.2	6.1		

Water Cooled Racks Performance



Comparison with ILC Requirements

- Graph shows vendor data for different water inlet temperatures, internal temperatures, power ratings. For ILC we have specified a maximum of 25C for inlet water
- Knurr1-Knurr2 show that 6 deg C rise in inlet water temp to maintain outlet temp at 35C drops power handling capacity from 22 to 10kW.
- Extrapolation for ILC from Knurr2
  - ILC-1 Raise inlet water 7C to 25C, get 42C outlet air at 10kW
  - ILC-2 Lower power to ~5kW, get ~35C outlet air temp
- Conclusion: With 25C inlet water max power slightly less than 10kW at 40C outlet air, and approx. 5kW at 35C outlet air.