SYSKA HENNESSY GROUP

Consulting + Engineering + Technology + Construction

Will Liquid Cooling Solutions Save Energy?

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Introduction

Introduction:

- Current best practices for data center cooling
  - "Medium density cooling" of 100 watts/square foot (5-10 KW/cabinet)
  - "High density cooling" of 300 watts/square foot (20-30 KW/cabinet)
  - There's no such thing as a space temperature (space is stratified)
  - There's no such thing as a space relative humidity (since it varies with space temperature)
  - CRAC Units / built-up Air Handling Units / Self-contained liquid-cooled racks are all acceptable means to cool the space
  - Energy efficient design is an economic necessity
  - Hot-aisle/Cold-aisle configuration of cabinets
    - Blanking panels
    - Floor Tile cutout sealing
    - Minimize cold air bypass
    - Minimize hot air recirculation
  - Placement of cabinets driven by air flow management requirements

Introduction - Continued:

- How did we get here?
- What are the current configurations for cooling high density loads?
- Where is the industry going?
  - To understand future direction, must get a little technical…but do stay awake because the future offers some VERY interesting developments!

- NOTE: Most IT Hardware today is air-cooled by liquid-cooled air conditioners
  - Heat generated by the chips, processors, memory, etc. is removed from the server by the server fans and are therefore AIR COOLED
  - The data center space heat (hot aisles) is removed by liquid-cooled air conditioners (CRACs, Air Handling Units, and/or “liquid-cooled” Cabinets)
  - The Chilled Water used to remove the heat from the CRACs, AHUs, and Liquid-Cooled Cabinets is cooled by refrigerant in the Chiller
  - The refrigerant in the Chiller is cooled by condenser water (water-cooled chiller) which is cooled by air at the Cooling Tower, or directly by air (air-cooled chiller)

Introduction – Continued:

Notable Exceptions:

- True “Liquid-Cooled” IT hardware has been around for a long time:
  - Water-Cooled Main Frames used water piped directly to the hardware and did not rely on air-conditioners or air-cooling
  - Large “Super-Computers” such as manufactured by CRAY use a dielectric liquid within the hardware to remove the heat to a heat exchanger that can be cooled directly by chilled water
  - Military hardware housed within jets and aircraft have used SprayCool technology to cool the IT hardware and move the heat to an external heat exchanger.
  - Typical Laptops and Notebook PCs use liquid-cooling of the hardware where the heat is then moved to a “heat pipe” that is air-cooled by the PC fan.

Present

Data Center Cooling - Present

- Mainframe computers and other liquid-cooled hardware are the exception, not the norm
- Most processing is done with servers, switches, compute devices, etc. placed in discrete cabinets
- Cabinets are placed in parallel rows, alternating direction of front and back of cabinets
- Loads commonly seen from 100 watts/square foot to 300 watts/square foot
- Chilled water no longer accepted inside data space (CRACs in perimeter corridors)
- Standardization by national organizations
  - Bellcore (Bell Labs Communications Research) →Telcordia
    - NEBS
  - ASHRAE Technical Committee 9.9 “Mission Critical Facilities, Technology Spaces and Electronic Equipment”
    - Thermal Guidelines for Data Processing Environments, 2004
  - Green Grid, LBNL, DOE are pushing for new standards specific to data centers regarding energy efficiency (PUE) and sustainability

Data Center Cooling - Present

- Thermal Guidelines for Data Processing Environments, 2004
  - Temperature and RH conditions at the data equipment INLET are the only relevant variables
  - Range of values is now acceptable (68-77F, 40-55%RH)
  - Front-to-Back, Front-to-Top/Back, Front-to-Top are the only recommended air flow protocols
  - ASHRAE Thermal Report should be provided by equipment vendor for each typical configuration of equipment
  - Improved emphasis on air flow management
    - Most common data center cooling problem is NOT insufficient cooling capacity – it's improper air flow management
    - Sometimes referred to as "Thermal Incapacity", or installed capacity that is not available to provide cooling directly to the IT hardware

Data Center Cooling - Present

- Thermal Guidelines for Data Processing Environments
  - Environmental specifications

Table 2.1 Equipment Environment Specifications

Class	Equipment Environment Specifications									
	Product Operation[a,b]							Product Power Off [b,c]		
	Dry-Bulb Temperature (°C)		Relative Humidity (%) Non-Condensing		Max. Dew Point (°C)	Max. Elevation (m)	Max Rate of	Dry-Bulb Temperature (°C)	Relative Humidity (%)	Max. Dew Point (°C)
	Allowable	Recommended	Allowable	Recommended						
1	15 to 32[d]	20 to 25	20 to 80	40 to 55	17	3050	5	5 to 45	8 to 80	27
2	10 to 35[d]	20 to 25	20 to 80	40 to 55	21	3050	5	5 to 45	8 to 80	27
3	5 to 35[d,e]	NA	8 to 80	NA	28	3050	NA	5 to 45	8 to 80	29
4	5 to 40[d,e]	NA	8 to 80	NA	28	3050	NA	5 to 45	8 to 80	29

Data Center Cooling - Present

- Thermal Guidelines for Data Processing Environments
  - Airflow protocols

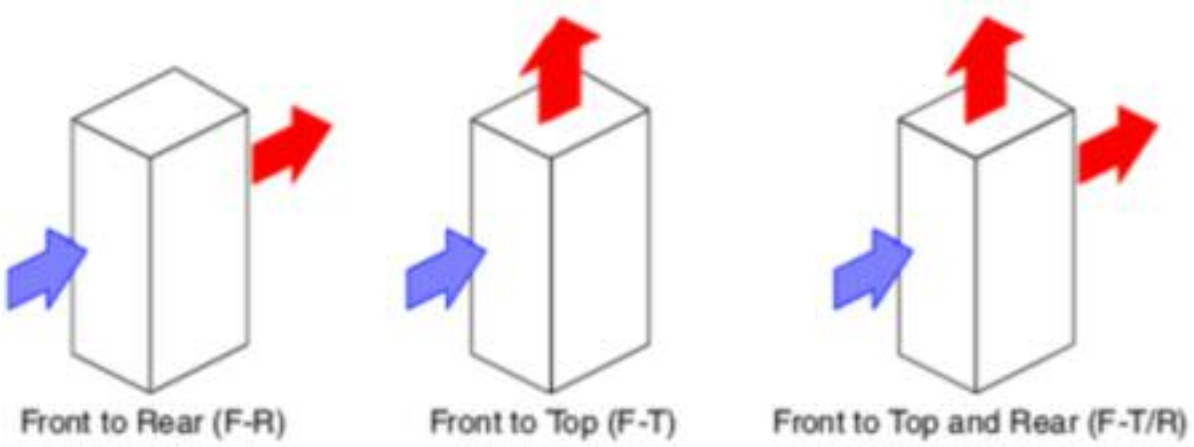


Figure 4.2 Recommended airflow protocol.

Data Center Cooling - Present

- Thermal Guidelines for Data Processing Environments
  - Hot aisle / Cold aisle with underfloor cooling
  - Hot aisle / Cold aisle with overhead cooling

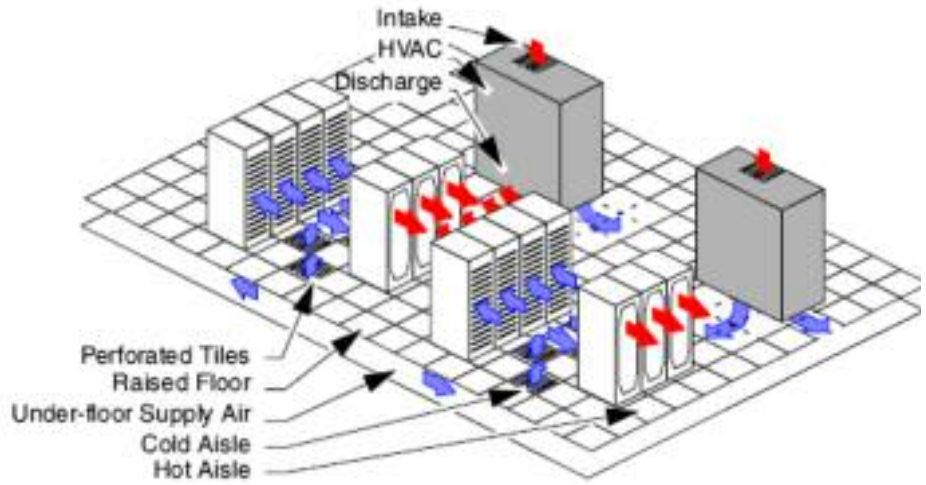


Figure 4.4 Example of hot and cold aisles with underfloor cooling.

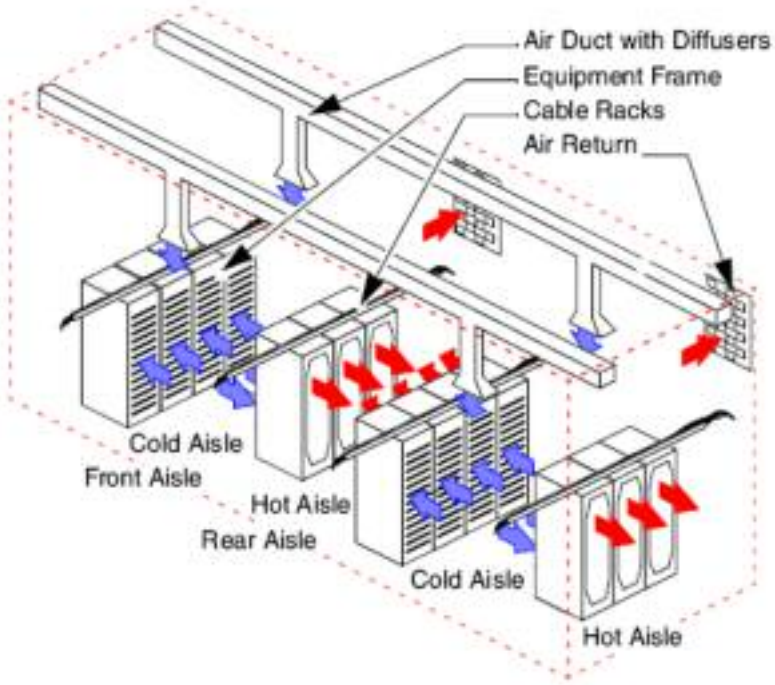


Figure 4.5 Example of hot and cold aisles for non-raised floor.

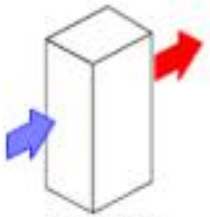
Data Center Cooling - Present

- Thermal Guidelines for Data Processing Environments
  - IT Equipment Manufacturer's Thermal Report

5.2.1 Example Thermal Report.

XYZ Co. Model abc Server: Representative Configurations

	Condition								
	Voltage 110 Volts								
	Typical Heat Release	Airflow[A], Nominal		Airflow, Maximum at 35°C		Weight		Overall System Dimensions[b] (W × D × H)	
Description	watts	cfm	(m^3/h)	cfm	(m^3/h)	lbs	kg	in.	mm
Minimum Configuration	1765	400	680	600	1020	896	406	30 × 40 × 72	762 × 1016 × 1828
Full Configuration	10740	750	1275	1125	1913	1528	693	61 × 40 × 72	1549 × 1016 × 1828
Typical Configuration	5040	555	943	833	1415	1040	472	30 × 40 × 72	762 × 1016 × 1828

ASHRAE Class	Airflow Diagram *Cooling scheme F-R*		
1, 2, 3	 *Front to Rear F-R*	Minimum Configuration	1 CPU-A, 1 GB, 2 I/O
		Full Configuration	8 CPU-B, 16 GB, 64 I/O (2 GB cards, 2 frames)
		Typical Configuration	4 CPU-A, 8 GB, 32 I/O (2 GB cards, 1 frame)

Data Center Cooling - Present

- Thermal Guidelines for Data Processing Environments
  - Best intentions…but still not perfect

Four foot cold aisle but only one row of perforated floor tiles

Poor cable mgmt blocks air flow through servers + perf tiles in the hot aisle

Data Center Cooling - Present

- Other High Density Solutions
  - Built-up Air Handlers
    - Higher efficiency than conventional CRAC units + easy to implement air-side economizers)
    - Fewer yet larger capacity units reduce maintenance & complexity
    - Don’t need to be in the data space (perimeter equipment galleries)

Data Center Cooling - Present

- Other High Density Solutions
  - Overhead Air Distribution
    - Can cool with less air than underfloor air distribution
    - Units can be located on roof or in mezzanines
    - Easier to implement outside air economizers for free cooling

Data Center Cooling - Present

- Other High Density Solutions
  - Liquid-Cooled Coolers and Cabinets
  - Fan-Assisted Cabinets

CHW coil open to cold aisle

CHW coil totally contained

Refrigerant coil open to hot & cold aisle

CO_2 rear door cooler

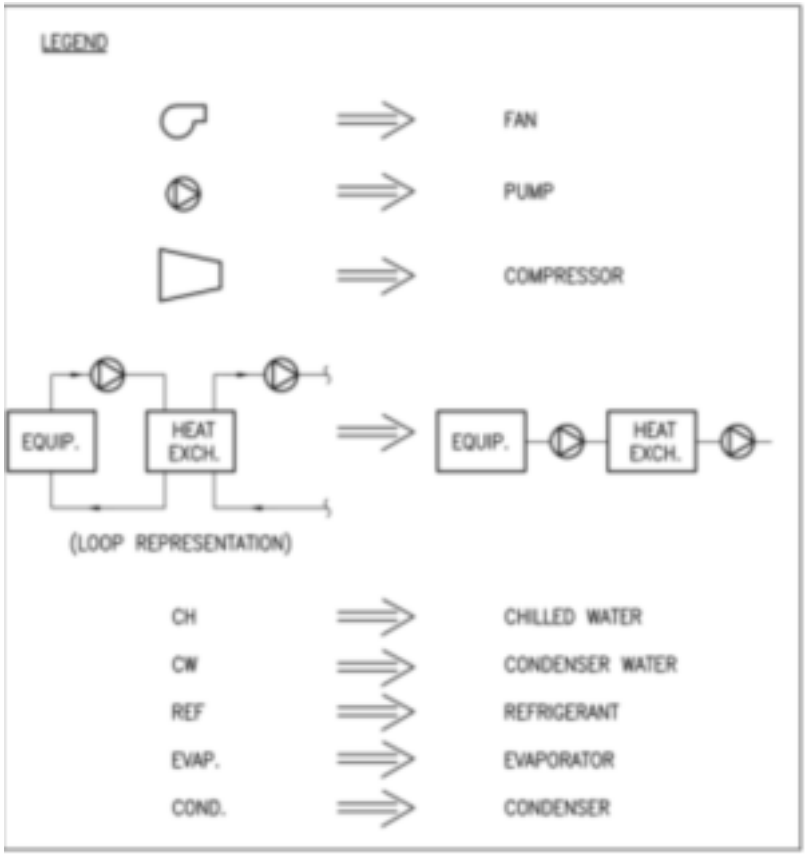
Data Center Cooling - Present

- Other High Density Solutions
  - Liquid-Cooled Coolers, Liquid-Cooled Cabinets, Fan-Assisted Cabinets
    - Some use underfloor air or room air
    - Some are self-contained (isolated from room)
    - Some use chilled water
    - Some use conventional refrigerant (R-134a)
    - Some use CO_2 (R-744)
    - All claim capacities approaching 25-30 KW/cabinet
    - All claim to be energy efficient
    - NONE are liquid-cooled IT Hardware equipment
  - Is liquid or water in proximity to the data equipment back to stay?!

Sorting Through the Options for HD Data Center Cooling

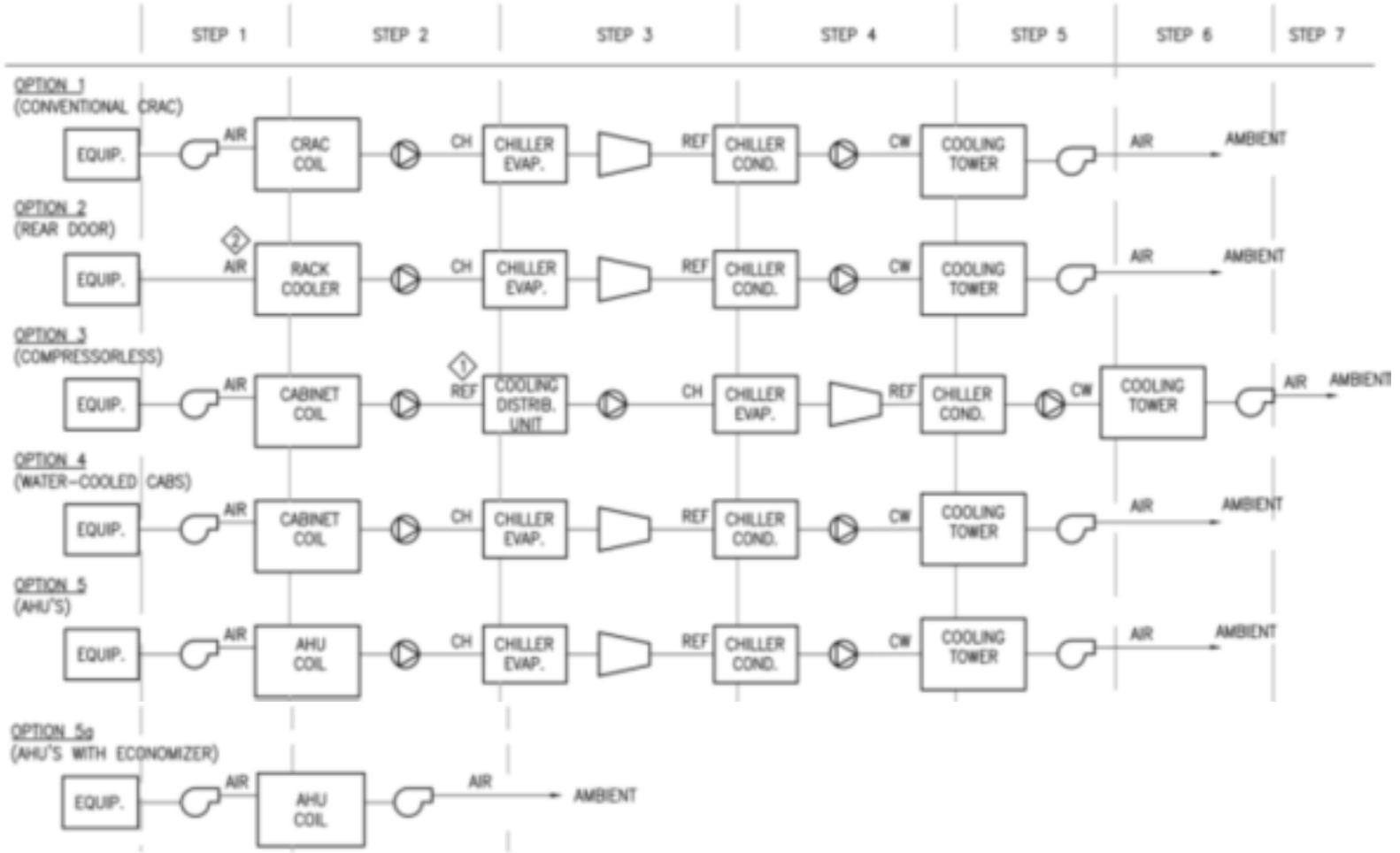
All solutions do just about the same thing – they move heat from a source to a sink

- Three heat transfer components:
  - heat generator (or source)
  - heat exchanger
  - heat sink
- Three movers that drive the fluid media:
  - fan
  - pump
  - compressor
- Several major types of fluid media:
  - water
  - air
  - refrigerant
- Two major modes of heat transfer:
  - Sensible (energy absorbed by a rise in temperature; energy released by a drop in temperature)
  - Latent (energy absorbed through evaporation or released through condensation)



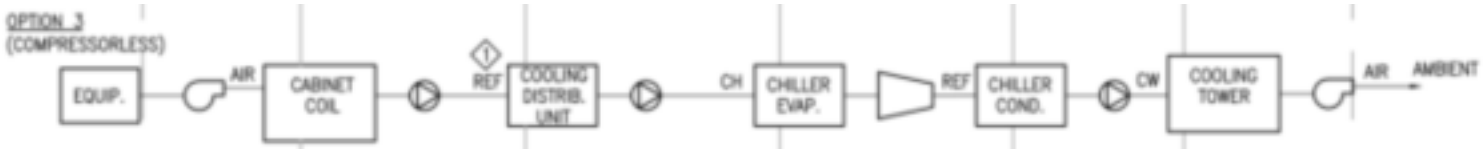
Data Center Cooling - Present

Breakdown of Current High-Density Solutions



Data Center Cooling - Present

- Calculating the Energy Consumption for Each Component
  - The heat transfer components are passive (do not use energy)
    - IT equipment “Cold Plates” or “Heat Pipes”
    - CRAC and AHU Cooling Coils
    - Chiller Evaporator and Condenser Tube Bundles
    - Cooling Tower Media or “Fill”
  - The movers are active (use energy) – pumps, fans, compressors
  - The energy associated with each mover can be calculated based on flow quantity, fluid density, viscosity, equipment efficiency, etc.
  - A few interesting generalizations:
    - The fewer steps in the heat transfer process, the more efficient the heat transfer process
    - Fewer steps increases reliability (less equipment, less complexity, less maintenance, means less risk of failure)
    - The larger the mover, the more efficient the heat transfer process (e.g. large fan efficiency = 85%, small fan efficiency = 65%)



Future

Data Center Cooling - Future

Air-Cooled Designs:

- To date, the maximum load density using current data equipment technology and cabinet designs may be somewhere near 500 watts/square foot.
  - There is ongoing research attempting to show that load densities of 1000 watts/square foot are achievable with air-cooled equipment and cabinets
  - A big challenge is how do you build a scalable facility based on air-cooling alone that can efficiently accommodate a 50 to 100 watts/sf load on day-one that can also support 1000 watts/square foot ultimate load?

New Standards and Guidelines specific to Data Centers

- ASHRAE Thermal Guidelines
  - ASHRAE TC9.9 is in process of revising the current guidelines issued in 2004
    - to expand the range of “recommended” temperatures
    - To expand the moisture range and move to dewpoint vs. relative humidity
- Green Grid, LBNL, and DOE are working on:
  - Environmental Performance Criteria for data centers
  - Possible LEED criteria for data centers

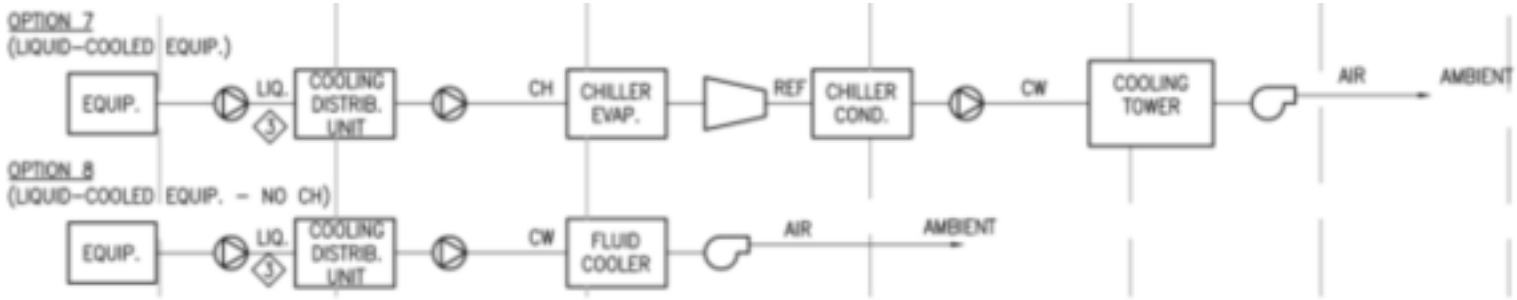
Data Center Cooling - Future

Liquid-Cooled Designs:

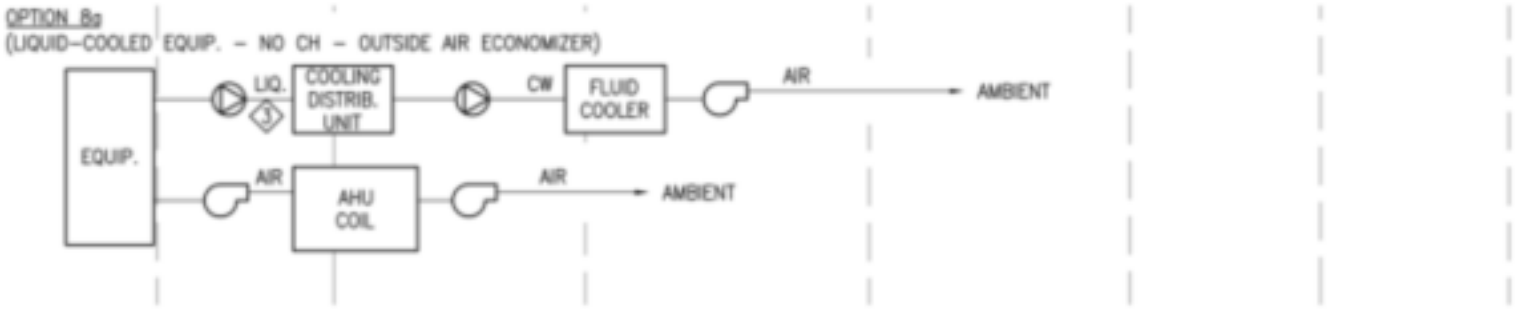
- The true breakthrough in load density will occur when data equipment is directly cooled by liquid
- There are many companies currently developing the technology to bring liquid-cooling media directly to the chips
- Removing heat by evaporation of a dielectric liquid on the chip surface is thousands of times more effective than cooling with air as the medium
- Consequently, the chip surface temperature of a liquid-cooled device can be LOWER than an equivalent design using air, even when the liquid temperature is higher than the air temperature
- The implications are huge:
  - Liquid-cooling with 85 degF liquid can be accomplished without mechanical cooling (chillers, compressors, etc.)
  - Ancillary loads that can be cooled by 75 degF air can be accomplished with air-side economizers (no mechanical cooling)
  - Scalability to accommodate lower “day-one” loads and ultimate “design” loads becomes easier to accomplish
  - Eliminating central plant chillers can save incredible amounts of energy and increase overall reliability with less maintenance and complexity

Data Center Cooling – Future (or is this "Back to the Future"?)

- Breakdown of Liquid-Cooled Equipment Solutions



- Still need air cooling in the near and intermediate future:
  - Legacy IT equipment
  - Power supplies
  - "Other" chips (vs. CPU processors)
  - Memory
  - Network gear
  - Disk arrays, etc.
- But these can be cooled effectively using air-side economizers!



Data Center Cooling Energy Comparisons – Present vs. Future

- Liquid-cooled equipment has the potential for eliminating the need for a chiller
- Chillers are easily the largest consumer of energy in the building (after the IT load)
- Chillers are typically the most complex, least reliable, and most maintenance-intensive component in the cooling process

Table 1: HVAC KW Input / 1000 KW of IT Equipment

	Step # (Reference Figure 1)							
Option	1	2	3	4	5	6		Total
1 - Conventional CRAC Units	13	16	145	10	5	-		188
2 - Rear Door Cooler	-	17	145	10	5	-		177
3 - Compressorless	21	4	8	145	10	5		192
4 - Water-Cooled Cabinet	21	17	145	10	5	-		198
5 - Air Handling Units	9	16	145	10	5	-		185
5a - Air Handling Units with OA Economizer	15	5	-	-	-	-		20
6 - Water-Cooled Equipment	16	145	10	5	-	-		176
7 - Liquid-Cooled Equipment	15	16	145	10	5	-		191
8 - Liquid-Cooled Equipment (no chiller)	15	10	5	-	-	-		30
8a - Liquid-Cooled Equipment (no chiller)	15	10	5	-	-	-		30
with OA Economizer	15	5	-	-	-	-		20

Note: All KW input numbers above represent the midpoints of ranges representative of variations in equipment, design, and implementation.

Data Center Cooling - Future

- So why isn't liquid-cooled equipment easily and commercially available for all IT equipment today?
- The "buzz" within the industry is "the first one to market LOSES!"
- A likely reason – IT managers will not purchase liquid-cooled equipment until there is a proven track record demonstrating that the liquid will not leak and damage their sizable investment.
- Given that legacy designs once used liquid at the chip level, there already should be sufficient data to demonstrate the concept.
- It could be any day when true liquid-cooled hardware is again available and clients choose to break that cycle and take that small risk.

GOAL – Eliminate the need for the Central Plant Chiller!!!

Caveat for "Liquid-Cooled" solutions:
Liquid-cooled cabinets, refrigerant-cooled cabinets, and other High Density cooling solutions available today can be appropriate and even necessary for deploying high density electronics in existing data centers that otherwise cannot accommodate these type loads.

Questions???

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