Dual Enclosure Liquid Cooling (DELC)

Chiller-less Data Centers with Liquid Cooled Servers To Enable Significant Data Center Energy Savings

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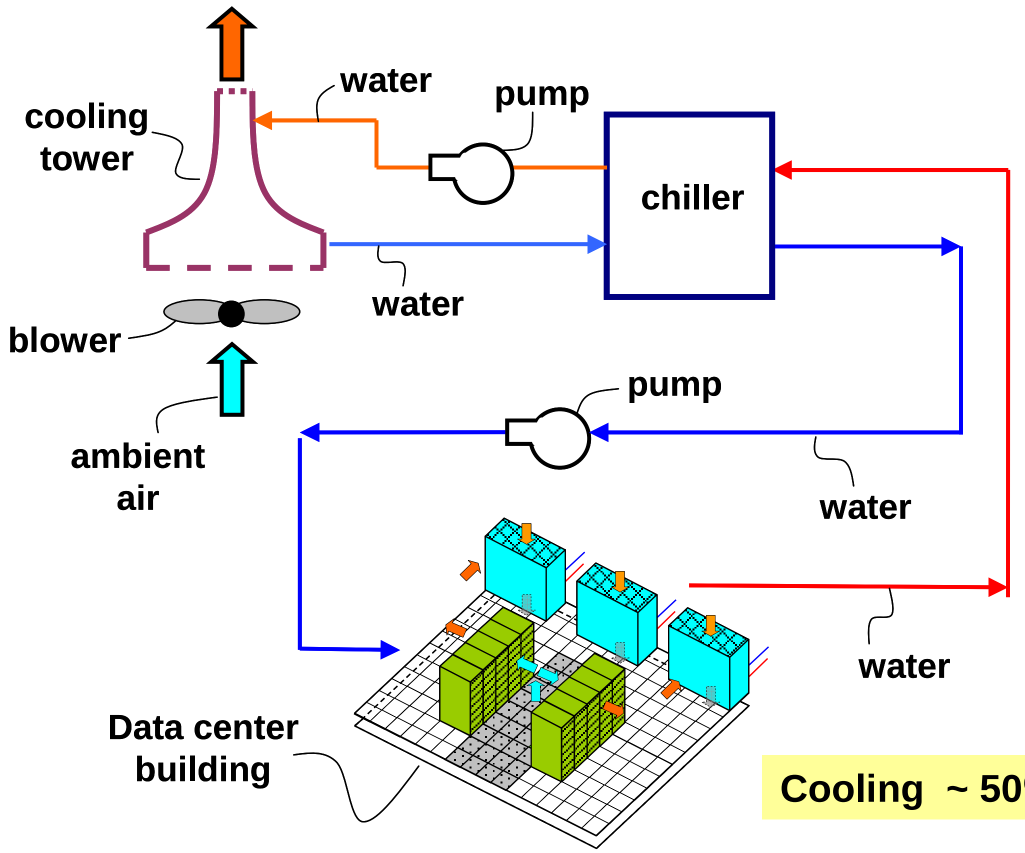
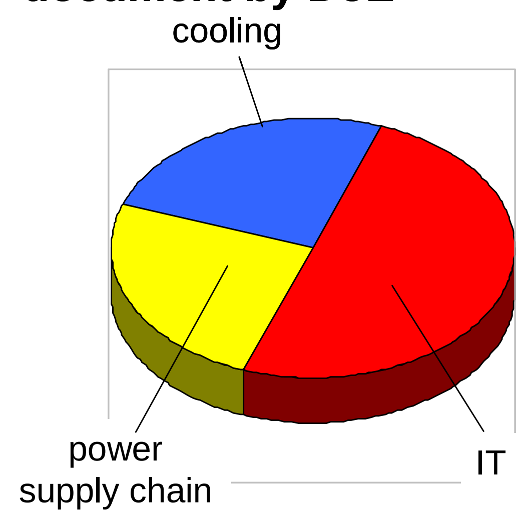
Traditional data center cooling infrastructure

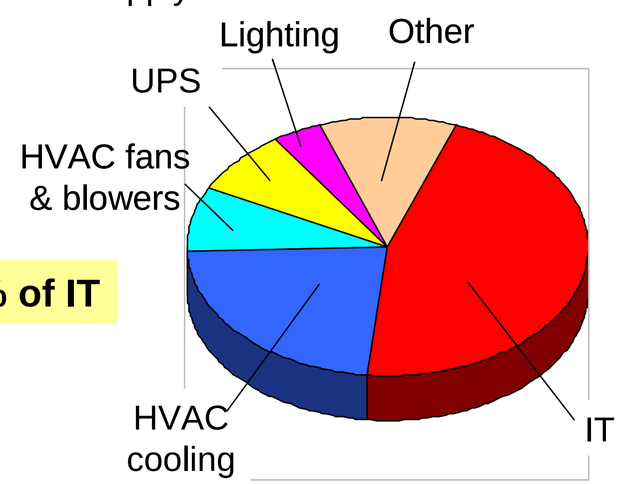


Cooling ~ 50% of IT

(a) Traditional data center facility

(b) 2009 Vision and Roadmap document by DoE





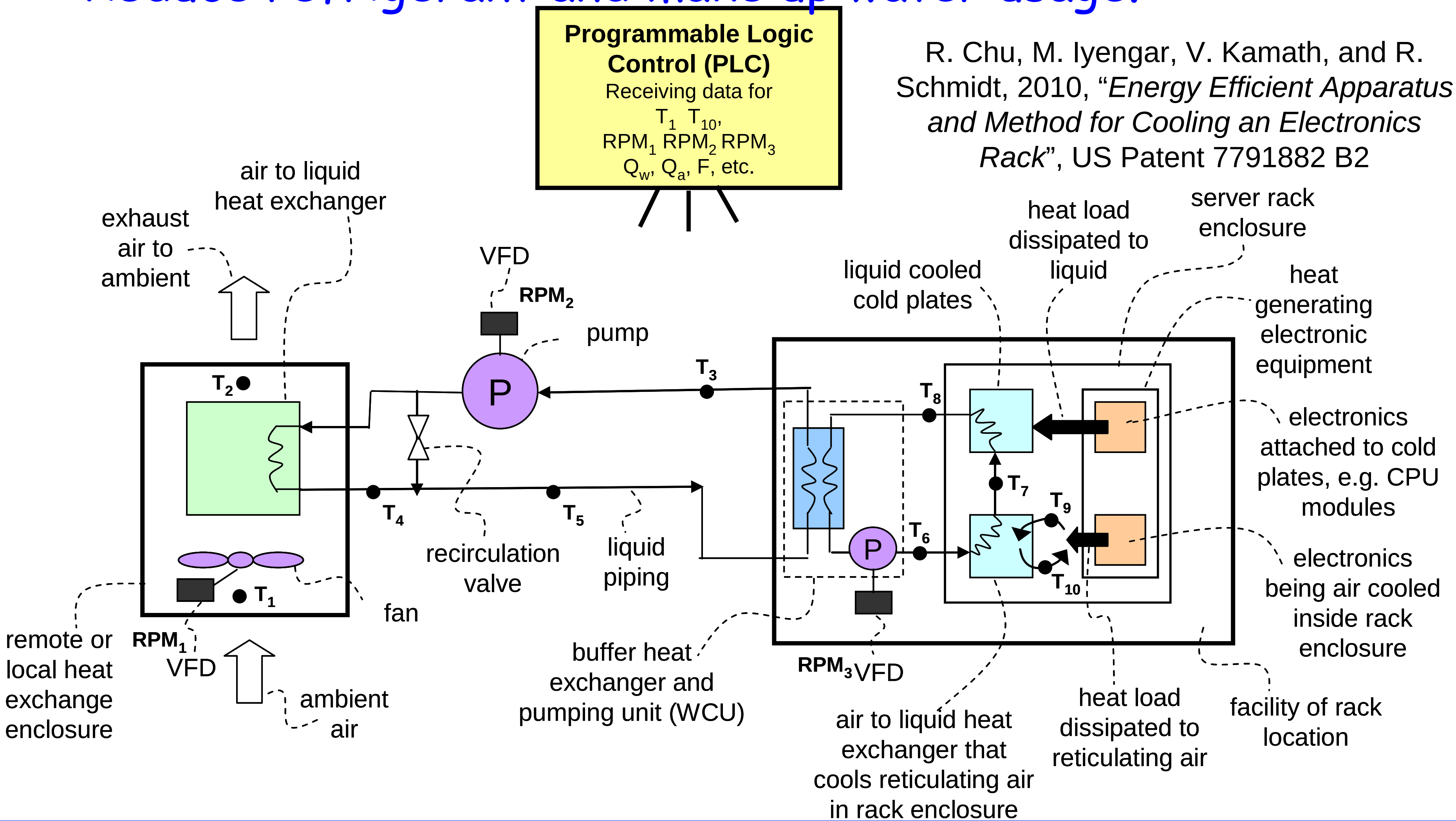
(c) ASHRAE book chart using LBNL case study data

Goal is to reduce data center cooling energy use to 10% of IT & 5% of a typical data center energy

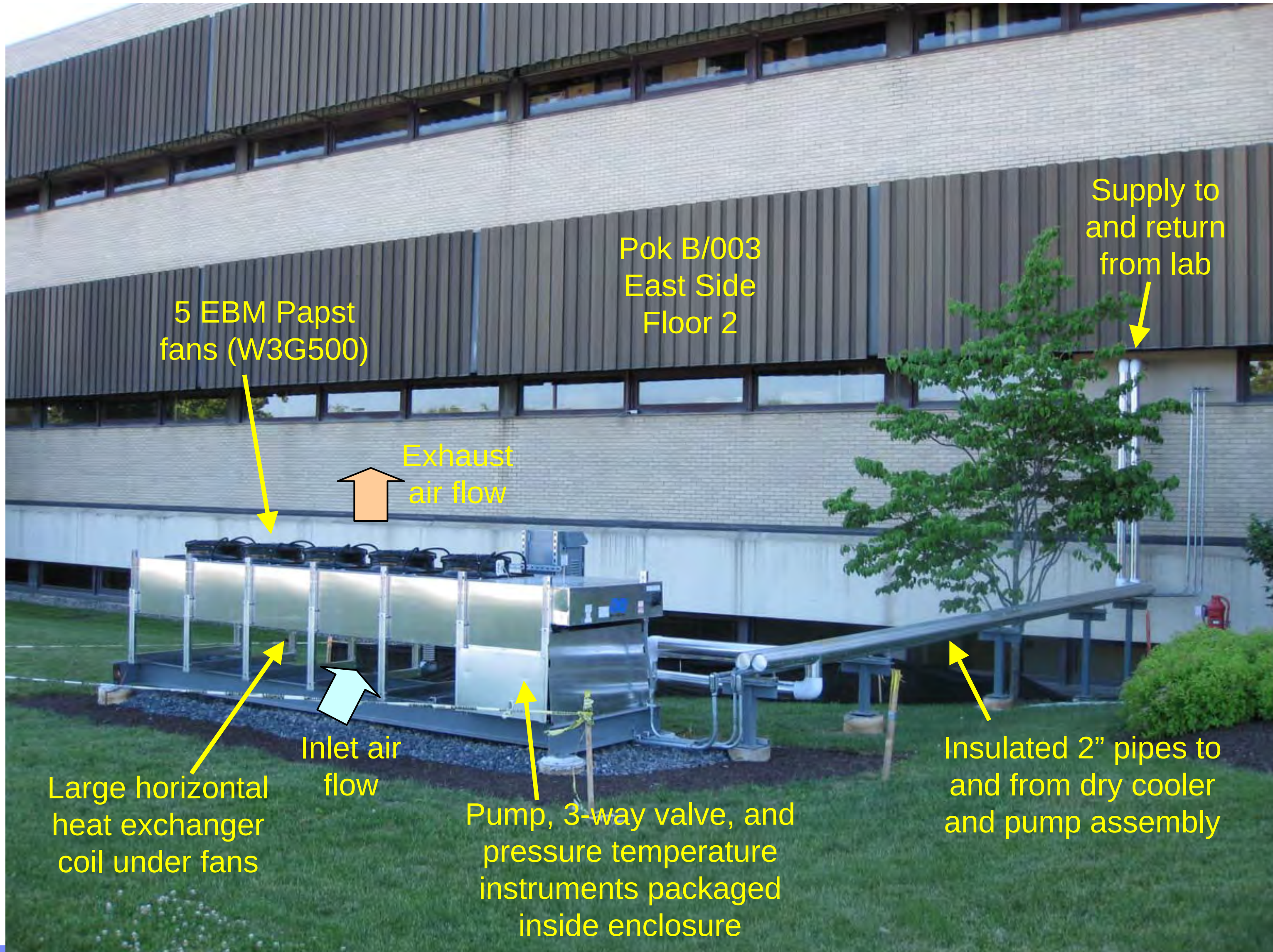
Innovative data center design

- Eliminate chillers and room air-conditioning.
- Reject heat to ambient using server liquid cooling.
- Reduce refrigerant and make up water usage.

R. Chu, M. Iyengar, V. Kamath, and R. Schmidt, 2010, "*Energy Efficient Apparatus and Method for Cooling an Electronics Rack*", US Patent 7791882 B2

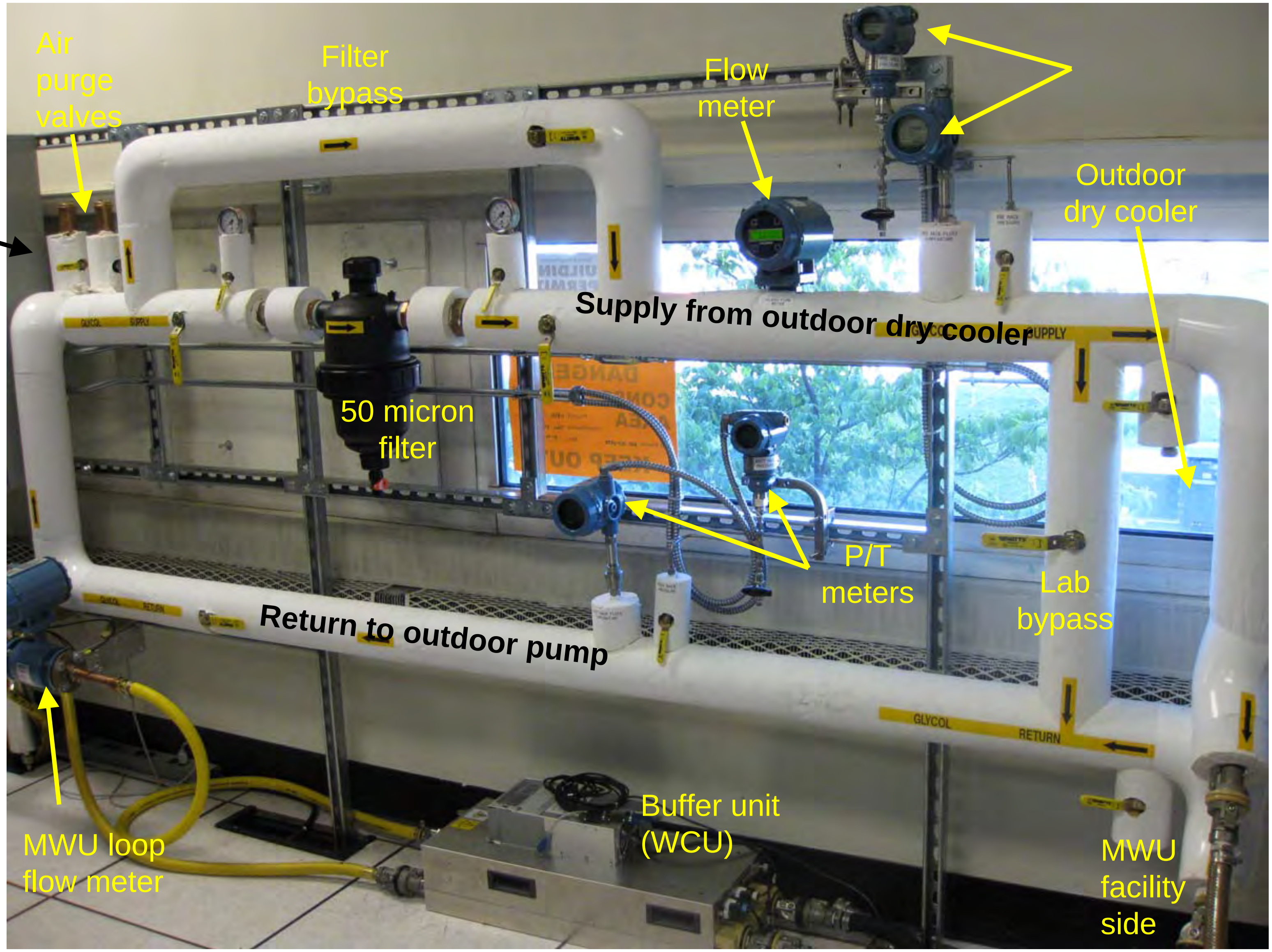


DOE outdoor loop layout (using a dry cooler to reject heat to the outdoor air)

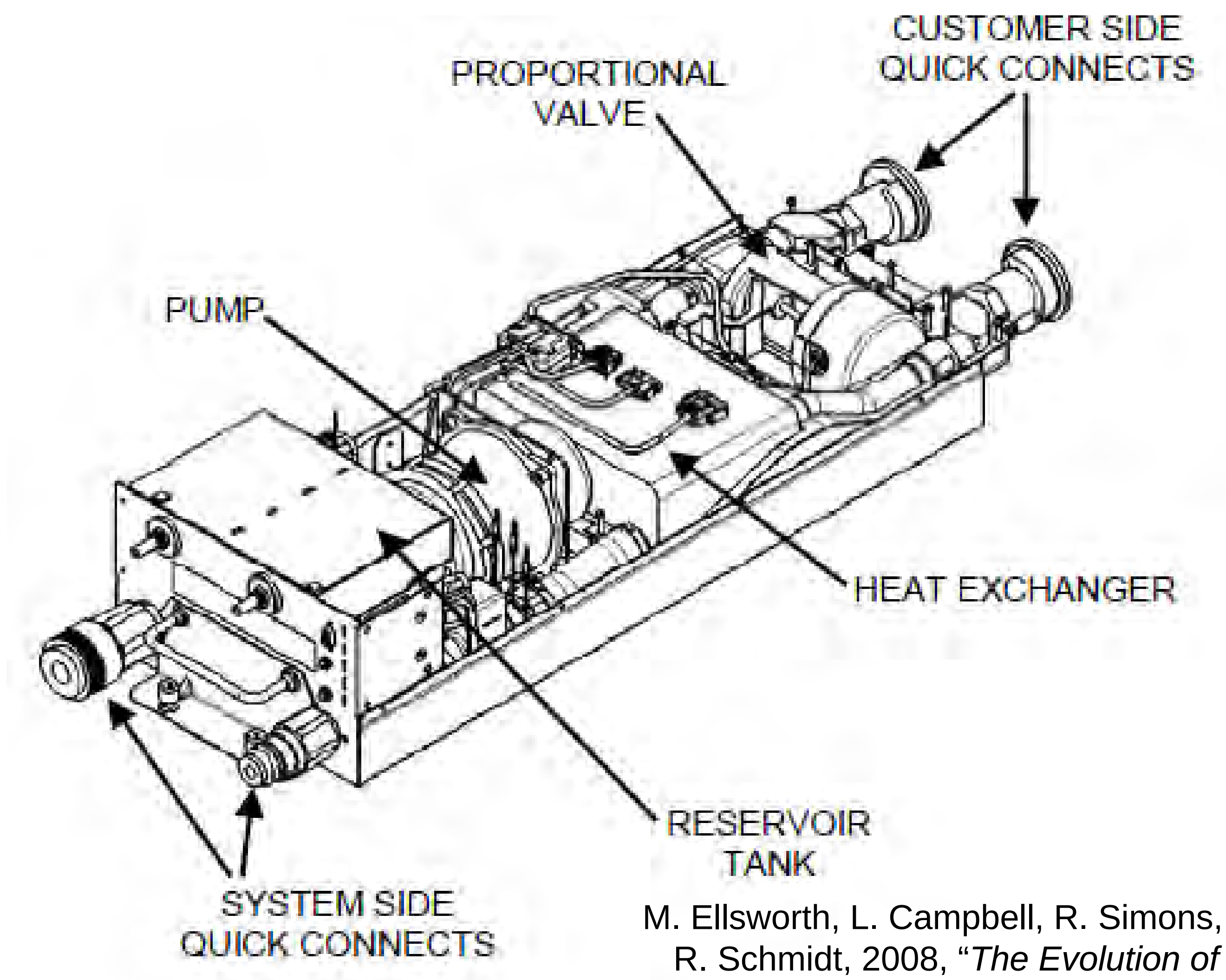


Piping layout inside the lab

Liquid supply from & return to outside



Water Cooling Unit (WCU) – Buffer unit



M. Ellsworth, L. Campbell, R. Simons, M. Iyengar, R. Chu, and R. Schmidt, 2008, "*The Evolution of Water Cooling for IBM Large Server Systems: Back to the Future*", Proceedings of the IEEE ITherm Conference in Orlando, USA, May.

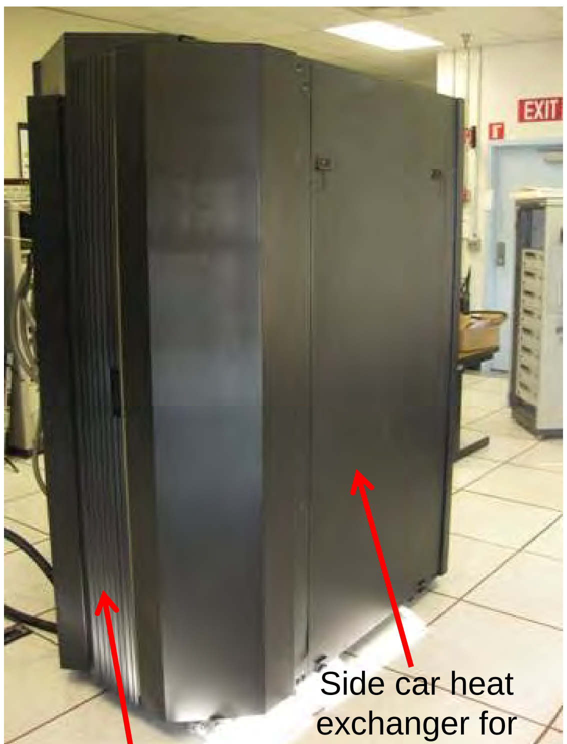
Programmable Logic Control (PLC)

- Collects power/thermal data from data center loop devices.
- Controls external pump, external fan, and three-way valve (winter).
- Allows Labview full control or uses embedded control algorithm for robust operation.
- Takes over control in case of "safety" events.
- Can be turned on and directly used in PLC mode.
- Provides learning for integrating commercial strength BMS with rack level operation.

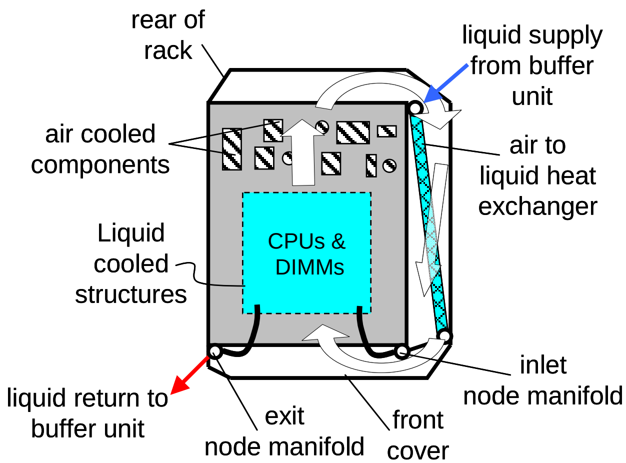
Rack level cooling design

- Cool servers using warm water and air supply.
- Totally (100%) liquid cooled at rack level.
- Advanced thermal interfaces in key locations.

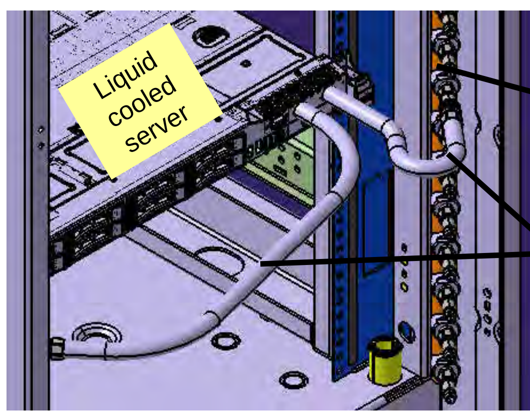
(a) Photograph of rack



(b) Rack plan view schematic



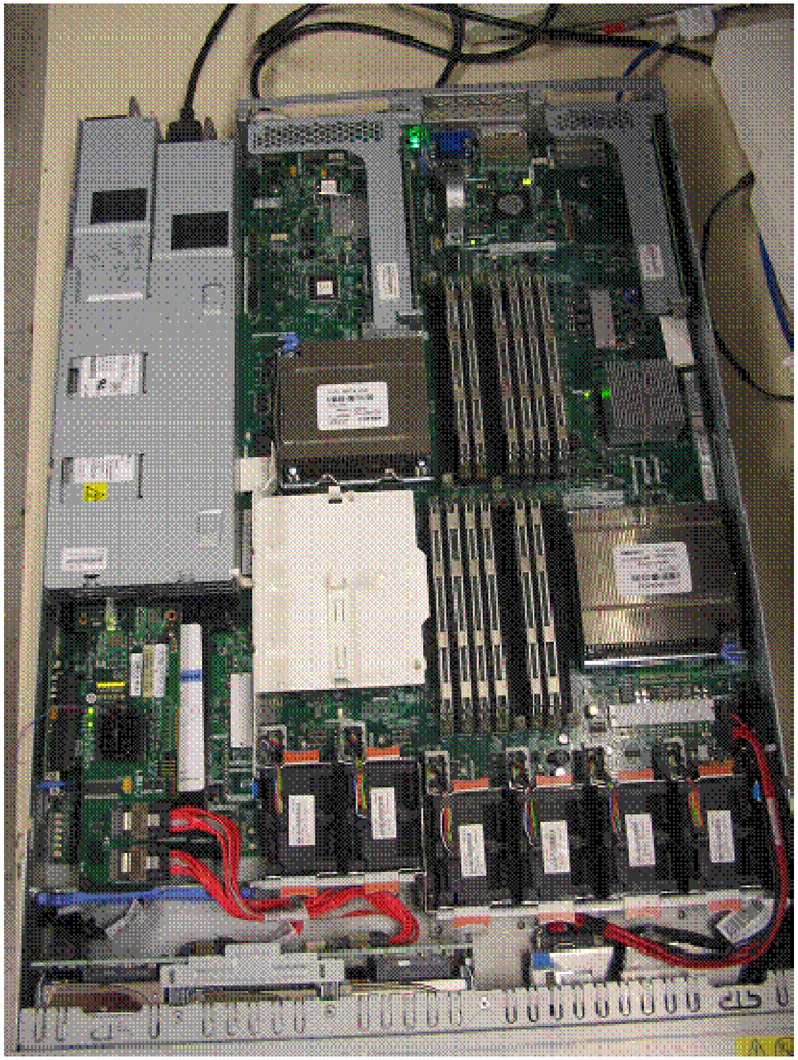
(c) Internal plumbing to liquid cooled node



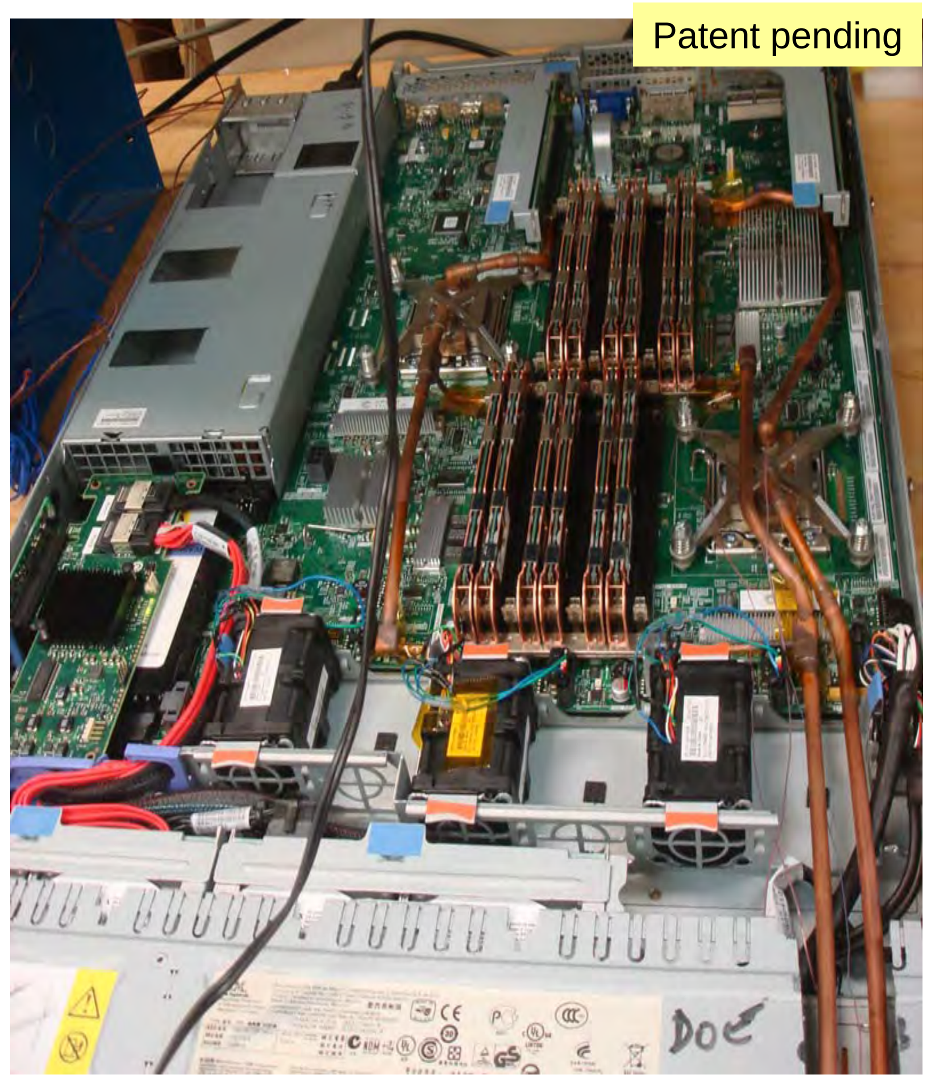
R. Schmidt, M. Iyengar, D. Porter, G. Weber, D. Graybill, and J. Steffes, 2010, "*Open Side Car Heat Exchanger that Removes Entire Server Heat Load Without any Added Fan Power*", Proceedings of the IEEE ITherm Conference, Las Vegas, June.

U.S. Patent 6,775,137, "Method and Apparatus for Combined Air and Liquid Cooling of Stacked Electronic Components," R.C. Chu, M.J. Ellsworth, Jr., E. Furey, R.R. Schmidt, and R.E. Simons

IBM System X 1U server – x3550M3



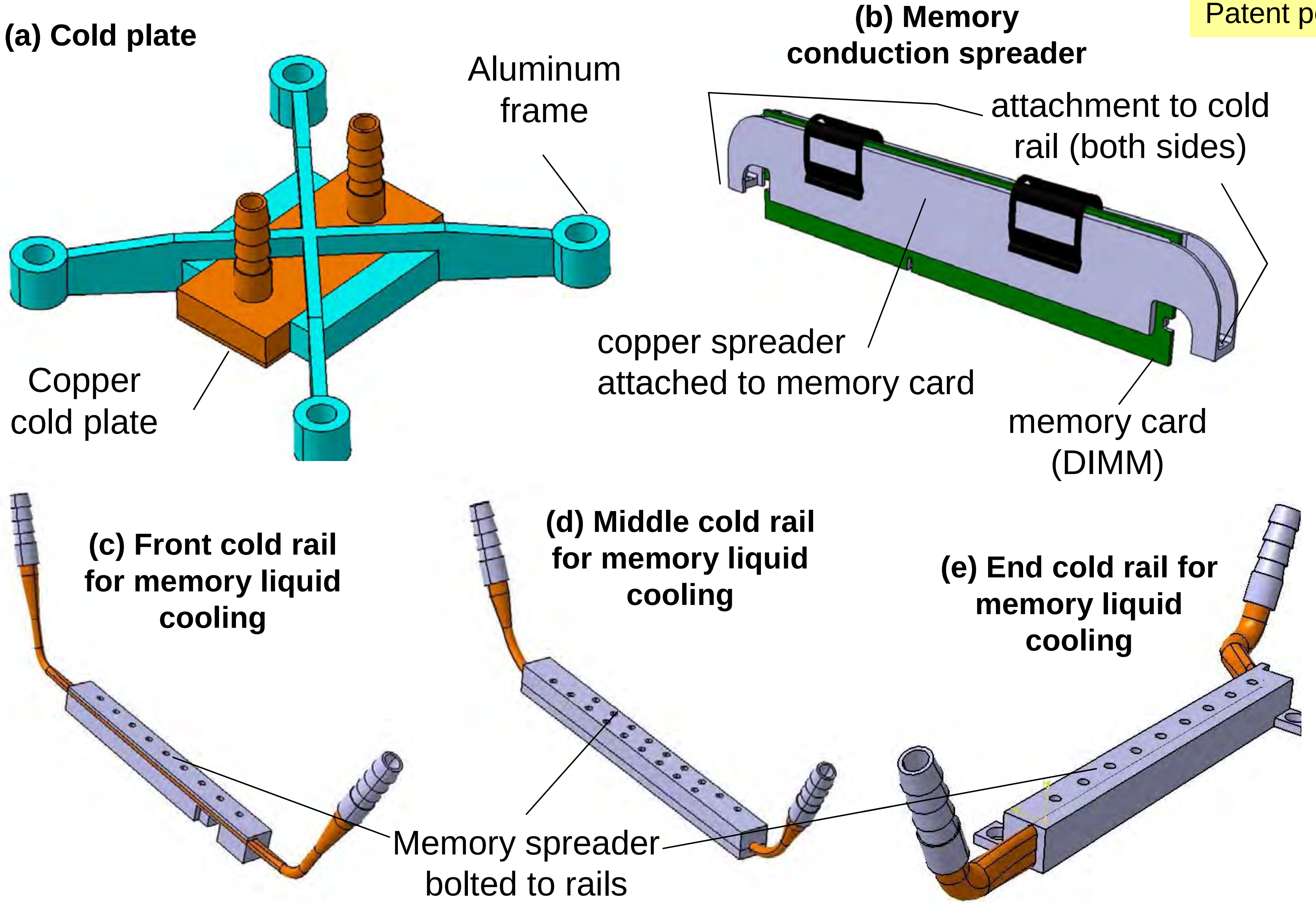
Air cooled server



Water cooled server with CPU and DIMM liquid cooling w/ 3 fans

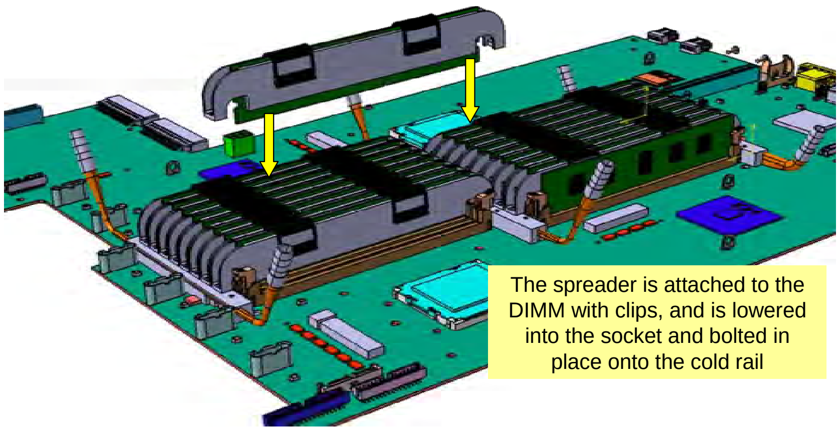
Server liquid cooling components

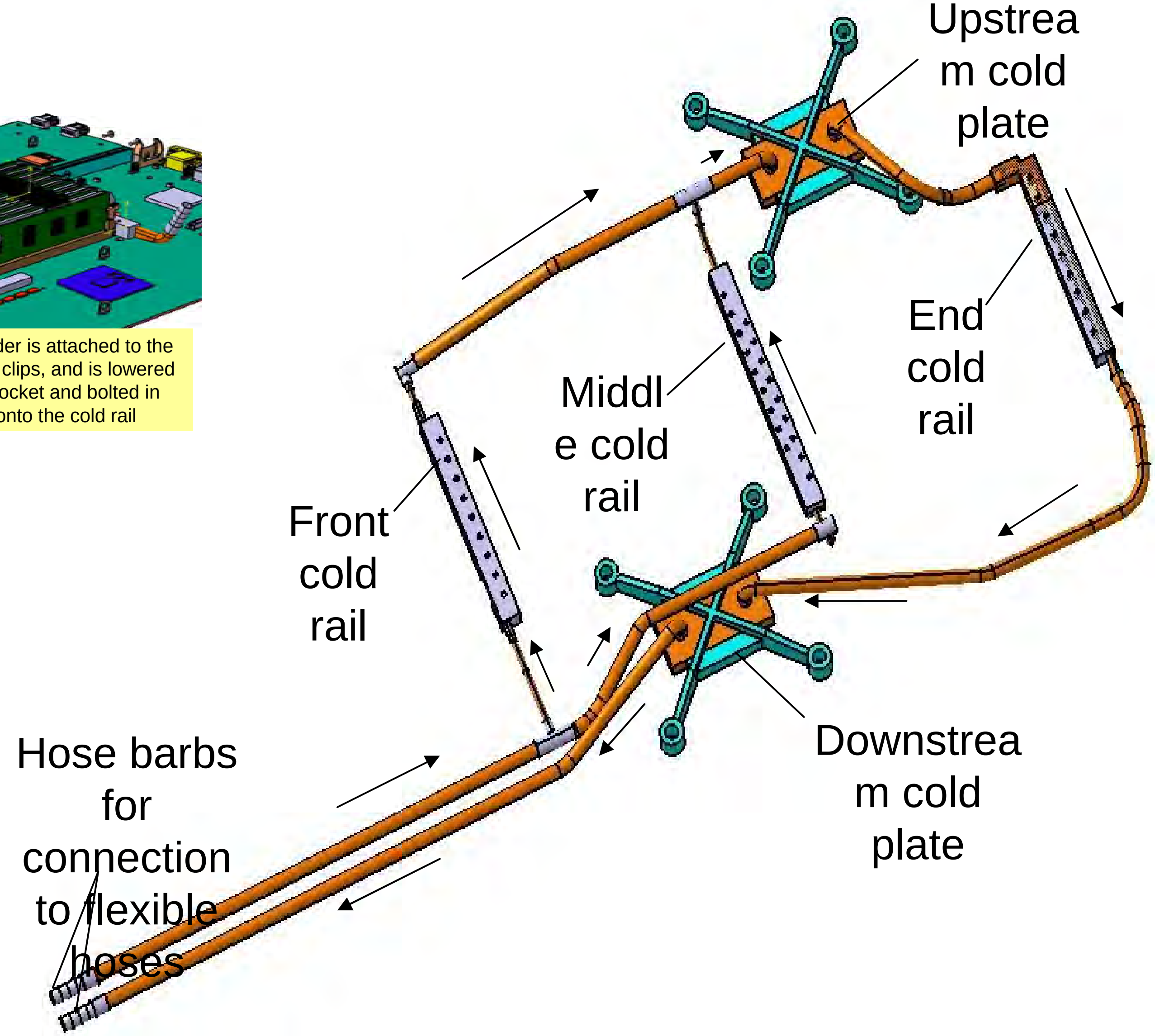
Patent pending



Server liquid cooling sub-assemblies

Patent pending



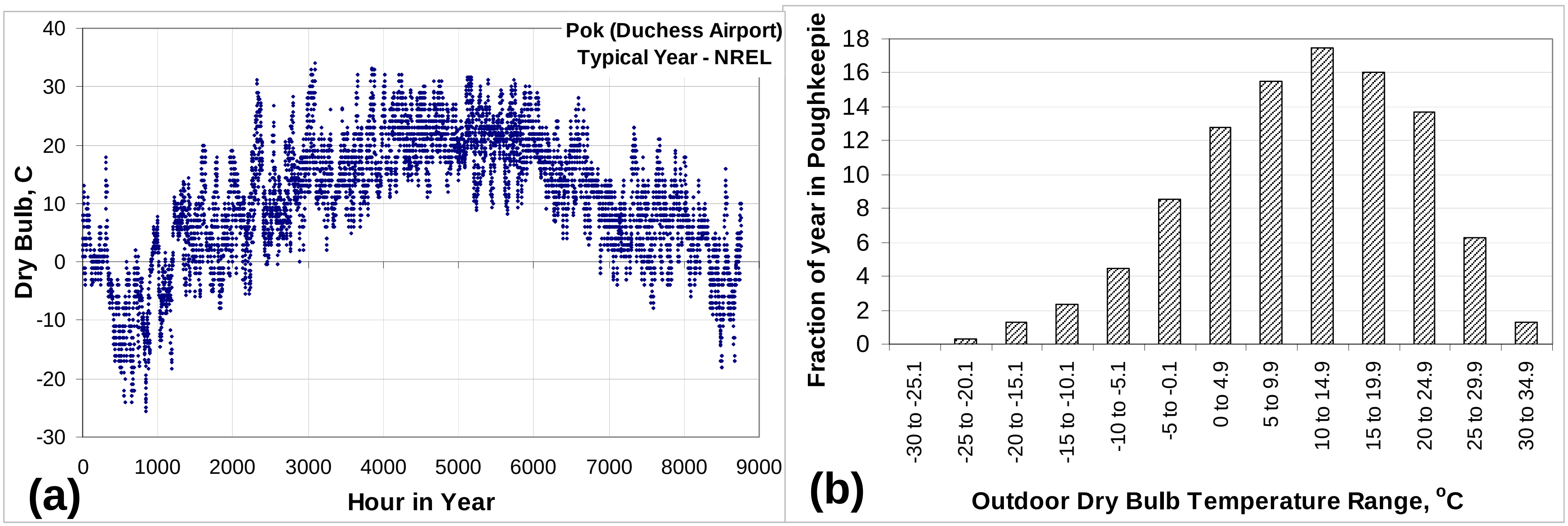


Thermal chamber test for air/liquid cooled servers

CASE A	CASE B
"Cool" air cooled node	**"Hot" air cooled node**
▪ 25.3ºC inlet air temperature	▪ 35.4ºC inlet air temperature
▪ Exerciser setting at 90%	▪ Exerciser setting at 90%
▪ 12 fans running at 7242 rpm (avg.)	▪ 12 fans running at 11978 rpm (avg.)
▪ System power = 395 W	▪ System power = 423 W
▪ Fan power = 19.1 W	▪ Fan power = 56.8 W
▪ CPU lid temps. = 65.3 ºC, 74 ºC	▪ CPU lid temps. = 68.9 º C, 71.9 ºC
▪ DIMM temperatures = 35-46 ºC	▪ DIMM temperatures = 35-46 ºC
▪ 12 x 8 GB DIMMS	▪ 12 x 8 GB DIMMS

CASE C	CASE D
"Hot" water cooled node	**"Cool" water cooled node**
▪ 49.9 ºC inlet air temperature	▪ 24.9 ºC inlet air temperature
▪ 45.2 ºC inlet water temperature	▪ 20.1 ºC inlet water temperature
▪ Exerciser setting at 90%	▪ Exerciser setting at 90%
▪ 3 fans running at 12612 rpm (avg)	▪ 3 fans running at 5838 rpm (avg)
▪ System power = 411 W	▪ System power = 354 W
▪ Fan power = 30.9 W	▪ Fan power = 8.3 W
▪ CPU lid temps. → 62.8ºC, 61.9ºC	▪ CPU lid temps. → 36.8ºC, 35.9ºC
▪ DIMM temperatures → 53-56 ºC	▪ DIMM temperatures → 28-33 ºC
▪ 12 x 8 GB DIMMs	▪ 12 x 8 GB DIMMs

Typical Poughkeepsie weather data (NREL)



Experimental data for 22 h test (August 2011)

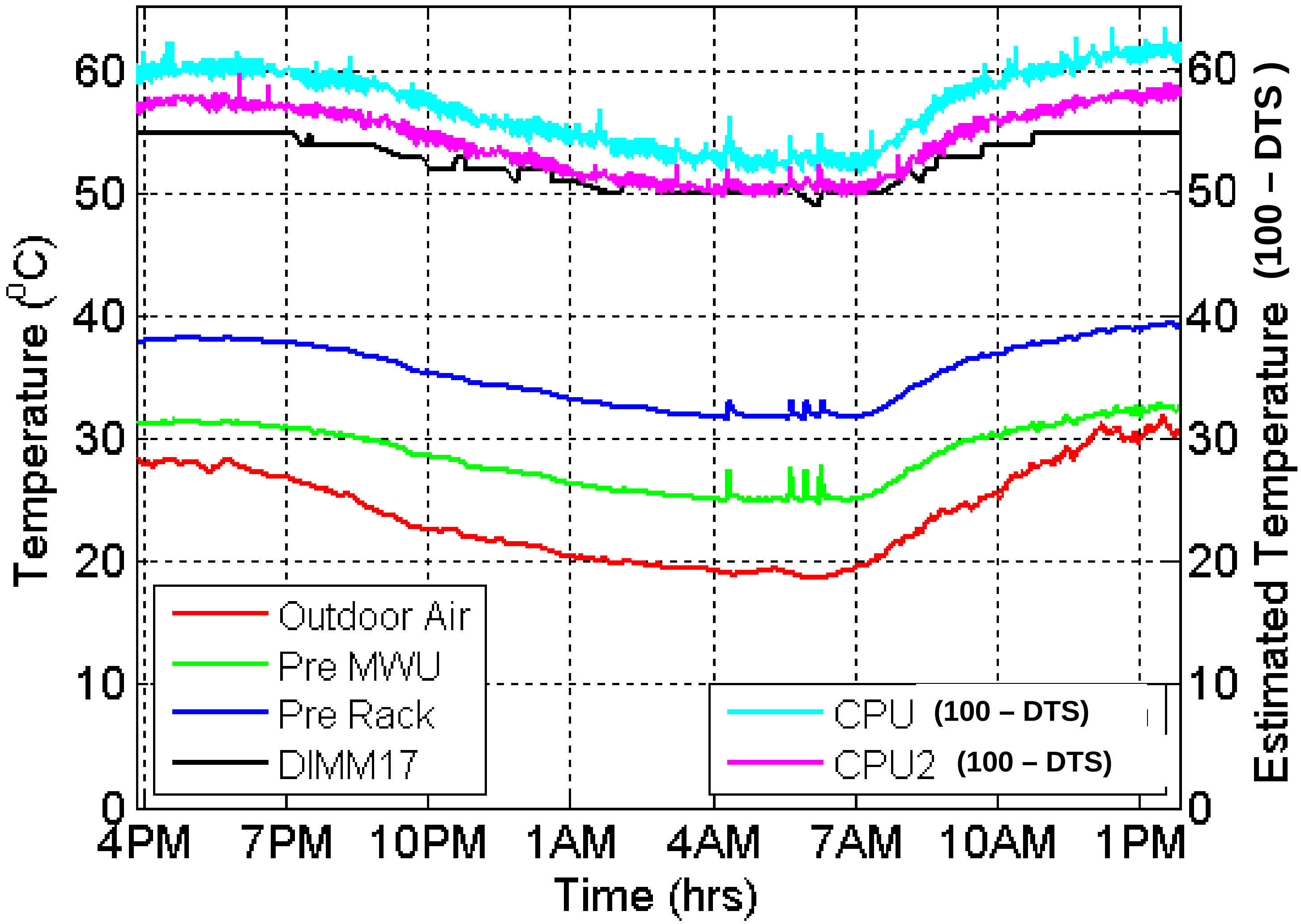
IBM

Total data center cooling power is less than 3.5% of IT for a hot NY summer day

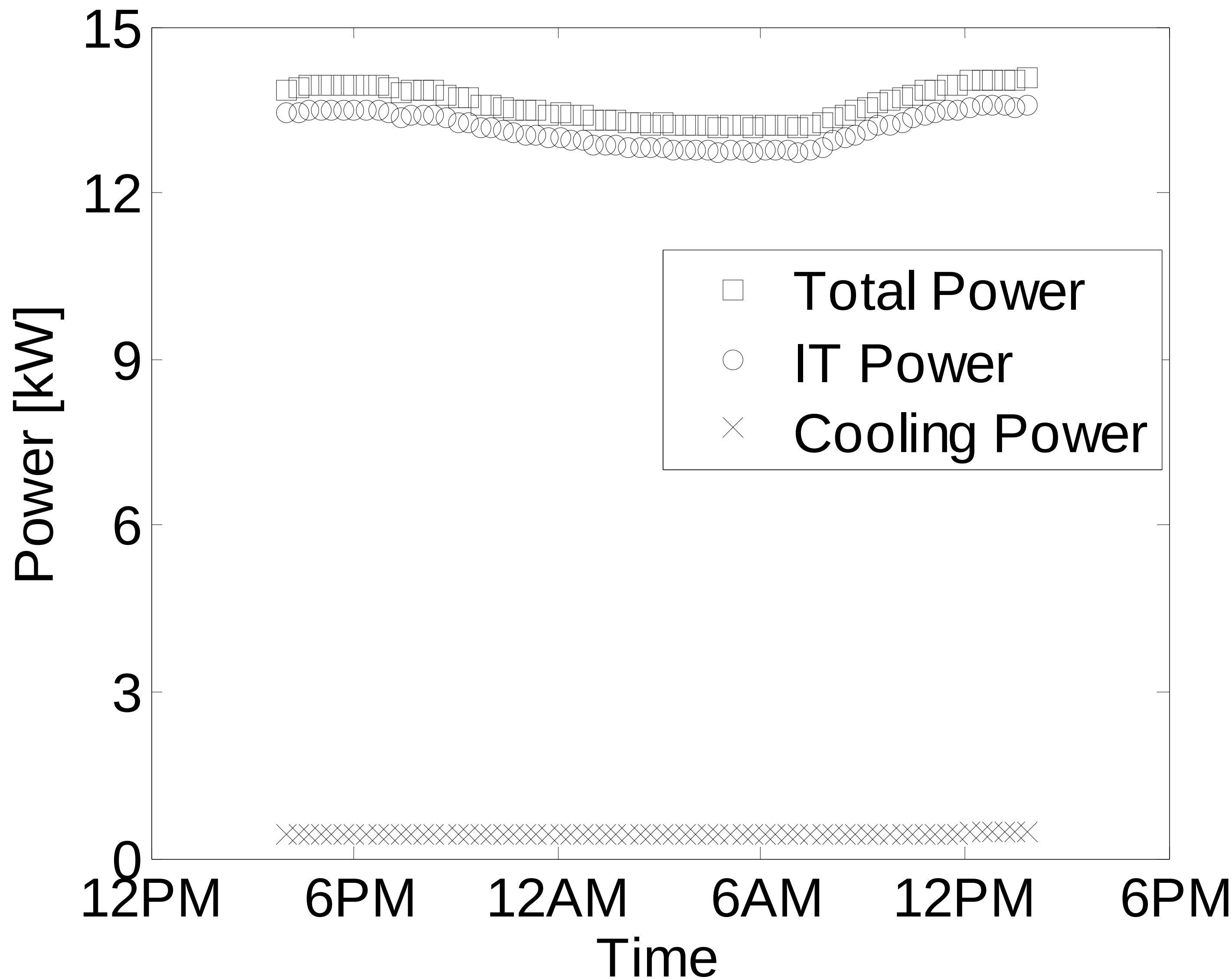
Date Stamp	Time Stamp	Ave. outside air temp C	Ave. IT Power kW	Ave. Cooling Power kW	Cooling power as % of IT	Ave. server inlet air temp C	Ave. rack inlet water temp C
8/4/2011	4:00:30 PM	28.1	13.43	0.440	3.28	38.1	36.3
8/4/2011	4:59:56 PM	28.1	13.47	0.442	3.28	38.5	36.4
8/4/2011	6:00:22 PM	27.9	13.50	0.441	3.27	38.6	36.4
8/4/2011	7:00:54 PM	27.3	13.48	0.440	3.26	38.5	36.2
8/4/2011	8:01:25 PM	26.3	13.43	0.433	3.23	38.2	35.8
8/4/2011	9:01:54 PM	24.9	13.36	0.433	3.24	37.7	35.2
8/4/2011	10:02:17 PM	23.2	13.22	0.438	3.31	36.9	34.2
8/4/2011	11:02:41 PM	22.4	13.09	0.437	3.33	36.2	33.3
8/5/2011	12:03:04 AM	21.7	12.99	0.439	3.38	35.5	32.6
8/5/2011	1:03:27 AM	20.9	12.96	0.440	3.39	35.1	32.0
8/5/2011	2:03:49 AM	20.2	12.88	0.443	3.44	34.6	31.2
8/5/2011	3:04:12 AM	19.8	12.81	0.441	3.44	34.3	30.8
8/5/2011	4:04:34 AM	19.4	12.77	0.442	3.46	34.0	30.4
8/5/2011	5:04:58 AM	19.1	12.76	0.443	3.47	33.9	30.3
8/5/2011	6:05:24 AM	19.0	12.76	0.448	3.51	33.8	30.4
8/5/2011	7:05:46 AM	19.0	12.77	0.440	3.45	33.9	30.4
8/5/2011	8:06:10 AM	20.8	12.79	0.437	3.41	34.3	31.1
8/5/2011	9:06:41 AM	23.3	13.01	0.432	3.32	35.8	33.3
8/5/2011	10:07:10 AM	25.0	13.21	0.432	3.27	37.2	35.0
8/5/2011	11:07:40 AM	27.4	13.37	0.437	3.27	38.0	35.9
8/5/2011	12:08:12 PM	29.1	13.48	0.449	3.33	38.6	36.6
8/5/2011	1:08:44 PM	30.5	13.58	0.465	3.43	39.3	37.3
8/5/2011	1:55:08 PM	31.0	13.58	0.477	3.51	39.5	37.6

Temperature data for 22 h test (August 2011)

Total data center cooling power is 3.5% of IT for a hot NY summer day

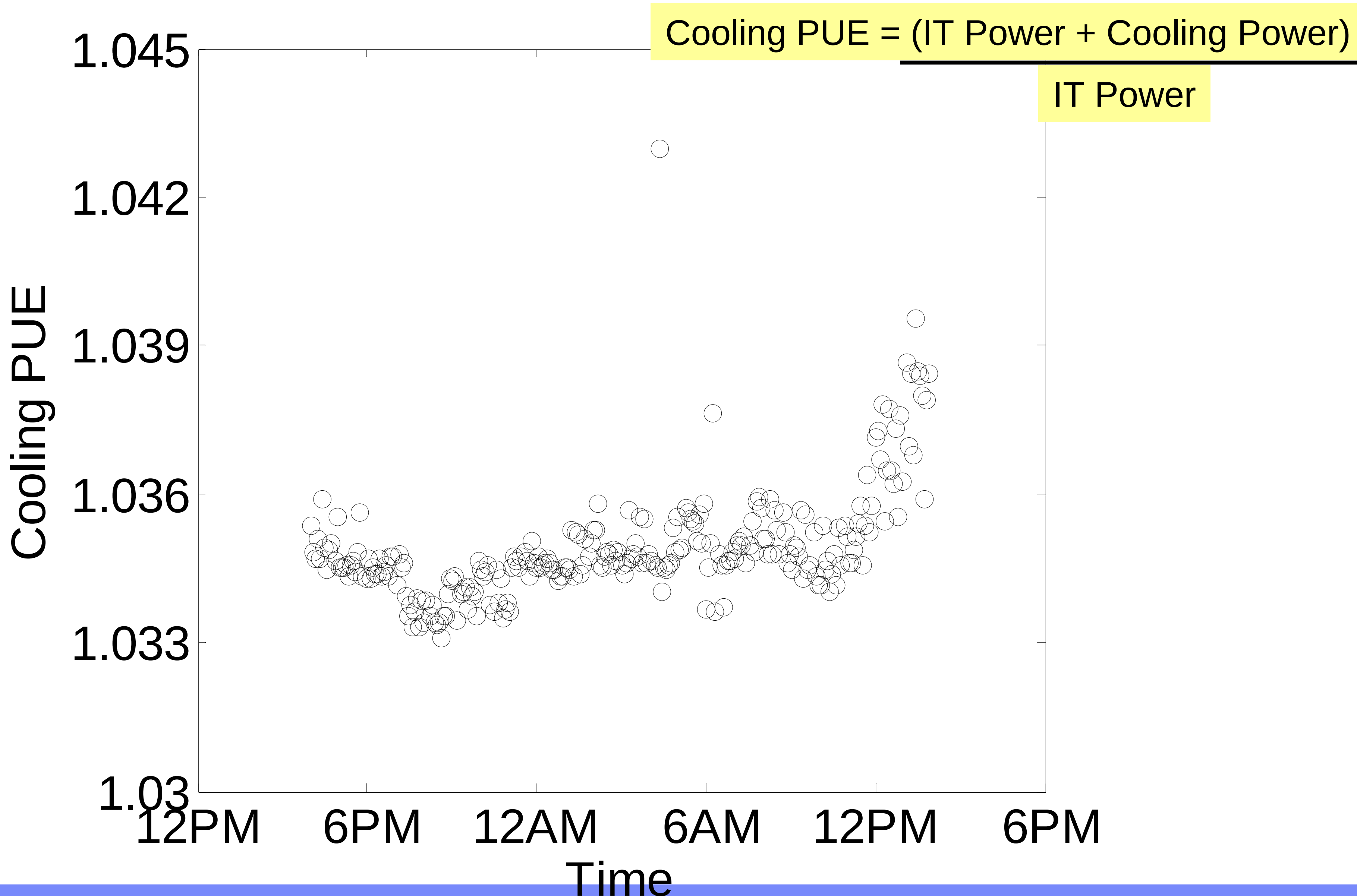


Power data for 22 h test

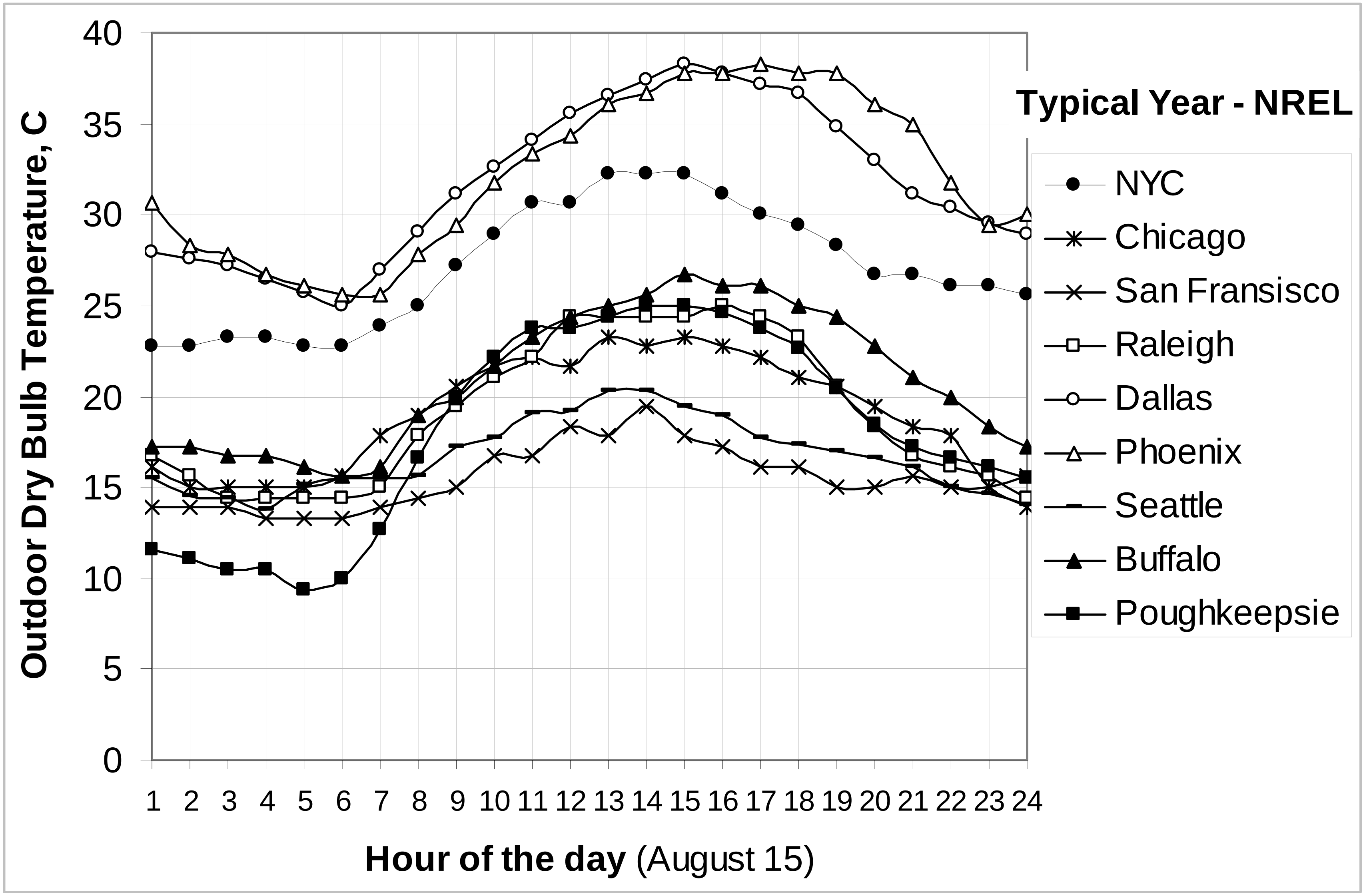


Cooling PUE data for 22 h test (August 2011)

IBM



Analyses for 9 US cities for a summer day



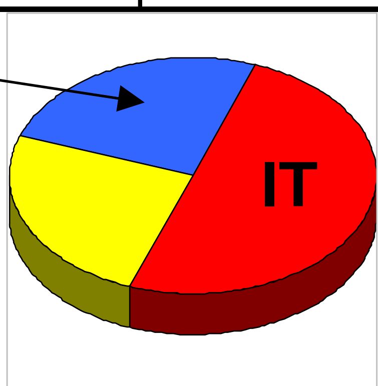
Energy and energy cost savings 9 US cities for a summer day 1000 kW IT load, Aug 15 ave.

http://www.electricchoic..com/electricity.prices-by-state.php
2010 Industrial rate assumed

	Typical data center cooling, kW	DELC based data center cooling, kW	Energy Savings, kWh	Local cost of electricity, $/kWh	Energy cost savings, $
New York City	500	20.7	11504	0.0973	1119.3
Chicago	500	15.4	11631	0.075	872.3
San Francisco	500	15.0	11640	0.1078	1254.8
Raleigh	500	15.6	11625	0.0613	712.6
Dallas	500	31.5	11243	0.0658	739.8
Phoenix	500	32.5	11220	0.0674	756.2
Seattle	500	15.0	11640	0.0396	460.9
Buffalo	500	16.0	11617	0.0973	1130.3
Poughkeepsie	500	15.5	11627	0.0973	1131.3

50% of IT power

DoE 2009 Vision and Roadmap document



Less than 3.5% of IT power

IBM warm water cooled cluster - 2012

Press room > Press releases >

Leibniz Supercomputing Centre Selects IBM Supercomputer Equipped with Next Generation Intel® Xeon® Processors to Support Ultra-challenging Research

Innovative hot-water cooled supercomputer to deliver up to three petaflops of peak performance when online in 2012

Press release   Contact(s) information
Related XML feeds

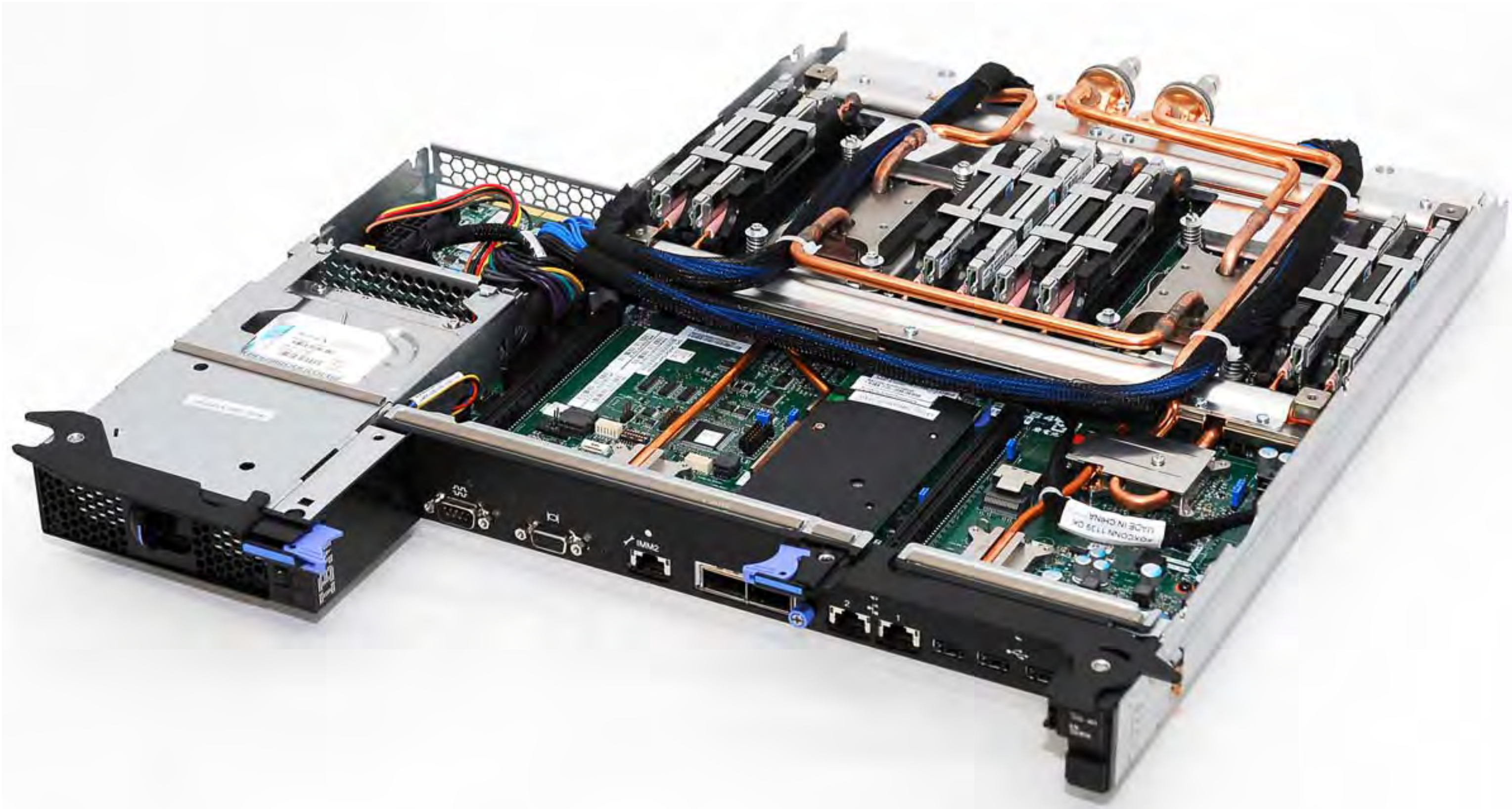
Garching/Munich/Stuttgart, Germany - 13 Nov 2010: The Leibniz Supercomputing Centre (LRZ) in Garching, Germany has signed a contract with IBM (NYSE: IBM) to develop and build a new general purpose supercomputer with next gen... advanced scientific research. The system will use i... consume 40 percent less energy than a comparab...

Named "SuperMUC", the new system is part of the ... Europe (PRACE) HPC infrastructure for researcher... Europe. It will enable LRZ's scientific community to ... predict outcomes as never before. The supercomp... federal government and the state of Bavaria.

I. Meijer, 2011, “*Hot Water Cooling for Energy-Hungry Datacenters*”.

- Highly energy-efficient hybrid-cooling solution:
  - Compute racks
    - 90% Heat flux to warm water
    - 10% Heat flux to CRAH
  - Switch / Storage racks
    - Rear door heat exchangers
- Compute node power consumption reduced ~ 10% due to lower component temperatures and no fans.
- Power Usage Effectiveness P_{Total} / P_{IT}: PUE ~ 1.1
- Heat recovery is enabled by the compute node design.
- Energy Reuse Effectiveness $(P_{Total} – P_{Reuse}) / P_{IT}$: ERE ~ 0.3

IBM warm water cooled servers - 2012



Ref.: I. Meijer, SC11, "*Hot Water Cooling for Energy-Hungry Datacenters*".

- Heat flux > 90% to water; very low chilled water requirement
- Power advantage over air-cooled node: warm water cooled ~10% (cold water cooled ~15%) due to lower $T_{components}$ and no fans.
- Typical operating conditions: T_{air} = 25 – 35°C, T_{water} = 18 – 45°C

Thank you

Q&A

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