Data Center Physical Infrastructure - Cooling

NEED FOR COOLING · ARCHITECTURES · TECHNOLOGIES · AIR & WATER/LIQUID COOLING · WATER TREATMENT · AIRFLOW MANAGEMENT · RACK COOLING · MONITORING & DCIM · OUTAGE STRATEGIES

STUDY & REVIEW

01 MUST KNOW

if you remember five things, remember these

01 **The ASHRAE window:** keep IT equipment between **64.4°F and 80.6°F** (18–27°C), dew point **15.8°F to 59°F** (–9 to 15°C), and **relative humidity below 60%**. Both extremes hurt: high heat burns chipsets, high humidity causes condensation and corrosion, low humidity invites electrostatic discharge. Plan roughly **1 ton of cooling (12,000 BTU/hr per 3,516 W) per 400 sq ft**.

02 **Cooling load ≠ just the servers:** the **cooling load** is the total heat needing removal to hold the ideal temperature. It depends on four things — heat from **data center equipment** (IT, power distribution, lighting, UPS), heat from **other elements/people** in the building, **outside temperature**, and the **air ventilation load**. Reduce operating equipment and you can reduce cooling.

03 **Three architecture choices:** every cooling design decides **how heat is removed** (9 methods, e.g. chilled water, air-cooled split, glycol, CRAH), **how air circulates** (*flooded → targeted → contained*), and **where the units sit** (*room / row / rack / hybrid*). Rack-based placement gives the shortest air paths and up to **50 kW per rack**.

04 **DX vs chilled water vs liquid: air-cooled, glycol-cooled, and condenser water-cooled** are **direct expansion (DX)** systems; **chilled water** swaps the refrigerant for water cooled in a chiller; **liquid-cooled** goes to the chip. **Cooling towers and dry coolers** are the two common **heat-rejection** systems that dump heat outdoors.

05 **Airflow is the whole game:** heat balances when `Q(AHU) = Q(IT)`, where `Q = 1.085 × ΔT × CFM`. The two enemies are **bypass airflow** (cold air that skips the IT) and **recirculation airflow** (server fans pulling warm air). **Hot/cold-aisle containment** plus blanking panels, sealed gaps, and correct tile placement drive the `CFM(AHU)`-to-`CFM(IT)` variance to **25% or less**.

02 KEY TERMS

TERM	DEFINITION
Cooling load / heat load	Total heat that must be removed to hold the ideal temperature; includes IT equipment, lighting, people, outside temperature, building architecture, and ventilation
CRAC	Computer room air conditioner — holds the refrigeration cycle and compressor; the DX/split-system unit
CRAH	Computer room air handler — uses chilled-water coils fed by a chiller; no compressor of its own
DX (direct expansion)	System that expands refrigerant to absorb heat; air-cooled, glycol-cooled, and condenser water-cooled units are DX
Chilled water system	Water (46.4°F–59°F) cooled in a chiller and pumped to CRAH coils, which absorb room heat
Economizer / free cooling	Mode that uses an alternative medium (e.g. cool outside air) instead of compressors, cutting electrical load
Heat rejection system	Equipment that dumps heat outdoors — cooling towers and dry coolers are the most common
Bypass airflow	Conditioned air that returns to the AHU without passing through IT equipment — wasted cooling
Recirculation airflow	Warm exhaust drawn back into server inlets when cold supply is inadequate
Containment	Enclosing hot or cold aisles to stop supply and return air from mixing; balances CFM(AHU) with CFM(IT)
DCIM	Data Center Infrastructure Management — tools giving a guided real-time view of space, power, performance, and efficiency

TERM	DEFINITION
Power density	Concentration of power in one rack; modern racks can exceed 20 kVA and 16 kW

03 AIR-BASED VS. WATER/LIQUID-BASED COOLING

differentiate the two families

DIMENSION	AIR-BASED COOLING	WATER/LIQUID-BASED COOLING
Heat carrier	Air moved by fans through a heat swapper to outdoors	Water/liquid through cooling towers, pumps, chillers, condensers
Best fit	Standard IT rooms; low initial and running cost	High-density data centers; absorbs heat more efficiently
Pros	Low investment; little maintenance (air-cooled just needs filter changes)	Highly cost-effective; small footprint; high heat absorption
Cons	Lower heat-transfer coefficient needs long piping; poor placement cuts performance	Large ductwork; filter upkeep; leak risk; must watch server humidity

04 THE CHILLED-WATER COOLING LOOP

how a CRAH-based system rejects heat

01 Chiller cools water to **46.4°F–59°F** → 02 Water pumped to the **CRAH** units in the IT room → 03 **Cold-water coils** absorb room heat as air passes through → 04 Warmed water returns; heat passes to a **condenser water** stream → 05 **Cooling tower** rejects the heat to the outdoor environment

05 POOR AIRFLOW — THE TWO CULPRITS

both waste cooling and both are fixable

BYPASS AIRFLOW

cold air that never does its job

— Conditioned air returns to the AHU **without passing through IT**
— Caused by oversupply, wrongly placed perforated tiles, open cable cutouts
— Wastes cold air and drops under-floor pressure

RECIRCULATION AIRFLOW

servers breathing their own exhaust

— Inadequate cold supply, so **server fans pull in nearby warm air**
— Raises inlet temperatures — risky for the equipment
— Fixed by containment and blanking panels, not by dumping in more air

06 EXAM TRAPS

where the knowledge check gets you

- × "CRAC and CRAH are the same unit." — A **CRAC** (air conditioner) contains the refrigeration cycle and compressor (a DX/split system); a **CRAH** (air handler) has no compressor and uses **chilled-water coils** fed by a chiller.
- × "Chilled water is a DX system." — No. **Air-cooled, glycol-cooled, and condenser water-cooled** are the DX systems; **chilled water** replaces the refrigerant with water cooled in a chiller.
- × "Turning on more CRAH units always lowers server temperature." — Adding air raises `CFM(AHU)`, lowers ΔT, and oversupplies air the server fans don't need. **Containment**, not more air, removes bypass and recirculation.
- × "Cold supply air at the inlets fixes bypass air." — It keeps inlet temperatures within limits but has **no effect on the proportion of bypass air**, and servers still face recirculation.
- × "More perforated tiles in the cold aisle is better." — **Too few → recirculation; too many → bypass.** Calculate the load, use an adequate number, and keep tiles in cold aisles only.
- × "Only high humidity is dangerous." — High humidity condenses and corrodes, but **low humidity causes electrostatic discharge** that damages equipment; high heat burns chipsets. All three are threats.
- × "Evaporative/free cooling works anywhere." — Evaporative cooling favors **dry, low-relative-humidity** climates and loses efficiency as humidity rises; water-side economizers have **limited operating hours**.
- × "If cooling capacity equals the heat load, you can recover from an outage." — During an outage there is **excess heat on top of the IT load**, so capacity = load can't return the room to normal. You need **excess/oversized** capacity.

07 SELF-QUIZ

answers are upside-down below

Q1 Per ASHRAE, what dry-bulb temperature range (°F) and maximum relative humidity should a data center maintain?

Q2 Name the four factors the cooling load depends on.

Q3 Which three cooling technologies are direct expansion (DX) systems?

Q4 What are the three methods of air circulation in a data center?

Q5 What are the four suitable locations for placing cooling units?

Q6 Write the data-center heat-transfer equation and the balance condition between the AHU and IT.

Q7 Name the two causes of poor airflow in a data center.

Q8 What are the two main types of data center water treatment systems?

Q9 Name the two predictive models used to rate heat after a power loss.

Q10 List the four strategies for managing cooling during a power outage.

ANSWER KEY (rotate the page)

Q1 64.4°F–80.6°F (18–27°C); relative humidity below 60% **Q2** heat from data center equipment; heat from other elements/people in the building; outside temperature; air ventilation load **Q3** air-cooled, glycol-cooled, and condenser water-cooled **Q4** flooded, targeted, and contained **Q5** room-based, row-based, rack-based, and hybrid **Q6** $Q = 1.085 \times \Delta T \times CFM$; balance requires $Q(AHU) = Q(IT)$ **Q7** bypass airflow and recirculation airflow **Q8** pulse-power and cooling tower blowdown (reverse osmosis) **Q9** well-mixed air prototype and computational fluid dynamics (CFD) **Q10** maintain sufficient (excess) cooling capacity; link backup power/UPS to cooling equipment; select quick-restart equipment; use thermal storage